

Foreign Exchange Market Interventions: New Empirical Views of Emerging Markets

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To Mathilda

"Shoot for the moon. Even if you miss,
you'll land among the stars."

-

Les Brown

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Acronyms

ADF	-	<i>Augmented Dickey Fuller</i>
AIC	-	<i>Akaike Information Criterion</i>
a.m.	-	<i>'ante meridiem' (Latin) alias 'mornings'</i>
AR	-	<i>Autoregressive</i>
ARCH	-	<i>Autoregressive Conditional Heteroskedasticity</i>
ARMA	-	<i>Autoregressive Moving Average</i>
ARS	-	<i>Argentine Peso</i>
Ass.	-	<i>Assets</i>
ATE	-	<i>Average Treatment Effect</i>
Avg.	-	<i>Average</i>
B	-	<i>Monetary Base</i>
BCRA	-	<i>Banco Central de la Republic Argentina</i>
BdR	-	<i>Banco de la Republica Colombia</i>
Bill.	-	<i>Billion</i>
BIS	-	<i>Bank for International Settlements</i>
BMB	-	<i>Broad Monetary Base</i>
BoJ	-	<i>Bank of Japan</i>
CHF	-	<i>Swiss Franc</i>
CNB	-	<i>Croatian National Bank</i>
Cond.	-	<i>Conditional</i>
c.p.	-	<i>'Ceteris paribus' (Latin) alias 'other things being equal'</i>
CPI	-	<i>Consumer Price Index</i>
CZK	-	<i>Czech Koruna</i>
DA	-	<i>Domestic Assets</i>
DCB	-	<i>Claims on the Domestic Central Bank</i>
DBB	-	<i>Deutsche Bundesbank</i>
DEM	-	<i>Deutsche Mark</i>

Dev.	-	<i>Deviation</i>
Diff.	-	<i>Differential</i>
DKK	-	<i>Danish Krone</i>
DL	-	<i>Domestic Liabilities</i>
Dom.	-	<i>Domestic</i>
ECB	-	<i>European Central Bank</i>
Eff.	-	<i>Effective</i>
e.g.	-	<i>'Exempli gratia' (Latin) alias 'for example'</i>
EMH	-	<i>Efficient Market Hypothesis</i>
EMU	-	<i>European Monetary Union</i>
EU	-	<i>European Union</i>
EUR	-	<i>Euro</i>
FA	-	<i>Foreign Assets</i>
Fed	-	<i>Federal Reserve Bank</i>
FRF	-	<i>French Franc</i>
FX	-	<i>Foreign Exchange</i>
G-X	-	<i>Group which consists of X of the world's leading economies</i>
GARCH	-	<i>General Autoregressive Conditional Heteroskedasticity</i>
GBP	-	<i>Pound Sterling</i>
GDP	-	<i>Gross Domestic Product</i>
GED	-	<i>Generalized Error Distribution</i>
HP-Filter	-	<i>Hodrick Prescott-Filter</i>
HRK	-	<i>Croatian Kuna</i>
H0	-	<i>Null Hypothesis</i>
I	-	<i>Intervention</i>
i.e.	-	<i>'id est' (Latin) alias 'that is'</i>
IFS	-	<i>International Financial Statistics</i>

Liab.	-	<i>Liabilities</i>
IMF	-	<i>International Monetary Fund</i>
Infl.	-	<i>Inflation</i>
LM	-	<i>Lagrange Multiplier</i>
Log	-	<i>Natural Logarithm</i>
Ma.	-	<i>Moving Average</i>
MAE	-	<i>Mean Absolute Error</i>
Max.	-	<i>Maximum</i>
Me.	-	<i>Marginal Effect</i>
Mill.	-	<i>Million</i>
Min.	-	<i>Minimum</i>
ML	-	<i>Maximum Likelihood</i>
NFA	-	<i>Net Foreign Assets</i>
Obs.	-	<i>Observation</i>
OLS	-	<i>Ordinary Least Squares</i>
OTC	-	<i>Over the Counter</i>
O/W	-	<i>Of Which</i>
PDF	-	<i>Probability Density Function</i>
PLN	-	<i>Polan Zloty</i>
p.m.	-	<i>'post meridiem' (Latin) alias 'in the afternoons'</i>
PPP	-	<i>Purchasing Power Parity</i>
Prob.	-	<i>Probability</i>
QML	-	<i>Quasi Maximum Likelihood</i>
Repo	-	<i>Repurchase Agreement</i>
Requ.	-	<i>Requirement</i>
RMSE	-	<i>Root Mean Squared Error</i>
Sa.	-	<i>Seasonally Adjusted</i>
SIC	-	<i>Schwarz Information Criterion</i>

SNB	-	<i>Swiss National Bank</i>
Specific.	-	<i>Specification</i>
Stat.	-	<i>Statistic</i>
Std.	-	<i>Standard</i>
Struct.	-	<i>Structure</i>
S&P	-	<i>Standard & Poor's</i>
UIP	-	<i>Uncovered Interest Rate Parity</i>
UK	-	<i>United Kingdom</i>
US	-	<i>United States</i>
US\$	-	<i>US Dollar</i>
VAR	-	<i>Vector Autoregression</i>

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Introduction

Besides current discussions about the role of monetary policy in the presence of financial turmoil, and its responsibility to avoid such crises, it is uncontested that the foremost task of monetary authorities is to achieve price stability. However, this final goal is not a clear-defined concept per se, which is why policy makers hark back on nominal anchors.¹ These anchors constitute the actual meaning of price stability.² Moreover, the use of such "help variables" influences the arguably most important determinant of price stability: The agent's expectation. The commitment to exchange rate stability, a monetary target, or an explicit numerical inflation goal are different possibilities of a nominal anchor. Of course, whether a central bank intends to manage exchange rate issues directly, or to steer the growth of monetary aggregates, is a matter of the country's monetary framework. Thereby, the choice of the specific strategy is based on the economic structure. In line with this choice, the relevance of the corresponding transmission channels determine the policy targets and the associated policy tool set.

Since the beginning, central banks have used a wide range of instruments to achieve the ultimate purpose of price stability via managing the underlying nominal anchors or other prefixed operating targets.³ The different measures are implemented with respect to the specific policy framework. Generally speaking, a monetary policy instrument should be characterized by the following two parameters: Concrete objectives, and a reliable effectiveness. It is fact that without these requirements, successful central banking is not possible. While the concrete objectives depend on the implemented policy strategy, a reliable effectiveness determines whether or not monetary policy is a trial and error process. Although, conducting monetary policy might sometimes be rather an art than a rule-based decision-making process, authorities must trust on these parameters.

One measure in the authorities' toolbox is a foreign exchange market intervention. The discussion about this instrument has come a long way. With the beginning of the free float era

¹In the end, monetary authorities seek to maximize social welfare. Bofinger (2001) argues: "*... the main aim of monetary policy is a control of the final targets of economic process ..., which have been set in such a way as to maximize the ultimate goal of social welfare.*", [Bofinger (2001), p. 125].

²See Mishkin (2007).

³See Bofinger (2001).

in the 1970s, central banks lost their ability to manage exchange rates arbitrarily. The abolition of the fixed exchange rate arrangements of Bretton Woods in 1974 marked the opening of new sources of exchange rate determinations, namely international financial markets. In this context, Dominguez and Frankel (1993) state: *"The foreign exchange market is a herd of steers, and central banks are herd dogs. They bark and nip at the heels of the steers, with the aim of moving the herd in the desired direction."* [Dominguez and Frankel (1993), p. 2]. So far, the discussion relied mainly on industrialized countries' experiences. Almekinders (1995), Dominguez and Frankel (1993), Edison (1993), Jurgensen (1983), Sarno and Taylor (2001a), and more recently Humpage (2003) constitute well-known studies dealing with this monetary policy tool. Their analysis and further contributions focused on examining the effectiveness of foreign exchange market interventions. The negative outcomes of these studies with respect to the effectiveness of the intervention tool, opened up a discussion, whether interventions should be used by the authorities to manage exchange rate aspects and other monetary issues. More precisely, is an intervention a genuine monetary policy instrument? If the answer is yes, then the reasons for as well as the outcomes of interventions should be reliable to a significant extent. Obviously, this is not the case. Despite the widespread believe that interventions do not constitute a reliable policy instrument, the BoJ and the SNB have intervened regularly in the foreign exchange market.

Due to inconclusive outcomes of interventions in developed countries, and the fact that most of their central banks have a bias towards letting their currencies float freely, the question about the dynamics of foreign exchange market interventions is now open to the subject-matter of developing and emerging market countries.⁴ This new field of research has just begun. Canales-Kriljenko (2003) discusses whether interventions in emerging markets are more effective compared to their use in countries issuing the world's main currencies. BIS (2005b) gives a comprehensive overview of emerging markets, and their experiences with interventions in the foreign exchange market. Many of these countries are highly dependent on the development of their currencies in an international context. The importance of trade for economic growth, and their domestic financial systems, which are infused with foreign currency, are only two

⁴In the following, emerging markets and developing countries are used synonymously.

aspects highlighting the role of exchange rate movements. Therefore, monetary policy in those countries often constitutes an active management of exchange rates. This emphasizes the role of exchange rates as a nominal anchor for the ultimate goal of price stability. Consequently, foreign exchange market interventions attract much attention. The economic structure and the lower depth of financial markets in developing countries give reasons to assume that this tool could be applied as a monetary policy instrument. However, its use might not be restricted on exchange rate aspects solely. In the style of Dominguez and Frankel (1993), the question is whether emerging market central banks can be seen as a herd of dogs guiding a herd of sheep in the desired direction, which is fenced in.

The basic discussions about intervention dynamics have had one essential drawback. Neither the primary literature of industrialized countries nor studies dealing with developing countries have considered the fact that intervention purposes and the corresponding effects are likely to vary over time.⁵ The negligence of this important aspect is somewhat surprising. While markets in developed countries become continuously refined, the strong dynamic character of emerging market countries is even more evident. In this context, it seems natural to think that the evolution of economic variables and financial markets entail varying needs for central banks to adjust the use of foreign exchange market interventions. This might stem from various sources, covering fiscal policy issues, trade developments, exchange rate developments, and the progress of financial market deployment. In the same way, exchange rates may react differently to central bank interventions over time. While this might be mainly based on shifts in market structures, changes in the use of interventions could explain time dependent effects as well. Against this background, it is important to get more insight into the factors, which drive intervention purposes, and the associated effects on exchange rates.

This thesis is designed to provide the reader with essential issues of central bank interventions, and aims to give further, as well as new contributions, in terms of empirical research on interventions in emerging markets. The main objectives of this study are the analysis of central bank intervention motives, and the corresponding effects on exchange rates in emerging

⁵One exception is provided by King (2003), who provides a very readable overview of intervention studies.

markets. The time dependency of both issues is explicitly considered, which states a novelty in academic research of central bank interventions. Additionally, the outcomes are discussed against the background of underlying economic and monetary policy fundamentals. This could well serve as a starting point for further research. The thesis is divided into two parts, covering seven chapters.

Part I provides all information required for knowing the status quo of this field of research. In order to assess and understand new empirical considerations, a thorough knowledge of the fundamental underpinnings and the actual empirical literature is necessary. Chapter *one* deals with rationales of central bank interventions. It discusses different intervention definitions and directly related aspects. Thereby, the matter of sterilization and motives for interventions are illustrated. The chapter closes with a description of the well-known *secrecy puzzle* of interventions. Chapter *two* concentrates on theoretical considerations of how an intervention influences exchange rates. Many intervention channels have opened up during the last decades. While the former theoretical models are based on a macroeconomic mindset of exchange rate determination, more recent explanations incorporate microstructural ideas. Chapter *three* presents the actual stance of the empirical literature. A wide range of econometric tools and their applicability to examine intervention dynamics is discussed. Additionally, this chapter provides surveys on empirical analysis in industrialized and emerging market countries.

Having elucidated the fundamental underpinnings and the literature on interventions, Part II deals with new empirical views of interventions in emerging markets. Chapter *four* states the basic questions of research and the applied methodologies, which are used to answer these questions. Furthermore, challenges of empirical research are described. Chapters *five* and *six* present two case studies. The experiences of Argentina and Croatia with their use of this controversial instrument constitute the research basis.⁶ Before showing empirical estimations, a description of the recent monetary policy and the role of interventions is given. Chapter *seven* discusses the outcomes of the case studies in a comparing context. The thesis ends with some concluding remarks.

⁶Chapter *five* is based on Brause (2008), and presents an improved, extended version.

Part I

**Fundamental Underpinnings and the
Literature on Interventions**

1 Rationales of Central Bank Foreign Exchange Market Interventions

The discussion on central bank foreign exchange market interventions hinges clearly on the rationales of interventions. The reasons for a central bank to intervene in the foreign exchange market, and the way this controversial monetary policy instrument is implemented, are of essential interest when analyzing this policy tool. Before discussing its motives, it is necessary to define an intervention. The distinction of central bank actions in the foreign exchange market leads to important conclusions concerning the analysis of their effectiveness. Closely related to this is the matter of sterilization. Absorbing monetary effects, which are caused by interventions in the foreign exchange market, attract a lot of attention in a policy context. Having this in mind, potential purposes for central banks to use this instrument are presented. So far, the academic literature has mainly focused on empirical objectives rather than theoretical perspectives. However, some of these aspects will be discussed below. It has been common practice throughout the years that monetary authorities were very reluctant in giving information about their intervention strategies. This discretionary attitude was accompanied by secret interventions. Most central banks tried to conceal their exchange market actions. This behavior constitutes the well-known *secrecy puzzle* of interventions. Although policy actions should be communicated publicly to avoid negative influences of agents' expectations, this behavior can be justified by several reasons. During the following sections a presentation of the rationales of central bank foreign exchange market interventions is given.

1.1 Definitions of Interventions

First and foremost, it is important to define a central bank intervention in the foreign exchange market. Surprisingly, no consensus position exists on this topic. The academic literature has discussed various approaches.⁷ Of course, an intervention is by definition an interference to alter

⁷See Adam and Henderson (1983) for an early contribution. Moreno (2005) presents a more up to date discussion. It is important to note that monetary policy interest rate changes are not included in the definition of central bank interventions. One has to distinguish between interventions in the money market and interventions

Definitions of Interventions According to:

- | | |
|------------------------|--|
| 1. Motives | <ul style="list-style-type: none"> - Exchange Rate "Neutral" Operations - Exchange Rate "Effective" Operations $\hat{=}$ <i>Intervention</i> |
| 2. Type of Transaction | <ul style="list-style-type: none"> - Broad Perspective (Passive Attitude) - Narrow Perspective (Active Attitude) |
-
-

Table 2: Definitions of a Foreign Exchange Market Intervention.

the status quo. From this point of view, central banks, which intervene in the foreign exchange market are seeking to alter the prevailing exchange rate behavior.

One possibility of defining interventions is to differentiate them according to their underlying motives. In this sense, the purchase or sale of foreign currency should be labelled as an intervention when intended to alter the exchange rate "effectively." Foreign currency transactions, which are conducted for other reasons can be summarized as exchange rate "neutral" operations. However, the essential drawback of this differentiation is that one needs to know the underlying objective of the central bank's intervention. However, knowing intervention motives is often challenging due to the fact that central banks are very reluctant to communicate their transactions and publish their motives. This makes it difficult to investigate the dynamics of exchange market operations empirically. Therefore, it is more convenient to define interventions with regard to the type of transaction. The big advantage is that no information about the actual motive is required. Table 2 summarizes both types of definition.

In the following, interventions will be categorized into a broad and narrow perspective. While the former type of transaction is characterized by an indirect impact through "passive" operations on the exchange rate, the latter perspective of interventions exhibits a direct influence by an "active" central bank.

in the foreign exchange market. In the following sections, money market interventions are neglected if not stated explicitly.

1.1.1 Broad Perspective of Interventions

Foreign exchange market interventions in the 'broad sense' can be understood as any attempt to influence the exchange rate, at least indirectly. This type of intervention also contains measures, which circumvent the foreign exchange market explicitly. Within the broad perspective of interventions, monetary authorities adopt a passive attitude. In this sense, interventions are initiated by other market members. One example are capital controls.⁸ Restricting capital flows implicitly points towards the purpose of managing exchange rate movements.⁹ Such restrictions can be modeled according to different underlying objectives, and can be adjusted to take into account term structures, and the usage of devices among others.¹⁰ While controls, which aim to limit short-term capital flight, are supposed to reduce exchange rate volatility, limits on long-term investments on the other hand might stem from political reasons.¹¹ Ariyoshi et al. (2000) distinguish two basic forms of capital controls. Direct or administrative measures seek to fix the volume of capital flows directly. This is achieved by outright prohibitions, quantitative limits, and approval procedures. Different to these direct measures, market-based controls are characterized by discouraging capital movements. A case in point is an implicit taxation of cross-border flows (e.g. Tobin tax; requirement of non-interest-bearing reserves). Capital restrictions have been imposed extensively during the 1990s by many Latin American and Asian countries.¹² The impact of this transaction type on currency relations clearly stems from restraining international capital transactions, which are major sources of exchange rate determination.

Besides these passive actions, monetary authorities can implement another broad intervention to manage exchange rates. Surrender requirements, as a tool of exchange controls, force e.g. exporters to surrender their foreign currency earnings to the central bank. By doing so, the

⁸Schulze (2000) gives an extensive textbook treatment on the use of capital controls.

⁹Many purposes of capital controls are mentioned in the literature. See e.g. Ariyoshi et al. (2000), and Frenkel et al. (2001). In the context of monetary policy issues, the most important objective of capital controls is to preserve central bank autonomy in the sense of focusing on domestic policy perspectives while alleviating exchange rate pressure.

¹⁰According to Alfaro (2004) further considerations are: 1) capture of domestic savings; 2) a stable tax base in the long run; 3) confinement of short-term flows in order to keep prices and wages sticky.

¹¹See Frenkel et al. (2001), and Neely (1999).

¹²See Kahler (1998), and Larraín (2000) for Latin American Countries. Clements and Kamil (2009) provide a most recent discussion on the effectiveness of capital controls in Colombia.

central bank offsets any potential exchange rate pressure. Ceding foreign currency to the authorities circumvents the exchange market and does not influence the price-setting of exchange rates directly. Surrender requirements have been imposed by several countries but were relaxed during the last years. One example is Argentina where this broad measure was implemented in the aftermath of the financial crisis in 2002.¹³

Furthermore, government transactions with foreign currency, which are not initiated by monetary authorities directly, can also be understood as a broad intervention. In this case, the public sector buys and/or sells foreign currency from or to the central bank. Hence, these transactions also circumvent the foreign exchange market, and thereby do not generate any direct exchange rate pressure.

1.1.2 Narrow Perspective of Interventions

While the definition of interventions in the broad sense includes measures, which affect the exchange rate at least indirectly, an intervention in the narrow sense can be understood as any transaction of a central bank in the foreign exchange market. This definition is different to many other views, which state that an intervention covers only operations intended to alter the current exchange rate behavior. The more general view, which includes the classical motive definition, can be justified by logic deduction of market mechanisms. In this context, any active central bank transaction (purchase or sale) of foreign currency influences the exchange rate. An observable impact is not necessarily required.¹⁴ This definition includes all types of direct market transactions. Most interventions are conducted on spot markets. However, some authorities also adopt forward transactions, swaps, and operations based on options to fulfill their objectives.¹⁵ In contrast to the broad perspective, monetary authorities adopt an active attitude by initiating an intervention. One may argue that changes in the foreign currency reserve level reflect foreign exchange interventions in the context of this definition. However, changes in foreign reserves

¹³See Irigoyen (2005). An overview of recent exchange restrictions and controls is given by Caruana (2007).

¹⁴This aspect will be of basic interest in chapter *four*.

¹⁵See Archer (2005), and Ito (2002). For instance, Colombian monetary authorities have adopted a rule-based intervention strategy with options. Against this background, Mandeng (2003) explicitly discusses the use of option contracts as an intervention measure. For a comprehensive discussion on the choice of market segments, see Canales-Kriljenko et al. (2006).

can be caused by several reasons and do not necessarily hint at central bank operations at the exchange rate market.¹⁶ Therefore it is excluded from the narrow perspective of interventions.

Most theoretical considerations on the mechanics of interventions focus on the motive-based discrimination of central bank operations. Consequently, the major part of the academic discussion on the use of this instrument is associated with this definition as well. It is argued that: "*OFFICIAL EXCHANGE rate intervention in the foreign exchange market occurs when the authorities buy or sell foreign exchange, normally against their own currency and in order to affect the exchange rate.*," [Sarno and Taylor (2001a), p. 839]. Another approach, which directly refers to the theoretic signaling channel, is given by Dominguez and Frankel (1993). The authors state: "*Foreign exchange market intervention is, most broadly defined, any transaction or announcement [oral intervention] by an official agent of a government that is intended to influence the value of an exchange rate...*," [Dominguez and Frankel (1993), p. 55]. Every signal monetary authorities give to the market should be seen as an attempt to alter the existing exchange rate. The understanding of this signal will be expanded in more detail in chapter *two*.

In contrast to these different definitions, I will refer to the narrow perspective of interventions if not stated explicitly.¹⁷ While the theoretical discussion is not hampered by this change, the empirical consideration in part II is clearly influenced. As mentioned earlier, the advantage of adopting this kind of definition stems from the fact that no information regarding the specific purposes are needed. This allows to examine the objectives, and the effectiveness of interventions without any further required assumptions. Furthermore, accounting for the broader perspective additionally possesses some advantages, which will become obvious in part II.

Central banks in emerging markets often use the above described intervention measures as reported by Mihaljek (2005). Based on a questionnaire, the author argues that some developing countries combine broad and narrow interventions to achieve their policy goals. Thereby, capital controls and further exchange regulations are often implemented to support active foreign currency transactions (i.e. fencing a herd of sheep).¹⁸ Some Asian developing countries reported

¹⁶Different sources are e.g. interest rate earnings, government transaction (broad perspective), and redemption of foreign currency debt.

¹⁷In the following, central bank interventions, operations, transactions, and measures are used as synonyms.

¹⁸von Hagen and Zhou (2005) discuss the determination of capital controls in the context of the underlying

that, according to their view, broad measures enhance the efficiency of narrow interventions. Their assistance becomes evident during turbulent times in foreign exchange markets. The advocates of this strategy based their opinion on two general arguments: Exchange restrictions enhance the relative size of narrow interventions in thin exchange rate markets by blocking large capital flows; broad interventions affect market expectations by signaling the will of monetary authorities to prevent unwelcome exchange rate movements. These arguments rest on theoretical considerations, which are part of chapter *two*. Other emerging markets did not make use of broader measures and focused solely on narrow interventions. They argued that broad interventions would impede the development not only of the financial but also the real economy.

1.2 Sterilization of Interventions

An important aspect of foreign exchange operations, which distinguishes them from normal monetary policy actions, concerns the sterilization of foreign currency purchases or sales. In order to clearly separate interventions from other monetary instruments, some authors refer to sterilized interventions when defining an intervention: "*... intervention means sterilized intervention,*" [Adam and Henderson (1983), p. 1].¹⁹ Basically, the sterilization of an intervention is the act of neutralizing domestic monetary expansion or contraction caused by the purchase or sale of foreign currency. Through neutralizing monetary effects, the central bank leaves the price for domestic money unchanged, and thus separates the intervention effect from an additional interest rate effect on the exchange rate. Furthermore, potential negative consequences of interest rate changes on an inflation target are ruled out. In this way, monetary authorities guarantee the independent use of their policy tools. Standard textbook treatments refer to sterilization as being based on a quantitative criterion.²⁰ However, this always depends on

exchange rate regimes. According to their results, the relationship between exchange rate regime flexibility and the degree of capital controls can best be described as a hump-shaped function.

¹⁹Moreno (2005) gives an overview on narrow versus broad interventions as well. His definition differs from mine in the way that only sterilized and motive lead interventions are contained in the narrow definition, whereas broad interventions are characterized by any foreign exchange transaction against the domestic currency. While surrender requirements are seen as an even broader definition of interventions, capital controls are excluded. Hence, his approach differs from the one adopted in this thesis in terms of generality.

²⁰In the end, sterilization refers to price stability in domestic currency.

Assets	Liabilities
<i>Intervention</i> = $\pm\Delta NFA$	\bar{B}
<i>Sterilization</i> = $\mp\Delta DA$	<i>Sterilization</i> = $\pm\Delta DL$

Table 3: A Stylized Central Bank's Balance-Sheet.

the adopted monetary framework. Especially in emerging markets it might be useful for the authorities to use foreign exchange transactions to manage domestic monetary conditions.

In order to isolate the effect of an intervention from the consequences of other monetary policy tools, a change in net foreign assets, caused by a central bank operation, must be compensated by an equal antithetical change in domestic assets. This leaves the monetary base unchanged, and does not affect domestic interest rates (see table 3). As a consequence, an intervention only changes the composition of the authorities' foreign and domestic assets. This classical form of sterilization runs through the asset side of the central bank's balance-sheet. Besides, the authorities can neutralize monetary changes by an expansion of their balance-sheet. In this context, the intervention induced monetary effect is absorbed by an equal directed shift in the domestic liabilities. The influence on the monetary base is taken away. Hence, sterilization can also run through the liability side of the central bank's balance-sheet.

1.2.1 The Mechanics of Sterilization

Table 4 illustrates the mechanics of sterilization running through the asset side. Let us assume that the origin of a foreign exchange intervention by the domestic central bank is the sale of foreign assets by the foreign banking system to the domestic banking system. Suppose, the foreign country to be the US, and the domestic country (currency area) to be the Eurozone. Furthermore, for the sake of simplicity, assume the exchange rate to equal 1.0 EUR/US\$. The rise in foreign and domestic claims (+ FA 100 US\$, + DA 100 EUR) is pitted against an ascent of the liabilities in both banking systems. The purchase of foreign assets leads to a higher supply of domestic currency, which is equivalent to an increase in the demand for foreign currency.

<i>Domestic Central Bank</i>		<i>Domestic Commercial Banks</i>		<i>Foreign Commercial Banks</i>	
Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
Repos 200 EUR	Reserves 200 EUR	Reserves 200 EUR	Repos 200 EUR		
Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
Repos 200 EUR	Reserves 200 EUR	Reserves 200 EUR	Repos 200 EUR	+ DA 100 EUR	+ FA 100 US\$
		+ FA 100 US\$	+ DA 100 EUR		
Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
Repos 200 EUR	Reserves 200 EUR	Reserves 200 EUR	Repos 200 EUR	DA 100 EUR	FA 100 US\$
I = + FA 100 US\$	+ DCB 100 EUR	FA 100 US\$	DA 100 EUR		
		- FA 100 US\$			
		+ DCB 100 EUR			
Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
Repos 200 EUR	Reserves 200 EUR	Reserves 200 EUR	Repos 200 EUR	DA 100 EUR	FA 100 US\$
- Repos 100 EUR	- Reserves 100 EUR	- Reserves 200 EUR	- Repos 100 EUR		
FA 100 US\$	DCB 100 EUR	DCB 100 EUR	DA 100 EUR		
Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
Repos 100 EUR	Reserves 100 EUR	Reserves 100 EUR	Repos 100 EUR	DA 100 EUR	FA 100 US\$
FA 100 US\$	DCB 100 EUR	DCB 100 EUR	DA 100 EUR		

Table 4: The Mechanics of Sterilization through the Asset Side of the Central Bank's Balance-Sheet.

Now, abstracting from any intervention motive, suppose that the domestic central bank absorbs the additional volume of foreign assets from the domestic banking system ($I = + FA 100 \text{ US\$}$). The domestic banking system cedes its foreign claims to the central bank and receives claims in domestic currency from the authorities ($+ DCB 100 \text{ EUR}$). This leads to higher monetary liabilities of the central bank, and raises the domestic money supply. At this point, the mechanics of sterilization become apparent. If the central bank does not want this transaction to have an effect on domestic monetary issues, it has the possibility to neutralize the expansionary effect by not revolving outstanding measures ($- \text{Repos } 100 \text{ EUR}$), which determine the reserves of the domestic banking system ($- \text{Reserves } 100 \text{ EUR}$). Alternatively, the central bank could sell other domestic assets (e.g. government bonds) to the domestic banking system. The crucial point is the requirement to absorb the excess liquidity from the domestic banking system in order to leave the monetary base unchanged. This in turn does not affect domestic monetary issues. While the sterilized intervention does not influence the monetary base (constant liabilities of the domestic central bank; $\text{Reserves} + \text{DCB} = \bar{B}$), the proportion of domestic and foreign assets in the central bank's balance-sheet changes ($\text{Repos } 100 \text{ EUR}, \text{FA } 100 \text{ US\$}$).²¹

1.2.2 Different Sterilization Measures

While in the above description, the central bank used Repos to sterilize the purchase of foreign currency, monetary authorities possess various measures to absorb excess liquidity or to offset monetary contraction. The application of different sterilization instruments always depends on the characteristic features of the domestic financial markets as well as the implemented monetary policy framework. As mentioned, monetary authorities can sterilize foreign exchange interventions by changing the stock of assets or by adjusting their liabilities. Several aspects are described in the literature covering the depth of sterilization and the applied measures.

Frankel and Okongwu (1995) distinguish between broad and narrow sterilization. While narrow sterilization measures leave the money base unaffected, broad sterilization refers to a constant money supply even if the monetary base changes. The idea is that interventions are

²¹A useful alternative presentation is given by IMF (2007a) Box 3.1.

sterilized as long as no monetary effect spills over into other sectors. Lavigne (2008) differentiates between market-friendly and non-market-friendly methods of sterilization. Market-friendly sterilization denotes open market transactions, which are based on voluntary bond purchases/sales. In contrast, non-market-friendly measures are designed so banks are forced to yield to sterilization instruments. These measures may contain forced bond transactions, mandatory deposits of commercial banks at the central bank or, most commonly, changes in reserve requirements.

Broad versus narrow, and market-friendly versus non-market-friendly distinctions can be seen as alternatives to a more comprehensive view proposed by Mohanty and Turner (2005).²² The authors break sterilization methods down into market and non-market instruments and discuss the factors, which determine the choice of a specific measure.²³ On the one hand, market instruments contain central bank assets or liabilities with a thorough market volume, which are actively traded by market members. This includes central bank securities, government bonds or money market instruments. On the other hand, a non-market instrument can be understood as an implicit taxation of the banking system. Reserve requirements are a common tool. Moreover, direct credit controls, interest rate taxation, and obligatory deposits at the central bank are further non-market sterilization measures.²⁴ Both instruments have their merits and should be considered carefully against the background of the underlying economic and financial situation. The main benefit of market instruments (with a high degree of marketability) is that they do not affect the depth of financial markets negatively. However, in case of thin and underdeveloped markets, as they can often be found in developing countries, the negative influence of market measures is obvious. After sterilizing foreign exchange interventions through the sale or purchase of bonds, prices may respond to an unpleasant extent, and the free development of the financial markets may be hampered. As noted by Mohanty and Turner (2006) prolonged sterilization could also impede the efficiency of banks, through gaining access to easy profits from holding large amounts of treasury securities. This calls for non-market sterilization methods, which in

²²See also Reinhart and Reinhart (1998) for a discussion of open market operations and changes in reserve requirements as different sterilization methods.

²³It is important to note that besides sterilization through monetary instruments, fiscal policy measures can be used to offset monetary effects as well. Thereby, the government might support the central bank. Whether this implies the central bank to be dependent on the government is another question.

²⁴It is common practice that reserve requirements and obligatory deposits yield no interest, and if so, only below market rates.

turn are not free from pitfalls themselves. The threat of an implicit taxation of the banking system becomes apparent in the case of capital inflows. Purchases of foreign currency to defend an appreciating exchange rate, which are sterilized by non-market measures, impose costs on the financial sector. This encourages financial disintermediation. Furthermore, domestic banks pass on inflicted sterilization costs to borrowers, leading to rising interest rates and triggers borrowing abroad. This could aggravate the situation, calling for even more foreign exchange interventions.

Another important aspect of sterilization, mentioned by Mohanty and Turner (2005), concerns the term-structure of market instruments. Whether to use long-term or short-term measures is basically a matter of flexibility and costs. For example, the issue of long-term bonds to non-banks is an effective method to offset excess liquidity from the economy (in the sense of Frankel and Okongwu (1995)). It implicitly restricts bank lending, forwards interest rate risks to the non-banking sector, and is an appropriate method when facing a continuous sterilization of long lasting interventions. Long-term bonds on the contrary may raise sterilization costs in the presence of significant inflation risks (risk premium), and do not possess enough flexibility when sterilizing temporary foreign exchange operations. For this reason, short-term instruments (swaps, short-term bills, direct borrowing from commercial banks) may be preferred. The flexibility of these methods allows the central bank to manage momentary exchange transactions and corresponding sterilization efforts more easily.²⁵ Sustained sterilization, however, uncovers their disadvantage. The perpetual renewal of sterilization leads to increasing costs in the presence of rising interest rates.²⁶ This constitutes the rollover problem of sterilization. On the other hand, the rollover problem may turn into a rollover opportunity in the case of sinking interest rates, reducing the sterilization costs of foreign currency purchases. In the end, the question which measure and related time structure to use cannot be answered pragmatically but depends on the specific conditions monetary authorities are facing.

²⁵Ho and McCauley (2006) discuss the use of several short-term money market instruments to absorb excess liquidity and its implications for monetary conditions in emerging markets.

²⁶Additionally, McCauley (2003) states that in the presence of similar government bonds, the issuance of high volumes of central bank securities may result in a market fragmentation leading to severe consequences for liquidity, price settings, and trading in domestic bond markets.

1.2.3 The Limits of Sterilization

How long can policies of a sustained sterilized intervention continue? When does it come to an end? Limits of sterilization basically refer to the case of sterilizing foreign currency purchases. The reason being that neutralizing foreign currency sales does not impose direct costs, except forgone earnings from declining foreign reserves. Furthermore, this kind of intervention is limited by the reserve level.²⁷ Basically, two broad barriers determine the limits of prolonged sterilization of purchase interventions.

(i) *The Inability of Controlling the Nominal Exchange Rate and Money Market Rates Simultaneously - The Impossible Trinity:*²⁸

While it is obvious that interventions are limited only in case of long lasting foreign currency sales through the level of foreign reserves, continuous purchases of foreign currency are not exposed to quantitative limits directly. Nevertheless, other criteria determine their limits. In this context, preventing interest rates from falling (neutralize foreign currency purchases) can generate even more appreciation pressure calling for more sterilization and rising costs. This leads to the decision whether to stop sterilization, and allow for falling rates, or stop the interventions, and allow the exchange rate to appreciate. In both cases, the exchange rate will appreciate in the long-run, if not in nominal terms then in real terms. However, depending on the domestic policy framework, reducing sterilization may not necessarily cause falling interest rates and/or rising inflation rates. One might think of interventions as a policy tool used to manage monetary aspects. More important is the question whether costs of sterilization rise to unsustainable levels.

(ii) *Costs Generated by Exchange Rate Developments and Interest Rate Differentials:*

Bofinger and Wollmershäuser (2003) and Wollmershäuser (2003) discuss prolonged sterilization from a budgetary costs perspective. The issuance of domestic debt to sterilize interventions

²⁷Besides common rules for a lower limit of foreign reserves as discussed by e.g. Williams (2005), Krugman (1979) argues that the quantitative limit of foreign currency sales is reflected by a critical threshold of net foreign assets. This level guarantees the credibility of foreign exchange transactions (sales) of monetary authorities.

²⁸This classical argument goes back to the Mundell-Fleming Model. A discussion of the history and the development of this model is given by Mundell (2001), and Obstfeld (2001).

produces costs for the central bank.²⁹ In contrast, the purchased foreign currency generates income through foreign interest rate gains and valuation effects. Interventions are limited with respect to the costs they cause. As soon as costs exceed earnings, the strategy of sterilization becomes unsustainable. Following Wollmershäuser (2003), sterilization charge and reserve income are described as:

$$C^s = C^i + C^V, \quad (1)$$

$$C^i = i^{domestic} - i^{foreign}, \quad (2)$$

$$C^V = -\Delta s. \quad (3)$$

Interest rate costs (C^i) occur if domestic rates exceed foreign rates. This implies that, in case of an increase in foreign reserves, foreign assets yield lower gains compared to domestic assets, and payments of domestic debt are greater compared to received earnings from foreign assets. Valuation costs (C^V) occur if the exchange rate appreciates (difference of the logarithm of the nominal exchange rate). An appreciating domestic currency lowers the value of foreign reserves expressed in domestic units. This leads to even lower revenues from foreign assets, and thus adds to total sterilization costs. The necessary condition for balanced costs and incomes is given by:

$$C^s = 0 \stackrel{!}{=} (i^{domestic} - i^{foreign}) - \Delta s. \quad (4)$$

This represents the validity of the UIP. Hence, as long as the UIP holds, no net expenses occur and sterilization is sustainable.

More recently, Frenkel (2007b) discusses the policy of sustained sterilization. Based on the contribution of Bofinger and Wollmershäuser (2003), he extends the discussion with respect

²⁹As is the case in classical models, authorities sell domestic bonds to sterilize interventions. See e.g. Argy (1994), Argy and Murray (1985). Against this background, Mohanty and Turner (2005) mention the problem of imperfect substitutability. In case these bonds carry a risk premium, agents call for an additional fee leading to higher interest rates. Now, higher bond rates raise opportunity costs and trigger an influx of money into domestic bonds, which leads to declining money market rates and produces a neutralizing effect on sterilization efforts. Hence, imperfect substitutability may impede sterilization to a significant degree.

to the level of foreign reserves and domestic liabilities. He explains that monetary authorities are able to sterilize their interventions (foreign currency purchases) indefinitely as long as the following condition holds:

$$i^{domestic} \leq (i^{foreign} + \Delta s) \frac{R}{L} = i^{max}. \quad (5)$$

According to equation 5, sterilization is sustainable as long as the domestic interest rate does not exceed earnings from foreign assets ($i^{foreign} + \Delta s$) weighted by the relationship of foreign reserves to domestic liabilities ($\frac{R}{L}$). The rationale being that the more the foreign reserves exceed domestic liabilities the greater earnings are compared to interest rate costs, assuming equal individual gains ($i^{domestic} = i^{foreign} + \Delta s$). In order to reequilibrate the relationship, the domestic interest rate paid on liabilities must rise up to i^{max} . In the end, sterilization is not only a matter of changes in interest rates and exchange rates but also a matter of the overall size of foreign reserves and liabilities.

The extension of level aspects and the estimation of earnings and costs, derived from sterilized interventions has, generally speaking, several constrictions. These restrictions are based on the above mentioned measures of sterilization. Firstly, domestic liabilities are assumed to be (equally) remunerated. However, it is common that central banks, especially in emerging markets, use non-interest-bearing instruments or several instruments with different remuneration rates when sterilizing foreign currency purchases. As described, the negative consequences do not only affect the central bank directly but also surface as a low degree of development of financial markets. Consequently, the above displayed interest rate i^{max} reflects the weighted average rate of all (interest-bearing) liabilities. Secondly, sterilization of foreign currency interventions can run through the liability side as well as the asset side of the central bank's balance-sheet. In this regard, sterilization costs may occur only partially. Thirdly, it is essential to compare costs and earnings from sterilized interventions. Therefore, only intervention induced changes in asset and liability stocks may be analyzed. This is particularly difficult when the sterilization is conducted through broad measures in general, and reserve requirements in particular. Fourthly,

the outcomes are extremely sensitive with regard to the employed interest rate, the distribution of different currencies in the foreign reserves, and the underlying duration of investments as well as the maturity of sterilization measures.³⁰ Only the exact knowledge of the applied measures and their actual structures allows to draw reliable conclusions. Hence, officially approved information are required to provide sufficient insights into the sterilization policy. For these reasons, the level extended UIP version serves as an indicator of sterilization sustainability and must be interpreted very carefully.

The costs and earnings of sterilized foreign currency purchases also surface in a different setting, being of a rather qualitative nature.³¹ In terms of qualitative earnings, depending on the nominal anchor, sterilization can signal stability by influencing expectations positively. Sterilization generates confidence in monetary targeting countries, which leads to stable expectations of the private sector. Moreover, growing foreign reserves result in falling sovereign risks, and declining costs of corporate finance. By contrast, several challenges of full sterilization do occur, especially in the context of emerging markets. Most of them were discussed by the different measures of sterilization. Additionally, Calvo (1991) argues that the issuance of domestic debt to sterilize foreign currency purchases may harm the authorities' credibility in achieving their goal of price stability. Rising debt costs, whether or not sustainable, may feed international investors' fear of a return to a high inflation rate policy, which is used to melt down the level of outstanding debts.³² In the end, the use of market or non-market instruments as well as their applied term structure has to be considered very carefully. If these matters are not addressed correctly, monetary imbalances, financial sector mismatches, and adverse implications for financial intermediation are the consequences leading to the inefficient allocation of resources.

³⁰For instance, the BCRA changed the composition of its foreign reserves in 2004, resulting in a shorter duration of the portfolio. This step was justified by an expected restrictive monetary policy by the Fed. Thus, authorities decided to be more flexible in the decision of investments. In 2007 the portfolio duration was extended again, so the central bank could maintain a more cautious investment strategy against the background of the stressed global financial situation. See BCRA (2004, 2007b).

³¹See Mohanty and Turner (2006) for more information on challenges of sterilization in emerging markets. The authors discuss the consequences in terms of fiscal costs, future monetary imbalances, financial sectors' imbalances and implications for financial intermediation.

³²See Kahler (1998) for several historical examples in Latin America.

1.3 Motives for Interventions

1.3.1 Some Short Considerations on Theoretical Aspects

Most academic contributions neglect the theoretical perspective as to why central banks intervene in the foreign exchange market. From a theoretic point of view, the matter of foreign exchange market interventions hinges upon the adopted exchange rate arrangement, and diminishes with the degree of exchange rate flexibility. In a classical fixed exchange rate arrangement, where monetary authorities peg the domestic currency to a foreign currency, the central bank intends to defend the exchange rate parity, which can be exposed to market pressure. Furthermore, theoretical exchange rate target-zone models incorporate foreign exchange market interventions by the central bank as being a "natural" monetary policy instrument used to defend the exchange rate target-zone. Krugman (1991), a famous contribution on exchange rate target-zones, proposes a model, which suggests that the investors' anticipation of foreign exchange market transactions, at the edge of the zone, should induce exchange rate stabilizing behavior of market participants. Hence, the official exchange rate arrangement influences the investors' expectations. In several contributions on the appropriate choice of exchange rate arrangements, Williamson (1996), a well-known advocate of intermediate exchange rate systems between fixed and floating rates (leading to a "*possible trinity*"), gives another theoretical perspective. According to his view, crawling rates/bands are the logical consequence, if the ills of exchange rate corner solutions outweigh their potential merits (fixed rate or floating rate). Consequently, foreign exchange interventions serve to defend the crawling band or peg. In contrast to fixed rates, exchange rate zone arrangements, or crawling pegs/bands, the reason for intervening within a policy framework of managed floating stems from the need to "manage" the exchange rate according the UIP. Wollmershäuser (2003) presents an extensive theoretical presentation of the managed floating theory as a monetary policy strategy.³³

³³However, the exchange rate system of managed floating is widely used by central banks to justify interventions without stating any concrete reason. This separates the theoretical underlyings of Wollmershäuser (2003) from practical use. The IMF gives the following definition: "*Managed floating with no predetermined path for the exchange rate: 8. The monetary authority attempts to influence the exchange rate without having a specific exchange rate path or target. Indicators for managing the rate are broadly judgmental (e.g., balance of payments position, international reserves, parallel market developments), and adjustments may not be automatic. Intervention may be direct or indirect.*" [IMF (2006), as of 20th January 2010].

In contrast to the systemic reasons for central bank foreign exchange market operations, it is not clear why authorities intervene in the exchange market when they have adopted an exchange rate arrangement which offers a high degree of independence in monetary policy? In this context, interventions of central banks, operating under a flexible exchange rate regime, are not thoroughly theoretically solved. Reitz and Westerhoff (2004) take a different perspective and discuss sterilized and unsterilized interventions in a chartist-fundamentalist model. According to the authors, the rationale for interventions stems from the goal of central banks to stabilize foreign exchange markets, which are exposed to speculative bubbles. Their idea is based on the noise-trading channel of exchange rate determination, which accounts for heterogenous market members.³⁴ Thereby, noise-trading behavior causes the exchange rate to move away from its fundamental value. Central bank interventions are necessary to keep the exchange rate within its fair level. Thus, market failures may justify the application of foreign exchange market operations in a full flexible system. It is intuitive that interventions, as a monetary policy tool, should help to reduce welfare costs (maximize welfare) as the ultimate goal of monetary policy. Especially in emerging market countries, which are more vulnerable to exchange rate movements, these costs might be significant. In this context, high exchange rate volatility affects the domestic economic and financial markets negatively, and rises welfare costs.³⁵ Hence, instead of serving as a shock absorber, which constitutes a positive feature of flexible exchange rates, free floating exchange rates might influence domestic welfare negatively when exposed to high volatility. This calls for interventions to calm exchange rate volatility. In a similar vein, Ho (2008) analyzes the welfare implications of central bank interventions in a general equilibrium model with microeconomic foundations. According to the author, foreign exchange operations induce an effect, which alters the allocation of liquidity in international financial markets.³⁶ As a result, interventions (sterilized or unsterilized) influence asset prices as well as real economic activity. In the end, the extent of the welfare effect, depends on the strength of the liquidity impact.

³⁴Theoretical intervention channels are discussed below.

³⁵See Bergin (2004).

³⁶The idea of an intervention liquidity effect goes back on Ho (2004), who presents an alternative intervention channel to the ones described in chapter *two*.

In general, the theoretical discussion on intervention motives is greatly hampered by the lack of an appropriate exchange rate determination model.³⁷ While some approaches perform quite well for different time horizons, others may be valuable for explaining different currency relations, at least to some extent. In this sense, Cheung et al. (2005) argue: *"In summarizing the evidence from this extensive analysis, we conclude that the answer to the question posed in the title of this paper [Empirical exchange rate models of the nineties: Are any fit to survive?] is a bold "perhaps." That is, the results do not point to any given model/specification combination as being very successful. On the other hand, some models seem to do well at certain horizons, for certain criteria. And indeed, it may be that one model will do well for one exchange rate, and not for another."* [Cheung et al. (2005), p. 1171]. If the academic literature has not found a reliable exchange rate determination model yet, one cannot expect to find a thorough approach explaining the rationale for central bank foreign exchange market interventions from a theoretic point of view. Of course, one could argue that open economy models should be seen as a basis for intervention determination models. However, since such models must also deal with the problem of insufficient exchange rate determination, and due to the fact that this thesis focuses on the empirical discussion of central bank interventions, I will not embark upon the existing insufficient theoretical background.

1.3.2 Empirical Motives

In this thesis, the discussion about intervention motives is restricted to non-fixed exchange rate regimes. It is intuitive that monetary authorities try to influence the exchange rate or accumulate foreign reserves. The various reasons to intervene depend on the importance of the currency's foreign value for the domestic economy. As touched upon earlier, central banks are very reluctant to publish their intervention motives. When communicating on their intervention strategies, if at all, monetary authorities do so in a very nebulous fashion. Over time, the following objectives have carried weight in intervention experiences in the past.³⁸

³⁷Meese and Rogoff (1983), a well-known paper dealing with exchange rate determination, find that a naive random walk outperforms other exchange rate forecasting models.

³⁸See e.g. Canales-Kriljenko et al. (2006), and Geršl (2004).

(i) *Correcting Exchange Rate Misalignments:*

Exchange rate misalignments include several outcomes of exchange rate behavior. Besides its role as a natural economic shock absorber, a stable nominal as well as a real exchange rate (equilibrium) is essential for economies. Nominal exchange rate stability signals economic steadiness, especially when credibility is lacking. Sudden short-term movements in either direction could endanger foreign currency denominated debt and deposit positions. Real stability, and by far more important, a stable real exchange rate equilibrium, determines the country's international competitiveness and its inflationary exposure. While an undervalued real rate could create inflationary pressure, an overvalued real rate may undermine the competitiveness of domestic producers in the world market. In any case, a stable nominal and real rate (equilibrium) reduces welfare losses, which are associated with currency mismatches. Furthermore, a stable exchange rate can meet the demands of a nominal anchor by curbing inflationary expectations. Basically, exchange rate misalignments are by far more important in emerging markets than in industrialized countries.³⁹ This is due to the fact that those countries are exposed to balance-sheet and exchange rate pass-through effects to a higher extent. The importance of sound exchange rate movements becomes evident in the light of dollarization and foreign-trade-based economic growth. In terms of correcting misalignments, the academic literature speaks of *leaning against the wind*, when monetary authorities try to counter an existing exchange rate trend, or *leaning with the wind*, in case a central bank tries to accelerate the actual exchange rate path.⁴⁰ Besides focusing on a fair value of the exchange rate, it is also possible that a central bank follows a policy of *begging the neighborhood*. Thereby, the authorities try to depreciate the domestic currency on purpose in order to enhance the country's foreign trade position so as to improve the current account.

(ii) *Preventing Disorderly Markets:*

It is an essential increment of intervention policies to guarantee a stable and appropriate functioning foreign exchange market, especially in developing countries. Typically, disorderly markets are characterized by high intraday exchange rate volatility, widening bid-ask spreads,

³⁹See Bergin (2004).

⁴⁰See e.g. Fatum and Hutchison (1999b, 2006).

accelerating exchange rate changes, and sharp changes in market turnover. When faced with such situations, central banks might step into the market in order to serve as a financial intermediate, matching supply and demand for foreign currency. In so doing, authorities play the role of a market maker and counter the negative conditions. Desiccating foreign exchange market liquidity can lead to severe consequences for the real economy. A disproportionate setting of exchange rate quotations could result in distorted distributions of resources, and encumber foreign trade development. Additionally, a thin market volume, combined with large intraday volatility, could lure speculative investors, resulting in even more irrational market behavior. However, the described market features can also be caused by changes in fundamental factors, and do not necessarily have to be traced back to disorderly markets. It is important not to restrict exchange rate market development. In this sense, some kind of inordinate market condition is necessary to stimulate hedging instruments, so as to enhance the mechanism of self-correction, and thus to wean the market from its dependence on the central bank.⁴¹ A properly functioning exchange rate market is an essential increment of a sound financial system. Hence, interventions to prevent a malfunctioning of markets should only be used if markets are in disorder.

(iii) *Accumulating Foreign Reserves:*

The confidence of foreign investors in the domestic economy depends, besides other factors, on the level of foreign reserves.⁴² Of course, the degree of a country's industrialization is another important factor. This highlights the relevance of this motive for developing countries. Foreign reserves provide a kind of collateral in case of debt defaults. Moreover, their level is a key determinant of the government's sovereign creditworthiness. Assuring debt repayments, and strengthening the external liquidity position, enhances the confidence of external investors, and improves the country's international credit ratings. Additionally, the vulnerability to external shocks can be alleviated through a strong external liquidity position.⁴³ Thus, a sound level of

⁴¹See Ötker-Robe and Vávra (2007).

⁴²Traditional theoretical thoughts deny the need of hoarding foreign reserves. Instead, they suggest that a country, which is operating with a floating exchange rate, does not require to accumulate foreign reserves due to the fact that the exchange rate generates adjustments in the presence of shocks. However, such an equilibrium process, if existent at all, can last very long to materialize and might be very costly.

⁴³See Mulder and Perrelli (2001). Several precautionary reserve benchmarks are discussed in the literature. The recommended minimum reserve levels account for short-term external debt, domestic monetary aggregates,

foreign reserves boosts the country's attractiveness and strengthens the economy in terms of financial and real economic shocks. With respect to the above stated definitions of interventions, the motive of accumulating foreign reserves clarifies the advantage of the broad/narrow perspective compared to the motive-based definition. The latter approach does not view such transactions to be interventions but rather to be exchange rate "neutral" operations. On the contrary, the former definition includes them, due to its direct influence on the exchange rate (narrow perspective), and due to its basic meaning in an economic context (broad perspective).

1.3.3 Alternative Empirical Motives

Although the above categorization captures the reasons for a central bank, operating under a flexible exchange rate regime, to intervene in the foreign exchange market, it has some drawbacks. The motives described above must be presented separately. For example, correcting exchange rate misalignments is a very broad definition of an intervention motive, which covers important self-standing aspects. In this context, the term-structure of intervention motives is not considered. Preventing exchange rate misalignments should be separated into a shorter and longer context. Based on the above objectives, it is more valuable to categorize the motives for interventions in four broad objectives. Therefore, central banks pursue the following intervention motives:

(i) *Short-Run Motive:*

Monetary authorities intervene to stabilize short-run exchange rate movements so as to assuage possible severe spillover effects from the perspective of financial and capital markets. Thereby, central banks try to alleviate potential pressure on the financial portfolios of private and public sectors. This includes the impact of exchange rate changes on debt and deposit positions. In this context, a short-term depreciation, although increasing the domestic value of foreign assets, expands foreign debt positions. While this might be unproblematic per se, it signals financial distress and could trigger capital flight. For a short-term appreciation, things imports, and GDP. A discussion of reserve levels in emerging markets is given by Green and Torgesen (2007).

do not seem as bad. However, overborrowing, especially at the short-end, is the seed of financial turmoils and should be watched carefully. Furthermore, short-term appreciation causes foreign currency denominated deposits to decrease in the domestic currency's value. Hence, there is always the other side of the coin. Consequently, this intervention motive is closely related to the matter of dollarization. In comparison to the above described objectives, the short-run motive refers to the desire of central banks to correct short-run exchange rate misalignments. Thereby, the time horizon may vary between several days.

(ii) *Medium-Run Motive:*

Monetary authorities intervene to stabilize medium-run exchange rate movements in order to support real economy development. While the short-run motive focuses on financial and capital market aspects, the medium-run motive mainly caters to real economic development (mainly international trade aspects). Since trade contracts are based on longer time horizons, the short-term motive does not cover real economic aspects sufficiently. Thus, the rationale for responding to medium-term exchange rate swings stems from the importance of stable exchange rate movements, which help to enhance the predictability of import and export prices. The economic growth of emerging market countries is often based on foreign trade relationships. The point is that not the exchange rate development per se is managed, which is determined by various economic fundamentals, but the amplitudes around a medium-term trend. Besides, predictable prices support investment decisions additionally. Closely connected to this intervention motive is the matter of real exchange rate stability. Its role for the international competitiveness is obvious. In addition to these trade considerations, accounting for medium-run stability supports inflationary expectations and signals economic strength. The time horizon may vary between several months.

(iii) *Target Motive:*

Although stating officially to let the exchange rate float freely, a central bank might try to defend an implicit exchange rate target. Of course, the purpose of targeting an exchange rate level undermines the very idea of free floating exchange rates. Nevertheless, it might be of practical relevance for central banks, especially in emerging countries. The idea of fixing the

exchange rate can be seen as a stronger outcome of the medium-run motive. Additionally, the role of the exchange rate as a nominal anchor for inflation expectations justifies this intervention objective. Authorities seek to "discipline" the exchange rate around an implicit target level. For instance, in the aftermath of a financial crisis exchange rates are prone to overreactions in either direction. Hence, the target should serve to calm global exchange rate reactions. Due to very restrictive consequences of a fixed level, a target band, which serves as a 'softened version' of this motive, might be of more practical value. As stated, fixing the exchange rate hampers the free development of exchange rate markets, especially in developing countries. Although the role of the exchange rate as a nominal anchor clearly dominates the target motive, the target bounds can be set for other reasons as well. An upper level compels the authorities to follow a *begging the neighborhood* policy, and takes account of the potential threat of imported inflation. A lower level may be set due to fiscal policy reasons based on tax revenues.

(iv) *Volatility Motive:*

The volatility motive reflects the aim of monetary authorities to calm down high exchange rate movements. A properly functioning exchange rate market is an essential ingredient of a sound financial system. Basically, it states that monetary authorities should prevent disorderly markets.

The objective of accumulating foreign reserves is not regarded explicitly. Besides these motives, a central bank might buy or sell foreign currency for reasons other than wanting to influence the exchange rate directly. Client transactions and portfolio adjustments are just two aspects. Moreover, further objectives might stem from domestic monetary policy considerations. Especially in the case of an underdeveloped domestic financial system and a high degree of foreign currency in the domestic economy, one source of monetary creation can be provided by exchange market transactions. Finally, the motive of gaining profits through interventions has to be mentioned at this point. Brought forward by Friedman (1953), the basic idea is that a central bank should buy foreign currency when its price is low and sell it when its price is high. By doing so, the authorities stabilize the exchange rate. According to Friedman (1953), speculations have a stabilizing character. However, he assumes market behavior to be based

on fundamental assessment. As will become clear in the next chapters, international investors do not act in this way but show irrational patterns of behavior. The profitability motive is associated with the purpose of stabilizing exchange rates. Ultimately, interventions are effective when gaining a profit. Thereby, the term structure is not fixed. Profits can be achieved within a day or within several years. Empirical studies testing the profitability of interventions are given by e.g. Jacobson (1983), Leahy (1989), LeBaron (1996), Pattanaik and Sahoo (2003), and Taylor (1982). While some reveal that monetary authorities have gained profits from their intervention policies, others show that central banks suffered significant losses. However, in my view this motive, though being attractive at first glance, is no valuable choice for empirical analysis of intervention objectives. Practical problems of measuring profits and, more importantly, the disconnection to price stability as the ultimate goal of monetary policy relativizes this "by-product" of exchange market operations.

1.4 The Secrecy Puzzle

An important aspect worth mentioning is the communication policy of a central bank with respect to its foreign exchange interventions. As mentioned above, monetary authorities are very reluctant to provide any information on their exchange market operations. This constitutes the well-known *secrecy puzzle*, which is still a challenge in the current academic literature. However, one should assume that interventions have to be communicated publicly, like monetary policy instruments in general. This transparency, which would be in line with the IMF's code of good practices on transparency in monetary and financial policies, should support a central bank's credibility and enhance its effectiveness in conducting monetary policy.⁴⁴ Most recent theoretical and practical considerations are given by Beine and Bernal (2007), Beine et al. (2009a), Chiu (2003), Ferré and Manzano (2009), and Gnabo (2008).⁴⁵ Basically, four reasons, which emerged from the academic discussion, can explain why central banks intervene secretly instead of communicating their operations actively.

⁴⁴See IMF (1999).

⁴⁵For previous works on the *secrecy puzzle*, see Bhattacharya and Weller (1997), and Dominguez and Frankel (1993).

(i) *Market Rumors:*

Monetary authorities are inherently reluctant to generate any rumors which could endanger the orderly market process and trigger speculative attacks. While this could be desirable when intended to affect the exchange rate directly, it is not welcome for other market operations. Thereby, authorities could try to "manage" the speculative behavior, which is in line with the noise-trading idea presented below. Nevertheless, client transactions, reserve accumulation, or portfolio adjustments justify the discretionary attitude of central banks.

(ii) *Policy Inconsistency:*

Inconsistency between actual interventions and the underlying monetary policy in general as well as the exchange rate policy in particular is an additional factor explaining interventions' secrecy. Exchange market operations are kept concealed in order not to lose credibility, which is perhaps the most efficient instrument a central bank possesses. Several examples exist for inconsistent intervention behavior. Supporting domestic exports in world markets while increasing domestic interest rates is one possible example. While such inconsistencies may be preferable in the short-run, it is assumed not to be of long-term nature. Another instance is given by the case of a foreign central bank asking for support in order to ensure a target level, or to conduct client transactions. The domestic authorities will not communicate those transactions in order not to send wrong signals to the market.

(iii) *Central Bank Dependency:*

Since some central banks are not entitled to decide whether or not to intervene, they might choose to do so in secrecy. Especially in conjecture with 'policy inconsistency,' such transactions might not reflect the bank's general view. Therefore, one has to distinguish between a monetary authority who is in charge of intervention decisions, and a central bank which is delegated by the government. In the second case, secret interventions might reflect a potential conflict between a central bank and its fiscal authorities. Beine and Bernal (2007) argue in the following way: "*...the central bank will, try to minimize the impact of any intervention decision by some external authority as long as it is considered inconsistent with own objectives or with the general stance of its policy.*" [Beine and Bernal (2007), p. 295]. However, if no conflict about the appropriate

exchange rate policy exists, interventions could also be kept secret due to the inconsistency between statements and actual interventions.

(iv) *Track Record:*

The success of previous central bank interventions is a further determinant for monetary authorities to keep interventions secret or to make them publicly known. The causality runs in both directions. If the central bank's previous interventions were ineffective in achieving their goals, monetary authorities will tend to conceal further interventions. The fear of losing or weakening their credibility warrants secrecy. Additionally, if the authorities lack sufficient credibility, they will not publish their transactions for the sake of not disturbing the market, which could result in higher exchange rate volatility. If, however, previous interventions have been effective, future interventions are likely to be published. Success enhances credibility, which in turn rises the power of monetary authorities when using foreign exchange market interventions.

Hence, the choice whether to intervene secretly or make interventions publicly known depends on various issues, and is therefore a complex decision-making matrix. The common consequences of the described arguments are the damage to the authorities' credibility, and the threat of speculative attacks. Moreover, an additional important aspect concerns the intervention tactics of the central bank. Besides the fact that the right timing of a secret intervention can enhance the effectiveness through inducing market-based transactions, an appropriate trading strategy supports the purpose of keeping foreign exchange transactions concealed. For the sake of secrecy, a central bank should deny trading with the most visible trading platforms and counterparts.⁴⁶ Furthermore, as noted by Dominguez and Frankel (1993), and Enoch (1998) the greater the size and the frequency of an intervention the more difficult it is to keep them secret. Furthermore, if maintaining the secret fails, the central bank's reputation might erode even more. In this vein, Gnabo (2008) states: *"As a result, a contradiction may emerge between the desire to intervene secretly and to preserve its reputation, and the necessity to invest sufficiently large amounts to ensure the efficiency of the operation,"* [Gnabo (2008), pp. 163-164].

⁴⁶See Canales-Kriljenko et al. (2006).

The above stated arguments for keeping intervention activities secret are important for emerging market central banks. According to Canales-Kriljenko's (2003) survey about practices on interventions in developing and transition countries, about half of the respondents reported that they did not announce their activity in the market when being present.⁴⁷ The potential consequences of loosing credibility, and attracting speculative attacks are too striking, especially if already vulnerable to those threats. Indeed, central banks in emerging markets experience credibility problems. This stems either from a crisis in recent economic history, or from being independent for only a short time. Thereby, a change in the monetary policy framework can cause poor reliability. In this case, the lack of independent policy-making experience might be directly related to the degree of credibility. Emerging markets tend to behave what Calvo and Reinhart (2000) call the *fear of floating*. Although stating to let their currencies float freely, developing countries implicitly follow a fixed or crawling exchange rate target. As stated by Archer (2005), official interventions to defend these targets may impel international investors to bet against the central bank. Therefore, keeping the central bank's action, or even its limit, to defend the targets a secret is of crucial importance. The question is whether investors perceive a central bank as strong enough to guarantee the target. Prolonged official interventions, which are ineffective, undermine the credibility of monetary authorities, and thus raise the probability of speculative attacks. However, this is also a matter of the appropriate exchange rate system. The strategy of managed floating (in the sense of the definition brought forward by the IMF), alleviates pressure on the central bank, since international investors do not know the exchange rate target to attack.

Most theoretic intervention channels, which will be discussed in the next section do not take secrecy into consideration. Instead, they require interventions to be published in order to have an impact on the exchange rate. Against this background, Dominguez and Frankel (1993) as well as Sarno and Taylor (2001a) favor interventions to be communicated actively.

⁴⁷It is very interesting that interventions are kept secret even within a central bank. Based on discussions at the conference "*New Challenges to Central Banking in the Global Financial System*" held at 11th and 12th, June 2009 in Namur (Belgium), members of the Bank of Indonesia and the Bank of Romania both agreed that they were not able to obtain data on foreign exchange market interventions conducted by their respective central banks.

Their arguments are based on the premises of the signaling channel. Within this approach, interventions provide a signal to the market. For adjusting their expectations more rapidly, market agents have to be informed about exchange market operations (signals). However, more recent approaches incorporate the issue of secrecy, and open a strand of theoretic thoughts which all try to explain why central banks intervene secretly. In this context, the noise-trading approach proposed by Hung (1997), and the microstructure models provided by Vitale (2006) as well as Ferré and Manzano (2009), account explicitly for secret interventions and the right timing of interventions. Thus, though the literature cannot thoroughly deal with the question why authorities intervene in the foreign exchange market, new intervention channels provide the base for explaining the even more complex issue of secret interventions.

2 Intervention Channels

In sharp contrast to the poor theoretical literature on intervention objectives, many discussions are available for theoretical effects of foreign exchange market interventions on the exchange rate. For this reason, I will give a more detailed presentation at this point. The channels by which interventions influence exchange rates are based on the several types of exchange rate determination models.⁴⁸ The main differences between these approaches concern the role of the exchange rate, the assumptions on expectations, the homogeneity of foreign and domestic assets, and the specific ways the behavior of market members are modeled. The literature has come a long way in explaining exchange rate movements.⁴⁹ The lack of an appropriate, generally accepted, exchange rate model impedes the evaluation of the intervention channels. Therefore, empirical evidence on these transmission channels is rather weak. Wollmershäuser (2003) summarizes empirical findings for the validity of intervention channels and their critical aspects. Although the following quote is given in the context of the portfolio-balance model, it is, in my view, very suitable to conclude the discussion on the empirical evidence of intervention channels: *"... is it scientifically correct to dismiss the effectiveness of interventions by using a model of exchange rate determination that is only casually suitable for explaining and predicting exchange rate movements? In our view it is not..."* [Wollmershäuser (2003), p. 202].

This chapter discusses the influencing channels of foreign exchange market interventions, focusing on the traditional asset approach and the more recent microstructure view of exchange rate determination. Foreign exchange market interventions are assumed to possibly work through five channels.⁵⁰ It is a mix of international money shifts, portfolio adjustments, expectation movements, adjustments of market participants' trade positions, and new information revealed through order flows, which can alter the exchange rate, if at all. The theoretical channels described below are very unlikely to appear on their own. Moreover, a combination of all mechanisms can be assumed. This aspect must always be kept in mind when drawing

⁴⁸There exists a vast body of literature dealing with this field of research and summarizing corresponding theoretic intervention channels. See e.g. Almekinders (1995), Edison (1993), Frankel (1993), Hallwood and MacDonald (2000), Humpage (1991), Hüfner (2004), Pilbeam (2006), and Sarno and Taylor (2001a, 2002).

⁴⁹For a thorough empirical discussion of exchange rate determination models, see e.g. Rosenberg (2003).

⁵⁰For a very readable short overview, see Geršl (2004).

conclusions on the underlying theoretic models. If not mentioned explicitly, small variables in the following sections indicate natural logarithms, except the interest rate, whereas capital letters reflect standard levels. A foreign country's variables are denoted with an asterik.

2.1 The Monetary Channel

The monetary model in determining exchange rates can be seen as a combination of the PPP and the quantity theory of money. This classical model assumes the exchange rate to be determined by the international supply and demand for money, and is associated to the asset approach. Domestic and foreign assets are seen to be equally risky. Therefore, their expected rates of return are equally as expressed by the UIP. The causality runs from a change in the money supply over a corresponding change in the price level (quantity theory) to a change in the exchange rate (PPP). The monetary channel is divided into two parts, which diverge with regard to the validity of the PPP. The flexible version of the monetary model assumes prices (wages, goods prices, exchange rates) to be perfectly flexible in the short-run as well as in the long-run. In contrast, the sticky version of the monetary model, which can be traced back to Dornbusch (1976), argues that in the short-run, prices are sticky and only flexible in the long-run. However, the exchange rate responds already in the short-run. Since the same outcome is reached by means of different ways, I will focus on the flexible-price version considering a two-country model.⁵¹

2.1.1 The Flexible-Price Model

Within the flexible-price monetary model, the PPP is assumed to hold continuously (equation 6). This implies that produced goods of a domestic and foreign country are perfect substitutes.

$$s_t = p_t - p_t^*. \tag{6}$$

Each country holds (issues) money and bonds. While both countries are assumed not to hold each others' money, domestic and foreign bonds are supposed to be perfect substitutes.

⁵¹The model is presented according to Hallwood and MacDonald (2000).

Furthermore, it is assumed that market participants do not face any capital restrictions, and can adjust their portfolios immediately as a response to any exogenous disturbance. The UIP holds perfectly, which implies that investors are risk-neutral (equation 7).

$$s_{t+1}^e - s_t = \Delta s_{t+1}^e = i_t - i_t^*. \quad (7)$$

Because the exchange rate serves as the relative price of two currencies, domestic and foreign money demand is of crucial importance. The countries' money markets are equilibrated, if the supply of money ($m_t^{S(*)}$), exogenously determined by the authorities, equals its demand ($m_t^{D(*)}$) as described by equations 8, and 9. The demand for money ($m_t^{D(*)}$) in both countries is related positively to real income ($y_t^{(*)}$), and the price level ($p_t^{(*)}$) but negatively to the nominal interest rate ($i_t^{(*)}$).

$$m_t = m_t^S = m_t^D = \beta y_t + p_t - \phi i_t, \quad (8)$$

$$m_t^* = m_t^{S*} = m_t^{D*} = \beta y_t^* + p_t^* - \phi i_t^*. \quad (9)$$

Accordingly, β (> 0) denotes the income elasticity of money demand, and ϕ (> 0) denotes the interest rate's semi-elasticity. For the sake of simplicity, β and ϕ are assumed to be identical across countries. By subtracting equation 9 from equation 8, and accounting for equation 6, a reduced-form equation for the exchange rate determination within the flexible-price monetary model is given by:

$$s_t = m_t - m_t^* - \beta (y_t - y_t^*) + \phi (i_t - i_t^*). \quad (10)$$

A relative increase in the domestic money supply leads, c.p. to an equal mark-up (depreciation) in the exchange rate (equation 10). This is due to the fact that a relative rise in the domestic money supply leads, via the quantity theory of money, to a higher domestic price level. This in turn makes domestic goods, which are equal to the foreign goods, more expensive. Following the PPP, the exchange rate depreciates.

A relative increase in domestic income results in an appreciation of the domestic currency.

Since more income raises money demand (transaction demand for money), the domestic market deteriorates. An equilibrium can only be achieved, if the domestic price level falls at a given interest rate. This in turn requires the PPP to hold strictly, and the exchange rate to appreciate accordingly. Thus, the rise of the domestic currency's foreign value unifies real money supply and demand.

A relative increment in the domestic interest rate leads to a fall in the foreign value of the domestic currency. This might seem counter-intuitive at first but stems from the impact on the money demand, and is a consequence of the above stated assumptions. Rising domestic interest rates boost the opportunity costs of holding money. The resulting decrease in money demand disequilibrates the domestic market. In order to renew the balance, the domestic price level must rise which, in turn, is only possible via a depreciation of the domestic currency. In both cases, the effect of a change in real income and price levels runs through the demand of money and the assumption of a strict PPP.

Alternatively, it is possible (as an expansion) to introduce expectations through the relationship between the interest rate differential and the exchange rate. With a continuously holding PPP and UIP, and using the Fisher parity, the following equation can be obtained:⁵²

$$i_t - i_t^* = \Delta s_{t+1}^e = \pi_{t+1}^e - \pi_{t+1}^{e*}. \quad (11)$$

The expected change of the exchange rate can be explained by the interest rate differential, or the expected difference of domestic and foreign inflation rates as expressed by equation 11. Consequently, a step up in domestic interest rates reflects a rise in expected inflation and increases the opportunity costs of holding money as described in equation 12.

$$s_t = m_t - m_t^* - \beta(y_t - y_t^*) + \phi(\pi_{t+1}^e - \pi_{t+1}^{e*}). \quad (12)$$

In order to restore the real money balance at a given money supply, domestic prices must

⁵²The Fisher parity states: $i_t^{(*)} = r_t^{(*)} + \pi_{t+1}^{e(*)}$; $\pi_{t+1}^{e(*)} = \Delta p_{t+1}^{e(*)}$. Real interest rates are assumed to be equal in both countries $r_t = r_t^*$.

increase and the exchange rate depreciates. This reflects the equal adjustment process of goods and asset markets within the flexible-price monetary model.⁵³ However, the role of expectations in determining exchange rates will be discussed in more detail below. Furthermore, since the focus is on the effect of interventions within the monetary model of exchange rate determination, I will discuss the impact of foreign exchange market interventions on the money supply.

2.1.2 The Effect of an Intervention in the Monetary Model

The meaning of interventions within the flexible-price monetary model is straightforward. The argumentation runs from the money supply side, duly determined by monetary authorities. An increase in the supply of money causes the exchange rate to depreciate, whereas a decline leads to an appreciation of the exchange rate. In this context, any purchase or sale of foreign currency, which is not neutralized, influences the monetary base, money supply in the money market, and thus alters the exchange rate. Because the sterilization of intervention leaves the monetary base unaffected, monetary models rule out the possibility of neutralized interventions to affect the exchange rate. The relative price of two monies cannot be changed, if the monetary base remains intact.⁵⁴ In this sense, Sarno and Taylor (2001a) note: *"In general, a strong consensus exists in the profession that nonsterilized intervention can influence the exchange rate similarly to monetary policy by inducing changes in the stock of the monetary base which, in turn, induces changes in broader monetary aggregates, interest rates, market expectations and ultimately the exchange rate."* [Sarno and Taylor (2001a), pp. 841-842].

⁵³At this point, a more in-depth note on the sticky-price model seems warranted. The crucial difference to the flexible-price model is that the PPP is assumed to be violated in the short-run but holds true in the medium-run and long-run. This modification, which is introduced by Dornbusch (1976) in his "overshooting" model, accounts for empirical observations of highly volatile real exchange rates. This fact is incompatible with a continuously holding PPP (constant real exchange rate). Since prices are assumed to be sticky, goods and asset markets experience different speeds of adjustment when being exposed to an exogenous shock (e.g. money supply). Because the asset market clears instantly, the exchange rate "over"-reacts in the short-run relative to its long-run level, which is determined by the PPP. In this context, a rise in real money supply ($\frac{M}{P} \uparrow \rightarrow$ prices are sticky) decreases domestic interest rates and triggers capital outflows. The exchange rate overshoots until the expected exchange rate appreciation equals the interest rate differential (validity of UIP). In the medium-run to long-run, however, real money supply decreases ($\frac{M}{P} \downarrow \rightarrow$ quantity theory of money), which in turn increases interest rates. The exchange rate converges to its long-run level determined by the PPP.

⁵⁴As stated by Geršl (2004), the impact of nonsterilized interventions on money market interest rates also depends on the existence of standing facilities, which prevent interest rates from departing too much from a predefined target. Hence, the discussion of the monetary effect must incorporate the implemented monetary framework (interest rate targeting, monetary targeting).

Due to the adopted definition of interventions in most academic discussions, the monetary channel only plays a minor role within the theoretical transmission processes of central bank interventions.⁵⁵ As explained above, many researchers only speak of sterilized foreign exchange operations as interventions. In this case, the monetary channel is excluded from the discussion on how interventions affect the exchange rate. Furthermore, the use of unsterilized interventions to manage exchange rate aspects can cause severe consequences. In this context, an intervention cannot be distinguished from normal monetary policy actions, and could hinder the management of domestic monetary aspects. Humpage (2003) states: "*As a general rule, central banks have little to gain from non-sterilized foreign exchange-market interventions. They can conflict with domestic monetary-policy objectives, and even when that is not the case, they are completely redundant to open market operations in domestic securities.*" [Humpage (2003), p. 7].

Independent of the discussion of whether an unsterilized intervention is a self-contained instrument or just a normal policy action, Almekinders (1995) points towards the importance of the underlying monetary base. An intervention may be just too small to generate a sizable change of monetary aggregates. While this holds true for industrialized countries, this transmission channel should be of more relevance in emerging market countries, since those markets have generally lower overall monetary base levels. Moreover, the monetary idea of interventions does not account for the issue of secrecy described in chapter 1.4. Whether a central bank publishes or conceals its intervention has no bearing on the exchange rate in the theoretical realm.

The non-interventionist policy of the first Reagan administration relied on the implications of the monetary model. During the years 1981 to 1984, the US government adopted an explicit policy of *laissez-faire* towards foreign exchange market interventions. The "Secretary for Monetary Affairs," Beryl Sprinkel, argued that, according to the monetary model, sterilized interventions would not have any effect on the exchange rate. He based this policy stance on the subsequent findings of the famous report of the working group lead by Philippe Jurgensen in the early 1980s, which points out that: "*Die Simulationsergebnisse ... bestätigen vielmehr, daß der Einfluß neutralisierter Interventionen viel geringer war als der von Interventionen,*

⁵⁵For surveys and discussions of monetary models of exchange rate determination, see e.g. Bilson and Marston (1984), Edison (1990, 1993), and Pentecost (1993).

die sich unmittelbar auf die monetären Verbindlichkeiten der Behörden (d.h. auf die monetäre Basis) auswirken konnten (nichtneutralisierte Interventionen)." [Jurgensen et al. (1984), pp. 99-100].⁵⁶

2.2 The Portfolio-Balance Channel

The introduction of market participants' expectations in the monetary model has been a starting point for shedding some new light on the behavior of exchange rates. The portfolio-balance approach goes one step further, and admits for imperfect substitutability of international assets. Furthermore, while the monetary model concentrates on the supply and demand for money as the crucial determinants for the exchange rate, this model incorporates all financial assets.⁵⁷

Within the portfolio-balance approach, global investors hold a diversified portfolio of domestic and foreign bonds (assets). Hence, agents optimize their investments according to their expectations regarding the profitability of domestic and foreign assets. The composition of their portfolios varies, due to the fact that international assets are imperfect substitutes. This assumption is intuitive, since different taxations, political situations, and liquidity considerations influence the investors' risk consciousness. The UIP described in equation 7 transforms to a risk-adjusted version:

$$\Delta s_{t+1}^e = i_t - i_t^* - \eta, \quad (13)$$

$$s_t = s_{t+1}^e - i_t + i_t^* + \eta. \quad (14)$$

As can be seen from equations 13 and 14, η states the risk premium required on domestic bonds/assets. A positive risk premium ($\eta > 0$) indicates that the domestic assets are seen to be riskier than foreign assets.⁵⁸ This in turn means that the return of domestic assets (i_t) is higher compared to the expected return of foreign assets ($i_t^* + \Delta s_{t+1}^e$). International investors require an additional fee to willingly take over more risk. Consequently, the positive risk premium

⁵⁶See also Jurgensen (1983).

⁵⁷See Rosenberg (2003).

⁵⁸See Pilbeam (2006).

on domestic currency constitutes a negative risk premium on foreign currency. In the case of a negative risk premium ($\eta < 0$) on the domestic currency (!), market members view foreign assets to be riskier and call for an additional fee in order to hold more chancy foreign assets.

In contrast to the monetary channel, the assumed risk aversion of asset holders, and the resulting fact that investors are not indifferent to the currency composition of their portfolios, make the influence of sterilized intervention on the exchange rate a worthwhile discussion topic.

2.2.1 The Basic Portfolio-Balance Model

The basic portfolio-balance model can be described by the following equations:⁵⁹

$$W = M + B + SF, \quad (15)$$

$$M = m(i, i^* + \Delta s^e) W \quad m_i < 0, m_{i^* + \Delta s^e} < 0, \quad (16)$$

$$B = b(i, i^* + \Delta s^e) W \quad b_i > 0, b_{i^* + \Delta s^e} < 0, \quad (17)$$

$$SF = f(i, i^* + \Delta s^e) W \quad f_i < 0, f_{i^* + \Delta s^e} > 0, \quad (18)$$

$$\text{Supply} = \text{Demand}. \quad (19)$$

The considered assets within the portfolio-balance model are money (M), domestic bonds (B), and foreign bonds (F). Again, domestic residents are supposed not to hold foreign money. Money and interest-bearing bonds constitute the wealth of domestic residents as expressed by equation 15.⁶⁰ Thereby, the demand for money and bonds depends on domestic and foreign interest rates and expected exchange rate developments, and are assumed to be homogenous functions in nominal wealth which allows the demand functions to be written in nominal terms (equation 16, 17, 18).⁶¹ An equilibrium in asset markets is reached, if the supply of assets, which

⁵⁹The model grounds on Hallwood and MacDonald (2000). The presentation focuses on the asset sector of the portfolio-balance model. The current account is neglected. Incorporating current account issues does not yield different results, but would expand the discussion unnecessarily. For a very readable presentation how the current account functions within the portfolio-balance model, see Pilbeam (2006). For more presentations of the portfolio-balance model, see e.g. Branson and Henderson (1985), Edison (1993), and Sarno and Taylor (2002).

⁶⁰Foreign bonds F are denoted in foreign currency. However, the wealth of a domestic resident is denoted in domestic currency. Therefore, the value of foreign bonds is converted into domestic currency SF .

⁶¹Actually, the asset demand functions and the wealth composition should be real termed. However, the assumption of homogeneity of assets to wealth makes prices negligible.

is assumed to be exogenously determined, equals the demand for assets (equation 19). Partial derivatives are given by x_k for $x = m, b, f$, and $k = i, i^* + \Delta s^e$. Furthermore, as mentioned above, domestic and foreign bonds are suggested to be imperfect substitutes, and a greater proportion of an increase in domestic wealth is held in domestic bonds (home bias). For the sake of simplicity, asset demand equations are not dependent upon income, and expectations are assumed to be static, so that $\Delta s^e = 0$. The assumption of static expectations, however, will be relaxed later on, since expectations are of crucial importance.

Figure 1 shows the short-run determination of the exchange rate in the basic portfolio-balance model. Due to the assumption of a small open country, the foreign interest rate is assumed to be exogenously given and equals the world interest rate ($i^* = \bar{i}^*$). The slopes of the lines in figure 1 are intuitive. The MM line locals all money market equilibria for a specific interest rate i and an exchange rate S . It is upward sloping because a rise in the price of foreign currency (exchange rate depreciation), which increases the level of wealth, needs a higher domestic interest rate in order to restore the money market by raising the opportunity cost of holding money. The same wealth effect, that pushes the money demand, drives the demand for bonds. Therefore, the BB line, which describes a balanced domestic bond market, has a negative slope. Since, for a given supply, a higher interest rate makes domestic bonds more attractive, the excess demand can only be rebalanced, if the exchange rate appreciates. This lowers wealth through a revaluation of foreign assets. An even foreign bond market is characterized by the FF line. Like the BB line, it is downward sloping because a fall in the domestic interest rate makes foreign assets more attractive and results in an increased demand for foreign bonds. Consequently, the price of foreign bonds must step up (exchange rate appreciation) in order to rebalance the market. However, the FF line is flatter since we assume foreign and domestic bonds to be imperfect substitutes. Point E determines the short-run equilibrium in the asset market. Given the wealth constraint in equation 15, an equilibrium in two of the three markets enclose an equilibrium in the third market. So, it is sufficiently to analyze two of three schedules.

Since sterilized interventions have no leeway within the monetary channel, the next section explicitly focuses on the effect of this kind of intervention within the portfolio-balance model.

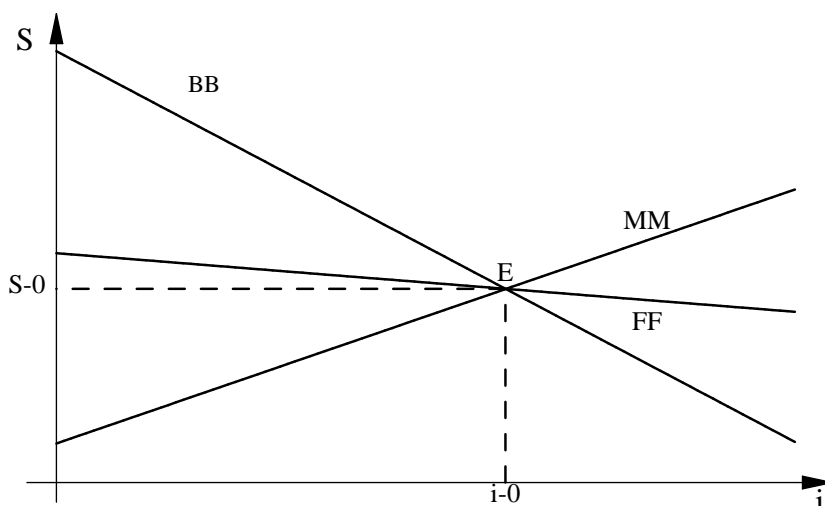


Figure 1: The Portfolio-Balance Model: Asset Market Equilibrium.

2.2.2 Sterilized Intervention within the Portfolio-Balance Model

Suppose the domestic central bank to intervene in order to bring down the domestic currency's value for the sake of an unaffected monetary base. Therefore, the authorities buy bonds denominated in foreign currency, and sell domestic bonds to the private sector simultaneously, in order to absorb the excess liquidity.⁶²

Figure 2 displays the adjustment process of a sterilized intervention.⁶³ Starting in equilibrium E , an instantaneous purchase and sale of foreign and domestic bonds respectively, causes an excess demand for foreign bonds, and an excess supply of domestic bonds. Consequently, the FF and BB lines shift upwards ($FF-1$, $BB-1$). Point $E-1$ characterizes the new equilibrium in the asset markets. The interest rate is higher ($i-0 \rightarrow i-1$) in order to absorb the excess supply of domestic bonds, and the exchange rate ($S-0 \rightarrow S-1$) has depreciated for the reason of absorbing the excess demand for foreign bonds. This switch leads to an exchange of domestic assets for foreign assets in the private sector's portfolio, leaving the total sector wealth unchanged.

⁶²When discussing the effect of sterilized interventions within the portfolio-balance model, attention should be paid to the fact that the domestic central bank cannot carry out a sterilized purchase or sale of foreign money (!). Domestic agents (and for the same reason foreign agents) are only supposed to hold their own money. The only possibility for a central bank to hold up or bring down the value of the domestic currency is to sell or buy foreign bonds to, or from, the private sector.

⁶³The adjustment is described according to Pilbeam (2006).

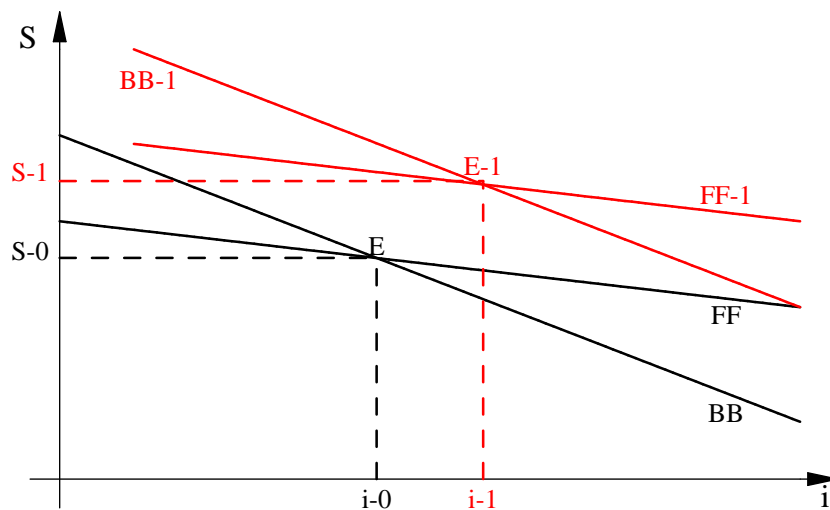


Figure 2: A Sterilized Intervention within the Portfolio-Balance Model.

This outcome is clearly in contrast to the monetary model presented above. Why does a sterilized intervention affect the domestic interest rate, although the monetary base is left unchanged? The answer is that monetary models assume domestic and foreign assets to be perfect substitutes. Therefore, changes in the portfolios of international investors need no adjustment in their specific yields. Thus, investors do not call for a risk premium. Instead, within the portfolio-balance channel, domestic and foreign assets are not seen as being equal. For investors to hold the excess supply of domestic bonds, it takes an additional increment, which makes such bonds more attractive. More precisely, they require a risk premium on domestic bonds. However, the assumption of risk aversion itself, does not automatically call for a risk premium.⁶⁴ If investors hold a portfolio of financial assets, which minimizes the risk, they do not require any inducement on any financial asset.⁶⁵ In this case, the UIP as a behavioral equation of international investors would hold perfectly (equation 7). But, as soon as a difference between their risk-minimizing portfolios and the actual portfolios (exogenously distorted by the central bank) occurs, investors require a nonzero risk premium on the additional supply of a financial asset. In this context, the sale of domestic bonds to the private sector in exchange for

⁶⁴According to Isard (1983), the required conditions for imperfect substitutability of domestic and foreign assets are: 1) a different degree of riskiness due to uncertainty over expected real rates of return; 2) risk-averse economic agents; 3) a difference between risk minimizing portfolio and actual portfolio.

⁶⁵Thereby, the riskiness stems from the uncertainty of the exchange rate behavior, and so, in the expected rate of return of foreign bonds.

foreign assets $\left(\frac{B\uparrow}{B^*\downarrow} \uparrow\right)$ forces investors to hold more of these bonds. This in turn deforms the risk-return balance of their portfolios. In order to restore this risk-return balance, they demand for a positive risk premium on domestic bonds. Consequently, the expected return on domestic bonds (i_t) has to rise compared to the expected return on foreign assets ($i_t^* + \Delta s_{t+1}^e$). Relaxing the assumption of static expectations, and assuming a constant expected exchange rate ($\overline{s_{t+1}^e}$), the current exchange rate must depreciate ($s_t \uparrow$), causing an expected appreciation or a less expected depreciation of the domestic currency.

$$f\left(\frac{B}{B^*}\right) = \eta = i_t - i_t^* - \Delta s_{t+1}^e, \quad (20)$$

$$f\left(\frac{B\uparrow}{B^*\downarrow} \uparrow\right) = \eta \uparrow - \overline{(i_t - i_t^* - s_{t+1}^e)} = s_t \uparrow. \quad (21)$$

According to equations 20 and 21, the risk premium can be seen as a positive function of the relative supply of domestic and foreign bonds. Under fixed exchange rate expectations and unaffected money markets, a change in the risk premium causes a change in the exchange rate. Hence, if a sterilized intervention is assumed to work within the portfolio-balance channel, it influences the exchange rate by prompting international investors to rebalance their portfolios of financial assets, which ultimately depends on the size of the risk premium.

Testing the portfolio-balance channel has been challenging throughout the years. Accordingly, empirical results are rather poor for validating this theoretical model.⁶⁶ The problems stem from theoretical as well as empirical considerations. Usually, contributions to the portfolio-balance channel focus on the estimation of the risk premium derived from inverted asset demand functions. However, this way of testing the portfolio-balance channel implicitly constitutes a joint hypothesis of assets' imperfections and expectation formation, hampering final inferences.⁶⁷

⁶⁶While Dominguez and Frankel (1993), and Frankel (1993) find positive results in favor of the portfolio-balance channel, the vast majority of empirical research neglects the meaning as a reliable exchange rate determination model and its relevance as an intervention channel. For a survey on empirical results, see e.g. Edison (1993), Hallwood and MacDonald (2000), Sarno and Taylor (2002), and Pentecost (1993).

⁶⁷See Edison (1993). Additionally, the role of the Ricardian equivalence has to be considered. In a Ricardian world, domestic agents take account of all future net taxes levied by the government. See, e.g. Felderer and Homburg (2003). This in turn means that the government cannot affect relative bond supplies systematically, and the exchange rate remains unaffected. Consequently, imperfect substitutability is not a sufficient condition for sterilized intervention to influence the exchange rate. However, for this discussion, interventions are assumed to affect asset supplies, and therefore the Ricardian equivalence is supposed not to hold. For a discussion on

From an empirical point of view, the most common argument against the portfolio-balance channel of interventions to be of crucial importance aims at the relative size of interventions. As noted by Humpage (1991), the total stock of outstanding US government securities exceed the central banks' intervention capacity significantly. In the same vein, Archer (2005) argues: "*The intervention capacity of the central bank is just too small compared with the total quantum of domestic and foreign assets that might be exchanged for each other.*," [Archer (2005), p. 42]. Another pitfall stems from the assumption of imperfect substitutability of assets involving the risk premium on domestic and foreign assets. In this context, the relative high equality of domestic and foreign assets (in industrialized countries) lowers the risk premia, and diminishes the effect of an intervention on the exchange rate. However, it can be argued that authorities in industrialized countries could operate with imperfectly substitutable assets. This in turn, however, directly points to the stated argument that the relative size of interventions is just too small. Against the background of these two arguments, interventions in emerging markets are supposedly more effective. A higher capacity to intervene (relative size) should support the portfolio-balance channel for these countries. Furthermore, emerging markets' assets usually carry a much higher risk premium than assets from industrialized countries.

Concerning the *secrecy puzzle*, the portfolio-balance channel does not provide a framework for explaining secret central bank operations in the foreign exchange market. Whether a central bank conceals or publishes its interventions does not influence the exchange rate directly. Furthermore, closely connected the matter of secrecy, Canales-Kriljenko et al. (2006) argue that a central bank does not necessarily have to possess reliability, since only a change in the relative supplies of domestic and foreign assets induce an effect on the exchange rate. This argument again supports the role of this transmission channel for emerging market central banks, which are lacking credibility and experience in conducting monetary policy independently.

the Ricardian equivalence and intervention effects, see e.g. Backus and Kehoe (1989), Obstfeld (1982), and Stockman (1979).

2.3 The Signaling (Expectation) Channel

Besides the monetary models and the portfolio-balance channel, the expectation channel represents a further framework through which interventions can influence exchange rates. The signaling channel, which was first introduced by Mussa (1981), emphasizes the role of interventions to alter market participants' expectations of future exchange rates. In contrast to the asset approaches described so far, the expectation channel does not explicitly account for changes in relative bond or money supply to affect the exchange rate.⁶⁸ The essential determinants of the current spot exchange rate are the underlying economic conditions, and market expectations about fundamental conditions in the future.

Since the "news" approach of exchange rate determination is the underlying exchange rate model, currencies should only change, if new, relevant, and unanticipated information occur. This reflects the famous EMH, which is part of the "news" approach in determining exchange rates. It states that, if capital markets are efficient, all relevant information should be incorporated in the actual prices, reflecting the expectation of market members about present and future prices.⁶⁹ This in turn would make it impossible to earn excess returns from speculations. According to Mussa (1981), new information is "signaled" by interventions in the foreign exchange market. This explains the name of this theoretical channel. Besides this interpretation of the expectation channel, one has to account for the fact that foreign exchange markets are not stringently information-efficient. Therefore, interventions could provide additional help in correctly processing publicly available data.⁷⁰

The signaling channel rests on the assumption of an asymmetric information distribution. It can best be described by using the basic asset market theory of exchange rate determination.⁷¹

⁶⁸However, in a formalized version of this channel described below, such monetary issues and substitutability aspects are considered. In order to clearly differentiate between the signaling and the portfolio-balance channel, assets are assumed to be perfect substitutes. This rules out any portfolio effects.

⁶⁹See Fama (1970).

⁷⁰According to the definition of interventions, it is clear that only published transactions and/or announcements designed to influence the exchange rate are interventions in the context of the signaling channel. However, interventions intended not to be made publicly known could provide a signal in the case that its occurrence gets known to market members.

⁷¹See Aguilar and Nydahl (2000), and Levich (2001) for a textbook treatment.

$$s_t = z_t + \alpha [E(s_{t+1} - s_t | \Omega_t)]. \quad (22)$$

According to equation 22, the current exchange rate (s_t) is determined by a set of fundamentals (z_t), and the expected change of the exchange rate ($[E(s_{t+1} - s_t | \Omega_t)]$) based on all currently relevant information (Ω_t), with α being the specific elasticity factor. Solving equation 22 for s_t , and successively substitute for future values, one obtains:

$$s_t = \frac{1}{1 + \alpha} \sum_{i=0}^{\infty} \left(\frac{\alpha}{1 + \alpha} \right)^i E(z_{t+i} | \Omega_t). \quad (23)$$

Equation 23 shows the current exchange rate to be dependent on the expected discounted sum of all future values of relevant fundamentals over an infinite time horizon. In general, the set of macroeconomic fundamentals can be regarded as the same set of fundamentals within the monetary models, namely national currencies, and real economic conditions. As indicated in chapter 2.1.1, even sterilized interventions can influence the exchange rate within the flexible-price monetary model by altering expectations about future underlying fundamentals. Equation 23 is the basic formulation of the signaling channel, since it emphasizes the role of new information ($\Omega_t + \text{"news"}_t$) and expectations. This channel gives interventions, whether sterilized or not, a leeway by providing information about the underlying fundamentals. Furthermore, Humpage (1986) emphasizes that not the purchase or sale of foreign currency per se affects the exchange rate but rather the information provided by these transactions. A central bank can forward its information or opinion to the market in two ways, which will be explained in detail in the following sections:⁷²

(i) *Intervention as a Signal of Future Monetary Policy*

(ii) *Intervention Enhancing the Informational Efficiency of the Foreign Exchange Market*

⁷²Although Mussa (1981) introduces both possibilities, most of the literature focuses on one of these two ways in providing new information. Allowing for a broad consideration of the expectation channel, both possibilities should be considered. Unfortunately, no general framework capturing these two channels exists. However, some authors present models for each of the possible interpretations. See e.g. Bhattacharya and Weller (1997), Reeves (1997), and Vitale (1999).

2.3.1 Intervention as a Signal of Future Monetary Policy

The first way to construe the signaling (expectation) channel of interventions is to assume that the central bank signals the future monetary policy stance by intervening in the foreign exchange market.⁷³ By way of sending a signal to the market, investors receive new information about future monetary policy actions, and change their expectations about future fundamental factors. In case of foreign currency purchases by the central bank, authorities send a signal of future monetary policy loosening. The increase in foreign reserves indicates a decline in domestic interest rates, and a depreciation of the domestic currency. In contrast, by selling foreign currency, the authorities signal future monetary policy tightening. Thereby, the informational advantage of a central bank stems from the knowledge about the future monetary policy course. It is important to note that the central bank has to fulfill the signals which were previously sent out in order not to endanger its credibility. The influence on the exchange rate is given by the extent to which the market believes the signs, and to which monetary policy is seen as credible. This in turn depends on the fact that the authorities need to back up their signals with real policy actions (depending on the implemented framework).

However, it is not clear why a central bank should use interventions to signal its future monetary policy stance. Particularly, since the purchase or sale of foreign assets should be followed by a change in the interest rate, interventions become completely redundant, and should therefore not be regarded as an independent monetary policy tool. In the same sense, whether or not a central bank sterilizes its transaction does not matter. The question arises why a central bank should take the inconvenient step of signaling monetary policy changes by intervening in the exchange market with all its associated risks (e.g. generating rumors, damaging credibility) and not just announce its plans? The common argument to justify this is that a central bank "buys" credibility, in that it uses its own money to support its intentions.⁷⁴ Furthermore, interventions need to be known by market participants. If conducted secretly, interventions cannot provide a signal of future monetary policy to the market, ruling out any potential effect on the exchange rate.

⁷³See e.g. Kaminsky and Lewis (1996), Klein (1992), and Klein and Rosengren (1991).

⁷⁴See Mussa (1981).

Reeves (1997) formalizes the expectation channel using sterilized interventions in the argumentation. The basic model, which is almost a flexible-price monetary model, is presented in the following. The forward-looking solution for s_t can be written as:

$$s_t = \frac{1}{1 + \alpha} \sum_{i=0}^{\infty} \left(\frac{\alpha}{1 + \alpha} \right)^i E_t [(m_{t+i} - m_{t+i}^*) - \beta (y_{t+i} - y_{t+i}^*)], \quad (24)$$

where $E_t x_{t+i}$ is the i -th-period ahead expectation of the underlying fundamentals.⁷⁵ Equation 24 emphasizes the key role of expectations about the future monetary policy in determining the actual spot exchange rate. In case investors assume the future monetary stance to be constant, the expected money supplies are settled ($m_0 = m$, $m_0^* = m^*$, with $y_t = y$, $y_t^* = y^*$). The initial equilibrium is characterized by equation 25:

$$s_0 = (m - m^*) - \beta (y - y^*). \quad (25)$$

If domestic and/or foreign central banks foretell a monetary policy change through a sterilized intervention in period 1, this transaction announces a future change in the money supply from period 2 on (equation 26).⁷⁶

$$m_t^{(*)} = m_0^{(*)} + \delta int^{(*)} \quad t \geq 2, \delta > 0. \quad (26)$$

with

$$int^{(*)} < 0 \rightarrow \text{sale of foreign currency}; \quad int^{(*)} > 0 \rightarrow \text{purchase of foreign currency}.$$

Equations 27, and 28 describe the way agents revise their expectations with respect to their beliefs about the credibility of the central bank. The monetary authorities' credibility is described by two parts; firstly, the probability $p^{(*)}$ ($0 < p^{(*)} \leq 1$) of conducting policy changes

⁷⁵Because the model focuses on isolating the effects of the signaling channel, the UIP is assumed to hold perfectly, which rules out any portfolio effects. Hence, domestic and foreign assets are assumed to be perfect substitutes. Furthermore, the PPP is supposed to hold continuously.

⁷⁶In order to account for the sterilization, it is assumed that $m_1 = m_0$. Furthermore, δint , δint^* should be interpreted as the growth rates of non-logarithm money supply.

which agents attach to central banks capturing the presence of partial credibility; secondly, the proportion κ ($0 < \kappa \leq 1$) of credible information used by market members to build their expectations, which opens the room for non-rationality.

$$E_1 m_t^{(*)} = p^{(*)} \left\{ \kappa \left(m_0^{(*)} + \delta int^{(*)} \right) + (1 - \kappa) m_0^{(*)} \right\} + (1 - p^{(*)}) m_0^{(*)}, \quad (27)$$

$$E_1 m_t^{(*)} = m_0^{(*)} + p^{(*)} \kappa \delta int^{(*)}. \quad (28)$$

From equations 24, and 25, in combination with equation 28 one can write the spot exchange rate response in period 1 as:

$$s_1 = s_0 + \kappa \delta \frac{\alpha}{1 + \alpha} \{ p int - p^* int^* \}. \quad (29)$$

It becomes clear that for a central bank, which is seen as absolutely credible by the market ($p = p^* = 1$), and for agents who build their expectations in a rationale way ($\kappa = 1$), interventions would have the greatest impact attainable.

The efficiency of intervention crucially depends on the central bank's credibility, and the relevant information used by agents to build their expectations. One important aspect concerning an intervention intended to serve as a credible sign is the fact that, if a central bank tries to target an exchange rate which is inconsistent with the underlying monetary policy strategy, an intervention will loose its ability to alter market expectations.⁷⁷ Different to Mussa's (1981) basic signaling theory, the size of an intervention influences the market's response. The model provided by Reeves (1997) comprises the basic ideas of the signaling channel in a fashionable way. Furthermore, it accounts for non-rational market participants, which means that these agents do not account for all exchange rate relevant information. However, because the exchange rate is a function of interventions, credibility, and rationality ($s_t = f(int, p, \kappa, \dots)$), it does not discuss whether interventions and the central bank's credibility can correct non-rationality ($\kappa \neq f(int, p)$). Furthermore, it does not incorporate the argument stated by Humpage (1986) that not the intervention per se affects the exchange rate but rather its announcement.

⁷⁷See Bhattacharya and Weller (1997).

2.3.2 Intervention and the Informational Efficiency of the Foreign Exchange Market

Suppose the foreign exchange market to be perfectly efficient. All relevant information would be captured and correctly processed into rational expectations for the future exchange rate. This in turn would make interventions, intended to adjust informational asymmetry, redundant. But despite the fact that professional foreign exchange traders have a strong incentive to incorporate all relevant information, the foreign exchange market faces real world uncertainty, bandwagon effects, speculative bubbles, and further market imperfections.⁷⁸ According to Fama (1970), the sufficient conditions for market efficiency are: 1) no transaction costs; 2) all information are free of charge; 3) all market members agree on the implications of the information. Obviously, this does not hold true for the exchange rate market. Especially if information is costly, market inefficiencies occur.⁷⁹ Hence, as soon as the market does not incorporate all relevant information about macroeconomic variables, markets cannot be regarded as efficient, and traders might lose sight of the fundamentals ($\kappa < 1$).⁸⁰

Therefore, the second way of understanding the signaling channel gives another perspective. Instead of signaling future monetary policy changes, monetary authorities intervene to tell the market its view on the actual exchange rate behavior, and to improve the flow of information.⁸¹ In this sense, interventions can only be effective, if the central bank is seen to possess an informational advantage compared to the market.⁸² Interventions serve to balance information asymmetry by providing and/or emphasizing neglected information about fundamentals.⁸³ Monetary authorities show the market how to interpret the existing economic conditions. In this context, the selling or purchasing of foreign currency should signal the market that the actual

⁷⁸Hung (1991a) provides a discussion and interpretation of the inconsistency of the EMH in the context of the foreign exchange market.

⁷⁹See Grossman and Stiglitz (1980), and Humpage (2003).

⁸⁰Simon (1959) argues that the human mind is limited in outlook and in drawing conclusions. For this reason, the assumption of market efficiency seems to be a wishful construction rather than reflecting the reality of markets in general, and foreign exchange markets in particular.

⁸¹See Rosenberg (1996).

⁸²See Mussa (1981).

⁸³As reported by Canales-Kriljenko (2003), especially central banks in emerging markets use foreign exchange and monetary regulations, among other controls, to increase their informational advantage. However, the potential lack of credibility might diminish the importance of the signaling channel for those countries.

level or trend is not consistent with the underlying fundamentals. Market participants should learn from this signal, and adjust their information processing and expectations about future exchange rates. However, if monetary authorities are not, or not seen as being, better informed, interventions could be the root of excessive volatility. Instead of sending trustworthy signals, exchange market transactions can confuse market participants. This could result in "bets against the central bank," and subsequently lead to unfavorable exchange rate movements.

As mentioned above, simple intervention announcements can also serve as a potential instrument as long as they are believed to be credible. The credibility of signals hinges, besides other factors, upon the authority's previous reputation. However, for simple announcements to work persistently, they have to be backed up through interventions. In general, the market incorporates new information by balancing its initial beliefs $(1 - \kappa)$ with the new information provided by an intervention (κ) . The stronger the prior market belief, and the more consistent information prior to an intervention has been, the less effective such signals will be ($\kappa \ll 1$). Investors are negatively attuned to information that disproves their initial thoughts, and positively attuned to new information supporting their convictions. Therefore, the market can be seen as impervious to new advice. Signals provided by interventions could be neglected even if a central bank is highly credible ($p \approx 1$).⁸⁴ From the theoretical point of view, this interpretation of the signaling channel does not fit in the context of the underlying exchange rate determination model, since the "news" approach assumes foreign exchange markets to be efficient. However, the existing empirical literature on the EMH tells another story.⁸⁵

Because of the important role of credibility within the signaling channel, most studies have differentiated between secret and public, as well as coordinated and unilateral intervention, when analyzing the effects of interventions within this transmission channel.⁸⁶ The great amount of

⁸⁴See Reeves (1997).

⁸⁵Sarno and Taylor (2002), who give a selected overview of the existing empirical literature, note: *"Overall, regardless of the increasing sophistication of the econometric techniques employed and of the increasing quality of the data sets utilised, one conclusion uncontroversially emerges from this literature: the simple efficient market hypothesis is rejected by foreign exchange market data."*, [Sarno and Taylor (2002), p. 35].

⁸⁶Another important aspect of credibility relates to the timing of interventions so as to reach the greatest impact effect. If credibility is low, monetary authorities may intervene in thin markets and during holidays, as done by the BoJ. This increases the relative intervention amount and helps to keep interventions secret. As discussed above, monetary authorities tend to intervene secretly when facing credibility problems. However,

contributions on the efficiency of central bank interventions conclude that: "*...studies using these high-quality data [i.e. intervention data] seems to us ... to conclude cautiously that official intervention can be effective if the intervention is publicly announced and concerted and provided that it is consistent with the underlying stance of monetary and fiscal policy,*" [Sarno and Taylor (2001a), p. 862]. This emphasizes the role of the signaling channel by explicitly highlighting publicity, coordinated intervention, and the consistency concerning monetary and fiscal policy, which all enhance the credibility of a foreign exchange market intervention as a trustworthy sign. However, results are mixed dependent on the underlying period, and the intervening central bank. Basically, one has to distinguish between two effects within this channel. From the discussion above, it should be clear that for interventions to work through this theoretical framework, they do not necessarily have to signal future monetary policy. This reflects the two ways of interpreting the expectation channel of foreign exchange market interventions.

The empirical evidence on interventions signaling future monetary policy stances is not clear-cut. Contributions of this field of research have focused on the experience of the Fed. Thereby, the relationship between interventions, and corresponding movements in the federal funds rates, and federal funds futures (expected change in monetary policy) have been examined.⁸⁷ Concerning expected future policy changes, Fatum and Hutchison (1999a) do not find a reliable relationship between interventions and federal funds futures. They conclude that Fed interventions did not signal future monetary stances between 1989, and 1993. Contrary to these negative results, Bonser-Neal et al. (1998), using two weeks cumulative interventions, find evidence that interventions signal future adjustments in the federal funds target between 1987, and 1994. Hence, cumulative interventions might provide stronger and more credible signals to the market. Kaminsky and Lewis (1996) find evidence that interventions, conducted by the Fed during the late 1980s, signaled a change in the monetary policy course. However, the

thin markets do not support the central bank's purpose of concealing transactions. In contrast, if monetary authorities do not face credibility problems, such tricky measures will not be part of the internal intervention decision. On the timing of interventions, see also Canales-Kriljenko et al. (2006).

⁸⁷A descriptive contribution is given by Humpage and Osterberg (2000). The authors compare the intervention direction of the Fed (purchase or sale of foreign currency) to the exchange rate movement on the same day between 1985 and 1997. They conclude: "*Central banks cannot regularly influence day-to-day exchange rate movements through sterilized intervention because they do not customarily possess an information advantage over private-sector traders.*", [Humpage and Osterberg (2000), pp. 3-4].

results do not confirm that those interventions were effective. Highlighting the ambiguity of the signaling story, the authors argue: "*... the estimates indicate that interventions signalled future monetary policy in the opposite direction from the signalling hypothesis for much of the period. For example, dollar sales [purchase of fx] in the foreign exchange market were frequently followed by contractionary monetary policies ... The implied movements in the exchange rate also tend to move perversely. For example, on the days following interventions viewed as conveying incorrect signals, all significant movements in the exchange rate were in the opposite direction intended by the intervention.*," [Kaminsky and Lewis (1996), p. 310].⁸⁸ More recently, Kim (2003) supports the signaling idea. Applying a structural VAR framework and using monthly data, he concludes: "*That is, sterilized foreign exchange intervention (net purchases of foreign currencies) signals future monetary policy changes (monetary expansion), so that the exchange rate changes (depreciates).*," [Kim (2003), p. 368].

Dominguez and Frankel (1993) explore whether interventions influence market participants' expectations about future exchange rates. Analyzing Fed and DBB interventions between October 1984, and December 1988, the authors use four weeks ahead survey forecasts of the US\$/DEM exchange rates on a weekly basis as well as official consolidated daily foreign exchange interventions, divided into reported and concealed transactions. By running simple linear regressions, they find evidence that only published interventions had a significant and correct impact on exchange rate forecasts. This result indicates that interventions might influence exchange rate expectations only if known to the market, supporting the signaling idea. A more recent strand of empirical literature turns to the analysis of probability density functions to examine the effect of interventions on higher moments of exchange rates. In this context, Galati et al. (2005) use press reports, and official intervention data to examine whether BoJ operations influenced the mean and higher moments of the JPY/US\$ exchange rate. Their results do not confirm an impact.⁸⁹

⁸⁸Lewis (1995) also finds some evidence for contrary relationships of interventions and monetary policy changes. See Watanabe (1994) for Japanese experiences.

⁸⁹See Galati and Melick (2002) for analyses of the PDFs around historical intervention cases.

2.4 The Noise-Trading Channel

The general rejection of the EMH requires the need of an alternative explanation of exchange rate movements. The concluding aspect that exchange rate changes are not only the result of rational patterns but also show fundamentally free psychological behavior, justifies an alternative approach of exchange rate determination, which incorporates the inconsistency of the EMH explicitly. In this context, the noise-trading approach, as proposed by Hung (1991a, 1991b, 1997), differs from the EMH in that a meaningful part of the market does not base its trading decisions on fundamental economic analyses. In fact, the model is an attempt to connect the irrational behavior of market participants, with a more traditional view of exchange rate determination. In contrast to other intervention channels and their underlying exchange rate determination models, heterogeneous expectations are introduced in order to draw a better picture of reality. The noise-trading approach can explain why exchange rates are prolonged misaligned and sometimes excessively volatile. Furthermore, the fact that central banks intervene secretly in foreign exchange markets, which is an essential drawback in the signaling channel, finds some expression within the noise-trading channel of intervention.

2.4.1 The Underlying Ideas of the Noise-Trading Channel

According to the noise-trading channel, the foreign exchange market consists of two groups of market participants.⁹⁰ The first group, which is labelled "noise-traders," relies on a short-run perspective (interday or intraday), and bases its trades on anything it believes to be relevant for future prices (exchange rates) even if it is not consistent with long-run economic fundamentals. Consequently, the analysis of long-run economic perspectives is no crucial part of its trading strategies. The group of noise-traders itself can be further divided into two heterogenous parts of investors, according to their trading styles. Some noise-traders behave like "chartists."⁹¹

⁹⁰Indeed, the foreign exchange market is characterized by a high degree of heterogeneity as reported by Cheung and Wong (2000), and Cheung and Chinn (2001). Results of these surveys, covering Asian and US markets, are in line with the ideas of the noise-trading channel. Irrational factors dominate the exchange rate, especially in the short-run, and are responsible for exchange rate misalignments, whereas economic factors become more important in the medium-run to long-run perspective.

⁹¹Chartists represent the basic idea of how noise-traders behave.

Their idea is that prices include all aspects of the market, whether they are: "... *economic or noneconomic, rational or irrational,*" [Hung (1991a), p. 12]. They base their trades on models which incorporate the analysis of past price movements to forecast future exchange rate movements. The second part of noise-traders, named "non-chartists," tries to maximize its profit by forecasting the reaction of the market to any news or myths.⁹² Hence, the trading strategies are not based on any model, but on comments, announcements, and speculations.⁹³ In contrast to noise-traders, the second group of market participants are rational maximizing "fundamentalists" or "smart money agents," who base their investment decisions, although not exclusively, on a fundamental analysis. Through the so called "uncovered arbitrage," smart money agents bring the exchange rate back to its fundamental value. Hence, fundamentalists buy a currency when it is undervalued, and sell a currency when it is overvalued.

The possibility of exchange rates to be misaligned over a long period of time, or excessively volatile, stems from the interaction of the heterogeneous market groups. The underlying assumption is that the uncovered arbitrage conducted by the fundamentalists is limited, because of risk considerations of the smart money agents.⁹⁴ Basically, the actions of the noise-traders push the exchange rate away from its fundamental value. This opens room for the fundamentalists to place investments. However, since risk is a crucial factor within the fundamental trading, smart money agents might not be able to restore the exchange rate. The noise-traders can push the exchange rate too far away from its "true" value, so that fundamentalists do not open balancing positions. Accordingly, the exchange rate can be prolonged misaligned.⁹⁵ Furthermore, smart money agents can temporarily turn into noise-traders. For instance, the occurrence of strong

⁹²However, the distinction of both noise-trading groups is often not clear-cut in the literature. Moreover, most authors combine both noise-trader groups, making a distinction more arbitrary.

⁹³One essential assumption is that investments related to noise-traders do not cancel out. Moreover, they are assumed to be correlated, and so are able to cause aggregate changes in demand for currencies.

⁹⁴Besides risk considerations, budget constraints also hinder fundamentalists to open investment positions.

⁹⁵Two types of risks are responsible, why fundamentalists are hampered in opening the necessary positions. Firstly, the best guess about the fundamental currency value might be wrong. Especially in the context of a not existing appropriate fundamental model, it is difficult for smart money agents to distinguish between exchange rate changes related to shifts in the surrounding economic conditions, or related to actions of the noise-trader group. Secondly, if it is clear for fundamentalists that the actual currency value is misaligned, the uncertainty stemming from the possibility that some news could arise, which push the exchange rate even farther away from its fundamental value, could stop the fundamentalists from opening new positions. Hence, the fear of generating losses limits the necessary arbitrage positions to bring the currency value back to its equilibrium rate. These two types of risks result in the fact that the currency demand of smart money agents could not be large enough to rebalance the exchange rate.

bandwagon effects force fundamentalists to engage in activities, which lead to further chaotic market conditions, and trigger excessive market volatility. The relationship of noise-traders and fundamentalists results in the determination of the *risk-adjusted equilibrium* exchange rate.

Unfortunately, Hung (1991a, 1991b, 1997) does not formalize this approach. Several authors have framed the class of so called chartist-fundamentalist models in a formal way.⁹⁶ One of the first contributions dealing with this kind of model has been proposed by Frankel and Froot (1987), who model three classes of players in the foreign exchange market: 1) fundamentalists; 2) chartists; 3) portfolio managers. On the basis of Frankel and Froot (1987), and further extended by De Long et al. (1990), more recent contributions by De Grauwe and Grimaldi (2005, 2006a) provide a nonlinear exchange rate model, which is slightly different from the noise-trading ideas of Hung (1991a, 1991b, 1997).

$$s_t^* = s_{t-1}^* + \varepsilon_t, \quad (30)$$

$$E_{f,t}(\Delta s_{t+1}) = -\theta(s_t - s_t^*), \quad (31)$$

$$E_{c,t}(\Delta s_{t+1}) = \beta \sum_{i=0}^T \alpha_i \Delta s_{t-i}. \quad (32)$$

As stated by equation 30, the fundamental exchange rate (s_t^*) is supposed to follow a random walk without a drift, due to the lack of a valid exchange rate model.⁹⁷ Equations 31 and 32 divide the market into two groups. The fundamentalists (equation 31) build their expectations about the future exchange rate change according to the deviation of the actual currency value (s_t) from its fundamental value at time t . Through a negative feedback rule, they expect the future exchange rate to move towards the fundamental rate with a constant speed of adjustment ($\theta > 0$), which is determined by the goods market. In contrast, chartists (equation 32) follow a positive feedback rule. Thereby, a moving average of the past exchange rate movements ($\sum_{i=0}^T \alpha_i = 1$), is extrapolated with a degree of β ($0 < \beta < 1$) into the future.⁹⁸ The distribution

⁹⁶For literature on the chartist-fundamentalist models, see e.g. De Grauwe and Dewachter (1993), Frenkel (1997), Schmidt and Wollmershäuser (2004), Shleifer and Summers (1990), and Westerhoff (2003a).

⁹⁷Alternatively, the PPP could be seen as reflecting the fundamental value.

⁹⁸At this point, the ideas of Hung (1991a, 1991b, 1997) diverge from the model in that the noise-traders only consist of agents using a model when building their expectations. Non-chartists are neglected.

of fundamentalists and chartists depends on the profitability of the specific forecasting rules. Through an ex post comparison of the profit ratios, agents decide whether to use the fundamental rule or the chartist rule. Thus, the fractions of agents ($w_{c/f,t}$) using one of the two rules is a function of the relative risk-adjusted profitability.

$$w_{c,t} = \frac{\exp \gamma (\pi_{c,t-1} - \sigma_{c,t-1}^2)}{\exp \gamma (\pi_{c,t-1} - \sigma_{c,t-1}^2) + \exp \gamma (\pi_{f,t-1} - \sigma_{f,t-1}^2)}, \quad (33)$$

$$w_{f,t} = \frac{\exp \gamma (\pi_{f,t-1} - \sigma_{f,t-1}^2)}{\exp \gamma (\pi_{f,t-1} - \sigma_{f,t-1}^2) + \exp \gamma (\pi_{c,t-1} - \sigma_{c,t-1}^2)}. \quad (34)$$

The net profits of the forecasting rules are $\pi_{c/f}$. Their specific risks are measured by $\sigma_{c/f,t}^2$, which are weighted averages $\left(\sum_{k=1}^{\infty} \lambda_k [E_{c/f,t-k}(s_{t-k+1}) - s_{t-k+1}]^2 \right)$ of the squared forecast errors, with λ_k being geometrically declining weights. In case the risk-adjusted net profit of one trading rule increases relatively, the fraction of market agents who base their trading on this specific strategy rises. The sensitivity of the rule adjustments depends on the switching parameter γ ($0 < \gamma < \infty$), which determines the speed of switching between the two rules. If γ equals zero, the market fractions would be constant and time independent. Each group would make up half of the market ($w_{c,t} = w_{f,t} = 0,5$). If γ nears infinity, investors will switch to the most profitable rule immediately. However, from a psychological point of view, investors are reluctant to change a decision once implemented.⁹⁹ Finally, the realized exchange rate change equals the market expectation plus a white noise error (ε_{t+1}), as can be seen in equation 35. Again, the relationship of noise-traders and fundamentalists results in the determination of a *risk-adjusted equilibrium* exchange rate.

$$\Delta s_{t+1} = -w_{f,t}\theta (s_t - s_t^*) + w_{c,t}\beta \sum_{i=0}^T \alpha_i \Delta s_{t-i} + \varepsilon_{t+1}. \quad (35)$$

⁹⁹See Kahneman et al. (1991).

2.4.2 Intervention within the Noise-Trading Channel

The noise-trading channel explicitly calls for central banks to intervene in the foreign exchange market. The possibility that exchange rates deviate from their fundamental values in a persistent way, calls for central banks to protect the equilibrium value of their currency.¹⁰⁰ Thus, the noise-trading channel offers a theoretical background for central banks, operating under a flexible exchange rate regime, to intervene in the foreign exchange market.

In order to restore irrational exchange rate behavior, monetary authorities have to tackle its roots. Hence, interventions are assumed to influence the noise-trader group of market members. More precisely, the effect of an intervention within the noise-trading channel must be distinguished, as the group of noise-traders consists of two parts.¹⁰¹ Starting with the non-chartists, suppose the exchange rate to be highly undervalued, and the central bank wants to intervene in order to bring the currency back to its fundamental value. If the market volume is high and its momentum strong, monetary authorities should not engage in the market. But as soon as non-chartists become uncertain about future exchange rate movements and question themselves whether they have pushed the exchange rate too far, the central bank should intervene in order to give non-chartists a mark to reverse their positions. For the so called *noise-trading signaling channel* to be effective it is necessary that non-chartists are uncertain, and are looking for any symbol to open new positions.¹⁰² The *noise-trading signaling channel* can also be labelled *coordination channel*, as described by Dominguez and Frankel (1993). So, instead of giving a signal, the central bank coordinates the failure of the foreign exchange market. Furthermore, if the market volume is low, and chart-techniques indicate no clear trading pattern, several successive, or one intensive intervention by the central bank may cause enough pressure on the specific currency that chartists open positions in line with the intervention objective of the central bank. This is especially relevant since chart-techniques usually give more weight to recent exchange rate movements. The shift in the market flow could cause a breaking of any technical

¹⁰⁰This implicitly assumes that central banks try to target the fair value of their currencies instead of manipulating the exchange rates intentionally.

¹⁰¹See Almekinders (1995), and Hung (1991a, 1991b, 1997).

¹⁰²This is in line with the findings of Goodhart and Hesse (1993) that central banks tend to intervene in thin foreign exchange markets.

indicator, which in turn serves as a new trading sign. In this sense, Hung (1991a) notes: "*The effect of sterilized intervention on the exchange rate by disturbing the flow market equilibrium may have been transitory itself, but noise-trading activities induced by the transitory effect of intervention may help amplify and prolong the effect of intervention.*," Hung [1991a, p. 20]. This can be labelled as the *chartist channel of intervention*. Since central bank interventions cause the noise-trading group to move in the favored direction, the exchange rate volatility could possibly increase. This fact is widely observed in the empirical literature on the effects of central bank interventions on exchange rates.¹⁰³ Thus, the central bank manages the exchange rate level with the risk of a higher exchange rate volatility.¹⁰⁴

What leeway do secret interventions have in the noise-trading channel? For the *noise-trading signaling channel*, interventions, which are highly visible, could provide a sufficient signal non-chartists have looked for. Whether the source of the shift in the supply and demand for foreign currency is interpreted as an intervention, or as a real change in the market flow, does not matter according to Hung (1991a, 1991b). However, it can be argued that visible interventions could encourage non-chartist to bet against the central bank, especially if monetary authorities are lacking credibility. For the *chartist channel of intervention*, central bank interventions should be kept concealed. Imagine, a central bank does not generate enough currency pressure to break any technical indicator. If monetary authorities made their transactions publicly known, they would endanger their ability to set credible signs in the market. But, if interventions have been kept concealed, it can be argued that the authorities have nothing to lose in respect to their esteem. Hence, within the noise-trading channel, interventions should rather be conducted secretly in order to be on the "safe side." The fact that, until now, most interventions are conducted secretly, especially in emerging markets, gives some credibility to postulate that central banks take the noise-trading character of the foreign exchange market into account.¹⁰⁵

¹⁰³See chapter *three*.

¹⁰⁴See Hung (1997).

¹⁰⁵In this context, the Reserve Bank of New Zealand states: "*Another reason why intervention might have an impact on the exchange rate in some cases is the idea that exchange rates are partly determined by the underlying structure of financial markets. For example, simple technical trading rules that try to take advantage of the continuation of short term trends in financial prices are used widely in the markets. If exchange rates are at times partially determined by trend following behavior rather than fundamentals, then it is possible intervention*"

A recent paper which models the impact of intervention in a noise-trading framework explicitly is provided by Beine et al. (2009b). Based on the nonlinear noise-trading framework presented by De Grauwe and Grimaldi (2005, 2006a), the authors assume that agents (fundamentalists and chartists) maximize their utility, derived from their level of wealth, using a mean-variance framework. By intervening in the foreign exchange market, the central bank alters the supply of foreign assets per capita ($\frac{\Delta Z_t}{N}$). For instance, a central bank's purchase of foreign assets ($\frac{\Delta Z_t}{N} < 0$) declines the supply of these assets, and leads to a depreciation of the exchange rate, as can be easily seen from equation 36, with μ being the coefficient of risk aversion of the market, and r being the domestic interest rate.

$$\Delta s_t = - \left(\frac{\mu}{1+r} \right) \frac{1}{\frac{w_{c,t}}{\sigma_{c,t}^2} + \frac{w_{f,t}}{\sigma_{f,t}^2}} \frac{\Delta Z_t}{N}. \quad (36)$$

According to equation 36, it can be seen that the effect of an intervention depends on the market structure. The distribution of chartists and fundamentalists in the market ($w_{c,t}$, $w_{f,t}$), and the associated forecast errors, made in the past ($\sigma_{c,t}^2$, $\sigma_{f,t}^2$), are further determinants of the transaction's effect. For this reason, the impact of an intervention is difficult to predict prior to a central bank action.¹⁰⁶ To analyze the effects of foreign exchange transactions, the authors introduce a simple intervention rule. They assume that central banks intervene in order to smooth over exchange rate swings around its fundamental value.¹⁰⁷ Thus, a *leaning against the wind* intervention rule is used as described by equation 37.

$$\Delta Z_t = \varsigma (\Delta s_{t-1}). \quad (37)$$

could have an impact on exchange rates if intervention disrupt the signals that trend followers look for. A relatively modest transaction by the central bank at the right time may be sufficient to slow or even prevent further movements of the exchange rate away from equilibrium. It might also be the case that intervention could encourage short term traders to jump in behind the Bank reinforcing the efficacy of the initial intervention transaction...Often, intervention will be very open and public. In these cases the Bank will issue a press release shortly after having intervened, ...Sometimes, though, the Bank may wish to intervene covertly, which will mean that there will be no comment from the Bank at the time of intervention.", [Eckhold and Hunt (2005), p. 14]. However, the Bank's balance-sheet data published each month clearly provides information about when interventions have taken place during the last month.

¹⁰⁶It should be noted that this model can only deal with sterilized interventions, since the money market is assumed to be left constant. See De Grauwe (1990) for model simulations with both, sterilized and unsterilized interventions.

¹⁰⁷The fundamental value is supposed to follow a simple random walk.

The central bank sells foreign assets when the exchange rate depreciates and vice versa, with an intensity measured by ς ($\varsigma \geq 0$).¹⁰⁸

Based on bi-weekly data, Beine et al. (2009b) analyze the EUR/US\$ dynamics (DEM before 1999) over a long horizon, ranging from 1985 to 2003. Empirical tests of this model suggest that central banks can revert the exchange rate towards its fundamental value significantly.¹⁰⁹ Through intervening in the foreign exchange market, monetary authorities influence the profitability of the specific forecast rules, i.e. an intervening central bank can change the market structure. However, this result can also be interpreted differently. On the one hand, it is in line with the underlying noise-trading idea that an intervention forces the exchange rate towards its equilibrium value by making fundamental trading rules more profitable. On the other hand, it is not explicitly assumed by Hung (1991a, 1991b, 1997) that the market structure changes. It is only suggested that noise-traders open positions in favor of the central bank. Here it is assumed that noise-traders turn into fundamentalists. Furthermore, which subsequent noise-trading channel is responsible for this outcome, can ultimately not be explained explicitly.¹¹⁰ Consequently, the intervention effect is explained by the *chartist channel of interventions*, since agents detect the increased profitability of fundamental exchange rate forecasting, which prompts them to align with the fundamentalists group. Nevertheless, the publicly known intervention rule of *leaning against the wind* actively communicates the intention of the central bank. Abstracting from the chartists, it can then be argued that an intervention signals the commitment of the authorities to achieve a fundamental value of the exchange rate. This symbol could cause non-chartists to turn into fundamentalists as well. Since an intervention rule is applied, which is not concealed, the model of Beine et al. (2009b) does not account for secrecy aspects explicitly. Unfortunately, this model has one important drawback. It cannot deal with the relationship between interventions and exchange rate volatility, which is one basic implication of the noise-trading channel as proposed by Hung (1991a, 1991b, 1997).

¹⁰⁸More intervention rules are analysed in De Grauwe and Grimaldi (2006b). For a discussion of intervention rules within a linear model, see Westerhoff (2003b), and Schmidt and Wollmershäuser (2004).

¹⁰⁹It would be very interesting to apply this model to emerging market data, to see whether results are similar. To my best knowledge, no efforts have been made to discover the noise-trading channel for emerging market central banks.

¹¹⁰This rests on the fact that the model neglects the presence of non-chartists.

2.5 The Microstructure Channel

The general failure of macro-based exchange rate determination models, at least in the short-run, caused a number of researchers trying to explain the exchange rate behavior on a microstructure basis. Competing with other exchange rate determination models, market microstructure models concentrate on foreign exchange markets' institutional conditions instead of the economic environment. Thus, the microstructure approach incorporates details of foreign exchange market trading. Similar to the asset market approach, the supply and demand for foreign currencies stems from the trade of international assets. In this context, the microstructure view extends the asset approach with a microstructural component. Furthermore, this channel allows for huge trading volumes observed on the foreign exchange markets, an aspect which is incompatible with macro-based exchange rate models.¹¹¹

When dealing with a pure microstructure approach, one variable in exchange rate determination takes on extra significance: Order flow.¹¹² The rejection of the EMH begs the question how to capture market views of future currency values, which explain actual exchange rate movements. Instead of trying to measure expectations of every single agent, one can easily comprise the aggregated expectations through the order flow. In this context, Rime et al. (2007) note: "*Unlike expectations measured by survey data, order flow represents a willingness to back one's belief with real money.*" [Rime et al. (2007), p. 2].¹¹³ Order flow can be defined as the signed transaction volume, where the signs are given by the initiators. For example, if one decides to sell 10 units of foreign currency in period 1, the order flow is -10. In contrast, if an agent buys 20 units of foreign currency in period 2, the order flow is +20. The transaction volume of both trading periods is 30, whereas the specific order flow is +10. Hence, a positive value means net purchasing pressure on foreign currency and vice versa. Consequently, order flow can be

¹¹¹According to BIS (2007), the average daily trading volume in foreign exchange markets amounts to 3.2 trill. US\$.

¹¹²See Lyons (2001b). Another important variable in the microstructure of exchange rate determination is the bid-ask spread. Spreads occur, besides other reasons as noted by Sarno and Taylor (2001b), due to the uncertainty of dealers to be badly informed, and because of this, due to the fear of losing money. The higher the uncertainty the higher the spread. However, the bid-ask spread is often neglected in formal descriptions and does therefore play no crucial role in this section.

¹¹³This is different to the noise-trading approach, where the heterogeneity of market agents is explicitly modeled through noise-traders and fundamentalists.

interpreted as a shift in total foreign currency demand. This in turn reflects changes in market expectations about future fundamentals. The role of order flow is therefore clearly determined. Foreign exchange rate dealers learn about fundamentals through order flow from non-dealers, who in turn learned about fundamentals from direct sources, and were willing to back up their beliefs with money. Thus, order flow is the transmitter of fundamental information, which is not known to all agents.¹¹⁴

2.5.1 Microstructural Exchange Rate Determination

In general, the foreign exchange market is a decentralized market. Even though no physical location exists, three distinct main geographical market places ensure trading possibilities 24 hours a day. These markets are located in New York, London, and Tokyo, whose trading sessions overlap a little bit.¹¹⁵ The communication of market participants takes place via telephone or computer network systems. This in turn leads to a split-up with a high degree of opacity.¹¹⁶ As a consequence of market fragmentation and resulting intransparency, the foreign exchange market is the most liquid financial market in the world.¹¹⁷ The foreign exchange market itself is basically divided into the interdealer market and the customer market.¹¹⁸ While the customer market describes the relationship between dealers and customers, the interdealer market describes the relationship between dealers. Generally, dealers execute the orders received from customers, whereas the source of such orders can be of differing natures (hedging transactions, financial investments, speculative trading, trade clearing). Besides customer transactions, dealers can also trade on their own account in order to generate profits or manage their outstanding risks.

¹¹⁴See Bjønnes and Rime (2003), and Lyons (2001a).

¹¹⁵The highest crossover is between America and Europe, followed by Europe and Asia with a smaller amount of combined trading hours. Accordingly, during these intersections, trading volume is higher. See Dominguez (2003). Furthermore, countries possess local (in each country) foreign exchange markets.

¹¹⁶Since agents trade via electronic media, it could be possible that transactions are conducted at the same time with different prices. This is due to the market opacity, based on the lack of one physical market, which makes price information difficult to observe for market agents.

¹¹⁷According to Sager and Taylor (2006), the absence of transparency is ultimately the reason, why the assumption of homogeneous informed agents is unsuitable for the foreign exchange market

¹¹⁸See Sager and Taylor (2006), and BIS (2007). Usually, dealers are large commercial banks, investment banks as well as securities houses. Customers can be divided in a financial and non-financial group. While the former includes mainly funds, investment banks, and insurance companies, the latter basically covers corporations and governments. Hence, some institutions can serve as dealers and financial customers simultaneously.

The idea of the foreign currency pricing can be seen as a two-stage mechanism.¹¹⁹ In the first stage, dealers, further referred to as market makers, receive orders from their customers and build up their expectation based on this idiosyncratic information (pure microstructure model). These orders are just a part of the whole market order flow. In addition, dealers may process publicly available information when forming their expectations (hybrid microstructure model). In the second stage, due to their own limits, risks, and price discovery considerations, market makers forward the positions received from their customers in the interdealer market. The open position runs like a "hot potato" through the interdealer market, until one market maker demands this position due to an order from a customer.¹²⁰ This makes the order flow visible, provides new information, and causes the dealers to reinterpret or confirm their expectations. Consequently, the interdealer market reveals private information, which is not publicly known. One interesting aspect, pointed out by Bjønnes and Rime (2003), concerns the visibility of interdealer trading. The more transparently interdealer trades are carried out, the more informative interdealer trading is. The most cognizable way is the indirect dealer trading via electronic trading platforms. In contrast, direct interdealing trading is the most intransparent way since only two participants of the whole market are engaged in the trading. To sum up, order flow is the source of private information, which conveys the beliefs of those who trade according to the observations of fundamentals. This private information is based either on different interpretations of news or the heterogeneity of expectations about future fundamentals. This way of explaining exchange rate determination is a further step towards accounting for real market patterns.

Theoretical models have been developed by several authors trying to best describe the characteristics of the foreign exchange market presented above.¹²¹ An often cited, and still most intuitive model is provided by Evans and Lyons (2002a), in the following called Evans-Lyons model, which serves as the reference point for most contributions on microstructural models.¹²²

¹¹⁹The DBB gives a very readable presentation of the microstructure idea of exchange rate determination, see DBB (2008).

¹²⁰This "hot potato" mechanism explains the high trading volume of the foreign exchange market.

¹²¹See e.g. Bacchetta and van Wincoop (2006), Evans and Lyons (2004), Sager and Taylor (2006), and Vitale (2007b).

¹²²Basically, the model presented by Evans and Lyons (2002a) rests on the insights of Kyle's (1985) sequential

Especially for the purpose of this section, this model is very fruitful since interventions can be modeled explicitly.¹²³ The Evans-Lyons model combines the idea of the portfolio-balance approach with the structural characteristics of the foreign exchange market, and can therefore be labelled as the *portfolio shift model*. It is assumed that orders are triggered by customers' portfolio shifts. These shifts are not common knowledge. Dealers, who are the counterpart of customer transactions, pass the orders down to the interdealer market as described above. Since dealers do not hold open positions over night, their inventory imbalances must be absorbed by the public at the end of each day. In line with the portfolio-balance model, customers are assumed not to be indifferent between two currencies. Exchange rates must adjust to induce agents to absorb the initial portfolio shifts from the interdealer market.¹²⁴

The determination of the exchange rate within one period is divided into three subperiods or trading rounds. Evans and Lyons (2002a) describe the interaction between N dealers, indexed by i , and a continuum of customers in an economy with two assets. One of them being riskless, and the other representing foreign currency with a stochastic payoff. The payoff on foreign currency consists of several increments ($R_t = \sum_{\tau=1}^t \Delta R_\tau$), representing the flow of common-known macroeconomic information (e.g. changes in interest rates). The Evans-Lyons model can be referred to as the hybrid version of microstructure exchange rate determination, incorporating both public available and private information.

In round one, reflecting customer dealer trades, all market participants observe public information provided by the payoff increment (ΔR_t). On this informational basis, every dealer i independently quotes his price ($P_{i,t}^1$) for buying and selling foreign currencies from and/or to customers. Dealers receive individual stochastic customer net orders ($C_{i,t}^1, C_{i,t}^1 \sim N(0, \sigma_C^2)$), which are executed at price ($P_{i,t}^1$) representing portfolio shifts. The individual net customer orders, which are not known to other dealers, aggregate to the public demand for foreign currency.

equilibrium model. See also Evans and Lyons (2002b) for an extended version.

¹²³See Evans and Lyons (2000).

¹²⁴The main difference between the portfolio-balance macro model, and the portfolio shifts model, provided by Evans and Lyons (2002a), stems from the role of asset supply. While in the macro version asset supply is the crucial factor driving the exchange rate, the microstructure version assumes the asset supply to be constant.

$$C_t^1 = \sum_{i=1}^N C_{i,t}^1. \quad (38)$$

Round two describes the interdealer trading. The dealers manage their open positions from the customer trades on the interdealer market. Hereby, they quote prices $P_{i,t}^2$ independently and simultaneously, at which they agree to buy and sell any amount of foreign currency. These quotes can be observed, and are available to all dealers in the market. Orders are passed through the market, making the initial public demand (C_t^1) known to every dealer through the sum of all interdealer trades ($T_{i,t}^2$) in round two. Hence, the interdealer order flow is defined as:

$$X_t = \sum_{i=1}^N T_{i,t}^2. \quad (39)$$

In order to know the public demand from round one, when observing X_t , it is necessary that each dealer passes his initial order with a constant proportion α down to other dealers as described by equations 40, and 41.

$$T_{i,t}^2 = \alpha C_{i,t}^1, \quad (40)$$

$$X_t = \alpha C_t^1. \quad (41)$$

As mentioned above, dealers are assumed not to hold overnight positions due to risk considerations. Knowing the initial customer demands from round one, dealers have to induce the public to absorb their open positions in round three ($C_t^3 = -C_t^1$).¹²⁵ Since customers are not indifferent to the composition of their portfolio, dealers adjust their quotes $P_{i,t}^3$, so that the public willingly takes up the inventory imbalances. Hence, the pricing in round three is a function of the net interdealer order flow (all available information), and the pricing in round two.

$$P_{i,t}^3 = f(P_{i,t}^2, X_t). \quad (42)$$

¹²⁵Dealers are confronted with a plethora of customers. Hence, the public possesses a much larger ability to carry overnight risks.

With this in mind, one can define the exchange rate change in period t as:

$$\Delta P_t = \beta_1 \Delta R_t + \beta_2 X_t. \quad (43)$$

According to equation 43, the exchange rate change in period t depends on publicly known as well as private information provided by ΔR_t and X_t respectively. The parameters β_1 and β_2 reflect the importance of both components. If customers are indifferent to the composition of their portfolios, order flows would have no influence at the end of the period ($\beta_2 = 0$). Similarly, if dealers would be risk-neutral, they would not pass their open positions down to the interdealer market, keeping private information concealed. Hence, such information would not affect the actual exchange rate at all. Evans and Lyons (2002a) test their model empirically by estimating the following relationship:

$$\Delta s_t = \beta_1 \Delta (i_t - i_t^*) + \beta_2 X_t + \varepsilon_t. \quad (44)$$

Applying nominal overnight interest rate differentials as the payoff increment, and using data on interdealer order flow, the authors apply equation 44 for US\$/JPY, and US\$/DEM relationships between May and August 1996. Their results show that order flow explained daily exchange rate changes significantly in both currency relationships. Similarly, changes in interest rate differentials were correctly signed, though being insignificant in the DEM case.

In line with these results, related papers have confirmed and extended the appropriateness of microstructure models in general, and the role of order flow in driving exchange rates in particular. For instance, Berger et al. (2008) show the high importance of interdealer order flow for exchange rate returns at high frequencies. Analyzing a comprehensive data set of EUR/US\$, and US\$/JPY exchange rates between 1999, and 2004, the authors confirm the presence of a significant relationship between interdealer order flow in one minute to one week exchange rate changes. However, the explanatory power of order flow declined at lower frequencies. Similarly, Dominguez and Panthaki (2006) support the role of order flow for high-frequency data. Analyzing data for EUR/US\$, and US\$/GBP exchange rates between 1999 and 2000,

the authors find evidence that order flow significantly affected exchange rates on a 20-minutes frequency. Based on a fixed exchange rate regime version of the Evans-Lyons model, Killeen et al. (2006), using FRF/DEM exchange rates, show that order flow had persistent effects on the exchange rate before the EMU parities were announced. After the announcement, the exchange rate and order flows were observed to be disconnected.¹²⁶

However, the source of order flow has not been examined explicitly in the literature. Is it true that order flow is the aggregated transmitter of individual expectations and/or interpretations of macroeconomic fundamentals? A paper that accounts for this matter is provided by Rime et al. (2007). The authors analyze the empirical relation between foreign exchange market order flow and macroeconomic information. Examining daily data on EUR/US\$, US\$/JPY, and US\$/GBP exchange rates, which were aggregated from high-frequency tick data and order flows between 2004 and 2005, the authors conclude: *"Macroeconomic information is identified to be a determinant of changes in order flow, which implies that exchange rate fluctuations are linked to macroeconomic fundamentals both via a direct link, as in classical exchange rate theory, and via order flow, as in the microstructure approach to FX,"* [Rime et al. (2007), p. 17]

2.5.2 Intervention within the Microstructural Approach

Evans and Lyons (2000) implement a theoretical model for the effects of interventions, based on their approach presented above. Interventions that are sterilized are assumed to be conducted secretly, so as to convey no signal of future monetary policy to private agents. Furthermore, sterilization assures that no relationship between the central bank action and the payoff increment exists ($Corr(I_t, \Delta R_t) = 0 \quad \forall t, \tau$). This in turn makes central bank interventions indistinguishable from private transactions. In this context, published intervention actions are not considered within this approach. Moreover, the model is based on the idea of how inter-dealer order flow reveals information about interventions. This is exactly the way how private information becomes publicly known, as described above. In order to capture interventions, the Evans-Lyons model is extended by an additional financial customer: The central bank. At the

¹²⁶See also Carlson and Lo (2006) for an intraday analysis of the DEM/US\$ exchange rate, and the traders' reaction on public information.

end of round one of the trading, a single trader is assumed to receive a central bank's order (I_t), besides other public contracts. With the intervention, the interdealer trades are:

$$T_{j,t}^2 = \alpha C_{j,t}^1, \quad (45)$$

$$T_{i,t}^2 = \alpha (C_{j,t}^1 + I_t), \quad (46)$$

where index j stands for all dealers except dealer i , who receives the central bank's order. The effect of an intervention is straightforward and comes from the portfolio shift as described above. Additionally, the authorities' order must be absorbed by the public at the end of trading round three. Therefore, the exchange rate must be adjusted appropriately. Hence, a central bank intervention, when sterilized and conducted secretly, influences the exchange rate like every other private trading. Again, the secrecy aspect clarifies that this intervention model operates within the portfolio shift idea of microstructure models. To test their model empirically, Evans and Lyons (2000) use hourly data from US\$/JPY and US\$/DEM markets. As in the Evans-Lyons model, their results suggest a correct but very short-lasting impact of order flows on the exchange rate.

In a more recent paper, Vitale (2006) develops a formulation of the foreign exchange market on the basis of Bacchetta and van Wincoop's (2006) dynamic monetary model. Thereby, foreign exchange dealers are subdivided into traditional dealers, who serve as brokers (automatically passing received customer orders down to the interdealer market), and dealer investors, who are risk-averse and try to generate a maximum yield from their portfolio (containing domestic and foreign assets).¹²⁷ In contrast to the Evans-Lyons model, which assumes interventions to work through a portfolio effect, Vitale (2006) incorporates a signaling effect as well. Hence, interventions can influence the exchange rate by signaling hidden fundamental information or via a portfolio effect. Another innovation of Vitale's (2006) model is that it analyzes two different intervention scenarios. Firstly, monetary authorities intervene individually by portioning up the intervention volume between several dealers (dealer-investors). Secondly, the central bank

¹²⁷Because information about fundamentals are known to the public, these model can be related to the hybrid version of microstructural models.

intervenes by employing one dealer, who serves as a broker, to enter the intervention amount into the interdealer market. It is intuitive that dealing with several dealers enhances the visibility of foreign exchange interventions.¹²⁸ Vitale (2006) argues that these two different intervention scenarios have different effects on the exchange rate and market conditions. If interventions have an informative content (e.g. targeting a fundamental value), individual operations reduce the market uncertainty about future fundamentals, due to the fact that the split of an intervention reveals more information about future fundamental movements. Hence, the visibility of central bank interventions in the foreign exchange market is clearly favored. In contrast, employing one single dealer increases market rumors, and raises exchange rate volatility. Hence, the signaling role of an intervention dominates the portfolio shift idea in terms of volatility. Consequently, interventions should be published when intended to provide information on fundamentals.

A different perspective on the *secrecy puzzle* within a microstructure framework is given by Ferré and Manzano (2009), whose model rests on the microstructure models provided by Kyle (1985) and Vitale (1999). Based on the signaling idea, they argue that authorities will prefer to conceal their operations in the presence of policy consistent interventions, and little information asymmetries. The reason is that the central bank is concerned about facing losses. By contrast, in the presence of high asymmetry of information between the authorities and market members, the central bank will publish its intervention. Additionally, the authors argue that in case of pure speculative intervention motives, monetary authorities will keep their operations secret.

Further, empirical studies of the microstructure channel of interventions are provided by e.g. Dominguez (2003, 2006), Payne and Vitale (2003), and most recently for an emerging market country by Scalia (2008). The overall findings support the role of the microstructure channel for foreign exchange interventions. However, the effects, if existent, have only a very short-run impact: *"The short-run results are supportive of both the portfolio balance and signaling channels, and suggest that interventions ... influence exchange rates at least within the day,"* [Dominguez (2006), p. 1069].

¹²⁸These diverse intervention scenarios were already taken into account by the Fed, as stated by Smith and Madigan (1988). Thus, depend on the degree of intervention visibility, the Fed chose to trade directly with several banks, or to contact one agent in the broker's market. Especially at the beginning of an intervention period, the Fed chose to operate directly with a number of banks simultaneously in order to enhance its visibility in the market.

3 Empirical Literature on Foreign Exchange Market Interventions

In order to answer the questions, why central banks intervene, and whether such interventions are effective, researchers have used several empirical techniques. The application of different approaches account for existing empirical and econometric problems. The lack of a commonly accepted exchange rate model, insufficient qualitative data on exchange rates as well as interventions, and most importantly, the so called *simultaneity bias*, has forced the academic literature to adjust its methodologies. Basically, two methods can be used to circumvent the problem of endogeneity.

Similar to the theoretical strands of central bank foreign exchange interventions, the empirical literature has mainly focused on the question, whether or not interventions are effective. Nevertheless, empirical research on the underlying intervention motives has been conducted to a much wider extent compared to the theoretical issues involved. Based on results from various methodologies, most researchers would agree that interventions in industrialized countries are mostly ineffective. If they work, effects are only of a very short-term nature, and interventions are likely to cause high exchange rate volatility. Nevertheless, monetary authorities have widely used this instrument to influence exchange rates.¹²⁹ This is the reason why the issue of central bank interventions has continuously attracted much attention. A more recent strand of empirical research has focused on the role of interventions in emerging market countries. In contrast to industrialized countries, central bank interventions in those markets are supposed to be more effective. Of course, the question is why these interventions are more powerful. Differences in the underlying economic structure, the degree of development, and the intervention strategy might be considered as decisive factors. During the following sections a presentation of the empirical literature dealing with central bank interventions in the foreign exchange market is given.

¹²⁹See Neely (2008) for surveys on intervention behavior of central banks.

3.1 Econometric Issues and Empirical Standard Tools

3.1.1 The Simultaneity Bias

3.1.1.1 The Problem of Simultaneity

Before presenting the empirical literature dealing with interventions in industrialized and emerging market countries, I will first discuss the simultaneity bias, which occurs if interventions and exchange rates are exposed to endogeneity. Here, simultaneity means that the exchange rate or its change, and interventions are determined in the same period. Hence, the question is what was first, the intervention, which is influenced by the exchange rate, or the exchange rate, which is determined by the intervention. More precisely, simultaneity occurs in case of feedback relationships between exchange rates and interventions. The problem is that neither the central bank operation nor the exchange rate (change) possesses an exogenous character. If not addressed, estimated coefficients are biased.¹³⁰

A simple example should suffice to illustrate the problem. While equation 47 states the impact effect of a central bank action (Int_t) on the exchange rate change (Δs_t), equation 48 can be seen as the central bank's reaction function. Thereby, the exchange rate return is supposed to be determined by the intervention amount.

$$\Delta s_t = \alpha Int_t + \varepsilon_t, \quad \varepsilon_t \text{ iid} \sim N(0, \sigma^2), \quad (47)$$

$$Int_t = \beta \Delta s_t + \nu_t, \quad \nu_t \text{ iid} \sim N(0, \sigma^2). \quad (48)$$

The reduced form for equation 47, and 48 yields:

$$Int_t = \frac{\beta}{1 - \alpha\beta} \varepsilon_t + \frac{1}{1 - \alpha\beta} \nu_t. \quad (49)$$

It can be seen that the necessary condition for unbiased estimation, $Cov(I_t, \varepsilon_t) = 0$, is not given. From equation 47 and 49, the OLS estimator for $\hat{\alpha}$, which captures the immediate impact

¹³⁰For discussions of the simultaneity bias in the context of central bank interventions, see e.g. Almekinders (1995), Dominguez and Frankel (1993), Galati et al. (2005), and Neely (2005a).

of an intervention on the exchange rate return, is:

$$\hat{\alpha} = \alpha + \left(\sum_{t=1}^n Int_t^2 \right)^{-1} \cdot Cov(Int_t, \varepsilon_t), \quad (50)$$

with

$$Cov(Int_t, \varepsilon_t) = \frac{\beta}{1 - \alpha\beta} Var(\varepsilon_t). \quad (51)$$

This shows that depending on the intervention strategy, coefficient $\hat{\alpha}$ is biased to a different extent. In this context, if a central bank *leans against the wind* ($\beta < 0$), i.e. purchasing foreign currency ($I_t > 0$) as a response to an exchange rate appreciation $\Delta s_t < 0$, and vice versa (smooth or reverse an existing exchange rate trend), coefficient $\hat{\alpha}$ is downward biased. In contrast, if the authorities *lean with the wind* ($\beta > 0$), i.e. purchasing foreign currency ($I_t > 0$) as a response to an exchange rate depreciation ($\Delta s_t > 0$) and vice versa (accelerate the actual exchange rate trend), coefficient $\hat{\alpha}$ is upward biased. Hence, the estimation of the immediate intervention impact captures the central bank's response on the exchange rate change.

3.1.1.2 Overcoming Simultaneity

As shown, the basic problem is the correlation between the regressor and the error term.¹³¹ Therefore, tackling the simultaneity bias requires to solve for the correlation. This can be done through two distinct approaches.¹³²

(i) Usage of Data:

The first method which can be applied to address the simultaneity problem concerns the use of data. Although not clear at first sight, the *secrecy puzzle* and the simultaneity bias are closely related. The fact that most interventions are conducted secretly or intervention data

¹³¹While the preceding discussion dealt with the inconsistency of the intervention impact coefficient $\hat{\alpha}$, the simultaneity concerns the reaction coefficient β as well.

¹³²See Gnabo et al. (2008) for a short discussion. At this point, I do not claim to present all possibilities, which can be used to overcome the simultaneity problem. Moreover, the methods discussed are widely used in the academic literature of foreign exchange market interventions.

is not published, caused researchers to use monthly changes in foreign reserves as a proxy for monthly interventions.¹³³ However, this is very problematic for at least two reasons. First of all, changes of foreign reserves are not a good proxy for intervention volumes as shown by Neely (2000a).¹³⁴ Second of all, even though intervention data is available, the inherent feature of high exchange rate dynamics is not taken into account when using monthly data.¹³⁵ Thereby, it is very likely that other factors than central bank interventions may have caused the exchange rate to move in one direction, which diminishes the potential explanatory power of central bank transactions. Moreover, monthly data is very likely to be exposed to simultaneity since central banks usually decide to intervene within days, hours, or even minutes. Hence, the question *'what was first ?'* cannot be answered when applying monthly data. Therefore, daily data is the next best time frequency to use.¹³⁶ Nevertheless, if the monetary authorities' decision to step into the market is done at higher frequencies, endogeneity remains. The most common way to solve simultaneity is to use one period lagged exogenous variables. This famous approach has been used by several studies dealing with foreign exchange interventions.¹³⁷ By doing so, the causality is fixed through time, and the estimated parameter is not biased. However, this does not allow to investigate the immediate impact of an intervention on the exchange rate. Furthermore, it is not free from critique. In this sense, Humpage (1999) argues that lagged interventions in equation 47 could introduce a specification error, given the martingale nature of exchange rates. This critical point is disputable when finding regressors with explanatory content for exchange rates. Besides, Humpage (1999) assumes central banks to make their decision on interventions within a given day. While this might be fine for some interventions, it is generally questionable when accounting for different intervention motives. Thereby, the authorities may monitor the behavior of exchange rates for several days or weeks before deciding to intervene. Moreover, the

¹³³See IMF (2007). This holds true mainly for emerging market countries. In contrast, some central banks issuing the world's major currencies have published intervention data.

¹³⁴As explained above, foreign reserve changes can be caused by various factors other than interventions. For this reason they should not be included in the definition of an intervention.

¹³⁵Some central banks in emerging markets publish aggregated monthly intervention data. For example, monetary authorities of the Czech Republic and India do provide such data.

¹³⁶The Economic Research Department of the Federal Reserve Bank of St. Louis provides daily intervention data of several central banks, even from emerging market countries: <http://research.stlouisfed.org/fred2/categories/32145> [as of 1st February 2010].

¹³⁷See e.g. Akinci et al. (2005a), Bernal and Gnabo (2009), Bonser-Neal and Tanner (1996), Dominguez (1993), and Guimarães and Karacadag (2006).

critique relies on foreign exchange markets to be efficient. However, as mentioned above, this assumption does not hold true. Overall, though being a simple approach, lagging regressors is, in my view, an appropriate way of dealing with simultaneity.

Another way refers to the right timing of exchange rate data. Since time-series analysis usually requires the use of stationary variables, empirical research uses daily exchange rate changes. In this sense, researchers may apply end of day exchange rate quotes to reckon daily exchange rate returns and to guarantee stationarity.¹³⁸ In this case, simultaneity should not be a problem when a central bank intervenes during normal business hours, i.e. the intervention is conducted between both exchange rate data points. But when monetary authorities intervene outside local business hours problems remain. Similarly, using opening and closing rates from the local intervention market for computing daily exchange rate changes is another way in this sense.¹³⁹ Indeed, it could be a viable choice, if interventions are conducted during the local business hours, and on the specific foreign exchange market.¹⁴⁰ Nevertheless, data limitations and central bank practices can impede this way of overcoming the simultaneity problem, especially in case of emerging market countries.

Finally, the investigation of high-frequency intraday data on interventions and exchange rates, as done e.g. by Dominguez (2006) as well as Payne and Vitale (2003), can avoid simultaneity, if the timing of the intervention is measured precisely, and the decision of monetary authorities to intervene is taken within the specified time frequency. Under those conditions, no feedback relationship between the exchange rate and an intervention occurs. However, central banks are very reluctant to publish intraday intervention data. To my best knowledge, only the SNB provides intraday data on their interventions for commercial usage. Other high-frequency data sets are restricted to special authorized application. For instance, while Dominguez (2006) analyzes G-3 intraday intervention data, Danish monetary authorities have most recently provided intraday data to Fatum and Pedersen (2009).

¹³⁸See Hillebrand and Schnabl (2006), who use end of the day exchange rate quotes from different local markets.

¹³⁹See Almekinders (1995).

¹⁴⁰It might be argued that using foreign exchange data from the local intervention market is not necessary due to arbitrage activity. However, local market data should be preferred due to the general low explanatory power of interventions for exchange rate movements. If an intervention influences exchange rate movements significantly, the impact can be assumed to be most visible on the local market.

(ii) *Estimation Techniques:*

The second way of circumventing the simultaneity problem deals with the applied estimation techniques. Structural models as proposed by Kearns and Rigobon (2005), and Neely (2005b) describe the interrelation between interventions and exchange rates explicitly. Vitale (2007a) mentions that when identified properly, these models are a good way to overcome the simultaneity bias. However, the proper identification reflects the limitation of these models. The lack of sufficient theoretical underpinnings makes it difficult to model the relationship between exchange rates and interventions. Furthermore, as it is the case with other econometric models, coefficients are not immune to structural breaks.

Besides establishing structural models, applying limited information estimations is another possibility to address the problem of endogeneity.¹⁴¹ Thereby, two-stage instrumental variable models have been used by some researchers.¹⁴² In this sense, intervention reaction functions serve to estimate the amount of interventions in a first step. In the following, predicted intervention values from the first estimation stage are then used as an instrument for real intervention activity in the second estimation stage. Basically, two-stage least squares estimation is commonly used for estimating simultaneous equation models similar to equations 47 and 48. However, the basic idea is that the predicted value of the endogenous variable from the first stage (intervention reaction function), is used as an instrument for the impact analysis in the second stage. Although being a fruitful approach in overcoming the simultaneity bias, at least partially, applying two-stage instrumental variable models has an essential drawback. Weak instruments can lead to biased instrumental variable estimators, which undermine the intention to use this approach.¹⁴³ In this context, instruments for interventions are usually weak in the sense that they are not orthogonal to the shocks affecting the exchange rate. Differently speaking, finding reliable instruments for central bank operations, which are uncorrelated to exchange rate changes, may be very difficult. The reason is that interventions may be determined by factors which influence exchange rate movements as well. Especially if intervention

¹⁴¹See Greene (2008) for a textbook presentation of limited information estimation methods.

¹⁴²See e.g. Disyatat and Galati (2007), IMF (2007a), Galati et al. (2005), Kamil (2008), and Tapia and Tokman (2004).

¹⁴³See Stock and Yogo (2002) as well as Stock and Watson (2006).

activity is exposed to a high degree of discontinuity, finding powerful instruments may be very challenging. Furthermore, simultaneity in the first stage remains. It is usually more difficult to find instruments for exchange rate movements compared to instruments for interventions. Galati et al. (2005) argue: "*Unfortunately, the notorious difficulty in explaining daily exchange rate movements means that it is highly unlikely that a good instrument can be found for the moment of the exchange rate.*" [Galati et al. (2005), p. 998].

Concerning the central bank's reaction function, binary response or ordered response estimation methods are further techniques which could be used to tackle endogeneity. In those approaches, which will be presented below, the intervention variable is an indicator taking discrete values. As noted by Ito and Yabu (2007), the choice of such an intervention indicator mitigates the simultaneity bias due to the fact that it collects the information of a daily intervention, which is (can be) portioned up on several occasions during the day. This in turn captures a decision-making process of authorities assessing the effect of one action and choosing to adjust the intervention amount within a given day. In other words, the indicator approximates an intraday reaction function. The authors note: "*... this way, we may mitigate the endogeneity problem: how much to intervene will be adjusted within the day depending on the success of intervention that is measured by the exchange rate movement. The righthand-side variables in the reaction function are those known to the authorities at the dawn of day t . This specification is more precise when the left-side variable is the indicator function than when the left-side variable is intervention amount. How intervention influences the market is evaluated by the authorities hourly, if not continuously, and additional intervention may be carried out if the exchange rate is not moving as intended. ... With the daily intervention data, the specification with the indicator may avoid this endogeneity problem.*" [Ito and Yabu (2007), p. 195]. Nevertheless, important information provided by the intervention amounts is neglected. Furthermore, this way of addressing the simultaneity bias clearly hinges on the assumption that authorities behave in the described way.

Finally, event-study analysis, as applied by Fatum and Hutchison (1999b, 2006) or Pierdzioch and Stadtmann (2003), have been used to solve the simultaneity issue. This way of tackling

the endogeneity neglects the influence of other economic variables and is therefore a partial appendage. Generally, within an event-study, the exchange rate behavior prior (pre-event window) to an event (intervention) is compared with the behavior after an event (post-event window). Hence, the problem of endogeneity as described by equations 47 - 51 is completely eluded by this atheoretic approach. However, the usage of event-studies does have some other drawbacks, which will be discussed below. These caveats make its usage very unsuitable for many questions related to foreign exchange dynamics.

3.1.2 Analyzing Motives for Central Bank Interventions

Basically, intervention reaction functions serve to examine factors explaining the occurrence of foreign exchange market interventions. By doing so, a researcher tries to disentangle the motives for central banks to step into the foreign exchange market, or to proof whether the purposes stated by the authorities are borne out by the data. Hence, reaction functions search for internal rules a central bank imposes on their actions in the foreign exchange market. Although investigating interventions is basically a matter of time-series analysis, microeconomic techniques have turned out to be suitable choices.¹⁴⁴ Several possibilities are given to explain the response (intervention) of a central bank to changing market conditions (suggested motives). The choice of an appropriate technique also depends on the distributional characteristic of interventions, which makes up another important obstacle of empirical research besides the above described problem of simultaneity.¹⁴⁵ However, estimation results have to be interpreted carefully. The reason is that reaction functions assume the underlying model to be the true data generating process, and therefore, estimation results indicate the strength of model. As mentioned previously, further aspects might drive monetary authorities to intervene in the foreign exchange market. To address this issue, some researchers include additional explanatory variables to enhance the power of the underlying model.

¹⁴⁴See Cameron and Trivedi (2005), Maddala (1983), Ronning (1991) as well as Winkelmann and Boes (2006) for thorough textbook treatments of microeconomic techniques.

¹⁴⁵Commonly, intervention reaction functions lack a theoretical framework. This is due to the above discussed fact that only little has been done in explaining central bank interventions from a theoretic perspective. Some exceptions are given by Almekinders and Eijffinger (1996) as well as Ito and Yabu (2007). Though formulating reaction functions from a theoretical perspective, their aspects are not commonly used.

It should be mentioned that the theoretical background of the following econometric techniques depends on the definition of an intervention and the used data sets as well as time frequencies. Basically, one can distinguish between the signaling idea, the case when only visible signals are given to the market, and the more broader asset approach (includes the signaling channel). However, as described in chapter 1.1, this work refers to the narrow definition of foreign exchange market interventions, which holds the advantage of contributing to a broader understanding why central banks intervene in the market.

A simple and valuable choice when examining intervention purposes is to use a standard OLS regression, as described by equation 52.¹⁴⁶ This basic approach serves as the standard workhorse model for all empirical analyses. Central bank transactions are treated as the left-hand or dependent variable, which are explained by several regressors or right-hand variables.¹⁴⁷ In this context, the intervention volume ($Int_t < 0$ sale of foreign currency; $Int_t > 0$ purchase of foreign currency) may be explained by different suggested motives, which are assessed according to the outcome of the parameter vector β . The estimation results and the significance of the single coefficients decide on the relevance of a specific intervention objective. Besides standard assumptions on OLS regressions, this way of modeling is appropriate as long as interventions occur in a continuous fashion.¹⁴⁸

$$Int_t = \beta_s motive_t^{short} + \beta_m motive_t^{medium} + \beta_t motive_t^{target} + \beta_v motive_t^{volatility} + \varepsilon_t, \quad (52)$$

$$Int_t = \beta \mathbf{X}_t' + \varepsilon_t, \quad (53)$$

$$\beta = (\beta_s, \beta_m, \beta_t, \beta_v), \quad (54)$$

$$\mathbf{X}_t = \left(motive_t^{short}, motive_t^{medium}, motive_t^{target}, motive_t^{volatility} \right). \quad (55)$$

However, as is mostly the case, foreign exchange market interventions occur in a discontinuous way. This may be due to the decision-making process of central banks, where authorities deliberate on the costs and benefits of interventions imposing an implicit band around explana-

¹⁴⁶See e.g. Ito (2002).

¹⁴⁷Additional variables in the reaction functions are neglected for now. Their relevance will be discussed in part II.

¹⁴⁸See Urban and Mayerl (2006) for a thorough and readable discussion on regression analyses.

tory variables in the reaction function, i.e. no intervention occurs due to only small changes in the regressors.¹⁴⁹ Thereby, authorities take special care not to endanger their credibility. This discontinuity leads to severe consequences for econometric estimation. Errors of a simple linear regression of non-continuous interventions on continuous right-hand variables are likely to be not normally distributed, making inferences problematic.¹⁵⁰ Furthermore, since the dependent variable may be censored or truncated in case of sporadic interventions, estimators are likely to be biased. The reason stems from the failure of the crucial assumption of mean independence between the error term and the regressors. Several ways, which refer to microstructural models, exist to address these problems. The methods are based on a latent variable approach. In this context, the latent (intervention) variable Int_t^* , which relates to the linear relationship of intervention motives and an error term, is only known to the central bank and cannot be observed. This reflects the internal decision-making process of the central bank. If Int_t^* would be observable, the standard OLS regression described above would provide all information. Under the Gauss-Markov assumptions, the obtained classical OLS estimators would be the minimum variance linear unbiased estimator.¹⁵¹ Unfortunately, Int_t^* is unknown, which requires the specification of a functional form between the latent and the observed intervention variable ($Int_t = f(Int_t^*)$).

One way to overcome the problems associated with discontinuous dependent variables is to apply binary response models (Logit, Probit), which are estimated by ML.¹⁵² Thereby, the dependent variable (intervention) is defined as a dummy variable taking 1 in case of an intervention (sale or purchase) and 0 if otherwise. In other words, Int_t as a dummy takes 1, if the unobserved intervention variable is greater than zero and vice versa. The basic model takes the following form:

¹⁴⁹See e.g. Ito and Yabu (2007), and Jun (2008).

¹⁵⁰Nevertheless, as long as the explanatory variables are uncorrelated with the errors, estimation is at least consistent.

¹⁵¹See Greene (2008).

¹⁵²See Beine and Bernal (2007), Frenkel and Stadtmann (2001), and Frenkel et al. (2005) for the logit approach, Baillie and Osterberg (1997), Guimaraes and Karacadag (2006), and Hillebrand and Schnabl (2006) for the probit approach. Most recently, Beine et al. (2009a) apply a nested logit model to disentangle the factors driving authorities to conceal or reveal their foreign exchange market interventions.

$$Int_t = \begin{cases} 1 & \text{if } Int_t^* > 0 \\ 0 & \text{if } Int_t^* \leq 0 \end{cases}, \quad (56)$$

$$Int_t^* = \beta \mathbf{X}_t' + \varepsilon_t, \quad (57)$$

$\varepsilon_t \sim \text{normal distribution} \rightarrow \text{Probit}$,

$\varepsilon_t \sim \text{logistic distribution} \rightarrow \text{Logit}$.

In both cases the regressors determine the conditional probability (π_t) for an intervention defined as:

$$\pi_t = P(Int_t^* > 0 | \mathbf{X}_t) = 1 - \Phi\left(\frac{0 - \beta \mathbf{X}_t'}{\sigma}\right) = \Phi(\beta \mathbf{X}_t'), \quad (58)$$

$$\pi_t = P(Int_t^* > 0 | \mathbf{X}_t) = \Lambda(\beta \mathbf{X}_t'), \quad (59)$$

with $\Phi(\cdot)$ and $\Lambda(\cdot)$ being the distribution functions of the standard normal and logistic respectively, and assuming the variance of ε_t in case of the normal distribution being 1.¹⁵³ The assumption of standard normal distribution is necessary for identification reasons. More precisely, the Probit model determines the probability for an intervention as being $\Phi\left(\frac{\beta \mathbf{X}_t'}{\sigma}\right)$. Thus, only the ratio $\frac{\beta}{\sigma}$ is identified. Therefore, a normalization is needed.¹⁵⁴ The distribution functions map the linear relationship of the intervention objectives onto the unit interval (0, 1). In contrast to standard linear OLS estimation, binary response models do not give any information on the linkage between the suggested purposes and the specific intervention volume. Instead, the regressors define the probability of an intervention. Applying this econometric technique for cases of continuous interventions would definitely lead to worthless estimations. The reason is that the dependent variable takes 1 at almost every observation in time. Furthermore, using such techniques requires to split interventions in sale and purchase transactions. Not doing so would dilute valuable interpretations of the estimation results. Moreover, these discrete choice models are associated to other econometric problems. For instance, while the inclusion of

¹⁵³Although both distribution functions are very similar, leading to very similar results (after scaling), the key difference between logit and probit is that the logistic distribution has slightly heavier tails.

¹⁵⁴Basically, setting $\sigma = 1$ holds for further microeconomic techniques applying the normality assumption.

lagged dependent variables is generally unproblematic for linear OLS regressions, it does impose drawbacks in case of non-linear models.¹⁵⁵

To cope with the unpleasant need of dividing interventions into foreign currency sale and purchase transactions, more general discrete choice models have been used in the literature.¹⁵⁶ Standard ordered response models, which are estimated by ML, provide a suitable choice. Thereby, the dependent variable takes 1 for foreign currency purchases, 0 in case of no action, and -1 in case authorities sell foreign currency. Again, the latent variable approach provides an intuitive motivation for ordered dependent variables. Moreover, the common feature of sporadic interventions is accounted for. In this context, the model can be seen as a reaction function with a neutral band around changes in the regressors where no interventions take place.¹⁵⁷ The model takes the following form:

$$Int_t = \begin{cases} 1 & \text{if } Int_t^* > \theta^+ > 0 \\ 0 & \text{if } \theta^- \leq Int_t^* \leq \theta^+ \\ -1 & \text{if } Int_t^* < \theta^- < 0 \end{cases}, \quad (60)$$

$$Int_t^* = \beta \mathbf{X}_t' + \varepsilon_t, \quad (61)$$

$$\varepsilon_t \sim N(0, \sigma^2). \quad (62)$$

Authorities will decide to intervene, if the latent intervention variable Int_t^* exceeds either of the thresholds (θ^+, θ^-) , reflecting that benefits of interventions are greater than their costs. The bigger the internal intervention amount, the greater the loss of no intervention. The thresholds can also be set to zero, however, this would undermine the idea of political costs associated with

¹⁵⁵Of course, the inclusion of lagged dependent variables in the OLS estimation is only unproblematic as long as no serial correlation of the error term exists. For more information see de Jong and Herrera (2004), de Jong and Woutersen (2004), and Gnabo et al. (2008).

¹⁵⁶See e.g. Gnabo (2008), and Ito and Yabu (2007) for ordered probit models.

¹⁵⁷Bernal and Gnabo (2009) apply a different ordered probit model to disentangle the use of oral and materialized interventions conducted by the BoJ. Thus, instead of defining a sale (-1), no action (0), and a purchase (1) intervention variable, the authors base their approach directly on the signaling idea of interventions. In their view, the case of a secret intervention and no action (0) cannot be distinguished, since in both cases no signal is provided to the market. The intervention variable takes 1, 2, 3 corresponding to oral, actual, and confirmed interventions respectively. Hence, the strongest signal is provided by actual confirmed interventions. It is clear that this approach is hampered by the fact that secret interventions are excluded from the analysis.

central bank interventions. With the error term ε_t being normally distributed, the standard ordered response model transforms into the widely known ordered probit model.¹⁵⁸ In this case, the conditional probability for a purchase $\pi_{t,(1)}$, sale $\pi_{t,(-1)}$, or no intervention $\pi_{t,(0)}$ at time t is given by:

$$\pi_{t,(1)} = P(Int_t^* > \theta^+ | \mathbf{X}_t) = 1 - \Phi\left(\frac{\theta^+ - \beta\mathbf{X}_t'}{\sigma}\right), \quad (63)$$

$$\pi_{t,(-1)} = P(Int_t^* < \theta^- | \mathbf{X}_t) = \Phi\left(\frac{\theta^- - \beta\mathbf{X}_t'}{\sigma}\right), \quad (64)$$

$$\pi_{t,(0)} = P(\theta^- \leq Int_t^* \leq \theta^+ | \mathbf{X}_t) = \Phi\left(\frac{\theta^+ - \beta\mathbf{X}_t'}{\sigma}\right) - \Phi\left(\frac{\theta^- - \beta\mathbf{X}_t'}{\sigma}\right). \quad (65)$$

The crucial drawback of binary choice, and more general ordered response models is that they do not incorporate all available information. The specific transaction amount is neglected, though intervention volumes may provide additional and important information on the central bank's response on changes in the specified explanatory variables. The econometric toolsets provide another estimation methodology to account for this fact reflected by the Tobit model.¹⁵⁹ In general, Tobit models are censored regression models and are estimated by ML.¹⁶⁰ The relationship is given by:

$$Int_t = \begin{cases} Int_t^* & \text{if } Int_t^* > 0 \\ 0 & \text{if } Int_t^* \leq 0 \end{cases}, \quad (66)$$

$$Int_t^* = \beta\mathbf{X}_t' + \varepsilon_t, \quad (67)$$

$$\varepsilon_t \sim N(0, \sigma^2). \quad (68)$$

Tobit models split the data generating idea in a qualitative and quantitative part. In this context, the dependent intervention variable is censored. The qualitative part explains whether or not an intervention has taken place. Thereby, the conditional probability $\pi_{t,(0)}$ of no central

¹⁵⁸For an ordered logit model, the distribution function takes $\Lambda(\cdot)$.

¹⁵⁹See e.g. de Jong and Herrera (2004), Kamil (2008).

¹⁶⁰Other estimation techniques for Tobit models are discussed in Ronning (1991). For more information on Tobit models, see Amemiya (1985), and Maddala (1983).

bank action is given by:

$$\pi_{t,(0)} = P(Int_t^* \leq 0 | \mathbf{X}_t) = \Phi\left(\frac{-\boldsymbol{\beta}\mathbf{X}_t'}{\sigma}\right). \quad (69)$$

If an intervention has occurred, the quantitative part models the intervention volume dependent on the regressors (censored regression). The density for interventions is given by:

$$f(Int_t | \mathbf{X}_t; \boldsymbol{\beta}; \sigma) = \frac{1}{\sigma} \phi\left(\frac{Int_t - \boldsymbol{\beta}\mathbf{X}_t'}{\sigma}\right), \quad (70)$$

with $\phi(\cdot)$ being the density function of the standard normal distribution. Although a Tobit model extends the used information set, the drawback of breaking interventions down into sales and purchases of foreign currencies remains. Thus, binary choice and Tobit models are only useful for one sided interventions.¹⁶¹

Finally, friction models as proposed by Rosett (1959) have turned out to be a very useful estimation technique for addressing the discontinuity of interventions, and using all available information simultaneously.¹⁶² Generally, a friction model can be understood as an extended version of the above presented ordered probit model. However, instead of accounting for sporadic interventions solely, friction models process more information by incorporating transaction volumes additionally.¹⁶³ Again, the latent intervention variable Int_t^* , which is only known to the central bank, models the demand and amount for an intervention to reach the desired objectives. Only if the latent intervention amount exceeds a certain threshold, which indicates that the benefit of a central bank action outweighs its costs, monetary authorities step into the market. The baseline intervention response model can be written as:

¹⁶¹A brief explanation on the consequences of OLS regressions in case of one sided, sporadic interventions seems warranted at this point. The more often the dependent variable takes 0, the higher are estimated coefficients biased. Thus, the non-intervention observations dilute the true relationship between an intervention and the underlying motives. See Ronning (1991).

¹⁶²See e.g. Almekinders (1995), Almekinders and Eijfinger (1996), Gnabo et al. (2008), Jun (2008), Kim and Sheen (2002), and Neely (2005b).

¹⁶³Another possibility would be to use a count data model as done by Frenkel et al. (2004). However, such a model is only suitable for special cases and does not represent a valuable alternative to the previously discussed reaction functions.

$$Int_t = \begin{cases} Int_t^* - \theta^+ & \text{if } Int_t^* > \theta^+ > 0 \\ 0 & \text{if } \theta^- \leq Int_t^* < \theta^+ \\ Int_t^* - \theta^- & \text{if } Int_t^* < \theta^- < 0 \end{cases}, \quad (71)$$

$$Int_t^* = \beta \mathbf{X}_t' + \varepsilon_t, \quad (72)$$

$$\varepsilon_t \sim N(0, \sigma^2). \quad (73)$$

In this context, three intervention scenarios are modeled explicitly and combined into the friction model, which is then estimated by ML. In case an intervention has taken place, the density for purchase and sale transactions is given by:

$$f(Int_t | \mathbf{X}_t; \beta; \sigma; \theta^+) = \frac{1}{\sigma} \phi \left(\frac{Int_t - \beta \mathbf{X}_t' + \theta^+}{\sigma} \right), \quad (74)$$

$$f(Int_t | \mathbf{X}_t; \beta; \sigma; \theta^-) = \frac{1}{\sigma} \phi \left(\frac{Int_t - \beta \mathbf{X}_t' + \theta^-}{\sigma} \right). \quad (75)$$

The conditional probability $\pi_{t,(0)}$ of a non-intervention observation is given by:

$$\pi_{t,(0)} = \Phi \left(\frac{\theta^+ - \beta \mathbf{X}_t'}{\sigma} \right) - \Phi \left(\frac{\theta^- - \beta \mathbf{X}_t'}{\sigma} \right). \quad (76)$$

Although the friction model seems to be the best choice when modeling central bank operations occurring in a discontinuous fashion, Jun (2008), however, challenges the use of friction models as a more viable choice compared to OLS regressions. He bases his arguments on results obtained from in-of sample as well as out-of sample forecasts of interventions conducted by the Fed and the Bundesbank. The author compares RMSE and MAE statistics derived from OLS regressions and friction models, using daily data on interventions in the US\$/DEM market between 1987 and 1993. While the friction model produced lower MAE, the corresponding RMSE was higher compared to OLS results. The difference indicates that while the majority of forecast errors are lower (MAE) for the friction model, large-size errors tend to exceed those of the linear OLS approach (RMSE). Although the MAE advantage did not outweigh the RMSE disadvantage, the friction model performed better in cases where an intervention had taken place.

Basically, friction models allow to address the arguments of political costs quite appropriately. Furthermore, their use reveals the interesting aspect of intervention asymmetry $(|\theta^+| \stackrel{?}{=} |\theta^-|)$.

3.1.3 Analyzing the Impact of Central Bank Interventions

Instead of trying to explain the occurrence of interventions by using exchange rate developments, examining intervention effects treats the exchange rate as the variable to be explained. Basically, analyzing intervention effects on the exchange rate is associated with the problem of explaining exchange rate movements in general. So far, no reliable exchange rate model has stood out. This makes empirical research even more challenging. In order to enhance the methods for examining intervention effects, additional factors are used to increase the overall reliability of the used estimation model. Naturally, these variables are of far greater importance compared to the additional factors for reaction functions. The poor results of interventions in the academic literature requires the baseline model (without intervention) to explain exchange rates to a sufficient extent. Similar to reaction functions, researchers have chosen between several techniques to analyze the impact of interventions on exchange rates. These techniques come from a partially analytical perspective or treat the exchange rate in a more theoretical context.

As it is the case for reaction functions, the basic approach is a linear OLS regression according to equation 77.¹⁶⁴ From a theoretic perspective, the exchange rate is seen according to the asset view of exchange rate determination.¹⁶⁵ Instead of modeling the relationship between the exchange rate level and regressors, exchange rate changes are used to ensure stationarity of the dependent variable, which is necessary for obtaining valuable results.¹⁶⁶

Exchange rate returns are modeled to be determined by a set of additional variables (\mathbf{Z}_t) and an intervention (Int_t). Coefficient β measures the impact of an intervention on the exchange rate return. The intervention variable may take several forms. On the one hand, one might include realized intervention volumes. On the other hand, especially when lacking sufficient

¹⁶⁴See e.g. Dominguez and Frankel (1993), Tapia and Tokman (2004). Kim (2003) uses a VAR approach to analyze interventions. While this might be useful in the context of further aspects explaining intervention and its associated effects it is clearly restricted to a lower frequency data analysis.

¹⁶⁵See Levich (2001).

¹⁶⁶The aspect of integration will be discussed in more detail below.

qualitative data, a dummy variable can replace intervention volumes to indicate an operation at time t . As discussed above, some studies also use an instrumental approach. Estimating a reaction function, and using fitted intervention variables $\left(\widehat{Int}_t\right)$ is a way of circumventing the simultaneity problem. The advantage of the instrument approach is that the contemporaneous impact of interventions on exchange rate changes can be estimated more precisely. However, all negative aspects mentioned, do not justify its common use.

$$\Delta s_t = \alpha + \beta Int_t + \zeta \mathbf{Z}'_t + \varepsilon_t. \quad (77)$$

In contrast to reaction functions, the set of explanatory variables (\mathbf{Z}_t) gain in importance. It may contain every variable a researcher assumes to possess explanatory content for exchange rate returns. Usually, interest rate differentials, government bond yields, stock market prices, and macroeconomic announcements of monetary authorities are included in this set. However, the choice of explanatory variables hinges on the analyzed data time frequency. In this context, it is not suitable to explain daily or even intraday exchange rate movements with macroeconomic variables. The match of time frequency is of great importance. Some attempts have been made to interpolate low-frequency data on higher frequencies. Estimation results for such variables are usually poor.¹⁶⁷ In addition, exchange rate changes might be exposed to seasonality. If not accounted for, this would affect residuals of OLS regressions, debasing standard errors and impeding test statistics accordingly. Therefore, daily dummy variables are sometimes included in \mathbf{Z}_t to capture seasonal patterns of exchange rate movements.¹⁶⁸

The biggest drawback of assessing the effectiveness of interventions through an OLS regression is that it does not account for the nearly inherent feature of time-varying volatility (heteroskedasticity) in high-frequency exchange rate time-series. In this context, times of low

¹⁶⁷See Kim and Sheen (2002) for a reaction function using interpolated data.

¹⁶⁸Another approach is to specify dummy variables taking 1 before and/or after a holiday. This would capture the effect whether investors have made transactions due to holiday reasons. Furthermore, analyzed high-frequency exchange rate data studies do often share the common characteristic of displaying complex intraday periodicities (non-normality due to very high kurtosis and long memory patterns). To account for this complex seasonality, Andersen and Bollerslev (1998) recommend a procedure using the concept of realized volatility and a Fourier flexible form model to capture intraday patterns of the residuals. See e.g. Dominguez (2006), and Fatum and Pedersen (2009).

volatility are followed by periods of high volatility. Not accounting for heteroskedasticity impedes interpretation of the estimated coefficients due to the biased coefficient variances and biased significance values.

In order to solve this problem and to examine the effect of foreign exchange market interventions on exchange rates, (G)ARCH models have turned out to be a very fruitful methodology.¹⁶⁹ Their popularity stems from a twofold advantage. Firstly, ARCH models capture the above mentioned feature of heteroskedasticity in exchange rate time-series by explicitly modeling the conditional volatility. The basic idea of GARCH models as an extension of ARCH is a parsimonious specification of high order ARCH models. Secondly, applying a (G)ARCH model allows to investigate the impact on the mean (equation 78) and the conditional volatility (equation 80) of exchange rate returns simultaneously. As is the case in OLS regressions, interventions may also be included as dummy variables, or as fitted values from a preceding reaction function. The basic setup takes the following form:

$$\Delta s_t = \alpha_0 + \beta_1 Int_t + \boldsymbol{\zeta}_1 \mathbf{Z}'_t + \varepsilon_t, \quad (78)$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2), \quad (79)$$

$$\sigma_t^2 = \mu + \sum_{i=1}^p \partial_i \varepsilon_{t-i}^2 + \sum_{i=1}^q \gamma_i \sigma_{t-i}^2 + \beta_2 |Int_t| + \boldsymbol{\zeta}_2 \left| \mathbf{V}'_t \right|. \quad (80)$$

Intervention volumes in the conditional volatility equation are included in absolute values. This is done to avoid a potential negative volatility. Furthermore, additional exogenous factors (\mathbf{V}_t) may influence the conditional volatility as well. In this context, one might think of stock market behavior or policy announcements, which could trigger market rumors or act in a calming way.¹⁷⁰ As for intervention volumes, the set of additional variables is included in absolute values as well. Since (G)ARCH models are estimated by ML, an assumption concerning the error

¹⁶⁹See e.g. Almekinders (1995), Cashin et al. (2006), Domaç and Mendoza (2004), Dominguez and Frankel (1993), Hillebrand and Schnabl (2006), Hoshikawa (2008), and Ito (2002). See Bollerslev (1986) and Engle (1982) for a general treatment of (G)ARCH models.

¹⁷⁰Basically, both sets of additional variables could contain the same variables ($\mathbf{Z}_t = \mathbf{V}_t$).

distribution is required. It is common that exchange rate returns are not normally distributed.¹⁷¹ Nevertheless, the normal (Gaussian) distribution is often applied for reasons of simplicity leading to a QML estimation in the sense of White (1982).¹⁷²

The basic drawback of the time-series techniques presented so far is that such techniques generally fail to capture the clustering of interventions over time. A famous method of examining the effectiveness, and accounting for the sporadic occurrence of central bank interventions, is the use of an event-study methodology.¹⁷³ Instead of analyzing the effect of interventions during a specific sample, the event-study approach examines the effect of a single (or few) central bank action(s) on the exchange rate. Event-studies compare exchange rate behavior prior to an intervention event with exchange rate movements after an intervention event. The basic assumption of this framework is that intervention effects do not materialize instantaneously, but might evolve over some days. This atheoretic methodology is executed in four steps.¹⁷⁴

First of all, an intervention event has to be defined. While in the finance literature defining an event is straightforward (e.g. mergers and acquisitions, issues of new debt), picking a single central bank action as an event is problematic. The reason being that central banks are usually active on successive days. In this context, events might clash, rendering subsequent conclusions senseless. To address this problem, Fatum and Hutchison (1999b) recommend to define an intervention event as: *"... a period of days with official intervention ... in one direction (in terms of purchases or sales), ... and possibly including a number of days with no intervention."* [Fatum and Hutchison (1999b), p. 9].¹⁷⁵ In practice, the "tranquility period" can vary between several

¹⁷¹See e.g. Enders (2004) as well as Krätzig and Lütkepohl (2004).

¹⁷²GARCH models will be discussed in more detail in chapter four.

¹⁷³Fatum and Hutchison (1999b) introduce the event-study approach, which is often used in the finance literature, for Fed intervention data. They argue: *"In order to address the issue of effectiveness, the methodological starting point of this paper is to recognize that standard time-series techniques may not be well suited when dealing with the analysis of intervention vis-à-vis the behavior of exchange rates. Exchange rates are typically highly volatile on a day-to-day basis, intervention tends to come in sporadic clusters ... the event study approach used in the finance literature seems to fit well. Specifically, a cluster of intervention operations constitutes a natural candidate for identification of a single event."* [Fatum and Hutchison (1999b), p. 4]. For further contributions using the event-study approach, see e.g. Bernal and Gnabo (2009), Égert and Komárek (2005), Fatum (2000, 2008), and Fratzscher (2005).

¹⁷⁴See Fatum (2000), and Fatum and Hutchison (1999b).

¹⁷⁵This points to another problem of how many days without central bank actions to allow for. Setting the event too short, researchers may deal with two or more events when, in fact, there is only one event. The opposite is the case when setting the event too long. Hence, researchers have to be aware of overlapping events when deciding how many days of no interventions to include in an intervention event.

days. While Fatum (2000, 2008) sets 5 days, Égert and Komárek (2005) apply 30 days. In a second step, the pre- and post-event windows have to be defined. The length of both windows is of crucial importance. Event-study approaches are only useful if both windows reflect normal exchange rate movements, which are not influenced by further interventions. As already mentioned, intervention effects are assumed not to appear immediately but might evolve during the course of several days. Both aspects have to be addressed when defining the window length.¹⁷⁶ For instance, Fatum and Hutchison (2006) set the window length to 15 days. The third step requires to settle different criteria of success. This constitutes the essential advantage over the classical time-series analyses described previously. Stating criteria for successful interventions provides more flexibility and is not restricted to assess the effectiveness of interventions according to an estimated coefficient. Whether analyzing the impact of a central bank transaction on the level, the trend, or the volatility of exchange rates is a matter of definition. In general, the criteria of success compare the exchange rate behavior prior to an intervention event with the exchange rate behavior after an intervention event. In this context, an intervention might be successful if alleviating an existing exchange rate trend ("smoothing" criterion), reverting a trend ("reversion" criterion), assuaging the exchange rate volatility ("volatility" criterion), or influencing the exchange rate level ("direction" criterion).¹⁷⁷ Of course, the intervention volume must be in line with the given objective of the central bank. The final step is characterized by applying statistical tests to verify the relationship between interventions and success criteria. Fatum and Hutchison (1999b) recommend non-parametric sign and match sample tests.¹⁷⁸

Although being essentially very fruitful, the key drawback of the event-study methodology is that it is only a partial analysis, which does not account for further important factors. Since those variables may contain explanatory content for exchange rate movements neglecting them can lead to biased results. Furthermore, it can be assumed that central banks stop to intervene either if the goal is reached, or if interventions are perceived as being unsuccessful. This makes a comparison of pre-event and post-event windows problematic. Besides their flexibility, event-

¹⁷⁶ Similar to the appropriate length of a transaction event, setting the pre- and post event windows too large might result in coinciding with windows from other intervention events.

¹⁷⁷ See Fatum (2008), and Fatum and Hutchison (1999b).

¹⁷⁸ See MacKinley (1997) for more details on tests in event-studies.

studies require an a priori knowledge or suggestion of the underlying intervention motive. This in turn limits the unprejudiced assessment of interventions. Additionally, the appropriate event and window choice seems to be a rather arbitrary decision. Furthermore, the event-study approach does not allow to draw any conclusions on the underlying theoretical intervention channel, being in charge of potential intervention effects.

A different strand of the empirical literature turns to option market data in order to examine the effect of an intervention on higher moments of exchange rates. One advantage of this approach is the possibility of directly analyzing the impact on foreign exchange market expectations about future exchange rate movements.¹⁷⁹ Using a simple OLS approach (equation 81), the moments (M_t^i) of a PDF are regressed on central bank interventions and a set of other explanatory variables, which are assumed to influence market expectations.¹⁸⁰ This allows to explore the potential impact of interventions on market sentiments. Analyzing PDFs is of special interest when assessing the signaling channel. Remember, central banks may intervene to signal the market their opinion on the appropriateness of the actual exchange rate behavior. Hence, following an intervention, moments of exchange rates should adjust accordingly.¹⁸¹ However, one essential drawback of using PDFs is data limitation. Until now, currency option data are not available for all currency pairs, and for appropriate time horizons. Especially for emerging countries this application is often restricted.

$$\Delta M_t^i = \alpha Int_t + \zeta \mathbf{Z}_t' + \varepsilon_t. \quad (81)$$

¹⁷⁹A recent contribution to this aspect is given by Nikkinen and Vähämaa (2009), who analyze the effects of interventions conducted by the BoJ on ex ante exchange rate correlations (JPY/US\$, EUR/US\$, GBP/US\$) derived from the option prices of OTC markets. According to their results, interventions affect market expectations about future currency co-movements significantly.

¹⁸⁰See Disyatat and Galati (2007), Galati et al. (2005), and Rogers and Siklos (2003). Gnabo and Teiletche (2009) analyze PDFs with the event-study approach. For more literature on the usage of option market data to estimate PDFs of the underlying exchange rate, see e.g. BIS (1999), Castrén (2005), Chang and Tabak (2002), and Malz (1997). A very good introduction to risk-neutral PDFs as a means for analyzing market expectations is given by DBB (2001). Finally, Galati et al. (2007) present a user's guide discussion on the usage of option market data for analyzing intervention effects.

¹⁸¹Bonser-Neal and Tanner (1996) use the implied volatility derived from option prices to test the effects of interventions on ex ante volatility. The underlying idea is that, according to the signaling channel, interventions should calm the market reflected by a decreasing of the implied volatility. However, the authors find evidence that Fed and Bundesbank interventions between 1985 and 1991 increased the implied volatility.

The four moments (M_t^{1-4}) of the PDF can be used to describe the market expectations of future exchange rates.¹⁸² The first moment (the mean) of a PDF describes the agents average expectation of the exchange rate on a specific future date. Since risk neutrality is assumed, the mean is equal to the forward rate. Alternatively, one can use the spot rate as well. The forward and the spot rate are connected directly through the covered interest rate parity. The second moment (the variance) characterizes the market's uncertainty on a particular day about future exchange rate movements.¹⁸³ The third moment (the skewness) gives information about the weight market participants assign to a weaker or stronger exchange rate with respect to the forward rate.¹⁸⁴ A negative value of the skewness corresponds to a left skewed PDF putting its peak to the right of the mean, whereas a positive skewness corresponds to a right skewed PDF putting its peak to the left of the mean. The fourth moment, the kurtosis describes the probability market participants assign to very large changes in either direction in the near future.¹⁸⁵ Due to the risk neutrality assumption, the market's view on exchange rate movements as well as its preference towards risk are captured simultaneously.¹⁸⁶ It is nearly impossible to discriminate between these two aspects. This makes it difficult to interpret PDFs precisely. An increase in the expected price of an asset may stem either from a higher demand for a specific asset caused by the perception of likely future gains, or from a higher preference or aversion towards risk. Nevertheless, in the short-run, it should be more likely that market views on future exchange rate changes will diverge than the agents' preference towards risk. Against this background, the estimated coefficient α describes the impact of a central bank intervention on a change in one of the PDF moments.

Finally, other attempts have been made to analyze intervention relationships in simultaneous equation models or structural models. Those models explicitly build on an interrelation between central bank interventions and exchange rate movements. As described earlier, the big

¹⁸²See Galati et al. (2007).

¹⁸³The implied volatility derived from at-the-money options serves as the measure of the second moment.

¹⁸⁴The risk reversal, which is the difference in the price between two equally out-of-the-money call and put options, serves as the measure of the third moment.

¹⁸⁵A strangle consists of a purchase or sale of an equal out-of-the-money put as well as call option. This instrument yields a significant gain in case of a large shift in the price of the underlying asset. It serves as the measure of the fourth moment.

¹⁸⁶See Galati and Melick (1999, 2002).

advantage of structural models is that they are able to capture the immediate impact of interventions on exchange rate changes (and vice versa) directly, without being exposed to the risk of simultaneity. However, this advantage is counterbalanced by the necessity of making strong assumptions in order to identify parameters. Furthermore, as mentioned frequently, the lack of an appropriate theoretical underpinning for explaining exchange rate movements hampers the use of structural models in practice. Both aspects challenge the feasibility of such models to investigate intervention dynamics. Kearns and Rigobon (2005), and Neely (2005b) apply structural models, which rely on very strong assumptions. While Neely (2005b) assumes that monetary authorities balance the sale and purchase of foreign currency, Kearns and Rigobon (2005) estimate their model by using structural breaks in the time-series.¹⁸⁷

3.2 Surveys on Empirical Analyses

3.2.1 Industrialized Countries

Until now, the basic discussion about central bank interventions has focused on developed or industrialized countries. Empirical analyses of these countries exist in an abundant amount. The discussion on interventions in industrialized countries thereby concentrates on the effects of sterilized interventions. Several summaries of the literature on the efficiency of foreign exchange market transactions have been composed by various authors during the last years.

Edison (1990, 1993) focuses on the literature between the mid 1970s and early 1990s. He gives a broad description of the literature dealing with the channels of influence, and related central bank policy reaction functions. The author concludes that interventions might have an effect through the signaling channel, although this effect is rather short lived. However, this must be qualified against the background of low data quality, which may have not been sophisticated enough to detect existing relationships between interventions and exchange rates appropriately. Concerning the question whether coordinated interventions are more effective than uncoordinated interventions, Edison (1993) notes that results differ across periods. This is rather strange,

¹⁸⁷See also Hillebrand et al. (2009).

since such interventions are usually characterized by higher transaction amounts, and are providing a stronger credible sign for foreign exchange markets. The best-documented periods in the aftermath of the Bretton-Woods system have been the Plaza-Accord and Louvre-Accord in 1985, and 1987 respectively.¹⁸⁸ While the Plaza-Accord stated the agreement of the G-5 to stop the ongoing appreciation trend of the US\$, the Louvre-Accord, signed by the G-6, stipulated to reverse the prevailing US\$ depreciation. In both cases the US\$ misalignments were countered by coordinated policy actions of industrialized markets. Besides others, Humpage (1988), and Obstfeld (1988) analyze the Fed's interventions during those periods. Unlike common opinion that the central bank actions have restored the US\$ movements, both authors argue that sterilized interventions during those periods have played an unimportant part in the exchange rate behavior. Instead, shifts in monetary policy, fiscal policy, and macroeconomic fundamentals affected the exchange rate path. However, in the short-run, some signaling effect of interventions has been found. The key incentive for central banks to intervene, though varying across countries, has been the will to smooth over fluctuations in the exchange rate. Furthermore, Edison (1993) emphasizes that interventions, conducted in the post-Louvre-Accord period were aimed at keeping the exchange rates within narrow bands. Hence, the main objective has been to limit the exchange rate flexibility.

Almekinders (1995) also highlights this aspect when giving an overview of studies dealing with the objectives of interventions and their efficiency. According to the studies reviewed, central banks tend to react differently when *leaning against the wind* in case of an under- or overvalued currency with respect to the PPP. While some prefer fighting a depreciation of the exchange rate, others are only concerned with an overvalued domestic currency. Such asymmetric responses give information about the specific underlying goals of central banks, like controlling for exchange rate pass-through effects on domestic prices, or enhancing the competitiveness of the domestic industry. Just like Edison (1990, 1993), Almekinders (1995) notes that no systematic effect of a sterilized intervention on investors' portfolios could be detected by previous studies. While this may be due to data limitations, it is perhaps more

¹⁸⁸Funabashi (1989) gives an extensive background report of both intervention periods.

conclusive to argue that the scales of interventions relative to the amount of outstanding stocks of assets have yet just been too small. Some of the reviewed literature argues that interventions have to be published in order to exert, at least, some effect on exchange rates, which supports the signaling idea of foreign exchange interventions. Nevertheless, results are mixed even for coordinated transactions, indicating that market participants incorporate further "news" when assessing the informational content of central banks' operations in the exchange market.

With the availability of more sophisticated high-frequency data during the 1990s, empirical studies became more supportive for interventions' efficiency. In this context, Sarno and Taylor (2001a) state that the availability of high-quality data enhances the usage of econometric methodologies. The corresponding results basically allow to draw the cautious conclusion that an intervention might possess explanatory power for exchange rate changes when being published, coordinated, and consistent with the basic fundamental underlyings. However, the results are far from being conclusive. Concerning the channels of influence, Sarno and Taylor (2001a) are in line with previous overviews in the way that they argue the portfolio-balance channel to be less important. Especially since the degree of substitutability between financial assets in an ongoing financial globalization increases, interventions will not be able to exert a significant effect on investors' international portfolio compositions. This in turn, emphasizes the signaling channel again as the primary one of either of the traditional channels of influence. Despite its popularity, one remarkable feature of central banks' transactions cannot be explained sufficiently: The *secrecy puzzle*. In this context, Sarno and Taylor (2001a) point towards the noise-trading channel as a possible third "important" way of thinking about how interventions might influence exchange rates.

According to Humpage (2003), some consensus understandings have emerged from the previous literature. Economist construe their results as supportive for the signaling idea, although these findings vary significantly across countries, time periods, and the used methodologies. Concerning the second moment of exchange rates, interventions tend to increase exchange rate volatility. In this context, central bank transactions can be viewed as being destabilizing because of the transmittal of new information in the foreign exchange market, which is characterized by

information imperfections (noise-trading channel). Differing from other summaries, Humpage (2003) concludes that coordinated interventions might provide a stronger signal to the market, and are therefore likely to be more powerful. Although theoretical models provided by Hung (1997), as well as Bhattacharya and Weller (1997) give some reasons for the efficiency of secret interventions, this controversy remains unsolved. Against the background of the lack of an appropriate exchange rate determination model, Humpage (2003) explains the influence of an intervention in the following way: "*Sterilized intervention affords monetary policy makers a means of occasionally pushing an exchange rate in a desired direction. The alternative level then serves as a new starting point for a random walk process compatible with existing fundamental.*" [Humpage (2003), p. 23]. This in turn makes it clear that a sterilized intervention, until now, cannot be seen as an independent monetary policy tool. In this context, unsterilized interventions can certainly affect currencies in a persistent way, although with the potential danger of conflicting with the actual monetary policy stance.

Most recently, the *International Journal of Finance and Economic* has afforded one complete volume on foreign exchange market interventions.¹⁸⁹ In interesting contributions, the authors focus on open questions and new relevant issues. Especially the paper provided by Vitale (2007a) discusses unsolved aspects in the analysis of foreign exchange interventions, and gives a review of past findings. He emphasizes that the mechanics of central bank interventions are far from being sufficiently understood. Several issues, like influence of an intervention on exchange rate volatilities, informative content of an intervention, and an intervention's lasting power still lack enough attention and/or understanding. Even the question of intervention purposes has not been answered conclusively. However, this is not astonishing since different countries face varying needs causing the authorities to intervene for diverse reasons. At least some consensus seems to exist that interventions are more effective if conducted in a coordinated fashion, and made publicly known. Reasons for this insufficient knowledge are mainly linked to data availability problems as well as on incomplete theoretical understandings. According to Vitale (2007a), the most likely way to yield positive results in tackling the open questions

¹⁸⁹See *International Journal of Finance and Economics*, Volume 24, Issue 2, Special Issue: Exchange Rate Intervention.

and to overcome the crucial criticism of the simultaneity bias, stems from the application of the microstructure channel. In this way, the use of high-frequency data, and the extended understanding of the microbasis of the foreign exchange market will shed more light on these continuous fields of research.

The outcome of all of these surveys is that interventions are by no means an independent monetary policy instrument. The academic literature, though applying more sophisticated methods and data during the last decades, has not changed much of its attitude towards favoring the signaling idea, and denying a substantial power of central banks' foreign exchange market interventions. However, a poll conducted by Neely (2008) with several central banks shows that monetary authorities have actively used foreign exchange interventions.¹⁹⁰ Hence, while negating their usefulness, the academic literature must have ignored essential aspects when analyzing intervention relationships. As encouraged by Vitale (2007a), the application of high-frequency intraday data mirrors the actual strand in the empirical intervention literature, although some contributions were given earlier.

In this way, Beattie and Fillion (1999) as well as Fatum and King (2005) have analyzed intraday intervention data of the Bank of Canada. Both studies find significant positive results for interventions to be effective in managing exchange rate behavior. While Beattie and Fillion (1999) show that interventions reduce exchange rate volatility using time-series analysis, Fatum and King (2005) apply an event-study framework, and find evidence that interventions influence the exchange rate level significantly in the intended direction. Furthermore, the authors agree on a reduction of exchange rate volatility in the short-run.¹⁹¹ Recently, Fatum and Pedersen (2009) favor the effectiveness of foreign exchange market interventions under certain circumstances. Using high-frequency intraday DKK/EUR exchange rate and intervention data, they conclude: 1) interventions can be used as a short-term exchange rate policy instrument; 2) interventions are effective when consistent with monetary policy fundamentals, and in time of high exchange rate volatility; 3) intervention effects materialize within 30 minutes, but not instantaneously,

¹⁹⁰Other polls of central banks' interventions are provided by Lecourt and Raymond (2006), Mihaljek (2005), and Neely (2000b).

¹⁹¹See also Cai et al. (2001), and Kim (2007) for intraday analyses of Japanese data, as well as Fischer and Zurlinden (1999) for a contribution on Swiss intraday data.

which might stem from the fact that Danish interventions are conducted secretly.

Thus, analyses using high-quality data mainly support the effectiveness of interventions.¹⁹² They do not perform better compared to contributions using daily data rather than support them in the way that they match the common view of interventions to be only effective in the very short-run. Against this background, Disyatat and Galati (2007) argue that: "*... the evidence on advanced countries suggest that the bulk of the impact of intervention on the level of the exchange rate occurs during the day in which it is conducted, with only a smaller [if any] impact on subsequent days.*" [Disyatat and Galati (2007), p. 388].

3.2.2 Emerging Market Countries

Studies on interventions in emerging markets exist sparsely. This is astonishing since central banks from major countries have not been as actively involved in the foreign exchange market as monetary authorities from emerging markets.¹⁹³ In this context, foreign reserves minus gold grew by 600% in emerging and developing countries, from 694.8 bill. US\$ in January 2000, to 4865.7 bill. US\$ in August 2009. This indicates a strong presence of those central banks in the foreign exchange market.¹⁹⁴ Basically, the scarcity of empirical analyses can be mainly explained by the same obstacles researchers had to face at the beginning of analyzing developed countries' interventions, namely the lack of appropriate data.

The most thorough and comprehensive contribution on interventions in emerging markets is provided by the Bank for International Settlements, BIS (2005b). Several aspects like motives for interventions, the role of governments, methods and tactics, and domestic consequences are discussed and supported by various countries experiences with foreign exchange interventions. Although this study covers a wide range of aspects and practical experiences, the contributions

¹⁹²Nevertheless, intraday studies might be biased if intervention data are obtained from newswire reports. Such reports can be exposed to a high degree of inaccuracy as reported by Fischer (2006). However, when faced with G-3 central bank actions, intervention news are likely to be accurate, as argued by Dominguez (2006).

¹⁹³Besides some recent occasional interventions of the SNB, the ECB has conducted foreign exchange transactions (US\$ swaps during the subprime crisis) on several occasions, which served to provide foreign currency liquidity to domestic banks. See http://www.ecb.int/mopo/implement/omo/html/top_history.en.html, [as of 4th June 2009].

¹⁹⁴Data source: IMF-IFS.

are of a more descriptive nature, and do not provide a detailed understanding of the relationship between interventions and exchange rates in developing countries.

A very useful overview is provided by Disyatat and Galati (2007), who, besides analyzing the intervention experience of the Czech Republic, outline the short history of the literature dealing with the effectiveness of interventions in emerging markets. Not surprisingly, the findings of the reviewed studies are mixed, showing only little similarities. Like results for major markets, the effectiveness is highly sample-dependent and varies across countries. Whether interventions are effective in influencing the exchange rate and/or its volatility is a matter of the specific country or sample.¹⁹⁵ However, one similarity is that the impact of interventions seems to be dependent on the implemented monetary framework and the associated monetary policy stance. In this context, Tapia and Tokman (2004) as well as Égert and Komárek (2005) show that interventions can be effective when being consistent with the actual policy stance. A rather important aspect of intervention effects is mentioned by Rhee and Song (1999). They argue that the impact of foreign exchange market operations is related to the depth and sophistication of capital markets. The authors find evidence that interventions in Korea became less effective as capital markets became more open.¹⁹⁶ Highlighting asymmetric intervention effects, Guimarães and Karacadag (2006) present case studies using daily data for tests on the effectiveness of interventions in Mexico and Turkey. Based on a GARCH framework, estimation results find mixed and asymmetric evidence for the effectiveness of interventions. In this way, only foreign currency sales in Mexico exerted a statistically significant effect on the exchange rate. In contrast, interventions in Turkey were ineffective in influencing daily exchange rate changes.¹⁹⁷ Concerning the exchange rate volatility, foreign exchange sales tended to increase the volatility in Mexico, whereas such transactions exerted a short-run decreasing effect in Turkey.¹⁹⁸

¹⁹⁵For instance, based on monthly data, Pattanaik and Sahoo (2003) analyze the interventions conducted by monetary authorities in India. While the authors do not find any influence on the exchange rate, its volatility was affected by the authorities' actions.

¹⁹⁶According to Ryu (2003), intervention transactions in Korea were effective in influencing the exchange rate in the desired way. Surprisingly, public announcements exerted no effects.

¹⁹⁷Domaç and Mendoza (2004) also find asymmetric effects. However, their results imply that foreign currency sales in both countries tended to appreciate the exchange rate, whereas purchases of foreign currency had no effect.

¹⁹⁸In contrast, Domaç and Mendoza (2004) support the calming effect of interventions on the exchange rate volatility in Mexico and Turkey.

The motives for interventions in emerging markets cover a wide range of objectives, reflecting the degree of market development and the implemented exchange rate regime. Managing exchange rates and associated intervention motives is a matter of multiple issues in those countries. Usually, international trade makes up a big part of their economic performance. Therefore, the exchange rate takes on special significance with respect to the aggregated demand and inflation. Since the exchange rate can serve as a nominal anchor of monetary policy, following an exchange rate target or limiting its flexibility might be worth considering. Furthermore, it is not an exception that emerging markets face a substantial degree of dollarization, which puts even more emphasis on a stable exchange rate. According to the experiences provided by BIS (2005b), the exchange rate volatility turned out to be of special interest. While many central banks aim to limit the volatility of foreign currency relations, others advocate desisting from interventions in order to enhance foreign exchange market development (hedging exchange rate risks), and to avoid any moral hazard behavior.¹⁹⁹ Furthermore, the role of governments differ across countries. Generally, the decision to intervene is made in consultation between the government and the central bank, although no clear responsibility patterns exist. This in turn shows that many central banks in emerging markets are not independent institutions. The methods and tactics of interventions also vary across authorities. While some prefer to step into markets when trading volume is low ("thin markets") in order to increase the impact of interventions, others are concerned about a rising exchange rate volatility under such circumstances. In this context, central banks, which are afraid of increasing volatility, usually try to hide and intervene secretly. However, this is naturally very difficult in thin markets. Furthermore, some central banks also intervene in different parts of the exchange rate market (spot-, future-markets). In recent years, emerging markets were fighting against appreciating exchange rates by continuously purchasing foreign currency, and at the same time trying to hold up money market rates for domestic policy reasons (i.e. fighting inflation). Under such conditions, sterilization faces several challenges, and is not likely to be sustainable. However, potential domestic spillover effects have not materialized yet. In this vein, Lavigne (2008), who examines the effects of sterilization in emerging markets, notes that sterilization operations are now more often con-

¹⁹⁹See Sokoler (2005).

ducted through non-market-friendly methods (e.g. change in reserve requirement ratios). This may result in adverse consequences for financial stability, and therefore needs to be carefully monitored. Furthermore, he emphasizes that as soon as markets view sterilization operations to be unsustainable, emerging market real exchange rates could be subject to speculative attacks towards an appreciation, requiring even larger sterilized interventions.

The most recent contributions to this new field of research are given by Disyatat and Galati (2007), Kamil (2008), and Scalia (2008). All these studies offer very interesting but different perspectives on the importance of foreign exchange market interventions in emerging market countries, and on what should be addressed in the future academic research.

Disyatat and Galati (2007) focus on the relationship between interventions and market expectations in the inflation targeting Czech Republic between 2001 and 2002. The authors estimate the impact of interventions on the spot rate and its expectations. Therefore, data from option markets are used to build measures for exchange rate expectations, as described above. Macroeconomic announcements serve as control variables to proof whether deviations from market expectations about macroeconomic fundamentals influence the exchange rate as well. In summary, their empirical results obtained from OLS regressions state that changes in the spot rate as well as in its expectation measures are hard to detect by interventions or macroeconomic announcements. While cumulative (5-day) interventions countered an existing exchange rate trend significantly, the impact was very small in economic terms. However, interventions influenced higher exchange rate moments. Although the impact on the implied volatility was estimated to be insignificant, interventions influenced the risk reversal significantly. A purchase of foreign currency indicated that the market viewed a depreciation of the domestic currency as a more likely outcome. In this sense, authorities influenced market expectations successfully. Concerning the impact of control variables, results suggest that higher than expected inflation data and retail sales caused the spot rate to appreciate. This is in line with the idea of inflation targeting. Higher inflation and growing economic activity is expected to be followed by an increase in interest rates, causing appreciation pressure on the domestic currency. Surprisingly, impacts on exchange rate expectations were estimated to be insignificant.

Kamil (2008) examines the experience of Columbia between 2004 and 2007, which, like the Czech Republic, has implemented an inflation targeting framework.²⁰⁰ The case of Colombia is interesting since authorities have followed a two way intervention strategy. Besides formulating explicit intervention rules, the BdR further claims to preserve the right to intervene in a discretionary way.²⁰¹ The author focuses on the consistency between discretionary interventions and the underlying monetary policy stance. During the whole sample, monetary authorities bought foreign currency with the purpose of alleviating an appreciation trend of the Peso against the US\$.²⁰² While the first part of the sample was aligned by a loosening monetary policy, the second part was characterized by a tightening of monetary conditions to tackle growing inflation and the threat of domestic economy overheating. Estimation results of a GARCH model reveal that intervention effects changed between the sub-samples. Being effective in the first sample period, interventions conducted during monetary policy tightening were almost ineffective. The author concludes that an intervention can only be used appropriately when it is consistent with other ("main") monetary instruments.²⁰³

Scalia (2008) uses whole new ways in the research of emerging market interventions. Based on the theoretical Evans-Lyons model of microstructure described above, he investigates the effectiveness of foreign exchange market interventions conducted by the authorities from the Czech Republic. Moreover, he examines whether news of interventions have an additional impact compared to secret interventions. Data on hourly exchange rate changes and on order flow were obtained from Reuters Spot Matching market, covering the second half of 2002. During this time the monetary authorities leaned against an appreciation trend of the EUR/CZK exchange rate. Intraday intervention data was obtained from information given by the central bank. His main findings are that the impact of order flow equals 0.076% per 10 mill. EUR. Only 80% of this impact persists throughout the day, indicating a very short-lasting intervention effect.

²⁰⁰See also Holub (2004) for intervention experience of the Czech Republic, which operates with an inflation targeting framework.

²⁰¹See BdR (2007).

²⁰²Kamil (2008) applied a Tobit estimation framework to disentangle the motives for discretionary interventions. He finds evidence that the BdR was mainly focused on calming day-to-day exchange rate returns, and deviations from a 20-day moving average.

²⁰³This is in line with the summary provided by Disyata and Galati (2007). See also Geršl and Holub (2006), who focus on the experience of the Czech Republic.

Furthermore, in case the central bank made their operations publicly known, the intervention effect increased by 0.039% per 10 mill. EUR additionally.

Although offering very interesting insights, the here presented studies and other contributions have mainly neglected the relationship between intervention motives, impact effects, and underlying economic as well as monetary policy fundamentals. While some contributions are dealing with the consistency of foreign exchange market transactions to the underlying monetary policy stance, a direct discussion about the associated motives and impact effects is missing. Nevertheless, based on the econometric evidence, though being not clear-cut, it seems that interventions in emerging markets can exert more pressure on the specific exchange rates as in industrialized countries. Especially when being consistent with the underlying monetary policy, an intervention might be a useful monetary policy tool. Additionally, the signaling idea of interventions appears to be on par with interventions in industrialized countries. However, other theoretical channels might be of higher relevance in emerging markets.

3.2.3 Are Interventions more Powerful in Emerging Market Countries?

As previously shown, recent empirical results tend to give more power to exchange operations conducted by monetary authorities from developing countries compared to those from industrialized markets. Since both set of countries differ significantly in their economic and monetary policy features, it is only naturally to assume that interventions lead to different effects on exchange rates. Based on the results from the IMF's 2001 Survey on Foreign Exchange Market Organization, Canales-Kriljenko (2003) emphasizes four basic reasons (which allow to draw tentative conclusions on the possible transmission channels of interventions), why official emerging market interventions should be more powerful.

(i) Monetary Effects of Interventions:

In contrast to interventions in developed countries, emerging market operations are not automatically fully sterilized. Hence, monetary authorities' transactions in the foreign exchange market directly affect the monetary base, and by doing so, directly affect the underlying fun-

damentals of exchange rates (monetary channel). This might not be surprising since emerging market countries have implemented various monetary policy frameworks with different operating targets, giving some leeway for unsterilized interventions. In this context, some monetary authorities substitute money market operations by foreign exchange operations (unsterilized interventions) in order to achieve domestic monetary policy objectives. This might be more effective than managing domestic purposes in underdeveloped domestic financial markets. Additionally, against the background of different exchange rate shocks, full sterilization might not be an appropriate response.

(ii) *Relative Intervention Amounts:*

Monetary authorities in emerging markets intervene with greater relative amounts. The volume of interventions plays an important role compared to stocks of outstanding domestic and foreign assets, exchange market turnover, and monetary aggregates (portfolio-balance channel, noise-trading channel, microstructure channel, monetary channel). In contrast to major central banks, monetary authorities in developing countries account for a much larger part of foreign exchange market turnover, as indicated by the survey results. Several reasons explain the bigger relative intervention amount. In this context, monetary authorities are important players in the foreign exchange market conducting transactions for exchange rate objectives and other domestic aspects. In this role, central banks also buy and/or sell foreign currency on behalf of the government. Furthermore, the use of foreign exchange regulations, monetary regulations, and banking regulations, which all hamper the development of foreign exchange markets, further help to explain the relative large size of foreign exchange interventions. One famous example are surrender requirements, which force exporters to sell their foreign exchange income directly to the central bank. Against the background of the above stated definition of intervention, authorities in emerging markets tend to actively use broad intervention measures to increase their market presence. Additionally, intervention strategies help to extend the relative size of market operations. Because authorities act like market makers in many developing countries, they can set narrow bid-offer spreads, crowding out interbank trading resulting in a low level of market volume.

(iii) *Informational Advantage:*

The above mentioned regulations also constitute a comprehensive framework to understand the actual market behavior and to serve as an information transmitter. Moreover, existing reporting requirements and regulations provide the authorities with a greater information base of market processes and the shifting of open positions. Basically, central banks in developing countries have a better understanding of the future path of the supply of domestic and foreign currency and the underlying exchange rate target level than other market participants. Such information is revealed through a detailed knowledge of the corresponding order flow. The informational advantage stems from the fact that financial markets in these countries are less transparent, and that, for this reason, agents have to infer the central bank's knowledge from public news. Based on a better grasp of how the market functions, the authorities can adjust the transparency of their exchange market actions. Whether pushing the exchange rate at the edge of technical indicator functions (chartist channel), or to provide direct market news (signaling idea) is a strategic question. While in the former case, noise-traders may be induced to open new positions, signaled by any technical rule breaking, the informational benefit in the latter case causes market participants to change their expectations about the future exchange rate path. This in turn leads to a change of net open foreign exchange positions of international agents, and finally affects the exchange rate. Hence, the process of interventions works either by signaling future monetary policy actions, or showing the correct interpretation of the underlying economic conditions. However, with matching the IMF's Code of Good Practices on Transparency in Monetary and Financial Policies, the informational advantage of the central bank in the context of their monetary policy actions should diminish.

(iv) *Moral Suasion:*

Emerging market monetary authorities try to support the effects of intervention by moral suasions. Since central banks in developing countries are often the supervisory authority, they can threaten market participants to withdraw required foreign exchange licenses, or suspending authorized dealers from engaging in the foreign exchange markets. This could be done if market participants challenge the objectives of the central bank. For this reason, foreign exchange

interventions send a signal of the central bank's objectives forcing the market dealers to trade supportively. However, this signal also depends on the intervention amount available to the central bank.

Another argument for emerging market interventions to be more effective is linked to the portfolio-balance channel of interventions. In this context, domestic and foreign assets of emerging markets are less substitutable compared to industrialized countries. A sterilized purchase of foreign assets increases the supply of domestic assets. To hold this excess supply, foreign investors ask for higher risk premia compared to industrialized assets. This can only be reached by a greater exchange rate adjustment. Especially the usage of capital controls is also responsible for the imperfect substitutability of international financial assets in developing and emerging market countries.

However, these arguments are not free from critique at all. Thereby, the aspect of high relative intervention amounts might not hold when referring to the portfolio-balance channel. Even if transaction volumes are significant with respect to the level of outstanding domestic debt, it always depends on the relative change in domestic and foreign debt. Since in most cases the US\$ is the counter currency, the problem becomes obvious. Therefore, the aspect of sizable relative intervention volumes is more appropriate with respect to the other theoretic channels (noise-trading channel, microstructural channel). High turnover data may be more informative. Besides, it is argued that emerging market central banks possess an informational advantage over market participants (compared to industrialized countries), resulting in a stronger effect of interventions in the context of the signaling channel and the noise-trading channel. However, this crucially depends on the credibility of the central bank. Monetary authorities in developing countries do not have the same experience, and the same track record as their industrialized colleagues. Canales-Kriljenko et al. (2006) argue: *"They tend to lack the record of prudent macroeconomic management that underpins the strong credibility of monetary authorities in advanced countries,"* [Canales-Kriljenko et al. (2006), p. 4]. Hence, their credibility is far from being comparable to industrialized countries. If emerging market central banks possess an informational advantage indeed, it is, however, likely to be the case that it is absorbed by a

lack of institutional and policy credibility. This might explain the greater intervention amounts of emerging market central banks. Monetary authorities try to "buy credibility." In this sense, an empirical analysis, conducted by Domaç and Mendoza (2004) on Mexico and Turkey finds evidence that monetary policy signals did not affect the exchange rate at all. In contrast, Tapia and Tokman (2004) emphasize that public announcements of future interventions by the central bank of Chile influenced the exchange rate significantly. Thus, the consequent question is whether authorities in Chile are more credible than its counterparts from Mexico and Turkey. Furthermore, Canales-Kriljenko et al. (2006) challenge the signaling channel in a broader sense. It is not only the lack of credibility, but also the continuous structural shifts in economic conditions, which makes it very difficult for market participants in emerging markets to establish a reliable relationship between economic variables, and thus between interventions and future stances of monetary policy. Nevertheless, existing reporting requirements in emerging markets provide a good overview of aggregated market conditions and the existing order flow. This might enhance the tactical ability to determine the best timing of market actions.

Part II

**New Empirical Views of Interventions
in Emerging Markets**

4 Questions of Research and Econometric Methodologies

Having discussed the fundamental underpinnings and the literature on interventions, this section presents the basic questions of research, and the applied econometric techniques. In order to assess whether interventions are successful, objectives and their relevance over time must be known to the researcher. In this context, Beine et al. (2009b) argue: *"One problem in assessing whether interventions have delivered the intended goal is that the objectives followed by the central banks are rarely known by external researchers ..., the objectives are likely to change over time and to differ across central bank.,"* [Beine et al. (2009b), p. 1187]. Empirical studies usually circumvent both aspects by choosing sub-samples with different perceived intervention motives, or choose a period where motives for interventions are believed to be constant. Moreover, King (2003) states: *"Empirical work conducted to test the effectiveness of intervention does not adequately address how these objectives may vary over time.,"* [King (2003), p. 249]. In the same way, there is no reason why intervention effects on exchange rate changes should be stable over time. Additionally, little has been done to disentangle such intervention dynamics in emerging market countries. Therefore, the following sections are the first effort to examine the relevance of foreign exchange operations in this new field of research over time. Furthermore, it is of interest whether motives of foreign currency operations and the impact on exchange rate changes can be explained by economic and monetary policy fundamentals. Backing intervention motives and its effectiveness with underlying fundamentals is important to understand why monetary authorities intervene, and why interventions influence the exchange rate in either way. Further insights into these questions will enhance the understanding of how to use the still disputed instrument of foreign exchange market interventions.

The sections above have dealt with various methodologies available to researchers who seek to analyze intervention dynamics. From this discussion, a very suitable econometric technique to estimate intervention reaction functions is a standard OLS regression in case of continuous intervention data, and a friction model in case of observed discontinuity in the central bank's intervention behavior. Furthermore, due to the inherent heteroskedastic nature of exchange rate changes, GARCH models are very useful to analyze the impact of interventions on exchange

rate developments. However, empirical work faces many theoretical and practical problems. Besides others, the main issues contain specification problems, error dynamics, and stationarity considerations. Theoretic necessities concerning these aspects are deciding over the use of the various methodologies presented above. Against the background of the empirical literature on foreign exchange market interventions, it is very surprising that these aspects have not been discussed in the literature so far, although their considerations are of outmost importance.

4.1 Basic Questions and Strategy

4.1.1 Matching Objectives, Effects, and Fundamentals

As shown above, academic literature dealing with the issue of foreign exchange market interventions in emerging markets has grown in recent years. Such countries often claim to preserve the right to intervene in special cases in order to influence the exchange rate.²⁰⁴ The literature on the effectiveness of intervention in both, industrialized and emerging market countries, is far from being conclusive. One crucial drawback, being chiefly responsible for this controversy, is the unsolved question when an intervention is effective. This in turn requires the knowledge of the underlying purpose of a central bank's intervention. For instance, a central bank which buys foreign currency to accumulate foreign reserves cannot be assessed as being incapable in managing exchange rates. In this case, monetary authorities simply did not intend to influence the exchange rate directly. Similarly, finding evidence that foreign exchange interventions have increased exchange rate volatility cannot be used to conclude that central bank transactions are ineffective a priori. If the motive has been to calm the market, then an intervention can be seen as unsuccessful, but if an intervention has taken place in order to calm an existing exchange rate trend, such a central bank action should not be assessed as being ineffective. Hence, it is of crucial importance to know why monetary authorities have stepped into the foreign exchange market. Based on this knowledge, researchers are capable to assess the effectiveness of foreign exchange market interventions more appropriately. Generally, monetary authorities do not give

²⁰⁴See Moser-Boehm (2005) for cross-country information on the institutional settings of monetary frameworks, exchange rate arrangements, and intervention policies.

much, if any, information explaining the motives of their foreign exchange market actions.²⁰⁵ The BoJ, representative of most central banks, defines its motive(s) in the following way: "*The Bank of Japan ..., conducts foreign exchange transactions (i.e. intervention) to stabilize the yen's value.*" [BoJ (2000), as of 12th February 2010]. This statement is far from being conclusive on specific objectives. Of course, making broader statements provides a central bank with more flexibility. However, in most cases no comments on actual interventions are given. Imposing this question of research emphasizes the advantage of defining foreign exchange interventions in the narrow sense, rather than applying the widely used motive-based definition. Thus, instead of relying on insufficient information provided by monetary authorities it is better to disentangle the purposes of central bank foreign exchange market actions. Furthermore, the fact that authorities do not give much information on their transaction objectives opens the rationale for motives to vary over time.

Little has been done to proof if motives and impacts for/of interventions are changing over time. However, changes over time are likely to be the rule, especially for emerging market countries. Such economies are exposed to high economic dynamics. Thereby, intervention motives could have changed from simply accumulating foreign reserves towards stabilizing the foreign value of the domestic currency. The level of foreign reserves can be seen as a signal to international investors for economic credibility and stability. Moreover, in case of a high degree of foreign currency in emerging markets, accounting for exchange rate stability is supposed to be a crucial issue of monetary policy. For instance, countries, which are highly indebted in foreign currency, may take special account of exchange rate volatility or short-term trend developments to minimize potential negative effects of currency mismatches. In this case, a sudden exchange rate depreciation increases the countries' foreign debt, and could trigger severe economic consequences. On the other hand, short-term excessive appreciation could lead to an overborrowing in foreign currency, which has all the trappings of an imminent financial

²⁰⁵Nevertheless, some exceptions exist. In this way, monetary authorities in New Zealand follow a very transparent way in terms of their intervention policy. Similarly, monetary authorities in Colombia also provide ample information on their foreign exchange market transactions. This stems from the fact that Colombian interventions are divided in several transactions. Besides intervening on a discretionary basis, for which motives are kept secret, authorities have implemented an option-based intervention framework.

crisis. In case of substantial amounts of foreign assets, causality turns around. Thereby, an exchange rate appreciation diminishes the value of foreign assets in domestic currency, whereas a depreciating exchange rate increases the amount of foreign assets denominated in domestic currency. Against this background, central banks should pay attention to the short-run stability of the exchange rate. Besides the issue of foreign currency substitution, the importance of exchange rate developments is further reflected by exchange rate pass-through effects, making countries prone to growing inflation in cases of a depreciating currency. On the other hand, medium-term appreciation endangers the position of domestic exporters in the international competition. Hence, medium-run stability can be a special purpose of monetary policy in emerging market countries as well. Thus, developing countries may well have considered all motives of interventions described in chapter 1.3.3. In the same way, it is important to proof if intervention effects have been stable over time. Due to the poor empirical support for the effectiveness of interventions in industrialized countries, and the arguments put forward by Canales-Kriljenko (2003) that central bank actions in emerging market countries should be more powerful, a time dependent consideration allows to obtain more insights. Finding no significant positive impact on the exchange rate in a global context, does not necessarily mean that interventions were not effective at all. The impact could have varied with a change in the intervention characteristic and/or a change in underlying financial and economic features.

The bulk of academic literature dealing with emerging market interventions has focused on countries operating under an inflation targeting framework. Nevertheless, interventions play only a minor role within this policy setting since exchange rates are assumed to float freely by law.²⁰⁶ Moreover, inflation targeting frameworks, like monetary policy in general, rest on the authority's credibility. Since the perennial question about the effectiveness of interventions has not been answered yet adequately, no clear intervention strategy surfaced, which goes to the heart of successful monetary policy: Credibility. Unfortunately, the role of interventions in policy settings different from addressing inflation targets explicitly, although being of special

²⁰⁶Of course, this is a dogmatic point of view. New Zealand and Colombia are the best examples of inflation targeting countries incorporating foreign exchange intervention in their monetary frameworks. See Hübner (2004) for more information on central bank interventions as a monetary policy instrument in inflation targeting countries.

interest, has not been discussed in the literature. For instance, in case of monetary targeting, the decision to intervene could either stem from managing domestic aspects, or from influencing the exchange rate. In this context, purchases or sales of foreign currency could have been used to manage domestic monetary aggregates. When being confronted with an underdeveloped domestic financial system, authorities do not possess sound money market instruments, which can be used to influence monetary aggregates. In such a case, the foreign exchange market is usually the most liquid financial market. This in turn makes the central bank prone to conduct monetary policy through operations in the foreign exchange market. Consequently, this always raises the question whether authorities do not follow a double-targeting strategy, since transactions in the foreign exchange market, though being directly linked to domestic aspects, influence the exchange rate as well. Besides these aspects, the discussion of interventions is not restricted to clearly stated monetary policy frameworks. Foreign exchange market interventions can also play a dominant role in emerging market countries imbued by different monetary policy arrangements. Thereby, the usage of interventions might be more flexible and not bound to specific policy rules. However, this does not necessarily support the authorities' credibility. The exchange rate, which often plays an essential role in emerging markets, can balance this problem. As a nominal anchor, the stability of the currency rate is directly aligned to the central bank's credibility. A stable valuta reflects a sound policy, and compensates for a poorly structured monetary policy framework.

Another drawback of the existing academic literature is that intervention dynamics are not explained against the background of underlying economic and policy fundamentals. However, depending on the economic structure and other policy measures, motives and transaction effects are likely to differ. The question why central banks focus on some motives rather than addressing all of them is a matter of additional policy measures and the underlying economic structure. For instance, why should a central bank focus on short-term exchange rate movements to assuage the impact on foreign assets and foreign debt when such levels make up only a tiny fraction of the country's total asset and debt volumes. The role of foreign trade, the fraction of foreign currency in the domestic economy, and the development of the domestic financial system should

all be taken into account when trying to understand, why central banks intervene in the foreign exchange market, and why these operations are effective or not.

4.1.2 Course of Action

From the discussion above the basic questions of research are:

1. Why do central banks in emerging markets intervene in the foreign exchange market?
2. Are these motives stable over time?
3. Are interventions effective?
4. Are impact effects stable over time?
5. Can motives and impact effects for/of interventions (intervention dynamics) be explained by economic and monetary policy fundamentals?

These questions are answered in the following three steps, which are summarized in table 5.

(i) *Reaction Function:*

A reaction function is applied to daily intervention data in order to disentangle motives for interventions. Thereby, the purposes of central banks to intervene are categorized according to the intervention motives described in chapter 1.3.3. For examining a possible time dependent variation of the suggested motives, the specific reaction function is estimated for three sub-samples to get a first impression, and additionally in a rolling way to obtain a concrete picture of how intervention motives have evolved over time. Two models described below, will be used to analyze intervention objectives in emerging market countries.

(ii) *Impact Analysis:*

With the development of central bank intervention objectives in mind, the effectiveness of interventions is assessed in a second step. This is done by estimating a GARCH model on daily exchange rate data. By doing so, the effect of central bank interventions on the mean, and the

Question	Step
1 Intervention Motives?	1a → Global Reaction Function
2 Stability of Motives?	1b → Local (Sub-sample/Rolling) Reaction Function
3 Intervention Impact?	2a → Global Impact Analysis
4 Stability of Impact?	2a → Local (Sub-sample/Rolling) Impact Analysis
5 Explanatory Content of Economic Background?	3 → Assessment of Underlying Fundamentals

Table 5: The Basic Research Procedure.

conditional volatility of exchange rate changes is estimated simultaneously. As is the case for the specific reaction function, the GARCH model is estimated for three sub-samples to get a first impression, and in a rolling way to obtain a clear view of how interventions have performed over time.

(iii) *Fundamental Assessment:*

Having examined intervention motives and intervention effects, the obtained results are assessed against the background of economic and monetary policy fundamentals. While the discussion of intervention objectives focuses on the country's economic structure and monetary policy framework, explaining impact effects is based on the arguments by Canales-Kriljenko (2003). This third step should help to understand why a central bank has emphasized specific motives, and why interventions were effective or not.

The empirical experiences of central banks in Argentina and Croatia with their use of interventions is examined in the next sections. After the financial crisis in 2001/2002, Argentina abandoned its currency board regime, and decided to let the exchange rate officially float freely. Meanwhile, the strategy of monetary targeting was implemented to pursue the goal of price stability. Although not officially stated, the BCRA followed a two way strategy. Besides targeting domestic monetary aspects, the exchange rate was clearly taken into account by the authorities throughout the years.²⁰⁷ Here, the period between 2003 and 2008 is examined. In contrast,

²⁰⁷See Frenkel and Rapetti (2007).

Croatian authorities did not follow an explicit monetary policy framework. Instead, the central bank used a policy mix to target the ultimate goal of price stability. The banking crisis in the late 1990s has shattered the Croatian economy, which is now on its way to implement stable monetary policy instruments with the purpose to join the Eurozone in the future. The recent monetary policy in Croatia can best be described as a quasi-currency board arrangement, emphasizing the importance of the exchange rate. For the Croatian example, the period between 2002 and 2008 is examined.²⁰⁸ To my best knowledge no study examining the time dependency of intervention dynamics in Argentina and Croatia exists so far.

Before presenting econometric techniques used to answer the above stated basic questions of research, I would like to briefly discuss the theoretic consistency of the procedure. Unlike some empirical contributions dealing with motives and the effectiveness of interventions, this approach is theoretical consistent in the way that the definition of intervention, the used reaction function, and the applied impact analysis are based on the same theoretical premises. An example should suffice to clarify this aspect. Imagine, analyzing intervention motives with an ordered probit model, and relying on an intervention definition based on the signaling idea. Furthermore, imagine examining the effectiveness with an event-study framework. In this case, the theoretical consistency of the procedure is not given. The inconsistency stems from the use of an event-study methodology, which is an atheoretic technique not allowing to draw theoretical conclusions. In contrast, the definition of intervention and econometric techniques used here are consistent in a broad sense. Especially the adopted intervention definition allows to capture effects, which are not solely based on the signaling channel. Nevertheless, which channel influences the exchange rate in the end remains another question, which will not be discussed in detail. This task is left for further research to answer.

²⁰⁸Both samples end before the crash of the investment bank "Lehman Brothers" in September 2008. Therefore, the empirical analyses are a pre-crisis discussions.

4.1.3 A Time-Varying Parameter Approach

As described above, the potential time variation in intervention motives and impact effects is examined by estimating the country's reaction function and impact analysis for three sub-samples, and then in a rolling way. The sub-samples are chosen according to a change in the conducted intervention strategy and/or underlying monetary policy decisions. Thus, the three phases of interventions differ in their characteristics. A change in the intervention strategy may indicate a change in the underlying objective causing the authorities to step into the foreign exchange market. Similarly, different characteristics of central bank actions might have different impact effects on exchange rate dynamics. It has been claimed that continuous interventions have a lower power due to their visibility in the market, which results in a high predictability by international investors. In contrast, when conducted occasionally, interventions might have greater influence on the exchange rate. This argumentation rests on the signaling idea so as interventions provide "true" new information to the market. If interventions occur frequently, the market's belief in the informational advantage of the central bank declines, and international investors do not pay much attention on the "weak" signals of the authorities.

In a next step, rolling estimations are applied to obtain a detailed view on motive and impact developments. This allows to draw concrete conclusions on the time dependency of intervention dynamics. The usage of rolling estimations is a simple but very fruitful way of accounting for parameters' time variation. This heuristic methodology can be found in several studies addressing the issue of parameter instability.²⁰⁹ However, rolling estimations have not been applied to the matter of central bank interventions before.²¹⁰ The big advantage of using rolling estimations is their simplicity. A constant estimation window is shifted through the whole observation range, providing coefficient results for every single sample window. Thereby, a time-series of estimated model coefficients can be obtained. This time-series provides a backward looking

²⁰⁹For recent contributions, see e.g. Brada et al. (2005), Canova (2009), D'Agostino et al. (2009), Groen et al. (2009), Groenewold and Fraser (1999), and Guirguis et al. (2005).

²¹⁰To my best knowledge, the only study, which has used rolling estimation in the context of foreign exchange transactions is Hillebrand and Schnabl (2006), examining the effects of interventions in Japan. The authors focus on structural breaks in the intervention impact. Thereby, rolling results serve as a primary indicator. Thus, their intention differs from mine.

development of possible time variation in the estimated coefficients. Nevertheless, this technique is not entirely free from critique. Concerning the window length, generally speaking, a trade-off exists between the amount of contained observations to enhance the informational content, and the possible inclusion of structural changes.²¹¹ Especially in the context of nonstationarity in time-series, shifting a constant window through the whole observation range may cover biased estimation results, which could lead to spurious conclusions about the underlying relationships of intervention dynamics. Therefore, the choice of the estimation windows must be considered against the background of the full sample length. Within a rolling estimation approach, the model specifications cannot be changed. This basically addresses a potential lag structure to capture serial correlation of the residuals. For this reason, extending the lag structure is a suitable choice to safely account for possible autocorrelation. Moreover, depending on the econometric technique, an estimation window must include foreign currency sale and purchase interventions. Keeping these aspects in mind, the purpose of the following sections is to examine whether intervention motives and impact effects vary over time or are constant. In order to answer these questions a simple heuristic approach is, in my view, the appropriate choice. Rolling estimation results may be sometimes very volatile, showing sharp variations of the results. This drawback could stem from the above mentioned choice of the window size. To address this critique, it is more suitable to interpret a trend of the estimated coefficient-series. Therefore, coefficient-series are smoothed using the HP-Filter.²¹² This famous, two-sided filtering technique decomposes a time-series into a trend and cycle component, and is widely used by macroeconomists.²¹³ A smoothing or penalty parameter λ controls the smoothness of the estimated trend component. The larger λ the smoother the trend component. Basically, it is important not to rule out too much variation in the generated coefficient-series. To account for this, λ is set to 68000. Compared to standard settings of λ for annual data ($\lambda = 100$), quarterly data ($\lambda = 1600$), and monthly data ($\lambda = 14400$), this value is still small, capturing enough variation of the coefficient-series to obtain valuable and well interpretable outcomes.

²¹¹Pesaran and Timmermann (2007) discuss the choice of the window length with respect to forecasts.

²¹²See Hodrick and Prescott (1997).

²¹³The business cycle literature focuses on the application of HP-Filters. See e.g. Kaiser and Maravall (2000), and Kozicki (1999).

As an alternative to rolling estimations, the Kalman Filter technique could be used instead.²¹⁴ The basic approach is designed for engineering problems by Kalman (1960). Thereby, the underlying model is formulated in a state space framework. Instead of estimating coefficients for every observation window, the coefficient vector is modeled as a separate process. Basically, no final arguments exist, which challenge the use of rolling estimation or Kalman Filtering in examining time-varying parameters. Both procedures have their merits. However, the following three essential aspects convinced me to prefer rolling estimations:

(i) *Simplicity:*

Rolling estimations are clearly favorable due to their simplicity. In this context, researchers may speak of a poor man's time-varying parameter model. However, only because it is simple to implement does not mean that its performance is bad. In the actual economic environment, highly sophisticated and complicated models have not proven to be of particular help to understand the business cycle and financial dynamics.

(ii) *Stability:*

Kalman Filtering constitutes a fragile procedure. The process of the coefficient vector must be determined exogenously, and is often modeled as a Random Walk. This severe drawback opens the room for manipulation, at least in an unintended way. Thereby, the explanatory content of the observed data is constrained. Furthermore, the inclusion of variables, which lack any explanatory power is likely to distort the results. This is important in the context of trying to disentangle potential intervention motives, which are unknown a priori. Hence, some suggested motives, which are not taken into account by the authorities, could distort final conclusions.

(iii) *Information Processing:*

Kalman Filter techniques possess the inherent idea of processing all available information in the time-varying coefficient process. In contrast, rolling estimation windows forget all observations (information), which are not included in the current sample window. Now, it can

²¹⁴See Sekine (2006) for an application on exchange rate pass-through effects. For an extensive treatment on time-series analysis by state space methods, see Durbin and Koopman (2001). For a more general treatment, see Harvey et al. (2004).

be discussed whether it is more appropriate to assume that central bankers incorporate all information from the past (previously conducted interventions), or just account for more current situations when taking the decision to intervene in the market. Especially, against the background that too much information may impede a decision-making process, using all information is, in my view, not the right entry.

One important aspect worth mentioning is the appropriate estimation of model coefficients. If not estimated consistently, parameters are biased as described above. This in turn would make an interpretation of the obtained estimation results problematic. The estimated coefficient-series could be lead by a variation in the estimated bias rather than reflecting a change in the intervention motive and/or its impact effect. Hence, coefficients could be interpreted spuriously as being exposed to changes or as being constant. It is therefore necessary to rule out possible correlation between regressors and the dependent variable which would result in biased estimates. This is done by lagging regressors, which are possibly exposed to endogeneity, as is common in the academic literature dealing with foreign exchange market interventions. Although this does not allow to estimate the contemporaneous effect, this is not crucial for the stated questions of research.

4.2 Intervention Reaction Functions

4.2.1 A Standard Workhorse

As shown in chapter 3.1.2, a standard workhorse for an intervention reaction function is an OLS regressions, which can be written as:

$$\begin{aligned} Int_t = & \beta + \beta_s motive_{t-1}^{short} + \beta_m motive_{t-1}^{medium} + \beta_t motive_{t-1}^{target} \\ & + \beta_v motive_{t-1}^{volatility} + \boldsymbol{\theta} \mathbf{C}_t' + \varepsilon_t, \end{aligned} \quad (82)$$

$$Int_t = \boldsymbol{\beta} \mathbf{X}_{t-1}' + \varepsilon_t, \quad (83)$$

$$\boldsymbol{\beta} = (\beta, \beta_s, \beta_m, \beta_t, \beta_v, \boldsymbol{\theta}), \quad (84)$$

$$\mathbf{X}_{t-1} = \left(1, motive_{t-1}^{short}, motive_{t-1}^{medium}, motive_{t-1}^{target}, motive_{t-1}^{volatility}, \mathbf{C}_t \right). \quad (85)$$

Int_t is the amount of daily intervention expressed in foreign currency. \mathbf{X}_t displays the set of explanatory variables containing the motives of interventions, and possible control variables \mathbf{C}_t .²¹⁵ The error term is given by ε_t . The amount of daily intervention is positive in case of a purchase of foreign currency and negative if otherwise. The different purposes included in the intervention motive vector reflect the development of exchange rates at different time horizons. All exchange rates are expressed in their natural logarithms in order to display percentage changes.

The short-run motive ($motive_t^{short}$) captures actual deviations from a short-run trend ($s_t - s_t^{short\ trend}$), or deviations between a short period of days ($s_t - s_{t-1,2,3,4,\dots}$). The medium-run motive ($motive_t^{medium}$) reflects deviations of the actual exchange rate from a medium-run exchange rate trend ($s_t - s_t^{medium\ trend}$). The time horizon may differ between several weeks or months. Choosing the correct horizon for each motive is not a straightforward issue. In the literature, several contributions have dealt with the time horizon of intervention motives.²¹⁶ The right choice depends clearly on the specific country. A practical problem can occur when specifying exchange rate movements for different horizons. In this context, multicollinearity between intervention motives might exist in case that time differences are small. Although this aspect does not invalidate coefficient results, estimated standard errors underestimate the significance of β .²¹⁷

The aim of targeting an exchange rate level ($motive_t^{target}$) is supposed to be captured by the deviation of the actual exchange rate from an assumed target level ($s_t - s_t^{target}$). As explained above, the target level might display the fundamental value, or an implicit fixed exchange rate level. Many contributions have focused on the PPP as being the fundamental value. However, the need of analyzing higher frequency data makes the use of a fundamental exchange rate problematic. Data to obtain equilibrium exchange rates are only available on a monthly basis

²¹⁵Control variables are directly discussed in the case studies presented below.

²¹⁶See e.g. Almekinders and Eijfinger (1996), Frenkel et al. (2005), Ito (2002), and Ito and Yabu (2007).

²¹⁷Multicollinearity does not distort coefficient outcomes but rather influences the estimated test statistics. Practically, estimated coefficient variances rise in the presence of multicollinearity, which in turn lowers the t-values. Hence, this problem could lead to not rejecting the null hypothesis that an intervention motive does not cause daily interventions.

(e.g. inflation). This in turn would require to interpolate monthly data at least on a daily basis, and thus would produce additional noise in the reaction function. Therefore, using a fundamental equilibrium exchange rate is not a suitable choice when analyzing intervention motives. Specific information on the individual country's experience may hint at the underlying implicit target level.

The volatility motive ($motive_t^{volatility}$) is displayed by the estimated conditional volatility (h_t) from a GARCH model of daily exchange rate changes during the full sample. Capturing volatility is somehow inconclusive in the academic literature. Instead of estimating the conditional volatility, which captures the inherent feature of time-varying exchange rate volatility, implied volatility derived from option market data might be used in the same way as discussed above. Both approaches have their merits. In case of efficiently priced options, the implied volatility reflects an unbiased estimate of the expected volatility. Thus, it is an ex ante volatility measure. However, option markets are usually thin in times of low volatility, which impedes data quality, especially for emerging market countries, if existent at all.²¹⁸ In contrast, the estimated conditional volatility provides an ex post volatility measure. Another approach would be to include realized volatility.²¹⁹ While using realized volatility has the advantage to be a less noisy measure, no universal argument in favor of using realized or implied volatility exists.²²⁰ Furthermore, realized volatilities are obtained by using intraday data, which is hardly available for emerging market countries.

Concerning the expected coefficient outcomes, $\beta_{s,m,t}$ should yield significant negative results, in case that the central bank takes account of the corresponding intervention motives. Since the exchange rate displays the price of the foreign currency expressed in domestic currency, a rising rate value indicates a depreciating domestic currency. Thus, a positive difference between the actual exchange rate and its associated trend/target ($motive_t^{short/medium/target} > 0$) indicates a weaker actual currency compared to its short-run trend, medium-run trend, or target level.

²¹⁸In case of low volatility, options are relative unattractive for international investors. This leads to a low option volume and inefficient price settings.

²¹⁹See, e.g. Andersen et al. (2002), and Beine et al. (2009a).

²²⁰See Dominguez (1998), Murray et al. (1996), Rogers and Siklos (2003).

This in turn should trigger foreign currency sales ($Int_t < 0$) in order to appreciate the domestic currency to close the gap. In contrast, coefficient β_v should show significant values. Negative or positive values indicate whether monetary authorities purchased or sold foreign currency as a response to increasing market volatility. However, it can be assumed that central banks sell foreign currency in case of high volatility, since they provide the market with more liquidity.

The interpretation of the coefficients is straightforward. The estimated parameters are the marginal effects of the regressors. This stems from the fact that relationships are linear and do not vary depending on the values of the other variables.

$$E(Int_t | \mathbf{X}_{t-1}) = \beta \mathbf{X}'_{t-1}, \quad (86)$$

$$\frac{\partial E(Int_t | \mathbf{X}_{t-1})}{\partial motive^j} = \beta_j. \quad (87)$$

Hence, a 100% deviation of the actual exchange rate from its trend or target triggers an amount equal to the estimated coefficient. The estimation procedure of OLS regressions is a standard approach and can be found in any basic textbook dealing with econometrics.²²¹

4.2.2 A Friction Model of Foreign Exchange Intervention

4.2.2.1 The Mechanics and Estimation of Friction Models

Central banks tend to intervene sporadically, and therefore interventions are discontinuous over time occurring in a clustered fashion. This fact is often explained by political and bureaucratic costs. At this point, a more detailed explanation seems warranted.²²² As mentioned above, authorities deliberate on costs and earnings of an intervention. Hence, they only intervene in case of significant changes in the regressors. The underlying idea is that a central bank is not keen on endangering its credibility. The cost and credibility argument can be discussed with respect to the critique of relative small intervention volumes, and vis-à-vis the signaling channel of interventions. In this context, big intervention volumes indicate a high

²²¹See e.g. Greene (2008).

²²²See Almekinders (1995), and Almekinders and Eijfinger (1996).

informational content of central bank interventions, whereas authorities intervening with low volumes are assumed to give no attention to the message they send to the market. Thus, when intervening frequently and with relative small volumes, monetary authorities face the problem of diminishing their chances to influence the exchange rate effectively. This in turn lowers the informational content, the authorities credibility, and the effectiveness of future actions.²²³ In this context, discontinuity of interventions (keep away from the market in case of small changes in regressors/motives) reflects the central bank's investment in potential future effectiveness of interventions, which are conducted at times of serious turbulences (regressors/motives exceed a certain threshold).

The basic friction model (censored dependent variable model) which I use in the proceeding sections can be written as:

$$Int_t = \begin{cases} Int_t^* - \theta^+ & \text{if } Int_t^* > \theta^+ > 0 \\ 0 & \text{if } \theta^- \leq Int_t^* \leq \theta^+ \\ Int_t^* - \theta^- & \text{if } Int_t^* < \theta^- < 0 \end{cases}, \quad (88)$$

$$Int_t^* = \beta \mathbf{X}'_{t-1} + \varepsilon_t, \quad (89)$$

$$\varepsilon_t | \mathbf{X}_{t-1} \sim N(0, \sigma^2). \quad (90)$$

Equation 89 states the relationship between a latent intervention variable (Int_t^*), which is unobservable and is only known to the central bank, and the suggested intervention motives as defined above. What outsiders can observe is the intervention volume (Int_t) when the internal volume (latent intervention variable) exceeds a threshold (θ^+, θ^-), reflecting internal costs, and an intervention takes place. As long as the central bank is indifferent to intervene, the latent intervention variable (Int_t^*) moves within the lower (θ^-) and upper (θ^+) intervention threshold, and no intervention can be observed. In other words, the central bank only steps into the market whenever the motives (changes in regressors) are strong enough, and market conditions require the authorities' action. The connection between the central bank's internal decision and the

²²³Of course, this only holds if authorities do not give sufficient information on the purposes of their actions.

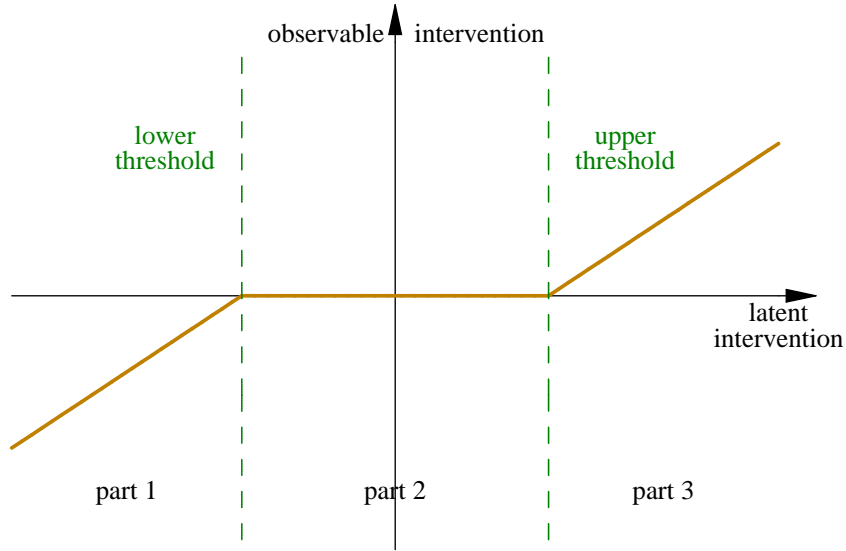


Figure 3: The Relationship between Latent and Observable Interventions within a Friction Model.

observed intervention volume is displayed in figure 3.

The parameters of a friction model are estimated by ML. Assuming normal distribution, the likelihood function is given by equation 91, which consists of three parts. While part 1 and 3 explain sales and purchases of foreign currency, part 2 models the probability of no central action by the monetary authorities. Thereby, $\phi(\cdot)$ and $\Phi(\cdot)$ refers to the standard normal density function, and the cumulative normal distribution function respectively. The intuition of part 1 to 3 of equation 91 is shown in figure 3. As long as the latent intervention amount moves within the thresholds (θ^+, θ^-) , the probability of no observable intervention is given. But as soon as the authorities actively intervene in the market, the transaction amount is explained by the suggested intervention motives.

$$L = \underbrace{\prod_{Int_t < 0} \frac{1}{\sigma} \phi \left(\frac{Int_t - \beta \mathbf{X}'_{t-1} + \theta^-}{\sigma} \right)}_{\text{part 1}} \cdot \underbrace{\prod_{Int_t = 0} \Phi \left(\frac{\theta^+ - \beta \mathbf{X}'_{t-1}}{\sigma} \right) - \Phi \left(\frac{\theta^- - \beta \mathbf{X}'_{t-1}}{\sigma} \right)}_{\text{part 2}} \cdot \underbrace{\prod_{Int_t > 0} \frac{1}{\sigma} \phi \left(\frac{Int_t - \beta \mathbf{X}'_{t-1} + \theta^+}{\sigma} \right)}_{\text{part 3}}. \quad (91)$$

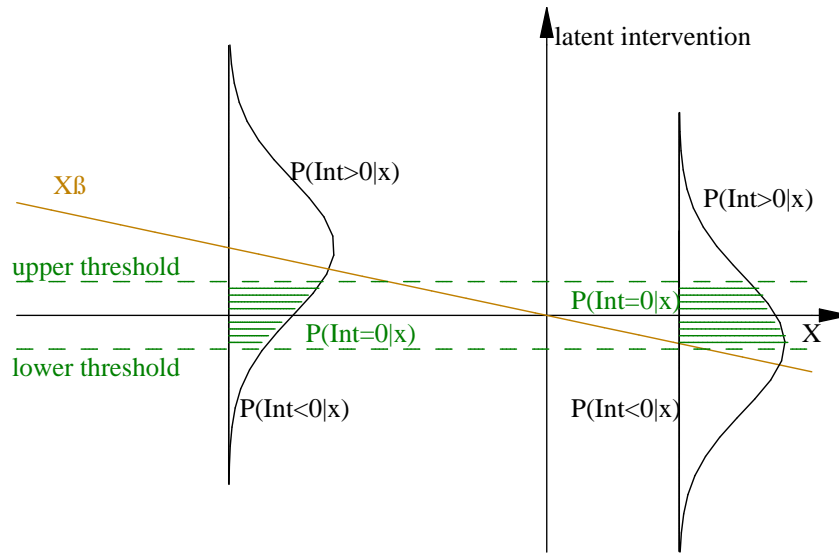


Figure 4: The Conditional Distribution of Int_t^* and Intervention Probabilities, Influenced by Different Intervention Objectives (Source: According to Jun (2008)).

Figure 4 provides an alternative perspective on the mechanism of the friction model in terms of estimated probabilities. Assuming the latent intervention variable being normally distributed, it explains the relationship between the assumed motives (\mathbf{X}_{t-1}), and the response of a central bank (Int_t). It is shown how changes in the regressors influence the probability of central bank actions with respect to the estimated thresholds (θ^+, θ^-). Thereby, the estimated coefficient vector β is assumed to be negative, as expected and described above. It can be seen that the greater the absolute values of the underlying intervention purposes (\mathbf{X}_{t-1}), the greater the probability that an intervention takes place, and accordingly, the smaller the probability of no action. This connection is displayed by the green lined area within the density functions. This reflects the same intuition as shown in figure 3. The central bank steps into the market in case the underlying intervention objectives lash out, exceeding the thresholds in either way, which indicates that the internal costs are smaller compared to the necessity of an intervention, i.e. the benefits of an intervention outweighs its costs.

4.2.2.2 Marginal Effects within a Friction Model

In contrast to standard OLS estimations, coefficients for regressors obtained from a friction model cannot be interpreted easily. This is due to the fact that, besides being a nonlinear process, coefficient results refer to the latent dependent variable, and not to the observed variable. For this reason the marginal effect of the regressors for the observed intervention amount must be obtained in the following way:²²⁴

Dropping the time subscript for notational simplicity, the conditional mean of the observed intervention volume is:

$$E(Int|\mathbf{X}) = P(Int > 0|\mathbf{X}) E(Int|Int > 0, \mathbf{X}) + P(Int < 0|\mathbf{X}) E(Int|Int < 0, \mathbf{X}). \quad (92)$$

From figure 4 it can be easily seen that the probabilities for an intervention are given by:

$$\begin{aligned} P(Int > 0|\mathbf{X}) &= P(\beta\mathbf{X}' - \theta^+ + \varepsilon > 0|\mathbf{X}) = P(\varepsilon > \theta^+ - \beta\mathbf{X}'|\mathbf{X}) \\ &= 1 - \Phi\left(\frac{\theta^+ - \beta\mathbf{X}'}{\sigma}\right), \end{aligned} \quad (93)$$

and

$$\begin{aligned} P(Int < 0|\mathbf{X}) &= P(\beta\mathbf{X}' - \theta^- + \varepsilon < 0|\mathbf{X}) = P(\varepsilon < \theta^- - \beta\mathbf{X}'|\mathbf{X}) \\ &= \Phi\left(\frac{\theta^- - \beta\mathbf{X}'}{\sigma}\right). \end{aligned} \quad (94)$$

Taking $(\frac{\varepsilon}{\sigma})|\mathbf{X} \sim N(0, 1)$, and $E(v|v > l) = \frac{\phi(l)}{1-\Phi(l)}$ when $v \sim N(0, 1)$, the two conditional expectation terms of the observed intervention volume are:

$$\begin{aligned} E(Int|Int > 0, \mathbf{X}) &= E(\beta\mathbf{X}' - \theta^+ + \varepsilon|\varepsilon > \theta^+ - \beta\mathbf{X}', \mathbf{X}) \\ &= \beta\mathbf{X}' - \theta^+ + \sigma \frac{\phi\left(\frac{\theta^+ - \beta\mathbf{X}'}{\sigma}\right)}{1 - \Phi\left(\frac{\theta^+ - \beta\mathbf{X}'}{\sigma}\right)}, \end{aligned} \quad (95)$$

²²⁴Overall, six marginal effects can be obtained from a friction model. However, for this case the effect of a change in the regressors on the observed intervention amount is sufficient. Gnabo et al. (2008) give an overview. The description of the marginal effect is based on Jun (2008).

and

$$\begin{aligned}
 E(Int|Int < 0, \mathbf{X}) &= E\left(\beta\mathbf{X}' - \theta^- + \varepsilon|\varepsilon < \theta^- - \beta\mathbf{X}', \mathbf{X}\right) \\
 &= \beta\mathbf{X}' - \theta^- - \sigma \frac{\phi\left(\frac{\beta\mathbf{X}' - \theta^-}{\sigma}\right)}{1 - \Phi\left(\frac{\beta\mathbf{X}' - \theta^-}{\sigma}\right)}.
 \end{aligned} \tag{96}$$

Hence, using symmetric properties of the standard normal distribution ($\phi(l) = \phi(-l)$, $1 - \Phi(-l) = \Phi(l)$), and plugging equations 93 to 96 into 92, the conditional mean of the observed intervention volume is:

$$\begin{aligned}
 E(Int|\mathbf{X}) &= \left[\Phi\left(\frac{\beta\mathbf{X}' - \theta^+}{\sigma}\right) (\beta\mathbf{X}' - \theta^+) + \sigma\phi\left(\frac{\beta\mathbf{X}' - \theta^+}{\sigma}\right) \right] \\
 &\quad - \left[\Phi\left(\frac{-\beta\mathbf{X}' + \theta^-}{\sigma}\right) (-\beta\mathbf{X}' + \theta^-) + \sigma\phi\left(\frac{-\beta\mathbf{X}' + \theta^-}{\sigma}\right) \right],
 \end{aligned} \tag{97}$$

and finally, the marginal effect of a change in the j -th regressor/motive is:

$$\begin{aligned}
 \frac{\partial E(Int|\mathbf{X})}{\partial motive^j} &= \beta_j \left[\Phi\left(\frac{\beta\mathbf{X}' - \theta^+}{\sigma}\right) + \Phi\left(\frac{-\beta\mathbf{X}' + \theta^-}{\sigma}\right) \right] \\
 &= \beta_j P(Int \neq 0|\mathbf{X}).
 \end{aligned} \tag{98}$$

It can be seen from equation 98 that the marginal effect of $motive^j$ depends on the level of the other intervention objectives.²²⁵ In other words, the effect depends on the probability that the central bank intervenes in the market, which is by itself determined by the regressors (\mathbf{X}). Thus, small levels in \mathbf{X} decrease the probability of an intervention, and diminishes the marginal effect of one single regressor accordingly.

Although marginal effects of both models are used to analyze intervention motives in emerging market countries, slight differences in the model outcomes remain. The marginal effects of the suggested intervention motives give the slope at the curve of the expected observed intervention given by $E(Int_{(t)}|\mathbf{X}_{(t-1)})$. While this slope is fixed for the linear model (OLS), it varies with the size of \mathbf{X} for the nonlinear model (friction model). Hence, for small absolute

²²⁵Marginal effects will be calculated at the mean levels of the regressors.

values of the suggested motives, marginal effects, which are estimated by the nonlinear model, tend to be lower compared to the linear model and vice versa. Nevertheless, the importance of the difference is assumed to be negligible, and so does not impede the discussion of estimation results. Moreover, and most importantly, both models are chosen to best describe the observed intervention data, and not to compare the estimation outcomes of linear and nonlinear models directly.²²⁶ However, having this aspect in mind helps to improve the understanding of the underlying econometric methodology.

4.3 Intervention Impact Analysis: A GARCH Model Approach

4.3.1 A GARCH Model with Interventions and its Basic Properties

Empirical studies have found evidence for unconditional lepturkotic in daily exchange rate changes.²²⁷ This in turn, points towards the existence of temporal clustering in the volatility of exchange rate changes. According to this, large exchange rate changes are followed by large exchange rate changes, and a relative low degree of exchange rate changes is followed by a low degree of exchange rate changes. In this context, Hsieh (1989) documents strong evidence of ARCH effects in the one step ahead prediction errors of daily US\$ exchange rates. This study, which is based on the first application of ARCH to price data provided by Engle (1982), indicates that the volatility of exchange rate changes on a daily frequency can be forecasted. In this line, Bollerslev (1986) extends the ARCH models for a generalized approach (GARCH), which allows the conditional variance to depend on past sample variances (squared errors), and lagged conditional variances as well. As mentioned above, this captures the idea of a parsimonious specification, which is comparable to the ARMA presentation of time-series proposed by Box et al. (1994). However, it is important to note that modeling the conditional volatility is not equal but similar to an ARMA formulation, since it is not stochastic. In this context, the conditional volatility (h_t) is determined by past squared errors, past conditional volatility, and potential additional explanatory variables. A further important aspect is that ARCH effects in

²²⁶Jun (2008) compares an OLS regression, and a friction model to US and German intervention data. His basic results are explained in chapter 3.1.2.

²²⁷See e.g. Hsieh (1988), and Westerfield (1977).

time-series do not stem from the serial correlation of the error term (linear relationship) but from the dependency caused by its second moment. Hence, the squared errors show significant autocorrelation, and the volatility can therefore be modeled as an autoregressive conditional process.²²⁸ The big advantage of GARCH models in the context of analyzing interventions is that the impact of exchange operations on the mean, and the conditional volatility of exchange rate changes can be estimated simultaneously. However, some care has to be taken in small samples, which will be discussed below.

The basic GARCH(p, q) model with additional explanatory variables, including interventions in the mean (equation 99), and the conditional volatility (equation 103) equation, which I use in the next sections can be written as:

$$\Delta s_t = \alpha_0 + \alpha_i \sum_{i=1}^l \Delta s_{t-i} + \frac{\beta_1 Int_{t-1}}{\beta_1^p Int_{t-1}^{fx\ purchase} + \beta_1^s Int_{t-1}^{fx\ sale}} + \boldsymbol{\zeta} \mathbf{Z}'_t + \varepsilon_t, \quad (99)$$

$$\varepsilon_t = \eta_t \sqrt{h_t}, \quad (100)$$

$$\eta_t \sim iid(0, 1), \quad (101)$$

$$\varepsilon_t | \Omega_{t-1} \sim iid(0, h_t), \quad (102)$$

$$h_t = \mu + \sum_{i=1}^p \partial_i \varepsilon_{t-i}^2 + \sum_{i=1}^q \gamma_i h_{t-i} + \frac{\beta_2 |Int_{t-1}|}{\beta_2^p |Int_{t-1}^{fx\ purchase}| + \beta_2^s |Int_{t-1}^{fx\ sale}|} + \boldsymbol{\omega} \left| \mathbf{V}'_t \right|. \quad (103)$$

Besides foreign exchange interventions (Int_{t-1}), additional explanatory variables (\mathbf{Z}_t) are included in the mean, and in absolute values (\mathbf{V}_t) in the volatility equation. This is done to extend the explanatory power of the estimated model. Although the results of $\boldsymbol{\zeta}$ and $\boldsymbol{\omega}$ might prove to be interesting, the focus is on the estimated impact of foreign exchange market interventions. Furthermore, exchange rates usually follow an AR process, which is captured by adding the dependent variable up to lag l to the set of regressors. Central bank interventions

²²⁸Besides standard (G)ARCH models, other models of conditional volatility exist which address further questions concerning the dependent variable. These models contain *integrated* GARCH models (IGARCH), *fractional integrated* GARCH (FIGARCH) models, *threshold* GARCH (TGARCH) models, *exponential* GARCH (EGARCH) models. For a more general theoretic summary of GARCH model extensions, see e.g. Li et al. (2002). Degiannakis and Xekalaki (2004) present more than thirty outcomes on the basis of the ARCH model.

are included in absolute values in the volatility equation. By doing so, the outcome captures whether any transaction, sales or purchases, had an impact on the conditional volatility. The reason for choosing absolute values refers to the avoidance of potential negative volatilities. Furthermore, it is interesting whether asymmetric intervention effects connected with purchases and sales of foreign currency exist. For this reason, central bank transactions are separated into purchase and sale interventions.

The error term in the mean equation consists of a white noise process (η_t) , and the conditional standard deviation $(\sqrt{h_t})$. The white noise process determines the distribution of ε_t conditional on a set of information in $t - 1$ (Ω_{t-1}). For the conditional moments of the error term follows that:

$$E(\varepsilon_t|\Omega_{t-1}) = E\left(\eta_t\sqrt{h_t}|\Omega_{t-1}\right) = 0, \tag{104}$$

$$E(\varepsilon_t^2|\Omega_{t-1}) = E(\eta_t^2 h_t|\Omega_{t-1}) = h_t. \tag{105}$$

Similar to ARMA models, there are stationarity conditions to be met. Due to the fact that the estimated variance is conditional, the unconditional moments are of interest for matching the stationarity. Since the unconditional first moment of ε_t equals 0, stationarity holds, if:

$$\sum_{i=1}^p \partial_i + \sum_{i=1}^q \gamma_i < 1. \tag{106}$$

In this case, the unconditional variance is finite, leading to a constant unconditional first and second moment of the error term ε_t according to equations 107 and 108.

$$E(\varepsilon_t) = E\left(\eta_t\sqrt{h_t}\right) = 0, \tag{107}$$

$$E(\varepsilon_t^2) = \frac{\mu}{1 - \sum_{i=1}^p \partial_i - \sum_{i=1}^q \gamma_i}. \tag{108}$$

In case of sum unity of equation 106, the process is not stationary. However, according to Bougerol and Picard (1992), Lumsdaine (1991), and Nelson (1990), this has no severe consequences since the model is strictly stationary or ergodic, and asymptotically based inferences are generally valid.

One big issue is the choice of the correct lag length for p and q , so as to rule out any remaining (G)ARCH effects of daily exchange rate returns. There is no general accepted rule to follow in order to determine the structure of the volatility equation. An approach used in the empirical literature is to choose the combination of p and q , which yields the lowest AIC and/or SIC.²²⁹ Basically, the AIC/SIC assess how well the chosen model fits the data. On the one hand, extending p and q reduces the sum of squares of the residuals, on the other hand, it also reduces the degree of freedom by estimating more coefficients. This trade-off is captured by both information criteria, which evaluate the inclusion of more variables against the background of a lowered degree of freedom (less information for estimating the model). The smaller the AIC/SIC the better the model fits the data. However, the AIC/SIC refers to the mean equation since it measures the squared residuals of the mean equation.²³⁰ Therefore, it is reasonable to check the volatility structure by analyzing the Ljung-Box Q-statistics of standardized squared residuals as well. This gives additional information about any remaining autocorrelation in the squared error terms up to lag k .²³¹ Hence, the approach is to choose the combination of p and q , which yields the lowest AIC/SIC against the background of the corresponding Q-statistics.²³²

Another important aspect is the interpretation of the (G)ARCH coefficients, which is often neglected in other studies using this approach. While coefficient ∂_i captures the impact of errors on the conditional volatility, γ_i displays its persistency. Hence, large values for ∂_i indicate a high impact of errors on the conditional volatility, i.e. the response of h_t to new information. Large values for γ_i show a high degree of autoregressive persistency, or a long memory of the conditional volatility series. The sum of both coefficients give information about the overall persistency of the conditional volatility.²³³

²²⁹The definition of various information criteria or model selection criteria can be found in any standard econometric textbook dealing with time-series analysis. See also Appendix A/B.1.2.

²³⁰Bollerslev et al. (1994) argues that the statistical properties of information criteria are basically unknown in the context of conditional heteroskedasticity.

²³¹See Harvey (1990, 1993), and Ljung and Box (1979) for more information on the Ljung-Box Q-statistics. See also Appendix A/B.1.1.

²³²Of course, standard diagnostic tests for remaining ARCH/GARCH effects can be used as well.

²³³See Enders (2004).

4.3.2 Estimation of GARCH Models in General, and the Impact of Interventions in Particular

GARCH models are estimated by using ML. Thereby, the mean and the volatility equation are estimated simultaneously. Assuming η_t being normally distributed ($\eta_t \sim N(0, 1)$), and abstracting from asymmetric intervention effects, the likelihood function for the GARCH model presented above is given by:

$$L = \prod_{t=1}^T \frac{1}{\sqrt{2\pi h_t}} \exp \left(-\frac{\left(\Delta s_t - \alpha_0 - \alpha_1 \sum_{i=1}^l \Delta s_{t-i} - \beta_1 Int_{t-1} - \zeta \mathbf{Z}'_t \right)^2}{2h_t} \right), \quad (109)$$

with

$$h_t = \mu + \sum_{i=1}^p \partial_i \varepsilon_{t-i}^2 + \sum_{i=1}^q \gamma_i h_{t-i} + \beta_2 |Int_{t-1}| + \omega \left| \mathbf{V}'_t \right|. \quad (110)$$

As previously mentioned, the likelihood function is derived under the assumption of conditional normality. However, it is common that exchange rate returns are not normally distributed. They usually display fat tails (lepturkotic feature), calling for more appropriate distributions like t-distribution or GED.²³⁴ However, it has been tested empirically that using these alternative distributions does not make a big difference in terms of estimation results for coefficients. Furthermore, tests for errors to come from fat tail distributions often fail to support their usage.²³⁵ Using the normal (Gaussian) distribution is often applied for reasons of simplicity. Maximizing a potential misspecified Gaussian log-likelihood function is justified by QML estimation in the sense of White (1982). Under the assumption that daily exchange rate returns are modeled correctly, and that the process is strictly stationary, estimation results are still consistent.²³⁶ Although QML leads to consistent estimations of the parameter vector, some adjustments have to be made in order to obtain consistent estimates of the covariance matrix leading to correct standard errors.²³⁷ Basically, the robust covariance matrix is obtained by the well-known

²³⁴See Herwartz (2004).

²³⁵See Hentschel (1995).

²³⁶See Bollerslev (1986), and Straumann (2005).

²³⁷See Hamilton (1994) for the computation of QML covariances and standard errors. See also Bollerslev and

sandwich estimator, which is an elementary method that yields an asymptotically consistent covariance matrix without necessarily making distributional assumptions even if the underlying model is incorrect.²³⁸

The intervention variable Int_{t-1} is included in both, the mean and variance equation. As stated above, this reflects the crucial advantage of examining the effect of central bank interventions on exchange rates, and its (conditional) volatility when using a GARCH framework. However, this procedure must be assessed carefully. Little has been written on the problem of including the same explanatory variable in the mean and volatility equation.

$$\varepsilon_t = \eta_t \sqrt{\mu + \sum_{i=1}^p \partial_i \varepsilon_{t-i}^2 + \sum_{i=1}^q \gamma_i h_{t-i} + \frac{\beta_2 |Int_{t-1}|}{\beta_2^p |Int_{t-1}^{fx\ purchase}| + \beta_2^s |Int_{t-1}^{fx\ sale}|}} + \omega |\mathbf{V}'_t|. \quad (111)$$

Although being included in its absolute value, it becomes obvious from equation 111 that the error term, and the intervention variable (in the mean equation) are connected, if the intervention variable yields a significant result in the volatility equation for β_2 (β_2^p, β_2^s). In case the intervention variable is significant, any purchase or sale of foreign currency drives the conditional volatility, and accordingly the error term as well. For the mean equation this means that interventions and the error term are connected. However, the connection is not linear, which is why $Cov(\varepsilon_t, Int_{t-1}) = 0$. In other words, the first derivative of the likelihood function with respect to β_1 (β_1^p, β_1^s) would be dependent on the error term. Hence, estimation results for central bank interventions in the mean equation are biased if a significant impact exist in the volatility equation. For this reason, the interpretation of the result in the mean equation must be conducted very carefully and only against the background of the outcome from the volatility equation.²³⁹ This fact was ignored by previous studies which used a GARCH approach to analyze the impact of interventions on exchange rate dynamics so far. However, although the errors and the regressor are not independent, the ML estimator is still consistent due to the fact

Wooldridge (1992).

²³⁸See Huber (1967), and White (1982). It should be noted that if the specified likelihood function is correct, the *sandwich estimator* is unnecessary since all asymptotic properties of ML estimation hold. See Greene (2008).

²³⁹Of course, this also holds for additional explanatory variables. But again, I will focus on the estimation of the interventions variable.

that the covariance of both variables equals zero. Thus, one could speak of a small sample bias. Nevertheless, this issue should always be kept in mind when interpreting empirical results.

4.3.3 An Alternative Assessment of the Effectiveness of Foreign Exchange Market Interventions

The question when central bank interventions are effective seems to be straightforward at first sight when having the objectives of interventions in mind. Various methods have been presented in chapter 3.1.3. In the context of the GARCH framework, which is used in the following sections, an econometrist might assess the success of an intervention according to the estimation results for coefficients β_1 and β_2 . In this sense, an intervention is successful, if a purchase of foreign currency ($Int_t > 0$) depreciates the domestic currency and vice versa. Accordingly, coefficient β_1 should yield positive significant estimation results. Moreover, interventions ($Int_t \gtrless 0$) are seen as effective in calming volatile exchange rate markets, if the impact on the conditional volatility is negative. Hence, coefficient β_2 is supposed to be significant negative or positive. Concerning the asymmetric effects, slight different outcomes are expected. A purchase of foreign currency ($Int_t^{fx\ purchase} > 0$) should depreciate the exchange rate, and a sale of foreign currency ($Int_t^{fx\ sale} > 0$) should appreciate the domestic currency. Hence, coefficient β_1^p and β_1^s should yield significant positive and negative values respectively. In case of an impact on the conditional volatility, things remain the same. The outcomes for β_2^p and β_2^s are expected to be significant and negative.

From this point of view, the effectiveness of interventions is defined clearly against the background of the underlying motives. However, when taking a closer look, the question of the effectiveness is not as clear cut as it seems to be. Abstracting from econometric model aspects, the questions that arise when assessing the effectiveness of interventions are: 1) what would have been the counterfactual, if the central bank had not intervened?; 2) is it justified to assess interventions as being ineffective, if the estimated coefficients are wrongly signed and/or insignificant having the intervention objectives in mind?

The first question is directly linked to the problem of modeling exchange rates in general. As explained above, no model has emerged from decades of exchange rate research, which determines exchange rate developments reliably. The stumbling blocks are obvious. All transaction data must be known, and more importantly, all the decision-determining factors of international agents must be known as well. It is obvious that these necessities are not given. On the one hand, it is an issue of missing data. In this context, central bank operations are analyzed with the available transaction data. However, the central bank is just one out of millions of players in the exchange rate market. On the other hand, it is an issue of behavioral economics. Why do agents act they way they do? A discussion of these problems goes far beyond the scope of this thesis. However, this should always be kept in mind when trying to estimate any exchange rate relationships. Thus, it is not possible to know how the exchange rate would have developed if a central bank had not intervened in the foreign exchange market.²⁴⁰

Though being connected to the counterfactual as well, the second question also refers to the matter of choosing a specific methodology to analyze the impact of central bank interventions. From a first point of view, it might not be justified to speak of inefficient interventions if the stated goal was not reached. Any purchase or sale of foreign currency absorbs any exchange rate pressure or adds to it. A central bank facing an appreciating exchange rate, and buying foreign currency to alleviate this current trend, absorbs the demand for the domestic currency to a certain extent. Whether the sale of domestic currency leads to a depreciation of the exchange rate (i.e. has the absorption been great enough?) is another question. For instance, it is hard to believe that the billions of JPY sold by the BoJ in the 1990s should have had no impact on the exchange rate, as is widely believed. There must have been an effect which smoothed the exchange rate appreciation. Again, the problem is that the counterfactual is not known. From a second point of view, other methodologies circumvent the problem of the counterfactual. However, their merits do not outweigh their drawbacks. To sum up, from an econometric point of view, it might be correct to assess an intervention as ineffective, if the according coefficient is

²⁴⁰Most recently, Fatum and Hutchison (2010) address to the matter of a missing counterfactual. The authors estimate the counterfactual as the ATE of interventions by applying the method of propensity score matching. Although being a new way of accounting for this well-known problem, it directly refers to the matter of insufficient exchange rate models.

wrongly signed and/or insignificant. However, the problem of the question of *'what could have been if...?'* should always be kept in mind. Nevertheless, it is not correct to assume or state that interventions are effective in driving the exchange rate in the desired way. It just reflects the idea that any intervention has a certain impact on the exchange rate.

4.4 Challenges in Empirical Modeling of Intervention Dynamics

4.4.1 Specification Problems

One basic problem, mentioned several times, in empirical work is the negligence of important variables, which could possess high explanatory content for explaining exchange rates and central bank interventions. This leads to the well-known problem of an omitted variable bias.²⁴¹ The challenge of explaining exchange rates is basically a problem of not capturing the essential variables, which are not available. Therefore, researchers have focused on proxy variables by stating theoretic conditions, and trying to explain the exchange rate movements. The overall poor outcomes are known well. In the same way, reaction functions are exposed to omitted variables as well.

Imagine a simple reaction function according to equation 112.²⁴² Suppose that important variables, which do not refer to the classical motives, are not included in the estimation. Domestic policy aspects (interventions are used for monetary issues), and debt repayments are only two possibilities. Such objectives can be summarized in \mathbf{C} . Not accounting for these variables does not mean that the problem is not recognized. Sometimes crucial variables are not available or, if any, on an insufficient time frequency. Basically, this problem leads to an estimator, which is biased according to the extent to which \mathbf{X} and \mathbf{C} are not orthogonal. However, as long as the omitted regressor is not correlated with the included regressors (\mathbf{X} and \mathbf{C} are orthogonal, $\mathbf{X}'\mathbf{C} = \mathbf{0}$), estimations are still valid and the parameter vector is not biased ($E(\hat{\boldsymbol{\beta}}^{OLS}) = \boldsymbol{\beta}$). Equation 112 and 113 describe this issue:

²⁴¹See e.g. Greene (2008).

²⁴²The following example can also be formulated for exchange rates.

$$Int = \beta \mathbf{X}' + \underbrace{\boldsymbol{\theta} \mathbf{C}'}_{\text{neglected}} + \varepsilon, \quad (112)$$

$$E(\widehat{\boldsymbol{\beta}}^{OLS}) = \boldsymbol{\beta} + (\mathbf{X}'\mathbf{X})^{-1} \mathbf{X}'\mathbf{C}\boldsymbol{\theta}. \quad (113)$$

Although the orthogonality of \mathbf{X} and \mathbf{C} seems to be questionable, it can be argued that domestic aspects can be independent from exchange rate movements. This in turn reflects the impossible trinity, where the central bank tries to maintain domestic policy, while at the same time managing external balances. Similarly, debt payments are not connected directly with exchange rate dynamics. Thus omitted variables, in the context of reaction functions, do not necessarily lead to false results. However, it does cause other consequences. The error term ε_t can be seen as a pot of influences from excluded variables.²⁴³ Hence, it catches the effects from omitted regressors on the dependent variable, causing the error term to show persistency reflected by autocorrelation. This autocorrelation has some severe drawbacks. Although the OLS estimator remains unbiased (for large samples), standard errors are wrongly estimated leading to unstable inferences. In this case, a typical strategy is to let the data choose the appropriate lag length in order to rule out any remaining serial correlation.²⁴⁴ Therefore, lagged dependent variables are included in the set of regressors.

It is often claimed that serial correlation in the error term is a clear sign of specification problems. A very interesting paper is presented by Keele and Kelly (2006), who discuss the role of lagged dependent variables from a different perspective. Instead of worrying about residuals and the standard procedure "*... of fitting a model to the data, testing for violations of the estimator assumptions, and searching for appropriate solutions when the assumptions are violated.*," [Keele and Kelly (2005), p. 186], the authors state that the occurrence of autocorrelation should be a starting point for formulating a theoretical concept around it. Hence, the model should be borne out of theoretic considerations, instead of fitting a static linear model. Their argumentation serves as an invitation to incorporate lagged dependent variables in the model. Moreover, Baker (2007) argues that including lagged dependent variables to account for

²⁴³See Verbeek (2008).

²⁴⁴See Patterson (2000). In this case one can think of ARMA modeling as proposed by Box et al. (1994).

error correlation is a good proxy for the omitted variables, especially if the omitted variable(s) is unknown or unmeasurable. Hence, omitted variables do not distort estimations, if addressed accordingly.²⁴⁵

The other way around does not impose severe consequences. Adding unnecessary regressors (\mathbf{W}) does not lead to any problems. Thus, suggested motives, which were not taken into account by the central bank, do not influence other objectives directly. Equations 114 to 116 describe this aspect.

$$Int = \beta \mathbf{X}' + \underbrace{\omega \mathbf{W}}_{\text{redundant}} + \varepsilon, \quad (114)$$

$$M_W = I - \mathbf{W} \left(\mathbf{W}' \mathbf{W} \right)^{-1} \mathbf{W}', \quad (115)$$

$$\hat{\beta}^{OLS} = \beta + \left(\mathbf{X}' M_W \mathbf{X} \right)^{-1} \mathbf{X}' M_W \varepsilon. \quad (116)$$

It can be seen that $\hat{\beta}$ is unbiased ($E \left(\hat{\beta}^{OLS} \right) = \beta$), if $E(\varepsilon) = 0$. In the context of the intervention reaction function adding a motive, which was not accounted for, is unproblematic since it will not be different from zero.²⁴⁶ The aspects of omitted/redundant variables has not been discussed in the literature of central bank interventions.

4.4.2 Error Dynamics

Estimation residuals must be proved carefully for correlations in the first and second moments. In the presence of lagged dependent variables within the set of regressors, the OLS estimator will be inconsistent, if there is serial correlation in the error term. While this is a standard textbook treatment, the relationship between the second moments deserves some additional attention. In this context, macroeconomists often do not care about the possibility of ARCH effects. Accounting for this fact, Hamilton (2008) states: "*There seems to be an assumption among many*

²⁴⁵For instance, Jun (2008) includes lagged interventions up to order 10 for daily DBB actions, and lagged interventions up to order 9 for daily Fed transactions. Moreover, the author does not estimate typical AR(9), AR(10) models but inserts only specific lags (Fed: Int_{t-1} , Int_{t-3} , Int_{t-5} , Int_{t-7} , Int_{t-9} ; DBB: Int_{t-1} , Int_{t-3} , Int_{t-4} , Int_{t-6} , Int_{t-10}).

²⁴⁶However, estimated variance of the coefficient vector is more efficient in case of dropping redundant variables.

macroeconomists that, if your primary interest is in the first moment [intervention reaction function], ARCH has little relevance..., " [Hamilton (2008), pp. 2-3]. Generally, it is claimed that in case of (G)ARCH process of the error term coefficients are still valid. Verbeek (2008) summarizes that: *"The presence of ARCH errors in a regression or autoregressive [!] model does not invalidate OLS estimation. It does imply, however, that more efficient (nonlinear) estimators exist than OLS."* [Verbeek (2008), p. 312]. Furthermore, in case of lagged dependent variables in the regressors, standard errors are biased since the squares of the disturbance term will be correlated with the squares of the regressors.²⁴⁷

Besides the fact that OLS standard errors can be quite misleading (inefficiency of estimators), Hamilton (2008) addresses the matter of the conditional mean function in case of (G)ARCH process in another way. He argues that inferences on the coefficients of the mean function can be affected by outliers, and high-variance episodes, if error dynamics are not incorporated into the estimation. In other words, not accounting for time-varying variance imposes the same weight to all observations when estimating a model. This in turn overweighs the impact of observations associated to periods of high variances, and can lead to wrong conclusions on the underlying relationship.

For this reason, it is also important to check the characteristics of the intervention data when specifying the reaction function. This can be done by simply looking at the squared values of the dependent variable (a heuristic approach) to examine any connections. Additionally, the underlying reaction function can be estimated by OLS in a first stage. Checking the residuals for any (G)ARCH process then, will determine whether to change the estimation procedure (towards (G)ARCH) in order to explicitly account for conditional heteroskedasticity, or to remain at the a priori suggested estimation method in the second stage. In the context of exchange rate changes, the characteristic feature of heteroskedasticity is well-known, and does not require a pre-analysis.

²⁴⁷See Engle (1982), and Patterson (2000).

4.4.3 Stationarity and Integration Aspects

It is crucial for basic estimation techniques and the following inferences that the dependent variable and the regressors are stationary. Thereby, a process (time-series) is seen to be stationary, if its mean, variance, and covariance is independent of time.²⁴⁸ In this case the time-series is called $I(0)$ - *integrated of order 0* - for a reason that will be clarified shortly. Unlike $I(0)$ series, a process with a time dependent first and second moment is nonstationary. The simplest form of a nonstationary process is a Random Walk. Such series can be made stationary after first differencing them, which is why they are also called *difference stationary* or $I(1)$ - *integrated of order 1*. More generally, a nonstationary time-series is $I(d)$ - *integrated of order d* - if the d -th difference ensures its stationarity.²⁴⁹ Directly related to the matter of stationarity is the *unit root* concept. If a time-series is $I(1)$, then the process contains a unit root. This can best be described in the context of a Random Walk. Suppose the following AR(1) process:

$$y_t = \phi y_{t-1} + \varepsilon_{y,t}, \quad (117)$$

$$\phi(L)y_t = \varepsilon_t, \quad (118)$$

with ε_t being white noise, and $\phi(L) = (1 - \phi L)$ being a polynomial in the lag operator. Equation 117 displays a stationary process, if the solution (z) of the characteristic equation ($1 - \phi z = 0$) is located outside the "unit circle." Hence, the process is stationary if $|\phi| < 1$, which corresponds to $|z| > 1$. In this case, the process is invertible, showing a constant first and second moment. It can easily be seen that a pure Random Walk ($\phi = 1$) does not match this requirement. The AR(1) transforms to:

$$y_t = y_{t-1} + \varepsilon_{y,t}. \quad (119)$$

The necessity of stationarity is crucial since the distribution of standard test statistics is based on the assumption of stationarity. The problem is that when dealing with $I(1)$ variables

²⁴⁸This form refers to weak or covariance stationarity. See Maddala and Kim (1998), and Verbeek (2008).

²⁴⁹See Davidson and MacKinnon (2004), and Maddala and Kim (1998). Nonstationary time-series are usually integrated of order 1. However, $I(2)$ variables are also existent in the economic environment. In this context, Hall (1986) considers the relationship of logarithm of wage, and logarithm of CPI, both being $I(2)$ variables.

spurious results are distorting any reliable interpretations of suggested relationships. The basic problem of spurious estimation results is that, with the dependent and the regressor both being I(1) variables, the error term is also I(1), making test statistics useless.²⁵⁰ Suppose η_t being the disturbance term of a regression of two I(1) variables y_t on x_t .

$$\eta_t = y_t - \alpha x_t. \quad (120)$$

By setting the initial condition $y_0 = x_0 = 0$ it can be seen that:²⁵¹

$$\eta_t = \sum_{i=1}^t \varepsilon_{y,i} - \alpha \sum_{i=1}^t \varepsilon_{x,i}. \quad (121)$$

It can be seen that the second moment of the disturbance term η_t increases over time, and the assumptions on standard testing (t-test, F-test, R^2) are violated. Although both series have nothing in common, except a *stochastic trend*, α is likely to show a significant result.²⁵² Hence, it is very important to check whether the intervention variable, suggested motives, exchange rate changes, and further control variables have a unit root.

More interesting is the case when variables of different order of integration are included in the estimation. This problem is referred to as an *unbalanced equation*. In this case an I(0) variable is explained by a set of I(1) or by a mix of I(0), and I(1) variables. It is often argued that results are useless in this case. The reason being that the residuals will also be I(1).²⁵³ Accordingly, if y_t is a stationary AR(1) process as defined in equation 117, equation 121 transforms to:

$$\eta_t = \sum_{i=1}^t \phi^i \varepsilon_{y,t-i} - \alpha \sum_{i=1}^t \varepsilon_{x,i}. \quad (122)$$

Although the first part converges, the error term η_t still experiences a trend caused by x_t

²⁵⁰However, nonstationarity does not automatically lead to spurious results, i.e. I(1) variables can be cointegrated in the way that linear combinations of I(1) variables exist, which are I(0). See e.g. Lütkepohl (2005).

²⁵¹See Enders (2004).

²⁵²See Patterson (2000).

²⁵³Pagan and Wickens (1989) state that in case of an unbalanced equation, residuals can only be I(0) if at least two I(1) regressors are included in the estimation of an I(0) dependent variable. Thereby, co-movements of the nonstationary regressors are responsible for this fact.

(I(1) variable). This aspect is of crucial importance when dealing with rolling estimations. It might be the case that some motives or even the intervention variable show different degrees of integration when a fixed estimation window is shifted through time. Results must be treated very carefully. One might argue this to be a crucial drawback of using rolling estimations. Indeed, this is a drawback. Thus, when applying this time dependent estimation, rolling unit root tests must be conducted for the underlying series. However, abstracting from this problem, the discussion on unbalanced equations is not concluded. In this context, Banerjee et al. (1993) argue: *"The mere fact that a regression is unbalanced may not be a matter of concern; for example, ADF statistics are computed from models that, in this terminology, are unbalanced. They are nevertheless valid tools for inference as long as the correct critical values are used,"* [Banerjee et al. (1993), p. 166].

One practical way to check if the inclusion of an I(1) variable distorts the results, is to estimate the model without the specific I(1) process, and compare the results with estimation outcomes including the I(1) process. Another way is to analyze residuals from estimations with the I(1) process for a possible unit root. These natural ways to examine estimation validity are applied by Baffes (1997). He suggests to test the residuals for a unit root process in order to check for model validity. Furthermore, he argues that a model with an I(0) dependent variable, and I(1) regressors may have I(0) disturbances for two reasons. Stationarity is given due to co-movements of two I(1) regressors or due to a poor explanatory content, where I(0) residuals reflect the stationarity properties of the dependent variable.

5 The Case of Argentina

5.1 Monetary Policy

Monetary policy in Argentina has changed substantially with the financial crisis in 2001/2002. After abandoning the currency board regime, in which the BCRA was obliged to convert the Peso into the US\$ on a one to one relation, in December 2001, Argentina chose to let the domestic currency officially float freely. However, the country faced a lot of problems in the aftermath of the crisis. Figure 5 displays economic and monetary policy features of Argentina between 2001 and 2008.

Capital outflows, exchange rate overshooting, and a run on the banking system rocked the country's economy. Foreign reserves declined by 64.6% between January 2001 and July 2002. Although household consumption began to rise slightly at the end of 2001, real GDP growth was still at a double digit figure in the negative. Several measures were used to alleviate these problems.²⁵⁴ At first, restrictions on capital outflows, and deposit withdrawals ("corralitos" - until early 2002, "corralón" afterwards) were imposed to forestall a bankruptcy. These restrictions were also used to hold back the demand for foreign currency to defend the Peso, and to secure the stock of foreign exchange reserves. Meanwhile, the government implemented a dual exchange rate system, with a fixed parity for certain trade and financial operations (1.4 US\$/ARS) and a free float for the rest of operations. However, due to IMF demands, the exchange rate market was unified soon afterwards.²⁵⁵ Due to this "inconvenient" step, the exchange rate depreciated up to 4 US\$/ARS in June 2002, which caused significant wealth destruction. Therefore, the government decided to convert US\$ denominated domestic debt into ARS one to one, in order to offset the increase in real debt level and to assuage the balance-sheet effect. The government further decreed to convert US\$ denominated deposits into ARS at a fixed rate, lower than the actual market exchange rate. These steps were part of the so called "Pesofication." Capital outflows were restricted by setting limits on monthly exchange transactions per person and by introducing surrender requirements for exporters. Thereby, exporters were forced to cede their

²⁵⁴See BCRA (2002b).

²⁵⁵See Frenkel and Rapetti (2007).

earnings to the central bank. All these measures, which were aimed at putting a domestic financial system (which was desiccated at the time) with a domestic currency in place, were supported by foreign exchange market interventions (purchases of foreign currency). In this environment, the central bank faced a not functioning financial system, and monetary policy was practically inexistent.²⁵⁶

In May 2002, the BCRA started to issue debt letters (“Lebac” – short term bills; “Nobac” – securities, since the end of 2003), as an intent to implement a new monetary policy instrument. This was done to push back dollarization, and to provide the Argentinean financial market with Peso denominated substitutes for US\$ denominated securities, and to regain control over monetary policy. In this context, the main objectives of the new BCRA debt instruments has been: *"Absorb surplus monetary market liquidity; Determine benchmark rates facilitating the development of a long term lending market; and Supply the market with an instrument which may be negotiated in the secondary market pursuant to its liquidity needs."* [BCRA (2003c), p. 49]. In mid 2004 the BCRA started to establish a reference short-term interest rate band, which was designed to reduce interest rate volatility, and effectively manage money market liquidity through the introduction of repo and reverse repo transactions. Additionally, both instruments also represent a form of "delayed" liquidity, which can be used under certain circumstances.²⁵⁷

After 10 years of dependent monetary policy, Argentinean authorities were lacking substantial experience in conducting monetary policy independently. Although many emerging market countries have turned to inflation targeting frameworks, Argentina was not able to implement this dominating monetary policy strategy. The inexistence of a sophisticated and stable domestic financial system made it impossible to focus on chasing inflation targets explicitly by controlling short-term interest rates. In contrast, Argentina’s monetary policy can be described as a transition towards this famous monetary policy framework. Since 2003, influenced by the IMF, monetary policy is based on a quantitative monetary target arrangement. At the end of each year, target ranges for each quarter of the following year are announced.²⁵⁸ These targets

²⁵⁶Government debt was in default. To compound things even further, fifteen different monies (‘quasi monies’) were in circulation. See McCandless (2005).

²⁵⁷See BCRA (2007b).

²⁵⁸Quarterly targets started in 2004. During 2003, the BCRA announced bi-monthly targets. See BCRA

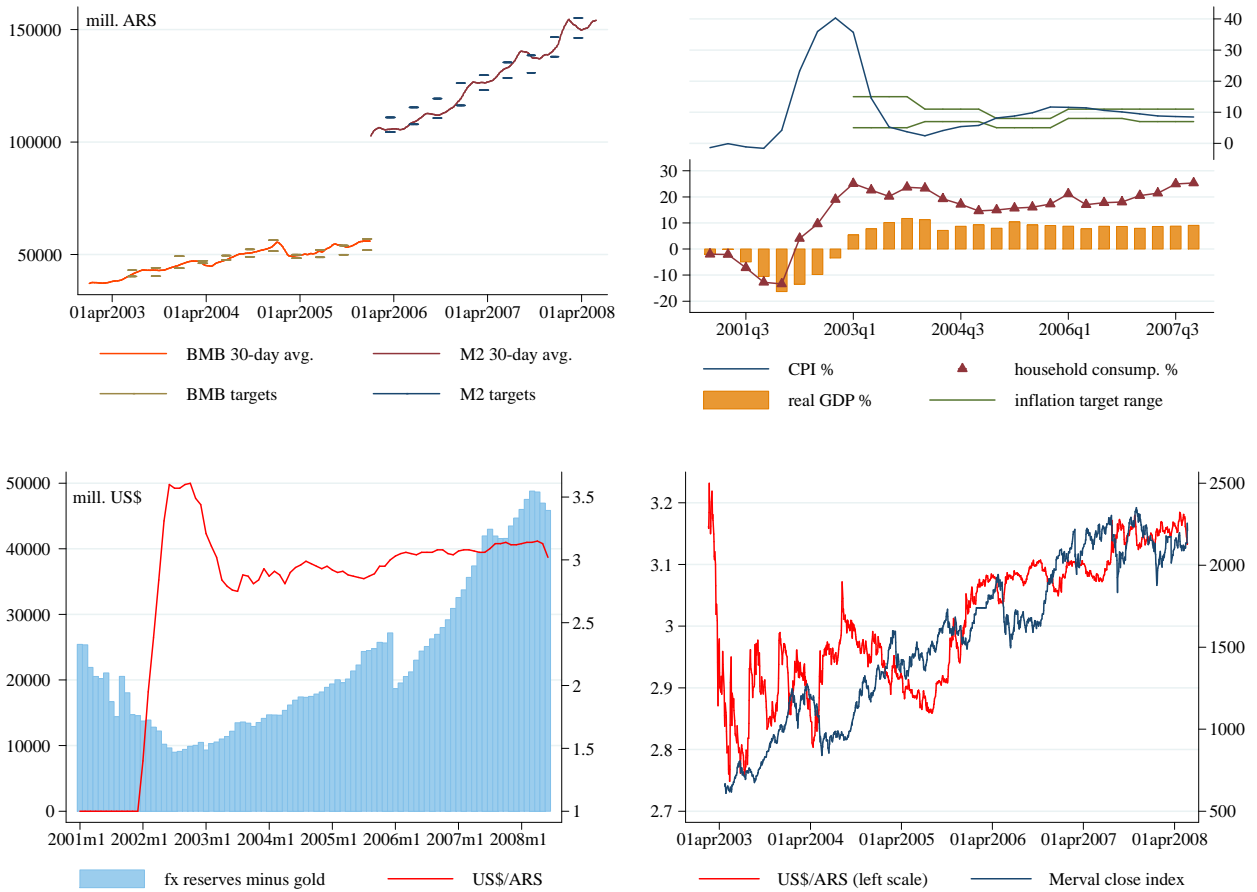


Figure 5: Economic and Monetary Policy Features of Argentina between 2001 and 2008 (Data source: BCRA, IMF-IFS, Bloomberg).

account for the ultimate goal of price stability as stated in the Central Bank Law.²⁵⁹ Hence, domestic prices are controlled through a monetary targeting strategy, and an expectation anchor given by the quantitative monetary targets. Concerning the exchange rate system, monetary authorities in Argentina stated that an exchange rate arrangement in line with the strategy of managed floating was implemented during the years. This system aimed at providing economic reliability, and calm excessive exchange rate volatility that could have deformed economic decisions.²⁶⁰

(2003a).

²⁵⁹The authorities state: „*The Central Bank of the Argentine Republic shall primarily and essentially preserve the value of currency.*”, [BCRA (2007c), p. 1].

²⁶⁰See BCRA (2007b).

The most important instrument applied by the BCRA in the most liquid market has been foreign exchange intervention to target the BMB (currency in circulation held by the nonfinancial sector adjusted for quasi-monies). This in turn points towards a double-targeting regime in Argentina. It seems that the authorities, when using foreign exchange market transactions to manage domestic policy issues, appear to have also taken exchange rate aspects into account. However, the central bank made no statements on the use of foreign exchange market interventions in order to target a specific exchange rate level. Moreover, authorities denied any exchange rate targets: "*...the BCRA does not pursue an exchange rate target ...*," [BCRA (2003b), p.10]. A change in the monetary target was announced at the end of 2005. Starting in 2006, the BCRA chose to control the broader monetary aggregate M2 (cash held by the public, current accounts held by the private and public sector in Peso, savings accounts in Peso of the private and public sector).²⁶¹ This change was justified by the fact that the money multiplier had increased over years, and that there was a significant expansion in credit lines, which caused M2 to grow.²⁶² As can be seen from the upper left panel of figure 5, throughout the years, the BCRA fulfilled its quantitative monetary targets and inflation rate came back from high double digit levels. However, with a strong increase in real GDP and household consumption growth, inflation began to exceed its target range.²⁶³ This points towards the disability of a monetary targeting framework to ensure stable and predictable domestic prices.

The importance of the exchange rate in the Argentinean economy is emphasized by McCandless (2005), who investigates transmission channels of monetary policy in Argentina after the 2001/2002 crisis. He concludes that while an interest rate channel exists, especially since the introduction of the Lebac, the exchange rate channel is assigned the greatest importance. Several reasons justify this fact. Frenkel and Rapetti (2007) as well as McCandless (2005) argue that, although not officially stated, the BCRA pursued a target range between 2.8 US\$/ARS -

²⁶¹See BCRA (2005a).

²⁶²The money multiplier, defined as the ratio of M2 and BMB, reached its maximum level of 1.9 in early 2006 compared to a minimum level of 1.2 in mid 2003. With a change in the target definition, the multiplier was stabilized around 1.6 (Data source: BCRA).

²⁶³The target range for growth of consumer prices was widened in 2006. Primarily, inflation was aimed to vary between 7% and 4% during 2006. These targets were defined according to the IMF. However, a change in relative prices caused through a higher demand for commodities, exerted additional upward pressure on domestic prices in Argentina (Data source: BCRA).

	F-stat.	P-value
$\Delta s_t \rightarrow \Delta \% Merval^a$	1.00551	0.4200
$\Delta \% Merval_t \rightarrow \Delta s_t^b$	1.92198*	0.0741

Sample: 1/02/2003 9/05/2008; lags included: 6; obs: 1413
^a H0: exchange rate does not Granger cause stock prices
^b H0: stock prices do not Granger cause the exchange rate
*10% - **5% - ***1% significance

Table 6: Pairwise Granger-Causality Test for Argentinean Stock Market Prices and Exchange Rates between 2003 and 2008 (Data source: BCRA, Bloomberg).

3.05 US\$/ARS to preserve and maintain a stable and competitive real exchange rate, which was given more emphasis in official policy.²⁶⁴ The importance, given to the lower exchange rate level, stemmed from the fact that the government's main income has been tax revenue from export earnings measured in Peso ("retentions"). Therefore, the government was clearly interested in a Peso not too strong vis-à-vis the US\$.

Furthermore, McCandless (2005) show that a stronger exchange rate signaled a strengthening of the domestic economy. The author find evidence for the exchange rate to influence (Granger cause) the Argentinean stock market index *Merval*. Thereby, an appreciation of the domestic currency was followed by a rise of stock market prices. In this sense, an appreciation of the Peso signaled more economic stability and confidence in the Argentinean economy, leading to more capital inflow. This indicates that the exchange rate, besides quantitative monetary targets, served as a type of nominal anchor for economic stability. While this result is obtained for a time period covering 2002 and 2003, Granger-Causality tests for data between 2003 and 2008 reveal some different perspectives. As shown in table 6, daily returns of stock market prices Granger caused exchange rate returns. This points towards the evolution of the foreign exchange and financial markets. While, at early stages, the exchange rate possessed a strong signaling power for economic stability, the causality had turned towards the stock market influencing the exchange rate. However, in both cases the importance of the exchange rate remained the same.

²⁶⁴See IMF (2005).

5.2 The Role of Interventions

Two reasons were mentioned by the authorities to intervene in the foreign exchange market. Firstly, foreign exchange market operations had been the main source of money growth in Argentina. The right panel of figure 6 shows that interventions accounted basically for all variations in the monetary base.²⁶⁵ In this context, the BCRA states that: *"... the Central Bank of Argentina (BCRA) holds reserve assets with the purpose of regulating the supply of money by means of the purchase and sale of foreign currency,"* [BCRA (2004), p. 45].²⁶⁶ After the collapse of the currency board and the resulting decapitalization, the financial system was desiccated. Therefore, foreign currency purchases were mainly used to monetize the financial system.²⁶⁷ While the above mentioned financial restrictions have diminished over time, foreign exchange interventions did not. Other monetary base factors were broadly used to restrict monetary expansions ensuring monetary targets (left panel of figure 6). Besides the above mentioned debt instruments issued since mid 2002, and financial operations since mid 2004, operations of the public sector, and the collection of rediscounts constitute other main monetary base factors.²⁶⁸

Secondly, the authorities attached a high importance to the rebuilding of foreign reserves in the aftermath of the financial crisis in 2001/2002. The need of holding foreign reserves depends on several aspects covering real economic and financial situations. In the case of Argentina, the need for accumulating foreign liquidity mainly stemmed from signaling confidence to international investors (e.g. improving credit ratings), and attracting long-term capital in

²⁶⁵Total changes of the monetary base consists of changes in central bank accounts, including minimum reserve requirements, and changes in the currency in circulation. The sharp increase of the monetary base in 2006 stemmed mainly from an increase in the reserve requirement, which was previously decreased. In 2006, BCRA accounts grew by 14.4 bill. Pesos compared to a decline of 1.2 and 8.4 bill. Pesos in 2004, and 2005 respectively. In contrast, changes of currency in circulation was fairly stable (about 10 bill. Pesos) over time until most recently, due to the financial crisis (Data source: BCRA).

²⁶⁶This statement can also be found in further reports of the BCRA.

²⁶⁷At the beginning of the "free" float era, the purchase of foreign currency also stemmed from surrender requirements imposed on traditional exporters. In the context of the stated definitions of interventions, this type of operation is referred to the broad perspective of interventions. The share of surrender requirements amounted for 20% of total foreign currency purchases. See BCRA (2003c).

²⁶⁸Furthermore, during the financial crisis, several quasi monies were introduced in various regions. These quasi monies replaced the functions of the Peso. At the beginning of the free float era (especially in 2003 and 2004), such regional monies were bought back by the BCRA in order to restore the monopoly of currency issuance to the central bank and to generate a monetary base.

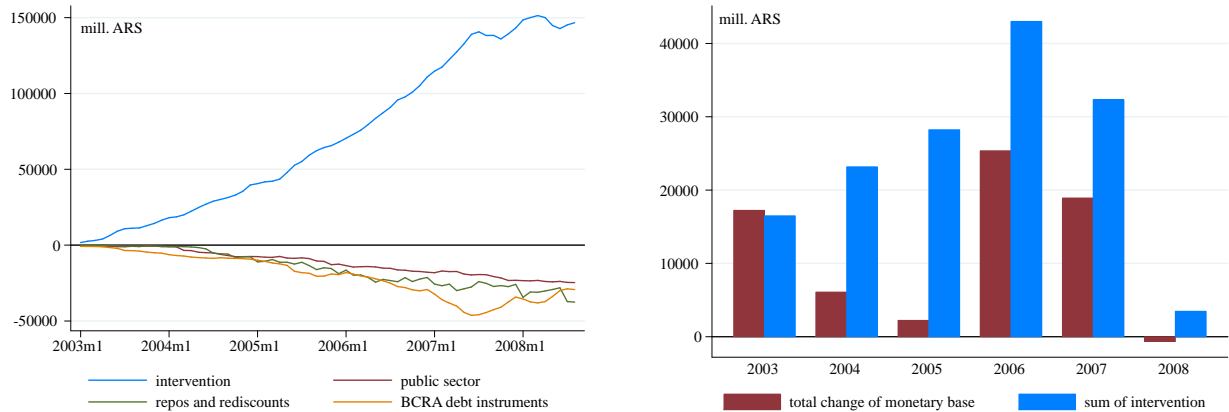


Figure 6: Development of the Monetary Base, and its Main Explanatory Factors in Argentina between January 2003 and June 2008 (Data source: BCRA, own calculation).

order to stimulate economic activity.²⁶⁹ In this context, the BCRA claims: *"... the accumulation of international reserves is one of the fundamental pillars of the monetary and financial policy implemented by the Central Bank."* [BCRA (2007b), p. 19]. The most important function of high foreign reserve levels in emerging markets is the insurance against capital outflows, especially since there is no lender of last resort in the international context. As can be seen in table 7, the rise in foreign reserves was accompanied by a rise in the country's rating for foreign debt. However, it must be noted that the presented ratings of Moody's and S&P were still below the investment grade.

Although exchange rate aspects in the context of exchange market interventions were denied by the authorities, official statements implicitly recognize the importance of foreign exchange interventions within the underlying monetary policy framework.²⁷⁰ The BCRA argues: *"The monetary and exchange rate policies that were followed generated an appropriate framework that enabled the stabilizing of the exchange rate and a considerable increase in international reserves."* [BCRA (2006c), p. 19]. Of course, this is no evidence but rather an orientation for a central bank to account for exchange rate movements directly.

²⁶⁹In the end, the different reserve level benchmarks lend themselves to attest to an economy's strength and reliability.

²⁷⁰See BCRA (2003b, 2005c). Furthermore, Frenkel (2007a) points towards the fact that BCRA interventions were used to maintain a certain exchange rate, and to accumulate foreign reserves.

	Reserves Minus Gold (mill. US\$)	Rating [†]	
		Moody's	S&P
2003	14153.4	Caa1	SD
2004	18884.3	Caa1	SD
2005	27178.9	B3	B-
2006	30903.5	B3	B+
2007	44682.1	B3	B+
2008	45850.8	B3	B-

[†] The displayed rating are long-term foreign currency ratings

Sub-Investment Grades:

Moody's: Ba1, Ba2, Ba3, B1, B2, B3, Caa1, Caa2, Caa3

S&P: BB+, BB, BB-, B+, B, B-, C+, C, C-

Table 7: Development of Sovereign Risk Ratings between 2003 and 2008 (Data source: IMF-IFS, Bloomberg).

As suggested by figure 6, the matter of sterilization consequently gained in importance. With a steadily rising broad monetary base, authorities faced an unpleasant situation, as their double-targeting instrument caused some tensions in the context of Argentinean monetary policy. Matching announced quantitative monetary targets, and ensuring the equilibrium on the money market was challenged by managing the exchange rate simultaneously. In this sense, excess money supply, caused by the purchase of foreign currency, was partially sterilized.²⁷¹ The sale of foreign currency in recent times to react to the global financial crisis did basically not lead to a change in the sterilization policy. In this context, the BCRA states: "*Until the end of June [June 2007] the Central Bank continued as in recent years with its international reserves accumulation policy, ensuring equilibrium in money markets by means of its strategy for thorough sterilization of excess money supply. ... It [the central bank] intervened in the exchange market, selling foreign currency ... at the same time as it provided a wide range of liquidity sources.*" [BCRA (2007b), p. 13]. Besides the main monetary base factors, authorities have used a wide range of instruments to sterilize foreign currency purchases.²⁷² These measures

²⁷¹It is important to note that, although the domestic financial system was desiccated, sterilization began in 2003. The monetization was not necessarily connected to a higher demand of the monetary base. Therefore, BCRA debt instruments were used to absorb excess liquidity. However, the BCRA stated: "*It is important to remark that as monetary aggregates could not be properly appreciated on account of foreign exchange market restrictions, money sterilization could not be clearly determined.*", [BCRA (2003c), p. 47].

²⁷²See BCRA (2006b).

	2003 - 2008
Δ	BCRA Debt Instrument+Public Sector +Repos+Rediscounts
Int	-.76***
$t - stat.$	-4.52
$\overline{R^2}$	.175
$F - stat.$	15.55***
$Q(10)^\dagger/Q^2(10)^\dagger$	.253/.725

OLS - Estimation using Newey-West Standard Errors & Covariance
 OLS - Regression: $y_t = c + \delta y_{t-2/6/7} + \alpha Int_t + \varepsilon_t$,
 $y = \Delta BCRA \text{ debt instrument} + \Delta \text{public sector} + \Delta \text{repos} + \Delta \text{rediscounts}$
 † p-values; *10% - **5% - ***1% significance

Table 8: Degree of Sterilization by the Main Instruments in Argentina between January 2003 and June 2008 (weekly data).

included: 1) anticipated cancellation of rediscounts, which were granted during the financial crisis in 2001/2002;²⁷³ 2) issuance of short-term debt instruments; 3) repo transactions, which were mainly designed as reverse repos when absorbing excess liquidity; 4) changes in minimum reserve requirements; 5) transactions with government bonds. While the first three accounted for the main sterilization instruments, transactions with bonds, and changes in the reserve requirement were only conducted occasionally.²⁷⁴ As indicated, besides monetary authorities, the public sector also accounted for a contraction of the monetary base as a result of the fiscal surplus, which was used to repay foreign debt.²⁷⁵ Hence, the sterilization of interventions was conducted by the central bank and the government.

As shown in table 8, main sterilization instruments neutralized 76% of foreign exchange market interventions. The degree of sterilization was obtained from the estimation of weekly data between January 2003 and June 2008.²⁷⁶ Standard estimation diagnostics indicate a well

²⁷³See BCRA (2001). Through the use of rediscounts the BCRA acted as a “lender of last resort” for the domestic financial system. This measure became a significant source of funding for domestic banks during the 2001/2002 crisis. Hence, sterilization worked through a precancellation of outstanding banks’ debts.

²⁷⁴In April 2006 the minimum reserve ratio was raised by 2% to 17% for sight deposits. While an additional increase of the ratio for sight deposits was introduced in August 2006, requirements for time deposits exceeding 180 days were eliminated. These changes caused an additional monetary absorption of 4.8 bill. Pesos. See BCRA (2006a, 2006c).

²⁷⁵In fact, the public sector purchased foreign currency from the central bank (sold domestic currency to the central bank) in order to repay international debt (broad intervention perspective). See BCRA (2006b).

²⁷⁶The data was adjusted according to its impact on the monetary base.

explanatory power of the estimation. Hence, the purchase of foreign currency caused an opposite effect on the aggregated main sterilization instruments.

The wide range of sterilization measures used by the BCRA contained nearly all characteristics described in chapter 1.2.2. Broad and narrow methods, asset side and liability side methods, market-friendly and non-market-friendly, and short-term as well as long-term instruments. Although this mix does not support the transparency of monetary policy, the BCRA has emphasized that the sterilization program was unprecedented in Argentinean history due to its quality and depth.²⁷⁷ Furthermore, it is claimed that all measures were well-accepted by the domestic financial system. Nevertheless, it can be assumed that the change of instruments served to fit the evolution of the financial environment. Concerning the time structure of sterilization measures, BCRA debt instruments were issued with a maturity ranging from some days to some years.²⁷⁸ In contrast, repo transactions had a shorter term-structure of a maximum of 90 days.²⁷⁹

Concerning the costs and earnings of sterilized interventions, the accumulation of foreign reserves lead to a decrease in sovereign risk, and the clear commitment to monetary targeting through sterilization supported the positive price developments, reflected by mainly single digit inflation rates. Additionally, the use of various sterilization instruments may have even helped the domestic financial system, instead of hampering it.²⁸⁰ Furthermore, against the background of partial sterilization, and the fact that some measures did not impose direct payments (public sector, collection of rediscounts), quantitative costs did not threaten the policy of sustained sterilization. The financial income situation of the BCRA reveals this point. Between 2003 and 2007 aggregated yearly financial net income (foreign reserves gains and financial expenses) of main sterilization instruments amounted to 3.44 bill. Pesos.²⁸¹ Thereby, the foreign reserve portfolio was actively managed by the monetary authorities. This provided enough flexibility

²⁷⁷See BCRA (2006c).

²⁷⁸During these years, the duration was extended in order to minimize rollover risks that could extend interest rate costs unnecessarily.

²⁷⁹See BCRA (2003c, 2004, 2005d, 2006c, 2007b).

²⁸⁰See chapter 1.2.3.

²⁸¹Data source: BCRA - various reports to the congress. At the time of concluding the thesis, data for 2008 was still not available from the BCRA. See table 17.

to react to changes in the global financial environment.²⁸² In this context, monetary authorities argue: *"Although the sterilization transactions incur cost, the result from rising level of international reserves, the revenue on the securities that the Central Bank hold in its portfolio and the collection of rediscounts, together, exceed the outflows that the issues of Central Bank bills and notes (LEBAC and NOBAC) [BCRA debt instruments] implies, the funds received on the repo market and the remuneration paid on the balances that the financial institutions hold in their current accounts as minimum cash reserves.,"* [BCRA (2007a), p. 57].

5.3 Empirical Estimation

From the discussion above, it becomes clear that the BCRA was, and still is, determined to manage the exchange rate directly via its operations in the foreign exchange market. The foreign value of the Peso is too important in the context of fiscal revenues, and in signaling economic stability. However, so far, nearly no official statements concerning the motives of interventions were given. For this reason, it is of interest for what purposes the BCRA stepped into the market. Given the financial crisis in 2001/2002, and the following evolution of Argentina's financial system, it is likely that motives have changed over time. Although considering the exchange rate volatility, it can be assumed that at the beginning of the "free" float era, monetary authorities were mostly concerned with the desiccated financial system, trying to flow the system with domestic currency. Meanwhile, as stated by Frenkel and Rapetti (2007), as well as McCandless (2005), an exchange rate target band is likely to have been taken into account by the central bank due to the strong appreciation path of the ARS after the crisis. Furthermore, it is interesting to proof whether short-term and medium-term exchange rate perspectives influenced the decision to intervene.

Another point of interest is whether interventions were effective in the way that the goals of interventions were reached, and whether the impact of interventions has changed over time. Especially against the background of Argentina's monetary targeting strategy, and the asso-

²⁸²A detailed description of the composition and duration of the foreign reserve portfolio is given in the yearly BCRA report to the congress.

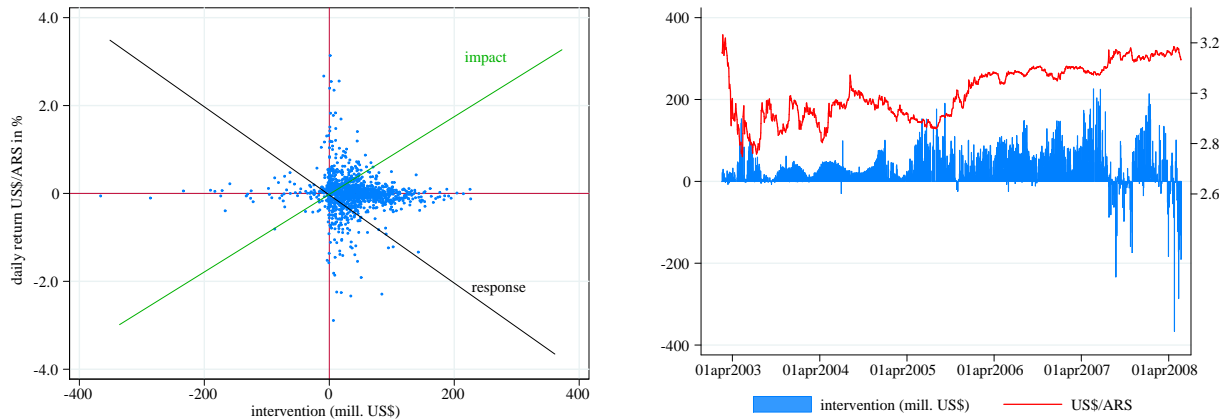


Figure 7: Daily Interventions and their Relationship to Daily Exchange Rate Dynamics in Argentina between February 2003 and May 2008 (Data source: BCRA, own calculation).

ciated sterilization policy, it can be assumed that interventions were effective due to partial sterilization. This would be in line with the arguments proposed by Canales-Kriljenko (2003) in the sense that interventions in emerging markets are more efficient due to incomplete sterilization of monetary effects. However, other restrictions imposed by monetary authorities could have supported the efficiency of foreign exchange market interventions as well. Thereby, broad intervention measures could act supportively.

Figure 7 gives a first overview of BCRA interventions and daily exchange rate movements. It is clear that the left panel of figure 7 reveals no information about the causality of interventions and exchange rate changes. However, it is useful to take a look at the relationship in order to get a first impression. In the context of this scatter plot, one would expect the relationship to meander around the green line for "best" impact effects. Thereby, large foreign currency purchases (sales) would cause the exchange rate to depreciate (appreciate) substantially. In contrast, the black line displays "best" responses of daily interventions on daily exchange rate returns. In case of short-run (daily) intervention motives, the relationship should vary around the black line, indicating foreign currency sales as a response to a high exchange rate depreciation. However, both causalities are shown since contemporaneous interventions and daily returns are displayed. The right panel of figure 7 shows the high frequency and evolution of

daily interventions, and the development of the exchange rate in the time span under investigation. It can be seen that purchases were the dominant transaction throughout the complete sample. Concerning the exchange rate development, it can be seen that the US\$/ARS rate appreciated sharply at the beginning of the sample, showing a relatively nervous pattern until mid 2004. In the following years, the exchange rate shows a fairly stable slight depreciation path.

Some remarks should be given on the institutional aspects of interventions in Argentina at this point. First of all, the BCRA has the right to intervene at its own discretion, and is therefore nominally not subjected to political pressure.²⁸³ Operations are conducted during normal business hours on the local exchange rate market (Buenos Aires) in the corresponding spot segment.²⁸⁴ In contrast to other emerging market economies, Argentina follows a very transparent communication policy concerning their foreign exchange market interventions. Results of transactions are published in daily press releases confirming interventions, and reporting the intervention volume. Although no statement is made immediately, operations are summarized in a weekly report, and are described in further detail in monthly monetary reports. Furthermore, statements on foreign exchange transactions can be found in quarterly inflation reports. An important feature of BCRA interventions is their almost daily frequency, which is mainly caused by the role of interventions as the main money creation instrument.²⁸⁵ In this context, exchange market operations can be assumed to be publicly known. The daily frequency will be further discussed when presenting the empirical estimation strategy.

²⁸³The political pressure on the central bank has become obvious in a different context. Most recently, the president of Argentina, Christina Fernandez de Kirchner, has tried to use the central bank's foreign reserves to repay 6.6 bill. US\$ of foreign debt during 2010. The standoff with the central bank ended with the resignation of the BCRA's president Martin Redrado.

²⁸⁴See Irigoyen (2005).

²⁸⁵Furthermore, the transparent ex-post information policy has helped to supervise the monetary program of the BCRA, and supported the building of the authorities reputation, which was shattered by a long history of monetary instability.

5.3.1 Reaction Function

Ljung-Box Q-statistics of squared intervention data suggest the presence of (G)ARCH process.²⁸⁶ This finding is supported by the analysis of residuals obtained from OLS estimations. The Ljung-Box Q-statistics of squared residuals and ARCH tests point clearly towards the presence of (G)ARCH errors. For this reason, the standard OLS reaction function presented above is replaced by explicitly accounting for conditional heteroskedasticity in the disturbance term. Due to this fact and the continuous fashion of Argentinean interventions, a GARCH(p, q) model is used as a reaction function to analyze potential motives for Argentinean monetary authorities to intervene in the foreign exchange market. The specified reaction function takes the following form:

$$\begin{aligned} Int_t = & \alpha_0 + \alpha_i \sum_{i=1}^l Int_{t-i} + \beta_1 (s_{t-1} - s_{t-6}) + \beta_2 (s_{t-1} - s_{t-1}^{90dm}) \\ & + \beta_3 (s_{t-1} - s^{t \text{ arg et}}) + \beta_4 h_{t-1} + \varepsilon_t, \end{aligned} \quad (123)$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, h_t), \quad (124)$$

$$h_t = b + \gamma_i \sum_{i=1}^p \varepsilon_{t-i}^2 + \partial_i \sum_{i=1}^q h_{t-i}. \quad (125)$$

In order to examine whether the BCRA accounted for the above stated objectives of central bank interventions, the following variables were chosen to explain daily interventions expressed in mill. of US\$.

(i) *Short-Run and Medium-Run Motive:*

Short-term exchange rate movements and deviations from a medium-term exchange rate trend vis-à-vis the US\$, expressed as the 5-day exchange rate return ($s_t - s_{t-5}$), and aberrations of the logarithm exchange rate from a 90-day moving average ($s_t - s_t^{90dm}$) respectively, are included in equation 123 (figure 8: "Explanatory Factor 1" and "Explanatory Factor 2"). By doing so, the BCRA's emphasis on short-term and medium-term exchange rate aspects (reflect-

²⁸⁶See table 33 in Appendix A.1.1 for detailed information.

ing the short-run and medium-run motive) is examined. The estimated coefficients β_1 and β_2 should take negative significant values, indicating that the BCRA accounted for stable short-run as well as stable medium-run exchange rate movements when intervening in the foreign exchange market.

(ii) *Target Motive:*

Although not officially stated, the BCRA included an exchange rate band in its monetary policy orientation (figure 8: "Explanatory Factor 3"). To capture this, the deviation of the actual logarithm exchange rate from the logarithm of the mid rate of the suggested band (upper level: 3.05 US\$/ARS, lower level: 2.8 US\$/ARS, mid rate: 2.925 US\$/ARS) is included in equation 123. This motive ($s_t - s^{target}$) tests whether the BCRA indeed took care for an implicit exchange rate target level. The strong appreciation path in the aftermath of the 2001/2002 crisis, and the importance of export taxes have been mentioned in this context. As is the case for short-term and medium-term aspects, β_3 should be negative and significant at the common levels, indicating that the authorities bought foreign currency when the US\$/ARS was below its implicit mid rate and vice versa.

(iii) *Volatility Motive:*

Due to the desiccated financial system, and threats of unstable price settings on the foreign exchange market, the conditional volatility (h_t) is assumed to explain BCRA's foreign exchange interventions as well (figure 8: "Explanatory Factor 4").²⁸⁷ Especially for Argentina, it is likely that the central bank had this aspects in mind while operating in the early stages of the free float period, matching supply and demand of foreign currency. Hence, daily conditional volatility estimated by a GARCH model, serves as an approximation for disorderly markets. Coefficient β_4 should yield significant results.

As can be seen in figure 8, and as mentioned above, interventions occur almost every day in the sample. Ljung-Box Q-statistics for daily interventions show high autocorrelation.²⁸⁸ In order to capture this persistency, lagged interventions up to order l are also included in

²⁸⁷Conditional volatility is estimated by a GARCH(3,1) model, which is again used in the impact analysis.

²⁸⁸See Appendix A.1.2. for correlograms of daily interventions.

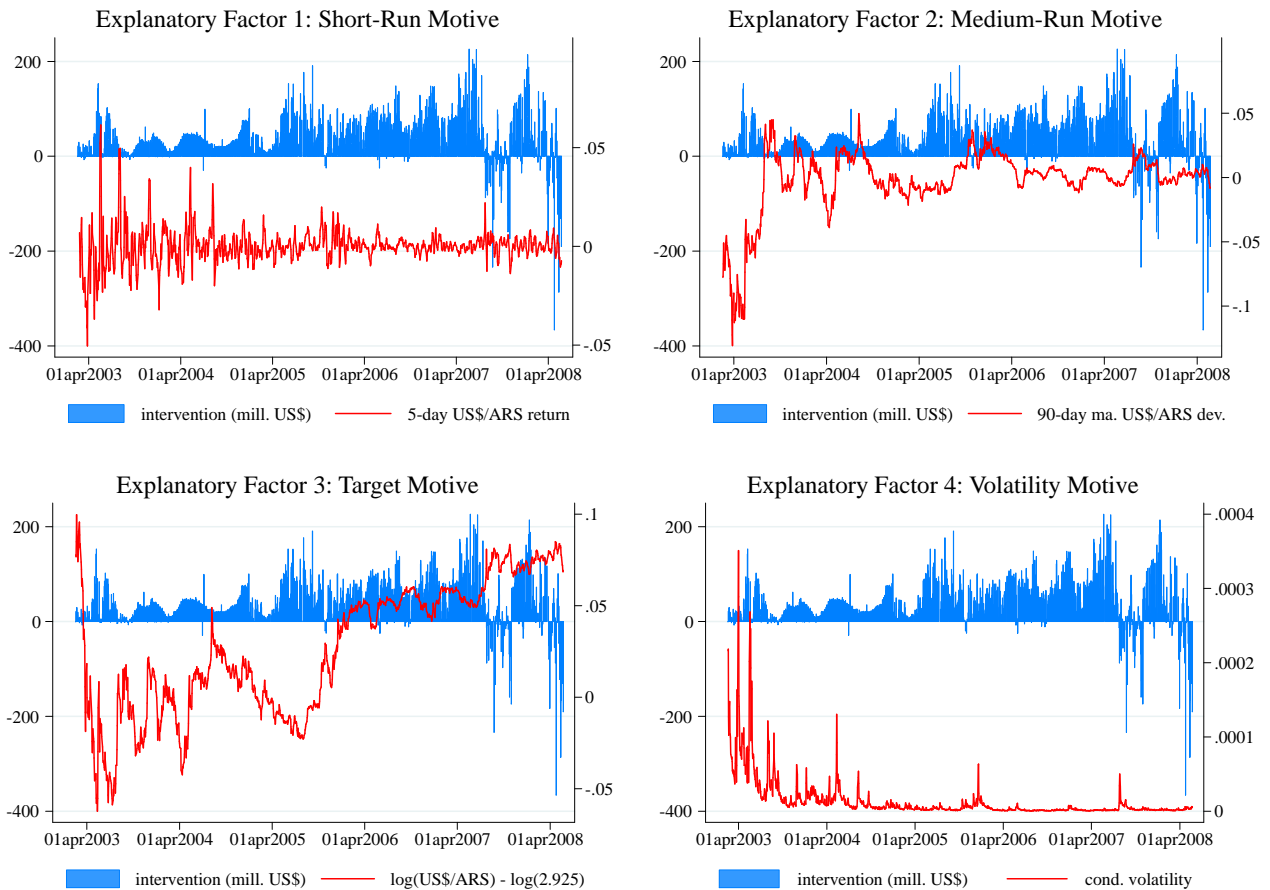


Figure 8: Explanatory Factors for Daily BCRA Foreign Exchange Market Interventions between February 2003 and May 2008 (Data source: BCRA, own calculation).

equation 123. The resulting $AR(l)$ -GARCH(p, q) process with additional explanatory variables also comprises further reasons for which the BCRA has intervened in the foreign exchange market. As discussed, two additional objectives for interventions were the management of domestic monetary aggregates, and the accumulation of foreign reserves. Concerning the former aspect, the inclusion of a variable reflecting a monetary base target turned out to be unsuitable. Target values are only given on a quarterly basis. Constructing a time-series for monetary targets is coherent with strong noise effects. As discussed above, especially at the beginning of the sample, the BCRA used foreign currency purchases to manage domestic liquidity aspects. The inclusion of an exogenous variable addressing the latter purpose is problematic as well. Data on foreign reserves are mostly available on a monthly basis. Hence, it would be necessary

to interpolate monthly foreign reserves on a daily basis. It is clear that this procedure would generate noisy estimation results.²⁸⁹ However, even if daily data were to be available, the question for the motive cannot be stated clearly. Is there an upper limit for foreign reserves? Furthermore, monetary authorities in Argentina always kept the level of foreign reserves in mind when buying foreign currency. Foreign currency purchases occurred almost every day. Hence, the explicit motive to accumulate foreign reserves should be seen as a by-product in case of Argentinean interventions, particularly with regard to foreign reserve targets imposed by the IMF.²⁹⁰

Since both alternative intervention objectives do not show volatile behavior due to their dullness, these motives are addressed by the $AR(l)$ structure. Basically, the purpose is to rule out any relationship in the error term resulting in uncorrelated disturbances, which otherwise would distort the test-statistics, and impede the interpretation of the estimation results. Hence, the correct specification of the mean equation is of crucial importance for the ML estimation. The estimation is conducted using QML robust covariances and standard errors according to Bollerslev and Wooldridge (1992). In order to overcome simultaneity problems, as described above, all right hand variables are included with a lag of one period (one day).

²⁸⁹Kim and Sheen (2002) include such inventory aspects through daily interpolation from monthly data into a reaction function for Australian interventions. However, estimation results were inconclusive.

²⁹⁰See BCRA (2003a).

5.3.2 Impact Analysis

The specified GARCH model, which is used to examine the effects of Argentinean interventions in the US\$/ARS exchange rate dynamics, takes the following form:

$$\Delta s_t = \alpha_i \sum_{i=1}^l \Delta s_{t-i} + \frac{\beta_1 Int_{t-1}}{\beta_1^p Int_{t-1}^{fx\ purchase} + \beta_1^s Int_{t-1}^{fx\ sale}} + \gamma_i \sum_{i=1}^{Thurd} D_i + \phi_1 \Delta \% Merval_t + \varepsilon_t \quad (126)$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, h_t) \quad (127)$$

$$h_t = b + \gamma_i \sum_{i=1}^p \varepsilon_{t-i}^2 + \partial_i \sum_{i=1}^q h_{t-i} + \frac{\beta_2 |Int_{t-1}|}{\beta_2^p |Int_{t-1}^{fx\ purchase}| + \beta_2^s |Int_{t-1}^{fx\ sale}|} + \phi_2 |\Delta \% Merval_t| \quad (128)$$

In order to examine whether the authorities' interventions effectively influenced daily exchange rate returns, and the associated conditional volatility, the following variables were chosen:

(i) *Intervention Variables:*

Intervention volumes (expressed in mill. US\$) are included in both the mean equation and the volatility equation. While total volumes (purchases/sales) enter the mean equation, absolute intervention volumes are included in the conditional volatility equation. Additionally, the impact analysis is conducted with separated purchase and sale interventions in both equations. This is done in order to examine whether the authorities' actions caused asymmetric effects on daily exchange rate dynamics. For interventions to be effective (from an econometric point of view), positive significant results are expected for β_1 and β_1^p , while negative significant results should be derived for β_1^s . This indicates that a purchase of foreign currency depreciates the Peso, while a sale of foreign currency appreciates the domestic currency. In case of influencing the conditional volatility, results should yield negative and significant values for β_2 , β_2^p , and β_2^s . The intervention variables were lagged by one day to avoid simultaneity problems.

(ii) *Day Dummies:*

Day dummies are supposed to capture possible effects of different days of the week on the exchange rate return. This is also known as capturing daily seasonality in exchange rate movements. Coefficients γ_i should yield significant results in case of daily seasonality. Dummy variables to account for any exchange rate effects due to holidays were included in preliminary estimations. The idea is that prior to a holiday, the exchange rate should experience additional pressure in either direction. This can be explained by foreign exchange dealers' expectations about future quotations. Investors who assume the domestic currency to get stronger after the holiday will buy additional currency prior to the holiday and vice versa. However, these factors had no explanatory content, and were therefore excluded from the GARCH model.

(iii) *Stock Market Data:*

The importance of the exchange rate for Argentina was shown by McCandless (2005). In early stages of the free float period, exchange rate returns influenced stock market prices. In the same sense, and as shown in Granger-Causality tests, capital inflows into stock markets influenced the exchange rate. Hence, daily changes in the closing price of the Merval stock market are included in both the mean and, in absolute values, the volatility equation. This is done to account for the contemporaneous impact of disturbances in other asset markets.²⁹¹ Negative signs are expected for ϕ_1 since an increase in stock market prices should cause the exchange rate to appreciate. Similarly, a rise in stock market prices should signal economic stability, and should therefore exert a negative influence on the conditional volatility ($\phi_2 < 0$).

Figure 9 displays the dependent and exogenous variables of the Argentinean impact analysis. To account for autocorrelation in daily exchange rate returns, past dependent variables are included up to lag l , leading to an AR(l)-GARCH(p, q) process with additional explanatory variables.²⁹² In order to overcome simultaneity problems, interventions are included with a lag of one period (one day). Estimation is conducted using QML robust covariances and standard errors according to Bollerslev and Wooldridge (1992).²⁹³

²⁹¹The inclusion of other asset markets is originally suggested by Bonser-Neal and Tanner (1996).

²⁹²See Appendix A.2.1 for detailed information on the autocorrelation of daily exchange rate returns.

²⁹³The daily overnight interest rate differential between Argentinean money market rates and US effective fed

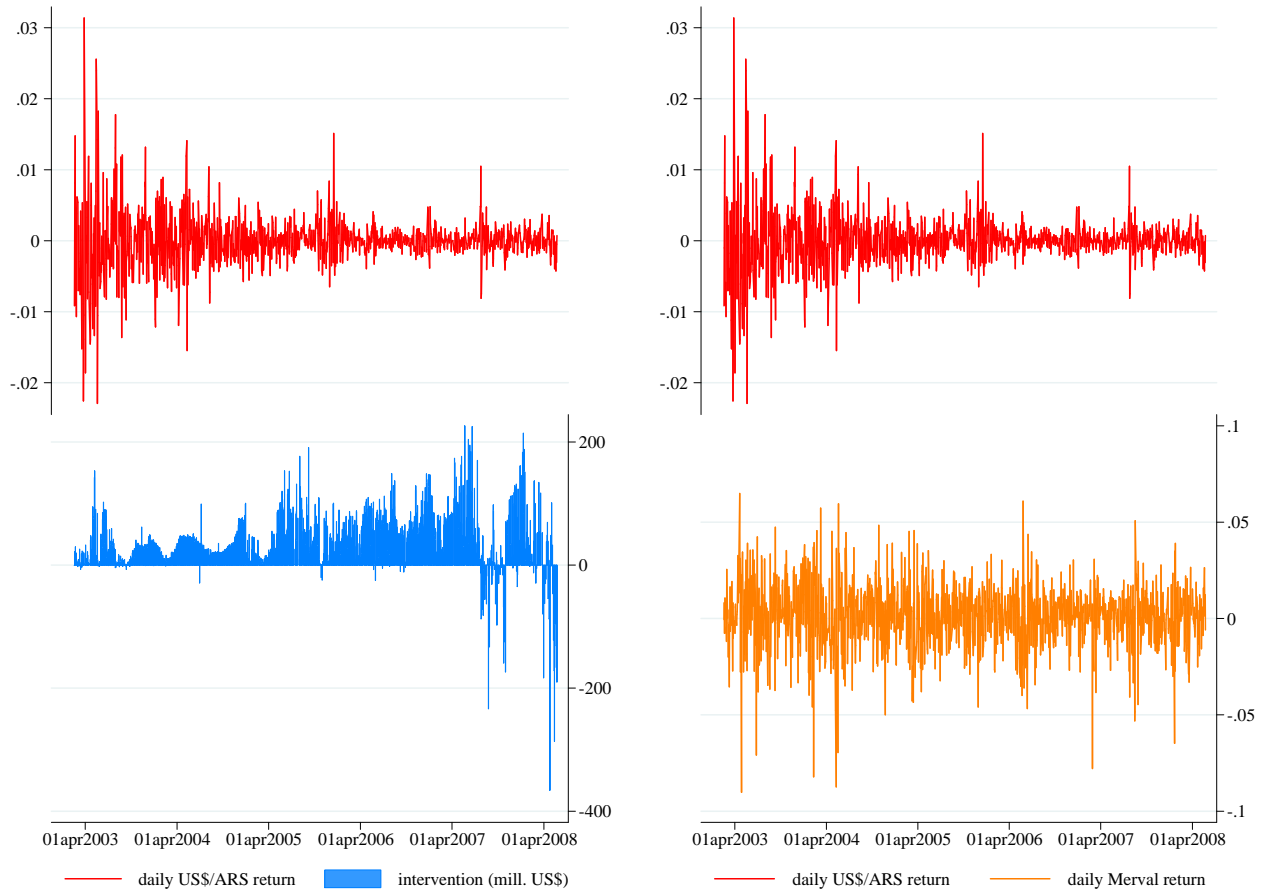


Figure 9: Explanatory Factors for Daily US\$/ARS Exchange Rate Returns between February 2003 and May 2008 (Data source: BCRA, Bloomberg, own calculation).

5.3.3 Data Description

The data used to examine Argentinean foreign exchange market interventions is obtained from different sources. Data on foreign exchange market interventions and exchange rate changes is obtained from the BCRA. Stock market prices are obtained from Bloomberg data service. Only data for trading days are examined, leading to the exclusion of weekends and public holidays.

A very important aspect, which has to be discussed, concerns the chosen exchange rate

funds were neglected. However, including interest rate differentials is common when modeling daily exchange rate returns. The logic being that, abstracting from risk considerations, international investors open positions in the currency, which generates the higher yield. Preliminary estimations with the interest rate differential as an additional explanatory variable did neither improve the estimation, nor has this variable been significant. Similarly, the constant parameter was dropped from the estimation due to insignificance throughout the time.

data. Basically, it is important to examine data reflecting the current situation on the specific exchange rate market. Since monetary authorities have intervened in the domestic local market (Buenos Aires), exchange rate data from this market must be collected accordingly. The used "Reference Exchange Rate" Communication "A" 3500 (Wholesale) is a daily average nominal exchange rate.²⁹⁴ The central bank conducts a survey of local entities three times per day (from 10 a.m. to 11 a.m., from 12 a.m. to 1 p.m., and from 2 p.m. to 3 p.m.). The "Reference Exchange Rate" is estimated as the average of that collected information. Thus, the processed exchange rate data is not taken directly from the local market at a specific time (e.g. opening rates, closing rates). Nevertheless, the analysis of the intervention reaction function and impact effects, captures potential existing relationships. Moreover, using average exchange rate data has some advantages. Suppose that interventions, which are conducted in early business hours have an immediate effect on the exchange rate but disappears during the day. In this case, analyzing the power of interventions on the closing rate would yield no positive outcome, and would result in wrong conclusions. In the same way, monetary authorities may discuss the actual exchange rate development before intervening. The need of lagging explanatory variables becomes obvious in this context.

The global sample statistics are summarized in table 9.²⁹⁵ The sample under investigation covers the period from 17th February, 2003 to 23th May, 2008. It can be seen that monetary authorities have intervened almost every day. Interventions were conducted in 96.3% of all business days. Thereby, Argentinean monetary authorities intervened with a mean level of 37.74 mill. US\$, buying a maximum amount of 226.2 mill. US\$, and selling a maximum amount of 366.0 mill. US\$. In most cases, the BCRA purchased foreign currency. 90.93% of all interventions were foreign currency purchases with a mean level of 45.75 mill US\$. Monetary authorities sold foreign currency on only 115 occasions making up a fraction of 9.07% of total interventions. Sale transactions were conducted with a mean level of 42.57 mill. US\$. Importantly, all estimation variables show no unit root process at the common significance levels.²⁹⁶

²⁹⁴See BCRA (2002a).

²⁹⁵The presentation focuses on the evolution of intervention data.

²⁹⁶See Appendix A/B.1.3 for more information on the unit root test.

Sample: 1316 Obs.	Mean	Max.	Min.	Unit Root ¹	Obs.
<i>Interventions</i>	37.74	226.2	-366.0	-7.365***	1268 (96.3%) ²
<i>Purchases</i>	45.75	226.2	.0054		1153 (90.93%) ³
<i>Sales</i>	42.57	366.03	.2200		115 (9.07%) ³
Δs_t	-1.34x10 ⁻⁵	.0313	-.0229	-28.69***	1316
$(s_t - s_{t-5})$	-5.98x10 ⁻⁵	.0615	-.0504	-7.741***	1316
$(s_t - s_t^{90dm})$	-.0017	.0497	-.1306	-3.397**	1316
$(s_t - s_t^{target})$	.0268	.0997	-.0622	-1.710* ⁴	1316
$\Delta \% Merval_t$	.0010	.0648	-.0902	-36.25***	1316
h_t	1.38x10 ⁻⁵	3.5x10 ⁻⁴	2.19x10 ⁻⁷	-6.130***	1316

¹ ADF test with a constant, SIC lag, H0 series is nonstationary; ⁴ without a constant

² Relative intervention frequency in parentheses - % of days with an intervention

³ Conditional intervention frequency in parentheses - in % of intervention days

*10% - **5% - ***1% significance

Table 9: Data Statistics: Argentina - Global Sample - 2/17/2003 to 5/23/2008.

In order to answer the question on time-varying intervention dynamics appropriately, the observation range is divided into three sub-samples (phase I - III) as a first step. These sub-samples are specified according to different intervention characteristics, which may reflect changing intervention motives and/or shifts in the impact effect of interventions on exchange rate changes. The breakdown is displayed in figure 10.

Phase I covers the time period between February 2003 and July 2005, including 615 observations, and is summarized in table 10. It can be seen that compared to the global sample, interventions were conducted more frequently although the difference is very low (+1.1%). Furthermore, intervention levels are lower. An average operation amounted to a purchase of 30.45 mill. US\$, and was conducted on 97.4% of total business days. The maximum amount of foreign currency purchased and sold in the market accounted for 153.1 mill. US\$, and 29.22 mill. US\$ respectively. Monetary authorities focused on low volume purchase interventions with a mean level of 32.09 mill. US\$, which occurred on 571 occasions, making up a fraction of 95.3% of total interventions. The BCRA only sold foreign currency on 28 business days with a mean of 2.91 mill. US\$. Besides the different intervention characteristics of phase I and II, the endpoint of phase I was set according to a change in the monetary target. As mentioned above, a shift

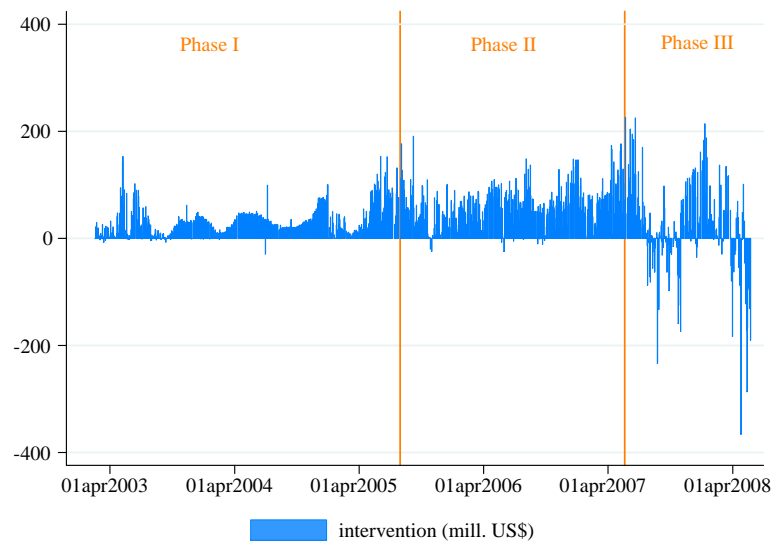


Figure 10: Central Bank Intervention Characteristics in Argentina: Phase I - III (Data source: BCRA).

Sample: 615 Obs.	Mean	Max.	Min.	Unit Root ¹	Obs.
<i>Interventions</i>	30.45	153.1	-29.22	-4.745***	599 (97.4%) ²
<i>Purchases</i>	32.09	153.1	.0054		571 (95.3%) ³
<i>Sales</i>	2.911	29.22	.2242		28 (4.7%) ³
Δs_t	-1.7×10^{-4}	.0313	-.0229	-19.92***	615
$(s_t - s_{t-5})$	-8.8×10^{-4}	.0615	-.0504	-4.836***	615
$(s_t - s_t^{90dm})$	-.0105	.0497	-.1306	-2.354*** ⁴	615
$(s_t - s_t^{target})$	-.0014	.0997	-.0622	-3.762***	615
$\Delta \% Merval_t$	.0015	.0648	-.0902	-24.10***	615
h_t	2.5×10^{-5}	3.5×10^{-4}	1.2×10^{-6}	-4.457***	615

¹ ADF test with a constant; SIC lag. H0 series is nonstationary; ⁴ without a constant

² Relative intervention frequency in parentheses - % of days with an intervention

³ Conditional intervention frequency in parentheses - in % of intervention days

*10% - **5% - ***1% significance

Table 10: Data Statistics: Argentina - Phase I - 2/17/2003 to 7/30/2005.

from the BMB to M2 was announced in mid 2005. This change might be connected to a change in the objectives of foreign currency interventions and/or intervention effects. As is the case for the global sample, all series are stationary in phase I.

Phase II, which is summarized in table 11, covers the time span between August 2005 and May 2007, including 451 observations. Phase I and II differ according to the intervention days and according to the amounts of foreign currency purchased and sold by the central bank. First of all, phase II is characterized by an increasing intervention frequency. Compared to phase I, the BCRA intervened on 98.7% of all business days in phase II (+1.3%). It is clear that the intervention frequency did not change substantially, and was also very high in phase I. However, even slight differences can point towards a change in the underlying objectives. Second of all, more striking is the change in the transaction amounts. The average central bank intervention in phase II accounted for a purchase of 55.79 mill. US\$, compared to 30.45 mill. US\$ in phase I (+83%), with a maximum purchase and sale volume of 190.8 mill. US\$, and 24.62 mill. US\$ respectively. Thereby, the average purchase intervention grew by 79% (32.09 mill. US\$ in phase I to 57.46 mill. US\$ in phase II), and sale interventions rose by 241% (2.911 mill. US\$ in phase I to 9.918 mill. US\$ in phase II). As required, all series are stationary in phase II.

Table 12 summarizes phase III. While phase I and II differ according to the intervention frequency and amounts, phase III, which covers the period between May 2007 and May 2008, including 250 observations, shows additional changes in the use of purchase and sale transactions. First of all, the tendency to intervene declined perspicuously (-9.1% compared to phase II). Monetary authorities stepped into the market in 89.6% of all business days. In contrast to phases I and II, which are characterized by a clear tendency towards foreign currency purchases, phase III shows a nearly balanced use of purchase and sale transactions. The total quantity of 224 interventions was divided in 148 purchase transactions and 76 sale transactions. Monetary authorities intervened with high amounts in each direction. The average levels accounted for 64.16 mill. US\$ in case of foreign currency purchases, and 61.92 mill. US\$ in case of foreign currency sales. The maximum interventions reached 226.2 mill. US\$, and 366.0 mill. US\$ for purchases and sales respectively. Lastly, all series have no unit root in phase III.

Sample: 451 Obs.	Mean	Max.	Min.	Unit Root ¹	Obs.
<i>Interventions</i>	55.79	190.8	-24.62	-6.045***	445 (98.7%) ²
<i>Purchases</i>	57.46	190.8	.0302		434 (97.5%) ³
<i>Sales</i>	9.918	24.62	.2938		11 (2.5%) ³
Δs_t	1.6x10 ⁻⁴	.0151	-.0064	-15.90***	451
$(s_t - s_{t-5})$	7.9x10 ⁻⁴	.0198	-.0111	-6.417***	451
$(s_t - s_t^{90dm})$	.0069	.0368	-.0117	-1.679* ⁴	451
$(s_t - s_t^{target})$	.0410	.0604	-.0227	-3.279**	451
$\Delta\%Merval_t$	8.2x10 ⁻⁴	.0608	-.0778	-21.67***	451
h_t	3.3x10 ⁻⁶	6.3x10 ⁻⁵	2.1x10 ⁻⁷	-3.113**	451

¹ ADF test with a constant; SIC lag. H0 series is nonstationary; ⁴ without a constant

² Relative intervention frequency in parentheses - % of days with an intervention

³ Conditional intervention frequency in parentheses - in % of intervention days

*10% - **5% - ***1% significance

Table 11: Data Statistics: Argentina - Phase II - 8/01/2005 to 5/20/2007.

Sample: 250 Obs.	Mean	Max.	Min.	Unit Root ¹	Obs.
<i>Interventions</i>	21.38	226.2	-366.0	-5.668***	224 (89.6%) ²
<i>Purchases</i>	64.16	226.2	.3644		148 (66.1%) ³
<i>Sales</i>	61.92	366.0	.4998		76 (33.9%) ³
Δs_t	7.3x10 ⁻⁵	.0104	-.0081	-12.55***	250
$(s_t - s_{t-5})$	3.9x10 ⁻⁴	.0219	-.0137	-4.127***	250
$(s_t - s_t^{90dm})$	.0039	.0259	-.0082	-2.142*** ⁴	250
$(s_t - s_t^{target})$	.0710	.0850	.0490	-2.600*	250
$\Delta\%Merval_t$	8.8x10 ⁻⁵	.0507	-.0647	-17.06***	250
h_t	3.3x10 ⁻⁶	5.0x10 ⁻⁵	7.0x10 ⁻⁷	-3.956***	250

¹ ADF test with a constant; SIC lag. H0 series is nonstationary; ⁴ without a constant

² Relative intervention frequency in parentheses - % of days with an intervention

³ Conditional intervention frequency in parentheses - in % of intervention days

*10% - **5% - ***1% significance

Table 12: Data Statistics: Argentina - Phase III - 5/21/2007 to 5/23/2008.

To sum up, the three phases can be characterized as: 1) frequent and low volume purchase interventions with some occasions of foreign currency sales in phase I; 2) very frequent and higher volume purchase interventions with some occasions of sale interventions in phase II; 3) lower frequent and high volume purchase as well as sale interventions in phase III.

5.4 Estimation Results

5.4.1 Motive Development

5.4.1.1 Global Sample

Table 13 shows global results for the Argentinean reaction function. The optimal lag structure of the AR process turned out to be an AR(5).²⁹⁷ This lag structure emphasizes the regular use of foreign currency interventions as a monetary policy instrument in Argentina. The fact that all lag coefficients are positive points towards the purpose of managing domestic monetary aspects (growth of monetary aggregates) and accumulating foreign reserves during the global sample. Tests for conditional heteroskedasticity of the residuals show no remaining ARCH effects in the estimation. The sum γ and ∂ is close to unity, revealing the persistency of volatility shocks and the importance of applying a GARCH framework.

According to table 13, it seems that the BCRA focused on medium-term rather than short-term exchange rate movements during the global sample. Although coefficients for both motives carry the suggested negative sign, the outcome for medium-term exchange rate trend deviations is estimated to be significant at the 5% level and greater in absolute value. In this context, the BCRA tended to sell(buy) 0.74 mill. US\$ when the Peso was 1% above(below) its 90-day exchange rate trend against the US\$. This result supports the fact that different measures were used by the authorities to dedollarize the domestic financial system which might have alleviated the need to stabilize short-term exchange rate movements, and focus on medium-term exchange rate aspects instead. In contrast, estimation results for the implicit target level do not point

²⁹⁷See Appendix A.1.2. for more information on the choice of the appropriate AR(l)-GARCH(p, q) structure for the global sample.

Explanatory Factors	Coefficient	Std. Error	z-Stat.	Prob.
Mean Equation				
α_0	4.759***	1.171	4.063	.000
Int_{t-1}	0.375***	0.034	10.84	.000
Int_{t-2}	0.093**	0.042	2.173	.029
Int_{t-3}	0.128***	0.041	3.070	.002
Int_{t-4}	0.083**	0.037	2.245	.024
Int_{t-5}	0.150***	0.039	3.813	.000
$(s_{t-1} - s_{t-6})$	-12.69	58.39	-2.173	.827
$(s_{t-1} - s_{t-1}^{90dm})$	-74.60**	36.40	-2.049	.040
$(s_{t-1} - s_{t-1}^{target})$	-23.72	19.49	-1.217	.224
h_{t-1}	-5.2x10⁴*	2.8x10⁴	-1.841	.065
Volatility Equation				
b	3.175	2.234	1.421	.155
ε_{t-1}^2	0.131***	0.028	4.630	.000
h_{t-1}	0.863***	0.025	34.12	.000
Log-Likelihood	-6113	ARCH Test: $k = 3$	LM-stat. F-stat.	1.771 0.589

*10% - **5% - ***1% significance

Table 13: Global Estimation Results for the Argentinean Reaction Function.

towards any relevance for daily foreign exchange interventions. Although being correctly signed, the coefficient is not significant at the common levels. This is somehow surprising since the meaning of an implicit exchange rate target is undisputed, as emphasized above. Concerning the conditional volatility, estimation outcomes are negative as well as significant at the 10% level. This result suggests that the BCRA was concerned about an appropriately functioning exchange rate market. Additionally, as supposed in the case of responding to market uncertainty, the authorities sold foreign currency to provide market members with enough liquidity to ensure a stable market process.

Although the outcomes of the global sample are basically in favor of the arguments discussed above, results for the target motive are inconclusive. Therefore, it is necessary to proof if intervention motives have changed over time, and whether a change in the intervention strategy is based on a change in the underlying motives.

5.4.1.2 Phases I-III

Table 14 shows the outcomes of the Argentinean reaction function for phases I-III. It is interesting to note that the optimal lag structure varied between phase I, II, and III.²⁹⁸ As mentioned above, this points towards the management of other monetary policy aspects, not explicitly addressed in the additional variables. However, the AR structures (lag-length) of the mean functions declined over time. While showing an AR(5) at the beginning, phase III only includes one day lagged interventions. Tests for conditional heteroskedasticity of the residuals show no remaining ARCH effects in the three sub-samples.

When comparing the development of the suggested intervention purposes it is very interesting that their relevance varied over time. Results show that every motive has had explanatory power for daily interventions, at least in one sub-sample.

In phase I, almost all assumed reasons of central bank actions are correctly signed and show significant result. The outcomes of coefficients β_1 and β_2 indicate that the BCRA did not account for short-term exchange rate movements (wrongly signed and insignificant), but addressed themselves to the management of medium-term aspects. Compared to global estimation, however, coefficient β_2 is greater in absolute value and significant at the 1% level, indicating greater relevance. Results of the target motive challenge the global effect. Table 14 shows that the authorities took care of an implicit exchange rate target. Coefficient β_3 is negative and highly significant. Concerning the aspect of stable foreign exchange market conditions, in line with the global output, the BCRA sold foreign currency in case of high market volatility reflected by a highly significant and negatively signed coefficient β_4 . Thereby, the BCRA served as a financial intermediate, matching supply and demand of foreign currency.

Phase II is characterized by a clear change in the intervention motives. Estimation outcomes show a rising importance of short-term exchange rate movements while target and volatility aspects were of no relevance. According to coefficient β_1 , the central bank tended to sell(buy) 6.5 mill. US\$ when the Peso depreciated(appreciated) by 1% during the last 5 days vis-à-vis the US\$. The absolute value of coefficient β_2 , showing significance at the 1% level, increased

²⁹⁸See Appendix A.1.2 for a detailed presentation of the correlograms and structure characteristics.

	Phase I	Phase II	Phase III
Explanatory Factors	2/17/2003 - 7/30/2005	8/01/2005 - 5/20/2007	5/21/2007 - 5/23/2008
GARCH Specific.	(2,1)	(1,1)	(1,1)
Mean Equation			
α_0	5.617*** [7.287]	31.70*** [5.615]	140.2*** [3.339]
Int_{t-1}	0.288*** [4.717]	0.294*** [5.752]	0.361*** [4.905]
Int_{t-2}	0.231*** [3.860]		
Int_{t-3}	0.065 [1.106]	0.092** [2.033]	
Int_{t-4}	0.030 [0.632]	0.129*** [2.795]	
Int_{t-5}	0.142*** [3.373]		
$(s_{t-1} - s_{t-6})$	57.50 [1.585]	-656.2* [-1.769]	-465.9 [-0.479]
$(s_{t-1} - s_{t-1}^{90dm})$	-108.7*** [-7.965]	-756.6 *** [-3.498]	-2305** [-2.564]
$(s_{t-1} - s_{t-1}^{target})$	-83.55*** [-7.435]	2.843 [0.039]	-1645*** [-2.661]
h_{t-1}	-4.1x10⁴*** [-3.253]	8.8x10⁴ [0.388]	-2.1x10⁵ [-0.304]
Log-Likelihood	-2457	-2189	-1383
ARCH Test: $k = 3$			
LM-stat.	0.498	3.010	0.198
F-stat.	0.165	1.001	0.065

*10% - **5% - ***1% significance; z-stat. in brackets

Table 14: Local Estimation Results for the Argentinean Reaction Function: Phases I to III.

compared to phase I. Again, this supports the growing meaning of medium-term exchange rate movements, and emphasizes this motive as being mostly relevant. In this context, policy makers operated with an amount of 7.5 mill. US\$ in case of a 1% exchange rate deviation from its 90-day trend. In contrast to phase I, results for the target motive and the conditional volatility are insignificant. Moreover, coefficients β_3 and β_4 are wrongly signed.

Results of phase III reveal that the central bank's general concern over exchange rate aspects clearly rose, reflected by a decrease in the lag length of the AR structure, and an increase in the absolute values of the underlying intervention objectives. While short-term exchange rate movements did not affect daily interventions, the BCRA reacted strongly on medium-term and exchange rate target aspects. According to the results, monetary authorities tended to sell(buy) 23 mill. US\$ when the Peso depreciated(appreciated) by 1% against its medium-term trend vis-à-vis the US\$. Very interesting is the fact that the target motive was re-included as a relevant aspect for monetary authorities. The estimation result for β_3 shows that the BCRA sold(bought) 16.4 mill. US\$ in case of a 1% depreciation(appreciation) of the Peso against its implicit target level. As is the case in phase II, market volatility did not explicitly trigger foreign currency interventions. It seems that the evolution of financial markets made it unnecessary for authorities to act as a financial intermediate ensuring stable market conditions.

The comparison of estimation results of the global, and three sub-samples reveals that the purposes to intervene have changed over time. Based on all available information, monetary authorities were mainly concerned about medium-term exchange rate movements, and to a lesser extent about market volatility aspects. Other intervention motives, although correctly signed, did not show a significantly stable relationship with daily interventions. However, when dividing the global sample, the need and the importance of contemplating the full time span separately becomes obvious.

In the beginning, medium-term exchange rate aspects, target considerations, and market volatility were monitored by the authorities. Against the background of the past financial crisis, and the strong exchange rate appreciation in 2003, it can be argued that the authorities tried to stabilize the exchange rate. Simultaneously, the BCRA served as a financial intermediate,

matching demand and supply of foreign currency to guarantee an appropriately functioning exchange rate market. Furthermore, the AR structure of the mean equation points out that daily foreign exchange interventions were used for other policy aspects as well. In this context, very frequent, small volume interventions were not only used to influence the exchange rate but also to manage domestic monetary aspects, and to accumulate foreign reserves.

Compared to the strong attention on different exchange rate aspects in phase I, estimation results of phase II indicate that the BCRA had focused on a medium-term trend, and to a lesser extent on short-term movements. As mentioned, the evolution of financial markets, and the end of the appreciation trend did not propel authorities to respond to market uncertainty, and target aspects respectively. Furthermore, together with a change in the domestic monetary target, the AR structure reduces slightly. At the same time, interventions were conducted less frequently but with higher volumes.

Lastly and very strikingly, phase III shows that the foreign value of the domestic currency was of great importance. Opposite directed interventions with high amounts were used to stabilize the medium-term trend and to defend the target level. It can be argued that the ongoing slight depreciation of the domestic currency caused the authorities to intervene in order to maintain the implicit target level. The great absolute values of estimation results denote the rising use of interventions to manage exchange rate aspects. Additionally, the decline in the AR structure shows that daily interventions gained in independence as an instrument mainly concerned with managing exchange rate aspects.

5.4.1.3 Rolling Sample

As a final step of examining the development of intervention purposes over time, the Argentinean reaction function is estimated in a rolling way.²⁹⁹ As discussed, the matter of stationarity is of crucial importance. While this issue did not occur in the global and phase estimations,

²⁹⁹The lag structure of the mean equation was set to AR(5) to capture possible higher order autocorrelation. The structure of the volatility equation was set to a GARCH(1,1) to follow the idea of a parsimonious specification. This choice is further justified by the optimal GARCH structures obtained from phase estimations. The window length was set to 500 days. Estimations with other window sizes did not lead to different outcomes. See Appendix A.1.3 for more information.

the rolling approach is exposed to this problem. Results of a rolling unit root test for daily interventions, and the underlying intervention motives suggest that the target motive has a unit root since early 2006, with some exceptions in some periods between 2007 and 2008.³⁰⁰ Hence, the specific results must be interpreted carefully. However, two natural ways to proof whether the inclusion of an I(1) variable distorts the estimation are: 1) compare estimation results of the reaction function with and without the target motive; 2) test residuals of the estimation with the target motive for a possible unit root.

Figure 11 shows the time dependent variation of the different BCRA intervention purposes. Each coefficient-series and the associated z-stats. are displayed together with the 10% significance band as a visual support. As mentioned above, estimation outcomes are smoothed using the HP-Filter.³⁰¹ Furthermore, to check for the I(1) problems, results of rolling estimations without the target motive are displayed as dashed lines. The exclusion of the target motive did not change the basic results, except the absolute outcomes of estimated z-stats. for the medium-term motive. This supports the appropriateness of the model. Rolling results broadly confirm the outcomes of phase estimations. Nevertheless, slight differences occur due to different sample sizes and model structures.

Starting with the short-run motive (figure 11: "Short-Run Motive"), results show that the BCRA was not thoroughly concerned about short-term exchange rate movements. While being insignificant until late 2006, 5-day exchange rate returns show some low significant periods between mid 2006 and mid 2007, and in early 2008. Although the absolute coefficient values for β_1 rise steadily, the z-stats. are scratching the 10% significance line. Basically, results do not change when estimating the reaction function without the target motive. However, beginning in 2008, results differ slightly. While rolling results in the last estimation windows barely cross the 10% significance line, estimation outcomes without the target motive indicate no relevance. Nevertheless, the difference is small, and one can conclude that the BCRA did not extensively monitor short-term exchange rate developments.

³⁰⁰See figure 37 in Appendix A.1.3 for the results of rolling unit root tests.

³⁰¹Figure 38 in Appendix A.1.3 shows unfiltered results of rolling reaction function estimations.

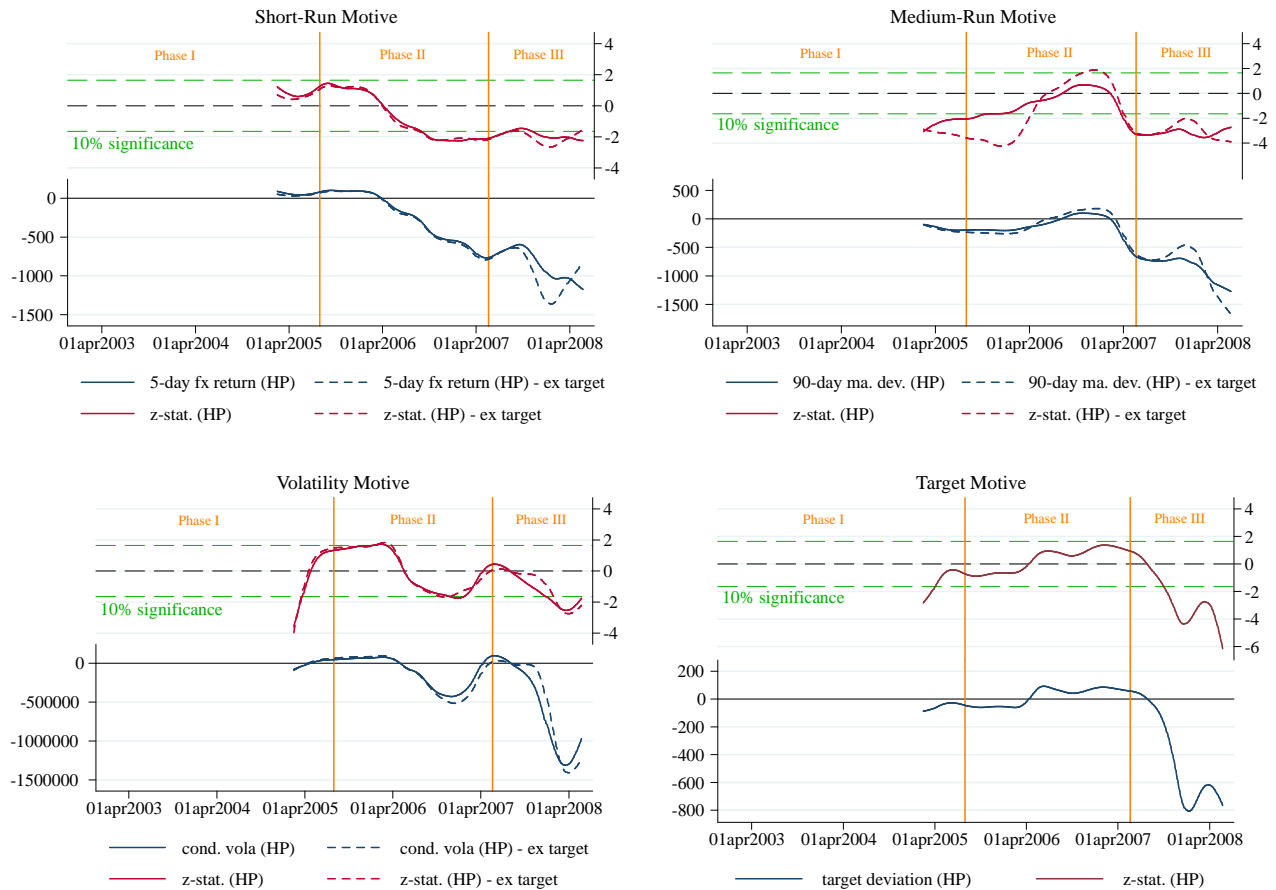


Figure 11: Local Estimation Results for the Argentinean Reaction Function: Rolling Estimations (window = 500 days; results are smoothed using HP-Filter [$\lambda = 68000$]).

Estimation results for medium-term exchange rate aspects reveal that authorities clearly emphasized the medium-run intervention objective (figure 11: "Medium-Run Motive"). However, its importance changed over time. Estimated z-stats. and coefficient outcomes are mostly negative, and (highly) significant throughout the sample. Beginning in 2007, parameter β_2 declines steadily, indicating the rising relevance of the medium-term trend for daily BCRA interventions. However, the period between April 2006 and April 2007 is characterized by insignificant and even partially positive coefficient outcomes. In this short period of time, the authorities switched their attention to short-term exchange rate movements. This is not surprising due to the fact that deviations from the medium-term trend meander closely around the zero line in

this period. Estimations without the target motive do basically not lead to different results.³⁰²

Results for the conditional volatility (figure 11: "Volatility Motive") broadly support the findings of phase estimations. Outcomes reveal that in the beginning, and if any, in the end of the estimation windows, the BCRA was concerned with disorderly markets. While the former period is characterized by clear significant negative coefficients β_4 , although being small in absolute value, the latter period shows higher coefficient values, which are, however, less significant. The presence of high conditional volatility at the beginning of the global sample clearly explains why the authorities were concerned with foreign exchange market stability. Concerning the difference to the alternative reaction function estimation, it can be seen that the results are practically not affected.

Similar to the intervention motives discussed so far, the coefficient-series for β_3 supports estimation results of phases I-III (figure 11: "Target Motive"). Most interesting is the fact that when being exposed to a unit root process, the target motive is mainly insignificant. As is the case for phase I, results for β_3 are significant at the very beginning, moving towards no explanatory power for daily interventions. This is in line with the purpose of stopping the strong appreciation path of the Peso after the financial crisis. In the following years, the implicit target has not been taken into account by the BCRA. This is because the exchange rate has broadly developed within the suggested exchange rate band. Estimated z-stats. do not cross the 10% significance lines. However, with the ongoing depreciation of the Peso, authorities seemed to be concerned about the widened target gap. Accordingly, β_3 coefficient results rise sharply, and estimated z-stats. exceed the significance threshold again in mid 2007.³⁰³

To sum up, the analysis of Argentinean foreign exchange market interventions shows clearly that a comparison of global and time dependent estimations is of great importance. Not comparing the two had lead to wrong conclusions about the BCRA's intention to intervene in the foreign exchange market.

³⁰²Differences in the estimated z-stats. give some leeway to the presence of multicollinearity. This reflects the above discussed problem when including intervention motives capturing different time horizons. However, the basic outcome does not change.

³⁰³It must be noted that the estimated reaction function assumes the target band to be constant. However, just like the relevance of different intervention motives changes over time, the band could have changed over time too.

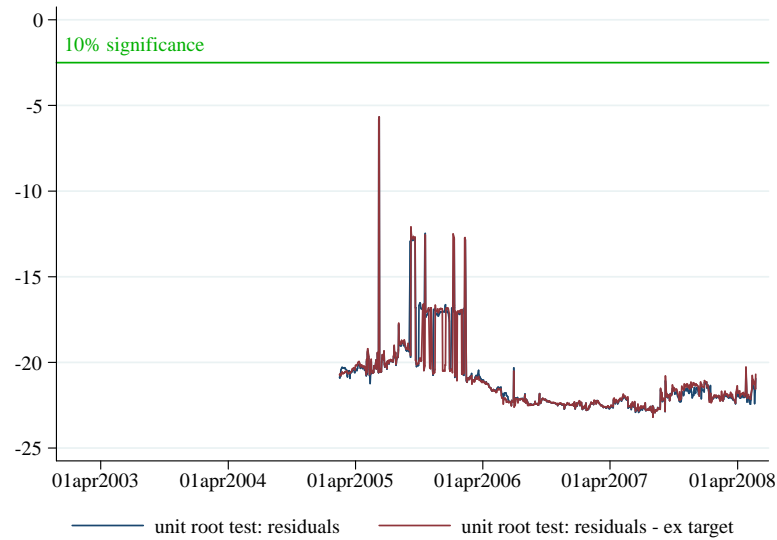


Figure 12: Rolling ADF Tests of Argentinean Reaction Function Residuals (window = 500 days, with a constant).

Based on the conducted estimations, one can conclude that medium-run perspectives attracted much more attention than short-run aspects. This is somewhat surprising since short-term exchange rate movements were relatively high, especially at the beginning of the global sample. Volatility issues gained preeminence only at the beginning and during phase III when conditional volatility reached the highest levels. This is in line with the assumption that in the aftermath of the financial crisis, authorities were concerned with the appropriate running of the market process. More recent results point towards the central bank monitoring market rumors closely to forestall potential problems. With respect to the target motive, estimation outcomes show that an implicit exchange rate level was taken into account by the authorities at the beginning of the sample, and during the last rolling sample windows. Mostly, the exchange rate moved within the suggested band, calling for no explicit action of the authorities. Furthermore, the inclusion of an $I(1)$ variable does not distort estimation results. Basically, the results do not change when dropping the target motive, which shows nonstationarity behavior in several periods. Rolling unit root tests for the obtained estimation residuals clearly reject the null hypothesis of nonstationarity (see figure 12). Turning to changes in the intervention strategy, results do not draw a clear picture. Intervention motives cannot be linked to differ-

ent intervention strategies. For instance, medium-term aspects are independent of any changes in the intervention strategy. Although the absolute outcome increases with the intervention amount, this is a natural estimation result valid for other motives as well. However, it can be seen from phase estimations that a change in the intervention strategy is related to a change in the AR structure of the mean equation. Beginning with higher volume interventions and a change in the underlying monetary target, the lag structure declines to only one lag in phase III. Hence, it seems that interventions gained in independence as a monetary policy tool used to influence exchange rate developments.

5.4.2 Impact Development

5.4.2.1 Global Sample

Table 15 presents global results for the estimated GARCH model described by equations 126 to 128. In order to rule out correlation in the error term, exchange rate changes at lag 1 and 2 are included in the mean equation. This leads to insignificant Ljung-Box Q-statistics, revealing no remaining autocorrelation in the errors. The applied GARCH(3,1) framework models the heteroskedastic feature of daily exchange rate returns appropriately. The combination of $p = 3$, and $q = 1$ yields the lowest AIC values. ARCH test results reveal no remaining (G)ARCH effects.³⁰⁴ The sum γ and ∂ is close to unity, revealing the persistency of volatility shocks.

Very interestingly, and in contrast to many other studies dealing with the effectiveness of daily foreign exchange market interventions, results reveal that interventions conducted by the BCRA were effective in influencing daily exchange rate returns during the whole sample.³⁰⁵ The estimation outcome for Int_{t-1} is positive and highly significant, indicating that the purchase of foreign currency caused the exchange rate to depreciate and vice versa. When separating interventions into purchase and sale transaction, estimation outcomes confirm the positive finding.

³⁰⁴See Appendix A.2.1 for more information on the model choice. When separating foreign exchange interventions into purchase and sale transactions in the global, and phase estimation, the structure of the GARCH models was not changed. Results for the ARCH tests, Ljung-Box Q-statistics, AIC, and SIC do not indicate the need to change the model structure, which supports the appropriateness of the model.

³⁰⁵The constant parameter was estimated to be insignificant, and was therefore dropped out.

Explanatory Factors	Coefficient	Std. Error	z-Stat.	Prob.
Mean Equation				
Δs_{t-1}	0.241***	0.033	7.238	.000
Δs_{t-2}	-0.149***	0.029	-5.108	.000
Int_{t-1}	3.7×10^{-6} ***	8.2×10^{-7}	4.489	.000
$Purchases_{t-1}$	2.7×10^{-6} ***	9.3×10^{-7}	2.945	.003
$Sales_{t-1}$	-6.9×10^{-6} ***	2.0×10^{-6}	-3.471	.000
<i>Monday</i>	-6.8×10^{-5}	1.0×10^{-4}	-6.582	.510
<i>Tuesday</i>	-2.5×10^{-4} **	1.0×10^{-4}	-2.461	.013
<i>Wednesday</i>	-1.2×10^{-4}	1.1×10^{-4}	-1.145	.252
<i>Thursday</i>	-3.1×10^{-4} ***	1.0×10^{-4}	-3.107	.001
$\Delta \% Merval_t$	-0.014***	0.003	-4.834	.000
Volatility Equation				
b	2.7×10^{-8}	1.8×10^{-8}	1.522	.128
ε_{t-1}^2	0.259***	0.049	5.297	.000
ε_{t-2}^2	0.032	0.068	0.475	.635
ε_{t-3}^2	-0.188***	0.049	-3.801	.000
h_{t-1}	0.898***	0.0179	50.204	.000
$|Int_{t-1}|$	4.8×10^{-10}	7.9×10^{-10}	0.610	.542
$|Purchases_{t-1}|$	5.1×10^{-10}	7.9×10^{-10}	0.654	.513
$|Sales_{t-1}|$	8.3×10^{-10}	2.2×10^{-9}	0.377	.706
$|\Delta \% Merval_t|$	-1.9×10^{-6}	2.1×10^{-6}	-0.898	.370
Log-Likelihood	6182	ARCH Test:	LM-stat.	1.698
		$k = 3$	F-stat.	5.092

*10% - **5% - ***1% significance

Table 15: Global Estimation Results for the Argentinean Impact Analysis.

Both coefficients are estimated to be highly significant, and are correctly signed. Furthermore, the difference in the absolute values of coefficients β_1^p and β_1^s indicate an asymmetric impact. However, the economic impact is rather weak. A purchase of 100 mill. US\$ tended to depreciate the domestic currency by 0.027%, while a sale of 100 mill. US\$ tended to appreciate the exchange rate by 0.069%. Thus, the average and maximum amount of foreign currency purchased by the BCRA depreciated the Peso by 0.012%, and 0.061% respectively. In case of sale interventions, the average and maximum amount sold in the market appreciated the Peso by 0.029%, and 0.249% respectively. Nevertheless, these impact effects account for a sizable amount, compared to the average daily exchange rate return (-0.0013%). Hence, sale interventions had a stronger impact on daily exchange rate changes. The difference in the impact of purchase and sale interventions might stem from the above mentioned consequence of continuous interventions. Because purchases were conducted more frequently, international investors got used to them. In contrast, sale transactions were only conducted sporadically, which is why market members were not able to anticipate such transactions.

Contrary to these positive findings, the impact on the conditional volatility is of no relevance. Total interventions show very low, and insignificant results. Moreover, separate interventions are both insignificant, and confirm the poor explanatory content for the conditional volatility. As discussed above, the fact that coefficient(s) $\beta_2^{(p,s)}$ are insignificant shows that the outcomes in the mean equation are not biased, which supports the reliability of the estimation results.³⁰⁶

Turning to control variables, results for day of the week dummies show some seasonality on Tuesdays and Thursdays. Both days exerted a significant influence on daily exchange rate changes. Stock market prices influenced the exchange rate in the suggested way. Estimation results for ϕ_2 indicate that an increase in stock market prices caused the exchange rate to appreciate, although the economic size is rather small. In case of influencing the conditional volatility, stock market prices were of no relevance.

Now, it is of interest, whether different intervention strategies had different impact effects, and so whether the power of foreign exchange market interventions has varied over time.

³⁰⁶Reestimation without intervention variables in the volatility equation left the parameter in the mean equation unchanged.

5.4.2.2 Phases I-III

GARCH model estimation results for phases I-III are presented in table 16. The lag structure in the mean equation only varies between the phase I/II, and III. In the same way, the optimal GARCH framework, modeling the heteroskedastic feature of the daily exchange rate, is stable since mid 2005. All chosen framework structures lead to insignificant Ljung-Box Q-statistics and ARCH tests, revealing no remaining autocorrelation in the errors and squared errors.³⁰⁷ The discussion of the results obtained from phases I-III focuses on the impact of interventions.

Throughout the three separate samples, the impact of interventions on exchange rate returns (β_1) was positive, though varying in its magnitude, and highly significant. These findings, and the result that interventions did not affect the conditional volatility, supports the evidence of the global sample estimation. Estimation results further show that stock market prices had a significant influence on daily exchange rate changes. A rise in the Merval index, reflecting a strengthening of the Argentinean economy, caused the exchange rate to appreciate. However, results for stock market prices might be biased in phase I, due to the significant result in the corresponding volatility equation. Interestingly, seasonality patterns change between the samples.

In phase I, similar to global results, interventions are estimated to influence the exchange rate in the suggested way. However, the highly significant result for coefficient β_1 shows that foreign currency transactions exerted more pressure on daily exchange rate returns. At the same time, asymmetric intervention impact effects are shown by estimation results for purchase and sale transactions. As is the case for global results, sale interventions are estimated to be more powerful compared to purchase transactions. The average(maximum) amount of foreign currency purchased in the market degraded the exchange rate by 0.028%(0.136%), while the average(maximum) volume of foreign currency sales strengthened the domestic currency by 0.021%(0.216%). Compared to the mean daily exchange rate change of -0.017%, the estimated impacts are of special importance. These positive findings are supported by the insignificance

³⁰⁷See Appendix A.2.1 for more information on the model choice.

	Phase I	Phase II	Phase III
Explanatory Factors	2/17/2003 - 7/30/2005	8/01/2005 - 5/20/2007	5/21/2007 - 5/23/2008
GARCH Specific.	(3,2)	(1,1)	(1,1)
Mean Equation			
Δs_{t-1}	0.227*** [5.268]	0.269*** [4.697]	0.290*** [4.406]
Δs_{t-2}	-0.195*** [-5.053]	-0.088** [-1.959]	
Int_{t-1}	9.6x10⁻⁶ [3.281]	3.0x10⁻⁶ [2.491]	4.9x10⁻⁶ [4.635]
$Purchases_{t-1}$	8.8x10 ⁻⁶ *** [2.732]	2.9x10 ⁻⁶ ** [2.406]	3.4x10 ⁻⁶ ** [2.185]
$Sales_{t-1}$	-7.4x10 ⁻⁵ ** [-2.394]	-6.5x10 ⁻⁵ ** [-2.000]	-7.5x10 ⁻⁶ *** [-30.68]
<i>Monday</i>	-8.8x10 ⁻⁴ *** [-3.572]	7.4x10 ⁻⁵ [0.536]	2.6x10 ⁻⁵ [0.139]
<i>Tuesday</i>	-9.4x10 ⁻⁴ *** [-3.901]	-1.8x10 ⁻⁴ [-1.503]	-1.2x10 ⁻⁴ [-0.625]
<i>Wednesday</i>	-4.9x10 ⁻⁴ * [-1.988]	-2.0x10 ⁻⁴ [-1.374]	-5.0x10 ⁻⁵ [-0.254]
<i>Thursday</i>	-3.0x10 ⁻⁴ [-1.138]	-4.5x10 ⁻⁴ *** [-3.745]	-2.8x10 ⁻⁴ [-1.543]
$\Delta \% Merval_t$	-0.017** [-2.678]	-0.013*** [-3.425]	-0.011* [-1.792]
Volatility Equation			
$|Int_{t-1}|$	1.4x10⁻¹⁰ [0.230]	2.6x10⁻⁹ [1.272]	-1.2x10⁻⁹ [-0.290]
$|Purchases_{t-1}|$	-9.1x10 ⁻⁹ [-0.661]	2.3x10 ⁻⁹ [1.134]	-1.6x10 ⁻⁹ [-0.346]
$|Sales_{t-1}|$	-3.1x10 ⁻⁷ [-0.201]	-1.7x10 ⁻⁸ [-0.194]	7.9x10 ⁻⁹ [0.854]
$|\Delta \% Merval_t|$	-2.0x10 ⁻⁶ *** [-14.335]	-1.1x10 ⁻⁷ [-0.029]	2.4x10 ⁻⁵ [1.343]
Log-Likelihood	2591	2349	1288
ARCH Test: $k = 3$			
LM-stat.	1.860	1.051	3.327
F-stat.	0.618	0.348	1.106

*10% - **5% - ***1% significance; z-stat. in brackets

Table 16: Local Estimation Results for the Argentinean Impact Analysis: Phases I to III.

of coefficient(s) $\beta_2^{(p,s)}$, stating that interventions did not affect the conditional volatility.

The impact of interventions changes slightly in phase II. Although results for the mean equation still carry the correct sign, and are estimated to be significant at the 5% level, the coefficient values for overall, and purchase transactions are clearly lower compared to phase I. Interestingly, asymmetry in sale and purchase effects rise remarkably due to the fact that the outcome of coefficient β_1^s changes only slightly. However, the overall impact is not driven by sale interventions, due to the fact that sales were only conducted on 11 occasions. Thus, despite the rising asymmetry, overall effects are mainly determined by purchase interventions. The average, and maximum amount purchased(sold) in the market depreciated(appreciated) the exchange rate by 0.016%(0.064%), and 0.055%(0.160%) compared to the average daily exchange rate return of 0.016%. In contrast to results for the mean equation, interventions remain of no relevance for the conditional volatility. Coefficients $\beta_2^{(p,s)}$ are estimated to be insignificant and of no economic importance.

While impact effects decline from phase I to phase II, results for phase III show that the power of interventions to influence daily exchange rate changes increases again. The outcome of β_1 is greater, compared to global results and phase II results, but does not reach the same level as in phase I. Furthermore, the asymmetry of purchase and sale effects decline in phase III. Coefficient results for sale and purchase transactions ($\beta_1^{(p,s)}$) become more balanced due to a decrease of sale effects. In this context, average(maximum) intervention amounts caused the exchange rate to depreciate by 0.021%(0.077%) in case of purchase transactions, and to appreciate by 0.046%(0.275%) in case of sale transactions. As before, interventions have no explanatory content for the conditional volatility. Coefficients $\beta_2^{(p,s)}$ are estimated to be of no relevance.

Results of table 16 reveal the importance of a time dependent consideration of intervention effects. Global results are supported by phase estimations, which draw a more concrete picture. In this context, the estimated impact effects are very interesting against the background of the different intervention strategies. Thereby, interventions were most powerful when conducted very frequently, and with small volumes in case of purchase transactions. A change to higher

intervention amounts, which were used less frequently, was primarily associated with declining intervention effects. However, in phase III, which is characterized by the greatest intervention amounts, impact effects shored up again, but remained below the level of phase I. Things are quite different for sale transactions. Phase I and II show similar intervention patterns. Very low, frequent sale transactions had the greatest effect on daily exchange rate changes. Results for sale transactions in phase III, which is characterized by more frequent interventions, show less power. Nevertheless, these outcomes basically challenges the previously stated assumption that frequent interventions are less powerful in driving exchange rates, at least in case of purchase transactions. Thus, other aspects must have been responsible for these estimation results.

5.4.2.3 Rolling Sample

Figure 13 displays the outcomes for the overall intervention variable, obtained from a rolling GARCH estimation as a final step of examining the development of intervention effects.³⁰⁸ Since the focus is on the time-varying nature of foreign exchange transactions, only coefficients for interventions are considered when presenting results of the rolling estimations. Each coefficient-series and the associated z-stats. are displayed together with the 10% significance band as a visual support. As mentioned above, estimation outcomes are smoothed using the HP-Filter.³⁰⁹

Left panels of figure 13 ("Intervention Effect: Mean Equation") display interesting results, which support the outputs of global and phase estimations.³¹⁰ It is shown that the impact of interventions on daily returns has the correct sign during the complete time span, indicating a depreciation of the Peso when the BCRA purchased foreign currency and vice versa. Moreover, estimated z-stats. show high significance. However, as is the case in global and phase estimations, absolute effects are rather small in the overall view, but important relative to exchange

³⁰⁸The lag structure of the mean equation was chosen as an AR(2) to capture possible autocorrelation. The structure of the volatility equation was set to a GARCH(1,1) to follow the idea of a parsimonious specification. This choice is further justified by the optimal GARCH structure obtained from phase estimations. As is the case for rolling reaction function estimations, the window length was set to 500 days. Other window sizes did not lead to different outcomes. For more information see Appendix A.2.2.

³⁰⁹Figure 44 in Appendix A.2.2 shows unfiltered results of the rolling impact analysis.

³¹⁰Rolling estimation results for purchase and sale transactions were not conducted due to very infrequent sale transactions within the estimation windows.

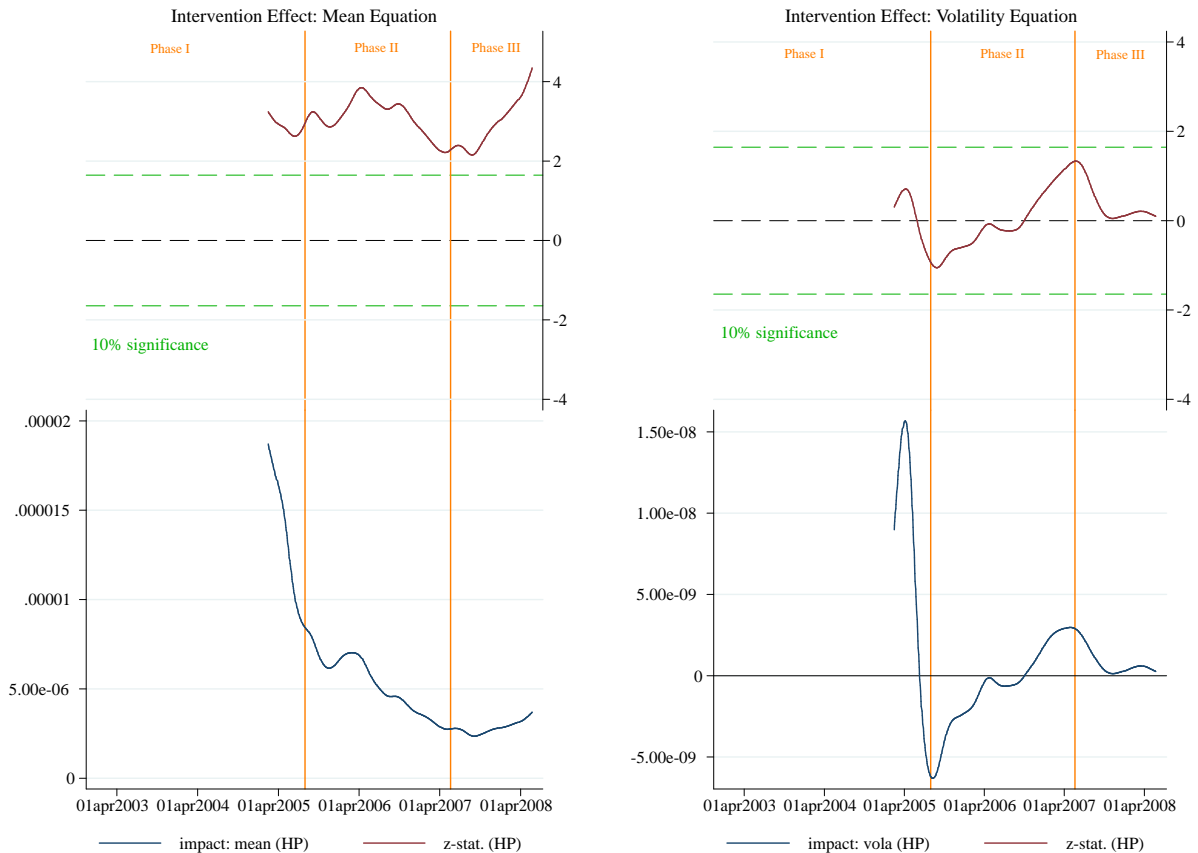


Figure 13: Local Estimation Results for the Argentinean Impact Analysis: Rolling Estimations (window = 500 days; results are smoothed using HP-Filter [$\lambda = 68000$]).

rate changes. Besides these positive overall findings, it can be seen that the estimation results for coefficient β_1 change over time. While showing highest values at the beginning of the sample, intervention effects in the mean equation decline in time, gaining back slightly at the end of the estimation windows. This reflects exactly the outcomes of phase I-III. In the case of estimated z-stats., figure 13 shows that they always move above the upper 10% significance line, varying around a z-stat. of three, which indicates high significance.

In case of conditional volatility, right panels of figure 13 ("Intervention Effect: Volatility Equation") reveal no explicit effects, supporting global and phase estimation results. While coefficient β_2 is estimated to have a greater impact on the volatility in the early sample windows, coefficient outcomes decline to no relevance. More importantly, during the complete time span,

effects on the conditional volatility are insignificant at the common levels. In this context, estimated z-stat. meander around the zero line. These results show that interventions did not have an impact on the conditional volatility of daily US\$/ARS exchange rate returns.

To sum up, the impact analysis of BCRA interventions clearly shows that authorities were able to influence the exchange rate significantly. Results also give evidence that the conditional volatility was not driven by daily foreign currency transactions. Moreover, rolling estimations show that impact effects changed over time, revealing the importance of a time dependent consideration. From these results the question arises, whether interventions have been successful. Against the background of the BCRA's intervention objectives, monetary authorities indeed succeeded at managing daily exchange rates. The fact that the conditional volatility was not influenced at all, cannot be used to assess interventions as being completely ineffective. Nevertheless, this specific goal has not been achieved. Turning to the relationship between impact effects and intervention strategies, it can be stated that a shift in the characteristics of foreign exchange transactions was associated with a shift in the impact effect. Surprisingly, small volumed transactions exerted the greatest pressure on daily exchange rate returns.

5.5 Economic Background

5.5.1 Explanation of Intervention Motives

Starting with the development of intervention motives, it is of interest, whether the main motives discerned in the preceding sections, and the negligence of other objectives can be explained by economic and monetary policy fundamentals. The scope of other policy aspects has been discussed in the previous sections presenting monetary policy in Argentina, and the role of interventions.³¹¹ Additionally, the reason for intervening in order to calm the foreign exchange market was mentioned several times.³¹² Thus, the open questions are:

³¹¹Furthermore, it must be noted that the time dependency of the underlying purposes is hardly explainable. One basic argument addressing this issue, though being very simple, is that specific exchange rate developments were of minor importance compared to others in time.

³¹²In this context, Irigoyen (2005) argues that the BCRA, in 2002 and 2003, intervened to calm the markets, and to replenish the stock of foreign reserves while monetizing the domestic financial system.

(i) *Why Did the BCRA not Chiefly Intervene in Response to Short-Term Exchange Rate Movements (Except on Some Occasions)?*

It is reasonable to assume that central banks in emerging market are mainly concerned with short-term exchange rate behavior. Although the BCRA has intervened in response to those exchange rate developments, it is a bit surprising that the authorities did not comprehensively act upon this objective. As touched upon above, short-term exchange rate movements exhibit a potential threat through boosting debt levels, and distressing financial stability in case of exchange rate depreciation. However, during the sample under investigation, the Argentinean economy was not confronted with an excessive short-term depreciation, which occurred after abandoning the currency board when the exchange rate depreciated by 300% up to 4 US\$/ARS. Besides depreciation, an excessive appreciation can also cause severe consequences. In the first half of 2003 the exchange rate appreciated strongly by 18%. Most importantly, the spillover of excessive exchange-rate movements hinges clearly on the relative size of foreign debt and deposits compared to domestic currency debt and deposits. In this context, several measures have been imposed by the authorities to tackle potential threats of short-term exchange rate movements for private and public sector portfolios. A conversion of foreign currency denominated debt and deposit was decreed. In February 2002, decree 214/02 established the conversion of foreign currency obligations into Peso.³¹³ However, this was done asymmetrically. While debts were converted one to one, deposits were converted with a rate of 1.4 US\$/ARS. This measure, although not directly intended to support interventions, exonerated monetary authorities from intervening in the foreign exchange market in order to forestall additional financial distress. Figure 14 displays the impact of decree 214/02 on debt and deposit levels. It can be seen that in January 2002 foreign currency denominated deposits and debt positions declined significantly from nearly 50 bill. Pesos to less than 10 bill. Pesos, and did not reach their former levels during the full sample. This kind of "Pesofication" attenuated potentially severe consequences of short-term exchange rate movements.

Hence, interventions in order to smooth excessive movements of the exchange rate in the short-run were not necessary until recently. Although these measures absorbed the need to inter-

³¹³See BCRA (2002b).

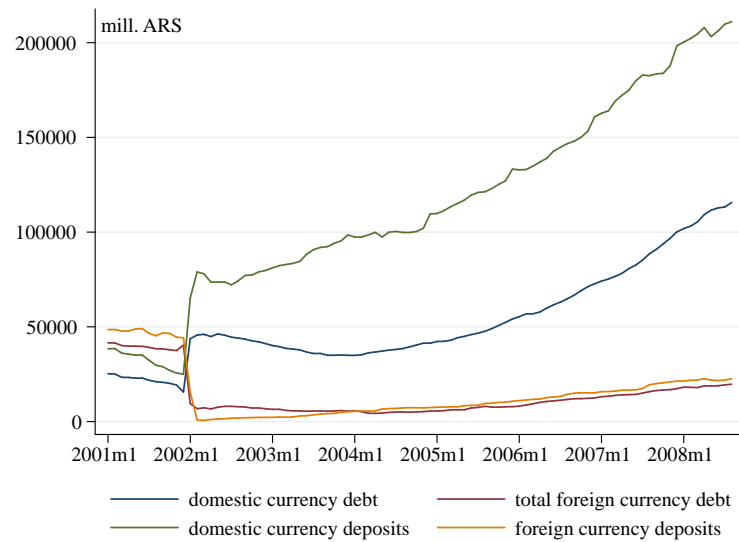


Figure 14: Development of Domestic and Foreign Currency Debts and Deposits in Argentina between January 2001 and June 2008 (Data source: BCRA).

vene in response to the short-run motive, the BCRA took sporadically care of stable short-term exchange rate movements. This can be seen as a reaction of the BCRA on a developing domestic financial system through providing credibility in a shattered global financial environment.

(ii) *Why Did the BCRA Intervene in Response to Medium-Term Exchange Rate Trend Deviations?*

Though not making clear statements on a nominal exchange rate behavior, authorities began to emphasize the importance of a stable and competitive (real) exchange rate. The importance of the exchange rate for the Argentinean economy was addressed above. However, the stability of the Peso can be further discussed from a different perspective. Since a substantial portion of the domestic economy relies on foreign trade, a stable medium-run foreign value of the Peso is essential. As can be seen in the left panels of figure 15, exports and imports of goods and services have increased since 2002 by about 250%. Since that time, Argentina has a continuous current account surplus. This surplus stems mainly from the positive trade balance, generated by exports of agricultural-related products.³¹⁴ Simultaneously, the relative size of foreign trade

³¹⁴Data is seasonally adjusted, using four period moving averages.

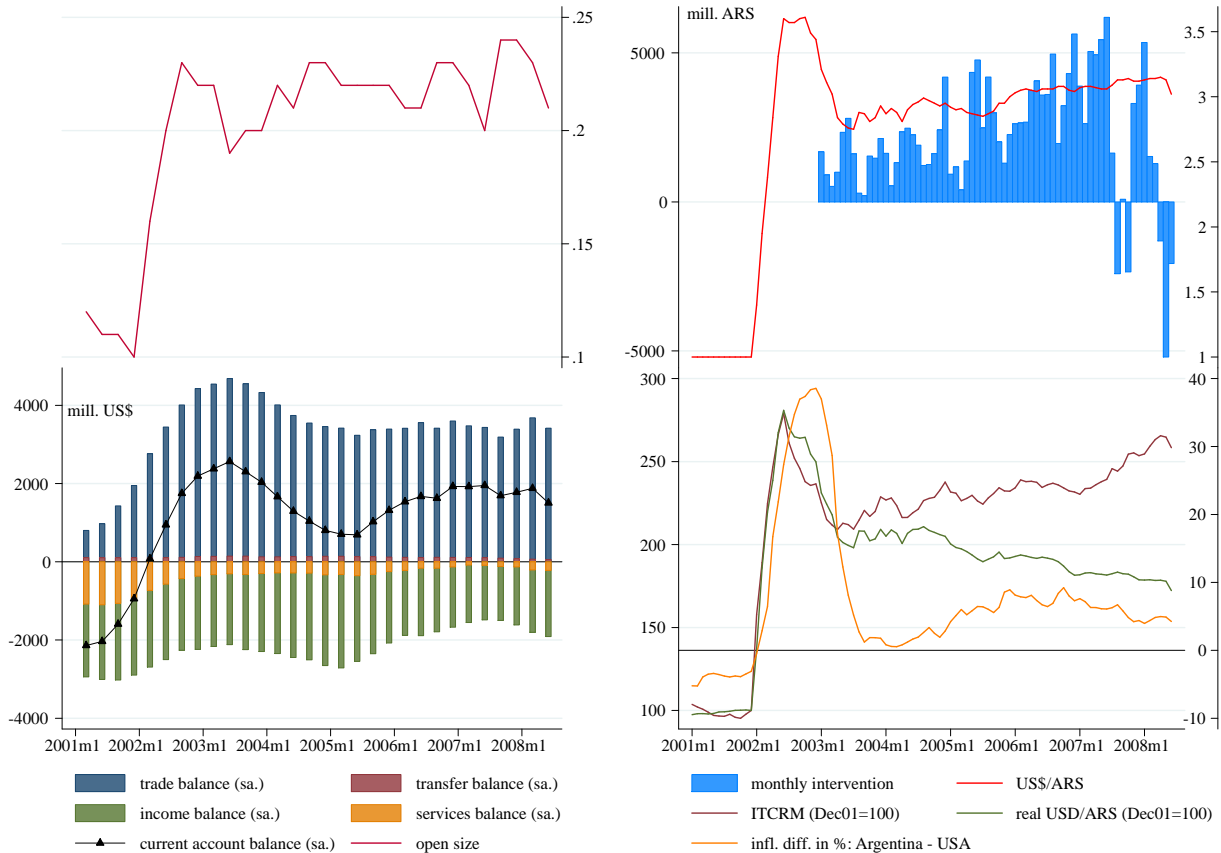


Figure 15: Development of Foreign Trade Aspects, and (Real) Exchange Rates in Argentina between 2001 and 2008 (Data source: BCRA, IMF-IFS, own calculation; Dec 2001 = 100).

$\left(\frac{\text{Export} + \text{Import}}{2 \text{ GDP}}\right)$ accounts for almost 25% of the Argentinean economy.³¹⁵ The current account surplus should cause the exchange rate to appreciate. The demand of international traders for Pesos to pay their current account transactions should raise the foreign price of the Argentinean currency, reflecting the balance of payments approach of exchange rate determination. However, the exchange rate experienced a slight depreciation, generated by continuous foreign currency purchases. In general, a stable foreign price of the domestic currency helps to enhance the predictability of import and export prices, and supports investment decisions.

³¹⁵ Although accounting for a substantial part of the domestic economy, the foreign trade did not add much to economic growth in recent years. As shown by Weisbrot and Sandoval (2007), exports only accounted for about 13% of total GDP growth. Furthermore, the current account surplus accounted for about 5% of the GDP between 2002 and 2008. Nevertheless, the substantial absolute volume of foreign trade to GDP calls for vigilant monitoring exchange rate movements.

Furthermore, a stable and competitive real exchange rate is essential for domestic producers of tradeable goods and services to compete in world markets. Against the background of the large foreign size of Argentina's economy, these issues are of special interest. The lower right panel of figure 15 displays the evolution of the real US\$/ARS exchange rate and the multilateral real exchange rate index (ITCRM), which measures Argentina's external competitiveness against its main trading partners.³¹⁶ It can be seen that while the real US\$/ARS rate appreciated, the ITCRM rate depreciated since the beginning of 2003, bolstering Argentina's international competitiveness. Although the nominal exchange rate was fairly stable, showing a slight depreciation tendency, the inflation differential caused the real US\$/ARS rate to appreciate. The mean difference in the inflation rates between Argentina and the USA amounted to 6.6 % between January 2003 and June 2008. Hence, the BCRA intervened in the US\$ market to influence the real exchange rate index additionally. Basically, managing real rates is designed to support the domestic foreign trade positions. Thereby, the ongoing foreign currency purchases helped to offset the high inflation differentials. However, it is clear that Argentina could influence its real rate index to a higher extent, if authorities would have improved the domestic price stability.³¹⁷ In this context, a stable nominal medium-run exchange rate is an important increment of positive international competitiveness developments as a long-run strategy.³¹⁸ Overall, the relevance of stable nominal as well as competitive real exchange rates caused the BCRA to intervene during the sample under investigation. This is supported by the results obtained for exchange rate deviations from a 90-day trend.

(iii) *Why Did the BCRA Focus on an Implicit Target Level?*

The reason why the BCRA targeted an implicit exchange rate or an exchange rate window is not clear at first sight. No official statement gives conclusive insights. Nevertheless, it was an open secret that the BCRA targeted the exchange rate: *"Staff noted that, while there was a need for the central bank to continue to augment reserves* [this emphasizes the above stated

³¹⁶For more information on the ITCRM, see BCRA (2005b).

³¹⁷For a detailed discussion of targeting real exchange rates, see Frenkel (2006), and Frenkel and Rapetti (2007).

³¹⁸Medium-run stability alleviates the potential threat of exchange rate pass-through effects on domestic prices. This effect is discussed in the context of the target motive. Nevertheless, this shows the high dependency of different intervention objectives.

other policy aspects for interventions], *intervention should be carried out in a manner that did not effectively peg the exchange rate. Staff noted that while Argentina had, de jure, a floating exchange rate regime, the exchange rate had, in fact, been confined within a very narrow range, and could be classified under an empirical rule as a currency peg.*" [IMF (2005), p. 21].

The intention of a target zone is to limit the pitfalls of both fixed and completely free exchange rates. A theoretical model is presented by Krugman (1991). The question of an appropriate exchange rate target band goes beyond this research. Nevertheless, I will give some arguments for it. In general, when defining a target band, a trade-off exists between enough flexibility for the exchange rate to serve as an economic shock absorber, and sufficient stability for the exchange rate to channel expectations and signal economic stability. In the context of Argentina, the exchange rate may fulfill this role.³¹⁹ Therefore, the economic and financial stability is assessed in terms of a stable exchange rate within an implicit range. However, this does not sufficiently explain an exchange rate band. Moreover, it is necessary to discuss the target range for Argentina more appropriately.

Fiscal policy was closely connected to exchange rate developments, explaining the floor of the target band. The reason is that tax incomes of exports was directly influenced by the exchange rate. Thereby, exporters had to pay about 20% of their earnings to the government, which makes up a substantial share of total government revenues as shown in figure 16.³²⁰ Hence, a domestic currency getting too strong diminishes tax revenues, and is therefore unfavorable for fiscal policy reasons. This explanation fits the rolling results of the target objective in such a way that in early estimation windows, which are characterized by stationarity of the target motive, results were correctly signed and highly significant. During this period the exchange rate rebounded from a sharp depreciation in the aftermath of the crisis, and authorities were concerned about fiscal income perspectives.

In contrast, the ceiling of the band stems from signaling financial stability, serving as a

³¹⁹One might argue that the quantitative monetary targets could serve as moving nominal anchors. While this is basically true, it can be argued that the endemic feature of a nominal anchor is to provide stable long-run perspectives and expectations in order to plan economic decisions. Quantitative targets are published at the end of every year for each quarter of the following year. By doing so, the natural purpose of a nominal anchor is not fulfilled clearly, since regularly changing quantitative targets do not support long-run perspectives.

³²⁰This export tax, and tax established for financial operations were the main factors driving fiscal adjustments. Both together constituted about 2.7% of the GDP in 2004. See Frenkel and Rapetti (2007).

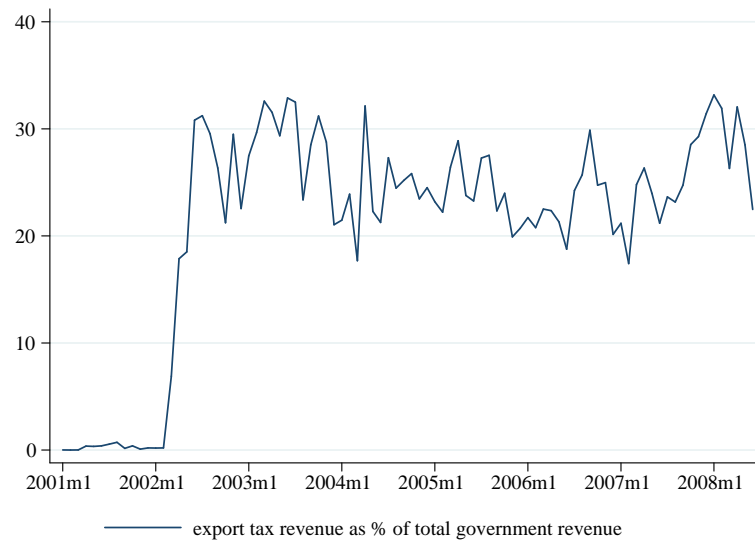


Figure 16: The Importance of Export Taxes in the Context of Total Government Revenues in Argentina between January 2001 and June 2008 (Data source: Bloomberg, own calculations).

nominal anchor, and assuaging the price impact of exchange rate depreciation.³²¹ The relationship between domestic prices and the exchange rate pass-through effect on domestic inflation in Argentina is examined by Ito and Sato (2007). They apply a structural VAR for the post crisis period between 2002 to 2006. Empirical results indicate that a one percent depreciation of the nominal effective exchange rate significantly increased import prices by 0.7%, producer prices by 0.4%, and consumer prices by 0.2%. These estimation results reveal the importance of an implicit upper exchange rate target.³²² However, in this case the question must be linked to the effects of a domestic currency depreciation vis-à-vis the US\$ (bilateral exchange rate) on domestic prices.

Therefore, I follow the VAR analysis of Ito and Sato (2006), and replace the nominal effective exchange rate by the bilateral US\$/ARS exchange rate.³²³ Figure 17 shows the impulse response function for a shock in the US\$/ARS exchange rate, and the development along the price chain.

³²¹One might argue that this aspect should better be connected with the medium-run motive. However, in my view, it is more appropriate to discuss it within the target motive. An upper exchange rate level serves as a better disciplinarian of price developments. Furthermore, medium-term upward swings do not necessarily cause domestic prices to rise.

³²²Moreover, it emphasizes the importance of a stable medium-run exchange rate path, as discussed above.

³²³For detailed information on the structure, and the impulse response definition, see Appendix A.3.

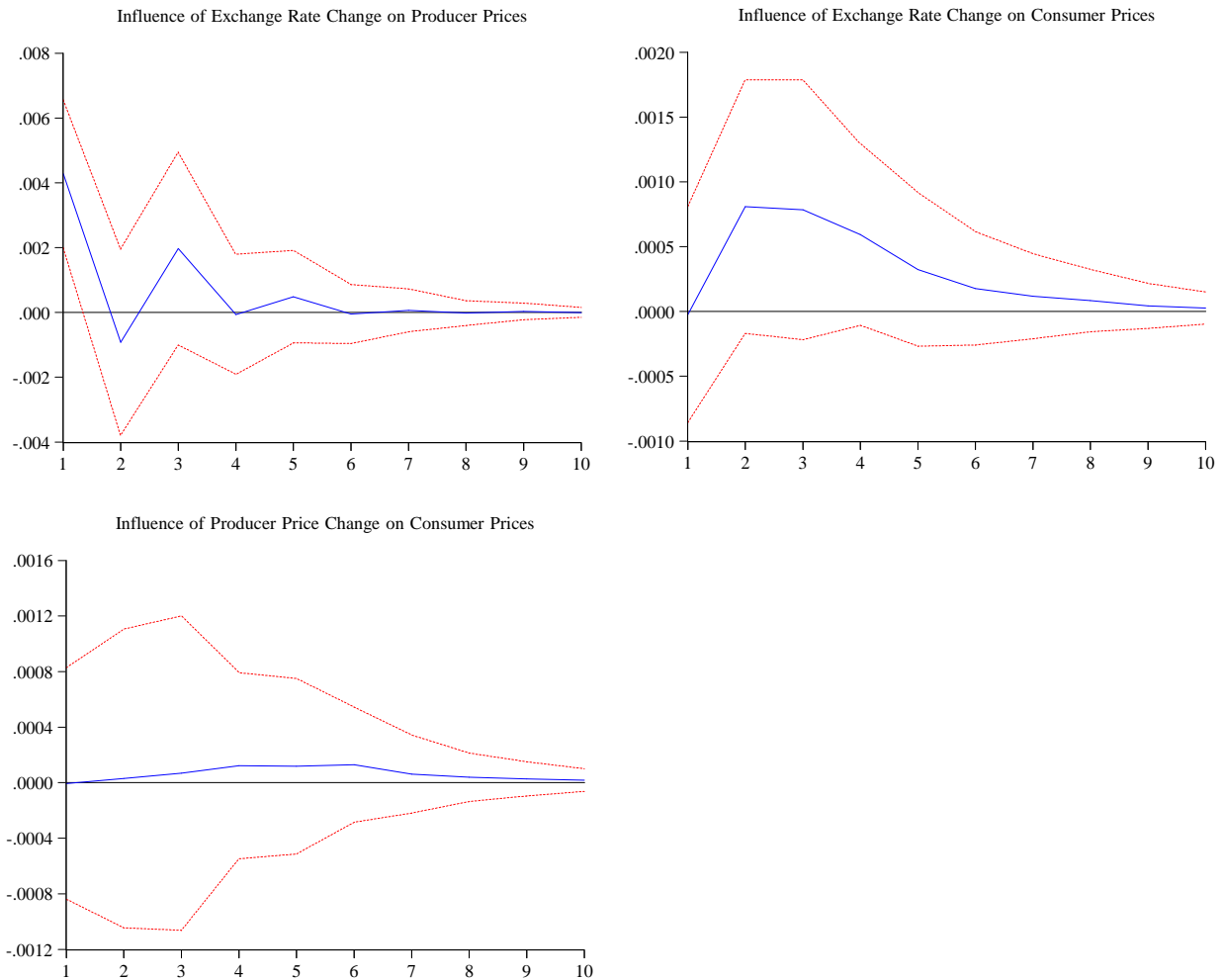


Figure 17: Exchange Rate Pass-Through Effects, and the Development along the Price Chain in Argentina between 2003 and 2008.

More precisely, the shock is defined as a Cholesky one standard deviation innovation in the exchange rate change.³²⁴ It can be seen that a shock in the bilateral exchange rate caused producer prices to rise by 0.4% but was only of a short-lived nature. In contrast, the effect on consumer prices was very small and insignificant throughout the periods. Concerning the development along the price chain, it can be seen that a rise in producer prices had no significant influence on consumer prices. At first sight, a bilateral exchange rate pass-through effect on consumer prices seems to be inexistent. This can be explained by a pricing to market strategy

³²⁴The empirical standard deviation for the monthly US\$/ARS exchange rate changes accounted for 1.5%, and 1% for producer price changes between January 2003 and July 2008.

of domestic producers. Thereby, domestic producers absorb the rise in producer prices when fixing prices for domestic goods which in turn attenuate exchange rate pass-through effects. One explanation for this effect is that exchange rate changes are considered to be temporary, leading to the presence of menu costs. In this case, adjusting prices is seen to be not useful. However, this absorbs their earnings, and is therefore no sustainable strategy. For this reason, the BCRA was vigilant against a nominal weak exchange rate, in order to support domestic producers and to enhance the real economy. This emphasizes again the real rate aspect mentioned above. Instead of supporting the economy by nominal weakness, the BCRA followed a long-run strategy, aiming for low and stable price developments.

5.5.2 Explanation of Intervention Effects

Turning to the effectiveness of interventions, the arguments of Canales-Kriljenko (2003) fit interventions conducted by the BCRA. Focusing on the first three aspects, it can be stated that in the case of Argentina:

(i) *Interventions Are not Fully Sterilized:*

Foreign exchange transactions were not fully sterilized throughout the sample. As can be seen from the upper left panel of figure 18, the intensity of sterilization has changed over time.³²⁵ Furthermore, as shown in the upper right panel of figure 18, the BCRA did not only use a variety of sterilization instruments but also applied them to different degrees. However, BCRA debt instruments have been the most important monetary policy sterilization instrument, followed by financial transactions, which contain repo and rediscount operations. It can be seen that the matter of monetary absorption gained in importance since mid 2005, reflected by a steadily rising degree of sterilization associated with an absolute increase in the estimated t-stats. This is due to the increasing growth of monetary aggregates, which caused the BCRA to change its quantitative target aggregate from the BMB towards the broader monetary aggregate M2. The upper left panel of figure 18 basically fits the outcomes of the rolling impact analysis. At the

³²⁵The panel displays the outcomes of a rolling estimation of the OLS regression, displayed in table 8. The estimation window is set to 68 weeks.

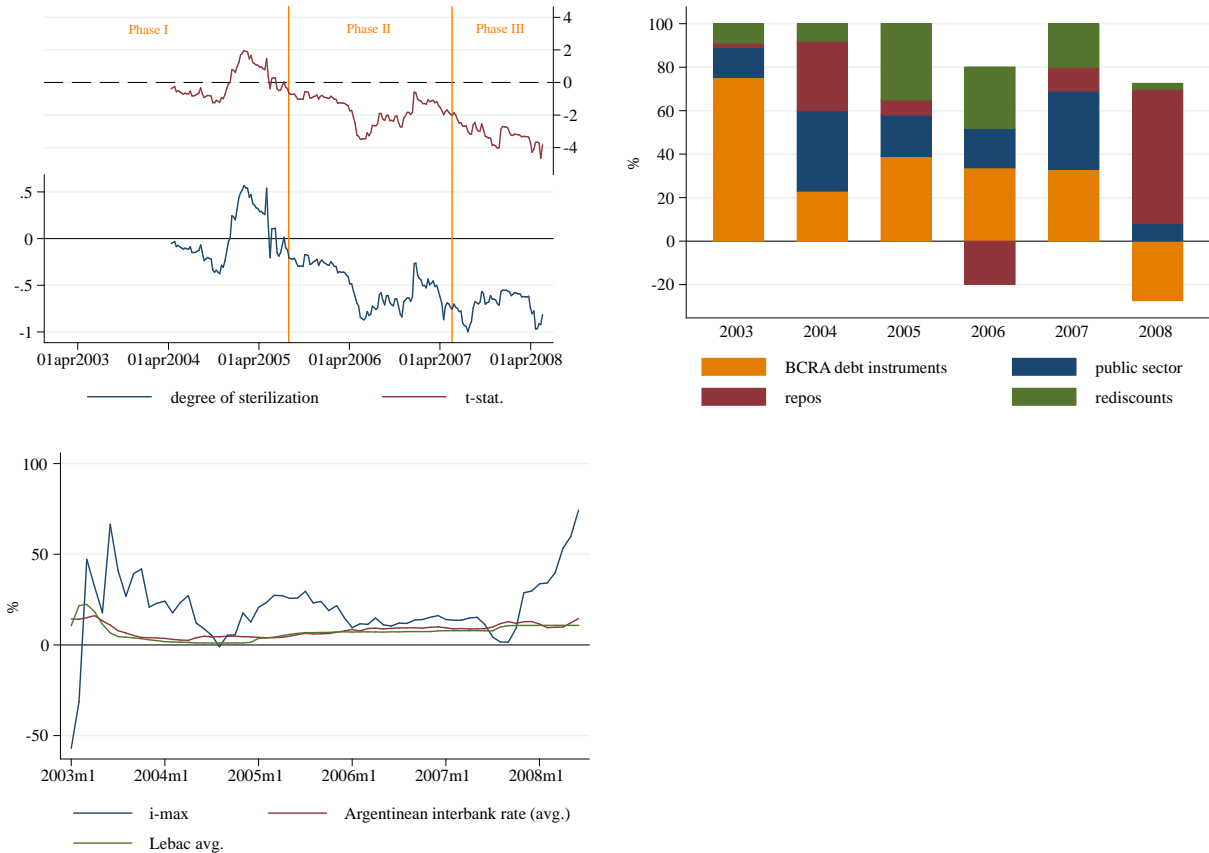


Figure 18: Development and Characteristics of the Main Sterilization Instruments in Argentina between January 2003 and May 2008 (Data source: BCRA, Bloomberg, own estimation and calculation).

beginning, higher impact effects are associated with a lower degree of sterilization.

Why were interventions at the beginning of the sample more effective? Clearly, the monetary channel of exchange rate determination pushed the exchange rate in the desired direction. Growing monetary aggregates, caused by the purchase of foreign currency, decreased money market rates as can be seen in the lower left panel of figure 18. This is in line with the monetary idea of how interventions are influencing the exchange rate as discussed in chapter 2.1, and explains that small sized interventions had the greatest estimated impact. However, with the change in quantitative monetary targets, interventions became more sterilized, and interest rates began to rise. Accordingly, the impact effect of interventions on the exchange rate diminished, although it was still signed correctly. This points towards another mechanism,

Bill. Pesos	2003	2004	2005	2006	2007
Income					
Interest on Reserves	0.36	1.01	1.99	3.06	5.60
Adjustments [†]	-3.43	1.73	0.86	2.06	6.37 [‡]
	<i>-3.07</i>	<i>2.74</i>	<i>2.85</i>	<i>5.12</i>	<i>11.97</i>
Expenses					
Interest on BCRA Debt	-1.24	-1.26	-2.01	-3.66	-6.27
Interest on Financial Transactions	-	-0.22	-0.58	-0.47	-0.46
Net Income	-4.31	1.26	0.26	0.99	5.24

[†]Includes price adjustments and exchange rate valuations on foreign assets/liabilities

[‡]Excluding securities

Table 17: Statement of Income and Expenses from Foreign Reserve and Domestic Securities in Argentina between 2003 and 2007 (Data source: BCRA).

which was responsible for intervention effects. Especially in 2008, when impact effects increased again, interventions did not affect the monetary base, and thus, other channels must have been responsible for the effectiveness of foreign exchange operations. This is interesting against the background of the change in the intervention strategy. While the effect of the monetary channel shrunk, the change in the intervention strategy bolstered the positive influence of daily interventions.

Concerning the sustainability of sterilized interventions, table 17 reveals some important facts. As discussed above, aggregated net earnings from sterilization amounted to 3.44 bill. Pesos between 2003 and 2007. The development of net earnings shows that in 2003, the BCRA faced significant losses from its intervention policy. A strongly appreciating exchange rate, and high interest rate differentials caused net earnings to melt down. In the following years, losses turned into profits, especially in 2007. When comparing exact information with the heuristic approach of a level adjusted UIP-based indicator, it can be seen that the maximum affordable domestic interest rate, which reflects the costs of domestic liabilities, behaves similarly (lower left panel of figure 18). While showing significant losses at the beginning of the sample, the indicator enters profit territory as of the end of 2007. Hence, according to the underlying information, the prevailing intervention policy has not been threatened since 2004.

(ii) *Intervention Volumes Account for a Substantial Fraction of Market Turnover, and Monetary Base:*

As mentioned above, interventions have been the main instrument for monetary growth in Argentina. Other instruments were widely used to absorb monetary expansion. In this context, as shown in table 18, daily interventions conducted by the BCRA accounted for approximately 9.5% of the overall daily market turnover between January 2003 and December 2004. Since 2005, the average relative intervention amount accounted for approximately 13% of daily overall turnover. Compared to industrialized market shares, this is a substantial amount. For instance, Japan was the only industrialized country intervening regularly until 2004. BoJ daily intervention volumes in terms of spot market turnover accounted for an average of approximately 2.2% between 2002 and 2004. During this time, the BoJ reached an average daily intervention amount of approximately 2.5 bill. US\$.³²⁶ When comparing the daily transaction volumes with stocks of money base and monetary aggregates, it can be seen from table 18 that the relative amounts of Argentina and Japan were similar with respect to the money base. However, they differed in respect to broader monetary aggregates. In this context, daily BCRA interventions made up a fraction of 0.19% between 2003 and 2004, and 0.24% between 2005 and 2008, for daily stocks of monetary base. In terms of the monetary aggregate M2, daily Argentinean interventions reached an average relative volume of 0.12% between 2003 and 2004, and 0.14% between 2005 and 2008. While these ratios seem to be small at first glimpse, it is the accumulated number of interventions (almost every day), which highlight these transaction volumes. The dominating role of intervention as a money creation instrument was presented above. Interestingly, the ratios increase over time. In contrast, though the mean relative intervention volume of 0.28% for the money base was greater, the average daily relative intervention amount of the Japanese authorities with respect to M1 made up only an average share of 0.06% between 2002 and 2004.

The relevance of intervention volumes to market turnover and monetary stocks supports the argument of Canales-Kriljenko (2003). Especially, the increase in the market share since 2005 could be a reason why interventions in Argentina have still been "successful" at times when the

³²⁶Data source: Ministry of Finance Japan, see <http://www.mof.go.jp/english/e1c021.htm> [as of 12th February 2010].

Intervention in % of:	BCRA		BoJ
	2003 – 2004	2005 – 2008	2002 – 2004
Market Turnover	9.5%	13%	2.2%
Monetary Base	0.19%	0.24%	0.28% [†]
M2 ⁺ /M1 [†]	0.12% ⁺	0.14% ⁺	0.06% [†]

[†] Monthly data was interpolated (linear) on a daily frequency
Data until June 2008/March 2004

Table 18: The Relative Size of Daily BCRA’s Foreign Exchange Market Interventions Compared to BoJ Interventions (Data Source: BIS, BCRA, Irigoyen (2005), BoJ, Japanese Ministry of Finance, own calculation).

importance of the monetary channel declined. In this sense, the effectiveness could be linked to some kind of microstructure channel. Through steadily intervening in the foreign exchange market, authorities influenced the order flow significantly. Thereby, the relative high amounts compared to total turnover, could have induced international investors to call for an additional fee in order to hold the additional amounts of foreign currency (microstructure portfolio-balance idea). Moreover, the effectiveness could, and should also be explained by the simplest way of reasoning about intervention mechanisms. Steady and high intervention amounts (almost every day) could have altered the supply of foreign currency persistently, and thus influenced its actual price.

(iii) *Central Banks Possess Additional Information through Reporting Requirements and/or Exchange Restrictions:*

Several exchange controls were established in the aftermath of the financial crisis. As it was the case when explaining intervention motives (negligence of short-run exchange rate developments), exchange controls and the corresponding reporting requirements might also be responsible for the effectiveness of interventions in Argentina. With the unification of the exchange market on January 11th, 2002, regulations for six main categories were imposed:³²⁷ 1) collections of proceeds from the export of goods; 2) payments for the import of goods; 3) other

³²⁷See BCRA (2002b).

current account payments (services, interest, profits, dividends); 4) servicing of debt principle; 5) setting up private sector foreign assets abroad; 6) repatriation of investments by non-residents. These controls gave the authorities a comprehensive insight into the foreign exchange market.

However, the controls were assuaged over time. Beginning in mid 2003 some restrictions started being relaxed. The main actions included surrender requirements, guiding a stable development of the exchange market, and putting limits on the creation of private external assets.³²⁸ Starting in June 2002, bills of lading of more than 200,000 US\$, and income for any amount of export advances and pre-finance were to be ceded to the central bank. This enhanced the central bank's relative share in the foreign exchange market significantly.³²⁹ The limit was raised to 1 mill. US\$ in January 2003, and was eliminated entirely in May 2003.³³⁰ Furthermore, the use of financial derivatives was gradually allowed for the purpose of hedging currency risks in foreign debt management. This was designed to circumvent any speculative attacks.³³¹ In the case of setting up foreign assets, the authorities imposed prior approval requirements. While investment amounts of 100,000 US\$ required prior approval in 2002, this limit was increased to 2 mill. US\$ in 2004.³³²

Again, this fits the evolution of impact effects. Being substantial at the beginning of the free float period, impact effects declined with lowering restrictions on foreign exchange trade. The informational advantage is often associated with the signaling channel of interventions, which is seen as being responsible for effectively influencing exchange rates. Thereby, interventions signal the central bank's view of the appropriate exchange rate to the market which in turn clearly hinges on the central bank's credibility. These controls must be understood as broad interventions, designed to communicate the intention of bolstering stable and reliable market conditions, and thus as an investment to back the authorities' credibility.

³²⁸ Various BCRA's reports to the government provide further, more detailed information on the exact terms of relaxation of the several measures in place.

³²⁹ Thus, surrender requirements were only in place at the beginning of the examined sample.

³³⁰ See BCRA (2003c).

³³¹ See BCRA (2004).

³³² See BCRA (2004).

6 The Case of Croatia

6.1 Monetary Policy

In contrast to Argentina, which abandoned its currency board regime in 2001, letting the Peso float freely and pursuing a monetary targeting strategy, monetary policy in Croatia has officially followed a more restrictive exchange rate policy. The Stabilization Programme launched in 1993 to stimulate economic activity after the war, introduced the exchange rate as a nominal expectation anchor, binding prices for tradeable goods which in turn diminished expectations for a devaluation of the Kuna and rising inflation.³³³ This reflected the beginning of a strong exchange rate dependency. Figure 19 displays economic and monetary policy features of Croatia between 1998 and 2008.

The rapid growth of small and medium sized banks, as a consequence of a liberalizing banking sector, turned out to be the seed of the banking crisis in the late 1990s (1998, 1999). During that crisis 14 banks collapsed, and economic activity went into a recession of 4% in 1998, and 1.5% in 1999. However, the exchange rate depreciated "only" by 9% between August 1998 (7.1 EUR/HRK) and March 2000 (7.73 EUR/HRK). After the banking crisis, Croatian banks were sold to foreign banks. Beginning in 2001, credit growth expanded. This was due to the conversion of the EUR causing an extreme inflow of foreign currency into the domestic banking system, which was owned by foreign banks from EMU countries.³³⁴ The large amount of foreign currency and domestic savings were used to increase credit activity, which rose at a double digit rate.³³⁵ The boost in credit growth was maintained at high levels by borrowing abroad, which led to a rise in foreign debt. Therefore, the CNB decided to tighten its monetary policy in 2003. Several measures were used to slow down domestic credit expansion, and to restrict the rise in foreign debt, which kept the CNB busy throughout the following years. In this context, banks were obliged to subscribe low yield CNB bills when exceeding a predetermined threshold

³³³In the early 1990s, due to war, the economic activity declined by 36%, and inflation climbed up to 38% per month in October 1993. See Vizek (2007).

³³⁴This eased the access of domestic banks to foreign fundings. See also Gardó (2008) for information on the structure of the Croatian banking system.

³³⁵See Kraft and Jankov (2005) for a discussion on the lending boom in Croatia.

of maximum annual credit accretion.³³⁶ Additionally, reserve requirements on foreign funding were implemented in 2005, to constrain the increase in external debt. Although the amount of lending and domestic demand increased remarkably since 2000, inflation remained low. Two factors were responsible for this effect. First of all, due to great import dependency, the rising current account deficit, absorbed high demand.³³⁷ Second of all, and more importantly, the combination of a high level of euroization and a stable exchange rate neutralized most pressure on domestic prices. Of course, the rationale behind the policy measures was that a reduced credit activity, which was triggered by foreign borrowing, would help to reduce balance of payments distortions, which could have had severe effects on exchange rate developments, resulting in price instability.³³⁸

The CNB has pursued the ultimate goal of price stability without stating an official inflation target or band.³³⁹ In order to fulfill this stated goal, monetary authorities have used a wide range of different instruments for conducting monetary policy during the last years.³⁴⁰ Therefore, it is not a straightforward matter to characterize the monetary policy framework of Croatia. With the lack of explicit policy rules, it is not possible to peg Croatia as an inflation targeter, or as a monetary targeter.³⁴¹ Nevertheless, when taking a closer look, Croatian monetary policy can best be described as a quasi-currency board system.³⁴² Ever since the Stabilization Programme, foreign reserves have been higher compared to domestic money supply. However, pursuing a currency board has never been the official purpose of Croatian authorities. No legal mandate existed, justifying a currency board system, which is basically seen as an anchor in case of lacking credibility. As displayed in the left panels of figure 19, foreign assets have made up about 100% of the central bank's assets, which comes close to the common balance-sheet structure of a

³³⁶See Lang and Krznar (2004).

³³⁷Current account in % of GDP is seasonally adjusted, using four period moving averages.

³³⁸See CNB (2003c).

³³⁹It must be noted that the ultimate goal of price stability was defined explicitly in 2001 by the Law on Croatian National Bank (The Croatian National Bank Act - 5 April 2001). Prior to that, Article 53 of the Constitution of the Republic of Croatia emphasized that the CNB, besides other duties, should be responsible for the stability of the currency.

³⁴⁰See Lang and Krznar (2004) for a description of the various policy instruments since 1992.

³⁴¹The IMF has discussed practical issues for the adoption of an inflation targeting framework in Croatia. See IMF (2002).

³⁴²See Vujčić (2003).

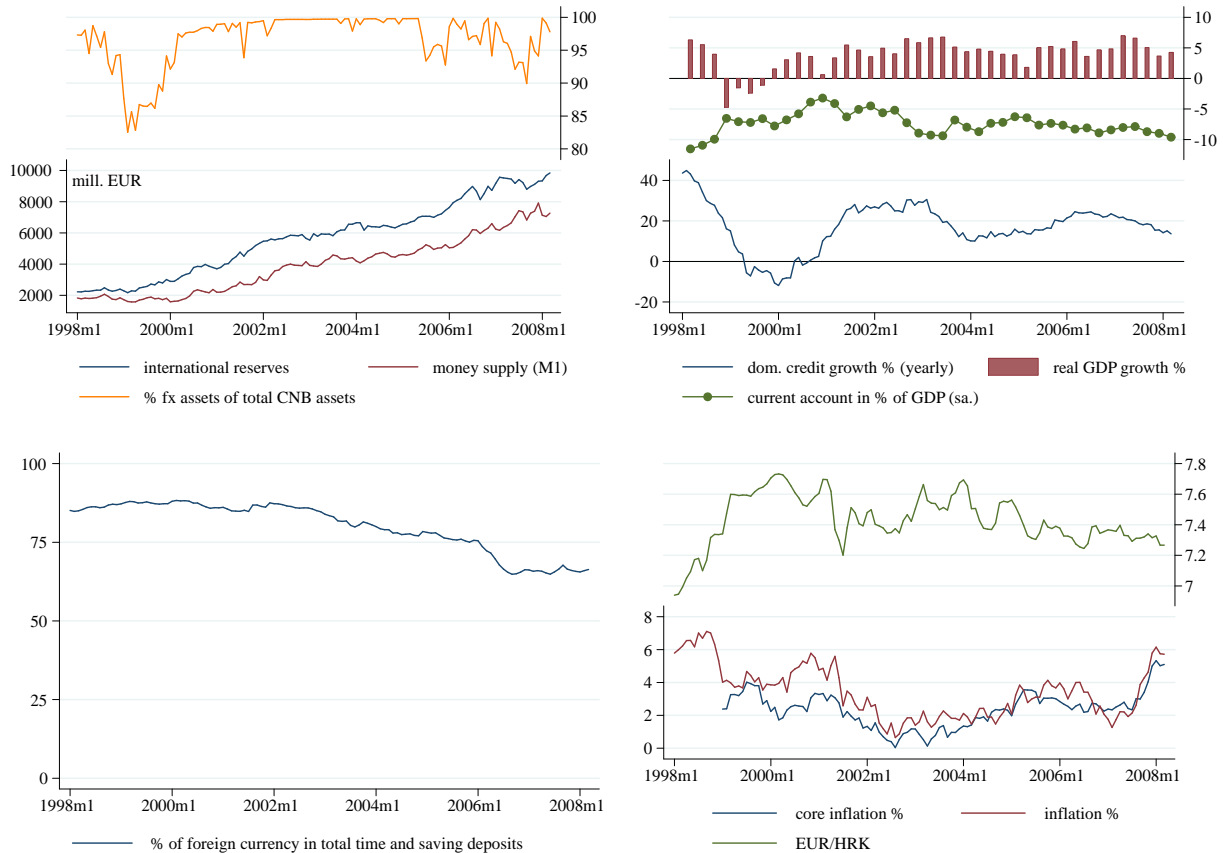


Figure 19: Economic and Monetary Policy Features of Croatia between 1998 and 2008 (Data source: CNB, IMF-IFS).

typical currency board regime. Additionally, foreign currency was widely spread in domestic deposits. This high level of euroization in Croatia was one main reason for the quasi-currency board regime, a fact, which will be addressed below.

Nevertheless, monetary authorities have been concerned about managing domestic liquidity without stating any targets for base money or credit aggregates.³⁴³ Thereby, the CNB did not chiefly follow an interest rate based monetary policy. Selling short-term bills, denominated in Kuna, and adjusting the rate and base of required reserves were measures in managing domestic liquidity. The described mix of monetary policy instruments makes it difficult to determine the exact policy stance of Croatian authorities during the last years.³⁴⁴ In 2005,

³⁴³One exception was the attempt to control excessive credit growth in the aftermath of EUR conversion. As described above, the CNB stated explicit credit growth limits.

³⁴⁴See Lang and Krznar (2004) for an attempt to construct a monetary condition index. The authors find

an active monetary policy instrument (open market operations) has been introduced with the purpose of implementing stable domestic money markets.³⁴⁵ Since Croatia follows the aim of entering the EMU in the near future, sound money markets and a stable interest rate channel are essential requirements for joining the Eurozone.

While the overall monetary framework has somehow not been clear-cut, an exchange rate policy of managed floating was adopted.³⁴⁶ In this context, while focusing on exchange rate stability, authorities did not officially predetermine any lower or upper exchange rate level. However, Vizek (2007) states that the CNB was intent on stabilizing the exchange rate within a band of 7.3 to 7.6 EUR/HRK in order to achieve its goal of price stability.³⁴⁷ Although interventions have been used to influence the exchange rate behavior, it was never the authorities' aim to fix the foreign value of the Kuna. According to Calvo and Mishkin (2003), this type of exchange rate regime, and Croatia's characteristic as a quasi-currency board allow to draw the conclusion that the CNB follows a strategy of floating with a "large life jacket." This in turn helps to limit any speculation on the exchange rate by convincing economic agents to address the issue of currency risks. Throughout the years monetary policy has been determined by the role of the exchange rate for the Croatian economy in order to ensure moderate and stable price developments. In this context, Šošić and Kraft (2006) state: *"Monetary policy in Croatia has been mainly dictated by the exchange rate regime and has relied heavily on foreign exchange intervention..."* [Šošić and Kraft (2006), p. 502].

As mentioned before, the exchange rate has played the most important role in the Croatian economy and monetary policy. It is uncontested that Croatia's low inflation rates compared to other transition countries in past years were based on a nominal exchange rate anchor vis-à-vis the EUR. In this context, monetary authorities state: *"... the central bank continued to implement monetary policy aimed at maintaining the stability of the nominal Kuna exchange*

evidence for a procyclical monetary policy (tightening during recession; easing during expansion), which is an inherent characteristic of small exchange rate targeting countries. In those countries, exchange rate depreciations are positive correlated to monetary tightening since depreciation pressure is commonly caused by recessions.

³⁴⁵See CNB (2005b).

³⁴⁶See CNB (2004a).

³⁴⁷Vizek (2007) argues that governor Rohatinski's interviews with the media gave reasons to assume this implicit exchange rate target band.

rate against the euro, which is the main anchor of domestic inflationary expectations and basic precondition for domestic price stability," [CNB (2007), p. 11]. The reason is that prices were, and still are, indexed to foreign currency.³⁴⁸ However, domestic prices are not thoroughly connected to exchange rate developments. Instead, indexation holds for most big items like real estate or cars. Hence, foreign currency (before 1999 DEM, afterwards EUR) serves partially as the unit of measure.³⁴⁹ The strong import dependency and the relative stability (slight appreciation) of the EUR/HRK exchange rate absorbed inflationary pressure during the last years. Between January 1998 and April 2008 the exchange rate moved within a span of about 10%, which is, compared to other emerging market countries, rather low.³⁵⁰ Furthermore, the high degree of euroization caused banks to index their loans to the exchange rate in order to avoid any currency mismatches. However, this translates the problem of currency risks on banks' balance-sheets into the risk of increasing defaults in case of sharp exchange rate depreciations.³⁵¹ The IMF (2007b) argues that the fact that nearly 80% of bank loans and time deposits were denominated in, or indexed to foreign currency, emphasizes the need for a stable exchange rate. Overall, the CNB refers explicitly to the role of high euroization and inflation expectations when stressing the importance of a stable exchange rate: *"The CNB maintains the stability of the Kuna/euro exchange rate in order to meet its primary objective of maintaining price stability. More specifically, in highly euroised economies, such as Croatia, prices are sensitive to exchange rate fluctuations. The exchange rate movements also influence household inflationary expectations, which are pronounced in particular as a result of Croatia's previous experience with high inflation,"* [CNB (2004a), as of 23rd February 2010].

The importance of the Kuna's foreign value is addressed by some studies when examining the influence of the exchange rate on real economic activity. In this context, using cointegration analyses and Granger-Causality tests augmented by an error correction model, Vizek (2007) analyzes, which monetary policy transmission channel (direct monetary channel, exchange rate

³⁴⁸See CNB (2005b).

³⁴⁹See Lang and Krznar (2004), and Vizek (2007).

³⁵⁰For instance, the EUR/CZK exchange rate moved within a band of 51% between January 1999 and April 2008. The EUR/PLN exchange rate moved within a band of 43% between January 1999 and April 2008. Data source: DBB.

³⁵¹See Šošić and Kraft (2006).

channel, interest rate channel) influenced Croatia's real activity (industrial production) between 1998 and 2006. Based on the obtained results, the author concludes that the exchange rate channel possessed the greatest relevance for Croatia's economic activity. Although differing in methodologies, Lang and Krznar (2004), applying VAR estimations and seemingly unrelated regressions, agree that the exchange rate channel is the most important monetary policy transmission channel for the authorities. Their arguments are mainly based on the structure of the Croatian economy, which is characterized by a developed banking system, an underdeveloped domestic financial market, and an unofficial high degree of euroization. Especially the low sophistication of financial markets impeded the evolution of a strong and reliable interest rate channel. However, as described above, the introduction of active money market instruments was designed to improve the effectiveness of the interest rate channel. The structural characteristics are important for the understanding of Croatia's monetary policy settings.

6.2 The Role of Interventions

Similar to Argentina, foreign exchange market interventions have been the most important instrument of monetary policy in Croatia. However, the use of foreign exchange market interventions in Croatia was closely linked to the management of the Kuna's foreign value. Officially, foreign exchange market interventions were, and still are, seen as the main exchange rate policy instrument of the CNB: *"The main foreign exchange policy instrument of the CNB are foreign exchange auctions through which the central bank purchases or sells foreign exchange to commercial banks,"* [CNB (2004a), as of 23rd February 2010]. Since monetary policy in Croatia is practically organized towards exchange rate stability, which is why the exchange rate became a key parameter, interventions can be seen as the monetary policy instrument of paramount importance. Contrary to the BCRA, which has given very few information concerning interventions, Croatian authorities always felt obliged to actively communicate their use of foreign exchange operations. In this context, the CNB itself addresses the most important question dealing with this policy measure: 1) when does the CNB intervene (motives); 2) are interventions crucial for the exchange rate level (effectiveness)?

Concerning the matter of intervention objectives, the CNB does not give detailed information about the reaction function: *"The CNB participates in foreign exchange market transactions in order to prevent excessive fluctuations in both directions."* [CNB (2004a), as of 23rd February 2010]. Moreover, monetary authorities deny that any fixed exchange rate band is explicitly accounted for: *"The CNB does not predetermine the lower and upper level of the Kuna exchange rate it is committed to defend (the upper and lower intervention point)."* [CNB (2004a), as of 23rd February 2010]. From these statements, which highlight the discretionary use of foreign exchange market interventions, it is not clear whether monetary authorities follow an explicit intervention strategy. Basically, this reflects the implementation of a managed floating exchange rate system. However, in standard presentations, exchange rate changes within a four day horizon are emphasized to explain foreign exchange transactions.³⁵² It seems that the CNB takes account of short-term exchange rate movements when deciding to intervene. This conjecture is supported by figure 20. It displays the relationship between intervention volumes and 4-day exchange rate changes. The scatter plot shows the suggested behavior. The greater the Kuna depreciated the higher the authorities responded with foreign currency sales and vice versa. However, comprehensive information on the intervention objective(s) are not given, calling for a deeper analysis of the CNB's reaction function.

Turning to the influence of interventions on the exchange rate level, the CNB negates their crucial importance by emphasizing the *"... very small portion of total purchases and sales on the foreign exchange market."* [CNB (2004a), as of 23rd February 2010]. It is very surprising why authorities highlight foreign exchange market interventions as the main exchange rate policy tool (for managing exchange rate aspects (!)), when, at the same time, this measure is officially labeled as rather meaningless for the evolution of the Kuna's foreign value. One explanation justifying this statement is that authorities try to minimize the fluctuations of the exchange rate around a long/medium-term path rather than managing it. Moreover, by denying the effectiveness of interventions, the authorities also try to ward off speculative attacks from international investors.

³⁵²See CNB (2010b).

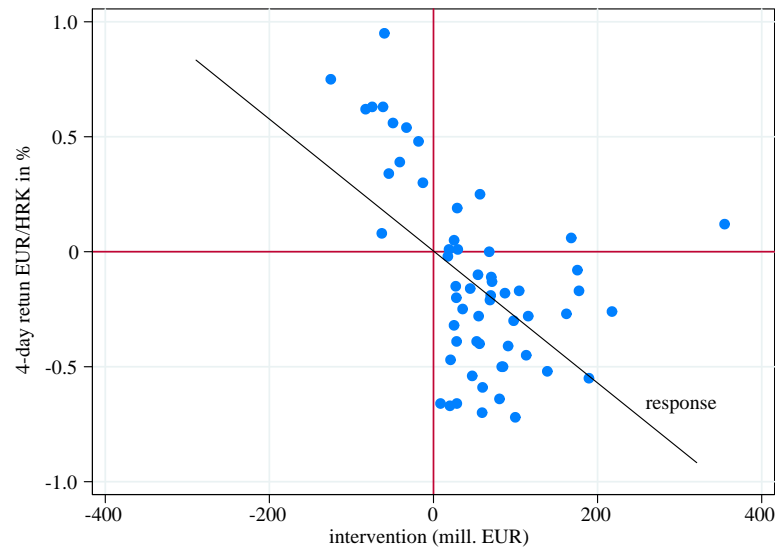


Figure 20: The Relationship between Daily Interventions and 4-Day Exchange Rate Returns in Croatia between March 2002 and April 2008 (Data source: CNB).

Foreign exchange interventions, mostly conducted as foreign currency purchases, caused an increase in domestic liquidity. In fact, foreign currency purchases have been the most important money creation instrument.³⁵³ Credits of the CNB to domestic banks have been almost inexistent compared to foreign assets. Between March 2001 and April 2008, the average share of domestic credits to foreign assets was only 1.8%.³⁵⁴ Hence, money creation was dominated by an increase in foreign currency assets, which is a typical characteristic of a (quasi-)currency board regime (see figure 19). Because monetary authorities have been bent on implementing a stable domestic money market, they were concerned about offsetting excessive liquidity. Moreover, neutralizing liquidity effects from foreign currency purchases was justified by preventing inflationary pressure caused by excessive credit growth and a widening current account deficit.³⁵⁵ Several studies argue in the same way, although pointing towards partial sterilization.³⁵⁶ In this context, two basic instruments were used during the last years to sterilize interventions.

³⁵³In this context, Kraft and Jankov (2005) note: *"The Croatian National Bank mainly affects monetary aggregates by interventions in the foreign exchange market. Interest rate based interventions have been rare and relatively unimportant."*, [Kraft and Jankov (2005), p. 108]. Thus, also having disparate basic meanings, the importance of interventions for domestic money constitutes a commonness of foreign exchange operations in Argentina and Croatia.

³⁵⁴Data Source: CNB.

³⁵⁵See CNB (2006d).

³⁵⁶See Galac et al. (2006), Šošić and Kraft (2006), and Vizek (2007).

Transactions with short-term CNB bills, and the reserve requirement instrument served as the main measures to absorb monetary intervention effects. Although a new policy instrument (open market operations), designed to manage Kuna liquidity (domestic money market rates), was introduced in 2005, this tool was not applied to sterilize foreign currency interventions explicitly.

"The first, direct instrument used to sterilize surplus kuna liquidity is the reserve requirement," [CNB (2002), p. 37]. Although the authorities speak of a direct measure, reserve requirements are of a more passive nature. However, this instrument can change into an active one when adjusting the calculation base and/or requirement ratio, as done by the CNB.³⁵⁷ The instrument consists of a Kuna portion and a foreign currency portion.³⁵⁸ For sterilization issues, it is important to separate these two parts. In this context, excess domestic liquidity, caused by foreign currency purchases of the central bank (sale of domestic currency), is neutralized by an increase in the Kuna part of the reserve requirements. Thereby, the sold domestic currency is absorbed from the banking system.³⁵⁹

"As the instrument of reserve requirements is not sufficient to sterilize all surplus liquidity, the CNB uses its CNB bills to withdraw from the market any remaining surplus," [CNB (2002), p. 37]. Such bills were issued in Kuna and foreign currency as well. Contrary to obligatory bills used to restrict excessive credit growth, the purchase of "sterilization" bills was voluntary. Although offering low interest rates, high liquidity of the banking system made the purchase of this instrument attractive. As is the case for the requirements, the CNB used domestic currency denominated bills in order to absorb excess liquidity. However, authorities argued that their usage became expansive, which is why such transactions were cancelled. Hence, sterilization was mostly conducted through an indirect measure.

³⁵⁷Between March 2002 and April 2008, the ratio declined from 19% to 17%. Data Source: CNB.

³⁵⁸For detailed information on reserve requirement calculation, see CNB (2009).

³⁵⁹It is important to note that the data on the Kuna part of the reserve requirements, which is provided by the CNB, include foreign currency reserve requirements, which are allowed to be settled in Kuna: *"... column 5 [reserve requirement which are held in Kuna] includes also the f/c component of reserve requirement that is set aside/maintained in kuna"*, [CNB (2010a), p. 4] Not accounting for this fact would distort sterilization analysis. However, the "true" Kuna part of total reserve requirements can be obtained approximately by applying the time specific ratios on Kuna deposits and foreign liabilities denominated in Kuna, including hybrid and subordinated instruments.

	2002 - 2008
Δ	Kuna Reserve Requirement + CNB Kuna Bills
<i>Int</i>	0.24***
<i>t - stat.</i>	3.00
$\overline{R^2}$	.181
<i>F - stat.</i>	6.16***
$Q(10)^\dagger / Q^2(10)^\dagger$	.826/.910

OLS - Estimation using Newey-West Standard Errors & Covariance
 OLS - Regression: $y_t = c + \delta y_{t-3/4} + \alpha Int_t + \varepsilon_t$,
 $y = \Delta$ Kuna reserve requirement + Δ CNB Kuna bills
 \dagger p-values; *10% - **5% - ***1% significance

Table 19: Degree of Sterilization by the Main Instruments in Croatia between March 2002 and April 2008 (monthly data).

As can be seen in table 19, about 24% of foreign exchange market interventions between March 2002 and April 2008 were neutralized. Since sterilization is conducted through the liability side, a purchase of foreign currency should lead to an increase in the reserve requirements or an increase in the outstanding amount of CNB bills. Therefore, the positive sign of coefficient α indicates the correct relationship. This result supports the statements put forward by several studies that the monetary authorities sterilized their transactions partially. The instruments chosen by the CNB to absorb monetary intervention effects refer directly to liability side measures. No asset side instruments were used. As mentioned already, CNB credits to the banking system were almost inexistent. The sterilization instruments cover narrow (bills) and broad measures (reserve requirements), market-friendly (bills) and non-market-friendly methods (reserve requirements), as well as market (bills) and non-market methods (reserve requirements). The term structure of the Kuna bills was set to 35 days between 2002 and 2004.³⁶⁰ This short time structure served to guarantee enough flexibility, and to minimize potential sterilization costs. Although the CNB cited increasing costs as a reason for canceling the issuance of Kuna CNB bills, the relationship between sterilization and its associated costs is not of great importance. The produced costs (quantitative) did not threaten the sterilization policy. Reserves held at the central bank were remunerated with very low rates (about 1% between 2002 and 2008).

³⁶⁰See CNB(2002, 2003c, 2004b).

Furthermore, CNB Kuna bills accounted for a small amount compared to the size of foreign assets.³⁶¹ On the income side, the authorities managed their substantial international reserves, of which the great majority were held in EUR, successfully by adhering to the principles of security.³⁶² In this context, aggregated yearly net income from international reserves, and Kuna denominated sterilization measures amounted to approximately 9.15 bill. HRK.³⁶³ Thereby, the foreign reserve portfolios were actively managed by the authorities, who only invested in highly secure and liquid assets.

6.3 Empirical Estimation

As discussed above, the exchange rate has played a crucial role for economic and monetary policy conditions in Croatia. The EUR/HRK exchange rate development has been an essential determinant for price stability. Although authorities give much more information compared to Argentina, they do not present deep insights into their motives for intervening in the foreign exchange market. For this reason, it is necessary to examine what factors prompted CNB interventions, and to what extent these factors constituted a reliable indicator for interventions over time. Of course, and as mentioned by the authorities, short-term exchange rate movements were closely followed by the authorities. The need to account for this motive stems from the high degree of unofficial euroization. Nevertheless, it is necessary to investigate the relevance of medium-run exchange rate movements and other factors as well. Especially the role of a target band may have played an important role in the decision-making process of exchange market operations. The above mentioned statements of the CNB concerning the use of foreign exchange interventions begs the questions as to the nature of an internal intervention rule. More importantly, the fact that authorities argue that they do not predetermine any intervention scenarios, points in the direction of time-varying motives. Thereby, foreign exchange market transactions can be used in a flexible way.

³⁶¹On average, CNB Kuna bills amounted to 9% of foreign assets between March 2003 and March 2004. Data source: CNB.

³⁶²See CNB (2002, 2003c, 2004b, 2005b, 2006d, 2007, 2008).

³⁶³Data source: CNB - various annual reports. See table 30.

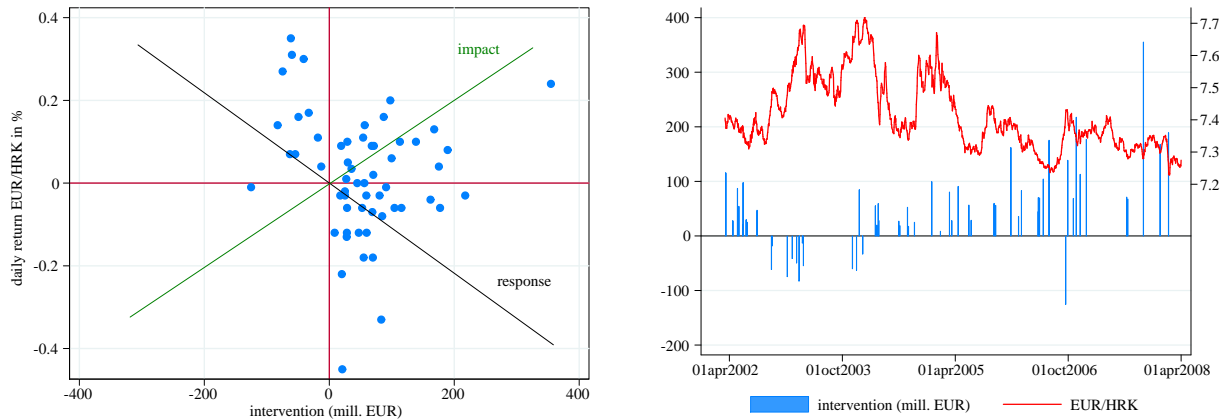


Figure 21: Daily Interventions and their Relationship to Daily Exchange Rate Dynamics in Croatia between March 2002 and April 2008 (Data source: CNB, own calculation).

Furthermore, the CNB's statement on the "ineffectiveness" of interventions seems to be a shield against speculative attacks betting against the central bank. Why do monetary authorities intervene in the foreign exchange market when they believe interventions to be of minor importance for the foreign value of the Kuna? Therefore, it is of outmost interest to analyze if interventions have been effective in driving the exchange rate in the desired way, and whether positive effects, if existent, have been constant over time. When referring to sterilization policy, it can be assumed that interventions were more effective in recent times when sterilization was turned down. This would support the findings of Argentinean impact effects, and would be in line with the arguments proposed by Canales-Kriljenko (2003).

Figure 21 gives a first overview of CNB interventions and exchange rate developments. Similar to Argentinean data, displayed in figure 7, the left panel of figure 21 shows no clear relationship between daily exchange rate returns and daily intervention volumes, due to the fact that impact and response causalities are both displayed. Neither is the linkage between daily CNB interventions and daily EUR/HRK exchange rate returns concentrated around the impact line, nor does it tend to behave according to the response line. However, as mentioned above, this pattern does not allow to draw rash conclusions about the underlying causality. Different to Argentinean central bank interventions, the CNB did not intervene as frequently

as can be seen from the right panel of figure 21. The intervention strategy of the CNB changed during the sample under investigation. In this context, daily foreign exchange operations varied in their occurrence, magnitude, and direction. Foreign currency purchases were the dominant transaction form. Concerning the exchange rate development, it can be seen that the EUR/HRK exchange rate was fairly stable throughout the time moving within a relative narrow band of about 6.6% between March 2002 and April 2008. However, since the end of 2003, the exchange rate experienced a slight appreciation path.

Some final aspects should be given on the institutional characteristics of the CNB before discussing the empirical estimation.³⁶⁴ Monetary authorities in Croatia gained in independence in implementing and conducting monetary policy. Although quarterly projections by the Council of the CNB monitor the use of interventions, the central bank management is in charge to choose the right timing and transaction amount of foreign exchange market operations. Monetary authorities intervened in the spot market during the last years. However, other types of transactions were considered in the past.³⁶⁵ Since November 2000, authorities have solely conducted transactions vis-à-vis the EUR. The reason being that the EUR/HRK exchange rate plays the dominant role for the CNB's monetary policy and Croatia's economy, as explained above. Basically, the very transparent communication of the CNB provides a lot of insights into the use of this important monetary policy tool. However, the authorities do not state any clear intervention strategy. For this reasons, it must be assumed that interventions are not known to market members a priori. In contrast, the CNB provides most information after an intervention has taken place. The exact amount and intervention currency are published on the central banks's website. Foreign exchange transactions are conducted through auctions. Thereby, using a multiple rate model, a predefined amount of offers is accepted.³⁶⁶ Only licensed banks are allowed to take part in these auctions. Since the CNB opens a one hour window for banks to place their offers, interventions are known when they take place.

³⁶⁴See Galac et al. (2006).

³⁶⁵The last swap auction was held on 3rd February 2000.

³⁶⁶This ensures the exact determination of the intervention amount.

6.3.1 Reaction Function

Ljung-Box Q-statistics of squared intervention data suggest the absence of (G)ARCH process.³⁶⁷ This finding is supported by the analysis of residuals obtained from OLS estimations. The Ljung-Box Q-statistics of squared residuals and ARCH tests clearly negate the presence of (G)ARCH errors. In contrast to the continuous character of the Argentinean intervention data, daily interventions conducted by the CNB occur sporadically. Due to the absence of (G)ARCH process, a technique, which suits the occasional features of intervention data in Croatia is used. In order to disentangle the reasons for Croatian interventions in the foreign exchange market, a friction model as presented above is used. The reaction function takes the following form:

$$\begin{aligned} Int_t^* &= \beta_1 (s_{t-1} - s_{t-5}) + \beta_2 (s_{t-1} - s_{t-1}^{90dm}) + \beta_3 (s_{t-1} - s^{t \text{ arg et}}) \\ &\quad + \beta_4 h_{t-1} + \varepsilon_t, \end{aligned} \quad (129)$$

$$\varepsilon_t | X_t \sim N(0, \sigma^2), \quad (130)$$

$$Int_t = \begin{cases} Int_t^* - \theta^+ & \text{if } Int_t^* > \theta^+ > 0 \\ 0 & \text{if } \theta^+ \geq Int_t^* \geq \theta^- \\ Int_t^* - \theta^- & \text{if } 0 > \theta^- > Int_t^* \end{cases} . \quad (131)$$

In order to examine whether the CNB addressed solely the matter of short-run exchange rate stability, or whether monetary authorities also accounted for the above stated objectives, and how sensible daily interventions responded to these motives (θ^+, θ^-) , the following variables were chosen to explain daily interventions expressed in mill. of EUR.

(i) *Short-Run and Medium-Run Motive:*

Short-term deviations $(s_t - s_{t-4})$ and medium-term trend deviations $(s_t - s_t^{90dm})$, expressed as (difference of logarithm rates) the 4-day exchange rate return, and the aberration of the actual exchange rate from its 90-day moving average respectively, are included (figure 22: "Ex-

³⁶⁷See table 43 in Appendix B.1.1 for detailed information.

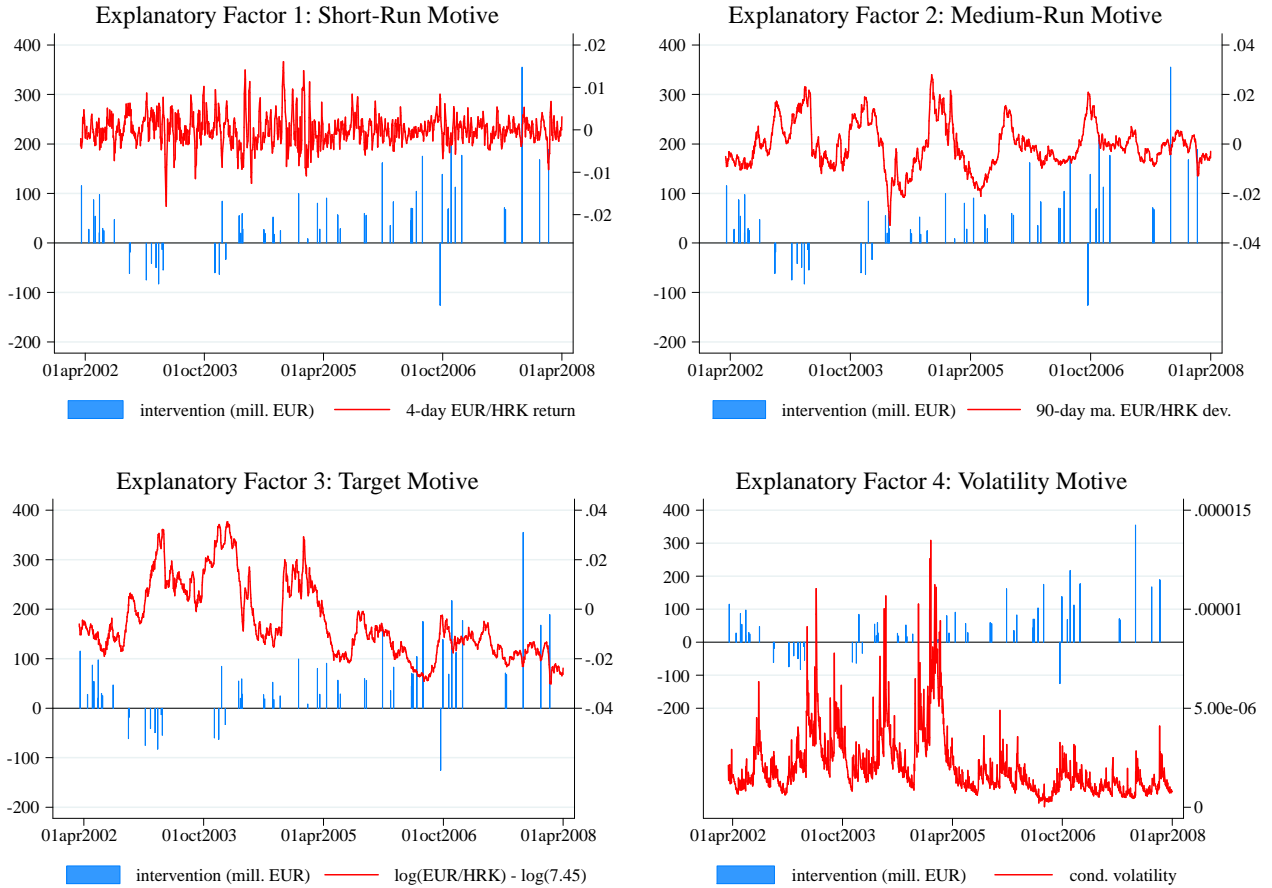


Figure 22: Explanatory Factors for Daily CNB Foreign Exchange Market Interventions between March 2002 and April 2008 (Data source: CNB, own calculation).

planatory Factor 1" and "Explanatory Factor 2"). While the former captures the inherent motive communicated by the CNB, the latter accounts for the possibility that medium-run exchange rate aspects triggered interventions as well. The estimated coefficients β_1 and β_2 should take negative significant values, indicating that the CNB indeed focused on stable short-run exchange rate movements, and also took medium-run exchange rate aspects into account when intervening in the foreign exchange market.

(ii) *Target Motive:*

As mentioned by Vizek (2007), the CNB accounted for an exchange rate band, although no intervention points were officially stated (figure 22: "Explanatory Factor 3"). For this reason, the deviation of the actual logarithm exchange rate from the logarithm of the mid rate

of the suggested band (upper level: 7.6 EUR/HRK, lower level: 7.3 EUR/HRK, mid rate: 7.45 EUR/HRK) is included in the reaction function. In Croatia, the rationale for targeting $(s_t - s^{target})$ an exchange rate level clearly stems from the exchange rate being a nominal anchor for inflationary expectations as discussed above. As is the case for the short-run and medium-run motive, β_3 should be negative and significant at the common levels.

(iii) *Volatility Motive:*

In a similar way, monetary authorities in Croatia emphasized the short-run stability of the EUR/HRK exchange rate, the conditional volatility (h_t) can be assumed to explain foreign exchange interventions (figure 22: "Explanatory Factor 4").³⁶⁸ When accounting for short-run stability, market disorders must be observed carefully. Hence, the CNB could also have supervised market rumors when intervening in the foreign exchange market to stabilize the Kuna exchange rate vis-à-vis the EUR. The estimated daily conditional volatility is used to reflect the degree of disorderly markets.

In contrast to the continuous fashion of Argentinean interventions, the Croatian reaction function is not extended with lagged interventions. Pre-analysis shows that no autocorrelation in daily interventions exist.³⁶⁹ Ljung-Box Q-statistics for daily Croatian interventions show no autocorrelation in the data. As is the case for the Argentinean reaction function, variables accounting for the motive of simply accumulating foreign reserves, and other domestic monetary aspects are neglected. The basic reasons are discussed above. Moreover, the fact that interventions in Croatia are not connected over time (no autocorrelation), suggests that this policy measure has been solely used as an independent monetary policy tool. This is further supported by official statements emphasizing foreign exchange intervention as the main exchange rate policy tool. Estimation is conducted by using heteroskedastic robust estimators. In order to overcome the well-known simultaneity problem, all right hand variables are included with a lag of one period (one day).

³⁶⁸Conditional volatility is estimated by a GARCH(1,1) model, which is further used in the impact analysis.

³⁶⁹See Appendix B.1.2 for correlograms of daily Croatian interventions.

6.3.2 Impact Analysis

The GARCH model to analyze the effect of CNB interventions on EUR/HRK exchange rate dynamics takes the following form:

$$\Delta s_t = \alpha_i \sum_{i=1}^l \Delta s_{t-i} + \frac{\beta_1 Int_{t-1}}{\beta_1^p Int_{t-1}^{fx\ purchase} + \beta_1^s Int_{t-1}^{fx\ sale}} + \gamma_i \sum_{i=1}^{Thurd} D_i + \phi_1 \Delta \% Crobex_t + \varepsilon_t \quad (132)$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, h_t) \quad (133)$$

$$h_t = b + \gamma_i \sum_{i=1}^p \varepsilon_{t-i}^2 + \partial_i \sum_{i=1}^q h_{t-i} + \frac{\beta_2 |Int_{t-1}|}{\beta_2^p |Int_{t-1}^{fx\ purchase}| + \beta_2^s |Int_{t-1}^{fx\ sale}|} + \phi_2 |\Delta \% Crobex_t| \quad (134)$$

This model is basically the same as the one which is applied to Argentinean exchange rate data. For this reason, only differences and important aspects are outlined.

Intervention volumes (total operations and separated transactions) are expressed in mill. EUR, and are included in the mean, and in absolute values in the volatility equation. Since its introduction, the EUR has played a paramount role in Croatia, and replaced the DEM as the primary counter currency. Actually, over 80% of CNB foreign reserves are held in EUR.³⁷⁰ To capture the effect of the contemporaneous impact of disturbances in other asset markets on the exchange rate, daily changes in the closing price of the Croatian stock market index *Crobex* are included.

Concerning the estimation outcomes of the intervention variables, things remain the same in the way that, for interventions to be effective, β_1 should yield significant positive outcomes. For CNB interventions to calm volatility effectively, β_2 is expected to be negative and significant at the common levels. Estimations with separated transactions should yield corresponding results for coefficients $\beta_{1/2}^{p/s}$.

³⁷⁰See CNB (2008).

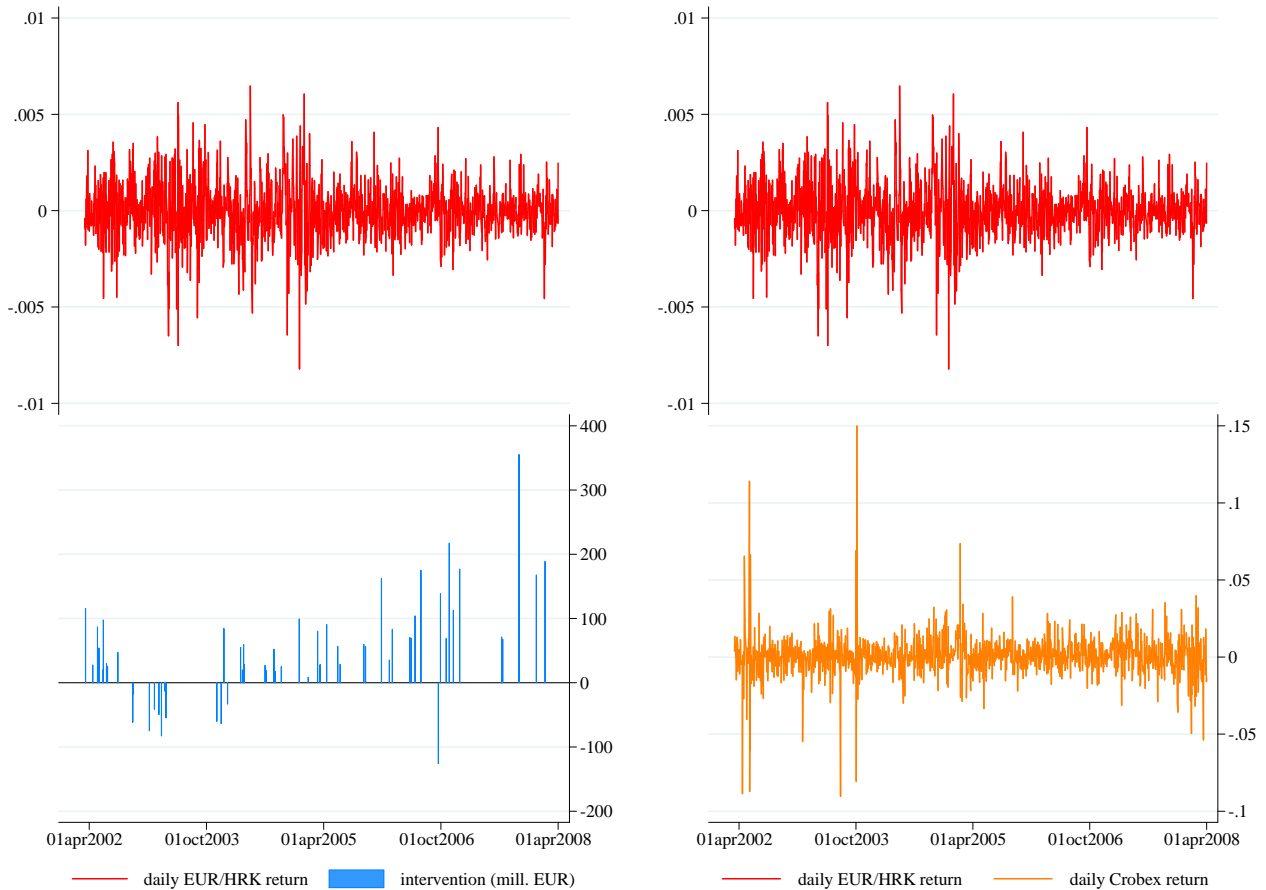


Figure 23: Explanatory Factors for Daily EUR/HRK Exchange Rate Returns between March 2002 and April 2008 (Data source: Bloomberg, CNB, own calculation).

Figure 23 displays the estimation variables of the Croatian impact analysis. To account for autocorrelation, past daily returns are included up to lag l , leading to an $AR(l)$ -GARCH(p, q) process with additional explanatory variables.³⁷¹ It is very important to rule out any correlation in the error term.³⁷² In order to overcome the simultaneity problem, as described above, interventions are included with a lag of one period (one day). Estimation is conducted using QML robust covariances, and standard errors according to Bollerslev and Wooldridge (1992).

³⁷¹See Appendix B.2.1 for detailed information on the autocorrelation of daily exchange rate returns.

³⁷²Similar to Argentinean impact analysis, daily overnight interest rate differentials between Croatian money market rates and Eurozone money market rates are neglected. Preliminary estimations with the interest rate differential as an additional explanatory variable did neither improve the estimation, nor has this variable been significant. Furthermore, the documented poor relevance of the interest rate channel confirms the negligence of daily interest rate differentials for explaining daily exchange rate returns. Similarly, the constant parameter was dropped from the estimation due to insignificance throughout the time.

6.3.3 Data Description

The data used to examine Croatian authorities' interventions in the foreign exchange market is obtained from different sources. Data on foreign exchange interventions, and exchange rate changes is obtained from the CNB. Although intervention data is available since 1996, the data set starts in March 2002. Extending the data set would include the banking crisis in the late 1990s. This in turn would impose additional problems reflected by structural changes on empirical estimation, generating additional noise. Therefore, it is not valuable to extend the data set, though more information could be used. Additionally and more importantly, the CNB has changed the documentation of exchange rate data a few times before 2002.³⁷³ By causing structural breaks, the changes make it impossible to use all available historical data as a consistent time-series. Stock market prices are obtained from Bloomberg data service. As it is the case for Argentinean interventions, only trading days are investigated, leading to the exclusion of weekends and public holidays.

It is important to discuss the chosen exchange rate data due to its documentation by the CNB. As previously mentioned, it is important to examine data reflecting the current situation of the specific exchange rate market where interventions take place. Since the CNB has intervened on the domestic market (Zagreb), exchange rate data from this market must be collected accordingly. In this context, the used exchange rate data obtained from the CNB is the: "*... arithmetic mean of the weighted buying and the weighted selling exchange rate of banks.*," [CNB (2004), as of 23rd February 2010]. However, it is important to know that the posted exchange rate at day t is based on information two days prior to day t . At day $t-1$, the CNB collects all trade information from domestic and foreign banks, natural and legal persons settled at day $t-2$. This information is processed and published for day t . Thus the actual exchange rate data does not represent the actual market rate but the average rate two days before. In this line Galac et al. (2006) state: "*... although the CNB middle FX rate is a very good approximation of the market FX rate, ..., it always represents the market FX rate from two days before...*," [Galac et al. (2006), pp. 8-9]. Hence, it is important to adjust the data set in the way that all data reflect

³⁷³See Galac et al. (2006).

Sample: 1520 Obs.	Mean	Max.	Min.	Unit Root ¹	Obs.
<i>Intervention</i>	52.33	355.2	-125.5	-39.01***	58 (3.8%) ²
<i>Purchases</i>	80.69	355.2	8.502		46 (79.3%) ³
<i>Sales</i>	56.38	125.5	12.9		12 (20.7%) ³
Δs_t	-1.2x10 ⁻⁵	0.0064	-0.0082	-20.13***	1520
$(s_t - s_{t-4})$	-5.7x10 ⁻⁵	0.0160	-0.0180	-8.261***	1520
$(s_t - s_t^{90dm})$	-7.1x10 ⁻⁴	0.0279	-0.0328	-4.7098***	1520
$(s_t - s_t^{arg et})$	-0.0050	0.0353	-0.0302	-2.752*	1520
$\Delta\%Crobex_t$	7.3x10 ⁻⁴	0.1497	-0.0903	-39.96***	1520
h_t	2.0x10 ⁻⁶	1.4x10 ⁻⁵	3.1x10 ⁻⁸	-4.539***	1520

¹ ADF test with a constant; SIC lag. H0 series is nonstationary

² Relative intervention frequency in parentheses - % of days with an intervention

³ Conditional intervention frequency in parentheses - in % of intervention days

*10% - **5% - ***1% significance

Table 20: Data Statistics: Croatia - Global Sample - 3/11/2002 to 4/01/2008.

the information of the same given day. Using the average rate does provide some advantages as described above.

The global Croatian data set is summarized in table 20.³⁷⁴ The sample under investigation covers the period 11th March, 2002 to 1st April, 2008. It can be seen that monetary authorities have used foreign exchange market interventions rarely. In contrast to Argentinean interventions, the CNB only intervened on 58 occasions, which makes up a fraction of 3.8% of all business days during the global sample. The average intervention level accounted for a purchase of 52.33 mill. EUR. The maximum volumes purchased and sold in the market by the CNB amounted to 355.2 mill. EUR, and 125.5 mill. EUR respectively. Similar to the Argentinean experience, the CNB purchased foreign currency in most cases. Thereby, 46 out of 58 (79.3%) interventions were purchase transactions with a mean level of 80.69 mill. EUR. Croatian authorities sold foreign currency on only 12 occasions, making up a fraction of 20.7% of total interventions. Sale transactions were conducted with a mean level of 56.38 mill. EUR. Worth highlighting is the fact that all estimation variables show no unit root process at the common significance levels.

³⁷⁴The presentation focuses on the evolution of intervention data.

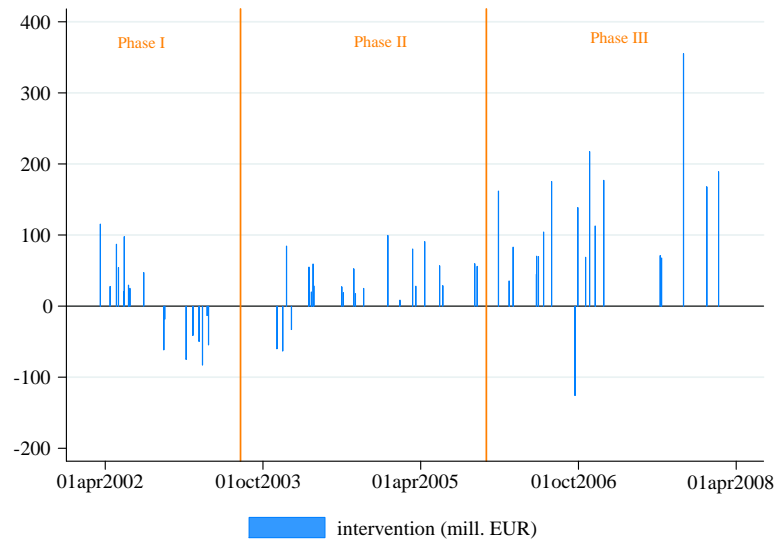


Figure 24: Central Bank Intervention Characteristics in Croatia: Phase I - III (Data source: CNB).

In order to answer the question on time-varying intervention dynamics appropriately, the observation range is divided into three sub-samples (Phase I - III) as a first step. These sub-samples are specified according to different intervention characteristics, which may reflect changing intervention motives, and/or a shift in the impact effect of interventions on exchange rate changes. The breakdown is displayed in figure 24.

Table 21 summarizes phase I, which covers the time period between March 2002 and July 2003, including 336 observations. It can be seen that compared to the global sample, interventions are conducted more frequently in phase I, although the absolute intervention occurrence is still low. Moreover, intervention levels are lower as well. An average CNB intervention amounted to a purchase of 6.46 mill. EUR, and was conducted on 5.0% of total business days. The maximum amount of foreign currency purchased and sold in the market by the CNB accounted for 115.5 mill. EUR, and 82.70 mill. EUR respectively. Furthermore, it is interesting that purchase and sale transactions are similarly used in phase I, although being clearly divided in time. Each transaction type basically accounts for 50% of total interventions. Additionally, the characteristics of both operation types are also similar. As is the case for the global sample, all series are stationary in phase I.

Sample: 336 Obs.	Mean	Max.	Min.	Unit Root ¹	Obs.
<i>Intervention</i>	6.459	115.5	-82.70	-17.67***	17 (5.0%) ²
<i>Purchases</i>	56.09	115.5	20.70		9 (52.9%) ³
<i>Sales</i>	49.37	82.70	12.90		8 (47.1%) ³
Δs_t	3.7×10^{-5}	0.0056	-0.0069	-7.022***	336
$(s_t - s_{t-4})$	1.3×10^{-4}	0.0086	-0.0180	-4.197***	336
$(s_t - s_t^{90dm})$	0.0014	0.0231	-0.0119	-2.251** ⁴	336
$(s_t - s_t^{target})$	9.6×10^{-4}	0.0322	-0.0189	-1.656* ⁴	336
$\Delta \% Crobex_t$	-5.1×10^{-5}	0.1139	-0.0885	-22.31***	336
h_t	2.2×10^{-6}	1.1×10^{-5}	6.2×10^{-7}	-3.029**	336

¹ ADF test with a constant; SIC lag. H0 series is nonstationary;⁴ without a constant

² Relative intervention frequency in parentheses - % of days with an intervention

³ Conditional intervention frequency in parentheses - in % of intervention days

*10% - **5% - ***1% significance

Table 21: Data Statistics: Croatia - Phase I - 3/11/2002 to 7/15/2003.

Phase II describes the time span between July 2003 and November 2005, including 588 observations, and is outlined in table 22. Phase II differs from phase I with respect to the intervention frequency, and the asymmetric use of sale and purchase transactions. Phase II is characterized by a decreasing intervention frequency. Compared to phase I, the CNB intervened on 3.7% of all business days (-1.3%). It is clear that the operation frequency is still low, and not substantially different to phase I. However, as mentioned above, even slight differences can point towards a change in the intervention objectives and intervention effects. More strikingly is the change in the use of purchase and sale transactions. While the average amount of both types did not vary significantly, the CNB clearly focused on purchase operations. In 19 out of 22 intervention days (86.3% compared to 52.9% in phase I) Croatian authorities bought foreign currency with a mean level of 47.18 mill. EUR. In contrast, the Croatian authorities conducted foreign currency sale transactions only on three occasions (13.7% compared to 47.1% in phase I) with a mean level of 52.02 mill. EUR. As required, all series are stationary in phase II.

Phase III spans the period between November 2005 and April 2008, covering 596 observations. While phase I and phase II mainly differ in the intervention frequency and transaction types, phase III shows additional changes in the intervention amounts, as can be seen from table

Sample: 588 Obs.	Mean	Max.	Min.	Unit Root ¹	Obs.
<i>Intervention</i>	33.65	99.50	-63.05	-24.54***	22 (3.7%) ²
<i>Purchases</i>	47.18	99.50	8.502		19 (86.3%) ³
<i>Sales</i>	52.02	63.05	33.00		3 (13.7%) ³
Δs_t	-3.3x10 ⁻⁵	0.0064	-0.0082	-11.80***	588
$(s_t - s_t^{4d})$	-1.3x10 ⁻⁴	0.0160	-0.0126	-6.006***	588
$(s_t - s_t^{90dm})$	-0.0015	0.0279	-0.0328	-2.856*	588
$(s_t - s_t^{target})$	0.0032	0.0353	-0.0216	-2.050** ⁴	588
$\Delta\%Crobex_t$	8.7x10 ⁻⁴	0.1497	-0.0903	-20.80***	588
h_t	2.8x10 ⁻⁶	1.3x10 ⁻⁵	5.9x10 ⁻⁷	-3.016**	588

¹ ADF test with a constant; SIC lag. H0 series is nonstationary;⁴ without a constant

² Relative intervention frequency in parentheses - % of days with an intervention

³ Conditional intervention frequency in parentheses - in % of intervention days

*10% - **5% - ***1% significance

Table 22: Data Statistics: Croatia - Phase II - 7/16/2003 to 11/15/2005

Sample: 596 Obs.	Mean	Max.	Min.	Unit Root ¹	Obs.
<i>Intervention</i>	115.0	355.2	-125.5	-24.64***	19 (3.2%) ²
<i>Purchases</i>	128.4	355.2	35.49		18 (94.7%) ³
<i>Sales</i>	125.5	125.5	125.5		1 (5.3%) ³
Δs_t	-1.9x10 ⁻⁵	0.0043	-0.0045	-13.69***	596
$(s_t - s_{t-4})$	-9.1x10 ⁻⁵	0.0083	-0.0093	-4.874***	596
$(s_t - s_t^{90dm})$	-0.0011	0.0208	-0.0128	-2.945**	596
$(s_t - s_t^{target})$	-0.0165	-0.0024	-0.0301	-2.609*	596
$\Delta\%Crobex_t$	0.0010	0.0397	-0.0536	-20.41***	596
h_t	1.2x10 ⁻⁶	4.9x10 ⁻⁶	3.1x10 ⁻⁸	-5.214***	596

¹ ADF test with a constant; SIC lag. H0 series is nonstationary

² Relative intervention frequency in parentheses - % of days with an intervention

³ Conditional intervention frequency in parentheses - in % of intervention days

*10% - **5% - ***1% significance

Table 23: Data Statistics: Croatia - Phase III - 11/16/2005 to 4/01/2008.

23. First of all, the CNB's tendency to intervene remained the same as in phase II. Monetary authorities stepped into the market in 3.2% of all business days. However, while phases I and II are characterized by similar intervention volumes, phase III shows a remarkable increase in the transaction amounts. Monetary authorities intervened with high volumes in each direction. Thereby, the average transaction volume increased by 172% for foreign currency purchases, and by 141% for foreign currency sales. Moreover, maximum CNB operation volumes accounted for 355.2 mill EUR, and 125.5 mill EUR for purchase and sale operations respectively. Besides the change in intervention volumes, Croatian authorities bought the domestic currency only on one day, leading to a widening intervention asymmetry. All series have no unit root in phase III.

To sum up, the three phases can be characterized as: 1) infrequent, low volume equal-balanced interventions in phase I; 2) infrequent, low volume asymmetric interventions in phase II; 3) infrequent, high volume asymmetric interventions (only one sale transaction) in phase III.

6.4 Estimation Results

6.4.1 Motive Development

6.4.1.1 Global Sample

As indicated by the Ljung-Box Q-statistics, no autocorrelation of Croatian intervention data exists in the global sample.³⁷⁵ For this reason no lagged interventions are included in the reaction function. Table 24 shows global results for the CNB's reaction function. The Wald test show high significance of the explanatory variables, supporting the appropriateness of the model specification.

According to table 24, the CNB seemed to focus on further exchange rate aspects besides the officially stated short-term motive. The coefficients are correctly signed and mostly significant at the common levels. Starting with 4-day exchange rate returns, estimation results confirm the elevated importance of short-run exchange rate movements for the CNB's decision to intervene

³⁷⁵See Appendix B.1.1 for more information.

Explanatory Factors	Coefficient ¹	Std. Error	z-Stat.	Prob.
$(s_{t-1} - s_{t-4})$	-1.7x10⁴*** (-303.8)	2860	-6.01	.000
$(s_{t-1} - s_{t-1}^{90d})$	-2496** (-44.11)	1079	-2.31	.021
$(s_{t-1} - s_{t-1}^{target})$	-3465*** (-61.24)	1104	-3.47	.002
h_{t-1}	2.9x10⁶ (5.2x10⁴)	4.3x10⁶	0.68	.496
θ^+	325.2***	37.30	8.72	.000
θ^-	-410.3***	46.04	-8.91	.000
σ	140.8***	13.52	12.1	.000
Log-Likelihood	-464.49	Wald- $\chi^2(4)$	78.90***	

*10% - **5% - ***1% significance; ¹ marginal effect in brackets

Table 24: Global Estimation Results for the Croatian Reaction Function.

in the foreign exchange market. The coefficient is highly significant, and the marginal effect indicates that the CNB tended to sell (buy) 3.0 mill. EUR in case of a 1% depreciation (appreciation) of the EUR/HRK exchange rate within 4 days. Similarly, medium-term exchange rate developments were monitored by the authorities as well. Although the corresponding coefficient is estimated to be significant at the 5% level, the meaning of the medium-term motive did not equal the importance of the short-term exchange rate aspects. In fact, the CNB tended to sell (buy) 0.4 mill. EUR when the Kuna was above (below) its 90-day exchange rate trend vis-à-vis the EUR. Estimation results for the implicit target level point towards its relevance for daily foreign exchange interventions, and corroborate the outcomes so far. The estimated coefficient is correctly signed as well as significant at the 1% level. Hence, the authorities indeed managed to hold the EUR/HRK exchange rate closely to its suggested target level. However, similar to the role of the medium-run motive, the meaning of the target motive did not equal the short-run exchange rate aspects, although being more relevant compared to the 90-day exchange rate trend. Concerning the conditional volatility, the estimation outcome is neither negative nor significant. Thus, the CNB was not concerned about an appropriate functioning exchange rate market.

As reported in table 24, the threshold variables are highly significant. This strongly supports the use of a friction model as an intervention reaction function for Croatia. Moreover, outcomes for threshold coefficients show some asymmetry of intervention decisions. According to the results ($|\theta^+| < |\theta^-|$), the CNB was more prone to foreign currency purchases compared to sale transactions. In other words, the authorities appear to have reacted stronger in order to depreciate the domestic currency. This may reflect the basic attitude of defending an appreciating currency.

Estimation outcomes of the global sample basically supports the officially stated role of foreign exchange interventions in Croatia. However, it is further interesting to note that additional exchange rate aspects have been monitored by the monetary authorities. Now, it is necessary to proof if intervention motives have changed over time, and so, if results from the global estimation show biased results. Additionally, local estimation results are of vital interest in order to check, whether a change in the intervention strategy is associated to a change in the underlying motives.

6.4.1.2 Phase I-III

Table 25 shows the estimation outcomes of the Croatian reaction function for phases I-III. As indicated by the Ljung-Box Q-statistics, no autocorrelation of Croatian intervention data exists throughout the phases.³⁷⁶ Wald tests for phases I to III indicate high explanatory power of the explanatory variables.

When comparing the development of the suggested intervention purposes it is very interesting that their relevance varied over time. Results of phase I to III show that nearly every motive has been monitored by the authorities when making their decision to intervene in the foreign exchange market.

In phase I, all suggested objectives of central bank actions are correctly signed. The results show that the CNB was mainly concerned about short-term exchange rate movements, and to

³⁷⁶See Appendix B.1.2 for a detailed presentation of the correlograms and structure characteristics.

Explanatory Factors	Phase I		Phase II	
	3/11/2002 - 7/15/2003	7/16/2003 - 11/15/2005	11/16/2005 - 4/01/2008	
	Coefficient ¹		Coefficient ¹	
$(s_{t-1} - s_{t-4})$	-1.4x10 ⁴ *** [-3.75] (-59.65)	-1.3x10 ⁴ *** [-4.40] (-166.7)	-5.4x10 ⁴ *** [-4.04] (-717.3)	
$(s_{t-1} - s_{t-1}^{90d})$	-7628*** [-2.72] (-31.44)	-894.0 [-0.83] (-11.47)	-1935 [-0.34] (-25.68)	
$(s_{t-1} - s_{t-1}^{t \text{ arg et}})$	-1427 [-0.89] (-5.882)	-2451* [-1.90] (-31.45)	-1.1x10 ⁴ [-1.54] (-148)	
h_{t-1}	-2.2x10 ⁷ [-1.62] (-8.9x10 ⁴)	1.3x10 ⁴ [0.00] (175.8)	8.4x10 ⁷ [1.55] (1.1x10 ⁶)	
θ^+	204.5*** [5.68]	226.7*** [6.73]	719.9*** [3.60]	
θ^-	-371.7*** [-4.86]	-348.7*** [-7.06]	-429.9*** [-2.78]	
σ	98.11*** [7.28]	103.1*** [8.77]	193.4*** [6.95]	
Log-Likelihood	-138.96	-190.88	-114.81	
$Wald - \chi^2$	29.17***	49.06***	26.31***	

*10% - **5% - ***1% significance; ¹z-stat. in [] brackets, marginal effect in () brackets

Table 25: Local Estimation Results for the Croatian Reaction Function: Phases I to III.

a lesser extent about the management of medium-term exchange rate aspects between March 2002 and July 2003. This supports the global results. Although both coefficients are highly significant, coefficient β_1 is greater in absolute value compared to β_2 . Moreover, the corresponding marginal effects draw the same conclusions. However, both coefficients indicate lesser relevance as in the global sample. In contrast to the global outcomes, the result for the target motive shows that the authorities did not care about an implicit exchange rate target. Though being negative, coefficient β_3 shows no significance at the common levels. Concerning the aspect of stable foreign exchange market conditions, the CNB, as in the global sample, did not respond to market disorders. Coefficient β_4 is estimated to be insignificant. Interestingly, the intervention thresholds show the same asymmetric pattern as in the global sample. Coefficients θ^+ and θ^- are highly significant but smaller in absolute values, indicating that the underlying potential costs of interventions were minor compared to the global case.

Phase II, is characterized by a clear change in the importance of the underlying intervention motives. Estimation outcomes show a rising relevance of short-term exchange rate movements as indicated by an increasing marginal effect. According to coefficient β_1 , the central bank tended to sell(buy) 1.6 mill. EUR when the Kuna depreciated(appreciated) by 1% during the last 4 days vis-à-vis the EUR. In contrast, medium-term aspects did not trigger CNB interventions significantly. While being of no relevance in phase I, the target motive shows the correct sign, and is estimated to be significant at the 10% level. Hence, the slight appreciation tendency of the Kuna in phase II caused the authorities to pay some attention to the overall exchange rate level. As in the global sample and in phase I, market rumors, reflected by the conditional volatility, played no role for the CNB's decision to intervene. Coefficient β_4 is wrongly signed and still insignificant. Concerning the threshold coefficients, the message remains the same. Asymmetry, and the tendency towards intervening to depreciate the exchange rate is indicated by estimation outcomes of θ^+ and θ^- .

Results of phase III clearly reveal that the central bank was mainly concerned about short-run exchange rate aspects. All coefficients, except β_1 , are estimated to be of no relevance for daily foreign exchange interventions. However, the target motive as well as the volatility motive

display significance values close to the 10% level. Therefore, they should be kept in mind. Nevertheless, coefficient β_1 is highly significant and shows a high absolute value. In the same way, it can be seen that the marginal effect of the short-term motive increases remarkably compared to the global sample, phase I, and phase II. Hence, the CNB tended to sell(buy) 7.2 mill EUR when the exchange rate depreciated(appreciated) by 1% during the last 4 days. Estimation results for threshold effects (θ^+, θ^-) show a change in the decision-making process for interventions. It can be seen that the CNB's political costs associated with purchase transactions rose strongly from phase II to phase III. Although, this is surprising because of higher intervention amounts, the decreasing transaction frequency is responsible for this outcome.

Hence, the comparison of the estimation results of the global and three sub-samples reveals that the purposes to intervene have partially changed over time. Based on all available information, monetary authorities were mainly concerned about short-term exchange rate movements, and to a lesser extent about medium-term aspects and target perspectives. However, when dividing the global sample, the need and the importance of contemplating the full time span separately becomes obvious. Nevertheless, the main intervention motive has been to stabilize short-term exchange rate movements. Throughout the phases, the authorities' political costs of intervening in the exchange market rose. This may reflect concerns on the part of the CNB to trigger speculative attacks against the central bank. Hence, interventions were only used when considered as being essential.

At the beginning, short-term exchange rate aspects, and medium-term exchange rate trend deviations were monitored by the authorities. Thereby, relative low marginal effects show that the authorities held off. In this context, small volume equal-balanced interventions were used to stabilize the exchange rate in the short-term and medium-term.

Compared to the relative weak attention to exchange rate movements in phase I, estimation results of phase II indicate that the authorities took more notice of exchange rate behavior in the short-run, and put a lesser premium on target perspectives. This outcome corresponds to an increase in the intervention volumes. Furthermore, the exchange rate experienced a slight appreciation trend in phase II, causing the CNB to take care of its implicit target level.

Lastly and very strikingly, phase III shows that the short-term motive was of great importance. Mostly, equal-directed interventions with high amounts were used to smooth 4-day exchange rate returns. Other aspects did not play an essential role for daily CNB interventions, although the target and volatility motive must be kept in mind.

6.4.1.3 Rolling Sample

As a final step of examining the development of intervention purposes over time, the CNB reaction function is estimated in a rolling way.³⁷⁷ As discussed earlier, the matter of stationarity is of crucial importance. In the same vein this issue did not occur in the global and phase estimations, the rolling approach is not exposed to this problem.³⁷⁸ As mentioned above, resulting coefficient-series and corresponding z-stats. are smoothed using the HP-Filter.³⁷⁹ Furthermore, the 10% significance band is included as a visual support. Due to the length of the estimation window (sale and purchase transactions must occur in every window), including 720 observations, rolling results do not occur within phase I. It can be seen that nearly all suggested objectives for Croatian authorities to intervene in the exchange rate market have experienced an evolution in the time span under investigation.

Starting with the short-term motive (figure 25: "Short-Run Motive"), rolling results show that the BCRA was thoroughly concerned with short-term exchange rate movements. Throughout the estimation windows, 4-day exchange rate returns are highly significant triggering daily foreign exchange interventions. Estimated z-stats. of coefficient β_1 are always below the lower 10% significance line, and even smaller than -4 . Furthermore, estimated marginal effects increase steadily over time. Being relatively small at the beginning, the importance of short-run exchange rate movements grew until the end of the sample. These results support the outcomes of global and phase estimations, and highlight the short-run motive as being the most important intervention objective of Croatian monetary authorities. Indeed, the officially stated purpose is corroborated by the estimation results.

³⁷⁷The window length was set to 720 days. Estimations with other window sizes did not lead to different outcomes. See Appendix B.1.3 for more information on the sample size.

³⁷⁸See figure 49 in Appendix B.1.3 for the results of rolling unit root tests.

³⁷⁹Figure 50 in Appendix B.1.3 shows unfiltered results of rolling reaction function estimations.

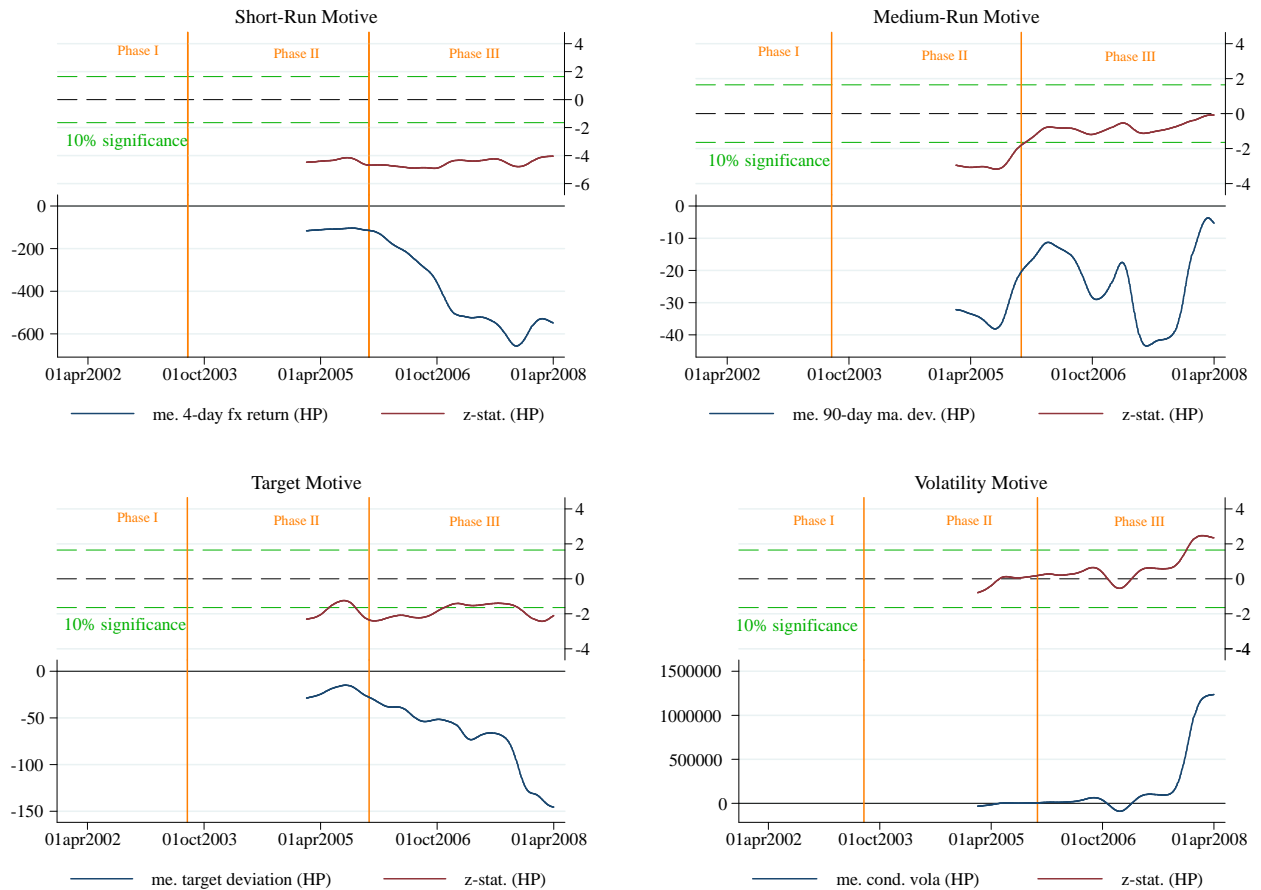


Figure 25: Local Estimation Results for the Croatian Reaction Function: Rolling Estimations (window = 720 days; results are smoothed using HP-Filter [$\lambda = 68000$]).

In contrast, estimation results for medium-run exchange rate aspects reveal that authorities changed their attitude to smooth out deviations from the 90-day exchange rate trend (figure 25: "Medium-Run Motive"). Estimated z-stats are significant until the end of phase II. Beginning with phase III, significance levels move into the lower part of the 10% band, indicating no relevance for interventions. The role of medium-term exchange rate aspects was of minor importance for the authorities. The estimated marginal effects of coefficient β_2 never reach the levels of the short-run motive. In this context, if any, only 0.4 mill. EUR were sold(purchased) by the CNB when the exchange rate was 1% above(below) its 90-day exchange rate trend. As is the case for the short-run motive, rolling results for β_2 support the outcomes of the global and phase estimations.

Rolling outputs for coefficient β_3 show no clear pattern for the meaning of the target motive throughout the estimation windows (figure 25: "Target Motive"). Estimated z-stats. meander around the lower 10% significance line. As is the case for the short-term exchange rate aspects, marginal effects of target deviations as an intervention objective increase steadily in absolute values. However, the levels remain below the marginal effects of the short-run motive. Estimated z-stats. of β_3 show partial significance, pointing towards some explanatory power for daily interventions. This is in line with the purpose of stopping the slight appreciation path of the Kuna in phase II. In the following years the importance of the implicit target has changed several times. This is because the exchange rate has been broadly stable. Estimated z-stats. at the end of the estimation windows indicate significance again, which is due to the fact that the exchange rate jumped below the suggested exchange rate band.³⁸⁰

Results for the conditional volatility (figure 25: "Volatility Motive") broadly support the findings of global and phase estimations. In most estimation windows, the CNB did not response to rising conditional volatility. Until the end of 2007, estimated z-stats. of coefficient β_4 move within the 10% significance band and marginal effects are very small. However, similar to the outcomes presented in table 25, rolling results indicate growing importance of disorderly markets at the end of phase III. These results are somehow surprising since high conditional volatility in phases I and II did not trigger interventions. Instead, relatively low market disorders at the end of phase III caused authorities to intervene in the market. As argued above, stepping off the market in case of high volatility can serve as a warning measure for an appropriate exchange rate market development. Nevertheless, in times of global financial turmoils, authorities may show special vigilance towards volatile market behavior.

Concerning the estimated threshold effects, figure 26 shows the same patterns as indicated by the phase estimations. Both thresholds (θ^+ , θ^-) are highly significant during all estimation windows. Furthermore, the suggested asymmetry of purchase and sale interventions is supported by the rolling outcomes. It can be seen that the difference between θ^+ and θ^- increases over time, and that, until the end, the political costs of intervening were lower for purchase transactions

³⁸⁰It must be noted that, equally to the Argentinean reaction function, the Croatian reaction function states the target band to be constant. However, just like it is suggested that motives change over time, the band could have changed over time, too.

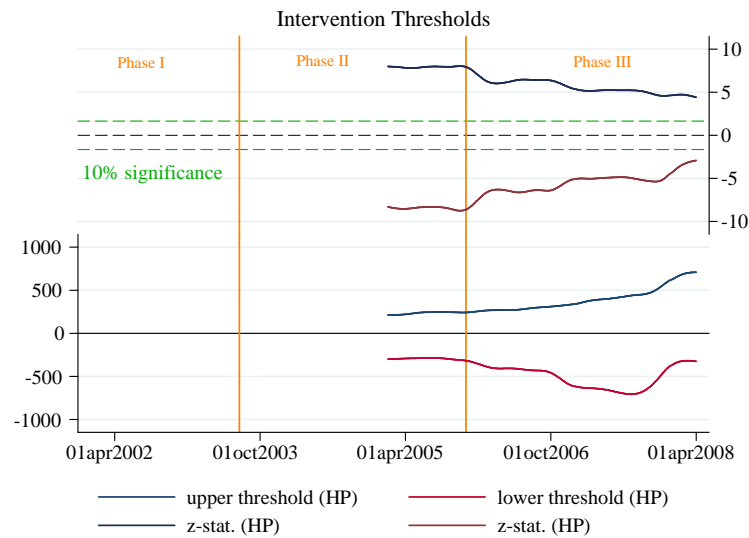


Figure 26: Asymmetric Croatian Intervention Response to the Underlying Motives between March 2002 and April 2008 (window = 720 days; results are smoothed using HP-Filter [$\lambda = 68000$]).

than compared to sale operations. This in turn points towards the CNB's average purpose of defending the EUR/HRK exchange rate, which experienced a slight appreciation during the last years. Furthermore, the fact that no lagged interventions are included in the reaction function (no necessity) supports the independent use of foreign exchange market transactions for managing exchange rate aspects.

To sum up, the analysis of Croatian foreign exchange market interventions clearly shows that a comparison of global and time dependent estimations is of great importance. Not doing so would have lead to wrong conclusions about the CNB's intention to intervene in the foreign exchange market. Nevertheless, the time dependent considerations only reveal some minor modifications in the intervention objectives. Overall, based on the conducted estimations, one can conclude that the short-run motive has caught most of the monetary authorities' attention. Medium-term and exchange rate target perspectives were given less importance. In contrast, volatility issues were only important for daily interventions at the end of phase III. Turning to changes in the intervention strategy, results do not draw a clear picture. Intervention motives cannot be traced back to different intervention strategies directly. For instance, short-run aspects are independent of any changes in the intervention strategy.

6.4.2 Impact Development

6.4.2.1 Global Sample

Table 26 presents global results for the estimated GARCH model, described by equations 132 to 134.³⁸¹ In order to rule out any correlation in the error term, daily exchange rate changes at lag 2 to 5 are included in the mean equation. This leads to insignificant Ljung-Box Q-statistics, revealing no remaining autocorrelation in the error terms. The applied GARCH(1,1) framework models the heteroskedastic feature of daily exchange rate returns appropriately. The combination of $p = 1$, and $q = 1$ yields the lowest SIC values. Results obtained from ARCH tests reveal no remaining (G)ARCH effects.³⁸² The sum γ and ϑ is close to unity, revealing the persistency of volatility shocks.

Estimation outcome for total daily interventions show that foreign exchange transactions conducted by the CNB were not effective in influencing daily exchange rate returns during the whole period from March 2002 to April 2008. The result for Int_{t-1} is positive but insignificant, indicating that the purchase of foreign currency did not cause the exchange rate to depreciate significantly and vice versa. However, when separating interventions into purchase and sale transactions, estimation outcomes reveal asymmetric impact effects. While coefficient β_1^p is insignificant and wrongly signed, coefficient β_1^s has the correct sign and is estimated to be highly significant. In this context, foreign currency purchases did not affect exchange rate changes.

³⁸¹It is important to note that a GARCH model has been applied to daily Croatian intervention data before. Égert and Lang (2005) use different GARCH models to examine the effect of interventions on daily exchange rate returns and its conditional volatility. Overall, their findings support the use of a simple GARCH model as opposed to more sophisticated versions mentioned above. Although the specifications are similar, they are different concerning some very important aspects. First of all, their analysis covers a different time span. Starting in 1996, the authors examine the effectiveness until 2004. This range, however, includes changes in the calculation of the used exchange rate provided by the central bank as mentioned above. Not accounting for these changes may distort the estimation results, leading to spurious conclusions on the impact effects of interventions on exchange rate dynamics. Second of all, the above discussed problem of recorderd exchange rate data is not accounted for. Instead, the authors include previous interventions up to lag eight. Third of all, Égert and Lang (2005) include interest rate differentials in the GARCH model. Interestingly, the corresponding results are not reported. Fourth of all, further dummy variables, which separate interventions in small and large volumes as well as closely followed interventions within a range of five days, are specified by the authors. However, all dummy results were insignificant, leading to no estimation improvements.

³⁸²See Appendix B.2.1 for more information on the choice of the model structure. When separating foreign exchange interventions into purchase and sale transactions in the global and phase estimation, the structure of the GARCH models was not changed. Results for ARCH tests, Ljung-Box Q-statistics, AIC, and SIC do not indicate the need to change the model structure, which supports the appropriateness of the model.

Explanatory Factors	Coefficient	Std. Error	z-Stat.	Prob.
Mean Equation				
Δs_{t-2}	0.273***	0.028	9.821	.000
Δs_{t-3}	0.089***	0.026	3.380	.000
Δs_{t-4}	-0.055*	0.028	-1.938	.052
Δs_{t-5}	-0.067***	0.026	-2.569	.010
Int_{t-1}	4.1x10⁻⁷	1.5x10⁻⁶	0.274	.784
$Purchases_{t-1}$	-8.2x10 ⁻⁸	1.4x10 ⁻⁶	-0.057	.954
$Sales_{t-1}$	-1.3x10 ⁻⁵ ***	4.8x10 ⁻⁶	-2.678	.007
<i>Monday</i>	-1.1x10 ⁻⁴	7.1x10 ⁻⁵	-1.522	.128
<i>Tuesday</i>	1.2x10 ⁻⁴ *	6.9x10 ⁻⁵	1.776	.076
<i>Wednesday</i>	5.8x10 ⁻⁶	6.7x10 ⁻⁵	0.086	.932
<i>Thursday</i>	-1.4x10 ⁻⁴ **	6.7x10 ⁻⁵	-2.115	.034
$\Delta\%Crobex_t$	-1.1x10 ⁻⁴	0.002	-0.045	.964
Volatility Equation				
b	2.2x10 ⁻⁸	3.7x10 ⁻⁸	0.587	.557
ε_{t-1}^2	0.082***	0.015	5.596	.000
h_{t-1}	0.905***	0.018	50.393	.000
$|Int_{t-1}|$	-1.4x10⁻⁹	2.3x10⁻⁹	-0.604	.546
$|Purchases_{t-1}|$	-1.5x10 ⁻⁹	2.3x10 ⁻⁹	-0.625	.532
$|Sales_{t-1}|$	3.3x10 ⁻⁹	1.3x10 ⁻⁸	0.259	.796
$|\Delta\%Crobex_t|$	1.5x10 ⁻⁶	1.9x10 ⁻⁶	0.784	.433
Log-Likelihood	7935	ARCH Test:	LM-stat.	4.931
		$k = 3$	F-stat.	1.645

*10% - **5% - ***1% significance

Table 26: Global Estimation Results for the Croatian Impact Analysis

In contrast, sale operations did influence daily exchange rate returns in the suggested way. Concerning the economic impact, the sale of 100 mill. EUR tended to appreciate the domestic currency by 0.13%. While this is not an outstanding effect in total terms, it is of economic relevance when compared to the average daily exchange rate return (-0.0012%). Thus, the average and maximum amount of foreign currency sold by the CNB appreciated the Kuna by 0.073%, and 0.162% respectively. The difference in the impact of purchase and sale interventions might stem from the above mentioned problem of continuous interventions. Although the CNB conducted both intervention types infrequently, the foreign exchange market witnessed more foreign currency purchases. In this way, foreign currency sales, which were conducted on only 12 occasions, making up a fraction of only 20.7% of total interventions, surprised market members causing them to adjust their foreign currency positions.

In contrast, the impact of interventions on the conditional volatility is of no relevance. Total operations show a very low negative signed result, which is insignificant. Moreover, separated intervention types are both insignificant, and confirm the poor explanatory content of daily CNB transactions for the conditional volatility. As discussed above, the fact that coefficients $\beta_2^{(p,s)}$ are insignificant shows that the outcomes in the mean equation are not biased, which supports the reliability of the estimation results.³⁸³

Turning to control variables, results for day of the week dummies show some seasonality on Tuesdays and Thursdays. Both days exerted a significant influence on daily exchange rate changes. Stock market prices did not influence the exchange rate at all. Results for $\phi_{1/2}$ are neither in the mean nor in the volatility equation estimated to be significant at the common levels.

Now, it is of interest, whether different intervention strategies had different impact effects, and whether the power of foreign exchange market interventions has varied over time.

³⁸³Reestimation without intervention variables in the volatility equation left the parameter in the mean equation unchanged.

6.4.2.2 Phase I-III

GARCH model estimation results for phases I-III are presented in table 27. The optimal AR-GARCH framework modeling the autocorrelation and heteroskedastic feature of daily exchange rate returns varies between the different phases. All chosen framework structures lead to insignificant Ljung-Box Q-statistics and ARCH tests, revealing no remaining autocorrelation in the error terms and squared error terms.³⁸⁴ The discussion of the results obtained from phases I-III focuses on the impact of interventions.

Most interestingly, and in contrast to the results obtained from the global sample, phase estimation results show that interventions, both purchase and sale transactions, were effective. However, foreign currency sales exerted a greater impact on daily exchange rate movements. These findings and the results that interventions did not affect the conditional volatility support the effectiveness of Croatian interventions in influencing daily exchange rate returns. Estimation results further show that stock market prices had a significant influence on the conditional volatility, which changed over time. Due to this significance, results in the mean equation may be biased. Interestingly, seasonality patterns were estimated not to explain daily exchange rate returns reliably.

In contrast to global results, interventions in phase I are estimated to influence the exchange rate in the suggested way. The highly significant result for coefficient β_1 shows that foreign currency transactions possessed substantial explanatory content for daily exchange rate returns. At the same time, slight asymmetric intervention effects are shown by estimation outputs for separated purchase and sale transactions. As is the case for global results, sale interventions are estimated to be more powerful compared to purchase transactions, although the difference is low. While the average(maximum) amount of foreign currency purchased in the market tended to depreciate the exchange rate by 0.05%(0.11%), the average (maximum) volume of foreign currency sales tended to appreciate the domestic currency by 0.07%(0.12%). Compared to the mean daily exchange rate change of 0.004% in phase I, the estimated impacts are of special

³⁸⁴See Appendix B.2.1 for more information on the model choice.

	Phase I	Phase II	Phase III
Explanatory Factors	10/02/2001 - 7/15/2003	7/16/2003 - 11/15/2005	11/16/2005 - 4/01/2008
GARCH Specific.	(1,1)	(2,2)	(1,1)
Mean Equation			
Δs_{t-1}	-0.271*** [-4.698]	0.149*** [3.436]	
Δs_{t-2}	0.379*** [7.031]	0.293*** [7.177]	0.173*** [3.924]
Δs_{t-3}	0.334*** [5.365]		
Δs_{t-4}		-0.121*** [-2.865]	
Δs_{t-5}	-0.126** [-2.252]		-0.114*** [-2.897]
Δs_{t-9}		-0.103*** [-2.663]	
Int_{t-1}	1.1x10⁻⁵ [3.471]	1.3x10⁻⁵ [2.458]	-1.2x10⁻⁶ [-1.075]
$Purchases_{t-1}$	<i>9.6x10⁻⁶</i> [2.672]	<i>5.8x10⁻⁶</i> [0.906]	<i>-4.4x10⁻⁷</i> [-0.373]
$Sales_{t-1}$	<i>-1.5x10⁻⁵</i> [-2.199]	<i>-3.3x10⁻⁵</i> [-2.309]	<i>-3.7x10⁻⁶</i> [-3.682]
<i>Monday</i>	-2.0x10 ⁻⁴ [-1.397]	-7.5x10 ⁻⁵ [-0.569]	-7.5x10 ⁻⁵ [-0.892]
<i>Tuesday</i>	6.6x10 ⁻⁵ [0.355]	4.1x10 ⁻⁵ [0.289]	1.5x10 ⁻⁴ * [1.751]
<i>Wednesday</i>	-6.8x10 ⁻⁵ [-0.416]	1.5x10 ⁻⁴ [1.085]	-3.2x10 ⁻⁵ [-0.434]
<i>Thursday</i>	2.4x10 ⁻⁵ [0.145]	-1.6x10 ⁻⁴ [-1.374]	-2.4x10 ⁻⁴ [-2.674]
$\Delta\%Crobex_t$	-0.001 [-0.349]	-1.0x10 ⁻⁴ [-0.200]	0.003 [0.795]
Volatility Equation			
$|Int_{t-1}|$	2.5x10⁻⁹ [0.164]	-1.0x10⁻⁸ [-1.243]	1.2x10⁻¹⁰ [0.040]
$|Purchases_{t-1}|$	<i>2.0x10⁻⁹</i> [0.128]	<i>-5.5x10⁻⁹</i> [-0.245]	<i>5.8x10⁻¹¹</i> [0.019]
$|Sales_{t-1}|$	<i>2.8x10⁻⁹</i> [0.076]	<i>-2.0x10⁻⁸</i> [-0.576]	<i>2.6x10⁻⁸</i> [0.810]
$\Delta\%Crobex_t$	-3.2x10 ⁻⁶ [-1.054]	-3.3x10 ⁻⁶ *** [-2.659]	8.3x10 ⁻⁶ ** [2.073]
Log-Likelihood	1705	2949	3268
ARCH Test: $k = 3$			
LM-stat.	0.639	2.083	0.431
F-stat.	0.211	0.692	0.143

*10% - **5% - ***1% significance; z-stat. in brackets

Table 27: Local Estimation Results for the Croatian Impact Analysis: Phases I to III

importance. These positive findings are supported by the insignificance of coefficient(s) $\beta_2^{(p,s)}$, stating that interventions did not affect the conditional volatility.

Intervention effects change slightly in phase II. The result for total transactions in the mean equation, which is slightly above the outcome of phase I, still carries the correct sign, and is estimated to be significant at the 5% level. However, the effect is clearly lead by sale transactions. While coefficient β_1^s is highly significant, the outcome of β_1^p is not of statistical relevance. In addition, CNB sale transactions had a stronger effect on exchange rate changes compared to phase I, and compared to the global estimation. Hence, intervention asymmetries increased remarkably. The average and maximum amount of foreign currency sold by the CNB caused the Kuna to appreciate by 0.17% and 0.21%. Again, this is a sizable effect when compared to the mean daily exchange rate change of -0.0033% in phase II. In contrast to results for the mean equation, interventions remain to be of no relevance for the conditional volatility. Coefficient(s) $\beta_2^{(p,s)}$ are estimated to be insignificant and of no economic importance.

While total intervention effects are correctly signed and significant in phase I and phase II, results for phase III show that the power of interventions to influence daily exchange rate changes declined. The outcome of β_1 is wrongly signed and insignificant. Again, results for both transaction types reveal strong asymmetric effects. While the authorities' foreign currency purchases were of no importance for daily exchange rate developments, the CNB's foreign currency sale caused the exchange rate to appreciate significantly. However, the sale transaction effect declined. In this context, the foreign currency sale intervention conducted in September 2006 appreciated the exchange rate by 0.046%. In the same way, CNB interventions had no explanatory content for the conditional volatility so far; no foreign currency transaction exerted a stable effect in phase III. Coefficients $\beta_2^{(p,s)}$ are estimated to be insignificant at the common levels.

Results of table 27 reveal again the importance of a time dependent consideration of intervention effects. Thereby, global results are challenged by phase estimations, and thus, draw a different, more accurate picture. The estimated impact effects are very interesting when read against the background of the different intervention strategies. Thereby, it is important

to distinguish between purchase and sale transactions. Concerning the former operation type, interventions were most effective when conducted infrequently, and with small volumes (phase I). A change to higher intervention amounts, which were used less frequently was linked to insignificant estimation results. With respect to the previously stated assumption that infrequent interventions perform better compared to frequently used transactions, these results are surprising. Concerning the latter transaction type, foreign currency sales exerted the strongest effect on daily exchange rate returns when being conducted on rare occasions.³⁸⁵

6.4.2.3 Rolling Sample

Figure 27 presents results for the overall intervention variable obtained from a rolling GARCH estimation.³⁸⁶ Since the focus is on the time-varying nature of foreign exchange market transactions, only coefficients for interventions are considered when presenting results of the rolling estimations. Each coefficient-series and the associated z-stats. are displayed together with the 10% significance band as a visual support. As mentioned above, estimation outcomes are smoothed using the HP-Filter.³⁸⁷

Left panels of figure 27 display interesting results which are in line with the outcomes of phase estimations.³⁸⁸ It is shown that the impact of interventions on daily exchange rate returns is positive in most estimation windows, indicating an appreciation of the Kuna when the CNB sold foreign currency and vice versa. In this context, coefficient β_1 is positive until the end of

³⁸⁵The estimation outcomes of Égert and Lang (2005) are basically in line with the results obtained above. With the problems of their used specification in mind, results show that the purchase of foreign currency caused the exchange rate to appreciate and vice versa within two days. This outcome clearly reflects the well-known problem of simultaneity, and the fact that the specific exchange rate documentation of the CNB has not been appropriately accounted for. Higher lagged interventions show the correct impact. The influence of exchange market actions on the conditional volatility is estimated to be insignificant, which supports my results. However, the authors do not find similar asymmetric impact effects of purchase and sale transactions. The reasons for the differences can be explained by the extended time samples and specifications.

³⁸⁶The lag structure of the mean equation was set to AR(5) with one additional intervention at lag 9 to capture possible autocorrelation. The structure of the volatility equation was set to a GARCH(1,1) to follow the idea of a parsimonious specification. This choice is further justified by the optimal GARCH structures obtained from phase estimations. The window length was set to 720 days to match the window size of rolling reaction function estimations. Other window sizes did not lead to different outcomes. For more information see Appendix B.2.2.

³⁸⁷Figure 57 in Appendix B.2.2 shows unfiltered results of the rolling impact analysis.

³⁸⁸Rolling estimation results for purchase and sale transactions were not conducted due to very infrequent sale transactions within the estimation windows.

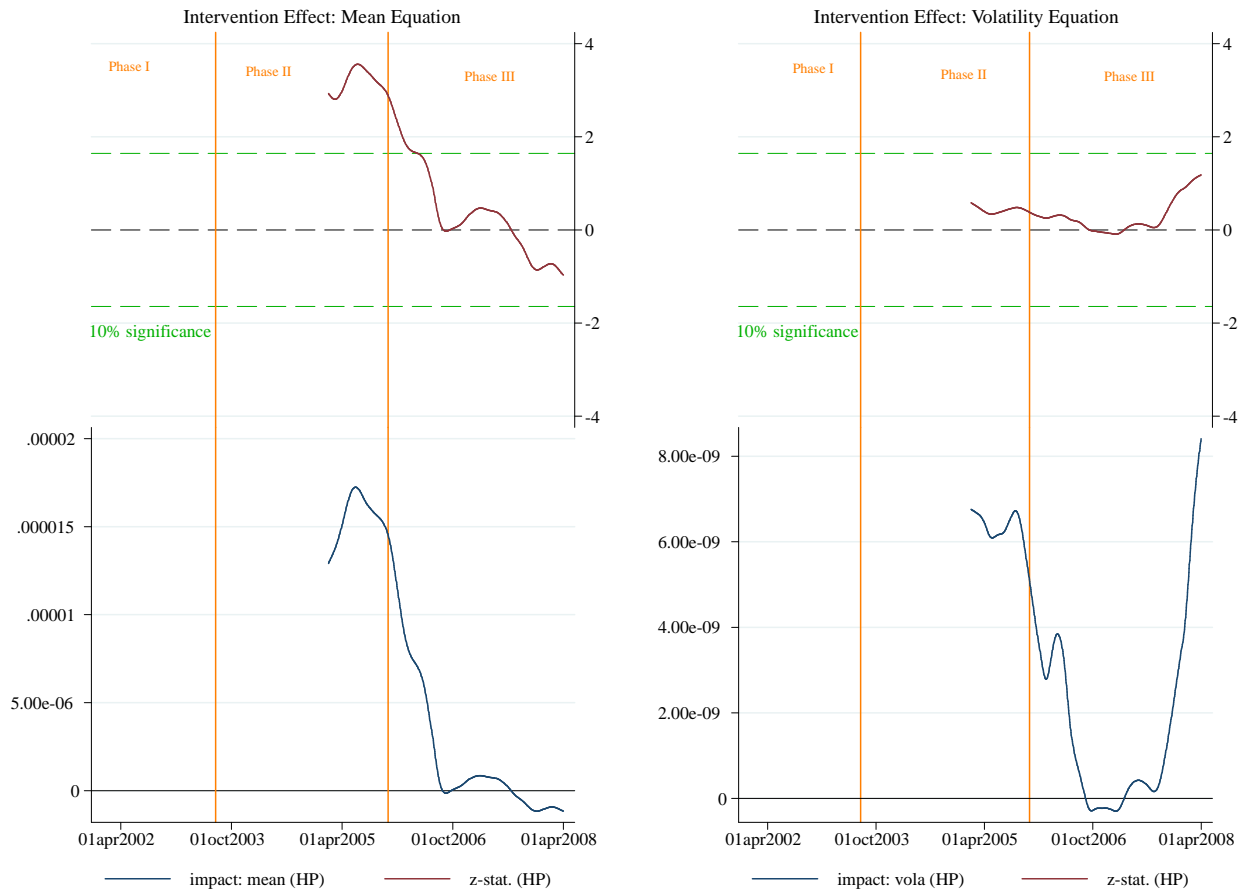


Figure 27: Local Estimation Results for the Croatian Impact Analysis: Rolling Estimations (window = 720 days; results are smoothed using HP-Filter [$\lambda = 68000$]).

2007. Meanwhile, estimated z-stats. show high significance in phase II, and in the early phase III, moving into the 10% significance band in 2006. Besides these positive overall findings, it can be seen that the estimation results for coefficient β_1 change over time. Showing highest values at the beginning of the sample, intervention effects in the mean equation decline in time. This reflects exactly the results obtained from phase I-III. Being significant and correctly signed at the beginning, the effect of overall interventions diminished. Furthermore, as is the case in the global and phase estimations, absolute effects are rather small in the overall view but important relative to exchange rate changes.

In case of conditional volatility, right panels of figure 27 reveal no explicit effects. Basically, global and phase estimation results are supported. Estimated coefficient β_2 displays a v-shape,

and shows very small levels. More importantly, during the complete time span, effects on the conditional volatility are estimated to be insignificant at the common levels. Z-stats. are closely to the zero line. These results show that CNB interventions did not have an impact on the conditional volatility of daily EUR/HRK exchange rate returns.

To sum up, the impact analysis for daily Croatian foreign exchange transactions shows that authorities were able to influence the exchange rate significantly at least between 2002 and 2006. However, results also give evidence that the conditional volatility was driven by other factors than daily foreign currency transactions, which supports the results for the exchange rate returns. Moreover, time dependent estimations show that impact effects changed over time, revealing the importance of the rolling analysis. From these results, the question arises whether interventions have been successful. Against the background of the CNB's emphasis on the short-run motive as well as trend and target perspectives rather than volatility aspects, monetary authorities indeed succeeded in managing daily exchange rates. The fact that the conditional volatility was not influenced at all cannot be used to pronounce interventions were ineffective. Turning to the relationship between intervention effects and operation strategies, it can be stated that a shift in the characteristics of foreign exchange transactions was associated with a shift in the explanatory content of interventions. Surprisingly, the development of purchase and sale effects was different. While foreign currency sales had the strongest impact when conducted sporadically and with greater volumes, purchase transactions influenced the exchange rate significantly when occurring frequently and with smaller volumes.

6.5 Economic Background

6.5.1 Explanation of Intervention Motives

Starting with the development of intervention motives, it is of interest whether the main motives of Croatian interventions discerned in the preceding sections can be explained by economic and monetary policy fundamentals. Thus, although it is clear that the CNB clearly emphasized the short-run motive, the questions are:

(i) *Why Did the CNB Chiefly Intervene in Response to Short-Term Exchange Rate Movements?*

Croatia is characterized by a high degree of financial dollarization (euroization).³⁸⁹ This fact basically explains, why the CNB was heavily interested in maintaining exchange rate stability. More precisely, the balance-sheet structure of the domestic financial system explains the crucial importance of the short-run motive. Table 28 gives detailed information on the asset and liability characteristics of Croatian commercial banks.³⁹⁰

The balance-sheet total accounted for a large sum in economic terms. Its size grew from 80% of Croatian GDP in 2002, to 106% of GDP in 2008. This reflects the growing importance of the financial system in Croatia. Moreover, a large part of assets and liabilities were denominated in other currencies. On average, 26% of total assets, and 55% of total liabilities were denominated in foreign currency. As discussed above, short-term exchange rate movements work in two different directions. On the one hand, short-run appreciation affects the asset side negatively, and may trigger additional unfavorable foreign funding. On the other hand, short-term depreciation boosts the debt level. A detailed look at the balance-sheet structure reveals some interesting facts.

The asset structure is dominated by claims on enterprises and households. Thereby, Kuna loans made up the biggest part of claims in both sectors. In contrast to households, enterprises used loans denominated in foreign currency as well. The reason being that besides all possible advantages of foreign currency loans, enterprises have a greater ability to hedge against potential currency risks compared to private people. Furthermore, banks offered foreign currency loans for certain import purposes.³⁹¹ However, due to the fact that domestic payments are usually

³⁸⁹At this point, I will not discuss the reasons for financial dollarization explicitly. However, Basso et al. (2007) develop a model to explain the determinants of financial dollarization. According to their results, based on Croatian data, the role of foreign banks, which facilitates the access to foreign funds is one of the main determinants of financial dollarization. Additionally, Stix (2008) argues that people's age is an important aspects as well. In this context, older people are more likely to hold foreign currencies due to bad experiences in the past. Mishikin (2007) states that in case of financial dollarization it is of major importance to focus on financial stability rather than stabilizing output. This is exactly what authorities tried to do when intervening in response to short-term exchange rate movements.

³⁹⁰Table 28 displays main items which is why they do not necessarily sum up to unity.

³⁹¹See Kraft (2003).

	2002	2003	2004	2005	2006	2007	2008 ¹
Balance-Sheet Total (% GDP)	80	86	92	97	112	107	106 ²
FX den. Assets (% Total Ass.)	29	29	31	28	25	23	17.6
FX den. Liabilities (% Total Liab.)	68	65	60	55	48	46	47
<i>Asset Structure</i> ³							
	% of Total Assets						
Foreign Assets	15.7	18.1	19.3	13.9	13.2	13.8	11.9
Claims against Government ⁴	13.2	11.0	9.3	11.3	9.3	8.6	8.8
o/w Kuna Loans	2.4	2.8	1.7	1.8	2.7	2.4	2.5
o/w FX Loans	0.9	0.8	1.6	2.7	1.6	1.3	1.7
Claims against Enterprises	31.2	27.6	26.0	26.2	27.9	27.4	28.1
o/w Kuna Loans	22.2	20.4	19.0	19.2	21.6	22.0	22.6
o/w FX Loans	6.2	4.9	4.7	5.1	4.5	3.6	3.8
Claims against Households	26.0	28.2	28.9	30.8	32.0	33.6	35.0
o/w Kuna Loans	25.9	28.1	28.8	30.6	31.9	33.5	34.9
o/w FX Loans	0.1	0.1	0.1	0.2	0.1	0.1	0.1
	% of Total Loans						
Kuna Loans	18.6	25.1	19.3	18.5	28.3	38.6	38.7
Kuna Loans Indexed to FX	68.2	63.8	68.8	67.4	61.0	52.6	52.5
Fx Loans	13.2	11.2	11.9	14.1	10.7	8.8	8.8
<i>Liability Structure</i> ⁶							
	% of Total Liabilities						
Foreign Liabilities	21.1	25.6	27.1	26.3	25.4	19.4	20.3
Deposits of Government ⁴	3.7	2.7	3.0	3.6	3.6	4.0	4.2
o/w Kuna	0.8	0.5	0.4	0.6	0.4	0.4	0.7
o/w FX ⁵	0.3	0.1	0.1	0.1	0.2	0.2	0.2
Deposits of Enterprises	16.0	15.9	14.9	13.4	14.4	16.1	14.0
o/w Kuna	10.4	10.4	9.2	8.5	10.5	11.3	9.6
o/w FX ⁵	5.6	5.5	5.7	4.9	3.9	4.7	4.4
Deposits of Households	44.6	41.4	39.3	38.9	37.6	37.0	37.0
o/w Kuna	7.3	8.4	9.0	10.3	12.6	12.3	12.3
o/w FX ⁵	37.3	33.0	30.3	28.6	25.0	24.7	24.7
	% of Total Deposits						
Kuna Deposits	23.5	25	25.8	26.9	35.4	42.9	41.5
Kuna Deposits Indexed to FX	5.9	7.4	7	10.8	10.9	4.7	4.3
Fx Deposits	70.6	67.6	67.2	62.3	53.7	52.5	54.2

¹Until April 2008; ²end of the year; ³excluding reserves with the CNB, claims against other banking institutions, and non-banking financial institutions; ⁴including funds; ⁵time/savings deposits; ⁶Excluding credits from central bank, restricted and blocked deposits, capital accounts

Table 28: Main Balance-Sheet Characteristics of the Croatian Banking System between 2002 and 2008 (Data source: CNB, own calculations).

conducted in Kuna, foreign currency loans were fairly stable at low levels.³⁹² Compared to the enormous relative size of the central bank's foreign assets (figure 19), such positions did not account for an equally large portion of total assets in the banking sector. However, the fact that a significant part of all Kuna loans have been indexed to foreign currency, emphasizes the importance of stable short-run exchange rate movements. From 2002 to 2008, more than 50% of all Kuna loans were indexed to foreign currency.

This indexation can be explained by the liability structure of the banks' balance-sheet. As can be seen in table 28, a large part of total liabilities were denominated in foreign currency. This reflects the typical reason for asset side indexation, namely to minimize exchange rate risks from liability dollarization.³⁹³ In this case, exchange rate risks are transferred to borrowers, resulting in a higher risk of credit defaults in case of a sharp depreciations.³⁹⁴ The largest part of all liabilities were foreign liabilities and deposits of households, making up more than 50% between 2002 to 2008. It is very interesting that the main part of household deposits are held in foreign currency. Thus, it seems that the Kuna is not used as a store of value, but partially as a means of payment and as a unit of account. Hence, different currencies are used for different functions of money.³⁹⁵

While the above discussion focuses on the balance-sheet structure of the domestic banking system, another aspect is also of major importance in the context of the short-run intervention motive. External debt positions of different sectors and, more particularly, of the government is an additional determinant for the CNB to react to excessive short-term exchange rate move-

³⁹²As reported by Kraft (2003) foreign currency cannot be used in common store payments or bank account transactions. However, luxury goods transactions, like cars or apartment sales were sometimes conducted through foreign currency transactions.

³⁹³In 2006, the CNB has published guidelines for the use of foreign currency induced credit risks. The authorities state: *"Currency induced credit risk also represents an integral part of credit risk, ... The main reason for an almost general acceptance of a currency clause ... was an intention to provide protection for creditors ... if a domestic currency depreciated significantly, currency induced credit risk would occur for loans granted in foreign currency ... A currency clause, in this case, does not provide a perfect hedge for a bank, but it rather depends on the currency structure of assets and liabilities ..."*, [CNB (2006c) p.1].

³⁹⁴Unfortunately, no data is available which break down the indexed Kuna loans. This would render more insights into the distribution of exchange rate exposures. Šošić and Kraft (2006) make a guess that about 70% of Kuna loans granted to enterprises are indexed to foreign currency.

³⁹⁵Dvorsky et al. (2008) analyze the question, why holding foreign currency is widespread in Croatia. Based on results obtained from a survey, they conclude that the motive to hold large amounts of EUR can be traced back to the EUR's good reputation being a stable and trustworthy currency. This supports the role of the EUR as a store of value and as a means of precaution.

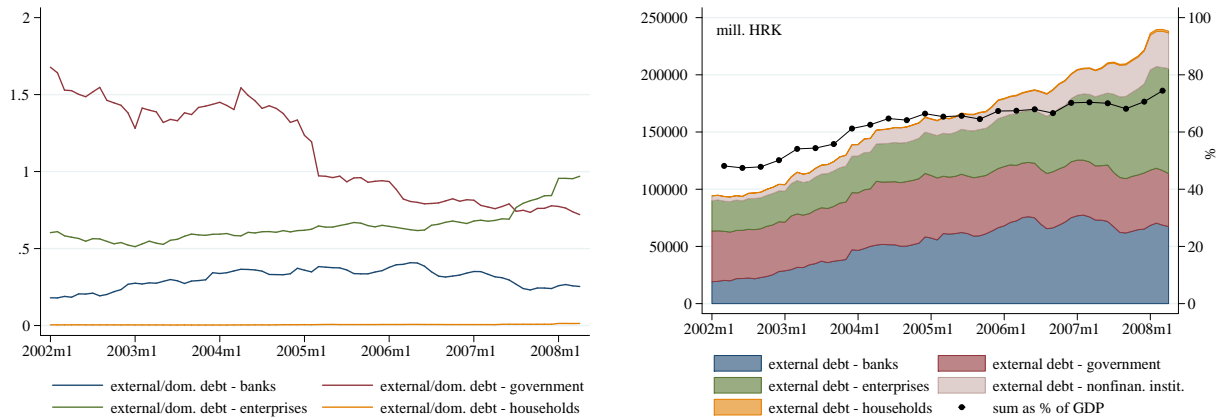


Figure 28: Development of Main External Debt Items, and their Economic Relevance in Croatia between 2002 and 2008 (Data source: CNB, IMF-IFS, own calculations).

ments.³⁹⁶ As can be seen in the left panel of figure 28, external debt made up a significant part, except for households, in the sectors' debt positions. The ratio of external debt to domestic debt (total liabilities minus foreign liabilities) varies between 20% to 40% for the banking system, reflecting the force of the measures implemented by the CNB (e.g. marginal reserve requirements on foreign funding) in order to restrict external debt growth. Concerning enterprises, the ratio reveals a rising level of external funding compared to domestic borrowing. Basically, foreign funding was facilitated by the structure of the domestic banking system, which is dominated by foreign-owned banks.³⁹⁷ Of particular interest is the external debt to domestic debt ratio for the government. Exceeding domestic debt by nearly 50%, the ratio fell under unity in early 2005, declining slightly in the following years. However, a large part of total government debt is still settled abroad. Hence, also the government is influenced by euroization, making short-term exchange rate stability even more important. While external debt plays a vital role in total funding, its importance becomes even more evident when considered in economic terms. As can be seen from the right panel of figure 28, main aggregated external debt items increased from about 55% in 2002 to nearly 80% of GDP in early 2008.³⁹⁸

³⁹⁶ See CNB (2006b) for more detailed information on external debt in Croatia.

³⁹⁷ Between 2002 and 2008, foreign-owned banks and domestic banks each made up about 50% of total banks. However, foreign-owned banks possessed about 90% of total assets in the banking system. See CNB (2008).

³⁹⁸ It is important to add that net external debt, defined as external debt reduced by the international reserves and banks' foreign assets, grew steadily from 17% of GDP in the first quarter of 2002, to 44% of GDP in the

(ii) *Why Did the CNB Intervene in Response to Medium-Term Trend Deviations, even though its Meaning Was of Lesser Importance?*

Although the importance of exchange rate movements for Croatia is mainly based on balance-sheet structures and the role of external debt, the stability of the Kuna also becomes important in the context of Croatia's foreign trade position. As can be seen from the left panels of figure 29, a substantial fraction of the domestic economy grounds on foreign trade. For this reason a stable medium-run foreign value of the Kuna is essential, as discussed above. The stability of the exchange rate helps to enhance the predictability of trade prices, and minimizes risks of exogenous price changes (non-trade price changes). More than 75% of Croatia's trade is conducted via the EUR.³⁹⁹ This highlights the EUR/HRK exchange rate in a real economy term, besides the above presented relevance for financial positions. Exports and imports have increased since 2002 by about 50%, and by 75% respectively. Thereby, Croatia has experienced a continuous current account deficit. This deficit stems chiefly from the import dependency of raw material.⁴⁰⁰ Although the tourism sector (services) had a positive influence on the current account throughout the years, the trade deficit, and the negative income balance caused a continuous current account deficit. It is clear that the deficit has been financed by the large growth in external debts. The relative size of foreign trade, measured as the relation of exports and imports of goods and services to GDP $\left(\frac{\text{Export} + \text{Import}}{GDP} \right)$ accounted for about 50 % of Croatia's economy during the time span under investigation.

What is clear, when taking a look at the upper right panel of figure 29, is that the exchange rate, between 2002 and 2005, experienced relative large swings compared to more recent times. Since 2005, Croatia has had a stable medium-term exchange rate. This exchange rate development justifies the negligence of the medium-run motive in phase II and III. Interestingly, the real effective exchange rate has appreciated by nearly 20% since 2002.⁴⁰¹ The real rate against the EUR, which accounts for about 75% of foreign trade, has been fairly stable, showing only

first quarter of 2008. Hence, the intention to restrict (net) external debt growth, although valid for some sectors, has been of no avail in the overall context. Data source: CNB, own calculation.

³⁹⁹See CNB (2008).

⁴⁰⁰Data is seasonally adjusted, using four period moving averages.

⁴⁰¹This path is mainly driven by the extreme appreciation of the real exchange rate vis-à-vis the US\$. US\$ transactions make up about 25% of foreign trade. Data source: CNB.

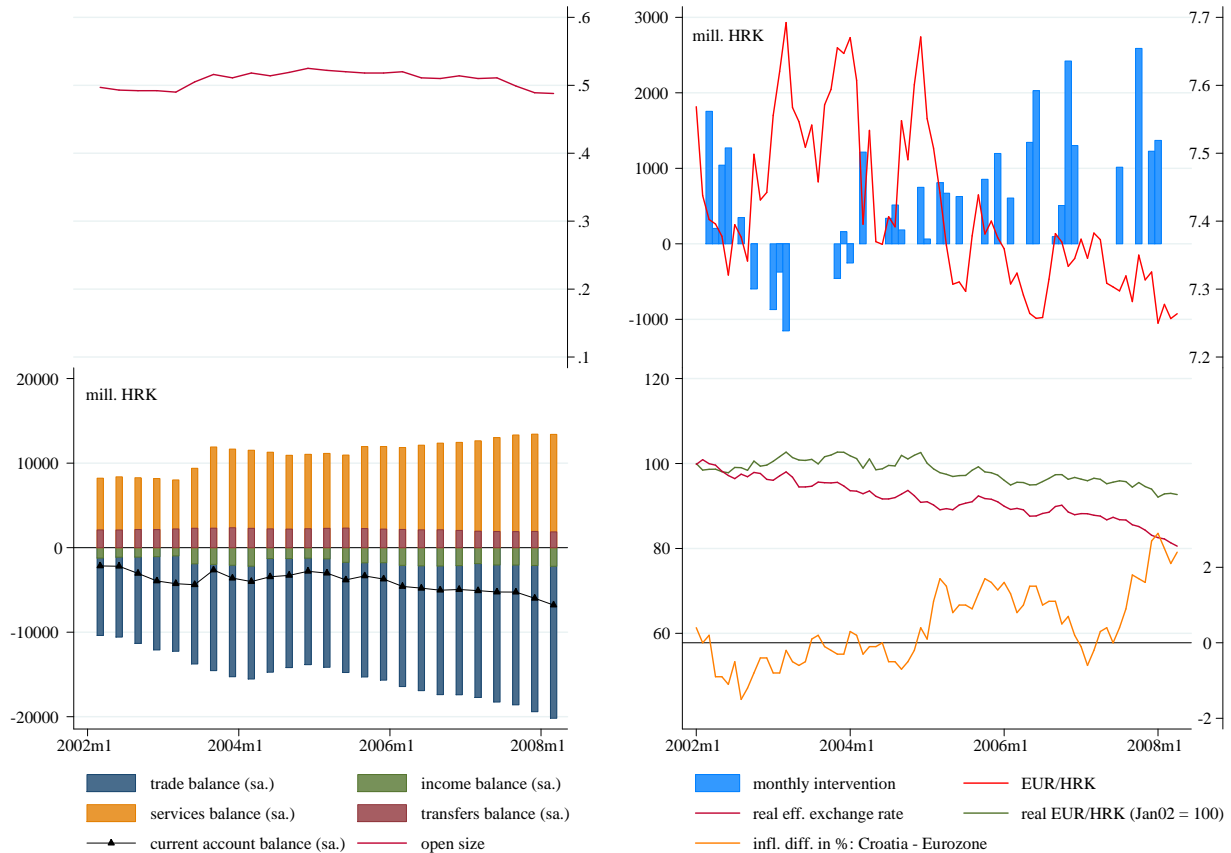


Figure 29: Development of Foreign Trade Aspects, and (Real) Exchange Rates in Croatia between 2002 and 2008 (Data source: CNB, IMF-IFS, own calculation; Jan 2002 = 100).

slight appreciation tendencies. Against the background of the significant trade deficit, a strong external competitiveness might help to alleviate the current account deficit. However, a depreciation of the real rates may only be guaranteed by a nominal development. The reason is that inflation in Croatia has been very low throughout the years. Consequently, inflation rate differentials between Croatia and the Eurozone moved around the zero line until 2008. Hence, the CNB, besides accounting for short-run and medium-run exchange rate stability, may also had real exchange rate developments in mind when purchasing foreign currency during the last years. However, supporting domestic exporters by improving their international competitiveness would put a substantial burden on the financial sector. This then is obviously no balanced relationship.

(iii) *Why Did the CNB Focus on an Implicit Target Level, at Least Occasionally?*

As shown above, the CNB also monitored an implicit exchange rate target level. However, the overall extent has been quite low as indicated by relative low marginal levels, and z-stats. being close to the 10% significance level. The basic rationale for targeting an exchange rate level or band has been discussed in the Argentinean case. Although Croatia's high external indebtedness determined an upper level, and supporting exporters constituted an implicit exchange rate floor, the reason why the CNB was aware of an implicit target level clearly stems from the signaling role of the exchange rate in Croatia. Again, high dollarization is one reason for the need of providing an expectation anchor. This requirement has been fulfilled by the exchange rate, which moved in a relative narrow range between March 2002 and April 2008 (6.6%). This overall tight exchange rate development influenced expectations. As mentioned above, the CNB has explicitly pointed towards the stability of the Kuna vis-à-vis the EUR being of crucial importance for prices stability: "*The key factors contributing to low and stable inflation in the domestic economy include a relatively stable kuna/euro exchange rate (which anchored domestic inflation expectations and stabilize the prices of raw materials and final goods imports from the eurozone)...*" [CNB (2006d), p. 33].⁴⁰² Furthermore: "*The exchange rate anchor was set as one of the main elements of the Stabilisation Programme in 1993.*" [Lang and Krznar (2004), p. 3].

Additionally, it can be assumed that price developments are influenced by the exchange rate as well. While the former aspect can be seen as uncontested, especially when monetary authorities are lacking a sound policy framework, the latter aspect is critically observed by several studies dealing with the exchange rate pass-through effect in Croatia. In this context, Billmeier and Bonato (2004), Gattin-Turkalj and Pufnik (2002), Kraft (2003) as well as Šošić and Kraft (2006) analyze the pass-through effect of exchange rate changes on domestic prices. Their results differ according to the time horizon and price indices affected by exchange rate changes. While Billmeier and Bonato (2004) find evidence that producer prices but not consumer prices are influenced in the short-run, exchange rate changes affect retail prices in the long-run.⁴⁰³ In

⁴⁰² Similar statements can be found in any annual report published by the monetary authorities.

⁴⁰³ According to their results, a 10% exchange rate depreciation caused retail prices to rise by 3.3%.

contrast, Gattin-Turkalj and Pufnik (2002) show that exchange rate changes influence (Granger cause) producer prices but not consumer prices. However, changes in producer prices have an effect on consumer prices, although being relatively small. Results obtained by Kraft (2003) support the pass-through effect on producer prices. Although stating different conclusions on the exchange rate pass-through effect in Croatia, these estimation results reveal the relevance of monitoring an implicit upper exchange rate target.⁴⁰⁴

Following the approach of Ito and Sato (2006), figure 30 shows the impulse response function for a shock in the EUR/HRK exchange rate and the development along the price chain.⁴⁰⁵ More precisely, the shock is defined as a Cholesky one standard deviation innovation in the exchange rate change as well as in producer price change.⁴⁰⁶ It can be seen that the pass-through experience of other studies is partially supported. While some connection between producer prices and consumer prices exist (0.1% response), exchange rate changes do not affect retail prices significantly. Surprisingly, while an exchange rate depreciation increases producer prices in the short-run, it turns into a decreasing effect after three months. When separating retail prices in a goods basket and services basket, a Kuna depreciation leads to an increase of goods prices (0.14% response). This result supports the official statements of the CNB in the way that exchange rate stability is important for price stability.

Nevertheless, it seems that more updated data denies a stable pass-through effect. This justifies the relative low importance of the target motive. However, measuring the exchange rate pass-through for Croatia might be very challenging for several reasons.⁴⁰⁷ Firstly, low pass-through effects might have been the consequence of the stable exchange rate development. Secondly, although liberalizing trade and market conditions, price regulations limited the spillover onto domestic prices. Thirdly, low inflation expectations attenuated the pass-through effect. This is of special importance since this argument is often stated by the authorities. Furthermore, as can be seen in figure 19, inflation remained at low single digit levels throughout the

⁴⁰⁴Moreover, it emphasizes the importance of a stable medium-run exchange rate path as discussed above.

⁴⁰⁵For detailed information on the structure, the impulse response definition, and stationarity conditions, see Appendix B.3.

⁴⁰⁶The empirical standard deviation for the monthly EUR/HRK exchange rate changes accounted for 0.6%, and 0.5% for producer price changes between March 2002 and April 2008.

⁴⁰⁷See Campa and Goldberg (2002), Kraft (2003), Šošić and Kraft (2006), and Taylor (2000).

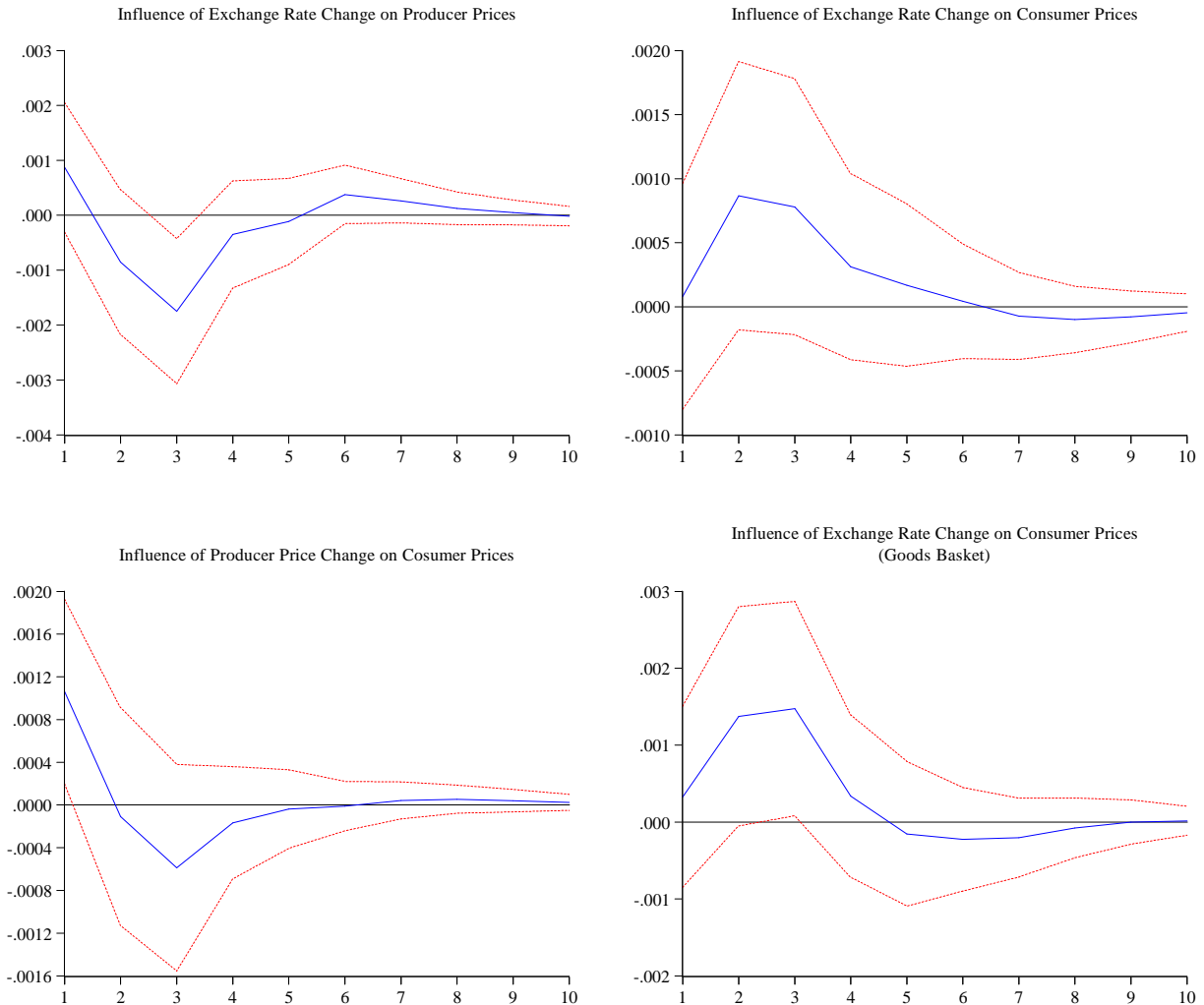


Figure 30: Exchange Rate Pass-Through Effects, and the Development along the Price Chain in Croatia between 2002 and 2008.

sample. Fourthly, as for Argentina, exchange rate changes might have been considered as being only temporary, especially since the CNB officially claims to maintain a stable exchange rate. This could have convinced enterprises not to adjust their prices immediately. Against the background of all of these aspects, which relativize a potential exchange rate pass-through effect on domestic prices, the target motive is more closely connected to the role of the exchange rate as an expectation anchor.

6.5.2 Explanation of Intervention Effects

Turning to the effectiveness of interventions, the arguments of Canales-Kriljenko (2003) fit interventions conducted by the CNB. Focusing on the first three aspects, it can be stated that in the case of Croatia:

(i) *Interventions Are not Fully Sterilized:*

The fact that reserve requirements have been used as the main sterilization instruments shows that foreign currency interventions were only partially sterilized throughout the sample period. This is not surprising due to the quasi-currency board characteristic of Croatia's monetary policy. Thereby money growth is to a large degree determined by the purchase of foreign currency. The reserve ratio was adjusted two times between 2002 and 2008 to create reserve money, and to guide a stable development of open market operations designed to manage domestic money market rates. Starting with 19%, the requirement declined to 18% in October 2004, and to 17% in December 2005, as can be seen in the left panels of figure 31. Basically, the use of reserve requirements is a very passive instrument to sterilize interventions. It does not possess much flexibility when faced with varying intervention amounts but provides an automatic liquidity absorber. Furthermore, the degree of sterilization is limited to the requirement ratio imposed on the calculation base. Hence, when applying reserve requirements, the issue of sterilizing monetary effects is not of great relevance. Therefore, to ensure a flexible sterilization handling, Kuna denominated bills were used in cases when the automatic sterilization was not powerful enough to achieve the desired effect.

As can be seen in figure 31, the use of Kuna bills was aborted in April 2004. Due to foreign currency sales, this short-term instrument was redeemed to provide liquidity to the banking system. The fact that Kuna bills were not used in the following years was officially justified by their costs. Table 29 shows results for the degree of sterilization. Splitting the global sample in two periods reveals that until May 2004, 42% of foreign exchange interventions were sterilized, while only 18% of intervention induced monetary effects were absorbed between May 2004 and May 2008. Of course, the additional use of bills caused a higher neutralization effect. After

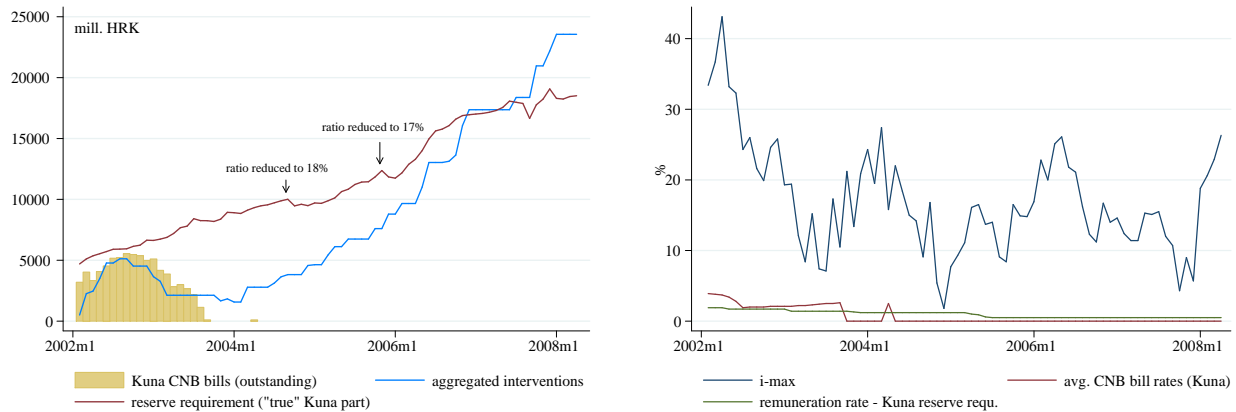


Figure 31: Sterilization Characteristics and their Sustainability in Croatia between 2002 and 2008 (Data source: CNB, IMF-IFS, own calculation).

stopping these transactions, the degree of sterilization returned to the reserve requirement level. Basically, this outcome is in line with Canales-Kriljenko (2003) that interventions in emerging markets are powerful due to incomplete sterilization. However, the sample split shows results which challenge the implication of this argument. In this context, interventions were most effective when being more sterilized.⁴⁰⁸

Table 30 shows costs and earnings from sterilization and foreign reserves respectively. Aggregated net earnings between 2002 and 2008 from sterilized foreign currency interventions amounted to 9.15 bill. Kuna. Throughout the years, the authorities never faced any losses. Instead, net income rose remarkably in recent years. Clearly, the reason is that sterilization did not cause substantial costs. The very low remuneration rate of Kuna reserve requirements and CNB bills, and the short duration of use of domestic currency denominated bills did not influence the income balance significantly. When comparing exact information with the heuristic approach of a level adjusted UIP-based indicator, it can be seen that the maximum affordable interest rate on domestic liabilities tells the same story (right panel of figure 31). The calculated maximum yield was far above the actual rates of sterilization measures. Hence, according to the underlying information, the prevailing intervention policy was not threatened at any time.

⁴⁰⁸This outcome points towards the relative low importance of domestic money market rates, which were highly volatile varying about several percentage points within several days.

	03/2002 - 05/2004	06/2004 - 05/2008
Δ	Kuna Reserve Requirement + CNB Kuna Bills	
<i>Int</i>	0.42**	0.18*
<i>t - stat.</i>	2.48	1.80
$\overline{R^2}$	.123	.145
<i>F - stat.</i>	2.68*	5.10***
$Q(10)^\top / Q^2(10)^\top$	.442/.574	.846/.843

OLS - Estimation using Newey-West Standard Errors & Covariance
 OLS - Regression: $y_t = c + \delta y_{t-3;4} + \alpha Int_t + \varepsilon_t$,
 $y = \Delta$ Kuna reserve requirement + Δ CNB Kuna bills
 $^\top$ p-values; *10% - **5% - ***1% significance

Table 29: Splitted Degree of Sterilization by the Main Instruments in Croatia between March 2002 and April 2008 (monthly data).

Furthermore, the use of CNB bills to sterilize interventions could have been used without causing any problems. However, authorities were not keen to absorb monetary effects from foreign currency purchases. The use of bills turned out to be an instrument for providing the banking system with liquidity when the CNB sold foreign currency in the market. In such circumstances, reserve requirements do not possess enough flexibility. Changing requirement ratios has usually more consequences.

Bill. Kuna	2002	2003	2004	2005	2006	2007	2008 ¹
Income on							
Foreign Reserves	1.04	0.74	0.86	0.88	1.23	2.09	3.02
Expenses on							
Reserve Requirement ²	0.09	0.11	0.11	0.08	0.07	0.09	0.03 ⁴
CNB Bills ³	0.09	0.04	0				
Net income	0.86	0.59	0.75	0.80	1.16	2.00	2.99

¹End of years data; ²"true" Kuna part of reserve requirements;

³Kuna denominated CNB bills; ⁴until April 2008;

Table 30: Income from Foreign Reserves and Costs of Kuna Denominated Sterilization Measures in Croatia between 2002 and 2008 (Data source: CNB, own calculations).

(ii) *Intervention Volumes Account for a Substantial Fraction of Market Turnover, and Monetary Base:*

As can be seen in the right panel of figure 32, interventions conducted by the CNB played an important role for overall market turnover. Galac et al. (2006) note: "*FX trading volume between the CNB and banks is very large on the day (or the week or even the month) of an intervention.*," [Galac et al. (2006), p. 10]. Between March 2002 and April 2008, the average relative daily intervention accounted for approximately 35.48% of daily market turnover.⁴⁰⁹ Again, compared to industrialized market shares, this is a substantial amount. Japanese daily intervention volumes in terms of spot market turnover accounted for an average of approximately 2.2% between 2002 and 2004. However, the relative size of interventions declined over time, although being substantial throughout the sample. This relative transaction pattern matches the evolution of intervention effects and supports the argument of Canales-Kriljenko (2003). At the very beginning, daily interventions made up nearly the total market volume on the corresponding intervention day. It is obvious that this determined the exchange rate. However, though being of substantial size throughout the whole sample, interventions were insignificant at the end of the sample. While the effectiveness could be linked to some type of microstructure channel until 2006, sporadic interventions at the end of the sample did not induce a persistent effect on the order flow, at least in case of purchase transactions. Nevertheless, this does not rule out the possibility that those interventions were effective within the day. The fact that this policy instrument is communicated in a very transparent way, and used in line with the monetary policy framework, induced market members to adjust their positions because of new information being transmitted by the intervention amounts (microstructure signaling idea). For this reason, the large relative intervention volumes point towards a microstructural thinking of exchange rate determination. Furthermore, since CNB interventions are conducted through auctions, interventions are known when they take place. This gives reason to think about a potential *noise-trading signaling channel*. Thereby, as discussed previously, the intervention provides a signal to non-chartists, who are uncertain about market behavior and are looking for

⁴⁰⁹It must be noted that data on market turnover is only available on a monthly frequency. Therefore, it is assumed that monthly transactions are equally distributed during the month.

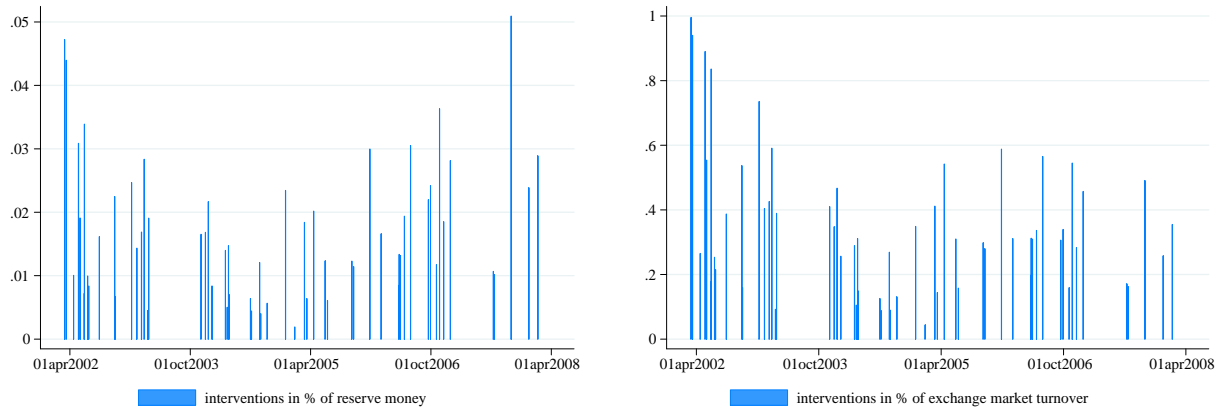


Figure 32: The Relative Size of Croatian Foreign Exchange Interventions between 2002 and 2008 (Data source: CNB, own calculations).

any symbol to open new positions

Similarly to market turnover, daily interventions accounted for a sizable fraction of the reserve money. Between March 2002 and April 2008, the average relative intervention amount accounted for 1.7% of the reserve money.⁴¹⁰ Thereby, the relative transaction volumes display a v-shape as shown in the left panel of figure 32. Although the CNB did not intervene frequently, the money base was clearly influenced by foreign exchange market interventions. In this way, the effect of interventions evolves in a longer context when referring to the impact on monetary aggregates. The relevance of intervention volumes vis-à-vis market turnover and monetary stock supports the argument of Canales-Kriljenko (2003).

(iii) *Central Banks Possess Additional Information through Reporting Requirements and/or Exchange Restrictions:*

Croatian authorities have actively regulated the foreign exchange market. In this context, the "Foreign Exchange Act" drafted by the CNB enumerates the following subjects: 1) capital transactions; 2) payments collections and transfers; 3) foreign exchange market (authorization of dealers) and the exchange rate; 4) safety provisions; 5) business books and reporting (!); 6)

⁴¹⁰Monthly data on reserve money were interpolated on a daily frequency. In terms of the monetary aggregate M1, the mean relative intervention amount accounted for 1.5%. Data source: CNB.

supervision; 7) penal provisions.⁴¹¹ Croatian authorities signed the "Stabilization and Association Agreement" in 2001 during the access negotiations of Croatia to the EU.⁴¹² Although, the agreement states full capital account liberalization by 2009, many bilateral treaties were signed in 2005 that precluded restrictions on capital flows.⁴¹³ In fact, only some controls are still in place. According to article 25(4) and article 27(2) of the "Foreign Exchange Act," non-residents are prohibited to purchase CNB bills. Hence, some controls are in place for capital accounts but not for current accounts. However, the overall degree of capital restrictions is very low.⁴¹⁴ Concerning the reporting requirements, articles 49 to 54 explicitly state that residents shall inform the central bank about the foreign exchange transactions, and shall give access to their business books. In the sense of Canales-Kriljenko (2003), the experience of Croatia indeed fits the argument that capital controls (though being of little significance) and, by far more important, reporting requirements cause an informational advantage of the central bank, and increase the authorities' market share and confidence respectively.

Besides capital account matters, the CNB has used additional instruments to achieve its goal of exchange rate stability. In this context, prudential regulations were imposed on the domestic banking system. Thereby, banks are obliged to restrict their total foreign exchange positions to 20% of their regulatory capital.⁴¹⁵ More precisely: *"Banks are obliged to adjust their total open foreign exchange position at the end of each workday in a manner that their total open foreign exchange position (increased by the position in gold) does not exceed 20% of the regulatory capital of a bank, as defined by the regulations of the Croatian National Bank.,"* [CNB (2003a), p. 2]. This measure was officially designed to restrict risks related to foreign currency exposures. However, it implicitly helped to alleviate excessive exchange rate pressure by preventing speculative behavior of the domestic banking system. Basically, domestic banks'

⁴¹¹See CNB (2003b, 2005a, 2006a).

⁴¹²See Commission of the European Communities (2001). Furthermore, in 2001 the "Foreign Exchange Act" was liberalized in the way that enterprises were allowed to purchase and hold foreign currency. See Lang and Krznar (2004), and Tatomir (2009).

⁴¹³See Šošić and Kraft (2006).

⁴¹⁴Due to the high degree of foreign-owned banks, this restriction is rather dispensable. Additionally, according to the "Stabilization and Association Agreement," capital controls are only valid for a period of six month. Extensions are subject to parliamentary approvals. See Commission of the European Communities (2001).

⁴¹⁵See CNB (2003a).

engagements in the foreign exchange market were controlled effectively. This increased the central bank's market share. The reporting requirements and official limitations on foreign currency exposures do not limit the development of the foreign exchange market but rather support the credibility of the CNB, while at the same time providing the monetary authorities with thorough information on exchange market processes, and restricting speculative behavior.

7 A Summarizing Depiction of the Case Studies

Having presented two case studies of different intervention practices, I want to get back to the fundamental questions of this research, and answer them in a comparing context. The experiences of Argentina and Croatia with interventions reveal very interesting facts, challenging the widespread opinion on central bank interventions in the foreign exchange market. These countries differ in their economic structures and monetary policy frameworks. However, both countries put a premium on the exchange rate channel compared to other monetary policy transmission channels. Furthermore, a foreign exchange market intervention is the most important policy instrument in these emerging markets. Obviously, the former commonality entails to the latter mutuality.

After abandoning the currency board regime due to the crisis in 2001/2002, Argentina has implemented a monetary targeting framework. This policy framework can be seen as a response to the desiccated financial system in the aftermath of the financial turmoils. Thereby, the BCRA was concerned with providing domestic currency in order to implement the stable processing of domestic financial markets. Meanwhile, the exchange rate has played a dominant role in terms of fiscal policy conditions, trade sector aspects, and because of its signaling effect. The BCRA has intervened on almost every day. However, no commitments or clear official statements about interventions as a direct policy instrument were given by the authorities. The use of foreign exchange transactions to manage monetary targets, however, points towards intervention as a double-targeting policy instrument. Hence, besides domestic monetary issues, the authorities had exchange rate aspects in mind when intervening in the foreign exchange market. Consequently, the authorities faced the need of sterilizing these operations, at least partially. Although interventions were not officially announced, it is reasonable to assume that they were publicly known as the market got used to daily central bank market transactions.

In contrast, Croatian authorities have used a wide set of tools to fulfill the stated goal of price stability. The most important policy characteristic has been Croatia's quasi-currency board regime, which lead to a high degree of euroization. In this context, the exchange rate constituted the nominal anchor for expectations on price developments. Due to this fact, the exchange rate

has played a central role in Croatia's monetary policy framework. The CNB emphasizes the need for stable developments of the Kuna's foreign value. In this context, interventions in the foreign exchange market have been actively communicated by the authorities as being the main instrument designed to guarantee exchange rate stability and low inflation. Besides this role, interventions served as the practical money creation instrument throughout the years, which called for partial sterilization. Credits to the domestic banking system were nearly inexistent. Although interventions have been an official instrument in the policy tool kit, authorities have applied them only sporadically and in a discretionary way.

While different fundamentals caused both central banks to apply foreign exchange market interventions for different reasons, the outcome of the interventions has been broadly positive in both case studies. This result is very interesting against the backdrop of the different underlying economic and intervention characteristics; it challenges the general opinion that interventions are not effective in influencing the exchange rate significantly. However, in both cases, interventions did not affect the exchange rate volatility. Concerning the time-varying nature of intervention motives and intervention effects, estimation results have shown that the objectives for exchange market interventions and the associated effects indeed vary over time. While the former result is a natural way to think about a monetary policy instrument and its reaction to changing fundamental conditions, the latter opens some leeway for the arguments put forward by Canales-Kriljenko (2003) on the effectiveness of interventions in developing and emerging markets. Additionally, the question arises whether a change in the intervention characteristics is associated with different intervention objectives and transaction effects.

7.1 Intervention Motives

Table 31 summarizes results for the Argentinean and Croatian intervention reaction functions. It must be noted at this point that the marginal effects of both reaction functions (GARCH model, friction model) will not be compared. The reason is that marginal effects from two different models, though expressing the same content, should not be assessed in a comparing

	Global	Phase I	Phase II	Phase III
<i>Argentina</i>				
GARCH Model				
n^1	96.3	97.4	98.7	89.6
$(s_{t-1} - s_{t-6})$	-12.69	57.50	-656.2 ^s	-465.9
$(s_{t-1} - s_{t-1}^{90dm})$	-74.60 ^s	-108.7 ^s	-756.6 ^s	-2305 ^s
$(s_{t-1} - s^{t\text{arg et}})$	-23.72	-83.55 ^s	2.843	-1645 ^s
h_{t-1}	-5.2x10 ^{4s}	-4.1x10 ^{4s}	8.8x10 ⁴	-2.1x10 ⁵
<i>Croatia</i>				
Friction Model ²				
n^1	3.8	5.0	3.7	3.2
$(s_{t-1} - s_{t-5})$	-1.7x10 ^{4s}	-1.4x10 ^{4s}	-1.3x10 ^{4s}	-5.4x10 ^{4s}
$(s_{t-1} - s_{t-1}^{90dm})$	-2496 ^s	-7628 ^s	-894.0	-1935
$(s_{t-1} - s^{t\text{arg et}})$	-3465 ^s	1427	-2451 ^s	-1.1x10 ⁴
h_{t-1}	2.9x10 ⁶	-2.2x10 ⁷	1.3x10 ⁴	8.4x10 ⁷
θ^+	325.2 ^s	204.5 ^s	226.7 ^s	719.9 ^s
θ^-	-410.3 ^s	-371.7 ^s	-348.7 ^s	-429.9 ^s

¹Relative frequency in terms of business days in %; ²estimated coefficients

^sResult is significant at the common levels

Table 31: Summary of Reaction Function Estimation Results: Argentina and Croatia.

context since the methodologies are different. As explained above, the idea was to apply a model which best suits the specific data. Therefore, estimated coefficient results of both models are displayed in table 31.

Starting with the short-term motive of interventions, the monetary authorities of Argentina and Croatia have addressed the matter of short-run exchange rate stability differently. While the BCRA was not chiefly concerned about managing exchange rate changes within several days, the CNB explicitly mentioned the importance of short-run stability; estimation results support official statements

The reason why Argentinean authorities did not strive for the short-run motive stems from the implementation of other policy measures, which undermined the importance of this mo-

tive. Foreign currency denominated debts and deposits were converted into Peso. Thereby, its asymmetric exchange alleviated the danger of financial distress. The rationale of maintaining short-run exchange rate stability was tackled by another policy measure, which was seen to be more efficient due to its persistent effect. However, phase estimation outcomes and rolling results show that the BCRA partially responded to short-term exchange rate changes. The corresponding coefficient is estimated to be significant in phase II. This can be justified as an adequate response in developing financial markets in order to ensure basic stability. Hence, the question why Argentina did not respond to short-run exchange rate returns globally, can be answered fairly easily: It did not need to.

In contrast, Croatia is characterized by a high degree of euroization. This led to the great importance of short-run stability. The specific coefficient is estimated to be highly significant in all samples. In this context, the balance-sheet structure of the domestic banking system, and the external debt positions of different sectors, including the government, are mainly responsible for the high relevance of the short-run motive. For this reasons, stabilizing short-dated exchange rate returns has been the main objective of Croatian authorities to intervene in the foreign exchange market, as officially stated. What is more, its relevance rose over time.

As is the case for the short-term objective, Argentinean and Croatian authorities catered to the matter of medium-term exchange rate stability to different extents. Whereas Argentina focused on stable medium-term exchange rate developments, Croatia did not pay much attention to this motive in the full sample context.

Monetary authorities in Argentina have closely monitored the medium-run motive. The corresponding coefficient is estimated to be significant in all samples. The concern of this intervention objective can be explained by the significant role of foreign trade for Argentina's economy. Therefore, stable and predictable import and export prices support the foreign trade sector, and improve investment incentives. Furthermore, the BCRA mentioned the need of a stable real exchange rate officially. In this context, the BCRA used interventions as a nominal measure to manage the real US\$/ARS exchange rate. However, much more leeway is given by inflation developments to improve the real rate index of Argentina. Therefore, influencing real

rates is not directly connected to the medium-term motive but rather constitutes a long-term strategy.

In contrast, although the current account plays a dominant role in Croatia, medium-term exchange rate stability has not been of crucial importance for daily CNB foreign exchange market interventions. The reason for the low relevance stems from the fact that the EUR/HRK exchange rate has been broadly stable. However, time dependent analysis shows that exchange rate deviations from a 90-day trend did significantly trigger interventions at the beginning of the sample. Nevertheless, with respect to the other motives, the extent was rather circumspect. Between 2002 and 2005, the EUR/HRK exchange rate moved within a band of -3.2%/2.7% around its medium-term trend compared to a bandwidth of -0.5%/2.0% between 2006 and 2008. Hence, the stability of the Kuna just did not call for policy measures. Lastly, real rate developments were mainly determined by nominal exchange rate developments due to general small inflation differentials between Croatia and the Eurozone.

Similar to the fact that authorities in Argentina and Croatia responded quite differently to the short-run and medium-run motive, the matter of stabilizing the exchange rate around an implicit target level was done for altogether different reasons and to different degrees.

The US\$/ARS exchange rate experienced a strong appreciation after the Peso depreciated by over 300% in the aftermath of the 2001/2002 crisis. As a consequence, the BCRA was concerned with stabilizing the exchange rate around an implicit target level (within an implicit band), especially at the beginning of the global sample in 2003/2004. On the one hand, fiscal policy reasons justified the objective of preventing the Peso from getting too strong. Since a crucial part of total government revenue is made up of export tax incomes, an appreciation of the exchange rate would diminish government revenues. On the other hand, the exchange rate exerted a pass-through effect on domestic producer prices. However, the effect did not spill over onto consumer prices, leading to a pricing to market strategy of domestic producers. The resulting pressure on this sector, however, is no favorable solution. Accordingly, the specific coefficient is estimated to be significant in phase I and III, and thus, in times when the Peso deviated from its implicit target level to a significant extent.

Croatia's authorities, on the contrary, have not thoroughly accounted for the target motive between 2002 and 2008. Phase estimations and rolling results show that periods with significant results are followed by insignificant outcomes. In both cases the overall outcomes are rather small compared to the short-term objective. Similar to the medium-run motive, the CNB just did not need to intervene to achieve the target motive. Between 2002 and 2008 the EUR/HRK exchange rate moved within a band of -3.0%/3.5% around its implicit target value. Furthermore, or perhaps due to this fact, no clear exchange rate pass-through effect on domestic prices is existent in Croatia. Most recently, this motive gained in importance due to an appreciation trend, which caused the gap between the actual exchange rate and its underlying target level to widen.

The exchange rate volatility was not extensively monitored by both countries. Therefore, the ramifications of this motive were neglected when explaining the intervention objectives in an economic and monetary policy context. However, the time dependent analysis shows that monetary authorities in Argentina were concerned about a stable market process at the beginning of the estimation sample in 2003/2004. The financial crisis, which caused the exchange rate to depreciate extremely, deteriorated the market process. Furthermore, an properly functioning exchange rate market was inexistent. Hence, the BCRA was concerned with a stable and reliable pricing process and served as a financial intermediate matching supply and demand of foreign currency. In this context, Argentinean authorities guided a stable exchange market development. In a similar way, the CNB did not show much interest in market rumors. Neither global nor time dependent estimations show convincing results, which give evidence that Croatian authorities intervened in response to a rising conditional exchange rate volatility, although more recent results may point towards an increasing relevance.

Concerning the intervention characteristics, neither in Argentina nor in Croatia a change in the intervention frequency and size can be associated to a change in the underlying objective. Other intervention motives, which are not explicitly addressed in the explanatory variables, also differed remarkably in both countries. The long AR structures of Argentina's reaction function show that other purposes, namely monetary targeting and reserve accumulation, have

caused the BCRA to purchase (and sell) foreign currency. However, the lag structure declines over time, revealing the growing independence of BCRA foreign exchange market interventions as an independent monetary policy tool for managing exchange rate aspects. The independent use of interventions in Argentina is supported by rising sterilization efforts. Contrary to this double-targeting instrument, Croatia did not explicitly use interventions for other reasons than exchange rate stability. Although foreign exchange transactions were the primary money creation instrument, this effect is a natural process in a quasi-currency board environment. Definitely, the main purpose of interventions in Croatia has been to stabilize the EUR/HRK exchange rate. Generally, the CNB was more prone to foreign currency purchases as opposed to foreign currency sales. The corresponding intervention thresholds show an asymmetric response behavior. This reflects the overall purpose of restraining the slight appreciation trend of the Kuna.

7.2 Impact Effects

Table 32 summarizes results for the impact analysis of Argentinean and Croatian interventions. Looking at the effects on daily exchange rate changes, estimations show positive results. It is interesting that both countries experience strong asymmetric effects concerning the power of purchase and sale interventions. Thereby, a purchase of 100 mill. US\$ by the BCRA depreciated the US\$/ARS exchange rate by 0.027% in the global sample. An equal amount sold in the market caused the US\$/ARS exchange rate to appreciate by 0.069%. Asymmetry is even more pronounced in the case of Croatian interventions. Estimation results for the global sample show that while sale transactions appreciated the exchange rate by 0.13% per 100 mill. EUR sold in the market, purchase operations are estimated to be insignificant showing no explanatory content for daily exchange rate changes.

Time dependent analyses reveal even more interesting results. Estimation results give evidence that impact effects of both intervention types change within the global sample. Being high in the beginning, the explanatory power of total transactions as well as separated operations for daily exchange rate returns decline. In the case of Argentina, overall effects rise slightly again

in phase III, due to an increasing power of foreign currency purchases. Asymmetric BCRA intervention effects witnessed in the global sample are confirmed by the fact that Argentina's sale interventions were more effective than purchase interventions throughout phases I-III. However, the scale of asymmetry declines. In case of Croatia, transaction effects increase slightly between phase I and II before falling sharply in phase III, leading to insignificant and wrongly signed intervention coefficients. This development is necessitated by the effect of sale transactions. While purchase operations are only effective in phase I, sale interventions had the correct impact during all sub-samples, and exerted more influence on daily exchange rate changes. This corroborates the high degree of the asymmetric impact of Croatian foreign exchange market operations. Concerning the impact on the estimated exchange rate volatility, neither Argentinean nor Croatian interventions exerted any influence. Estimation results are insignificant at all sub-samples, and are of no relevance in economic terms. Again, this supports the validity of the results for the mean equation coefficients.

With respect to the intervention characteristic, the impact analyses disclose very interesting aspects. Estimation outcomes of both countries lend credibility to the previously stated assumption that infrequent interventions are more powerful, holding partially true for both countries and across intervention types. Basically, it could have been assumed a priori that interventions in Croatia should be more powerful due to their sporadic nature. However, this is not the case. Instead, estimated coefficients of BCRA sale transactions are greater in absolute values in all sub-samples, and CNB purchase operations are not significant in phase II and III. Hence, even when accounting for the differences in US\$ and EUR, interventions conducted by the BCRA had a greater influence on the exchange rate. However, when looking at each intervention type, the infrequency of sale operations of both central banks indeed resulted in a greater impact on daily exchange rate changes. Foreign currency purchases, which have been the dominant intervention type of both central banks, were not as powerful. In this sense, it can be argued that the market got used to them and was not surprised, causing no changes in the expectations. When comparing the sub-samples of each operation type, the infrequency argument, however, does not hold generally. Any statements about this assumption are only reliable under c.p. conditions.

GARCH - Model	Global n^1/β	Phase I n^1/β	Phase II n^1/β	Phase III n^1/β
<i>Argentina</i>				
Δs_t				
<i>Int</i> _{<i>t</i>-1}	96.3/3.6x10 ⁻⁶ <i>s</i>	97.4/9.2x10 ⁻⁶ <i>s</i>	98.7/3.0x10 ⁻⁶ <i>s</i>	89.6/4.9x10 ⁻⁶ <i>s</i>
<i>Purchases</i> _{<i>t</i>-1}	87.6/2.7x10 ⁻⁶ <i>s</i>	92.8/8.8x10 ⁻⁶ <i>s</i>	96.2/2.9x10 ⁻⁶ <i>s</i>	59.2/3.4x10 ⁻⁶ <i>s</i>
<i>Sales</i> _{<i>t</i>-1}	8.73/-6.9x10 ⁻⁶ <i>s</i>	4.6/-7.4x10 ⁻⁵ <i>s</i>	2.5/-6.5x10 ⁻⁵ <i>s</i>	30.4/-7.5x10 ⁻⁶ <i>s</i>
h_t				
<i>Int</i> _{<i>t</i>-1}	96.3/4.8x10 ⁻¹⁰	97.4/1.4x10 ⁻¹⁰	98.7/2.6x10 ⁻⁹	89.6/-1.2x10 ⁻⁹
<i>Purchases</i> _{<i>t</i>-1}	87.6/5.1x10 ⁻¹⁰	92.8/-9.0x10 ⁻⁹	96.2/2.3x10 ⁻⁹	59.2/-1.6x10 ⁻⁹
<i>Sales</i> _{<i>t</i>-1}	8.7/8.3x10 ⁻¹⁰	4.6/-3.1x10 ⁻⁷	2.5/-1.7x10 ⁻⁸	30.4/7.9x10 ⁻⁹
<i>Croatia</i>				
Δs_t				
<i>Int</i> _{<i>t</i>-1}	3.8/4.1x10 ⁻⁷	5.0/1.1x10 ⁻⁵ <i>s</i>	3.7/1.3x10 ⁻⁵ <i>s</i>	3.2/-1.2x10 ⁻⁶
<i>Purchases</i> _{<i>t</i>-1}	3.0/-8.2x10 ⁻⁸	2.7/9.6x10 ⁻⁶ <i>s</i>	3.2/5.8x10 ⁻⁶	3.0/-4.4x10 ⁻⁷
<i>Sales</i> _{<i>t</i>-1}	0.8/-1.3x10 ⁻⁵ <i>s</i>	2.3/-1.5x10 ⁻⁵ <i>s</i>	0.5/-3.3x10 ⁻⁵ <i>s</i>	0.2/-3.7x10 ⁻⁶ <i>s</i>
h_t				
<i>Int</i> _{<i>t</i>-1}	3.8/-1.4x10 ⁻⁹	5.0/2.5x10 ⁻⁹	3.7/-1.0x10 ⁻⁸	3.2/1.2x10 ⁻¹⁰
<i>Purchases</i> _{<i>t</i>-1}	3.0/-1.5x10 ⁻⁹	2.7/2.0x10 ⁻⁹	3.2/-5.5x10 ⁻⁹	3.0/5.8x10 ⁻¹¹
<i>Sales</i> _{<i>t</i>-1}	0.8/3.3x10 ⁻⁹	2.3/2.8x10 ⁻⁹	0.5/-2.0x10 ⁻⁸	0.2/2.6x10 ⁻⁸

¹Relative frequency in terms of business days in %; *s* result is significant

Table 32: Summary of Impact Analysis Estimation Results: Argentina and Croatia.

It is clear that this necessity is not given. In this context, the development of other underlying factors must be taken into account when drawing conclusions on the frequency argumentation. Furthermore, Argentina and Croatia display two corner solutions of applying the instrument of foreign exchange interventions. In circumstances where interventions are used almost every day, basic assumptions might not hold for exchange market members.

The underlying fundamentals explaining the success of Argentina and Croatia in driving daily exchange rate returns are similar. Incomplete sterilization, relatively high market shares of foreign exchange market interventions, and informational advantages (reporting requirements, capital controls - broad interventions) influenced the effectiveness of the countries' interventions. These aspects directly refer to the arguments of Canales-Kriljenko (2003).

Both countries are characterized by incomplete sterilization of their foreign exchange interventions. Thereby, Argentina and Croatia have used different instruments to sterilize monetary effects. While the CNB focused on liability side sterilization through the reserve requirement ratio and transactions with short-term central bank bills, Argentinean authorities have used a much wider set of sterilization measures. The main instruments covered asset and liability side tools, including the cancellation of rediscounts, transactions with short-term central bank debt instruments, and repo transactions. Additionally, the public sector also contributed in absorbing liquidity effects caused by the purchase of foreign currency. As is the case for intervention effects, the degree of sterilization also changed over time. Thereby, the developments in both countries were different. At the beginning of the global sample, interventions in Argentina were sterilized fractionally while exerting the strongest effects on daily exchange rate changes. In contrast, Croatian interventions were most effective when being sterilized to the highest degree. However, during that time only 42% of Croatian interventions were neutralized. Hence, although both countries basically match the argument that partial sterilization influences the effectiveness of interventions positively, the time dependent considerations qualify the importance of the underlying monetary channel. In both countries, the accrued costs did never threatened the sterilization policy, except in Argentina in 2003 when the revaluation of their foreign reserves produced large losses.

Interventions of both central banks accounted for a relative large share of market turnover, especially when compared to industrialized countries. BCRA interventions accounted for approximately 9.5% between 2003 and 2004, growing to 13% between 2005 and 2008. Thereby, the increase in the relative operation volumes might explain why interventions have still been effective in times when the importance of the monetary channel of interventions declined. By intervening continuously in the foreign exchange market, authorities influenced the order flow significantly, triggering a shift in the composition of the investors' portfolios. Even more convincing, CNB interventions in 2002 made up nearly the total market turnover. While the relative share declined over time, interventions accounted for an average fraction of approximately 35.48%. It is obvious, that these allotments influence the daily pricing of exchange

rates. Concerning the theoretical channel, the large intervention volumes in both countries have surely worked through a microstructure channel. While the high frequency of BCRA interventions clearly point towards microstructural induced exchange rate changes, based on the portfolio-balance idea, the relative infrequent CNB interventions, which are responsible for a significant market share, can be traced back to the signaling idea.

Finally, Argentina and Croatia have regulated their foreign exchange markets. The BCRA implemented direct exchange controls in the aftermath of the financial crisis for six main categories. This enhanced the market share of their interventions, and gave the central bank comprehensive insights into foreign exchange market actions. In this context, the imposed restrictions provided an informational advantage for the Argentinean authorities. However, these restrictions were assuaged over time, which fits the development of the effectiveness of their interventions. Although Croatian authorities have also actively regulated their foreign exchange market, they have not imposed as restrictive direct current account measures as the BCRA. Furthermore, the signing of the "Stabilization and Association Agreement" stipulated that Croatia should fully liberalize its capital account. Hence, broad intervention measures were of minor relevance for the effectiveness of Croatia's interventions. Nevertheless, the CNB imposed other restrictive exchange measures. In this context, banks were obliged to restrict their total foreign exchange positions to 20% of their regulatory capital. On the one hand, this should serve to restrict speculative behavior, on the other hand this measure increased the central bank's market share. Furthermore, the authorities implemented comprehensive reporting requirements allowing the CNB to draw a clear picture of the market process.

Concluding Remarks

During the last years, central banks all over the world were facing an unprecedented financial and economic environment. While their past decisions might have added to these severe conditions, authorities now recognize the limits of their standard policy instruments. This led to the application of unconventional monetary measures, and a rethinking of the basic monetary policy toolset.⁴¹⁶ Although foreign exchange market interventions are still perceived as controversial, even industrialized countries have used this policy tool in recent times.⁴¹⁷ It seems that particular circumstances require special actions. However, as shown in this work, foreign exchange market interventions can be used as a standard instrument as well. While this might not hold for industrialized countries and emerging markets in general, the experience of Argentina and Croatia in respect to the use of exchange market operations has shown, that this measure can be a central part of the monetary policy arrangement. Of course, this ultimately depends on the financial and economic setting of the country in question. However, is this not perfectly normal to consider the use of policy measures?

The academic perspective on exchange market transactions in emerging markets has just begun. In this context, this thesis is aimed at contributing to this field of research. It provides a broad and thorough presentation of the underlying fundamentals of the discussion about foreign exchange market interventions. Moreover, it discusses why the central banks in Argentina and Croatia have intervened and whether their actions have been successful. Furthermore, empirical estimations are designed to examine the relevance of intervention objectives, and transaction effects over time, and to what extent these issues can be explained by economic and monetary fundamentals. The results are discussed extensively above. Intervention motives and their time dependent development can be explained by the economic and policy background. Different policy measures and real economic fundamentals are responsible for the purposes of central bank interventions. This fact has been widely neglected in other studies dealing with emerging market interventions so far. The explanation of transaction effects supports the arguments of

⁴¹⁶Furthermore, some recent discussions started to focus on a rethinking of macroeconomic policy in general. See Blanchard et al. (2010).

⁴¹⁷The SNB intervened most recently to defend the CHF from appreciating against the EUR.

Canales-Kriljenko (2003). These arguments must be seen in a complementary context. Thereby, it is outstanding that both countries are characterized by partial sterilization and large relative intervention amounts. However, it is not a single intervention channel but rather a mix of several influential mechanisms, which cause the exchange rate to behave in the according way.

Future research should focus on the aspects brought forward in this paper. Basically, three aspects should stand in the center of future analyses: 1) the relationship between interventions and policy settings; 2) the use of econometric techniques; 3) high-quality data analyses.

It is of interest, how other emerging markets, operating under different monetary policy frameworks, have performed with regard to foreign exchange market interventions. Moreover, against the background of the ongoing financial turmoils, a comparison between emerging market interventions and industrialized market interventions would enhance the understanding of this policy instrument. Thereby, it is essential to account for various policy aspects in the sense of broad intervention measures. The ongoing sophistication of financial markets will require even more detailed analyses in order to disentangle the mechanisms of how interventions add to the determination of exchange rates. Econometric theory does provide many methodologies which are useful to examine intervention objectives and its effects on exchange rates, and to cope with empirical problems researchers are confronted with. As outlined, their benefits depend on the underlying data characteristics. Nevertheless, to understand the complete intervention dynamics, i.e. to shed light on the decision-making process and the final effects on exchange rates, future research should move towards the application of structural models. This would provide a full-fledged consideration of central bank intervention dynamics by combining a reaction function and an impact analysis instead of conducting two partial analyses (reaction function, impact analysis). However, as described, this in turn depends on the knowledge of exchange rate determination in general. Reliable and thorough information of how exchange rates behave, would afford the discussion of intervention objectives with a comprehensive theoretical basis. Structural models should be based on theoretical thoughts on intervention dynamics, and how these policy measures influence the exchange rate. In general, these issues may be clarified by the availability of sufficient high-quality data. While some central banks provide detailed

data on their foreign exchange market transactions (e.g. SNB, Bank of Canada), high-quality data on exchange rate settlements and their underlying causes are needed as well. However, whether such data can be collected at all, is another question all together. Abstracting from all practical problems, this would enhance the evolution of theoretic models for exchange rate determination in a first step, and ultimately solve the conundrum of foreign exchange market interventions.

Central banks all over the world can use a wide set of policy tools in order to fulfill their ultimate goals of which price stability has been assigned the top priority. Even if some tools are seen as being unconventional, or even threatening the authorities' credibility strategy due to their controversial nature, a careful consideration and analysis of the underlying monetary policy and economic fundamentals may allow a different perspective on these measures. It has often been claimed that foreign exchange market interventions are by no means an independent policy tool, and are therefore not distinguishable from normal policy actions. However, a policy instrument can never be applied independently in a strong sense. Its use must always be considered in the context of other policy measures and the stated goals. Hence, central bank interventions can widen the set of monetary policy tools providing the authorities with flexible and effective measures to pursue their ultimate policy goal.

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Appendix

A Argentinean Data and Results

A.1 Reaction Function

A.1.1 Squared Intervention Data and OLS Residual Analysis

Table 33 displays pre-analyses of intervention data and OLS residuals to check for potential heteroskedasticity. OLS residuals ε_t are obtained from estimating the Argentinean reaction function without accounting for conditional heteroskedasticity. The lag structure was chosen according to the analysis of intervention data presented below.

- Ljung-Box Q-statistic:

$$Q(n) = T(T+2) \sum_{i=1}^n \frac{\tau_i^2}{T-i} \sim \chi_n^2 \quad (135)$$

with $\tau_i = \text{autocorrelation of order } i$

$T = \text{number of observations}$

H0: no autocorrelation up to order n

- ARCH test:

$$\varepsilon_t^2 = c + \sum_{i=1}^k \alpha_i \varepsilon_{t-i}^2 + \nu_t \quad (136)$$

H0: $\alpha_1 = \dots = \alpha_k = 0 \rightarrow \text{no ARCH up to order } k$

– Engle's LM Statistic :

$$T \cdot R^2 \sim \chi_p^2$$

– F – Statistic :

$$\frac{R^2/k}{(1-R^2)/(T-(k+1))} \sim F(k, T-(k+1))$$

		<i>Intervention²</i>			
		Global	Phase I	Phase II	Phase III
<i>Ljung – Box Statistics</i>					
	$Q(1)$	104.7***	191.7***	86.08***	4.186**
	$Q(5)$	290.7***	549.5***	225.6***	7.882
	$Q(10)$	462.9***	808.9***	291.7***	11.97
		<i>OLS – residuals</i>			
		Global	Phase I	Phase II	Phase III
<i>Ljung – Box Statistics</i>					
	$Q^2(1)$	41.36***	58.19***	13.78***	3.811**
	$Q^2(5)$	97.39***	234.5***	36.59***	4.337
	$Q^2(10)$	169.4***	324.9***	39.50***	6.334
<i>ARCH Test – LM – Stat.</i>					
<i>F – Stat.</i>					
	$k = 1$	41.67***	57.82***	13.75***	3.976**
		42.97***	63.69***	14.12***	4.008**
	$k = 2$	47.82***	78.52***	28.08***	4.211
		24.76***	44.87***	14.87***	2.116
	$k = 3$	55.18***	82.10***	24.58***	4.242
		19.14***	31.44***	8.593***	1.415

*10% - **5% - ***1% significance

Table 33: Ljung-Box Q-statistics and ARCH Tests of Argentinean Intervention Data and OLS Residuals.

A.1.2 Model Structures

The model structures are chosen in the following way. In a first step, intervention data is analyzed by examining the correlogram. From all correlograms (figures 33 to 36), it can be seen that the daily Argentinean interventions display a typical AR behavior with additional seasonality at some higher lags. The suggested AR structure, which is determined according to Box et al. (1994), is then estimated (a GARCH(1,1) serves as the baseline model). Based on this estimation, insignificant lags are dropped out of the model and the reaction function is reestimated. The AIC, SIC as well as Ljung-Box Q-statistics for standardized residuals are used to assess whether the exclusion of insignificant lags lead to an improvement of the model. The procedure continues until no insignificant variables are existent, or until the AIC and/or SIC variable indicates no model improvement from neglected insignificant variables. Based on the chosen AR structure, the structure of the volatility equation is determined in a second step. Starting with a GARCH(1,1), AIC, SIC, and Ljung-Box Q-statistics for squared standardized residuals are used to choose the appropriate volatility structure. Extending the volatility equation unnecessarily bears the risk of overparametrization, which leads to the problem of not finding a global maximum of the likelihood function. Therefore, the maximum of lags is set to 3 for the (G)ARCH parts of the conditional volatility.

- AIC:

$$AIC = -2 \left(\frac{\ln L}{T} \right) + 2 \left(\frac{k}{T} \right). \quad (137)$$

- SIC:

$$SIC = -2 \left(\frac{\ln L}{T} \right) + \frac{k \log(T)}{T}. \quad (138)$$

with $\ln L = \log \text{Likelihood}$

$k =$ number of parameters

-
- According to table 34, AIC and SIC indicate different structures for the volatility equation (SIC - GARCH(1,1), AIC - GARCH(2, 2)). In order to follow the idea of parsimonious specification an AR(5)-GARCH(1,1) was chosen.
 - Although the exclusion of lag 3 and 4 lead to lower AIC and SIC values, autocorrelation increased at higher lags. It can be argued that significance at lag 10 is not of crucial relevance. However, to make sure that no autocorrelation remains, lag 3 and 4 were not removed. Furthermore, it is important to note that estimation results for intervention motives were independent from the ex-/inclusion of lag 3 and 4. According to table 35 the chosen structure was an AR(5)-GARCH(2,1)
 - According to table 36, AIC and SIC values clearly indicate an AR('1','3','4')-GARCH(1,1) model.
 - According to table 37, AIC and SIC values clearly indicate an AR(1)-GARCH(1,1) model.

Sample: 2/17/2003 5/23/2008
Included observations: 1316

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	0.587	0.587	454.15	0.000
		2	0.467	0.187	741.97	0.000
		3	0.426	0.148	981.52	0.000
		4	0.402	0.113	1195.2	0.000
		5	0.401	0.117	1407.7	0.000
		6	0.359	0.034	1578.5	0.000
		7	0.320	0.014	1714.0	0.000
		8	0.301	0.026	1833.9	0.000
		9	0.328	0.095	1977.1	0.000
		10	0.295	-0.000	2092.7	0.000

Figure 33: Correlogram of Daily Argentinean Foreign Exchange Interventions - Global Sample.

AR Struct.	GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 5; 9		9.3573	9.4128	.884	.942	.970
1 to 5		9.3541	9.4055	.894	.729	.703
GARCH Structure		AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)		9.3541	9.4055	.281	.316	.377
(2,1)		9.3512	9.4065	.918	.394	.446
(2,2)		9.3505	9.4098	.965	.890	.715
(3,1)		9.3517	9.4110	.945	.532	.528
(3,2)		9.3532	9.4164	.954	.504	.511
(3,3)		9.3630	9.4216	.960	.512	.503

[†] p-values

Table 34: Structure Characteristic of the GARCH Model Reaction Function: Argentina - Global Sample.

Sample: 2/17/2003 7/29/2005

Included observations: 615

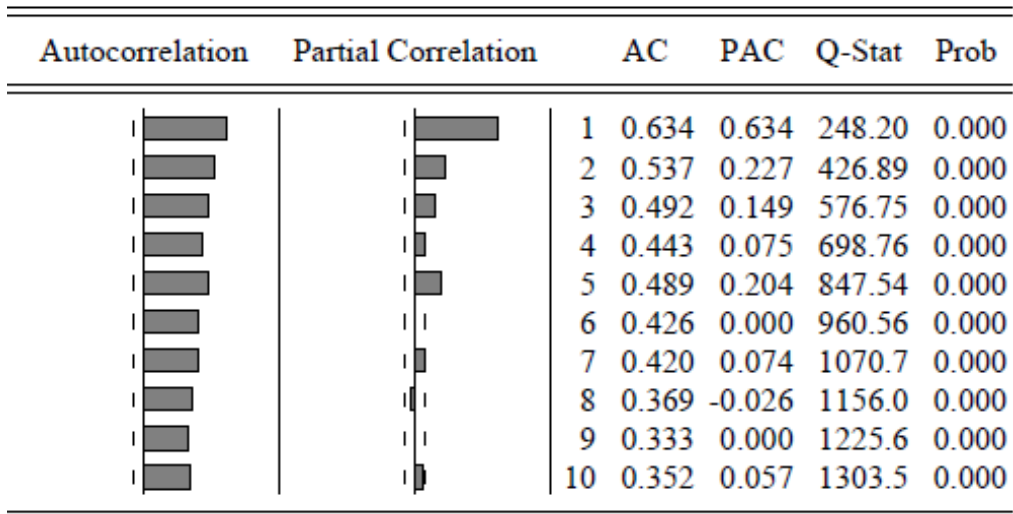


Figure 34: Correlogram of Daily Argentinean Foreign Exchange Interventions - Phase I.

AR Struct.	GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 5; 7		8.1266	8.2281	.319	.480	.182
1 to 5		8.1206	8.2147	.339	.519	.200
1 to 2; 5		8.1182	8.1979	.540	.173	.015
GARCH Structure		AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)		8.1206	8.2147	.455	.438	.535
(2,1)		8.1175	8.2139	.886	.582	.617
(2,2)		8.1208	8.2295	.887	.581	.617
(3,1)		8.1208	8.2294	.890	.579	.616
(3,2)		8.1232	8.2392	.956	.622	.645
(3,3)		8.1288	8.2519	.881	.365	.673

[†] p-values

Table 35: Structure Characteristic of the GARCH Model Reaction Function: Argentina - Phase I.

Sample: 8/01/2005 5/18/2007

Included observations: 451

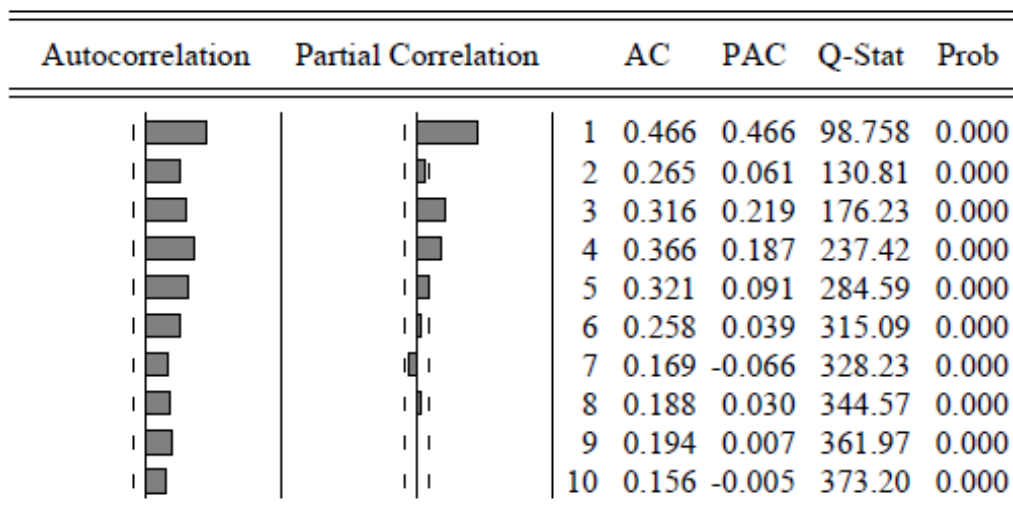


Figure 35: Correlogram of Daily Argentinean Foreign Exchange Interventions - Phase II.

AR Struct. GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1; 3 to 5	9.7630	9.8724	.726	.798	.794
1; 3 to 4	9.7595	9.8598	.793	.667	.676
GARCH Structure	AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)	9.7595	9.8598	.620	.697	.877
(2,1)	9.7623	9.8717	.975	.931	.973
(2,2)	9.7657	9.8842	.997	.990	.992
(3,1)	9.7659	9.8845	.993	.984	.988
(3,2)	9.7699	9.8976	.944	.991	.992
(3,3)	9.7699	9.9067	.738	.867	.920

[†] p-values

Table 36: Structure Characteristic of the GARCH Model Reaction Function: Argentina - Phase II.

Sample: 5/21/2007 5/23/2008

Included observations: 250

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	0.559	0.559	78.993	0.000
		2	0.449	0.199	130.20	0.000
		3	0.362	0.076	163.66	0.000
		4	0.318	0.069	189.62	0.000
		5	0.318	0.102	215.56	0.000
		6	0.294	0.052	237.89	0.000
		7	0.268	0.028	256.44	0.000
		8	0.229	-0.000	270.09	0.000
		9	0.262	0.098	288.04	0.000
		10	0.213	-0.022	299.97	0.000

Figure 36: Correlogram of Daily Argentinean Foreign Exchange Interventions - Phase III.

AR Struct. GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 2	11.1377	11.2786	.879	.910	.802
1	11.1377	11.2644	.555	.621	.506
GARCH Structure	AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)	11.1377	11.2644	.830	.998	.999
(2,1)	11.1457	11.2865	.850	.998	.999
(2,2)	11.1451	11.3000	.666	.957	.968
(3,1)	11.1259	11.2808	.767	.915	.996
(3,2)	11.1241	11.2931	.777	.997	.997
(3,3)	11.1317	11.3148	.780	.999	.998

[†] p-values

Table 37: Structure Characteristic of the GARCH Model Reaction Function: Argentina - Phase III.

A.1.3 Rolling Estimation Aspects

The optimal lag structure of equation 139 is chosen according to the SIC criterion. Figure 37 displays test statistics and the associated 10% significance levels for daily interventions, and its suggested motives with and without a constant variable β . As discussed, the choice of the window size reflects a trade-off between the informational content and the possibility of biased results due to nonstationarity. The window size of 500 balances both aspects. While smaller sample sizes were characterized by unit roots, bigger sizes did not lead to any improvements or different results. Thus, except the target motive, which is clearly I(1) since early 2006 with some I(0) periods in 2007 and 2008, all variables reject the null of a unit root process throughout the time.

- ADF test for stationary process:

$$\Delta y_t = \alpha y_{t-1} + \underbrace{\beta}_{cons.} + \gamma_i \sum_{i=1}^{p-1} \Delta y_{t-i} + \varepsilon_t \quad (139)$$

H0: y_t has a unit root (is nonstationary); $\alpha = 0$

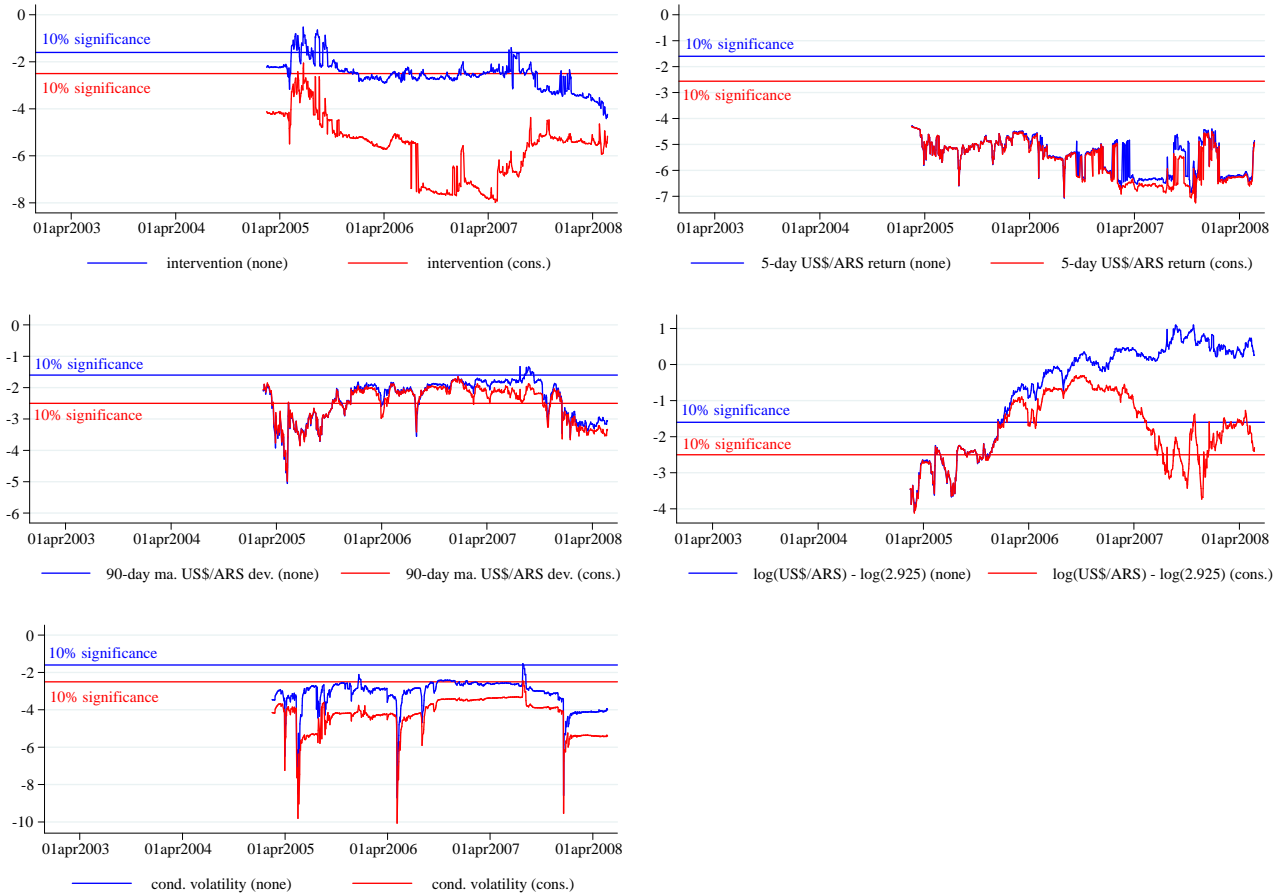


Figure 37: Rolling ADF Tests between February 2003 and May 2008 - Argentinean Reaction Function Variables (window = 500 days).

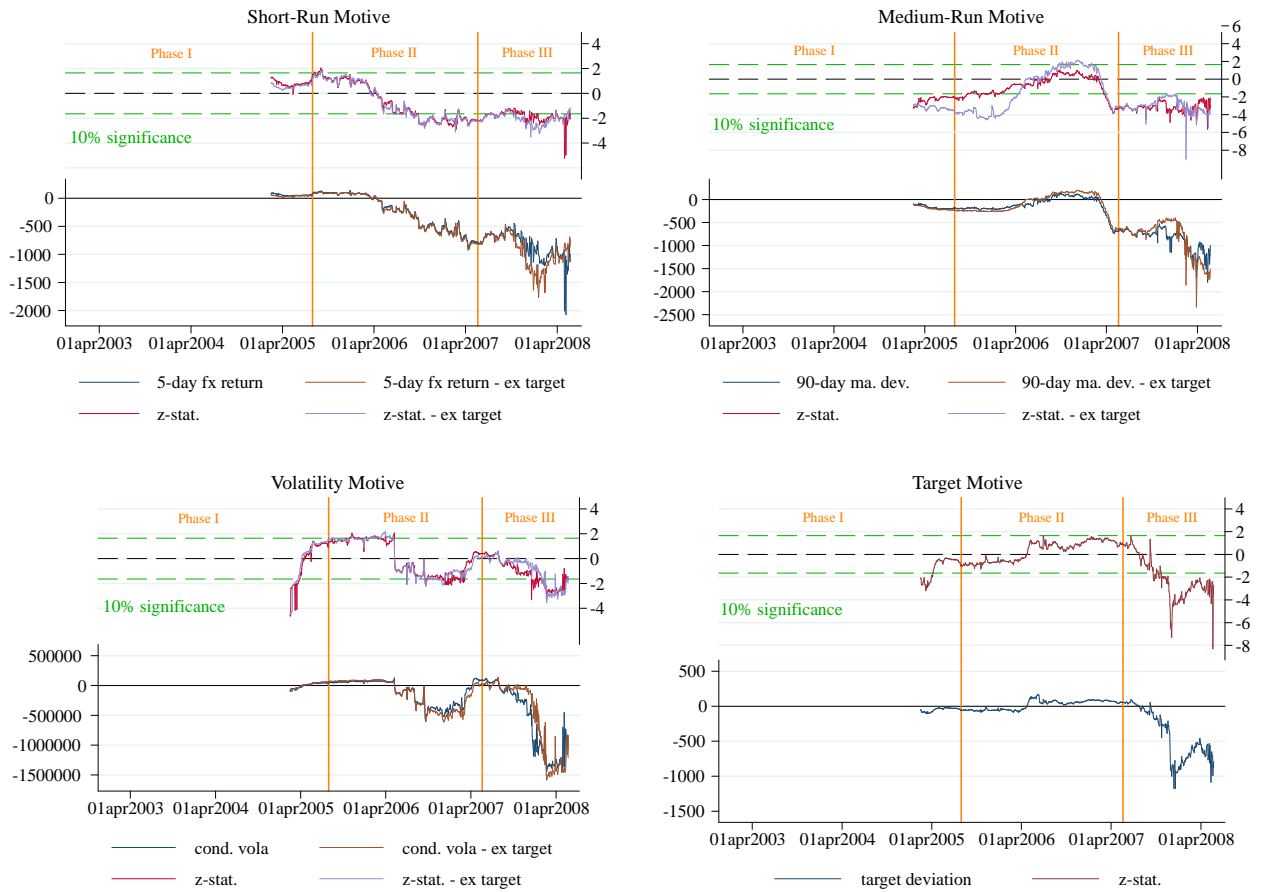


Figure 38: Unfiltered Local Estimation Results for the Argentinean Reaction Function: Rolling Estimations (window = 500 days).

A.2 Impact Analysis

A.2.1 Model Structures

The choice of model structures is described in Appendix A.1.2. Figures 39 to 42 present the correlograms of daily exchange rate changes.

- According to table 38, AIC and SIC indicate different structures for the volatility equation (SIC - GARCH(1,1), AIC - GARCH(3, 1)). Due to the fact that a GARCH(1,1) model displays autocorrelation of the squared residuals at lag 10, an AR(2)-GARCH(3,1) specification was chosen.
- According to table 39, AIC and SIC values clearly favor an AR(2)-GARCH(3,2) model.
- According to table 40, AIC and SIC indicate different structures for the volatility equation (SIC - GARCH(1,1), AIC - GARCH(3, 2)). In order to follow the idea of parsimonious specification, an AR(2)-GARCH(1,1) specification was chosen.
- According to table 41, AIC and SIC indicate different structures for the volatility equation (SIC - GARCH(1,1), AIC - GARCH(2, 2)). Due to the fact that a GARCH(2,2) model displays autocorrelation of the squared residuals, an AR(1)-GARCH(1,1) specification was chosen.

Sample: 2/17/2003 5/23/2008

Included observations: 1316

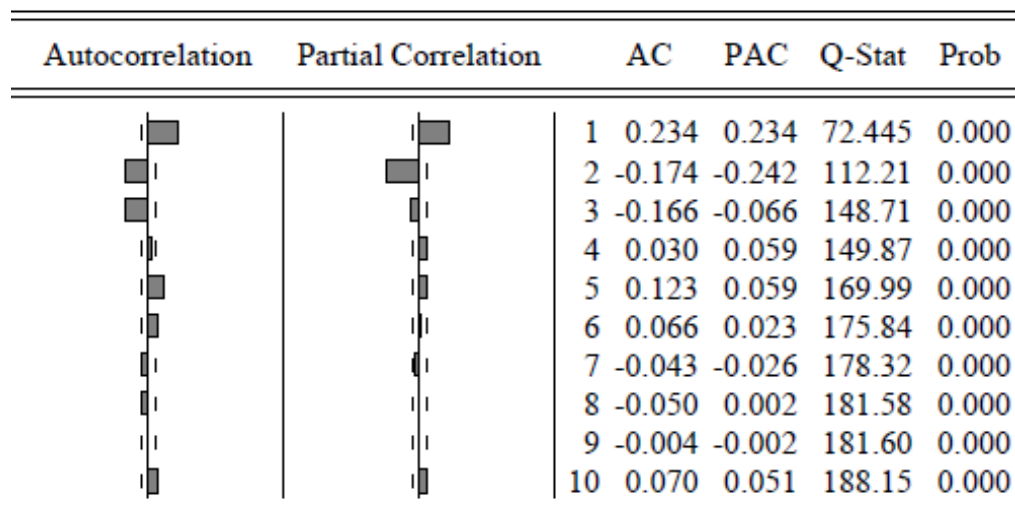


Figure 39: Correlogram of Daily US\$/ARS Exchange Rate Returns - Global Sample.

AR Struct. GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 5; 10	-8.8850	-8.8176	.814	.403	.800
1 to 2	-9.3809	-9.3297	.206	.166	.208
GARCH Structure	AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)	-9.3809	-9.3297	.759	.105	.007
(2,1)	-8.7785	-8.7233	.560	.954	.999
(2,2)	-9.1427	-9.0836	.000	.000	.000
(3,1)	-9.3880	-9.3289	.937	.380	.274
(3,2)	-8.7698	-8.7067	.000	.000	.000
(3,3)	-8.8710	-8.8039	.000	.000	.000

[†] p-values

Table 38: Structure Characteristic of the GARCH Model Impact Analysis: Argentina - Global Sample.

Sample: 2/17/2003 7/29/2005

Included observations: 615

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	0.236	0.236	34.528	0.000
		2	-0.189	-0.259	56.665	0.000
		3	-0.181	-0.072	76.988	0.000
		4	0.029	0.059	77.527	0.000
		5	0.134	0.062	88.671	0.000
		6	0.083	0.036	92.912	0.000
		7	-0.047	-0.033	94.319	0.000
		8	-0.067	-0.004	97.116	0.000
		9	-0.009	0.001	97.165	0.000
		10	0.081	0.055	101.24	0.000

Figure 40: Correlogram of Daily US\$/ARS Exchange Rate Returns - Phase I.

AR Struct. GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 2	-8.3700	-8.2763	.224	.502	.771
GARCH Structure	AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)	-8.3700	-8.2763	.846	.608	.364
(2,1)	-8.3676	-8.2667	.815	.340	.258
(2,2)	-8.3669	-8.2588	.775	.451	.262
(3,1)	-8.3904	-8.2823	.574	.319	.595
(3,2)	-8.3991	-8.2838	.423	.689	.626
(3,3)	-8.3725	-8.2500	.372	.745	.585

[†] p-values

Table 39: Structure Characteristic of the GARCH Model Impact Analysis: Argentina - Phase I.

Sample: 8/01/2005 5/18/2007

Included observations: 451

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 0.202	0.202	18.553	0.000
		2 -0.124	-0.171	25.504	0.000
		3 -0.079	-0.016	28.362	0.000
		4 0.081	0.088	31.367	0.000
		5 0.083	0.032	34.542	0.000
		6 -0.021	-0.030	34.753	0.000
		7 -0.022	0.017	34.967	0.000
		8 0.101	0.103	39.627	0.000
		9 0.013	-0.052	39.702	0.000
		10 0.020	0.059	39.892	0.000

Figure 41: Correlogram of Daily US\$/ARS Exchange Rate Returns - Phase II.

AR Struct.	GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 2; 4; 8		-10.3523	-10.2156	.311	.691	.783
1 to 2		-10.3592	-10.2407	.258	.558	.747
GARCH Structure		AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)		-10.3592	-10.2407	.563	.856	.986
(2,1)		-10.3592	-10.2315	.878	.873	.980
(2,2)		-10.3550	-10.2182	.916	.878	.981
(3,1)		-10.3555	-10.2187	.857	.831	.976
(3,2)		-10.3632	-10.2174	.950	.904	.987
(3,3)		-10.3588	-10.2038	.665	.885	.988

[†] p-values

Table 40: Structure Characteristic of the GARCH Model Impact Analysis: Argentina - Phase II.

Sample: 5/21/2007 5/23/2008
Included observations: 250





















Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	0.223	0.223	12.614	0.000
		2	0.003	-0.049	12.617	0.002
		3	-0.077	-0.071	14.133	0.003
		4	-0.105	-0.076	16.950	0.002
		5	-0.053	-0.016	17.685	0.003
		6	-0.121	-0.121	21.479	0.002
		7	-0.036	0.003	21.817	0.003
		8	-0.022	-0.033	21.944	0.005
		9	0.023	0.014	22.079	0.009
		10	-0.079	-0.121	23.723	0.008

Figure 42: Correlogram of Daily US\$/ARS Exchange Rate Returns - Phase III.

AR Struct.	GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1; 6; 10		-10.2258	-10.0286	.540	.927	.997
1		-10.2098	-10.0407	.767	.964	.839
GARCH Structure		AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)		-10.2098	-10.0407	.332	.432	.406
(2,1)		-10.1608	-9.9777	.837	.694	.746
(2,2)		-10.2218	-10.0246	.047	.027	.054
(3,1)		-10.2165	-10.0193	.818	.150	.300
(3,2)		-10.1995	-9.98824	.448	.280	.110
(3,3)		-10.2033	-9.97794	.254	.349	.456

[†] p-values

Table 41: Structure Characteristic of the GARCH Model Impact Analysis: Argentina - Phase III.

A.2.2 Rolling Estimation Aspects

- Figure 43 displays results of rolling ADF test statistics and the associated 10% significance levels for daily exchange rate returns, and explanatory variables with and without a constant variable β as described in Appendix A.1.3.
- Figure 44 displays unfiltered results from the rolling impact analysis estimation.

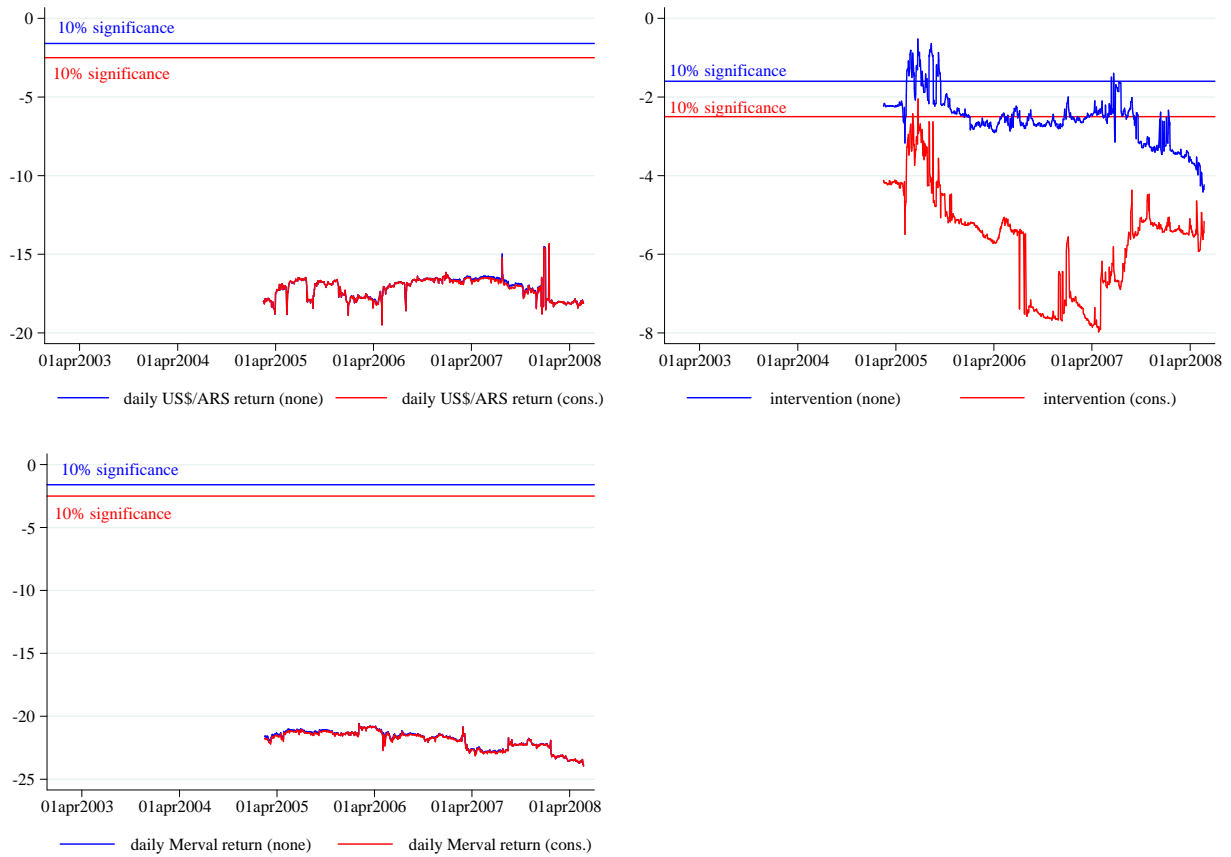


Figure 43: Rolling ADF Tests between February 2003 and May 2008 - Argentinean Impact Analysis (window = 500 days).

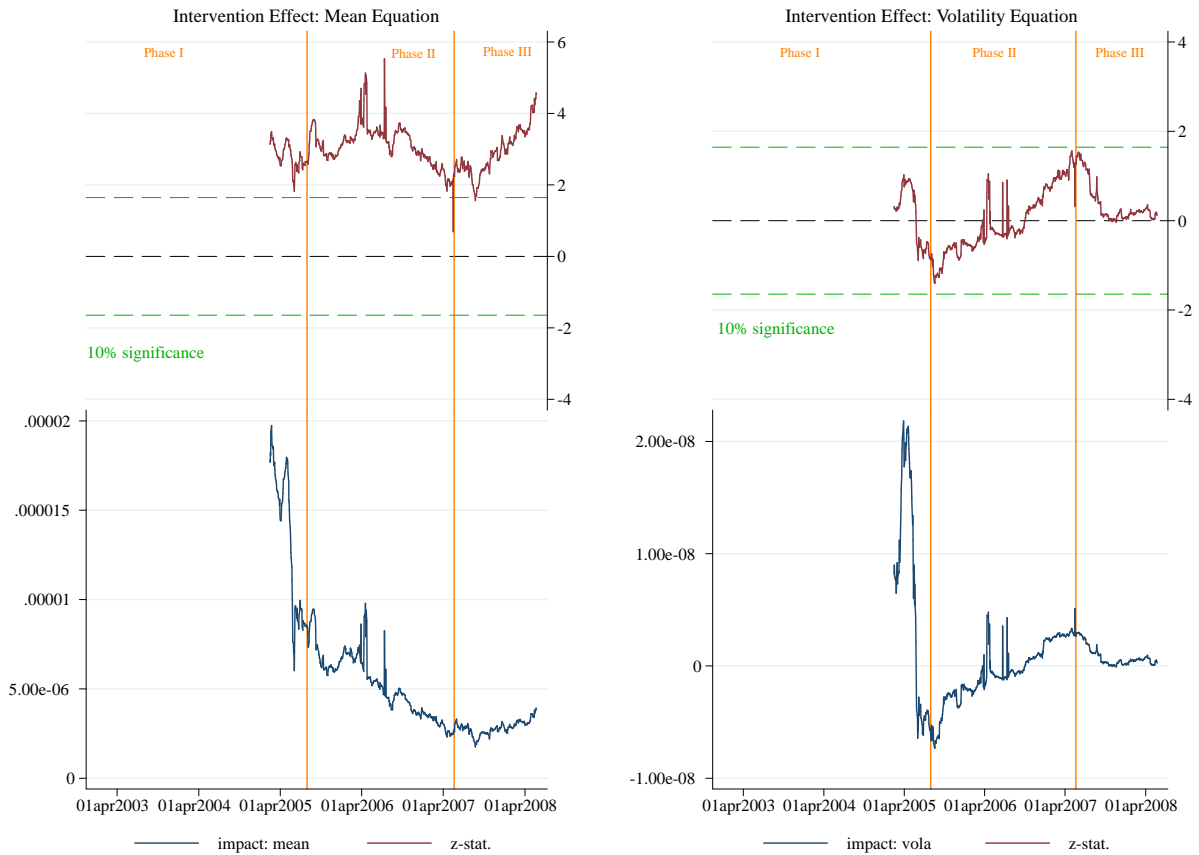


Figure 44: Unfiltered Local Estimation Results for the Argentinean Impact Analysis: Rolling Estimations (window = 500 days).

A.3 Exchange Rate Pass-Through

Similar to Ito and Sato (2006), I use the following standard form (reduced form) 6-variables VAR(2) model:

$$x_t = (\Delta oil_t, gap_t, \Delta money_t, \Delta fx_t, \Delta ppi_t, \Delta cpi_t). \quad (140)$$

All monthly data is indexed (2003M1 = 100) and is included as the difference of its natural logarithm, except the output gap. All of the data does not display any unit root behavior as shown in table 42. The VAR includes two lags. Oil_t is taken from IMF-IFS Statistics and displays the average of Texas, UK Brent, and Dubai spot prices; the output gap_t is generated by applying an HP-Filter on industrial production taken from the IMF-IFS Statistics, λ was set to 14400 as it is suggested for monthly data; $money_t$ is the broad money as calculated by the BCRA; fx_t is the monthly US\$/ARS exchange rate, and is taken from the BCRA; ppi_t and cpi_t display producer and consumer prices and are taken from the IMF-IFS Statistics.

	Δoil_t	gap_t	$\Delta money_t$	Δfx_t	Δppi_t	Δcpi_t
H0: Unit Root	-8.0***	-6.2***	-8.0***	-6.3***	-6.9***	-4.9***

ADF test with a constant; SIC lag.

*10% - **5% - ***1% significance

Table 42: Unit Root Tests for Variables in the Exchange Rate Pass-Through Analysis of Argentina.

The rowing of the data has important implication for the VAR model and for the identification of structural shocks. Basically, the order must be chosen according to the shock development, i.e. according to contemporaneous unaffected shocks. Therefore, the oil prices, which are ordered first, are assumed to be unaffected contemporaneously by other shocks. The price indices are ordered on the fourth and fifth position.⁴¹⁸ This is common in the literature on exchange rate pass-through effects since it is assumed that prices are contemporaneously

⁴¹⁸For a more detailed explanation of the ordering, see Ito and Sato (2006, 2007).

influenced by all other shocks while no shock is exerted from prices to other variables.⁴¹⁹ According to these arguments, similar to Ito and Sato (2006), structural shocks are generated using a Cholesky decomposition of the matrix Ω , which is the variance-covariance matrix of the reduced-form VAR residuals (u_t). The relationship between the reduced form residuals and the structural disturbances is given by:

$$\begin{pmatrix} u_t^{oil} \\ u_t^{gap} \\ u_t^{money} \\ u_t^{fx} \\ u_t^{ppi} \\ u_t^{cpi} \end{pmatrix} = \begin{pmatrix} S_{11} & & & & & \\ S_{21} & S_{22} & & & & \\ S_{31} & S_{32} & S_{33} & & & \\ S_{41} & S_{42} & S_{43} & S_{44} & & \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{oil} \\ \varepsilon_t^{gap} \\ \varepsilon_t^{money} \\ \varepsilon_t^{fx} \\ \varepsilon_t^{ppi} \\ \varepsilon_t^{cpi} \end{pmatrix}. \quad (141)$$

⁴¹⁹However, some controversial discussions deal with the matter of an appropriate ordering of the variables when analyzing exchange rate pass-through effects. See e.g. Belaisch (2003), Hahn (2003), Kim and Roubini (2000), Kim and Ying (2007).

B Croatian Data and Results

B.1 Reaction Function

B.1.1 Squared Intervention Data and OLS Residual Analysis

Table 43 displays pre-analysis of intervention data and OLS residuals to check for potential heteroskedasticity. OLS residuals ε_t are obtained from estimating reaction function 129 without accounting for discontinuity and threshold effects of interventions explicitly. The lag structure was chosen according to the analysis of intervention data presented below. Test statistics are described in Appendix A.1.1.

One could argue that applying OLS residuals might not be the right choice and that an analysis of generalized residuals as proposed by Gourieroux et al. (1987) should be used instead. This group of residuals refers to latent variable models whose errors are not directly observable. Therefore, errors of latent variable models are replaced by their best predictions. The obtained residuals can be used for testing hypotheses, and detecting specification errors. However, generalized residuals do not converge to the true errors asymptotically, and must be interpreted very carefully. Particularly, as discussed by Chesher and Irish (1987), if the underlying data generating process has homoskedastic errors, generalized residuals typically show a heteroskedastic behavior. Although a deeper econometric analysis of residuals is very interesting, it is beyond the scope of this empirical analysis. Furthermore, its potential interpretation problems do not generate clear benefits.

		<i>Intervention²</i>			
		Global	Phase I	Phase II	Phase III
<i>Ljung – Box Statistics</i>					
	$Q(1)$	0.004	0.096	0.247	0.087
	$Q(5)$	0.245	1.020	0.959	0.429
	$Q(10)$	2.276	1.735	6.416	0.718
		<i>OLS – residuals</i>			
		Global	Phase I	Phase II	Phase III
<i>Ljung – Box Statistics</i>					
	$Q^2(1)$	0.059	0.025	0.185	0.047
	$Q^2(5)$	0.312	0.773	0.936	0.288
	$Q^2(10)$	0.578	1.295	6.347	0.557
<i>ARCH Test –</i>					
	<i>LM – Stat.</i>				
	<i>F – Stat.</i>				
	$p = 1$	0.059	0.025	0.184	0.047
		0.059	0.025	0.184	0.047
	$p = 2$	0.131	0.159	0.425	0.098
		0.065	0.078	0.211	0.049
	$p = 3$	0.190	0.300	0.513	0.146
		0.063	0.098	0.170	0.048

*10% - **5% - ***1% significance

Table 43: Ljung-Box Q-statistics and ARCH Tests of Croatian Intervention Data and OLS Residuals.

B.1.2 Model Structures

Tables 45 to 48 display autocorrelation and partial correlation of daily Croatian interventions and the corresponding Ljung-Box Q-statistics. It can be seen that the matter of autocorrelation did not play a role in the global sample as well as sub-samples.

Sample: 3/11/2002 4/01/2008
Included observations: 1520

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
||	||	1	-0.002	-0.002	0.0042	0.948
||	||	2	-0.010	-0.010	0.1530	0.926
||	||	3	0.007	0.007	0.2248	0.973
||	||	4	0.000	-0.000	0.2248	0.994
||	||	5	0.004	0.004	0.2455	0.999
||	||	6	-0.003	-0.003	0.2560	1.000
||	||	7	-0.006	-0.006	0.3044	1.000
||	||	8	-0.036	-0.036	2.2403	0.973
||	||	9	0.005	0.005	2.2760	0.986
||	||	10	0.001	0.000	2.2766	0.994

Figure 45: Correlogram of Daily Croatian Foreign Exchange Interventions - Global Sample.

Sample: 3/11/2002 7/15/2003

Included observations: 336

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 0.032	0.032	0.3469	0.556
		2 0.011	0.010	0.3909	0.822
		3 0.029	0.028	0.6752	0.879
		4 -0.001	-0.003	0.6753	0.954
		5 0.076	0.076	2.6606	0.752
		6 0.000	-0.006	2.6606	0.850
		7 0.000	-0.001	2.6606	0.915
		8 0.066	0.062	4.1600	0.842
		9 0.000	-0.004	4.1600	0.901
		10 0.000	-0.007	4.1600	0.940

Figure 46: Correlogram of Daily Croatian Foreign Exchange Interventions - Phase I.

Sample: 7/16/2003 11/15/2005

Included observations: 588





















Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 -0.015	-0.015	0.1275	0.721
		2 -0.015	-0.015	0.2557	0.880
		3 0.034	0.034	0.9519	0.813
		4 0.004	0.005	0.9609	0.916
		5 -0.015	-0.014	1.0910	0.955
		6 0.055	0.054	2.8954	0.822
		7 0.030	0.031	3.4186	0.844
		8 -0.015	-0.012	3.5507	0.895
		9 -0.117	-0.121	11.739	0.228
		10 0.036	0.030	12.534	0.251

Figure 47: Correlogram of Daily Croatian Foreign Exchange Interventions - Phase II.

AR Struct.	Coefficient	Std. Error	Log-Likelihood	Wald-Test
Friction Model				
Int_{t-9}	-1.769	1.209	-188.125	50.21
No Lag			-190.888	49.06

Table 44: Structure Characteristic of the Friction Model Reaction Function: Croatia - Phase II.

Sample: 11/16/2005 4/01/2008

Included observations: 596

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
|||	|||	1	-0.012	-0.012	0.0846	0.771
|||	|||	2	-0.020	-0.020	0.3146	0.854
|||	|||	3	-0.008	-0.008	0.3517	0.950
|||	|||	4	-0.008	-0.008	0.3875	0.983
|||	|||	5	-0.012	-0.013	0.4757	0.993
|||	|||	6	-0.020	-0.020	0.7103	0.994
|||	|||	7	-0.020	-0.021	0.9462	0.996
|||	|||	8	-0.062	-0.064	3.2880	0.915
|||	|||	9	0.017	0.014	3.4558	0.943
|||	|||	10	-0.013	-0.016	3.5533	0.965

Figure 48: Correlogram of Daily Croatian Foreign Exchange Interventions - Phase III.

B.1.3 Rolling Estimation Aspects

- Figure 49 displays results of rolling ADF test statistics and the associated 10% significance levels for daily interventions, and its suggested motives with and without a constant variable β as described in Appendix A.1.3. As discussed, the choice of the window size reflects a trade-off between the informational content and the possibility of biased results due to nonstationarity. Furthermore, it is important to include both sale and purchase interventions when applying a friction model. For these reasons, the window size was set to 720. As can be seen in figure 49, unit roots had not been an issue in the context of the impact analysis. Some unit roots can be discovered on few occasions in 2007 for target deviations. However, they disappear soon afterwards and are therefore of no practical importance.
- Figure 50 and 51 display unfiltered results from the rolling reaction function estimation.

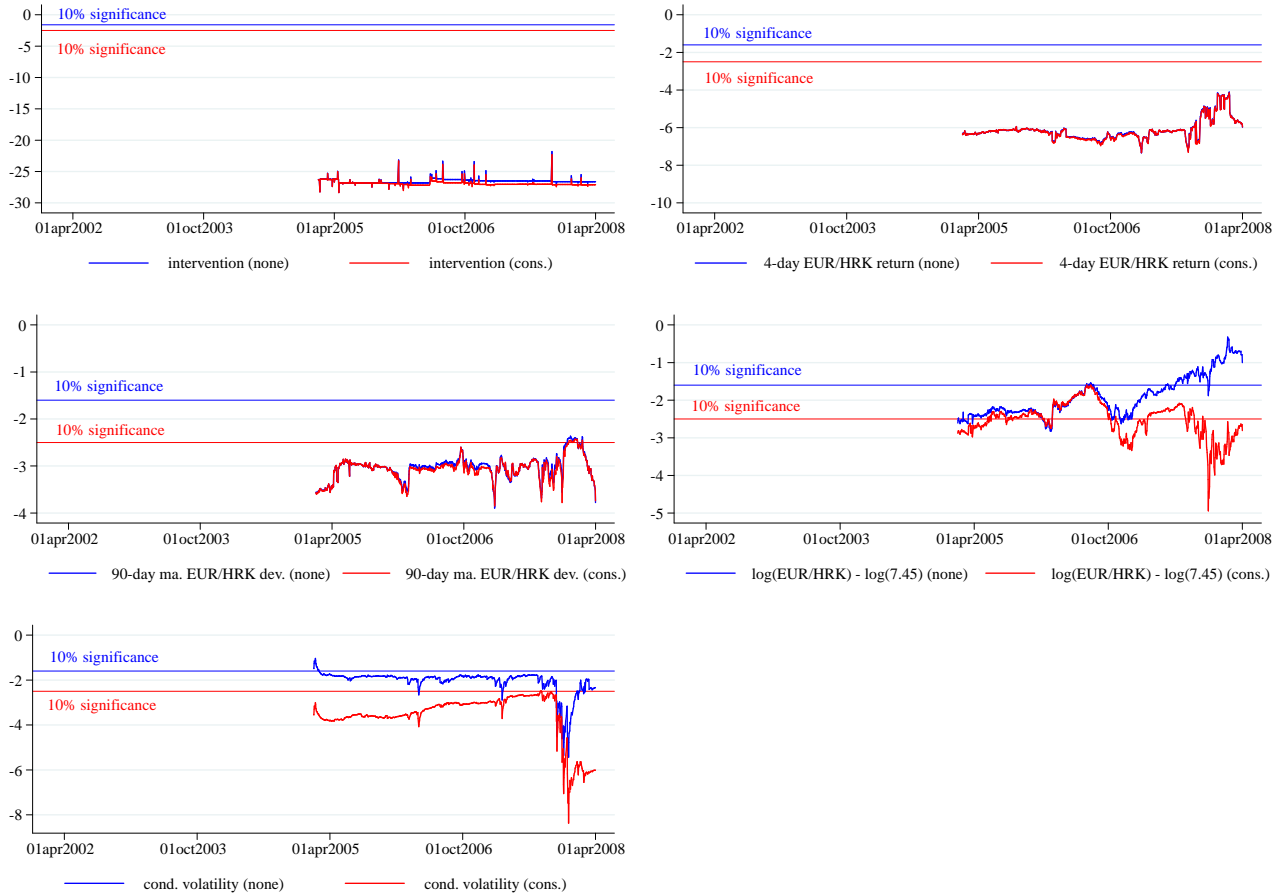


Figure 49: Rolling ADF Tests between March 2002 and April 2008 - Croatian Reaction Function (window = 720 days).

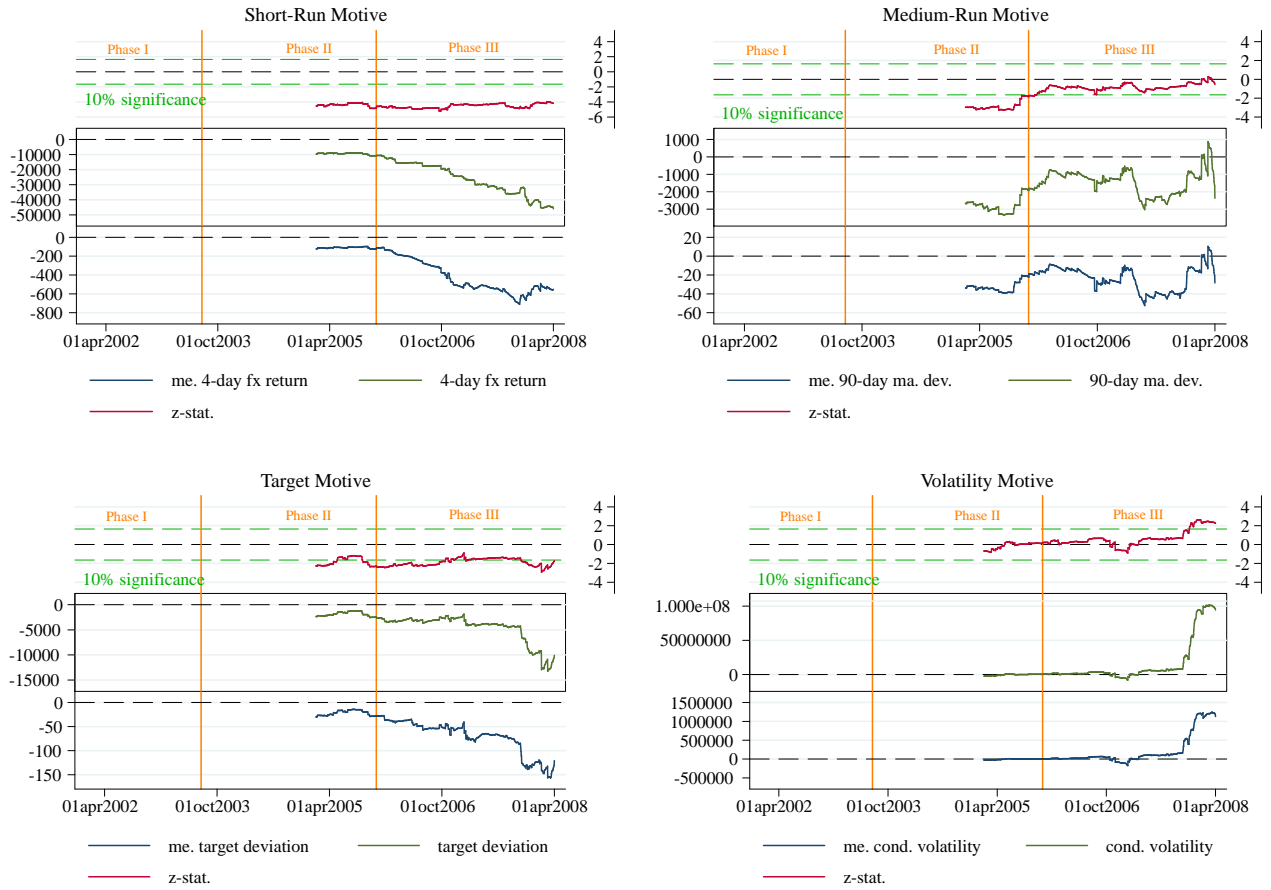


Figure 50: Unfiltered Local Estimation Results for the Croatian Reaction Function: Rolling Estimations (window = 720 days).

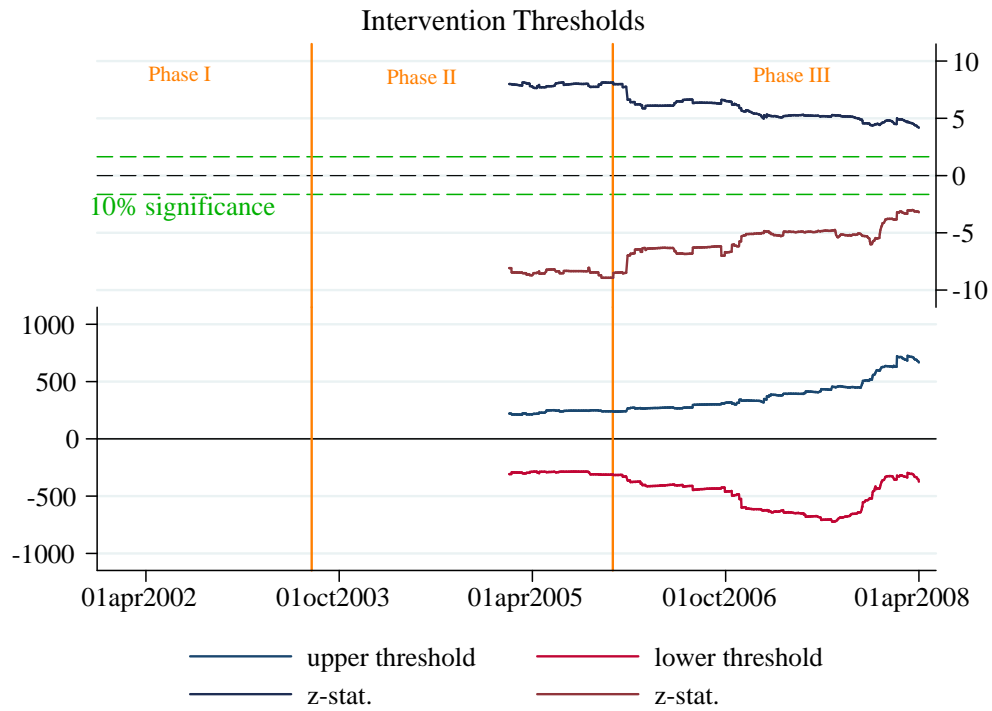


Figure 51: Unfiltered Asymmetric Croatian Intervention Response to the Underlying Motives between March 2002 and April 2008 (window = 720 days).

B.2 Impact Analysis

B.2.1 Model Structures

Figures 52 to 55 present the correlograms of daily exchange rate changes. The choice of model structures is described in Appendix A.1.2.

- According to table 45, AIC and SIC indicate different structures for the volatility equation (SIC - GARCH(1,1), AIC - GARCH(3, 2)). In order to follow the idea of parsimonious specification, an AR('2','3','4','5')-GARCH(1,1) was chosen.
- According to table 46, AIC and SIC indicate different structures for the volatility equation (SIC - GARCH(1,1), AIC - GARCH(3,3)). In order to follow the idea of parsimonious specification, an AR(3,'5')-GARCH(1,1) was chosen.
- According to table 47, AIC and SIC values clearly favor an AR(2,'4','9')-GARCH(2,2) model.
- According to table 48, AIC and SIC indicate different structures for the volatility equation and mean equation (SIC - AR('2','5')-GARCH(1,1), AIC - AR(2,'5','7')-GARCH(1,1)). In order to follow the idea of parsimonious specification, an AR('2','5')-GARCH(1,1) was chosen.

Sample: 3/11/2002 4/01/2008
Included observations: 1520





















Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	0.055	0.055	4.5948	0.032
		2	0.278	0.276	122.36	0.000
		3	0.089	0.068	134.48	0.000
		4	0.014	-0.074	134.78	0.000
		5	-0.022	-0.070	135.52	0.000
		6	0.009	0.024	135.66	0.000
		7	-0.056	-0.028	140.42	0.000
		8	-0.044	-0.046	143.32	0.000
		9	-0.047	-0.027	146.67	0.000
		10	-0.058	-0.027	151.82	0.000

Figure 52: Correlogram of Daily EUR/HRK Exchange Rate Returns - Global Sample.

AR Struct.	GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 5		-10.4542	-10.3980	.328	.824	.900
2 to 5		-10.4554	-10.4027	.195	.712	.850
GARCH Structure		AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)		-10.4554	-10.4027	.115	.340	.293
(2,1)		-10.4584	-10.4022	.923	.572	.581
(2,2)		-10.2695	-10.2098	.001	.000	.000
(3,1)		-10.4595	-10.3998	.983	.949	.866
(3,2)		-10.4638	-10.4005	.983	.999	.920
(3,3)		-10.4625	-10.3957	.994	.997	.911

[†] p-values

Table 45: Structure Characteristic of the GARCH Model Impact Analysis: Croatia - Global Sample.

Sample: 3/11/2002 7/15/2003

Included observations: 336





















Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 -0.241	-0.241	19.757	0.000
		2 0.340	0.299	59.044	0.000
		3 0.089	0.255	61.719	0.000
		4 0.096	0.078	64.849	0.000
		5 -0.047	-0.155	65.596	0.000
		6 0.061	-0.082	66.874	0.000
		7 -0.031	0.004	67.204	0.000
		8 -0.100	-0.098	70.638	0.000
		9 0.085	0.071	73.170	0.000
		10 -0.144	-0.044	80.408	0.000

Figure 53: Correlogram of Daily EUR/HRK Exchange Rate Returns - Phase I.

AR Struct. GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 3; 5	-10.2113	-10.0390	.915	.727	.829
GARCH Structure	AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)	-10.2113	-10.0390	.574	.707	.863
(2,1)	-10.2054	-10.0216	.676	.747	.892
(2,2)	-10.2093	-10.0140	.465	.771	.863
(3,1)	-10.1993	-10.0041	.674	.753	.896
(3,2)	-10.2003	-9.9936	.460	.753	.767
(3,3)	-10.2203	-10.0020	.704	.951	.537

[†] p-values

Table 46: Structure Characteristic of the GARCH Model Impact Analysis: Croatia - Phase I.

Sample: 7/16/2003 11/15/2005

Included observations: 588





















Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	0.202	0.202	24.055	0.000
		2	0.281	0.251	70.815	0.000
		3	0.103	0.011	77.128	0.000
		4	-0.023	-0.123	77.445	0.000
		5	0.016	0.008	77.592	0.000
		6	-0.012	0.025	77.682	0.000
		7	-0.053	-0.054	79.371	0.000
		8	-0.029	-0.024	79.871	0.000
		9	-0.143	-0.120	92.048	0.000
		10	-0.053	0.005	93.730	0.000

Figure 54: Correlogram of Daily EUR/HRK Exchange Rate Returns - Phase II.

AR Struct.	GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 2; 4; 9		-10.1154	-10.0024	.443	.836	.987
GARCH Structure		AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)		-10.1154	-10.0024	.268	.666	.683
(2,1)		-10.1172	-9.9967	.965	.749	.812
(2,2)		-10.1307	-10.0027	.284	.755	.499
(3,1)		-10.1146	-9.9865	.966	.884	.884
(3,2)		-10.1122	-9.9766	.977	.944	.911
(3,3)		-10.1302	-9.9871	.141	.701	.706

[†] p-values

Table 47: Structure Characteristic of the GARCH Model Impact Analysis: Croatia - Phase II.

Sample: 11/16/2005 4/01/2008

Included observations: 596





















Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 0.102	0.102	6.2143	0.013
		2 0.175	0.166	24.593	0.000
		3 0.052	0.021	26.231	0.000
		4 -0.020	-0.057	26.472	0.000
		5 -0.079	-0.088	30.204	0.000
		6 -0.014	0.012	30.315	0.000
		7 -0.104	-0.074	36.830	0.000
		8 -0.000	0.022	36.830	0.000
		9 0.033	0.060	37.501	0.000
		10 0.046	0.039	38.781	0.000

Figure 55: Correlogram of Daily EUR/HRK Exchange Rate Returns - Phase III.

AR Struct.	GARCH(1,1)	AIC	SIC	Q(1) [†]	Q(5) [†]	Q(10) [†]
1 to 2; 5; 7		-11.0247	-10.9132	0.740	0.880	0.728
2; 5		-11.0185	-10.9221	0.122	0.478	0.417
GARCH Structure		AIC	SIC	Q ² (1) [†]	Q ² (5) [†]	Q ² (10) [†]
(1,1)		-11.0185	-10.9221	.588	.343	.654
(2,1)		-11.0176	-10.9138	.889	.333	.648
(2,2)		-11.0159	-10.9047	.720	.447	.781
(3,1)		-11.0146	-10.9034	.828	.393	.666
(3,2)		-11.0085	-10.8898	.728	.521	.792
(3,3)		-10.9889	-10.8629	.093	.468	.326

[†] p-values

Table 48: Structure Characteristic of the GARCH Model Impact Analysis: Croatia - Phase III.

B.2.2 Rolling Estimation Aspects

- Figure 56 displays results of rolling ADF test statistics and the associated 10% significance levels for daily exchange rate returns, and explanatory variables with and without a constant variable β as described in Appendix A.1.3.
- Figure 57 displays unfiltered results from rolling impact analysis estimation.

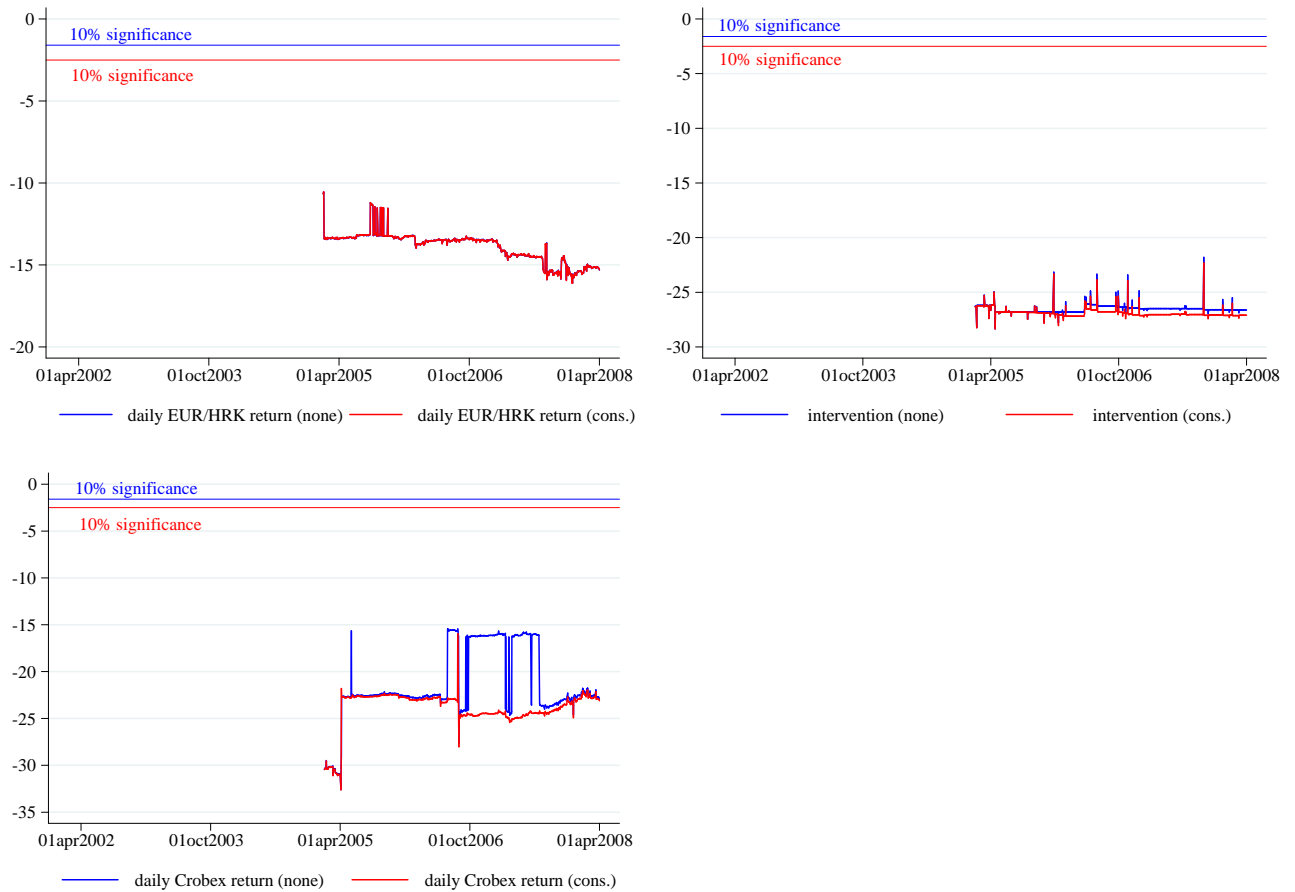


Figure 56: Rolling ADF Tests between March 2002 and April 2008 - Croatian Impact Analysis (window = 720 days).

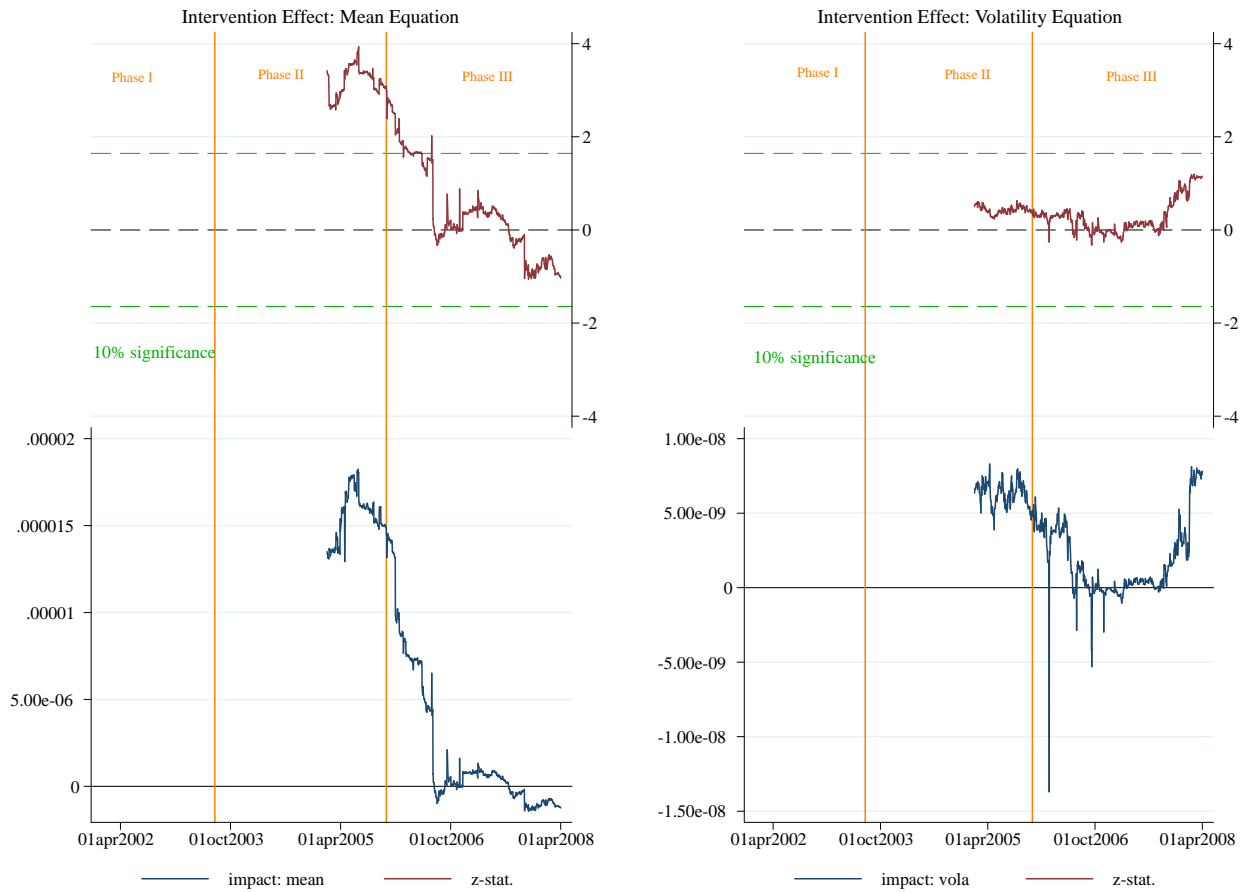


Figure 57: Unfiltered Local Estimation Results for the Croatian Impact Analysis: Rolling Estimations (window = 720 days).

B.3 Exchange Rate Pass-Through

Similar to Ito and Sato (2006), I use the following standard form (reduced form) 6-variables VAR(2) model:

$$x_t = \left(\Delta oil_t, gap_t, \Delta money_t, \Delta f x_t, \Delta ppi_t, \Delta cpi_t / \Delta cpi_t^{goods} \right). \quad (142)$$

All monthly data is indexed (2002M3 = 100) and is included as the difference of its natural logarithm, except the output gap. All of the data does not display any unit root behavior as shown in table 49. The VAR includes two lags. Oil_t is taken from IMF-IFS Statistics and displays the average of Texas, UK Brent and Dubai spot prices; the output gap_t is generated by applying an HP-Filter on industrial production taken from the IMF-IFS Statistics, λ was set to 14400 as it is suggested for monthly data; $money_t$ is the broad money (M4) as calculated by the CNB; $f x_t$ is the monthly EUR/HRK exchange rate and taken from the CNB; ppi_t and cpi_t (cpi_t^{goods}) display producer and consumer prices (goods basket) and are taken from the CNB.

	Δoil_t	gap_t	$\Delta money_t$	$\Delta f x_t$	Δppi_t	Δcpi_t
H0: Unit Root	-9.0***	-5.7***	-8.0***	-7.2***	-8.9***	(-6.3/-5.9)***

ADF test with a constant; SIC lag., test-statistics of beta

*10% - **5% - ***1% significance

Table 49: Unit Root Tests for Variables in the Exchange Rate Pass-Through Analysis of Croatia.

The rowing of the data has important implication for the VAR model and to identify structural shocks. Basically, the order must be chosen according to the shock development, i.e. according to contemporaneous unaffected shocks. For this reason the oil prices, which are ordered first, are assumed to be unaffected contemporaneously by other shocks. The price indices are ordered on the fourth and fifth position. This is common in the literature on exchange rate pass-through effects since it is assumed that prices are contemporaneously influenced by all other shocks while no shock is exerted from prices to other variables. According to these

arguments, similar to Ito and Sato (2006), structural shocks are generated using a Cholesky decomposition of the matrix Ω , which is the variance-covariance matrix of the reduced-form VAR residuals (u_t). The relationship between the reduced form residuals and the structural disturbances is given by:

$$\begin{pmatrix} u_t^{oil} \\ u_t^{gap} \\ u_t^{money} \\ u_t^{fx} \\ u_t^{ppi} \\ u_t^{cpi}/u_t^{cpi^{goods}} \end{pmatrix} = \begin{pmatrix} S_{11} & & & & & \\ S_{21} & S_{22} & & & & \\ S_{31} & S_{32} & S_{33} & & & \\ S_{41} & S_{42} & S_{43} & S_{44} & & \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{oil} \\ \varepsilon_t^{gap} \\ \varepsilon_t^{money} \\ \varepsilon_t^{fx} \\ \varepsilon_t^{ppi} \\ \varepsilon_t^{cpi}/\varepsilon_t^{cpi^{goods}} \end{pmatrix}. \quad (143)$$