

# **A Theory of Managed Floating**

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vorgelegt von:

Diplom-Volkswirt Timo Wollmershäuser  
aus Rothenburg ob der Tauber

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Betreuer: Prof. Dr. Peter Bofinger

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## **Chapter I: Introduction**

During the 1990s momentous changes have occurred in the monetary and exchange rate regimes of most industrial and emerging economies. For several decades, high inflation has been the main threat to monetary stability. The Bundesbank and the Federal Reserve both played an exceptional role as independent central banks with a sustainable low inflation record in the late 1970s and the 1980s. Apart from these, the only – at least temporarily – successful way for small open economies to establish an environment of low inflation was to import this stability from one of the two havens of stability by means of an exchange rate peg. These soft pegs, however, turned out to be highly vulnerable and instable so that economic stability was mostly of a short-term nature, often followed by severe economic crises. On a theoretical level monetary targeting represented an important alternative, but in practice it was hard to implement mainly due to unstable money demand relations. The emergence of inflation targeting offered a promising alternative to exchange rate targeting. Since it was explicitly adopted by many central banks in industrial countries in the early 1990s, it has proved to be highly successful in keeping inflation under control and promoting high economic growth. Despite this historically high level of economic stability, the floating rate exchange rate system has however been characterised by large gyrations of currency values of the major industrialised nations. Extended long-run misalignments of the exchange rates and high short-run volatility seemed to be the unavoidable costs of monetary independence.

Emerging market economies subsequently followed the example of the small open industrial countries. In Latin America, after decades of extreme swings in inflation and in the exchange rate, massive outflows of capital and repeated systemic disruptions in the domestic financial systems, successful reforms radically changed the landscape in the second half of the 1990s. Brazil and Chile were among the first emerging market economies to introduce inflation targeting, and many others followed. Today, in most countries inflation is under the control of independent central banks, capital mobility is generally very high, and exchange rates are far more flexible but nonetheless far more stable than previously – an outcome that is mainly due to interventionist behaviour of central banks which in many cases exceeds that of the industrialised countries by far. A similar picture has emerged in East Asia where countries are recovering from devastating currency and banking crises that have interrupted years of price and exchange rate

stability. Since 1998, more and more countries officially adopted inflation targeting regimes and the exchange rate regimes in the majority of the East Asian countries no longer exhibit the characteristics of the soft pegs of the 1980s and the early 1990s. With the exception of China, Hong Kong and Malaysia, all the countries in the region altered their exchange rate regimes in the direction of greater flexibility, without any pre-commitment to a particular parity, but nonetheless with heavy interventions in the foreign exchange market. Eastern European economies are a further example of this development. After the fall of the Iron Curtain, in many countries inflation rates came down to single digit levels within a few years. The initially adopted fixed or crawling rate regimes that mainly contributed to the successful disinflation were gradually replaced with managed and independently floating regimes and explicit inflation targets.

Academically, an important development in the area of monetary policy analysis in the 1990s was the convergence of approaches used by academic and central bank economists. While until the mid nineties the implementation of monetary policy was mainly discussed in terms of monetary aggregate growth rates among academics, it was probably the contribution of Taylor (1993a) which stimulated and encouraged academics to focus on policy rules expressed in terms of short-term interest rates, thereby conforming to actual central bank practices. Closely related to this development was the shift of academic focus away from money supply targeting strategies towards inflation targeting strategies which were introduced by many central banks in the 1990s without any preceding specific academic research on inflation targeting. Since the mid 1990s an increasing number of academics followed the path initiated by central bank economists and started to do research on the topic. Now there is a large volume of accumulated research, one of the most cited of which is the contribution of Svensson (1999).

What is missing in economic theory is a rationale for the developments in the countries' choices of exchange rate regimes, in particular on the flexible side of the exchange rate spectrum. Macroeconomic theory is still dominated by the paradigm of the impossible trinity which explains monetary policy of the so-called corner solutions of absolutely fixed and purely floating exchange rates. In particular, it is argued that the monetary regime of inflation targeting (like its predecessor money supply targeting) is only compatible with a fully market determined exchange rate, thus being completely at odds with actual central bank practice. The present study can be thought of as an attempt to provide – on the basis of a standard open economy macro

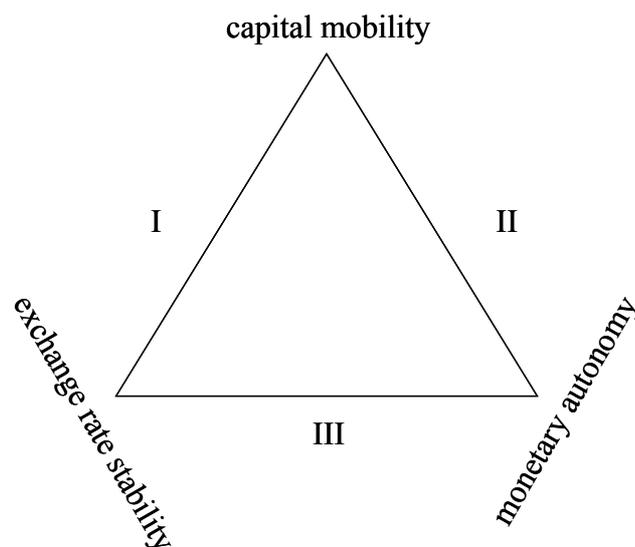
model – an economic rationale for the central banks' observed reluctance to really let their currencies float.

### **I.1 The theory of the shrinking middle**

With the crisis of the European Exchange Rate Mechanism in 1992/93 a consensus-like doctrine has emerged influencing much of the new literature about the choice of the appropriate currency regimes. Eichengreen (1994) was one of the first proponents of the so-called 'theory of the shrinking middle' or 'hollowing out theory' according to which only the two corner solutions 'hard pegs' and 'full floats' are viable in a world of high capital mobility. With progressive liberalisations of domestic and international financial markets during the 1980s in industrial countries and later during the 1990s in emerging market economies private international capital flows rose significantly which appears to make any revocable peg indefensible, no matter if it was conducted in the form of a crawling, an adjustable, or a constant peg. The fragility of these so-called intermediate regimes is primarily caused by an exchange rate illusion of financial institutions that are engaged in the respective economy. "When the capital account is open, there will be more scope for banks gambling for redemption to lever up their bets. (...) Foreigners will more freely fund the risky activities of emerging-market banks if they are confident that governments regard those banks as too big to fail. In the presence of government guarantees, they will be attracted by the high interest rates characteristic of capital-scarce emerging markets" (Eichengreen, 1999, pp. 41). This overborrowing and overlending in the financial sector aggravated the macroeconomic consequences of the large devaluation which occurred with the abandonment of the pegs after massive reversals of speculative capital flows. Eichengreen continues: "If there is one explanation, it is that governments failed to prepare the markets for the change in the exchange rate. The currency peg having been the centrepiece of their economic policy, jettisoning it was a heavy blow to their policy credibility. It raised doubts about their competence and about their commitment to their stated policy goals. Their stated commitment to the peg lulled banks and firms into the mistaken belief that there was no need for costly insurance against exchange rate fluctuations" (Eichengreen, 1999, p. 104). If lack of credibility was the predominant factor that brought down the pegs, the logic goes, then either an irrevocable fixing of the exchange rate (currency boards, dollarisation or monetary unions) or the complete abandonment of any promises about the exchange rate safeguards against crises.

This consensus, however, is nothing new in economic theory. The basis for the corner solution hypothesis is the so-called ‘impossible trinity’ theorem which simply states that a country cannot simultaneously maintain exchange rate stability, monetary autonomy, and capital mobility. It can be traced back to Padoa-Schioppa (1987), earlier Haberler (1937), and undoubtedly earlier antecedents. Figure I.1 gives an illustration of the theorem. If a government chooses stable exchange rates and capital mobility (regime I), it has to give up monetary autonomy. If it chooses monetary autonomy and capital mobility (regime II), it has to go with floating exchange rates. Finally, if it wishes to combine stable exchange rates with monetary autonomy, it has to impose capital controls (regime III). As the effectiveness of controls for capital inflows and outflows is very limited, at least on a sustained basis (see Ariyoshi et al., 2000, for a comprehensive overview), the menu is usually reduced to the first two options.

**Figure I.1: Impossible trinity**



## **I.2 The actual behaviour of central banks**

### ***I.2.1 Official floaters directly intervene in the foreign exchange market***

The corner solution view described in the previous Section can only be confirmed by using the official declarations of national authorities. By comparing the exchange rate regimes of member countries of the International Monetary Fund in 1991 and 1999, Fischer (2001, p. 5) comes to the following result: “The percentage of countries with hard pegs increased from 16 to 24 percent; the percentage with floating rate regimes increased from 23 to 42 percent (...). Thus, it does

appear that during the 1990s, countries were moving away from the intermediate arrangements and toward either hard pegs or floating exchange rate regimes.”

Actual policies however often diverge from official declarations. While hard peg regimes can be easily identified by looking at the exchange rate time series and the institutional setting surrounding the currency regime, the floating corner can only be verified by examining the behaviour of foreign exchange reserves. According to the textbook model of floating exchange rates, central banks do not intervene in the foreign exchange market so that the level of the central bank’s foreign exchange reserves should remain constant or at least be characterised by very little volatility (in particular in comparison with intermediate regimes or fixed rate regimes).<sup>1</sup> Empirical work by Calvo and Reinhart (2000) and Levy-Yeyati and Sturzenegger (2002), however, found that in practice countries that officially declare that they allow their exchange rate to float frequently intervene in the foreign exchange market. While foreign exchange reserves are highly volatile for these countries, the volatility of the nominal exchange rate is relatively low (in particular in comparison with countries that really let their currency float). Thus, Calvo and Reinhart (2000, p. 30) come to the conclusion that “the supposedly disappearing middle accounts for the lion’s share of country practices.”

By concentrating on the floating rate corner, in Bofinger and Wollmershäuser (2001) we confirmed the result that most of the official floaters heavily intervene in the foreign exchange market. Additionally, we built an index that classifies foreign exchange market interventions according to their objective which can be divided into two main categories: exchange rate smoothing and exchange rate targeting (Jurgensen, 1983). According to the smoothing objective, interventions are undertaken to counter erratic short-term (day-to-day) exchange rate movements, but not to alter the market determined trend. The changes in the foreign exchange reserves that are related with this objective should be randomly distributed around zero. According to the targeting objective, interventions are undertaken to establish a level or a path for the exchange rate. The changes in the foreign exchange reserves that are related with this

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<sup>1</sup> For an appropriate definition of direct foreign exchange market interventions many authors rely on an influential report of the Working Group on Exchange Intervention, commissioned by the Versailles Summit of June 1982 (Jurgensen, 1983). Accordingly, foreign exchange market interventions are narrowly defined as all transactions of the central bank that it actively undertakes with the participants of the inter-bank foreign exchange market. A somewhat broader definition further comprises the so-called passive interventions which are foreign currency transactions of the central bank with other entities (e.g. governments) that otherwise would have dealt directly with the participants of the inter-bank foreign exchange market. This broad definition makes intervention

objective are expected to exhibit a high degree of persistence (a purchase of foreign exchange is followed by several successive purchases and vice versa) since their purpose is to counter an existing market trend. The results of our study in which we investigated the behaviour of foreign exchange reserves of 44 countries for the periods in which they officially declared to follow an independent or a managed float (between 1975 and 2000) are striking. We found that 77 per cent of the official independent floaters actually pursued an exchange rate targeting strategy. 10 per cent intervened to smooth erratic exchange rate movements, and only 13 per cent behaved according to the textbook model of floating exchange rates and rarely made use of their foreign exchange reserves. In relation to the official managed floaters, we found that 89 per cent pursued an exchange rate targeting strategy and that 11 per cent intervened to smooth erratic exchange rate movements.

Further convincing evidence on the intervention behaviour is provided by the publicly recorded information on foreign exchange market intervention practices which can be found on the central banks' websites and in other official publications. All the countries shown in Table I.1 were classified as inflation targeting countries by the authors shown in the reference at the bottom of the Table. As an additional information we report the official IMF classification in the first column in parentheses (if = independently floating, mf = managed floating, crb = crawling band). Even though intervention practices appear to vary widely among central banks – ranging from full rejection in the case of Poland to heavy use in the case of Singapore – most (academic) proponents of inflation targeting agree with each other and do not see any role for foreign exchange market interventions. Taylor (2001, p. 263) for example argues as follows: “The only (...) monetary policy that can work well in the long run is one based on the trinity of (i) a flexible exchange rate, (ii) an inflation target, and (iii) a monetary policy rule.”

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equivalent to every change in the central bank's foreign reserves (eventually excluding any interest rate earnings on existing assets).

**Table I.1: Intervention practices of inflation targeting countries during 2001**

<b>Australia</b> (if)	The Reserve Bank of Australia intervenes when the exchange rate is overshooting; and when market conditions are unsettled.
<b>Albania</b> (if)	The Bank of Albania undertakes limited foreign exchange interventions to help smooth excessive fluctuations.
<b>Algeria</b> (mf)	The Bank of Algeria manages the exchange rate float in a flexible way to safeguard competitiveness and dampen external shocks.
<b>Brazil</b> (if)	The Central Bank of Brazil may intervene on a regular basis, to adhere to the inflation target, or in exceptional situations.
<b>Canada</b> (if)	The Bank of Canada intervenes only in exceptional circumstances.
<b>Chile</b> (if)	The Central Bank of Chile has the authority to intervene in exceptional circumstances; these interventions must be publicly announced and justified.
<b>Colombia</b> (if)	The Banco de la Republica does not intervene in the exchange market to define a particular exchange rate, although auctions of foreign currency sale options are used to accumulate international reserves.
<b>Croatia</b> (mf)	The Central Bank of Croatia intervenes on the foreign exchange market through foreign exchange auctions, but does not defend any predetermined exchange rate or band.
<b>Czech Rep.</b> (mf→if)	Interventions only to moderate large fluctuations in the exchange rate.
<b>Dominican Rep.</b> (mf)	The Banco Central de la República Dominicana increased exchange rate flexibility during 2000 (adjusting it weekly), due to the high private sector demand for foreign exchange. The exchange rate spread widened to 2 percent and there was a devaluation of the same amount.
<b>Euro area</b> (if)	The European System of Central Banks has the technical capacity to conduct, if need be, intervention operations in order to counteract excessive or erratic exchange rate fluctuations of the euro against the major non-EU currencies.
<b>Guatemala</b> (mf)	The Banco de Guatemala intervenes to maintain a stable currency.
<b>Honduras</b> (crb)	The Banco Nacional de Honduras intervenes to maintain the external competitiveness of the currency.
<b>Hungary</b> (crb)	The National Bank of Hungary intervenes to maintain the forint in a +/- 15 percent band.
<b>Iceland</b> (if)	The Central Bank of Iceland intervenes only to adhere to inflation target or sees exchange rate fluctuations as a potential threat to financial stability.
<b>Indonesia</b> (if→mf)	Sterilised increases in the supply of foreign exchange to the market are undertaken to control base money and to mitigate the depreciation pressure and exchange rate volatility.
<b>Israel</b> (crb)	The Bank of Israel has not intervened since 1997, allowing market forces to determine the appropriate level of the exchange rate within the exchange rate band. (The width of the band against a basket of currencies is 39.2 percent.)
<b>Jamaica</b> (mf)	Intervention to smooth demand pressures.
<b>Japan</b> (if)	The Foreign Exchange and Foreign Trade Law stipulates that the Minister of Finance shall endeavour to stabilise the external value of the yen by taking necessary measures including foreign exchange transactions. The Bank of Japan closely monitors exchange rate developments. It intervenes in the foreign exchange market as an agent of the Minister of Finance, when necessary.
<b>Kazakhstan</b> (mf)	The Central Bank of Kazakhstan intervenes to keep the currency within a certain band, because of large capital inflows.
<b>Korea</b> (if)	The Bank of Korea has intervened in the foreign exchange market in recent years.
<b>Mauritius</b> (if→mf)	The Bank of Mauritius intervenes, as and when necessary, mainly to signal perceived misalignments of the exchange rate.
<b>Mexico</b> (if)	The Banco de Mexico lets the peso float freely.
<b>New Zealand</b> (if)	The Reserve Bank could intervene directly in the foreign exchange market to counteract 'disorderly market conditions'; in practice the Reserve Bank has not intervened since 1985.
<b>Norway</b> (mf→if)	The Central Bank of Norway intervenes when the currency moves significantly out of line with reasonable fundamentals and at the same time exchange rate developments impair the prospects of achieving the inflation target. Interventions may also be necessary in the event of large short-term fluctuations of the currency when foreign exchange market liquidity is reduced.

**Table I.1: Intervention practices of inflation targeting countries during 2001**

<b>Peru</b> (if→mf)	The Banco Central de Reserva del Perú undertakes foreign exchange operations to restore financial market confidence in conditions of high foreign exchange rate volatility.
<b>Philippines</b> (if)	The Bangko Sentral ng Pilipinas occasionally enters the foreign exchange market, largely to maintain order and stability in the foreign exchange market and to dampen sharp fluctuations in the exchange rate.
<b>Poland</b> (if)	A pure floating exchange rate regime has been in place since April 2000.
<b>Romania</b> (mf→crb)	The National Bank of Romania has intervened regularly to maintain the exchange rate within a band.
<b>Russia</b> (mf)	During 2000, the Bank of Russia bought foreign exchange in the domestic market to replenish international reserves, took timely and purposeful steps to smooth sharp exchange rate fluctuations in the domestic foreign exchange market caused by transient factors, and prevented the ruble from getting strong in real terms.
<b>Singapore</b> (mf)	The Monetary Authority of Singapore intervenes in the foreign exchange market from time to time to ensure that movements of the Singapore dollar are orderly and consistent with the exchange rate policy. The currency is managed against a basket of currencies and is allowed to float within an undisclosed target band. The level and the width of the band are reviewed periodically to ensure that they are consistent with the economic fundamentals and market conditions.
<b>Slovak Rep.</b> (mf)	The National Bank of Slovakia may intervene in the event of excessive volatility in the crown exchange rate through foreign exchange transactions.
<b>Slovenia</b> (mf)	The Bank of Slovenia has intervened recently in the foreign exchange market to offset the impact of exchange rate changes on prices and complement interest rate actions.
<b>South Africa</b> (if)	The Reserve Bank did not intervene in the foreign exchange market during 2000 except to buy foreign exchange to lower the net open foreign exchange position.
<b>Sri Lanka</b> (mf)	The Central Bank of Sri Lanka participates actively in the foreign exchange market through buying and selling foreign exchange at or near market prices.
<b>Sweden</b> (if)	The Riksbank intervened in the currency market in June 2001, for the first time in years, to limit the impact of a sudden depreciation on inflation.
<b>Switzerland</b> (if)	The Swiss National Bank may intervene to calm disorderly foreign exchange markets.
<b>Thailand</b> (if→mf)	Direct foreign exchange intervention is limited.
<b>United Kingdom</b> (if)	The Bank of England can intervene in the foreign exchange market.
<b>United States</b> (if)	US Monetary Authorities may intervene to calm disorderly foreign exchange markets. They did not intervene in FX market during 2001.
<b>Uruguay</b> (crb)	Crawling band of 15 percent, economy highly dollarised, therefore primary objective of the monetary policy is to keep the currency stable.
<b>Venezuela</b> (crb)	The Central Bank of Venezuela promotes orderly behaviour of the exchange rate within the framework of a scheme of floating exchange rate bands.

Sources: Carare et al. (2002), Carare and Stone (2003), Stone (2003), central bank websites and publications

To sum up, the corner solution view cannot be confirmed by actual central bank practices. In particular at the floating rate corner the analysis of foreign exchange reserves and the reading of central bank publications show that a purely market determined exchange rate without any foreign exchange market interventions is more of an exception than a rule. Reinhart (2000, p.65) calls this finding “an epidemic case of ‘fear of floating’.” Additionally, there seem to be differences in the objective of interventions within the group of countries that intervene in the

foreign exchange market. The majority are engaged in exchange rate targeting interventions, whereas only a minority aims at smoothing erratic exchange rate movements.

### ***1.2.2 Sterilisation of foreign exchange market interventions***

Interventions in the foreign exchange market have a direct one-to-one impact on the monetary base, and hence on the short-term interest rate which serves the central bank as the operating target. If a central bank wishes to preserve the independence of its operating target, it has to isolate the direct effects of intervention operations from interest rate targeting operations which can be achieved by sterilising the liquidity impact of the intervention on the monetary base. Accordingly, a sterilised intervention is defined as an intervention in which the change of the net foreign assets is offset by an equivalent change of the net domestic assets so as to restore the monetary base to its original size (Jurgensen, 1983; see Chapter V for a detailed treatment of the sterilisation issue).

Studies estimating the degree of sterilisation of foreign exchange market interventions of the Federal Reserve, the Bundesbank, the Bank of Japan and the Bank of England (all of which officially floated) in the 1970s and 1980s almost unanimously found a high tendency to sterilise (often even full sterilisation) the impact on the domestic monetary base (see Dominguez and Frankel, 1993b, and Edison, 1993, and the literature cited there). Among the more recent studies, Wu (1999) who analyses monetary policy in Singapore (an official managed floater) estimates a degree of sterilisation of 84 per cent for the period from 1978 to 1995. For the Bank of Korea, which also officially declared to follow a managed float, Rhee and Song (1999) found that 84 per cent of the foreign exchange market operations between 1980 and 1994 were sterilised (see also a study by Kwack, 1994, for similar results). In Bofinger and Wollmershäuser (2001), we estimated the degree of sterilisation of those central banks that predominantly use interventions to target a level or a path of the exchange rate (see the presentation of our study in Section I.2.1). We found that 10 (19) out of 27 countries in the sample sterilised more than 90 (70) per cent of the impact of the change of foreign reserves on the monetary base. Hufner (2003) investigated the intervention policy of five independently floating inflation targeting countries (Australia, Canada, New Zealand, Sweden, United Kingdom) between 1990 and 2001. For those countries which showed a high intervention activity during that period (Australia, Canada, New Zealand, Sweden) he estimated a degree of sterilisation of 70 per cent for Australia, 80 per cent for Sweden, 100 per cent for Canada and New Zealand.

Another way to approach the sterilisation issue is to measure the degree of monetary independence under floating rates (cum interventions) and to compare it with the degree of monetary independence under absolutely fixed exchange rates. Borensztein et al. (2001) compared the sensitivity of domestic interest rates in Hong Kong and Singapore to US interest rate shocks. While the interest rates of Hong Kong's currency board system react one-for-one to US interest rates (which is in line with a textbook model of absolutely fixed exchange rates), the floating rate system of Singapore, in which foreign exchange market interventions take place on a regular basis (see Section I.2.1), enjoys a high degree of monetary independence. In a related study, Frankel et al. (2002) used an extended panel data set including 46 countries from the early 1970s to the late 1990s. Based on the official declaration of exchange rate regimes that is published by the International Monetary Fund, they found that interest rates of countries with more flexible regimes adjust far more slowly to changes in international interest rates than interest rates of countries with fixed exchange rates. They conclude that "floating regimes appear to offer at least a degree of temporary monetary independence" (Frankel et al., 2002, p. 31).

### ***1.2.3 The use of interest rates to stabilise exchange rates***

The finding that many central banks less-than-fully sterilise the impact of interventions on the short-term interest rate suggests that the short-term interest rate is additionally used to stabilise movements in the exchange rate.<sup>2</sup> In their influential study, Calvo and Reinhart (2000) found that the interest rate volatility of those countries with fear of floating is significantly higher compared with the interest rate volatility of true floaters. From this finding they conclude that "there is an apparent change in the conduct of monetary-exchange rate policy in many emerging markets – interest rate policy is (at least partially) replacing foreign exchange intervention as the preferred means of smoothing exchange rate fluctuations" (Calvo and Reinhart, 2002, pp. 404).

This tendency of central banks to indirectly influence the exchange rate by interest rate adjustments is largely confirmed (even for developed countries) by empirical work on monetary policy rules. One strand of evidence results from the estimation of structural VARs in which, among other dynamic relationships such as aggregate demand, an equation for the monetary

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<sup>2</sup> Note, however, that this interest rate reaction can also be achieved by a traditional open market operation so that non-sterilised changes in the foreign reserves do not necessarily have to occur for explaining the use of interest rates to stabilise exchange rates.

policy instrument has to be specified. For example, Clarida and Gertler (1997) reported estimates according to which the Bundesbank responded to a depreciation of the real exchange rate with a rise in short-term interest rates. Based on a small-scale model of the Australian economy, Brischetto and Voss (1999) and Dungey and Pagan (2000) found that the Reserve Bank of Australia reacts with the short-term interest rate to movements in the exchange rate.

Another strand of empirical evidence results from the direct estimation of monetary policy rules. Clarida et al. (1998) found a small, but significant reaction of the nominal interest rate of the Bundesbank (1979-1993), the Bank of Japan (1979-1994) and the Bank of England (1979-1990) to the real exchange rate. Gerlach and Smets (2000) estimated interest rate policy rules according to which the Reserve Bank of New Zealand and the Bank of Canada respond significantly with the short-term interest rate to changes in the nominal exchange rate, whereas the Reserve Bank of Australia does not. Investigating the inflation targeters Australia, Canada, New Zealand, Sweden, United Kingdom Hüfner (2003) found that the exchange rate term in the policy rule is only significant for the United Kingdom and New Zealand. He explains the differences to the study of Gerlach and Smets (2000) mainly by a somewhat larger sample period. For the emerging market economies Chile, Israel, South Africa, the Czech Republic and Mexico Ades et al. (2002) also found significant (and, in comparison with the developed economies of the aforementioned studies, larger) exchange rate coefficients in the interest rate policy rule.

### **I.3 Classifying exchange rate and monetary policy regimes**

In this Section, we will address the question of how the actual behaviour of central banks fits into the traditional classification of exchange rate and monetary policy regimes. We will show that the observed intervention practices at the floating corner of the exchange rate spectrum form the basis of two open economy monetary policy strategies that so far have attracted very little attention in the literature. In order to differentiate them from the traditional corner solutions we set-up a classification scheme for a complete monetary and exchange rate strategy according to which a monetary policy maker has to make a decision on three levels. First, as will be described in Section I.3.1, the central bank has to make a decision concerning the role of the exchange rate. The crucial question is whether the exchange rate shall be principally determined by the market or by the monetary policy maker. Second, as will be described in Section I.3.2, the central bank has to make a decision about the way in which monetary policy decisions shall be implemented. This implies above all the choice of the operating target and the specification of a policy rule for

the operating target. Third, as will be shown in Section I.3.3, the central bank has to make a decision about the nominal anchor with which the private sector anchors its expectations in the long-run.

### ***I.3.1 Classification in terms of the role of the exchange rate***

The official spectrum of exchange rate regimes that play an important role today ranges from independently floating exchange rates over managed floating and crawling pegs to fixed exchange rates. Quite often the fixed exchange rate corner is further divided into conventionally unilateral pegs, multilateral fixed rate systems, currency board arrangements and exchange rate arrangements with no separate legal tender (dollarisation or currency unions). For the purpose of analysing the impact of the exchange rate regime on the conduct of monetary policy, however, it is sufficient to concentrate on the fact that for each of these sub-regimes the level of the exchange rate is fixed vis-à-vis another currency.<sup>3</sup>

We will start the classification with the most flexible system and we will gradually move to more rigid arrangements. A common definition of an *independent float* is a regime in which the exchange rate is purely market determined and in which the monetary authority sets its instrument exogenously and independently of any direct exchange rate developments. According to the classification of the International Monetary Fund, foreign exchange market interventions may occur under independently floating exchange rates, but in sharp contrast to managed floating exchange rates these interventions are only “aimed at moderating the rate of change and preventing undue fluctuations in the exchange rate, rather than at establishing a level for it” (see the monthly print versions of the International Financial Statistics on page 3).

A very broad definition for systems of *managed floating* exchange rates can be found in the Oxford Dictionary of Economics: “The system under which a country’s exchange rate is not pegged, but the monetary authorities try to manage it rather than simply leaving it to be set by the market. This can be done in two ways: small fluctuations in the exchange rate can be smoothed out by the authorities buying the country’s currency when its price would otherwise

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<sup>3</sup> This is not to say that the institutional differences between the fixed rate regimes are not important for monetary policy. On the contrary, the more institutionally backed the fixed exchange rate is, the more credibility it will have and the higher the probability that it will survive. This explains for example why many economists distinguish between soft pegs (unilaterally and multilaterally fixed exchange rates), which can be easily adjusted or

fall and selling it when its price would otherwise rise. The authorities can also influence the exchange rate through their macroeconomic policies. Higher interest rates tend to bring inward capital flows and improve the trade balance through their effect in depressing domestic activity; lower interest rates have the opposite effects. This type of exchange rate management is sometimes referred to as a 'dirty float'. There is no obvious justification for the pejorative description, and this policy regime is in fact widespread."<sup>4</sup> This definition distinguishes between two important types of systems of managed floating, in particular with respect to the way the exchange rate is managed.

In a so-called dirty float the central bank responds with its traditional monetary policy instrument (i.e. the short-term interest rate) to movements of the exchange rate. As the instrument constitutes an important fundamental determinant of the exchange rate (as we shall see below in Chapter II), such a policy is classified as exchange rate management. It is however important to bear in mind that the central bank only changes a fundamental determinant of the exchange rate and leaves it to the market to map this new 'information' on the exchange rate. Instead of using the somewhat 'pejorative' term of the above definition we refer to this strategy as an *indirect managed float* in order to distinguish it from a managed float in which the central bank directly intervenes in the foreign exchange market (in the sense of sales and purchases of foreign exchange). According to our definition such direct interventions are not part of an indirect managed floating strategy (except maybe for the same 'smoothing' motive as under independently floating exchange rates). Note, however, that the change in the interest rate can also be achieved by a change in the central banks net foreign assets, and hence by interventions in the foreign exchange market (instead of the net domestic assets as in the case of open market operations). If the indirect managed float is implemented in that way, interventions are non-sterilised simply because their primary objective is precisely to change the interest rate, and by this, the exchange rate.

In the second type of managed floating the central bank directly targets the level of the exchange rate by selling or purchasing foreign exchange, and hence by directly intervening in the foreign exchange market. We refer to this kind of strategy as a *direct managed float*. This does not mean that the exchange rate is necessarily entirely policy determined. We will show in Chapter V that

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abandoned, and hard pegs (currency boards, dollarisation and currency unions), in which the costs of altering the system are prohibitively high.

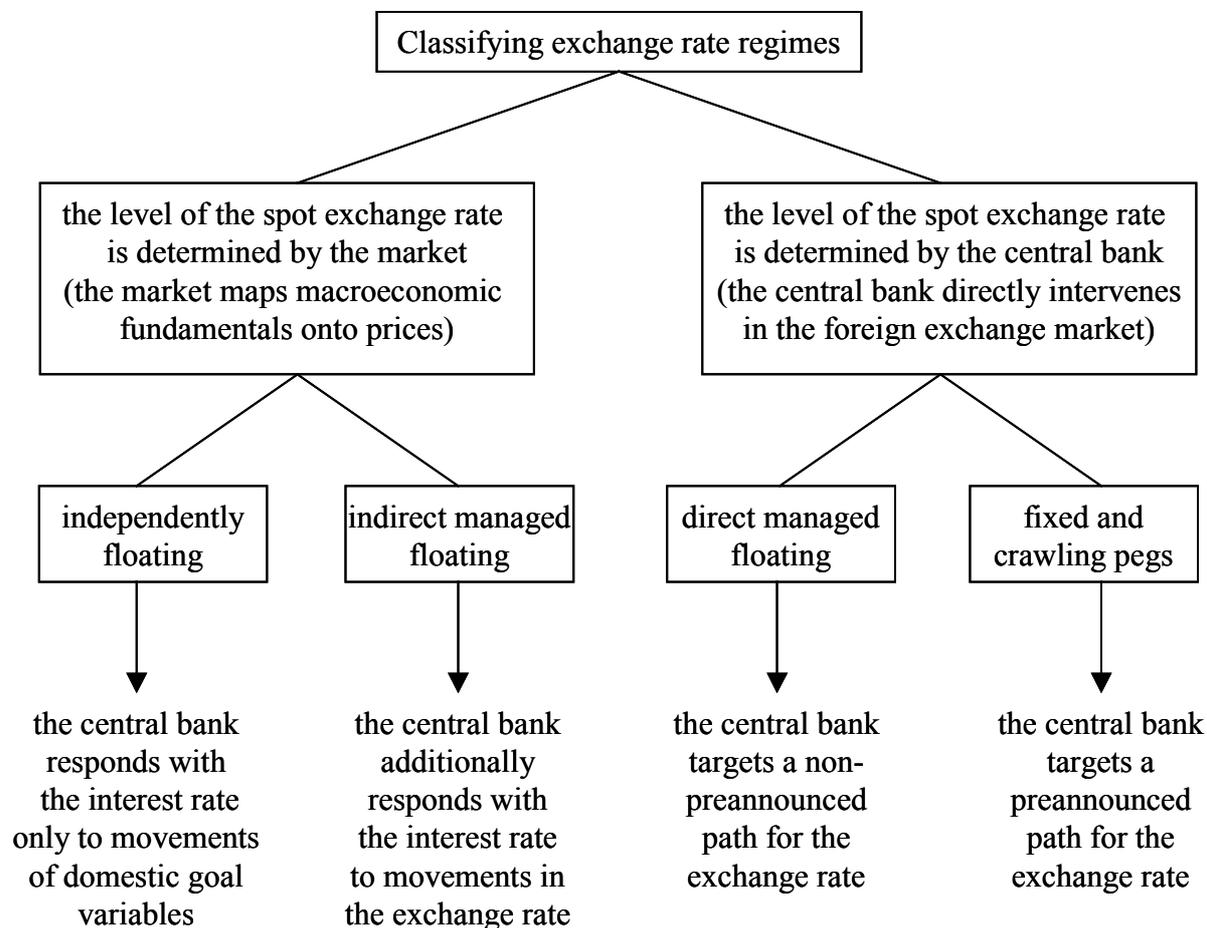
<sup>4</sup> See: <http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t19.002361>.

in situations when the private sector's expectations are fully compatible with the central bank's exchange rate path (which is simply derived from a perfectly functioning foreign exchange market) the market's exchange rate and the central bank's exchange rate target are identical. An important feature of a direct managed float is that the effect of sales and purchases of foreign exchange on the traditional monetary policy instrument is sterilised. If it were not, any intervention in the foreign exchange market would feed back on domestic short-term interest rates. Thus, there would be no difference to directly changing the short term interest rates, and hence to an indirect managed float. In our view, however, this distinction is very important and it is usually not that pronounced in the literature. Many economists subsume *each* policy action to influence the course of the exchange rate under a strategy of managed floating. Williamson (2000) is a prime example of this view. He defines managed floaters as follows: "They announce no parity or band, (...) and they intervene, or change interest rates (...) with a view to having an impact on the exchange rate" (Williamson, 2000, p. 47). However, he points out another important feature of direct managed floating: the exchange rate target is not announced. This is in sharp contrast to fixed exchange rates and crawling pegs in which central banks pre-commit to a constant rate of change of the nominal exchange rate (which is zero in the case of fixed exchange rates and different from zero in the case of crawls). This aspect is also reflected in the exchange regime classification system of the International Monetary Fund. Since its revision in January 1999 formerly called 'Managed floating' arrangements are labelled more precisely as 'Managed floating with no preannounced path for the exchange rate'. The International Monetary Fund provides the following definition: "The monetary authority influences the movements of the exchange rate through active intervention in the foreign exchange market without specifying, or precommitting to, a preannounced path for the exchange rate" (see the monthly print versions of the International Financial Statistics on page 3).

*Crawling pegs* and *fixed exchange rates* share the common feature that the future exchange rate path is predetermined. While under a crawl the central bank preannounces a constant rate of change of its currency against an anchor currency, under a fixed rate regime it makes a commitment to keep the level of its currency constant. It is clear that in both regimes the determination of the exchange rate is not left to the market. The central bank has to subordinate all its policy actions to the goal of maintaining the preannounced fixed or crawling exchange rate path. This includes interest rate policy as well as foreign exchange market interventions. However, as we will show in the next Section, under idealised conditions foreign exchange market interventions should not be sterilised under fixed or crawling exchange rates.

Figure I.2 summarises the results of this Section.

**Figure I.2: The exchange rate's role in monetary policy**



### *1.3.2 Classification in terms of the operating targets of monetary policy*

The above classification of the role of the exchange rate has important implications for the choice of the operating targets of monetary policy. As operating targets we define those variables which the central bank directly controls by means of its instruments. The traditional operating target of monetary policy is a short-term interest rate<sup>5</sup> which is controlled by the central bank either through interventions in the domestic money market or through non-sterilised interventions in the foreign exchange market. If the exchange rate is considered as operating

<sup>5</sup> Alternatively, a central bank could target the monetary base. Since most central banks today control some short-term interest rate, we leave the possibility of base money targeting aside (see Chapter IV for a short discussion of the relationship between the monetary base and the short-term interest rate).

target, the central bank controls it through sterilised interventions in the foreign exchange market.<sup>6</sup>

The traditional currency regimes of purely market determined exchange rates (independently and indirect managed floating) and fixed (or crawling) exchange rates are characterised by a single operating target. Under *market determined exchange rates* the theoretical analysis of monetary policy is to a great extent coined by the analysis in closed economies. The operating target of the central bank is a short-term interest rate which the central bank sets autonomously in order to achieve its ultimate goals. Whether the central bank responds with the interest rate to exchange rate movements or not (i.e. whether it pursues an indirect managed float or an independent float) is only of minor importance, since in both cases the market determines the value of the exchange rate. Thus, under a system of market determined exchange rates (independently floating or indirect managed floating) the exchange rate is considered (by definition) as endogenous variable.

In systems of *fixed exchange rates* or *crawling pegs* the spot exchange rate is regarded as an intermediate target and the interest rate is the operating target. In order to keep the exchange rate on the desired (constant or crawling) path, the central bank has to set the interest rate solely with a view to avoiding any pressure on the exchange rate, thereby giving up alternative ultimate goals. Thus, while the exchange rate path is set exogenously by the central bank, the interest rate becomes fully endogenous. In principle, a central bank acting in such a system could fully renounce the use of any interest rate setting instruments and leave the determination of the interest rate to the market. This very stringent variant of a market-determined monetary policy instrument is realised under a currency board arrangement where the monetary policy authority is to a large extent restricted in the use of the assets of its balance sheet by law. The endogeneity of the interest rate also makes clear that in an idealised exchange rate peg, sterilisation of foreign exchange market interventions is a policy tool that is non-compliant with such a system. If there is pressure on the exchange rate, then the pressure should not be reduced by sterilised interventions (which leave the interest rate unaffected), but by an adjustment of the interest rate.

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<sup>6</sup> It is important to emphasise that in our view non-sterilised interventions in the foreign exchange market are not an appropriate instrument to control the exchange rate if the exchange rate is considered as an operating target. As non-sterilised interventions alter the interest rate and as the interest rate constitutes an important determinant of the exchange rate (which we will see below in Chapter II), we are only able to indirectly control the exchange rate.

Under a *direct managed float* the central bank has two operating targets: the interest rate and the exchange rate. While the practice of interventions in the domestic money market to control short-term interest rates and its efficiency is widely uncontested today among economists, the assumption that central banks use sterilised foreign exchange market interventions as an additional and independent tool of monetary policy to control exchange rates is rather unusual in the context of modelling monetary policy strategies, and hence innovative.

Table I.2 summarises again the operating targets of monetary policy under different currency regimes.

**Table I.2: Operating targets of monetary policy in an open economy**

	independently / indirect managed floating	direct managed floating	crawling pegs / fixed exchange rates	
			central bank	currency board
short-term interest rate	operating target	operating target	operating target	market- determined
spot exchange rate	market- determined	operating target	intermediate target	intermediate target

### ***1.3.3 Classification in terms of the nominal anchors of monetary policy***

A nominal anchor is usually viewed as a necessary condition for macroeconomic stability since, at least in the long-run, all nominal variables will converge to the pre-set value of the anchor. Assuming that appropriate fiscal and microeconomic policies are in place, the price stability brought about by a nominal anchor should ensure that the economy achieves long-run economic growth. Thus, a prerequisite for a successful monetary policy strategy is that it clearly provides a nominal anchor for the inflation expectations of the private sector.

Under market determined exchange rates the dominant nominal anchor is a direct inflation target. Although an *inflation targeting* framework could be defined very flexibly, and definitions vary somewhat between authors, there is some consensus that the following ingredients are essential (see e.g. Mishkin and Savastano, 2000): First and foremost, the public announcement of an explicit numerical goal for inflation – the inflation target itself – that is to be achieved within a specific medium-term horizon and that serves as nominal anchor; second, an institutional

commitment to that target as the primary goal of monetary policy, to which other goals that might conflict with inflation are subordinated; third, an information-inclusive strategy in which many variables, and not just monetary aggregates or the exchange rate, are used for deciding the setting of the policy instrument; and fourth, the adoption of high levels of transparency and accountability, thereby fostering the credibility of the inflation target. By using a negative criterion, another possible definition of inflation targeting is a monetary policy strategy in which no traditional intermediate target is available (see Bofinger, 2001, chapter 8, for a discussion). This contrasts inflation targeting in particular with monetary targeting where the money supply is at the same time the intermediate target and the nominal anchor (see Chapter II for a short discussion of the relationship between inflation targeting and monetary targeting in macroeconomic models).<sup>7</sup>

In strategies in which the exchange rate serves as an intermediate target (fixed exchange rates and crawling pegs) the exchange rate target is the nominal anchor. The basic rationale of *exchange rate targeting* strategies is that in countries with a low degree of credibility of monetary policy the exchange rate peg helps inherit the credibility of monetary policy of the low-inflation anchor country. While under fixed exchange rates there is only a unique nominal anchor (namely the fixed level of the exchange rate peg, and hence the foreign rate of inflation), crawling peg regimes provide an additional degree of freedom as the central bank can freely choose the rate of crawl. Thus, for a given medium term inflation target of the foreign country, the preannounced rate of crawl is a function of the domestic inflation target. From this follows that the crawling peg regime is in fact a system with two nominal anchors: the domestic inflation target and the preannounced exchange rate path. While this duality of anchors is compatible in the medium and long-run (along the lines of purchasing power parity), practical experience showed that conflicts may arise in the short-run, in particular due to the fact that the central bank only has a single operating target at its disposal (see e.g. Leiderman and Bufman, 2000)(see also Table I.2). If the level of the interest rate that is required to meet the inflation target differs from that resulting in no pressure on the exchange rate path, the central bank has to make a choice. Because of this conflict economists usually recommend to establish a clear hierarchy of the nominal anchors (see e.g. Debelle, 2000). If the central bank makes a commitment to an inflation

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<sup>7</sup> Until the mid 1990s monetary aggregates were viewed as the dominant nominal anchor under market determined exchange rates. They lost however most of their (mainly academic) popularity in favour of inflation targeting which was mainly due to the fact that, given the instability of money demand in most economies, targeting monetary aggregates is neither theoretically optimal nor easy to do in practice. For this reason we do not further discuss money supply targets as alternative nominal anchor under market determined exchange rates.

target as primary objective, exchange rate objectives must be clearly subordinated to the inflation target. But this is in fact an abandonment of the crawling peg system and a step towards managed floating or independently floating exchange rates.

In a strategy of direct managed floating central banks adopt an inflation targeting framework, and not, as many might suppose, an exchange rate targeting framework. The reason for this is simply that a non-preannounced path for the exchange rate which is a basic element of a direct managed float cannot serve as a nominal anchor. In contrast to our view, the literature on inflation targeting in open economies has a rather negative attitude towards interventions in the foreign exchange market that are aimed at targeting a non-preannounced path for the exchange rate. While we fully agree with the basic prerequisite for successful inflation targeting that “exchange rate objectives must be clearly subordinated to the inflation target” (Carare et al., 2002, p. 5), we do not agree with the implication that the authors draw subsequently: “Therefore the central banks should endeavor to make clear that foreign exchange market interventions and change in the policy interest rate intended to influence the exchange rate are only aimed at smoothing the effects of temporary shocks” (Carare et al., 2002, p. 5). In our view, not only independently floating or indirect managed floating exchange rates (and hence, market determined exchange rates, eventually supplemented by exchange rate smoothing interventions) are compatible with inflation targeting, but also a strategy of a direct managed floating with exchange rate targeting interventions if it is implemented the way we define it.

**Table I.3: Nominal anchors of monetary policy in an open economy**

	independently / indirect managed floating	direct managed floating	preannounced crawling pegs	fixed exchange rates
nominal anchor	domestic inflation target	domestic inflation target	domestic inflation target and nominal exchange rate	nominal exchange rate (foreign inflation rate)

#### **I.4 Intention and structure of the analysis**

The intention of the present analysis is to provide a rationale for the observed fear of floating. The literature typically explains this fear with a large pass-through from exchange rate changes to inflation and with the existence of large currency mismatches in the balance sheets of firms, banks, households or the government (see, among others, Hausmann et al., 2001). Thus, the policy response to fear of floating is treated as the natural behaviour of central banks that is to a large extent explained by the fear of the direct consequences of a sudden currency depreciation. It is however not integrated in a central bank's tool box as integral part of its strategy, which is astonishing given the range of measures used by central banks to counteract exchange rate movements. The literature on monetary policy still treats the interest rate as the central bank's only operating target.

Our approach is based on a standard open economy macro model typically employed for the analysis of monetary policy strategies. The consequences of freely floating and market determined exchange rates are evaluated in terms of a social welfare function, or, to be more precise, in terms of an intertemporal loss function containing a central bank's final targets output and inflation. We explicitly model the source of the observable fear of floating by questioning the basic assumption underlying most open economy macro models that the foreign exchange market is an efficient asset market with rational agents. We will show that both policy reactions to the fear of floating (indirect managed floating and direct managed floating) can be rationalised if we allow for deviations from the assumption of perfectly functioning foreign exchange markets and if we assume a central bank that takes these deviations into account and behaves so as to reach its final targets. In such a scenario with a high degree of uncertainty about the true model determining the exchange rate, the rationale for indirect managed floating is the monetary policy maker's quest for a robust interest rate policy rule that performs comparatively well across a range of alternative exchange rate models. We will show, however, that the strategy of indirect managed floating still bears the risk that the central bank's final targets might be negatively affected by the unpredictability of the true exchange rate behaviour. This is where the second policy measure comes into play. The use of sterilised foreign exchange market interventions to counter movements of market determined exchange rates can be rationalised by a central bank's effort to lower the risk of missing its final targets if it only has a single instrument at its disposal. We provide a theoretical model-based foundation of a strategy of direct managed floating in which the central bank targets, in addition to a short-term interest rate,

the nominal exchange rate. In particular, we develop a rule for the instrument of intervening in the foreign exchange market that is based on the failure of foreign exchange market to guarantee a reliable relationship between the exchange rate and other fundamental variables.

To sum up, the present analysis can be understood as an approach to develop a theoretical framework for two strategies that – even though they are widely used in practice – have not attracted very much attention in monetary economics. In particular we would like to fill the gap that has recently been criticised by one of the few ‘middle-ground’ economists, John Williamson, who argued that “managed floating is not a regime with well-defined rules” (Williamson, 2000, p. 47).

In Chapter II we begin by presenting three generations of open economy macro models (the Mundell-Fleming model, the New-Classical model, and the New-/Neo-Keynesian model) which are all based upon the idea of a functioning foreign exchange market. We will show that all three models are basically influenced by the paradigm of the impossible trinity. Thus, the ‘hollowing out theory’ is a compelling consequence of this theoretical thinking. In particular, neither of these models assigns any role to sterilised foreign exchange market interventions.

In Chapter III we take a deeper look at the exchange rate models that constitute a major building block of the open economy models. We will show that the two important arbitrage conditions, purchasing power parity and uncovered interest parity, do not enjoy much empirical support over the short- and medium-run, which is the most important in the context of monetary policy. As the workhorse model for the analyses in Chapters IV and V is of the Neo-Keynesian type, and as deviations from purchasing power parity are sufficiently considered in this type of models, our focus will be on the theoretical approaches to explaining the so-called uncovered interest parity puzzle.

Chapter IV analyses monetary policy under market determined exchange rates. In order to take account of the poor empirical evidence of uncovered interest parity we model the central bank’s decision making process as being confronted by a high degree of exchange rate uncertainty. Exchange rate uncertainty is defined as the risk that instead of uncovered interest parity another exchange rate model is a better description of the exchange rate behaviour at a certain moment in time. We will show that this uncertainty provides a rationale for a central bank to follow a

strategy of indirect managed floating, but that it also translates into high risk that a central bank fails to pursue a successful stabilisation policy.

Chapter V then turns to the strategy of direct managed floating. We will present the channels of how sterilised foreign exchange market interventions are supposed to work and we will implement the interventions as an additional and independent monetary policy instrument in a standard Neo-Keynesian open economy macro model. We will finally compare the performance of the three monetary-exchange rate strategies of independently floating, indirect managed floating and direct managed floating.

The last Chapter summarises the main results and offers some concluding remarks.

## **Chapter II:**

### **The Role of Exchange Rates in Macroeconomic Theory**

How can the empirical observation that the floating rate corner of the exchange rate spectrum is characterised by a high degree of exchange rate management – be it in the form of direct sterilised foreign exchange market interventions, or indirectly via changes in the interest rate – be reconciled with economic theory? In order to address this question, this Chapter discusses the role of the exchange rate in three standard open economy macro models. Before getting there, however, we take a short look at the historical debate about the different views on the macroeconomic role of independently floating exchange rates. At the core of the debate of whether such an exchange rate regime is a desirable strategy or not is basically one's attitude towards the question of whether speculators behave in a stabilising or destabilising way.

An early case against independently floating exchange rates was made in the years preceding the establishment of Bretton Woods exchange rate system. The disappointing experience of floating exchange rates in the inter-war period influenced many economists to come to the conclusion that under purely market determined exchange rates destabilising speculative forces cause major instability in the foreign exchange market and create crises with no underlying reason and with disruptive impact on a country's trade, investment and growth. At that time the most popular advocate of this view was Ragnar Nurkse (1944, p. 118): "The dangers of such cumulative and self-aggravating movements under a regime of freely fluctuating exchange rates are clearly demonstrated by the French experience of 1922-26. Exchange rates in such circumstances are bound to become highly unstable, and the influence of psychological factors may at times be overwhelming. French economists were so much impressed by this experience that they developed a special 'psychological theory' of exchange fluctuations, stressing the indeterminate character of exchange rates when left to find their own level in a market swayed by speculative anticipations." In his assessment of floating exchange rates he continued: "If there is anything the inter-war experience has clearly demonstrated, it is that paper currency exchanges cannot be left to fluctuate from day to day under the influence of market supply and demand. (...) If currencies are left free to fluctuate, speculation in the widest sense is likely to play havoc with exchange rates – speculation not only in foreign exchanges but also, as a result, in commodities entering into foreign exchange" (Nurkse, 1944, pp. 137).

The same scepticism was shared by one of the most influential architects of Bretton Woods system. In 1941, with reference to the interwar period, John Maynard Keynes wrote: “To suppose that there exists some smoothly functioning automatic mechanism of adjustment which preserves equilibrium if only we trust to matters of laissez-faire is a doctrinaire delusion which disregards the lessons of historical experience without having behind it the support of sound theory” (Moggridge, 1980, pp. 21). He continued: “Moreover in the interval between the wars the world explored in rapid succession almost, as it were, in an intensive laboratory experiment all the alternative false approaches to the solution – (i) the idea that a freely fluctuating exchange rate would discover for itself a position of equilibrium (...)” (Moggridge, 1980, p. 22). Given this scepticism towards market determined exchange rates, one must, however, not conclude that Keynes favoured absolutely fixed exchange rates. In contrast, he considered the rigidity of the gold standard as one of the leading causes of the great depression of the 1920s (see Muchlinski, 2003, for a recent discussion). Seen from today’s point of view, he favoured a system that could be interpreted as an early predecessor of a direct managed float, though in a world of very low capital mobility and with well-defined ‘rules of the game’. Thus, the outcome was a new monetary system with pegged but adjustable exchange rates, created in 1944 and built around a new institution, the IMF.<sup>8</sup>

The debate about the desirability of independently floating exchange rates was quickly revived a few years after the foundation of the Bretton Woods system. In his celebrated case for flexible exchange rates, Milton Friedman (1953, p. 175) questioned Nurkse’s view that private speculation would be destabilising: “People who argue that speculation is generally destabilizing seldom realize that this largely equivalent to saying that speculators lose money, since speculation can be destabilizing in general only if speculators on the average sell when the currency is low in price and buy when it is high.” According to this assumption about private agents’ behaviour, the source of highly variable market determined exchange rates has to be looked for elsewhere. In the same paper Friedman (1953, p. 158) states: “Instability of the

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<sup>8</sup> The institutional ‘rules of the game’ soon turned out to be the Achilles’ heel of the Bretton Woods system. Each member country had to fix its exchange rate against the US dollar, at a level approved by the IMF. If ever a fundamental disequilibrium (a term which has never formally been defined) developed in the member country’s balance of payments, it retained the right to adjust its central parity, upon securing the concurrence of the IMF. However, only few years after the establishment of the currency system, it became clear that the right (the obligation) to adjust the parity of a member country’s currency had a predominantly political dimension. In practice, governments began to go to enormous lengths of absolutely fixed exchange rates to avoid the ‘defeat’ of an altered parity. The reluctance to adjust the parity in a timely fashion generated one-sided bets triggering speculative attacks, increasingly so as borders became more porous to capital flows. These outflows, far from

exchange rates is a symptom of instability in the underlying economic structure.” Following this view, the unfavourable outcome of the interwar period had been caused by unstable monetary and fiscal policies rather than by destabilising private speculation.<sup>9</sup> Thus, it was implicitly assumed that foreign exchange markets process macroeconomic data in an efficient way which means that an independently floating exchange rate is mainly determined by macroeconomic fundamentals.

In such an environment the merits of flexible exchange rates are centred around the potential role of the exchange rate as shock absorber that promotes economic stability and that insulates an economy from the rest of the world, thereby ensuring an autonomous monetary policy. Concerning the economic stability argument, Friedman (1953) argued that if wages and prices move slowly, it is both faster and less costly to move the nominal exchange rate in response to a shock that requires an adjustment in the real exchange rate than to wait until excess demand in the labour and goods market pushes nominal wages and prices down. Astonishingly, this view was not only shared by monetarists (such as Friedman and Johnson), but also by traditional Keynesian fixed-price economists like Robert Mundell (1961) who argues that the case for exchange rate flexibility is especially strong if a small open economy is mainly hit by asymmetric shocks to the goods market. Thus, floating was viewed as a natural way of automatically assigning the exchange rate to take care of external balance so that the domestic central bank suffers minimal inconvenience in getting on with macroeconomic stabilisation.

The monetary autonomy argument in favour of floating exchange rates is closely related to the economic stability argument, and it was above all emphasised by Harry G. Johnson (1972, p. 210): “Flexible rates would allow each country to pursue the mixture of unemployment and price trend objectives it prefers, consistent with international equilibrium, equilibrium being secured by appreciation of the currencies of ‘price-stability’ countries relative to the currencies of ‘full-employment’ countries.” Thus, instead of importing the long-term rate of inflation from the rest of the world – as is the case under fixed exchange rates – a flexible exchange rate allows each small open economy to insulate itself completely from changes in foreign prices and to determine independently its own rate of inflation.

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disciplining macroeconomic policies, were often viewed by policy makers as an affront and vigorously combated with an intensification of capital controls.

<sup>9</sup> More recently, Dornbusch and Park (1999, p. 15) put this as follows: “Don’t blame the speculator who pushes down a currency because he sees deficits and inflation in the making.”

In the following Sections we will show that the basic arguments of Friedman (1953) and the other advocates of floating exchange rates

- that the foreign exchange market is an efficient speculative market with stabilising behaviour on the part of private agents,
- that independently floating exchange rates promote economic stability, and
- that independently floating exchange rates ensure monetary autonomy

have all been implemented in the three generations of open economy macro models that have been dominated macroeconomic thinking in the second half of the 20<sup>th</sup> century: the Mundell-Fleming model (Section II.1), the New-Classical / Monetarist model (Section II.2), and the New-Keynesian / Neo-Keynesian model (Section II.3). Regardless of the underlying paradigm the two main results will be

- that all the models are stamped by the impossible trinity theorem, and
- that neither school provides a rationale for sterilised foreign exchange market interventions.

For each of the three open economy models we proceed as follows. We first present the model's basic structure. We then ask how the exchange rate is determined and we present the linkage between the monetary policy instrument and the exchange rate under market determined exchange rates. In a next step we take a short look at the implications of an absolutely fixed exchange rate for monetary policy. We do not explicitly refer to systems of crawling pegs since their logic is quite similar to fixed pegs.<sup>10</sup> We finally analyse the scope for the two dimensions of managed floating. Compared to the first two models we will spend some more time on the New-Keynesian / Neo-Keynesian model which will be the baseline model of our quantitative analysis in Chapters IV and V.

## II.1 The Mundell-Fleming model

Until today, the 'workhorse' of traditional open-economy textbook macroeconomics is the Mundell-Fleming model. In several papers Mundell (collected in Mundell, 1968) and,

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<sup>10</sup> Modelling crawling pegs would require to specify a model for the anchor country in which the inflation target diverges from that of the small open economy. This would make the model too complex, given the purpose of this Chapter.

subsequently, Fleming (1962) extended the Keynesian income-expenditure model by introducing international capital flows into the analysis.

### *II.1.1 The structure of the model*

The model, which we present in the standard stochastic version, can be reduced to three equations. The first reflects an equilibrium in the goods market and determines the logarithm of output  $y_t$  in an open economy by an open economy IS curve:

$$(II.1) \quad y_t = \beta_0 - \beta_i i_t + \beta_s s_t + \varepsilon_t^y$$

where  $i_t$  is the nominal interest rate on domestic bonds and  $s_t$  is the logarithm of the nominal exchange rate (domestic price of the foreign currency).<sup>11</sup> The second expresses the equilibrium in the money market (LM curve)

$$(II.2) \quad m_t - p_t = \kappa_y y_t - \kappa_i i_t + \varepsilon_t^m$$

where  $m_t$  is the log of the money supply (defined as the sum of foreign reserves and credits to the domestic banking system) and  $p_t$  is the log of the price level which is assumed to be fixed. The elasticities in both equations and  $\beta_0$  are positive, and the error term is white-noise. The third equation expresses an equilibrium in the balance of payments. Under perfect capital mobility, arbitrage is assumed to ensure that bond yields are continually equalised so that the domestic interest rate must equal the foreign interest rate at all times  $t$ :

$$(II.3) \quad i_t = i_t^f.$$

Exchange rate expectations are assumed to be static  $E_t s_{t+1} = s_t$ , i.e. the average expectation is that the exchange rate will not change. The assumption of static expectations is of course consistent with basic nature of the Mundell-Fleming model as a fix-price model: if there are no expected price changes, then the exchange rate should also expect to be constant.

### *II.1.2 The determination of the exchange rate*

The exchange rate is defined as the relative price that leads to an equilibrium in the balance of payments. This so-called balance of payments approach (or sometimes flow approach) to the determination of the exchange rate starts from the observation that the exchange rate is actually determined in the foreign exchange market by the demand for and supply of foreign exchange, and that it moves to bring these demands and supplies into equality and hence to restore equilibrium in the balance of payments. Thus, the basic idea is that flows resulting from changes in any of the positions of the balance of payments (traditionally exports and imports of goods and capital movements) create this additional demand for and supply of foreign exchange. An exogenous increase in domestic income ( $\varepsilon_t^y > 0$ ), for example, leads to an incipient increase in the domestic interest rate which, in turn, leads to a capital inflow and an exchange rate appreciation. As a consequence the trade balance worsens and aggregate demand declines. The exchange rate appreciation will go on as long as the balance of payments equilibrium is restored (see Appendix II.A for an analytical treatment).

The balance of payments approach can be criticised for several shortcomings, amongst which the fact that it neglects the exchange rate's asset-price nature. Modern exchange rate models share the view of the exchange rate as an asset price, determined so as to induce investors willingly to hold existing stocks of the various assets available in the world economy. Thus the exchange rate must adjust instantly to equilibrate the international demand for stocks of assets (as opposed to adjusting to equilibrate the demand for and supply of flows). Closely related to the stock-flow criticism is the fact that asset prices are basically determined by agents that have rational expectations. Thus, the assumption that exchange rate expectations are static fundamentally contradicts this idea and is odd, even in the context of the Mundell-Fleming model. The exchange rate is free to float, and presumably must be changing on a day-to-day basis in response to a policy change, yet foreign exchange market participants regard each day's exchange rate as essentially fixed and have no anticipation of any future change. Thus the foreign exchange market fails to predict the monetary policy action or its subsequent effects.

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<sup>11</sup> Note that, as we assume prices are fixed, the nominal and the real exchange rate are identical.

### ***II.1.3 Monetary policy under market determined exchange rates***

The instrument of monetary policy in the Mundell-Fleming model is the money supply. Monetary policy actions impact on the level of the exchange rate by the extent to which the central bank creates temporary imbalances in the capital account. An expansive monetary policy, for example, conducted by an open market purchase of bonds by the central bank, leads to an excess of liquidity in the money market. With domestic interest rates effectively fixed at the world level and constant prices the only way money market equilibrium can be restored is via an increase in income. The latter will occur because the expansionary monetary policy leads to an incipient decline in the domestic interest rate which in turn leads to a capital outflow and exchange rate depreciation (see also equation (II.34) in Appendix II.A). The rising price of foreign exchange will result in an improved trade balance and have an expansionary effect on income as demand is switched from foreign goods to home goods. Thus, independently floating exchange rates preserve, yet enhance monetary autonomy, not in the sense of a free choice of the desired rate of inflation (which is always zero by assumption), but in the sense of an – in comparison with the closed economy IS/LM model more – efficient monetary policy concerning the stimulation and stabilisation of output (see also equation (II.35) in conjunction with the policy rule (II.36) in Appendix II.A).

### ***II.1.4 Monetary policy under fixed exchange rates***

While under market determined exchange rates the central bank chooses the money supply in accordance with its ultimate output goal, under fixed exchange rates the monetary policy instrument is entirely subordinated to the exchange rate target (see equation (II.37) in Appendix II.A with  $f_s$  approaching infinity). Take a negative demand shock as an example. If the central bank had full autonomy over its money supply, it would simply keep  $m_t$  constant and let the exchange rate adjust so as to re-equilibrate the balance of payments and stabilise output. If the spot exchange rate has to be kept unchanged, the depreciation that would result from the negative demand shock has to be countered by a restrictive monetary policy stance. Thus, output declines even further, and the goal of economic (output) stability has been abandoned in favour of exchange rate stability.

### *II.1.5 The scope for managed floating*

The main purpose of the Mundell-Fleming model is to analyse monetary (and fiscal) policy in an open economy under independently floating and absolutely fixed exchange rates. Under the former, the central bank refrains from foreign exchange market interventions and maintains currency reserves at a constant level. Thus, foreign reserves, and hence the money supply is exogenous, whereas the spot exchange rate becomes endogenous in the model. Under the latter, the central bank defends a certain level of the exchange rate at which it must satisfy the public's demand for foreign currency by intervening in the foreign exchange market. Thus, the spot exchange rate is given exogenously, whereas foreign reserves, and hence the money supply, become endogenous. This analysis forms the foundation for the impossible trinity introduced in Chapter I.

Roper and Turnovsky (1980) presented a first attempt to analyse intermediate exchange rate regimes by proposing an indirect managed floating policy reaction function of the following kind:

$$(II.4) \quad m_t = -f_s s_t$$

The optimal monetary policy is to choose  $f_s$  in (II.4) to minimise the variance of income around its target level. But it is clear that for a single final target which can be perfectly stabilised under independently floating exchange rates and a fully autonomous monetary policy, the performance of a policy rule like (II.4) can only be inferior to independently floating (see the formal discussion in Appendix II.A, in particular equation (II.39)). Thus, indirect managed floating does not provide any advantage to the policy maker.

The message of the Mundell-Fleming model is similar for strategies of direct managed floating. With sterilised foreign exchange market interventions in exchange rate systems other than absolutely fixed exchange rates the effects of a purchase of foreign exchange, for example, are off-set by a reduction of the central bank's credits to the domestic banking system. Thus, while the money supply would remain unchanged (and monetary autonomy preserved), the constant

money supply would also leave the balance of payments, and hence the exchange rate, unaffected (thereby rendering sterilised interventions ineffective).<sup>12</sup>

## II.2 The New-Classical / Monetarist open economy model

The introduction of rational expectations into macroeconomic models in the 1970s marked the beginning of the so-called New-Classical economics. In contrast to the Keynesian Mundell-Fleming model

- output is determined by an aggregate supply function in conjunction with the assumption of rapid price and wage adjustments in competitive instantaneously-clearing markets, and
- the exchange rate is treated as an asset price which clears the market for relative stocks of money.

### II.2.1 The structure of the model

The simple stochastic open economy model that is typical for the New-Classical literature has the following structure (see for example Turnovsky, 1984b). The demand side of the economy is described by an equilibrium of the domestic money market which is specified by

$$(II.5) \quad m_t - p_t = \kappa_y y_t - \kappa_i i_t + \varepsilon_t^m.$$

Note that this LM curve is equivalent to equation (II.2) in the Mundell-Fleming model. Rational expectations are assumed to enter the model through the behaviour of firms, and hence the supply side which is given by a New-Classical Lucas supply function:

$$(II.6) \quad y_t = \gamma_p (p_t - E_{t-1} p_t) + \varepsilon_t^y.$$

According to (II.6) the output gap  $y_t$  which measures the deviation of the supply of real output from its full employment level, depends on the unanticipated component of the logarithm of the

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<sup>12</sup> Note that under absolutely fixed exchange rates sterilisation can be used as an instrument to maintain temporary disequilibria in the balance of payments which result from a central bank's attempt to conduct an autonomous monetary policy.

current domestic price level. All the structural parameters of the model are assumed to be positive, and the stochastic disturbances  $\varepsilon$  are white noise.<sup>13</sup>

### II.2.2 The determination of the exchange rate

The exchange rate is determined by a standard monetary model according to which the spot rate adjusts to clear the money market. Under the assumption that in the foreign economy the money market is described by an LM curve similar to (II.5) and that purchasing power parity (PPP)<sup>14</sup> holds continuously

$$(II.7) \quad s_t = p_t - p_t^f$$

the exchange rate can be expressed as the relative price of two monies

$$(II.8) \quad s_t = m_t - m_t^f - \alpha_1 (y_t - y_t^f) + \alpha_2 (i_t - i_t^f) + \varepsilon_t^s$$

where the superscript <sup>f</sup> denotes foreign variables and  $\varepsilon_t^s$  is a composite monetary disturbance. If additionally uncovered interest parity (UIP)<sup>15</sup> is assumed to perfectly hold

$$(II.9) \quad i_t = i_t^f + E_t s_{t+1} - s_t$$

then (II.8) can be written as

$$(II.10) \quad s_t = m_t - m_t^f - \alpha_1 (y_t - y_t^f) + \alpha_2 (E_t s_{t+1} - s_t) + \varepsilon_t^s$$

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<sup>13</sup> The slope of the supply curve  $\gamma_q$  can be understood by a distinction between local and aggregate supply shocks: individual producers will only be willing to supply more if the price of their product rises relative to the general price level ( $p$ ). Each individual producer is assumed to know the price of its own product, but, because of information barriers, they cannot directly observe the price of other products (Lucas, 1972: 'islands'), thus, for any given price change, they must infer whether this is a local or an aggregate price shock. To the extent that their guess is incorrect, the economy will be able to deviate from the natural level of output and generate business cycles.

<sup>14</sup> Purchasing power parity states that because of goods market arbitrage consumers should be able to buy the same bundle of goods in any country for the same amount of currency (see Chapter III below for a detailed presentation of purchasing power parity).

<sup>15</sup> Uncovered interest parity states that, if the international capital markets are free from capital controls and international investors are risk neutral, then speculation should ensure that the expected rates of return on

which can be solved for  $s_t$  by forward iteration. After summarising the economic fundamentals of the spot exchange rate by  $x_t = m_t - m_t^f - \alpha_1 (y_t - y_t^f) + \varepsilon_t^s$ , the basic asset-pricing model of the exchange rate is characterised by the following equation (Mussa, 1990):

$$(II.11) \quad s_t = \frac{1}{1 + \alpha_2} \sum_{j=0}^{\infty} \left( \frac{\alpha_2}{1 + \alpha_2} \right)^j E_t x_{t+j}.$$

According to (II.11),  $s_t$  is determined by the present discounted sum of current and expected future economic fundamentals affecting the foreign exchange market.

Such an approach to the determination of the exchange rate has an important implication for the functioning of the foreign exchange market. Since expectations play the dominant role in equation (II.11), the question emerges of how these expectations are formed. This introduces rational expectations for a second time into the New-Classical open economy model. Each economic agent is assumed to form subjective expectations according to the mathematical predicted value, conditional on an information set containing all publicly available information. If economic theory and data are available to calculate the future equilibrium price, then market participants should use this knowledge, because otherwise there would be unexploited profit opportunities. These unexploited profit possibilities would exist as long as subjective expectations were at variance with mathematical prediction. Thus, at the end, mathematical prediction and subjective expectations on the one hand, and realised value on the other hand, should coincide on average. A market in which all agents behave according to the rational expectations paradigm and in which the asset price in question always correctly reflects all available information is then defined as an speculative efficient asset market.<sup>16</sup> Note that speculation enters the monetary model of exchange rate determination through uncovered interest arbitrage as defined by equation (II.9).

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domestic and foreign assets are identical. If uncovered interest parity holds, the foreign exchange market is said to be efficient (see Chapter III below for a detailed presentation of uncovered interest parity).

<sup>16</sup> The definition of rational expectations used here goes back to a seminal paper by Muth (1961). The efficiency of markets is defined in accordance with Fama (1970).

### ***II.2.3 Monetary policy under market determined exchange rates***

In New-Classical models, monetary policy is typically implemented in the form of a money supply rule. One strand of the literature followed the hypothesis of policy irrelevance put forward by Sargent and Wallace (1975) and advocated the abandonment of any monetary stabilisation policy. This hypothesis draws on the assumption that with rational expectations output can only be altered systematically by the central bank by surprising the public into making expectational errors. As these deviations are completely offset in the following period when expectations are revised, the only effect of monetary policy is an increase in the variability of output and prices. Thus, the best a central bank can do (if it possesses no better information than the public) is to follow a fixed policy rule according to which the supply of money is kept constant whatever happens. By doing so, monetary policy can be fully anticipated by the public.

To demonstrate this, take a supply shock as an example. If the central bank keeps the money supply constant in response to the shock, the expectational error resulting from a fall in  $p_t$  induces a self-stabilising reduction in output. Since nominal wage contracts were set in  $t-1$  the occurrence of the unexpected supply shock in  $t$  leads to an increase in real wages and hence to a contraction of the firm's supply. A second channel of stabilisation opens up due to the appreciation of the exchange rate (which results from the fall in  $p_t$ ). With given expectations about the future spot exchange rate<sup>17</sup> and a given foreign interest rate, the domestic nominal interest rate has to fall according to the uncovered interest parity relationship (II.9). Again, for a given money supply, the domestic price level falls (see the LM equation (II.5)), and the supply of output returns to equilibrium.

### ***II.2.4 The scope for managed floating***

Following this strand of the literature it becomes clear that there is no feedback from monetary policy actions on the exchange rate since the money supply is kept constant. However, the policy ineffectiveness hypothesis has been seriously questioned by a number of authors (see e.g. McCallum, 1980, for an overview of the debate at that time). A basic prerequisite for flexible monetary policy rules to be ineffective under rational expectations was that the feedback rule

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<sup>17</sup> In fact, the exchange rate is expected to return to equilibrium in  $t+1$ , since the market is aware of the fact that the disturbance is only temporary (i.e. white noise) with an expected value of zero in  $t+1$  (see Appendix II.B, equation (II.49); for  $f_s$  in policy rule (II.46) set to zero, we get the fixed money supply rule; thus, we can easily calculate the value of  $E_t s_{t+1}$  by setting  $f_s$  to zero and taking expectations of equation (II.49)).

relates  $m_t$  to past values of the model's variables such as  $y_{t-1}$  or  $p_{t-1}$ , and hence, to information that has already been considered when the private sector forms its expectations. In order to re-establish the effectiveness of an active (or flexible) monetary stabilisation policy Turnovsky (1984a, 1984b) proposed a policy rule that responds to movements in currently observable (market) data which is assumed to provide information about the sources of unobservable random shocks to the economy. Exploiting this additional information then allows a greater degree of stability to be achieved in the economy (see also Turnovsky, 1994, for a more recent treatment). A simple variant of Turnovsky's policy rule with the spot exchange rate as feedback variable has the following structure:

$$(II.12) \quad m_t = \bar{m} - f_s s_t .$$

$\bar{m}$  is the fixed exogenous component of the domestic money supply representing the nominal anchor of the economy that can be freely chosen by the central bank. The response coefficient  $f_s$  is chosen by the monetary authority so as to minimise an objective function usually containing output and price level stability as arguments. Thus, instead of keeping the money supply fixed at a level  $\bar{m}$  (i.e.  $f_s = 0$  in our stationary model), the central bank can adjust  $m_t$  in response to disturbances having an impact on the spot exchange rate. If the central bank increases the money supply in the above supply shock example, output will increase further, thereby reducing the fall in the domestic price level. It directly follows that this monetary expansion reduces the appreciating pressure on the spot exchange rate. In sum, as a consequence of the policy intervention of the central bank the volatility of the price level is reduced whereas the volatility of output increases (see also Appendix II.B for an analytical treatment).

The introduction of flexible policy rules by Turnovsky (1984a, p. 156) was an early attempt to understanding intermediate exchange rate regimes: "Traditionally, the international macroeconomic literature has been concerned almost exclusively with analysing perfectly fixed or perfectly flexible exchange rate regimes. Yet both of these regimes represent polar forms of intervention policy. In the former, the domestic monetary authorities continually intervene in the foreign exchange market so as to maintain the exchange rate at some given target level. In the latter case, the domestic monetary authorities abstain from any active intervention, allowing the exchange rate to fluctuate freely in response to market forces. Intermediate between these two extremes is that of a 'managed float' in which the monetary authorities intervene partly to offset

movements in the exchange rate so that the adjustment to changes in market pressure are met by a combination of both movements in the exchange rate and the accumulation or decumulation of foreign reserves.”

An interesting feature of this quotation is the way Turnovsky defines the instrument with which the central bank implements the managed float: accumulation or decumulation of foreign reserves. In our view, the definition of managed floating as a monetary policy strategy by optimised changes in the foreign reserves, and hence optimised foreign exchange market interventions is arbitrary since the model makes no distinction between changes of the domestic component of (base) money (through open market operations) and changes of its foreign component (through sales and purchases of foreign reserves). The necessary policy reaction in response to shocks is rather formulated in terms of changes in the (base) money supply which can be realised by an adjustment of either of its two components. And it is the change of one of the fundamental determinants of the exchange rate (namely  $m_t$ ) which brings about the change in the spot rate (see also Laffargue, 1984, for the same criticism). A better definition for managed floating in this kind of models would therefore be an non-sterilised change of the foreign reserves as an optimum policy response under market determined exchange rates. In Chapter I we referred to this variant of managed floating as indirect managed floating since it is still the market which maps the fundamental change in the money supply onto the current exchange rate.

The possibility of sterilised foreign exchange market interventions is not addressed within the context of Turnovsky's interpretation of New-Classical open economy macro models which is mainly due to the fact that in these models (as in monetary models of exchange rate determination in general) domestic and foreign assets are viewed as perfect substitutes. As sterilised interventions only change the ratio of domestic to foreign assets held by the public and leave the money supply constant, the exchange rate would be unaffected in this model by a sterilised purchase or sale of foreign exchange. Note that the assumption of perfect substitutability is reflected in the uncovered interest parity condition that is assumed to hold perfectly.

### ***II.2.5 Monetary policy under fixed exchange rates***

Fixed exchange rates can be modelled as a special case of policy rule (II.12). By setting  $f_s$  equal to infinity the central bank fully accommodates every movement in the spot exchange rate by changes in the money supply. As a result, the spot exchange rate remains at a constant level, irrespective of the nature of the shock that hits the economy (see equation (II.49) in Appendix II.B:  $\lim_{f_s \rightarrow \infty} s_t = 0$ ), and the domestic price level is entirely determined by the foreign price level (which in fact represents the nominal anchor). Thus, as the money supply is fully endogenous and subordinated to the exchange rate target, the central bank gives up the autonomy of choosing the desired price level.

## **II.3 The New-Keynesian / Neo-Keynesian open economy model**

In contrast to the New-Classical paradigm in which wages and prices can be adjusted without delay in every period the New-Keynesian / Neo-Keynesian approach reintroduced important nominal rigidities. In particular,

- the supply-side was modified by introducing sticky prices and wages so that output is demand determined in the short-run, and
- the nominal exchange rate is allowed to transitorily deviate from purchasing power parity so that movements in the real exchange rate occur.

Additionally, nominal short-term interest rates play the leading role as the instrument of monetary policy, with money relegated to a behind-the-scene role.

### ***II.3.1 The structure of the model***

In the following, we present three types of the open economy model: a purely forward-looking New-Keynesian specification (Section II.3.1.1), a hybrid specification with forward-looking and backward-looking elements (Section II.3.1.2), and a purely backward-looking Neo-Keynesian specification (Section II.3.1.3). Appendix II.C summarises some popular specifications of the open economy model that can be found in the literature.

### *II.3.1.1 A New-Keynesian specification*

The New-Keynesian specification of the open economy model combines elements from New-Classical and Real Business Cycle models (rational expectations and intertemporal optimisation of agents) with elements from Keynesian economics (imperfect competition and costly price adjustment). Due to Goodfriend and King (1997) this merger has also become popular under the notion of the New Neoclassical synthesis. As a typical feature of the microfoundation of the behavioural relationships of the economy the reduced forms of the aggregate demand and the Phillips curve equation become purely forward-looking.

Specifically, the demand side is represented by an expectational IS function

$$(II.13) \quad y_t = E_t y_{t+1} - \beta_i (i_t - E_t \pi_{t+1}) + \beta_q q_t + \varepsilon_t^y$$

in which the current output gap  $y_t$  is determined by expectations about the future output gap, the real interest rate (which is defined as the nominal interest rate  $i_t$  minus the expected rate of inflation  $E_t \pi_{t+1}$ ) and the real exchange rate  $q_t$ . This equation is a simple extension of a typical New-Keynesian closed economy IS curve (see e.g. Clarida et al., 1999, and Woodford, 2002a) to an open economy. As for the closed economy case, it nests the open economy demand obtained by the log-linear approximation to the Euler conditions for the optimal consumption path of households. Consumers are assumed to maximise their lifetime expected utility, leading to a behaviour that is often referred to as consumption smoothing. In the resulting optimising IS equation (also often called intertemporal IS equation) consumption, and hence output, immediately adjusts in response to news about expected lifetime income prospects (due to, for example, current or expected future changes in the real interest rate). The real exchange rate appears for two reasons: first, it determines the relative cost of foreign and domestic goods which both enter the consumption bundle of domestic households, and second, there is additionally a world demand for domestic goods (see e.g. Galí and Monacelli, 2002, and McCallum and Nelson, 2000, for the derivation of an open economy IS curve).

As already mentioned in the introduction of Section II.3, an important prerequisite for short-run demand management to be effective are sticky prices. While the New-Classical microfoundation assumed agents being enabled to revise wages and prices every period (which led to the Lucas

supply curve, see equation (II.6) in Section II.2), it was mainly due to Taylor (1979b, 1980) that a more realistic wage- and price-setting process was taken into consideration. He developed a model in which nominal wages are assumed to be set for two periods and in which every period half of the workers conclude new wage contracts. As a result, in each period the new contract overlaps with the already existing contract of the previous period, thereby leading to staggered wage contracts.<sup>18</sup> Since workers are assumed to be concerned about real wages and unemployment over the life of their contract, they have to form expectations about the future price level. Additionally, the average real contract wage is assumed to be increasing in the level of real economic activity. The firm finally sets prices as constant mark-up over wages. An alternative model for rationalising sticky prices goes back to Calvo (1983) who introduces staggered price adjustments by assuming that firms follow time-contingent price adjustment rules. Each firm keeps its price fixed (e.g. due to costs associated with price adjustment, see Rotemberg, 1987) until it receives a random signal that it can change its price. When a firm has the opportunity to change its price, it sets its price equal to the average desired price until the next expected price adjustment. The desired prices result from a firm's profit maximisation problem in a world of monopolistical competition. As shown by Rotemberg and Woodford (1997) a log-linearised version of this optimal price setting rule together with the definition of an aggregate price index implies a log-linear relationship between inflation, expected inflation and marginal costs.

For a small open economy, Gali and Monacelli (2002) derive – under the assumption that domestic firms set prices in a staggered Calvo (1983)-style fashion – the following inflation equation

$$(II.14) \quad \pi_t^d = E_t \pi_{t+1}^d + \gamma_y y_t + \varepsilon_t^\pi$$

which corresponds, as far as domestic inflation  $\pi_t^d$  is concerned, to a closed economy Phillips curve.<sup>19</sup> The stochastic disturbance  $\tilde{\varepsilon}_t^\pi$  is an i.i.d. supply shock with mean zero. The rate of

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<sup>18</sup> This is the basic difference to the New-Classical view about monetary policy transmission. The existence of a fixed contract ties the hand of half of the workforce at any one time removing their ability to respond to systematic monetary policy, even though it may be perfectly anticipated.

<sup>19</sup> However, Gali and Monacelli (2002) show that the degree of openness affects the dynamics of domestic inflation through its influence on the slope of the Phillips curve  $\gamma_y$ . In an open economy, a change in domestic output not only affects marginal cost through its impact on employment, but also the terms of trade. An increase in openness,

overall (CPI) inflation  $\pi_t$  is defined as a weighted average of domestic  $\pi_t^d$  and imported inflation  $\pi_t^m$ :

$$(II.15) \quad \pi_t = (1 - \gamma_q) \pi_t^d + \gamma_q \pi_t^m$$

where  $\gamma_q$  is the degree of openness. Imported inflation is defined as foreign inflation expressed in domestic currency terms

$$(II.16) \quad \pi_t^m = \pi_t^f + (s_t - s_{t-1})$$

where  $\pi_t^f$  is the foreign rate of inflation expressed in foreign currency terms. Movements in the real exchange rate are due to deviations from purchasing power parity:

$$(II.17) \quad q_t - q_{t-1} \equiv s_t - s_{t-1} + \pi_t^f - \pi_t$$

If purchasing power parity held continuously (as was assumed in the New-Classical open economy model, see equation (II.7) in Section II.2.2), the right-hand side of (II.17) should be equal to zero. However, since prices are sticky, changes in the nominal exchange rate lead to a contemporaneous change in the real exchange rate. Solving (II.17) for the change in the spot rate and inserting the resulting expression into (II.16) gives

$$(II.18) \quad \pi_t^m = \pi_t + (q_t - q_{t-1}).$$

Now substituting (II.18) into (II.15) and solving for  $\pi_t$  gives

$$(II.19) \quad \pi_t = \pi_t^d + \frac{\gamma_q}{1 - \gamma_q} (q_t - q_{t-1}).$$

Equations (II.14) and (II.19) then describe the supply side of the small open economy.

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for example, lowers the size of the adjustment in the terms of trade necessary to absorb a change in domestic output (relative to world output), thereby lowering the coefficient  $\gamma_y$ .

### II.3.1.2 *A specification with habit formation in consumption and persistence in inflation*

The purely forward-looking and optimised behaviour of households and firms has been subject to sharp criticism because it implies dynamics of inflation and output that is seriously at odds with the data (see e.g. Estrella and Fuhrer, 2002). Due to the fact that one of the major determinants of inflation and output are their own expected future values, they act like jump variables in response to news about the other determinants on the right-hand side of equations (II.13) and (II.14). Autocorrelation functions and impulse response functions from empirical VAR models, however, typically reveal that consumption exhibits smoothness (Campbell and Deaton, 1989) and that inflation has a high degree of persistence (Fuhrer and Moore, 1995, Mankiw, 2001).

As a consequence, economists adjusted the underlying microfoundation in a way that lead to hybrid specifications, with partly forward-looking and partly backward-looking expectations. One widely used alteration to the standard derivation of the IS equation from dynamic rational expectations models is habit formation. Habit formation assumes a utility function for which the standard consumption-smoothing motive not only applies to the level of consumption, but also to the change of the level of consumption.<sup>20</sup> From the latter clearly follows that the adjustment of consumption, and hence output, to news is then more gradual and less jumpy. Fuhrer (2000) derived such a hybrid IS curve for a closed economy, and Choi and Jung (2003) present a model for an open economy. Somewhat simplified, it takes the following form:

$$(II.20) \quad y_t = (1 - \beta_y) y_{t-1} + \beta_y E_t y_{t+1} - \beta_i (i_t - E_t \pi_{t+1}) + \beta_q q_t + \varepsilon_t^y.$$

Concerning the dynamics of inflation, Fuhrer and Moore (1995) criticise Taylor's staggered wage contract model for its unrealistic contracting specification. While contracts are still negotiated in nominal terms, in their model workers are assumed to compare the implied real wage with the real wages on overlapping contracts in the recent past and the near future. As a result of this concern about relative wages (instead of absolute wages), current inflation not only depends on the current state of economic activity and the expected future rate of inflation, but also – and most importantly for creating inertia in inflation – on lagged inflation:

$$(II.21) \quad \pi_t^d = (1 - \gamma_\pi) \pi_{t-1}^d + \gamma_\pi E_t \pi_{t+1}^d + \gamma_y y_t + \varepsilon_t^\pi$$

The complete supply side of the open economy is then described as in the purely forward-looking New-Keynesian specification, except for the fact that equation (II.14) is replaced with equation (II.21).

### II.3.1.3 A Neo-Keynesian specification

A purely backward-looking Neo-Keynesian specification of the open economy model was presented by Ball (1999b). The model is a direct extension of the closed economy workhorse models of Ball (1999a) and Svensson (1997a). According to Ball (1999b, p. 128) the advantage of the backward-looking specification is that it “is similar in spirit to the more complicated macroeconomic models of many central banks.” This superiority of the backward-looking specification in practical use is also confirmed by a study of the Bank for International Settlements (1995) in which 11 central bank models were compared to each other, all of which were purely backward-looking. Another advantage of the backward looking specifications is that their dynamic implications are much more consistent with the behaviour of actual data that usually shows a high degree of persistence in both, inflation and output (see Estrella and Fuhrer, 2002, and the papers cited there).

The demand side of the Ball (1999b) model is given by the following open economy IS equation:

$$(II.22) \quad y_t = \beta_y y_{t-1} - \beta_r r_{t-1} + \beta_q q_{t-1} + \varepsilon_t^y$$

which is a dynamic sticky-price version of (II.1). Output depends on lags of the real interest rate and the real exchange rate, its own lag and a demand shock. The supply side is given by the following Phillips curve equation:

$$(II.23) \quad \pi_t = \pi_{t-1} + \gamma_y y_{t-1} + \gamma_q (q_{t-1} - q_{t-2}) + \varepsilon_t^\pi.$$

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<sup>20</sup> In other words, a consumer’s current utility depends on current consumption relative to a reference level that is assumed to be equal to consumption in the previous period.

To derive this equation the (overall CPI) inflation rate  $\pi_t$  is again defined as a weighted average of domestic  $\pi_t^d$  and imported inflation  $\pi_t^m$ :

$$(II.24) \quad \pi_t = (1 - \gamma_q) \pi_t^d + \gamma_q \pi_t^m.$$

The domestic inflation process is governed by a backward-looking accelerationist<sup>21</sup> closed economy Phillips curve in which the current rate of domestic inflation is positively related to the lagged value of the output gap and to the lagged value of overall inflation:

$$(II.25) \quad \pi_t^d = \pi_{t-1} + \tilde{\gamma}_y y_{t-1} + \tilde{\varepsilon}_t^\pi.$$

This form of the Phillips curve is one possible formulation of the well-known expectations-augmented Phillips curve in which  $E_{t-1} \pi_t$  is proxied by  $\pi_{t-1}$  (see for example Romer, 2001, chapter 5.4). The exchange rate impacts indirectly via wage-setting (real wages are deflated by the overall rate of inflation) onto domestic inflation. A more direct exchange rate effect is captured by imported inflation:

$$(II.26) \quad \pi_t^m = \pi_{t-1}^f + (s_{t-1} - s_{t-2}) = \pi_{t-1} + (q_{t-1} - q_{t-2})$$

which is defined as the domestic price of foreign inflation  $\pi_t^f$ . In contrast to the New-Keynesian approach presented above, Ball (1999b) assumes a one period lag for the impact of exchange rate changes onto import prices (see Chapter III for an explanation). The right hand side of (II.26) can be obtained by replacing the nominal exchange rate change with equation (II.17). By inserting (II.26) and (II.25) into (II.24) and by setting  $\gamma_y = (1 - \gamma_q) \tilde{\gamma}_y$  and  $\varepsilon_t^\pi = (1 - \gamma_q) \tilde{\varepsilon}_t^\pi$  we finally get the open economy Phillips curve as described by (II.23).

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<sup>21</sup> The theorem of acceleration states that the natural rate of unemployment (and hence the output gap) is consistent with any rate of inflation. There is no stable relationship between unemployment and inflation, but only between unemployment and changes in the rate of inflation. This implies that the coefficient of  $\pi_t$  on the right-hand-side of the Phillips curve equation (II.25) has to equal one. In other words, the long-run Phillips curve is vertical.

### II.3.2 *The determination of the exchange rate*

The nominal exchange rate is modelled as an asset price that is inherently forward-looking and expectations determined. The basic relationship underlying the dynamics of the exchange rate is uncovered interest parity:

$$(II.27) \quad i_t = i_t^f + E_t s_{t+1} - s_t + u_t^s.$$

In contrast to the New-Classical model it is now possible that deviations  $u_t^s$  from uncovered interest parity occur. These deviations are typically referred to as the foreign exchange risk premium that “incorporates any exogenous residual disturbances to the exchange rate, including changes in portfolio preferences, credibility effects, etc.” (Svensson, 2000, p. 163). Since the existence of risk premia implies risk aversion on part of the investors making portfolio decisions, it is important to note that this assumption does not fundamentally alter the model. The reason for this is that the demand for and the supply of stocks of assets which become directly affected by the non-substitutability of domestic and foreign assets only figure in the background of the model as residual variables (see below in Appendix II.D). This is in sharp contrast to the monetary models of the New-Classical approach.

By forward iteration, equation (II.27) can be solved for the nominal exchange rate:

$$(II.28) \quad s_t = E_t \sum_{j=0}^{\infty} (i_{t+j}^f - i_{t+j} + u_{t+j}^s).$$

Accordingly, the fundamental determinants of  $s_t$  are current and expected future interest rate differentials as well as current and expected future risk premia. This is the core relationship of an efficient speculative foreign exchange market in which the exchange rate fully reflects information available to market participants and in which every new piece of information should be immediately mapped into prices.<sup>22</sup>

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<sup>22</sup> Note that the reduced form of the exchange rate depends on the central bank’s policy rule (see below in Section II.3.3) and the specification of the demand and supply side of the economy. Since the dynamic structure of the New-Keynesian / Neo-Keynesian models presented above is more complicated than in the New-Classical model or the Mundell-Fleming model, it is only possible to find an analytical solution in some special cases. Detken and Gaspar (2003) for example derive such a reduced form for a purely forward-looking model in which the exchange

### II.3.3 *Monetary policy under market determined exchange rates*

The monetary policy instrument in New-Keynesian models is the short-term nominal interest rate. It is either implemented as a simple policy rule where the interest rate responds to a small subset of the central bank's information, or as an optimal policy rule which is derived from a dynamic programming procedure and according to which a central bank responds to all information available. We will return to the discussion of simple and optimal rules in Chapter IV.

An important characteristic of the interest rate rules is that they constitute an integral part of an inflation targeting strategy which developed into the dominant monetary policy strategy under floating exchange rates in the 1990s. In Chapter I we defined this strategy by four of its most important elements of which the third required a clear guideline for setting the policy instrument in order to meet the inflation target. The interest rate policy rule provides such guideline. Taylor (2000, p. 11) uses the following metaphor: "Inflation targeting is like the destination for a sailboat. A policy rule is how to sail the boat to get to the destination: for this you need to describe the angle of attack, the sail trim, the contingency for wind change, and so on." In a similar vein, Svensson (1999, p. 614) characterises the interest rate policy rule in an inflation targeting framework as "a prescribed guide for monetary policy conduct" that replaces traditional intermediate targets, such as monetary aggregates or the exchange rate (see Appendix II.D for a short note on the role of money in the New-Keynesian / Neo-Keynesian inflation targeting models).<sup>23</sup> One of the most simple and most popular policy rules in this context is the so-called Taylor rule (proposed by Taylor, 1993a)

$$(II.29) \quad i_t = \bar{r} + \pi_t + f_\pi (\pi_t - \pi^T) + f_y y_t$$

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rate term in the Phillips curve is omitted and in which the central bank follows an optimal policy rule. In Chapter IV and V we will present analytical solutions of the exchange rate.

<sup>23</sup> In Section II.1 and II.2 we called  $m_t$  the instrument of monetary policy. This view implicitly assumes that the central bank is perfectly able to control the money supply with its genuine instruments, i.e. the short-term interest rate or the supply of base money. Thus, it would be more correct to define  $m_t$  as an intermediate target that can be controlled with the central bank's instruments.

that relates the short-term nominal interest rate to deviations of current inflation from the target level  $\pi^T$  and the current output gap.  $\bar{r}$  is the neutral short-term real interest rate. The weights  $f_\pi$  and  $f_y$  can be chosen by the central bank so as to optimise an objective function.

In an open economy the transmission of monetary impulses triggered by changes in nominal interest rates can be explained by two channels: the interest rate channel and the exchange rate channel. With the former, monetary policy affects aggregate demand – like in a closed economy – via its effect on the short-term real interest rate. Since prices of goods and services are slower to adjust than those of financial instruments, a cut in short-term nominal interest rates, for example, reduces real interest rates providing a stimulus to investment, and hence to aggregate demand. The rise in aggregate demand impacts on domestic inflation via the Phillips curve relation.

The exchange rate channel becomes effective since uncovered interest parity provides an instantaneous and efficient-market based link between the current nominal interest rate and the current nominal exchange rate (see equations (II.27) and (II.28)). If the central bank lowers nominal interest rates, the nominal exchange rate depreciates immediately, and with it, the real exchange rate (see equation (II.17)). The transmission of the change in the real exchange rate is further divided into a direct and an indirect exchange rate channel. The direct channel explains inflation fluctuations via the pass-through of exchange rate fluctuations to import prices, and hence on inflation. Indirectly, the real exchange rate affects the relative price between domestic and foreign goods, which in turn has an impact on both, domestic and foreign demand for domestic goods, and hence contributes to the aggregate demand channel for the transmission of monetary policy.

#### ***II.3.4 Monetary policy under fixed exchange rates***

In order to keep the spot exchange rate constant and unchanged, the central bank strictly sets its interest rates according to uncovered interest parity. This signifies that, as long as the peg is credible (i.e. there are no expectations of future exchange rate changes), the short-term nominal interest rate has to equal the short-term nominal interest rate of the anchor country (eventually plus a risk premium):

$$(II.30) \quad \begin{aligned} i_t &= i_t^f + E_t s_{t+1} - s_t + u_t^s = \\ &= i_t^f + u_t^s. \end{aligned}$$

Thus, the nominal interest only reacts to shocks that put pressure on the exchange rate. In the case of domestic demand and supply shocks which directly impact on inflation and output the central bank cannot react. Note, however, that changes in the domestic inflation rate lead to changes in the real interest rate and the real exchange rate for given levels of  $i_t$  and  $s_t$ . An increase in  $\pi_t$ , for example, lowers the real interest rate, thereby stimulating the economy even further. Of course, the concurrent real appreciation counteracts the expansive impulse from the real interest rate, so that in the end the question whether fixed rate regimes are stabilising or destabilising crucially depends on the degree of openness (the parameters  $\beta_q$  and  $\gamma_q$  in relation to  $\beta_{i/r}$ ) of the economy.

### ***II.3.5 The scope for managed floating***

The mainstream view on the need of direct foreign exchange market interventions in New-Keynesian / Neo-Keynesian models can be summarised by the following statement of Svensson, one of the most prominent academic advocates of inflation targeting: “Another potential additional instrument consists of foreign-exchange interventions, meaning sterilized foreign-exchange interventions that do not involve adjustment of the instrument rate. (...) I see no reason why a transparent inflation-targeter should undertake foreign-exchange interventions” (Svensson, 2001, p. 48). In another paper he explains the reasons for his view: “In practice, flexible inflation targeting, with a longer horizon to meet the inflation target and concern for output-gap variability, will normally mean a more gradual approach and a less activist policy and hence reduced interest rate variability. Since interest rate changes lead to exchange rate changes, everything else equal, this also reduces exchange rate variability. Increased credibility and increasingly stable inflation expectations will reduce a major source of shocks to both interest rates and exchange rates. Thus, successful and credible flexible inflation targeting is likely to contribute to less variability of interest rates and exchange rates” (Svensson, 2002a, pp. 272).

This statement perfectly reflects Friedman’s view described at the beginning of this Chapter. If the interest rate that is set in an appropriate way, it is a sufficient instrument for stabilising both, the exchange rate and the economy, and hence for achieving the ultimate goals of monetary

policy. There is no need for direct sterilised interventions in the foreign exchange market as long as the exchange rate is determined on an efficient foreign exchange market in which only changes in the interest rate provoke changes in the spot rate according to the mechanism described by uncovered interest parity.<sup>24</sup>

If, additionally, disturbances to uncovered interest parity as summarised by foreign exchange risk premia are only of minor importance (or even zero), there is even no need to respond to exchange rate movements with the monetary policy instrument (in the sense of indirect managed floating). As the exchange rate only responds to changes in the interest rate, it provides no additional independent information that is useful for forecasting or stabilising the economy. In fact, as has been shown by Clarida et al. (2001), under such conditions the central bank's monetary policy design problem for the small open economy is isomorphic to the problem of the closed economy. The exchange rate's main role in these models is to provide a channel through which monetary policy can additionally affect the economy. We will come back to this issue in Section IV.1.4.3.

However, it should not be left unmentioned that in the above quotation, Svensson (2002a, p. 273) continues as follows: "Exchange rates are by nature volatile asset prices and are affected by a number of shocks beyond inflation expectations and interest rate changes. Such shocks will continue to cause unavoidable exchange rate variability." And these shocks exactly are at the core of the present study. Thus, in the following Chapters we will show that

- the fundamental link between the interest rate and the exchange rate – as predicted by uncovered interest parity – is weak, instable or even non-detectable (Chapter III);
- shocks stemming from the asset price nature of exchange rates are an important source of uncertainty in a central bank's monetary policy strategy since the true exchange rate model is not very well understood (Chapter IV);
- under these modified conditions, exchange rate behaviour contains important information for the central bank and provides a rationale for managed floating in both of its dimensions – an interest rate response to exchange rate movements and sterilised foreign exchange market interventions (Chapters IV and V).

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<sup>24</sup> In accordance with the New-Classical model, non-sterilised interventions in the foreign exchange market have the same impact on the exchange rate as interest rate changes resulting from traditional open market operations (see Chapter V below).

## II.4 Summary of the results

Economists are accustomed to monetarists and Keynesians debating whether monetary policy should be used actively for influencing aggregate demand, whether the Phillips curve exists, whether prices are sticky, and so on. Surprisingly, however, the advocacy of floating exchange rates for promoting economic stability and enhancing monetary autonomy is shared equally by both schools (see Table II.1). The reason for this agreement is simple: In each of the three models presented above there is always a clearly defined link between the use of the instrument of monetary policy ( $m_t$  or  $i_t$ ) and the exchange rate. While the instrument can be set autonomously, the exchange rate is entirely endogenous and not an independent source of disturbance.

**Table II.1: Friedman's predicted benefits from independently floating exchange rates**

	Mundell-Fleming	New-Classical	New-/Neo-Keynesian
stabilising speculation	static expectations + capital mobility ( $i_t = i_t^f$ )	rational expectations + foreign exchange market efficiency (UIP)	rational expectations + foreign exchange market efficiency (UIP)
promotion of economic stability	balance of payments equilibrium	exchange rate channel (flexible adjustment of prices)	exchange rate channel (price rigidities, impact on aggregate demand and aggregate supply)
guarantee of monetary autonomy	free choice of $y_t$	free choice of $\bar{m}$ , and hence of $p_t$	free choice of $\pi^T$

This also explains why in any of the models no direct sterilised foreign exchange market intervention to influence the course of the exchange rate is needed to achieve anything that cannot be achieved by using the traditional monetary policy instrument. The benefits of indirect managed floating only appear in the New-Classical model (see Table II.2). It must be stressed, however, that this result only holds against the alternative of a passive monetary policy.

Under absolutely fixed exchange rates, the central bank subordinates the benefits from the independently floating exchange rates (autonomy, stability) to the goal of exchange rate stability (see Table II.3).

**Table II.2: Benefits of a strategy of indirect managed floating**

Mundell-Fleming	New-Classical	New-/Neo-Keynesian
indirect managed floating is inferior to independently floating where the central bank perfectly stabilises output	advantage over a fixed money supply rule	exchange rate provides no additional information for the central bank

**Table II.3: Costs and benefits from absolutely fixed exchange rates**

Mundell-Fleming	New-Classical	New-/Neo-Keynesian
subordination of $m_t$ to the goal of exchange rate stability at the expense of economic (output) stability and monetary autonomy	subordination of $m_t$ to the goal of exchange rate stability at the expense of monetary autonomy; price stability is guaranteed through price flexibility, whereas output stability is given up	subordination of $i_t$ to the goal of exchange rate stability at the expense of economic stability and monetary autonomy

Thus, regardless of the underlying paradigm the main results of this Chapter are that

- all the models reflect the basic message of the impossible trinity theorem;
- indirect managed floating only provides advantages if the alternative under independently floating is a passive monetary policy;
- neither school provides a rationale for sterilised foreign exchange market interventions.

## Appendices to Chapter II

### II.A Solution of the Mundell-Fleming model

The model is summarised by the following equations:

$$(II.31) \quad y_t = \beta_0 - \beta_i i_t + \beta_s s_t + \varepsilon_t^y$$

$$(II.32) \quad m_t - p_t = \kappa_y y_t - \kappa_i i_t + \varepsilon_t^m$$

$$(II.33) \quad i_t = i_t^f.$$

The endogenous variables are  $y_t$  and  $s_t$ , and the exogenous random shocks that affect the course of the economy are  $\varepsilon_t^m$ ,  $\varepsilon_t^y$  and  $i_t^f$ . The domestic price level is fixed at  $\bar{p}_t$ . The policy instrument is the domestic money supply  $m_t$ .

Analytically, the reduced form of the exchange rate is obtained by using the IS equation (II.31) to eliminate  $y_t$  in the LM curve (II.32) and by solving the resulting equation for the log of the spot exchange rate  $s_t$ :

$$(II.34) \quad s_t = \left( -\frac{\beta_0}{\beta_s} - \frac{\bar{p}_t}{\beta_s \kappa_y} \right) + \frac{1}{\beta_s \kappa_y} m_t + \left( \frac{\kappa_i}{\kappa_y \beta_s} + \frac{\beta_i}{\beta_s} \right) i_t^f - \frac{1}{\kappa_y \beta_s} \varepsilon_t^m - \frac{1}{\beta_s} \varepsilon_t^y.$$

Note that the domestic interest rate  $i_t$  has been replaced with (II.33). Inserting (II.34) into (II.31) gives the reduced form of output:

$$(II.35) \quad y_t = \frac{\bar{p}_t}{\kappa_y} + \frac{1}{\kappa_y} m_t + \frac{\kappa_i}{\kappa_y} i_t^f - \frac{1}{\kappa_y} \varepsilon_t^m.$$

Thus, under independently floating exchange rates, the adjustment mechanism of the balance of payments perfectly absorbs IS shocks ( $\varepsilon_t^y$ ), so that a central bank that aims at stabilising output around a target level remains passive. This can also be seen from the optimal policy rule that a central bank with an output target should follow:

$$(II.36) \quad m_t = -\kappa_i i_t^f + \varepsilon_t^m$$

Inserting (II.36) into (II.35) results in an output level that is perfectly stabilised at its target level, as the central bank fully compensates LM shocks ( $\varepsilon_t^m$ ) and foreign interest rate shocks ( $i_t^f$ ).

If the central bank is assumed to follow a policy rule according to which the money supply only reacts to movements in the exchange rate (indirect managed floating)

$$(II.37) \quad m_t = -f_s s_t$$

the reduced form solutions of  $s_t$  and  $y_t$  are

$$(II.38) \quad s_t = \left( \frac{-\beta_0 \kappa_y - \bar{p}_t}{\beta_s \kappa_y + f_s} \right) + \left( \frac{\kappa_i + \beta_i \kappa_y}{\beta_s \kappa_y + f_s} \right) i_t^f - \left( \frac{1}{\beta_s \kappa_y + f_s} \right) \varepsilon_t^m - \left( \frac{\kappa_y}{\beta_s \kappa_y + f_s} \right) \varepsilon_t^y$$

$$(II.39) \quad y_t = \left( \frac{-\beta_0 f_s - \beta_s \bar{p}_t}{\beta_s \kappa_y + f_s} \right) + \left( \frac{\beta_i f_s + \kappa_i \beta_s}{\beta_s \kappa_y + f_s} \right) i_t^f - \left( \frac{\beta_s}{\beta_s \kappa_y + f_s} \right) \varepsilon_t^m - \left( \frac{f_s}{\beta_s \kappa_y + f_s} \right) \varepsilon_t^y.$$

For values of  $f_s$  approaching infinity the exchange rate is absolutely fixed, at the expense of output stability. While under fixed exchange rates LM shocks are fully absorbed, the volatility output increases with  $f_s$  when demand shocks occur:

$$(II.40) \quad \frac{\partial \text{Var}[y_t]}{\partial f_s} = \frac{2f_s \beta_s \kappa_y}{(f_s + \beta_s \kappa_y)^3} \text{Var}[\varepsilon_t^y] > 0.$$

In the case of foreign interest rate shocks, the sign cannot be predicted a priori:

$$(II.41) \quad \frac{\partial \text{Var}[y_t]}{\partial f_s} = \frac{2\beta_s (f_s \beta_i + \beta_s \kappa_i) (\beta_i \kappa_y - \kappa_i)}{(f_s + \beta_s \kappa_y)^3} \text{Var}[\varepsilon_t^{if}]$$

## II.B Solution of the New-Classical open economy model

The model is summarised by the following equations:

$$(II.42) \quad m_t - p_t = \kappa_y y_t - \kappa_i i_t + \varepsilon_t^m$$

$$(II.43) \quad y_t = \gamma_p (p_t - E_{t-1} p_t) + \varepsilon_t^y$$

$$(II.44) \quad s_t = p_t - p_t^f$$

$$(II.45) \quad i_t = i_t^f + E_t s_{t+1} - s_t$$

$$(II.46) \quad m_t = \bar{m} - f_s s_t.$$

The endogenous variables are  $y_t$ ,  $p_t$  and  $s_t$ , and the exogenous random shocks that affect the course of the economy are  $\varepsilon_t^m$ ,  $\varepsilon_t^y$ ,  $p_t^f$  and  $i_t^f$ . Compared to the model in Section II.2 the foreign variables are assumed to be independent from each other (that is, we do not specify any foreign money market equilibrium). The policy instrument is the domestic money supply. Note that by inserting (II.45) into (II.42) we can eliminate the domestic nominal interest rate. The solution of the system can be found by using the method of undetermined coefficients in conjunction with the minimal state variable approach (McCallum, 1983). Assuming that the disturbances are uncorrelated white noise processes implies that the expectational terms are equal to zero so that the endogenous variables can be expressed in reduced form as (see Turnovsky, 1994, for details):

$$(II.47) \quad y_t = \frac{\gamma_p (\kappa_i + f_s) p_t^f + (1 + \kappa_i + f_s) \varepsilon_t^y + \gamma_p \kappa_i i_t^f - \gamma_p \varepsilon_t^m}{1 + \kappa_i + f_s + \kappa_y \gamma_p}$$

$$(II.48) \quad p_t = \frac{\bar{m} + (\kappa_i + f_s) p_t^f - \kappa_y \varepsilon_t^y + \kappa_i i_t^f - \varepsilon_t^m}{1 + \kappa_i + f_s + \kappa_y \gamma_p}$$

$$(II.49) \quad s_t = \frac{\bar{m} - (1 + \kappa_y \gamma_p) p_t^f - \kappa_y \varepsilon_t^y + \kappa_i i_t^f - \varepsilon_t^m}{1 + \kappa_i + f_s + \kappa_y \gamma_p}.$$

In the case of a supply shock the variances of the goal variables are given by

$$(II.50) \quad \text{Var}[y_t] = \left( \frac{1 + \kappa_i + f_s}{1 + \kappa_i + f_s + \kappa_y \gamma_p} \right)^2 \text{Var}[\varepsilon_t^y]$$

$$(II.51) \quad \text{Var}[p_t] = \left( \frac{\kappa_y}{1 + \kappa_i + f_s + \kappa_y \gamma_p} \right)^2 \text{Var}[\varepsilon_t^y].$$

From (II.51) it clearly follows that the more the central bank responds to exchange rate movements (i.e. the higher  $f_s$ ), the lower the variance of the price level. An interpretation of (II.50) requires somewhat more algebra. Calculating the first derivative gives

$$(II.52) \quad \frac{\partial \text{Var}[y_t]}{\partial f_s} = \frac{2\kappa_y \gamma_p (1 + \kappa_i + f_s)}{(1 + \kappa_i + f_s + \kappa_y \gamma_p)^3} \text{Var}[\varepsilon_t^y] > 0.$$

Thus, the variance of output increases in consequence of the central bank's policy intervention. This is the typical trade-off result obtained from the analysis of supply shock.

Concerning the 'intervention' objective of the policy rule (II.46), inspection of (II.49) reveals that the variance of the spot exchange rate depends negatively on the policy parameter  $f_s$ . Thus the more the central bank responds to movements of the exchange rate with changes in the money supply (the higher  $f_s$ ), the smaller the variance of  $s_t$ . At the limit, if  $f_s$  approaches infinity, the exchange rate is perfectly fixed. If the central bank keeps the money supply constant ( $f_s = 0$ ), the variance of the exchange rate is exclusively influenced by non-policy parameters, and hence by the market.

Another interesting point concerns the choice of the autonomous component of the money supply rule  $\bar{m}$ . As can be seen from the reduced forms of the model's endogenous variables (equations (II.47) to (II.49)) it provides the economy with a nominal anchor: while the level of  $\bar{m}$  determines  $p_t$  and  $s_t$  even in the absence of shocks, it has no influence on real output.

## II.C New-Keynesian / Neo-Keynesian open economy models

This Appendix summarises a range of widely used New-Keynesian / Neo-Keynesian open economy models. In all models it is assumed that changes in the real exchange rate (i.e. deviations from purchasing power parity) are defined as

$$(II.53) \quad q_t - q_{t-1} \equiv s_t - s_{t-1} + \pi_t^f - \pi_t .$$

Most of the models are hybrid specifications. In Table II.4 we sorted them by decreasing degree of backward-lookingness. Table II.5 and Table II.6 explain the parameters.

**Table II.4: The demand und supply side in typical small-scale open economy macro models**

Guender (2001, 2002) (a)	$y_t = E_t y_{t+1} - \beta_i (i_t - E_t \pi_{t+1}) + \beta_q q_t + \varepsilon_t^y$ <hr/> $\pi_t = E_t \pi_{t+1} + \gamma_y y_t + \gamma_q q_t + \varepsilon_t^\pi$
Batini and Nelson (2000a) (q)	$y_t = E_t y_{t+1} - \beta_i (i_t - E_t \pi_{t+1}) + \beta_q \left( \frac{1}{4} \sum_{j=1}^4 q_{t-j} \right) + \varepsilon_t^y ;$ <hr/> $\pi_t = (1 - \gamma_\pi) \pi_{t-1} + \gamma_\pi E_t \pi_{t+1} + \gamma_y y_{t-1} + \gamma_q \Delta \left( \frac{1}{4} \sum_{j=1}^4 q_{t-j} \right) + \varepsilon_t^\pi$
Batini and Haldane (1999) (a)	$y_t = (1 - \beta_{yy}) y_{t-1} + \beta_{yy} E_t y_{t+1} - \beta_i (i_t - E_t \pi_{t+1}) + \beta_q q_t + \varepsilon_t^y$ <hr/> $\pi_t = (1 - \gamma_\pi) \pi_{t-1} + \gamma_\pi E_t \pi_{t+1} + \gamma_y (y_t - y_{t-1}) + \gamma_q \left[ (1 - \gamma_\pi) \Delta q_t + \gamma_\pi E_t \Delta q_{t+1} \right] + \varepsilon_t^\pi$
Di Bartolomeo et al. (2003) (a)	$y_t = (1 - \beta_{yy}) y_{t-1} + \beta_{yy} E_t y_{t+1} - \beta_i (i_t - E_t \pi_{t+1}) + \beta_q q_t + \varepsilon_t^y$ <hr/> $\pi_t = (1 - \gamma_\pi) \pi_{t-1} + \gamma_\pi E_t \pi_{t+1} + \gamma_y y_t + \gamma_q q_t + \varepsilon_t^\pi$
Leitemo and Söderström (2001) (q)	$y_t = \beta_y \left[ (1 - \beta_{yy}) y_{t-1} + \beta_{yy} E_{t-1} y_{t+1} \right] - \beta_i (i_{t-1} - 4E_{t-1} \pi_t^d) + \beta_q q_{t-1} + \beta_{yf} y_t^f + \varepsilon_t^y$ <hr/> $\pi_t = (1 - \gamma_q) \pi_t^d + \gamma_q \pi_t^m$ <hr/> $\pi_t^d = (1 - \gamma_\pi) \pi_{t-1}^d + \gamma_\pi E_{t-1} \pi_{t+1}^d + \gamma_y E_{t-1} y_t + \gamma_{qq} E_{t-1} q_t + \varepsilon_t^\pi$ <hr/> $\pi_t^m = \pi_t^f + (s_t - s_{t-1}) = \pi_t + (q_t - q_{t-1})$

**Table II.4: The demand und supply side in typical small-scale open economy macro models**

	$y_t = \beta_y y_{t-1} - \beta_r \sum_{\tau=0}^{\infty} E_{t-1} r_{t-1+\tau} + \beta_q E_{t-1} q_t + \varepsilon_t^y$
Svensson (2000) (q)	$\pi_t = (1 - \gamma_q) \pi_t^d + \gamma_q \pi_t^m$ $\pi_t^d = (1 - \gamma_\pi) \pi_{t-1}^d + \gamma_\pi E_{t-2} \pi_{t+1}^d + \gamma_y [E_{t-2} y_t + \gamma_{yy} (y_{t-1} - E_{t-2} y_{t-1})] + \gamma_{qq} E_{t-2} q_t + \varepsilon_t^\pi$ $\pi_t^m = \pi_t^f + (s_t - s_{t-1}) = \pi_t + (q_t - q_{t-1})$
Dennis (2000) (a)	$y_t = \beta_y y_{t-1} - \beta_i [i_t - \beta_\pi E_{t-1} \pi_{t+1} - (1 - \beta_\pi) \pi_{t-1}] + \beta_q q_{t-1} + \beta_{yf} y_t^f + \varepsilon_t^y$ $\pi_t = (1 - \gamma_q) \pi_t^d + \gamma_q \pi_t^m$ $\pi_t^d = (1 - \gamma_\pi) \pi_{t-1}^d + \gamma_\pi E_t \pi_{t+1}^d + \gamma_y y_t + \varepsilon_t^\pi$ $\pi_t^m = \pi_t^f + (s_t - s_{t-1}) = \pi_t + (q_t - q_{t-1})$
Leith and Wren- Lewis (2001) (a)	$y_t = \beta_y y_{t-1} - \beta_i (i_t - E_t \pi_{t+1}) + \beta_q q_t + \varepsilon_t^y$ $\pi_t = (1 - \gamma_q) \pi_t^d + \gamma_q \pi_t^m$ $\pi_t^d = (1 - \gamma_\pi) \pi_{t-1}^d + \gamma_\pi E_t \pi_{t+1}^d + \gamma_y y_t + \varepsilon_t^\pi$ $\pi_t^m = \pi_t^f + (s_t - s_{t-1}) = \pi_t + (q_t - q_{t-1})$
Ball (1999b) and Leitemo et al. (2002) (a)	$y_t = \beta_y y_{t-1} - \beta_r r_{t-1} + \beta_q q_{t-1} + \varepsilon_t^y$ $\pi_t = \pi_{t-1} + \gamma_y y_{t-1} + \gamma_q (q_{t-1} - q_{t-2}) + \varepsilon_t^\pi$

Note: (a)/(q) signifies that the model is annual/quarterly.

**Table II.5: Demand-side parameters**

$\beta_i, \beta_r$	interest rate elasticity of aggregate demand
$\beta_q$	exchange rate elasticity of aggregate demand
$\beta_y$	persistence in aggregate demand
$\beta_{yy}$	degree of forward-lookingness of consumers
$\beta_{yf}$	impact of foreign demand on aggregate demand

**Table II.6: Supply side parameters**

$\gamma_\pi$	degree of forward-lookingness of the price / wage setters
$\gamma_y, \gamma_{yy}$	degree by which tightness in the labour market impacts on price / wage setting
$\gamma_q$	weight of imported inflation $\pi_t^m$ in CPI inflation $\pi_t$
$\gamma_{qq}$	weight on the effect of expected costs of imported intermediate inputs (or expected impact of future exchange rate changes on CPI inflation, and hence on domestic real wages)

## II.D A note on the role of money in the New-Keynesian / Neo-Keynesian models

In the discussion of the Mundell-Fleming model and the New-Classical model it was assumed that the nominal supply of money can be treated as the instrument (or intermediate target) of monetary policy. However, most central banks actually implement monetary policy by controlling a short-term nominal interest rate (without relying on any specific intermediate target). This development in monetary policy modelling gives rise to two important questions: First, is there any role for money in New-Keynesian / Neo-Keynesian models? And second, how is the long-run price level determined in these models?

With regard to the first question, it would be possible to append a money demand function such as

$$(II.54) \quad m_t - p_t = \kappa_y y_t - \kappa_i i_t$$

where  $m_t$  is the log of the nominal money stock. But, as many authors have noted, that equation would serve only to determine the values of  $m_t$  that are needed to implement the  $i_t$  policy rule. To control the nominal interest rate, the central bank must allow the nominal supply of money to adjust endogenously to ensure the real demand for money is equal to the real supply. Thus, the role of money is assumed to be a passive one, in the sense that money is demand determined (see e.g. King, 2002, and Rudebusch and Svensson, 2002). Note that this is exactly opposite to the relationship between money and interest rates in the New-Classical model (see Appendix II.B).

Regarding the second question, it is clear that with the abandonment of targets for the money supply, an important nominal anchor to tie down inflation expectations got lost. In rational expectations models of the New-Classical / Monetarist type, the effect on the price level of any predicted change in  $m_t$  (irrespective of whether the central bank follows a fixed or a flexible policy rule) will be fully reflected in  $E_{t-1}p_t$ . In New-Keynesian / Neo-Keynesian models with the interest rate as monetary policy instrument the nominal anchor is provided by an explicit inflation target  $\pi^T$  that is contained in the monetary policy reaction function. McCallum (1986) showed that under interest rate targeting such an inflation target effectively fixes the long-term

growth of the money supply if the model is simply extended by a money demand function. An intuitive explanation can be given via the long-term level of the nominal interest rate. Once  $\pi^T$  is defined, the equilibrium nominal interest rate  $i^T$  is determined as the sum of the (exogenous) equilibrium real interest rate  $\bar{r}$  and the (policy-determined) inflation target  $\pi^T$ . Thus, fixing  $\pi^T$  is equivalent to fixing the money supply.

## Chapter III:

### Puzzling Exchange Rate Behaviour as Source of Exchange Rate Uncertainty

With the demise of the Bretton Woods system in 1971 an era of generalised floating was instituted which has certainly not delivered anything approaching the degree of stability its advocates hoped to see. Currency values have been subject both to wild day-to-day fluctuations and to long-term swings into apparent over- or undervaluation (see Obstfeld, 1995, for an impressive overview). As a reaction, central banks developed a range of policy measures to counteract the gyrations in the exchange rate that have been largely described in Chapter I. In the last Chapter we showed that standard macroeconomic models which are used to derive rules for central banks' stabilisation policy do not provide any explanation for the observable managed floating behaviour.

In this Chapter we take a deeper look at the exchange rate theories underlying the three macroeconomic models. As the balance of payments flow approach of the Mundell-Fleming model is widely rejected today in favour of the asset market approach (see also Section II.1.2), it will not be explicitly addressed. We will rather concentrate on purchasing power parity and uncovered interest parity which constitute the fundamental theories for the determination of the exchange rate in the New-Classical model and in the Neo-Keynesian / New-Keynesian model.

#### III.1 Exchange rate puzzles – an overview

##### *III.1.1 Exchange rate disconnect puzzle*

During the 1970s economists developed a range of models of the determination of exchange rates, all of which have in common that the exchange rate is regarded as an asset price. The most popular among them are the flex-price monetary model, the sticky-price monetary model (Dornbusch overshooting model) and the portfolio balance model. All of these models share the feature that the exchange rate is the equilibrium price of two financial stocks (two monies, two bonds) that can be exchanged on the international financial markets. The financial stocks as well as their determinants (interest rates, output, prices) are usually referred to as the macroeconomic fundamentals of the exchange rate.

In a recent paper, Obstfeld and Rogoff (2000, p. 34) identified the exchange rate disconnect puzzle as one of the six major puzzles in international macroeconomics, “a name that alludes broadly to the exceedingly weak relationship (except, perhaps, in the longer run) between the exchange rate and virtually *any* macroeconomic aggregates.” Numerous studies found that there is remarkably little evidence that macroeconomic variables have consistent strong effects on floating exchange rates (see e.g. Frankel and Rose, 1995, and Taylor, 1995, for survey articles on empirical evidence). The most notorious empirical rejection was made by Meese and Rogoff (1983). In an influential paper they showed that standard macroeconomic exchange rate models, even with the aid of ex post data on the fundamentals, forecast exchange rates at short to medium horizons no better than a naïve random walk. “After nearly two decades of research since Meese and Rogoff’s pioneering work on exchange rate predictability (...), the goal of exploiting economic models of exchange rate determination to beat naïve random walk forecasts remains as elusive as ever” (Kilian and Taylor, 2003, p. 1).

In addition to the fact that movements in the exchange rate appear to be disconnected from movements in the underlying fundamentals, the finding that after the end of the Bretton Woods fixed exchange rate system the variability of exchange rates (in both, nominal and real terms) has dramatically increased seemed to be puzzling to most economists. Baxter and Stockman (1989) and Flood and Rose (1999) found that, at the same time, there is no evidence that the variability of the fundamentals identified by the asset market models has increased compared to the fixed exchange rate period. This is clearly at odds with the basic message of the fundamentals based models according to which the variability of the exchange rate can only increase when the variability of the underlying fundamental variables increases.

### ***III.1.2 PPP puzzle***

The purchasing power parity (PPP) puzzle could be interpreted as just one manifestation of the exchange rate disconnect puzzle. Compared to many other models of exchange rate determination the failure of PPP has, however, attracted the most attention since it relies on arbitrage arguments. According to PPP, consumers should be able to buy the same bundle of goods in any country for the same amount of currency. The basic idea is that if goods market arbitrage enforces broad parity in prices across a sufficient range of individual goods, then there should also be a high correlation in aggregate price levels. Thus, if PPP holds, the nominal exchange rate is proportional to the ratio of domestic and foreign price levels:

$$(III.1) \quad s_t = p_t - p_t^f$$

where  $s_t$  is the logarithm of the nominal exchange rate (the domestic price of foreign currency) and  $p_t$  and  $p_t^f$  are the logarithms of the domestic and foreign price level, respectively. On the basis of equation (III.1) the logarithm of the real exchange rate  $q_t$  can be defined as

$$(III.2) \quad q_t = s_t - p_t + p_t^f$$

which is usually viewed as a measure for the deviation from PPP. If equation (III.1) held continuously,  $q_t$  would simply be a constant reflecting differences in units of measurement.

Thus, much of the empirical literature on the validity of PPP grounds on the testing the time series properties of the real exchange rate (see Rogoff, 1996, for an influential survey article). A general finding is that in floating rate regimes the real exchange rate and the nominal exchange rate are closely correlated. In addition, the early literature typically failed to reject the hypothesis that the real exchange rate follows a random walk. This so-called first generation of the PPP puzzle has the important implication that anything which pushes the nominal exchange rate away from its PPP value will be permanent, and hence fundamentally at odds with the expected constancy of the real exchange rate.

This first generation of the puzzle was largely resolved by using long-span data sets of real exchange rates. Researchers found that the real exchange rate seems to follow an AR(1) process with a large degree of persistence rather than a random walk. It is obvious that, if PPP deviations damp sufficiently slowly, it requires many decades of data for one to be able to reject the random walk of the real exchange rate. Lothian and Taylor (1996), for example, estimated the following equation for the dollar/sterling exchange rate, using annual data ranging from 1792 to 1990:

$$(III.3) \quad q_t = 0.18 + 0.89q_{t-1} + \varepsilon_t$$

implying a rate of decay for real exchange rate deviations of 11 per cent per year (or a half life of PPP deviations of almost 6 years). Even though one was successful in rejecting the random walk

hypothesis by showing that real exchange rates exhibit mean reversion, it still remains puzzling why adjustment speeds are so slow. This large degree of persistence is what today is usually referred to as the PPP puzzle.

### ***III.1.3 UIP puzzle***

The uncovered interest parity (UIP) condition represents a behavioural relationship of speculators on international financial markets. It is not an exchange rate model per se, but it constitutes the fundamental law governing the functioning of an efficient speculative asset market. Due to this characteristic, UIP is a central relationship in virtually all asset market models of the exchange rate as well as all open economy macro models.

UIP simply states that, if the international capital markets are free from capital controls and international investors are risk neutral, then speculation should ensure that the expected rates of return on domestic and foreign assets are identical:

$$(III.4) \quad \dot{i}_{t,k} = i_{t,k}^f + E_t s_{t+k} - s_t$$

where  $s_t$  is the log of the spot price of foreign currency at time  $t$ ,  $E_t$  is the rational expectations operator and  $i_{t,k}$  and  $i_{t,k}^f$  are the nominal interest rates available on similar domestic and foreign securities (with  $k$  periods of maturity), respectively.

One way of testing the validity of equation (III.4) is to estimate a regression equation of the form

$$(III.5) \quad s_{t+k} - s_t = \beta_0 + \beta_1 (i_{t,k} - i_{t,k}^f) + \varepsilon_{t,t+k}$$

where  $\varepsilon_{t,t+k}$  is a white noise error term. Instead of regressing the ex-post exchange rate change on the interest rate differential the latter is often substituted for the forward discount (premium) by assuming the validity of covered interest parity (CIP)

$$(III.6) \quad s_{t+k} - s_t = \beta_0 + \beta_1 (f_{t,k} - s_t) + \varepsilon_{t,t+k}.$$

In both cases the null hypothesis usually tested consists of a joint hypothesis of foreign exchange market efficiency (rational expectations) and valid UIP. The former implies that on average investors make no errors when predicting the future spot exchange rate

$$(III.7) \quad s_{t+k} = E_t s_{t+k} + \eta_{t,t+k}$$

where  $\eta_{t,t+k}$  is uncorrelated with information available at time  $t$ . The latter implies that  $\beta_0 = 0$  and  $\beta_1 = 1$ . Under this null hypothesis the forward rate provides an unbiased forecast of the future spot exchange rate. However, the vast literature on the estimation of a UIP equation like (III.5) or (III.6) overwhelmingly rejects the hypothesis that  $\beta_1$  equals one. For low inflation countries and for horizons  $k$  of up to one year researchers typically come to the result that<sup>25</sup>

1. the coefficient on the forward premium is negative,
2. the coefficient on the forward premium is often found to be insignificantly different from zero and in almost most studies significantly different from one, and
3. the fit of the regressions is poor, with adjusted  $R^2$  statistics close to zero.

The sum of these three findings is normally referred to as the so-called forward premium/discount puzzle/bias, or briefly UIP puzzle. Early evidence of this puzzle can be found in Bilson (1981), Fama (1984), Cumby and Obstfeld (1984) and some more recent evidence in Mark and Wu (1998), Meredith and Chinn (1998) and Roll and Yan (2000) – just to mention a few.

The puzzle is in particular a striking result since uncovered interest parity is – under the assumption of fully rational expectations – a pure arbitrage condition which should hold at every  $t$  for freely convertible currencies. If the forward premium is negatively related to the subsequent change in the spot rate, the domestic currency will appreciate (depreciate) when its nominal interest rate is higher (lower) than the foreign interest rate. This suggests a simple and profitable trading scheme: Buy the bonds of the country whose nominal interest rate is higher. That trading rule produces a greater local currency return for sure; and it will likely be supplemented by an

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<sup>25</sup> See Bansal and Dahlquist (2000) for more favourable evidence of the unbiasedness hypothesis in the case of countries with lower per capita income and higher inflation uncertainty; see Meredith and Chinn (1998) and Alexius (2001) for promising estimates of UIP on the basis of long term government bond yields.

exchange rate appreciation. However, the low t-values for  $H_0 : \beta_1 = 0$  that are often found in empirical work indicate that such a trading rule is rather dangerous.

**Figure III.1: The (in)significance of  $\beta_1 < 0$**



Note: The figure graphs the 208 slope coefficients obtained from an unbiasedness regression similar to equation (III.6) based on rolling monthly 5-year sub-samples for the DM-\$ exchange rate beginning with the sample from March 1973 until February 1978, ending with the 5-year sample from December 1990 through to November 1995. The dashed lines give the conventional two OLS standard error confidence bands. Source: Baillie and Bollerslev (2000)

Note, however, that a non-negligible number of studies examining the UIP for the 1980s even found that the negative  $\beta_1$  was significantly different from zero. As has been shown recently by Baillie and Bollerslev (2000) the systematic  $\beta_1 < 0$  case appears to be an artefact of the long swings in the US dollar in the 1980s. Using monthly 5-year rolling regressions they find for the mark/dollar exchange rate that “there is a period in the middle of the floating regime where the estimated  $\beta_1$  coefficients are statistically negative based on the conventional asymptotic two standard error bands. This era extends from the October 1980 through to September 1985 sub-period to the June 1985 to May 1990 sub-period” (Baillie and Bollerslev, 2000, p. 477). For the remaining part of the estimation period  $\beta_1$  was found to be insignificantly different from zero (see Figure III.1).

### ***III.1.4 Summary: Exchange rate puzzles and monetary policy modelling***

In our view, the exchange rate disconnect puzzle is a rather general description of a phenomenon that has its roots in the second and third puzzle. In Chapter II, for example, we showed that in the New-Classical macro model the exchange rate is determined according to the flexible-price monetary model which is mainly based on PPP and UIP. Since the two parity conditions are basic constituents of almost every exchange rate model, in the following we concentrate on explanations for the PPP and UIP puzzle.

The importance of PPP and UIP has also been emphasised in Chapter II where we have shown that both play an important role in the New-Classical and in the Neo-Keynesian / New-Keynesian open economy model. In contrast to the New-Classical model in which PPP was assumed to continuously hold, deviations from PPP were explicitly taken into account in the Neo-Keynesian / New-Keynesian model by allowing for movements in the real exchange rate. While, in our view, there is a widespread consensus among economists today on how to implement the empirical anomalies of PPP into the models (see the open economy Phillips curves presented in Chapter II and below in Section III.2), a valid UIP condition is still a widespread assumption among economists. In both macro models UIP appears as the core relationship for the determination of the exchange rate. Additionally, in the Neo-Keynesian / New-Keynesian model where the central bank is assumed to pursue an activist stabilisation policy it opens a second important transmission channel of impulses from the short-term interest rate to the final targets. Thus, the suspicion arises that the exchange rate uncertainty stemming from the puzzling short-run evidence on UIP could provide a rationale for the observable fear of floating. In Section III.3, we will therefore present three explanations for the UIP puzzle which will then be implemented in a Neo-Keynesian open economy model in Chapter IV.

## **III.2 Purchasing power parity**

### ***III.2.1 Explanations for the PPP puzzle***

The fundamental building block of PPP is the so-called law of one price (LOP) which states that once expressed in a common currency, the same good should have the same price in different countries. The basic argument why the LOP should hold is generally based on the idea of frictionless goods arbitrage. Empirically however, the validity of the LOP is rejected by the

literature, with the typical finding that LOP deviations are highly correlated with nominal exchange rate movements (see Goldberg and Knetter, 1997, for an overview).

One widely accepted explanation is the friction in international arbitrage due to transportation costs and (tariff and non-tariff) trade barriers which drive a wedge between domestic and foreign prices (see for example Engel and Rogers, 1996, on the so-called border effect). An alternative explanation for the failure of the LOP are price rigidities under variable nominal exchange rates (Krugman, 1987). Instead of immediately passing-through the changes in the exchange rate to the consumers of the domestic market, foreign firms selling on the domestic market keep the prices unchanged in domestic currency and accept therefore corresponding changes in their profit margin (which is expressed in foreign currency). One reasoning for this so-called pricing-to-market behaviour (or sometimes local currency pricing) of international firms is the existence of irreversible menu costs which delay the continual pass-through in sales prices in the event of exchange rate fluctuations. Instead, the selling prices are often not adjusted until the lower earnings expected for the following periods and arising from the decision not to adjust prices exceed the menu costs. Such an imperfect exchange rate pass-through finally results in sticky import prices which only gradually adjust to the level implied by the LOP. This short-run disconnect between inflation and exchange rate variation has recently been confirmed by Campa and Goldberg (2002) for a range of OECD countries. They found that the degree of pass-through is partial in the short-term and that it becomes complete only in the long-term.

### ***III.2.2 Implications of the PPP puzzle for the conduct of monetary policy***

On a macroeconomic level pricing-to-market implies that import prices (and hence consumer price inflation) do not move immediately and in a one-to-one relation with the exchange rate. Thus, pricing-to-market acts to limit the pass-through from exchange rate movements to inflation. This has important implications for the efficiency of monetary policy actions (interest rate changes) in an open economy environment.

As has been shown in Chapter II within the context of a New-Keynesian / Neo-Keynesian open economy model, a central bank usually has the objective to stabilise inflation and output around a given target. Compared with the closed economy case, the central bank exploits an additional transmission channel in an open economy, namely the exchange rate channel. The idea is that via UIP interest rate changes directly impact on the exchange rate. An increase in interest rates, for

example, is accompanied by a contemporaneous appreciation of the domestic currency which impacts on both, aggregate demand by changing the relative costs of foreign and domestic goods, and inflation by passing-through exchange rate changes to import prices, and hence to CPI inflation.

In order to illustrate how the degree of pass-through influences the transmission of monetary impulses, in the following we derive the open economy Phillips curve for different degrees of pass-through. The rate of CPI inflation is defined as a weighted average of domestic  $\pi_t^d$  and imported inflation  $\pi_t^m$ :

$$(III.8) \quad \pi_t = (1 - \gamma_q) \pi_t^d + \gamma_q \pi_t^m,$$

where  $\gamma_q$  is the degree of openness (see equations (II.15) and (II.24)). Domestically produced goods are assumed to be priced according to a purely backward-looking domestic Phillips curve relation

$$(III.9) \quad \pi_t^d = \pi_{t-1} + \tilde{\gamma}_y y_{t-1} + \tilde{\varepsilon}_t^\pi$$

where  $y_{t-1}$  is the output gap, and  $\tilde{\varepsilon}_t^\pi$  is a i.i.d. supply shock with mean zero (see also equation (II.25)). Note that in this formulation of domestic inflation the exchange rate enters indirectly into domestic prices through wage contracts that are deflated with CPI inflation.

For import goods we allow for different degrees of delay between movements in the exchange rate and the adjustment of imported goods prices. The three cases of immediate, gradual and no pass-through are summarised in Table III.1.

**Table III.1: Import prices under various degrees of exchange pass-through**

full and immediate pass-through	$\pi_t^m = \pi_t^f + (s_t - s_{t-1}) = \pi_t + (q_t - q_{t-1})$
imperfect and gradual pass-through	$\pi_t^m = \pi_{t-1}^f + (s_{t-1} - s_{t-2}) = \pi_{t-1} + (q_{t-1} - q_{t-2})$
no pass-through	$\gamma_q = 0 \Leftrightarrow \pi_t^m = \pi_t^d$

The overall price equation in terms of the CPI is obtained by inserting (III.9) and the import price equation (see Table III.1) into (III.8). Under immediate pass-through we get

$$(III.10) \quad \pi_t = \pi_{t-1} + \frac{\gamma_y}{1-\gamma_q} y_{t-1} + \frac{\gamma_q}{1-\gamma_q} (q_t - q_{t-1}) + \frac{1}{1-\gamma_q} \varepsilon_t^\pi$$

where  $\gamma_y = (1-\gamma_q)\tilde{\gamma}_y$  and  $\varepsilon_{t+1}^\pi = (1-\gamma_q)\tilde{\varepsilon}_{t+1}^\pi$ . If the pass-through is assumed to take place only gradually we get

$$(III.11) \quad \pi_t = \pi_{t-1} + \gamma_y y_{t-1} + \gamma_q (q_{t-1} - q_{t-2}) + \varepsilon_t^\pi.$$

Finally, if the pass-through is zero, CPI inflation is solely determined by domestic price inflation:

$$(III.12) \quad \pi_t = \pi_{t-1} + \gamma_y y_{t-1} + \varepsilon_t^\pi.$$

A comparison of the three open economy Phillips curves reveals that changes in the monetary policy stance at time  $t$  are transmitted quite differently to inflation. Under a full and immediate pass-through monetary policy is able to affect inflation via changes in the exchange rate with no lag. If, by contrast, the pass-through is assumed to be zero, monetary policy impulses are exclusively channelled through output. In the intermediate case, the exchange rate affects inflation with a lag of one period (which is still faster than the impact of interest rate changes on inflation in situations with zero pass-through where the interest rate affects output with lag of one period and output affects inflation with an additional lag of one period). Thus, the monetary transmission lag, and hence the implied degree of inflation control, crucially depends on the degree of exchange rate pass-through. Since the imperfect exchange rate pass-through makes the exchange rate channel less effective, more of the adjustment in response to shocks needs to be borne by the domestic interest rate channel which primarily affects domestic demand (see also Smets and Wouters, 2002, on this point).

### III.3 Uncovered interest parity

The literature provides three explanations for the observed UIP anomaly. The first and maybe most popular is that there is a time-varying risk premium that drives a wedge between the forward rate and the future spot rate. Assuming rational expectations risk averse international investors demand a higher rate of return (compared to the risk neutral UIP condition (III.4)) from the investment that they expect to be more risky. A second explanation questions the informational efficiency of the foreign exchange market. A deviation from the rational expectations hypothesis possibly explains the bias in the forward discount and the interest rate differential since regressions on the basis of (III.5) or (III.6) are fundamentally based on the null that the expectation of the exchange rate at time  $(t+k)$  formed in time  $t$  is an unbiased predictor of the realised exchange rate in time  $(t+k)$  (the so-called joint hypothesis). The third explanation takes into account policy behaviour. Central banks which use short term interest rates as their operating targets are assumed to set interest rates according to a rule in which the exchange rate figures as an important variable. Thus, the left-hand side and the right-hand side in (III.5) are jointly (simultaneously) determined which implies that the OLS estimation will be biased and inconsistent.

#### *III.3.1 A risk premium explanation for the UIP anomaly*

In the following, we will present a model which is able to show why risk averse investors demand a risk premium for holding risky assets. We will then derive the conditions under which the existence of a risk premium explains the UIP anomaly. Finally, we will check whether there is empirical support for these conditions and hence for the risk premium explanation of the UIP anomaly.

##### *III.3.1.1 The Lucas model to derive risk premia in the foreign exchange market*

The determinants of a risk premium can be derived on the basis of an intertemporal asset pricing model which was developed by Lucas (1982).<sup>26</sup> We will not present the model in full detail; rather, we will concentrate on the most important elements in order to understand under which conditions international investors might wish to be compensated by a risk premium. The model is based on the following structure:

- there are two countries (home and foreign) in each of which a consumption good is produced exogenously;
- there are two agents (one in each country) with equal preferences over the two consumption goods, implying that each agent consumes half of the domestic and half of the foreign production;
- every period, each country's agent is endowed with money to be able to buy its consumption goods (cash-in advance-constraint);
- agents solve the problem of deciding how much of today's income to consume and how much to save until tomorrow by optimising their consumption plans on the basis of their expected infinity lifetime utility function;
- the savings decision of the agents which are assumed to be risk averse is made on a complete international securities markets so that there is a complete pooling of risk (thus, in equilibrium all agents hold the same portfolio).

Specifically, the agents are assumed to maximise

$$(III.13) \quad E_0 \sum_{t=0}^{\infty} \delta^t U(C_t)$$

where  $U$  is an additively time-separable utility function (which is frequently assumed to be of the constant relative risk aversion form),  $C_t$  is an agent's consumption basket consisting of one-half of the foreign production and one half of the domestic production and  $\delta$  is the common discount factor. In a closed economy case the first-order condition for the maximisation of (III.13) subject to the agent's intertemporal budget constraint

$$(III.14) \quad W_{t+1} = R_t (W_t - C_t)$$

gives the so-called Euler equation

$$(III.15) \quad U'(C_t) = \delta E_t [U'(C_{t+1})] R_t$$

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<sup>26</sup> For more recent presentations of the model see Hodrick (1987), Lewis (1995b), Engel (1996), Obstfeld and

where  $R_t$  is the gross rate of return on assets between period  $t$  and  $(t+1)$  and  $W_t$  is the agent's real wealth. The Euler equation simply states that at a utility maximum the consumer cannot gain from feasible shifts of consumption between periods. A basic assumption is that in intertemporal consumption models (similar to the most basic two-period Robinson Crusoe models) agents value returns in real terms.<sup>27</sup> Using nominal bonds with a riskless nominal payout  $(1+i_t)$  the first-order Euler condition could be reformulated as

$$(III.16) \quad \frac{1}{P_t} U'(C_t) = \delta E_t \left[ U'(C_{t+1}) \frac{1}{P_{t+1}} \right] (1+i_t)$$

or, after rearranging

$$(III.17) \quad 1 = \delta E_t \left[ \frac{U'(C_{t+1})(1+i_t)}{U'(C_t)} \frac{P_t}{P_{t+1}} \right]$$

which introduces the future price level as an additional risk factor.

In an open economy with international securities markets the agent has the alternative to invest his savings abroad. Either he takes an uncovered position in the foreign bond which translates (III.17) into

$$(III.18) \quad 1 = \delta E_t \left[ \frac{U'(C_{t+1})(1+i_t^f)}{U'(C_t)} \frac{S_{t+1}}{S_t} \frac{P_t}{P_{t+1}} \right]$$

after replacing  $(1+i_t)$  with  $E_t S_{t+1}/S_t (1+i_t^f)$ , or he covers the exchange rate risk so that we get

$$(III.19) \quad 1 = \delta E_t \left[ \frac{U'(C_{t+1})(1+i_t^f)}{U'(C_t)} \frac{F_{t,1}}{S_t} \frac{P_t}{P_{t+1}} \right].$$

By taking the difference between (III.18) and (III.19) and by dividing the resulting expression by  $\delta$  and  $(1+i_t^f)$ , we obtain

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Rogoff (1996) and Sarno and Taylor (2002).

<sup>27</sup> This is because in such models we can think of the payoff as units of goods which is a real measure by definition.

$$(III.20) \quad E_t \left( A_{t,t+1} \frac{S_{t+1} - F_{t,1}}{S_t} \right) = 0$$

where  $A_t$  denotes the real intertemporal marginal rate of substitution of consumption:

$$(III.21) \quad A_{t,t+1} = \delta \frac{U'(C_{t+1})/P_{t+1}}{U'(C_t)/P_t}.$$

If we assume that variables are jointly log-normally distributed, equation (III.20) can be written in logarithmic form as

$$(III.22) \quad f_{t,1} - E_t s_{t+1} = 0.5 \text{Var}[s_{t+1}] - \text{Cov}[s_{t+1}, p_{t+1}] + \text{Cov}[s_{t+1}, a_{t,t+1}] \approx \text{Cov}[s_{t+1}, a_{t,t+1}]$$

which defines the risk premium (that we denote  $u_{t,t+1}^s$  henceforth) as the gap between the forward rate and the rationally expected future spot rate (see Sarno and Taylor, 2002, for this transformation). The lower case letters are the logs of the levels. The fact that we ignore the so-called ‘Jensen’s inequality terms’  $0.5 \text{Var}[s_{t+1}] - \text{Cov}[s_{t+1}, p_{t+1}]$  is due to the weight of the available evidence suggesting that they are empirically unimportant.<sup>28</sup> For a better illustration we specify the utility function as follows

$$(III.23) \quad U(C_t) = \frac{1}{1-\varphi} C_t^{1-\varphi}$$

where  $\varphi$  is the coefficient of relative risk aversion. It can be shown that with this utility function (III.22) can be transformed into

$$(III.24) \quad u_{t,t+1}^s = f_{t,1} - E_t s_{t+1} = -\varphi \text{Cov}[s_{t+1}, c_{t+1}]$$

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<sup>28</sup> See Engel (1996) for a detailed treatment of the (un)importance of these terms. Jensen’s inequality is at the heart of the so-called Siegel’s paradox according to which the expectations of a variable (e.g.  $E_t S_{t+1}$ ) and its inverse

where Jensen's inequality terms have been ignored again (see again Sarno and Taylor, 2002, for this transformation).<sup>29</sup>

According to (III.22), the domestic currency is risky (and hence the risk premium positive) when  $\text{Cov}[s_{t+1}, a_{t,t+1}]$  is positive. This is because the value of the domestic currency tends to be low ( $s_t$  is high) at the same time that consumption is low (see (III.24)). Or, expressed in terms of the foreign currency, a foreign investment tends to pay off in just those scenarios when marginal utility is high (and thus consumption is low). While the domestic currency thus serves as a poor hedge against bad states of nature, the foreign currency decreases the overall riskiness of the investor's portfolio since it reduces the non-diversifiable covariance risk of the entire portfolio.<sup>30</sup> From this follows that domestic and foreign assets are imperfect substitutes as long as the risk premium term (III.24) is different from zero.

From equation (III.24) it can also be seen that if investors were completely risk neutral then  $\varphi = 0$  and the risk premium would be equal to zero. Thus, for the risk premium to explain a significant portion of the forward rate forecast error either there must be a very large coefficient of relative risk aversion, or consumption must be highly (positively or negatively) correlated with the exchange rate.

( $E_t[1/S_{t+1}]$ ) are not equivalent when the variable is in level. The reason for this is that  $1/x$  is a convex function (see also Obstfeld and Rogoff, 1996, pp. 586).

<sup>29</sup> Note that the real intertemporal marginal rate of substitution of consumption  $A_{t,t+1}$  of (III.23) is  $(C_t/C_{t+1})^\varphi$ . Investors are indifferent if the left-hand side of (III.20) is equal to zero. Since  $C_t$  is known at time  $t$  (when expectations are formed) and since  $C_t$  is non-zero, (III.20) can equally be expressed as  $E_t[(1/C_{t+1})^\varphi(S_{t+1}-F_{t,1})/S_t]=0$ .

<sup>30</sup> The positively signed risk premium in this example (and hence the relatively risky domestic assets) was intentionally chosen. It is often argued that risk averse investors should be rewarded with a risk premium for holding risky *foreign* assets and that the *domestic* asset serves as the riskless investment. Thus, according to this line of argumentation positive risk premia (i.e. risk premia on domestic assets) would never occur and a risk premium adjusted UIP condition does not represent an equilibrium on the international financial markets any more (if Germans require a risk premium for Hungarian assets, the Germans' expected return on Hungarian assets would have to exceed the return on domestic riskless assets; by the same logic, the Hungarians would also require a risk premium for German assets). The crux of the intertemporal asset pricing model just presented is that the *real* return from assets enter the private agents' value function (and the real return counts because agents evaluate real consumption over time). Thus, riskless domestic nominal assets become risky in real terms, since the future price level is uncertain. In contrast to this foreign exchange risk only represents an additional risk when PPP is expected not to hold; otherwise it would be perfectly diversifiable (Frankel, 1979). In the words of Engel (Engel, 1996, p. 148): "In modern models of return on financial assets, a risk premium is awarded only when the return on an asset covaries with some benchmark (such as the return on the market portfolio, or the aggregate marginal rate of substitution in consumption) that makes risk undiversifiable. The foreign exchange risk premium depends on the relative riskiness of domestic and foreign nominal assets."

### III.3.1.2 Explaining the UIP anomaly with the existence of time-varying risk premia

Fama (1984) was influential in shaping one of the most popular explanations for the apparent failure of UIP by providing a decomposition of the regression coefficient  $\beta_1$  into its statistical components.<sup>31</sup> If UIP holds under risk neutrality and with rational expectations, the probability limits (i.e. for an infinitely large sample size) of the OLS coefficient estimate of  $\beta_1$  is given by

$$(III.25) \quad \beta_1 = \frac{\text{Cov}[f_{t,k} - s_t, s_{t+k} - s_t]}{\text{Var}[f_{t,k} - s_t]}.$$

If the forward premium  $f_{t,k}$  were an unbiased predictor of the future exchange rate  $s_{t+k}$  then  $\beta_1$  should be equal to one. A central assumption for (III.25) to be valid is that expectations are formed rationally (joint hypothesis, see also equation (III.7))

$$(III.26) \quad s_{t+k} - s_t = E_t s_{t+k} - s_t + \eta_{t,t+k}$$

with the forecast error  $\eta_{t,t+k}$  being orthogonal to the information set available at the time at which expectations are formed (i.e. uncorrelated with time  $t$  variables).<sup>32</sup> In that case

$$(III.27) \quad \begin{aligned} \text{Cov}[f_{t,k} - s_t, s_{t+k} - s_t] &= \text{Cov}[f_{t,k} - s_t, E_t s_{t+k} - s_t + \eta_{t,t+k}] = \\ &= \text{Cov}[f_{t,k} - s_t, E_t s_{t+k} - s_t] + \text{Cov}[f_{t,k} - s_t, \eta_{t,t+k}] = \\ &= \text{Cov}[f_{t,k} - s_t, E_t s_{t+k} - s_t]. \end{aligned}$$

and  $\beta_1$  can equally expressed as

$$(III.28) \quad \beta_1 = \frac{\text{Cov}[f_{t,k} - s_t, E_t s_{t+k} - s_t]}{\text{Var}[f_{t,k} - s_t]}.$$

If investors are risk averse the UIP condition is adjusted by a risk premium

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<sup>31</sup> See Engel (1996) for a recent paper focusing on the risk premium explanation

$$(III.29) \quad E_t s_{t+k} - s_t + u_{t,t+k}^s = i_{t,k} - i_{t,k}^f$$

or

$$(III.30) \quad E_t s_{t+k} - s_t + u_{t,t+k}^s = f_{t,k} - s_t.$$

The numerator in (III.28) can be substituted for

$$(III.31) \quad \begin{aligned} \text{Cov}[f_{t,k} - s_t, E_t s_{t+k} - s_t] &= \text{Cov}[E_t s_{t+k} - s_t + u_{t,t+k}^s, E_t s_{t+k} - s_t] = \\ &= \text{Cov}[E_t s_{t+k} - s_t, E_t s_{t+k} - s_t] + \text{Cov}[E_t s_{t+k} - s_t, u_{t,t+k}^s] = \\ &= \text{Var}[E_t s_{t+k} - s_t] + \text{Cov}[E_t s_{t+k} - s_t, u_{t,t+k}^s]. \end{aligned}$$

so that the asymptotic OLS estimate for  $\beta_1$  is given by

$$(III.32) \quad \beta_1 = \frac{\text{Var}[E_t s_{t+k} - s_t] + \text{Cov}[E_t s_{t+k} - s_t, u_{t,t+k}^s]}{\text{Var}[f_{t,k} - s_t]}.$$

From (III.32) directly follows that a necessary (though not sufficient) condition for  $\beta_1$  to be negative is a negative correlation between the risk premium and the expected rate of change in the spot rate (since variances are non-negative by definition). Allowing for a weaker assumption that  $\beta_1$  should be less than 1/2 (which is of course also true if it is negative) gives another important condition for obtaining the UIP anomaly. Rewriting first the denominator in (III.32) as

$$(III.33) \quad \begin{aligned} \text{Var}[f_{t,k} - s_t] &= \text{Var}[E_t s_{t+k} - s_t + u_{t,t+k}^s] = \\ &= \text{Var}[u_{t,t+k}^s] + 2\text{Cov}[E_t s_{t+k} - s_t, u_{t,t+k}^s] + \text{Var}[E_t s_{t+k} - s_t] \end{aligned}$$

and solving the resulting inequality

$$(III.34) \quad \frac{\text{Var}[E_t s_{t+k} - s_t] + \text{Cov}[E_t s_{t+k} - s_t, u_{t,t+k}^s]}{\text{Var}[u_{t,t+k}^s] + 2\text{Cov}[E_t s_{t+k} - s_t, u_{t,t+k}^s] + \text{Var}[E_t s_{t+k} - s_t]} < \frac{1}{2}$$

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<sup>32</sup> If this were not the case, forecasters would be ignoring information that should be useful in predicting.

for  $\text{Var}[u_{t,t+k}^s]$  gives

$$(III.35) \quad \text{Var}[u_{t,t+k}^s] > \text{Var}[E_t s_{t+k} - s_t].$$

In other words, for  $\beta_1$  to be small or even negative the rational expectations risk premium must have a greater variance than the expected exchange rate change.

Note that the sole existence of a risk premium is not a sufficient condition to explain the UIP anomaly. If the risk premium is constant over time,  $\beta_1$  should be unity which can be easily shown with the help of the left-hand side of (III.34). Constancy of  $u_{t,t+k}^s$  requires both the covariance terms and  $\text{Var}[u_{t,t+k}^s]$  to be zero, and accordingly  $\beta_1$  is the quotient of two identical terms. Instead of providing an explanation for the UIP anomaly a constant risk premium rather explains why  $\beta_0$  in regression equation (III.5) might be different from zero.

### III.3.1.3 Empirical evidence on time-varying risk premia in the foreign exchange market

In order to explain the UIP puzzle with the existence of risk premia there are at least three empirical issues that have to be addressed:

1. Is there in fact a non-zero risk premium?
2. If so, is it variable?
3. If variable, is it sufficiently volatile to explain the negative  $\beta_1$ ?

Concerning the first question a natural starting point for an empirical examination are the first-order conditions of the Lucas model (as expressed by equations (III.20), (III.22) or (III.24)). The problem that most researchers are confronted with is the finding that consumption is relatively smooth in advanced economies. In contrast to this the nominal exchange rate is a lot more volatile so that  $\text{Cov}[s_{t+1}, c_{t+1}]$  turns out to be quite small. Thus, for the risk premium to attain a value that fills the gap between  $f_t$  and  $E_t s_{t+1}$  the coefficient of relative risk aversion  $\varphi$  must be much higher than generally viewed to be plausible. The findings of Mark (1985) are typical of the results that appear in the subsequent literature. Depending on the definition of consumption he estimates the parameter of risk aversion to be 17.5 (excluding services) or 43.5 (including

services), both of which exceeds by far the ‘reasonable’ values of 2 (4), as contended by Krugman (1981) (Romer (2001)) (see Engel, 1996, and Lewis, 1995b for extensive summaries of the empirical literature).<sup>33</sup>

Given the result that for reasonable values of  $\phi$  the ingredients in the risk premium models do result in significant levels of the risk premium it was even harder to find any variable that fluctuates sufficiently to explain the required volatility of the risk premium given by equation (III.35). Lewis (1995b) for example calculates values of  $\text{Var}[E_t s_{t+k} - s_t]$  (where  $k$  is one month) in the range of 60 (!). Thus, “a fair assessment of such empirical evidence would be to say that it is not supportive of the existence of a time varying risk premium (although there is some evidence suggestive of a constant risk premium)” (Hallwood and MacDonald, 2000, p. 275).

Summing up, while the risk premium explanation of the UIP anomaly is appealing – mainly due to its foundation in modern finance theory – it is not able to account for the striking extent of the anomalous behaviour of excess returns. Lewis (1995b, p. 1949) concludes: “Researchers who believe that forecast errors must be uncorrelated with everything in the lagged information set are forced to accept the view that these predictable excess returns are the result of an equilibrium risk premium model. However, no risk premium model with believable measures of risk aversion has yet been able to generate the variability in predictable excess returns that are observed in the data.”

### ***III.3.2 A failure of the foreign exchange market efficiency hypothesis***

The poor empirical support for the risk premium explanation of the UIP anomaly opened up a new strand of literature arguing that the UIP anomaly is due to informational inefficiencies. We start this alternative explanation by giving an overview of the reasons why the famous Friedman (1953) argument according to which speculation should produce stabilising effects if the exchange rate is allowed to float freely might be wrong. We then present two models that explicitly consider agents forming their expectations heterogeneously. In Section III.3.2.2, we finally take a look at the empirical evidence on the existence of non-rational expectations in the foreign exchange market.

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<sup>33</sup> Engel (1996, p. 151) gives the following interpretation for a risk aversion parameter of 2: “This implies that one is indifferent between a four percent reduction in consumption and accepting a gamble that reduces consumption by 20 percent or increases consumption by 20 percent with equal probability.”

### *III.3.2.1 Limits to arbitrage as an explanation for noise, chartism and heterogeneity in beliefs*

The efficient markets hypothesis is mainly challenged by limits of stabilising speculation (or arbitrage) – which constitutes the basic force behind UIP. These limits result from institutionally imposed restrictions that lead to a behaviour of market participants differing from what they would prefer under more perfect circumstances. A first limitation stems from short (i.e. finite) time horizons of investors (Shleifer and Summers, 1990). From interviews with practitioners we know that their investment decisions are typically made at very short time horizons (Menkhoff, 1998). A majority of foreign exchange trading is done intra-day, i.e. dealers buy or sell foreign exchange which they sell or resell before the end of the day. In order to explain why stabilising speculation is limited under such circumstances we have to introduce a fraction of market participants that are subject to systematic biases, the so-called noise traders. Their behaviour is based on noisy information which is generally unrelated to economic fundamentals. Accordingly, they form their expectations on the basis of pseudo signals from some financial opinion leaders, chartist techniques or other simple heuristics, all of which is incompatible with the rational behaviour hypothesis and which drives exchange rates away from fundamental values. The basic rationale for using such rules of thumb is the psychological evidence that economic agents often have a tendency to view events as typical or representative of some specific class and to ignore the laws of probability in the process (Kahneman and Tversky, 1973). As the movements of the noise trader sentiment are in part unpredictable, arbitrageurs<sup>34</sup> betting against such misalignment run the risk, in particular in the short run, that the noise trader sentiment becomes more extreme and the exchange rate moves even further away from the fundamental value. If the arbitrageurs had an infinite time horizon, they would simply wait until the bubble bursts and the exchange rate will move back to its fundamental value. The consequence of such noise trader risk, however, is that arbitrage positions can lose money in the short run.

This is where the second source of limited arbitrage emerges. Institutional investors typically manage other people's money. When they run the risk of losing funds under management when performance is poor, the risk of deepening misalignment reduces the size of positions they take.

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<sup>34</sup> In the noise trader literature, arbitrageurs with finite time horizon are in fact speculators since they hold uncovered positions. None the less, their speculative activity is stabilising as they form fully-rational expectations about future exchange rates.

The reason for this is quite simple. Those providing the fund manager with capital would infer from this loss that the manager is not as competent as they previously thought. They would withdraw their funds and refuse to provide him with more capital. Thus, the misalignment will persist even longer due to the reduced stabilising speculative activity (Shleifer and Vishny, 1997).

#### III.3.2.1.1 A noise trader model to explain the UIP anomaly

A first approach to develop a theoretical foundation of the UIP anomaly due to the existence of noise traders was made by Mark and Wu (1998). Their model is an overlapping generations model with two countries and two-period lived agents in the tradition of the noise trader model presented by De Long et al. (1990). The young generation does not consume but makes portfolio decisions in order to maximise expected utility of second period wealth which is entirely consumed when old. The international financial market is assumed to clear when the net sales of assets of the current young (domestic and foreign) equals the net purchases of assets of the current old (domestic and foreign).

A fraction  $\nu$  of the young investors are fundamentalists (or arbitrageurs) who have rational and stabilising expectations. The remaining fraction  $(1-\nu)$  consists of noise traders whose beliefs concerning future investment returns are distorted. Their investment strategies are highly correlated so that the noise trader's transactions as a whole drives the exchange rate into a single direction, possibly away from its fundamental value. Mark and Wu (1998, p. 1699) characterise their behaviour as follows: "Noise traders will appear to overreact to news and to display excess pound [the domestic currency, T.W.] pessimism (...) for they believe the pound will be weaker in the future than is justified by the fundamentals." Specifically they draw on results from a survey data based study of Froot and Frankel (1989) according to which investors place excessive weight on the forward premium when predicting future changes in the exchange rate (see below in Section III.3.2.2 where we present the results of the relevant literature).

In equilibrium, if the economy was purely fundamentalist (i.e.  $\nu = 1$ ), the investors would pursue an investment strategy that results in an unbiased UIP relation. As soon as noise traders enter the economy (i.e.  $\nu < 1$ ) currency tends to move away from the fundamental (UIP) value in one or the other direction, thereby imposing an additional risk upon the fundamentalists. "Fundamentalists and noise traders both believe, ex ante, that they will earn positive profits from

their portfolio investment. It is the differences in their beliefs that lead them to take opposite sides of the transaction. When noise traders are excessively pessimistic and take short positions in the pound, fundamentalists take the offsetting long position” (Mark and Wu, 1998, p. 1700). As a result they show that in equilibrium UIP can be modified to

$$(III.36) \quad \upsilon E_t \Delta s_{t+1} + (1 - \upsilon) \epsilon_t \Delta s_{t+1} = i_t - i_t^f$$

where  $E_t$  is the rational expectations operator and  $\epsilon_t$  denote the biased expectations of the noise traders.

The key implication of the noise trader model is that the risk incorporated in the exchange rate is generated by the behaviour of noise traders and is not captured in models with “traditional” risk premia. According to the conventional wisdom among economists coined by Friedman (1953), destabilising speculators (such as noise traders who buy high and sell low) will on average lose money and be driven out of the market in the long run. In noise trader models, however, noise traders survive in the long run because they are rewarded with a higher return for the risk they create themselves: “Noise traders’ collective shifts of opinion increase the riskiness of returns to assets. If noise traders’ portfolios are concentrated in assets subject to noise trader risk, noise traders can earn a higher average rate of return on their portfolios than sophisticated investors [fundamentalists, T.W.]” (De Long et al., 1990, p. 713). It is important to note again that for prices to deviate from fundamental values because of the noise trader risk, noise trading must be accompanied by shorter horizons or similar blockages on the part of the fundamentalists.

#### III.3.2.1.2 A chartist-fundamentalist approach to model the exchange rate

Principally, the source of noise used by the noise traders could literally be taken to be anything that they believe to be useful in predicting exchange rate behaviour. One of the most popular interpretations however is to view the use of chartist techniques as a prime example for noisy behaviour. This specific form of the noise trader approach to describing exchange rate behaviour was first modelled by Frankel and Froot (1990) in continuous time and then extended by De Grauwe and Dewachter (1993), Frenkel (1997) and De Grauwe and Grimaldi (2002) in discrete time.

Before presenting the behavioural relationships of the model we have to make a few assumptions about the fundamental process determining the exchange rate. Instead of using a monetary model for the determination of the fundamental exchange rate path (as in the papers of De Grauwe and Dewachter (1993), Frenkel (1997) and De Grauwe and Grimaldi (2002)) we assume that the exchange rate is determined according to UIP. In the absence of any disturbances the rational expectations solution of equation (III.4) yields an expression for the fundamental spot rate

$$(III.37) \quad s_t^{\text{fund}} = E_t \sum_{j=0}^{\infty} (i_{t+j}^f - i_{t+j}).$$

In this Section, however, our basic interest lies not in the precise model determining the path of the fundamental exchange rate. We are rather interested in the forces driving away the current exchange rate from its fundamental value. Thus, in order to keep the model simple, the fundamental exchange rate is assumed to be given exogenously. In Chapter IV below we will specify the process determining the path of the expected interest rate differential on the basis of a complete macro model.

As in the previous Section the model assumes that two types of international investors with heterogeneous behaviour influence the exchange rate: fundamentalists and chartists. These two actors behave differently when forming their expectations about the future development of the exchange rate because they have different information sets. The fundamentalists have macroeconomic fundamentals in their information sets which they map according to some model (as e.g. given by (III.37)) onto the fundamental exchange rate. One way to capture this behaviour is to base the fundamentalists' forecasts on regressive expectations, i.e. they compare the current market exchange rates with the fundamental rate and they forecast the future exchange rate to move towards the fundamental rate. Regressive expectations of the fundamentalists can be formulated as

$$(III.38) \quad E_t \Delta s_{t+1} = \theta^f (s_t^{\text{fund}} - s_t)$$

where the parameter  $\theta^f$  (which is assumed to be positive) denotes the speed of regression of  $s_t$  to its fundamental value. This formulation of expectations comes closest to the fundamentalists'

view, because the long-run equilibrium to which investors expect the exchange rate to return,  $s_t^{\text{fund}}$ , is determined by fundamental factors in the real economy.

In contrast to the forward-looking fundamentalists, the chartists typically use standardised techniques of the so-called technical analysis which are entirely based on past movements of the exchange rate. Thus, their information set contains only the past history of the exchange rate itself which they use to detect patterns that can be extrapolated into the future. Being restricted to the use of technical analysis is not a shortcoming for the chartists because a primary assumption behind technical analysis is that all relevant information about the future development of the exchange rate is contained in the past history of the exchange rate. Thus, technical analysis directly contradicts the efficient markets hypothesis. One such popular decision rule is the so-called moving average (MA) rule which can be formalised as

$$(III.39) \quad \epsilon_t \Delta s_{t+1} = \theta^c \left( s_t - \frac{1}{n+1} \sum_{i=0}^n s_{t-i} \right),$$

where  $\theta^c$  is the factor with which the noise traders extrapolate the past into the future. Chartists buy foreign currency if the current spot rate exceeds the  $n$ -day moving average of past exchange rate realisations.<sup>35</sup> As a consequence,  $s_t$  will rise further which ends up in destabilising ‘bandwagon’ process.

The resulting aggregate market expectation  $E_t^m$  for the future exchange rate is a weighted average of chartist and fundamentalist behaviour

$$(III.40) \quad E_t^m \Delta s_{t+1} = \nu E_t \Delta s_{t+1} + (1-\nu) \epsilon_t \Delta s_{t+1}$$

which can be solved for  $s_{t+1}$  after inserting (III.38) and (III.39). In accordance with De Grauwe and Grimaldi (2002) we added a white noise error term to the exchange rate equation implying

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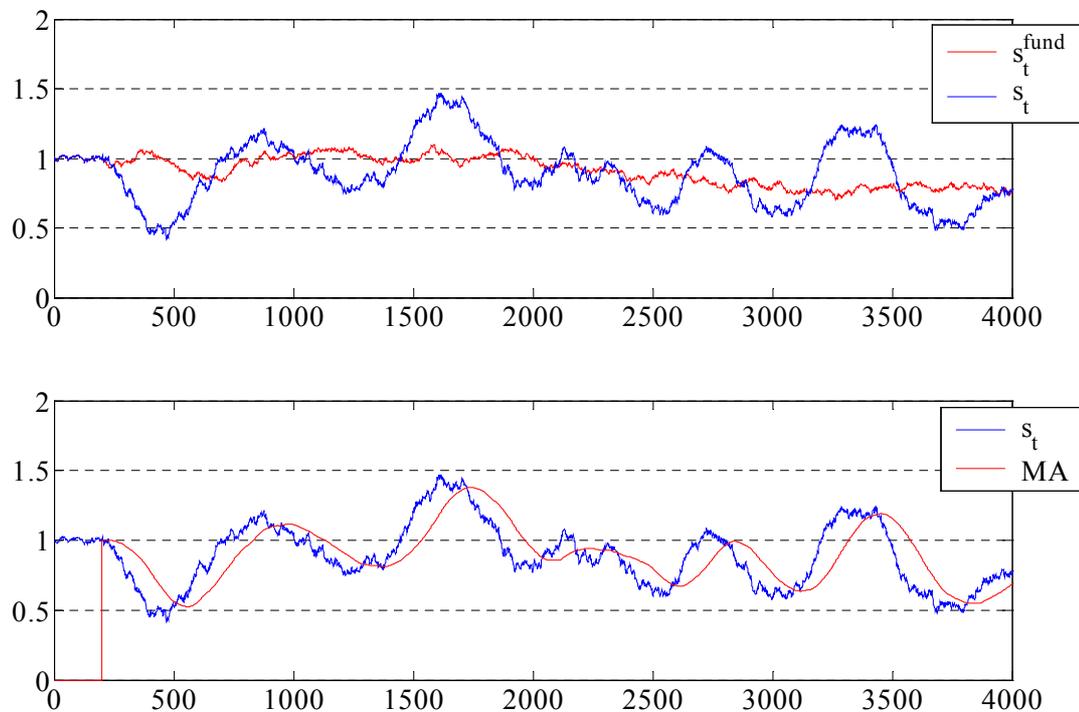
<sup>35</sup> Note that the trading rule presented here should be understood as only one example out of a huge battery of trading rules that range from simple to quite elaborate. The moving average has the advantage of simplicity, and for this reason it is often used for research purposes. The basic idea, however, is the same with all trading rules (see Luca, 2000 for a comprehensive overview of trading techniques that are used in the foreign exchange market).

that the realised market rate in  $t+1$  equals the aggregate market forecast plus some news that could not be predicted at time  $t$ :

$$(III.41) \quad s_{t+1} = s_t + \nu\theta^f (s_t^{\text{fund}} - s_t) + (1-\nu)\theta^c \left( s_t - \frac{1}{n+1} \sum_{i=0}^n s_{t-i} \right) + \varepsilon_{t+1}.$$

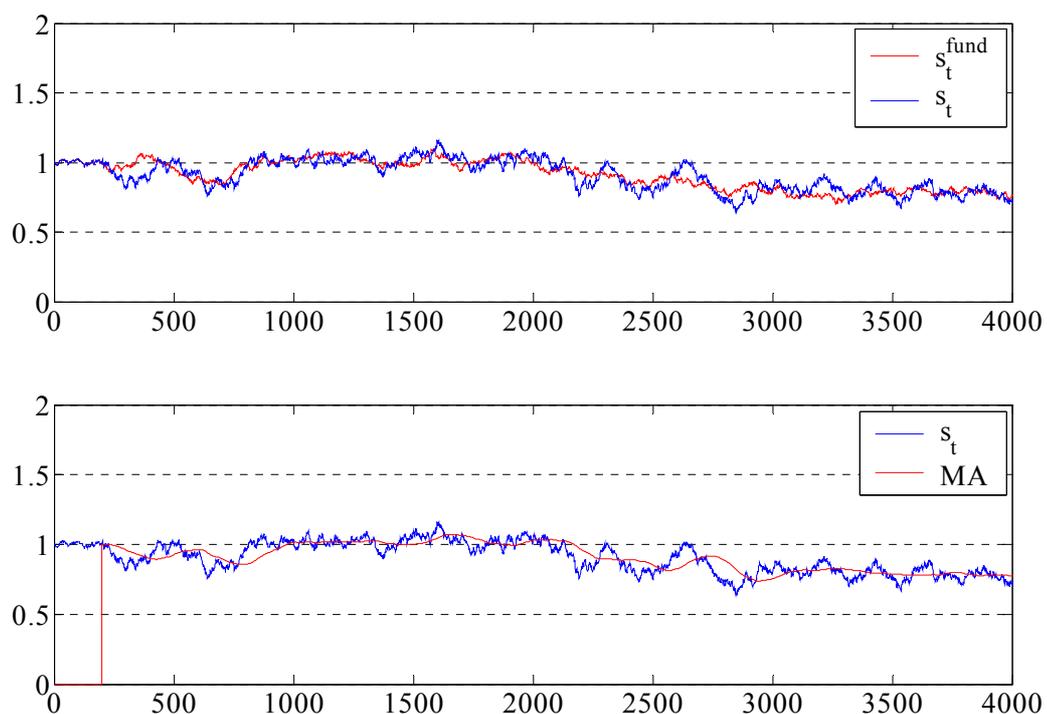
In the following we will present the dynamics of the model by means of simulation. For this purpose we set the variance of  $\varepsilon_t$  to 0.01. The fundamental exchange rate is assumed to follow a random walk with a variance of the shock term of 0.005. Following De Grauwe and Grimaldi (2002) we set the weight  $\nu$  to 0.5 implying that half of the investors are chartists and half are fundamentalists. With regard to the parameterisation of the decision rules of the investors the degree of extrapolation  $\theta^c$  was held constant at 0.02, while the fundamentalists' speed of regression  $\theta^f$  was set to 0.01 in Figure III.2 and to 0.05 in Figure III.3.

**Figure III.2: Chartist-fundamentalist interaction with a low speed of adjustment on the part of the fundamentalists**



The most obvious result that can be obtained from the two Figures is that with a higher speed of adjustment on the part of the fundamentalists (i.e. the higher  $\theta^f$ ) the spot exchange rate comes closer to its fundamental value. If in contrast to this  $\theta^f$  decreases, the deviations from the fundamental UIP path become more persistent. However it should be clear that besides the level of  $\theta^f$  the basic force pushing back the exchange rate to its fundamental value is the degree of misalignment. While chartists move away the exchange rate from  $s_t^{\text{fund}}$ , the implicit fundamentalist's weight increases and with it, the reverting pressure on the exchange rate. This interaction which is nicely illustrated in Figure III.2 finally ends up in pronounced swings of the exchange rate around its fundamental value over time.

**Figure III.3: Chartist-fundamentalist interaction with a high speed of adjustment on the part of the fundamentalists**



### III.3.2.2 Empirical evidence on non-rational expectations in the foreign exchange market

#### III.3.2.2.1 Evidence on biased expectations from survey data

In the tradition of the risk premium explanation by Fama (1984), Froot and Frankel (1989) provided a decomposition of  $\beta_1$  that extracts a measure for the failure of the rational expectations

hypothesis. Instead of imposing the condition that the expectational error  $\eta_{t,t+k}$  is orthogonal to the information set at time  $t$  (as in Section III.3.1.2 where we set  $\text{Cov}[f_{t,k} - s_t, \eta_{t,t+k}]$  to zero; see equation (III.27)), we allow for the possibility of systematic expectational errors. Equation (III.25) can then be transformed into

$$(III.42) \quad \beta_1 = \frac{\text{Cov}[f_{t,k} - s_t, E_t s_{t+k} - s_t] + \text{Cov}[f_{t,k} - s_t, \eta_{t,t+k}]}{\text{Var}[f_{t,k} - s_t]}$$

where the second covariance term in the numerator takes into account non-rational behaviour. In order to explain the typical finding that  $\beta_1 < 1$  the forecast error has to be negatively correlated with the forward premium, i.e. with a variable already observable to the investor which is clearly inconsistent with the efficient markets hypothesis.

The standard approach for estimating  $\beta_1$  is to impose rational expectations and to infer from ex post data what investors must have expected. Testing for the unbiasedness of UIP then involves a joint hypothesis. If one questions, however, the rationality of the market, an alternative approach is required. Instead of using ex post realisations of the exchange rate, Froot and Frankel (1989) based their estimations on survey data as an independent source of information on investors' expectations. To ensure that the bias cannot be explained by the existence of a risk premium they proposed a decomposition of  $\beta_1$  into a component due to the risk premium  $\beta_1^u$  and a component due to the forecast error  $\beta_1^e$

$$(III.43) \quad \begin{aligned} \beta_1 &= \frac{\text{Var}[E_t s_{t+k} - s_t] + \text{Cov}[E_t s_{t+k} - s_t, u_{t,t+k}^s] + \text{Cov}[f_{t,k} - s_t, \eta_{t,t+k}]}{\text{Var}[f_{t,k} - s_t]} = \\ &= \frac{\text{Var}[f_{t,k} - s_t] - \text{Var}[u_t^s] + \text{Cov}[E_t s_{t+k} - s_t, u_{t,t+k}^s] + \text{Cov}[f_{t,k} - s_t, \eta_{t,t+k}]}{\text{Var}[f_{t,k} - s_t]} = \\ &= \frac{\text{Var}[f_{t,k} - s_t]}{\text{Var}[f_{t,k} - s_t]} - \frac{\text{Var}[u_t^s]}{\text{Var}[f_{t,k} - s_t]} - \frac{-\text{Cov}[f_{t,k} - s_t, \eta_{t,t+k}]}{\text{Var}[f_{t,k} - s_t]} = \\ &= 1 - \beta_1^u - \beta_1^e \end{aligned}$$

which can be obtained after replacing  $\text{Cov}[f_{t,k} - s_t, E_t s_{t+k} - s_t]$  with equation (III.31). They then ran the following three regressions in order to determine the three  $\beta_1$ s

$$(III.44) \quad \Delta s_{t+k} = \beta_0 + \beta_1 (f_{t,k} - s_t) + \varepsilon_{t,t+k}$$

$$(III.45) \quad \Delta s_{t+k}^e - \Delta s_{t+k} = \beta_0^e + \beta_1^e (f_{t,k} - s_t) + \varepsilon_{t,t+k}^e$$

$$(III.46) \quad \Delta s_{t+k}^e = \beta_0^u + (1 - \beta_1^u) (f_{t,k} - s_t) + \varepsilon_{t,t+k}^u$$

where  $\Delta s_{t+k}^e = s_{t+k}^e - s_t$ , and  $s_{t+k}^e$  is the expected spot rate at time  $t+k$ , based on the survey measures taken at time  $t$ . The hypotheses to test are that survey respondents are rational ( $\beta_1^e = 0$ ) and that there is no time-varying risk premium ( $\beta_1^u = 0$ ).

**Table III.2: Empirical estimates from studies of survey forecasts**

survey conducted by	k (in months)	dates	$\beta_1$	$\beta_1^u$	$\beta_1^e$
Economist <sup>a)</sup>	3	06/81 – 12/85	-1.21	-0.30	2.51
Economist <sup>a)</sup>	6	06/81 – 12/85	-1.98	-0.00	2.99
Economist <sup>a)</sup>	12	06/81 – 12/85	0.29	0.19	0.52
MMS <sup>a)</sup>	1	11/82 – 01/88	-1.74	-2.07	4.81
MMS <sup>a)</sup>	3	01/83 – 10/84	-6.25	1.18	6.07
AMEX <sup>a)</sup>	6	01/76 – 07/85	-2.42	-0.22	3.63
AMEX <sup>a)</sup>	12	01/76 – 07/84	-2.14	0.03	3.11
CFD <sup>b)</sup>	3	02/88 – 02/91	-2.88	0.58	3.30
CFD <sup>b)</sup>	12	02/88 – 02/91	-3.41	-0.06	4.47
BIC <sup>c)</sup>	3	01/86 – 12/90	-4.03	-0.93	5.97
BIC <sup>c)</sup>	6	01/86 – 12/90	-3.86	-0.22	5.35
BIC <sup>c)</sup>	12	01/86 – 12/90	-4.55	-0.05	5.60

Notes: The regression coefficients are taken from a) Froot and Frankel (1989), b) Frankel and Chinn (1993), c) Cavaglia et al. (1994). For a detailed description of the survey data see these papers.

Similar estimations (though with different sources for the survey data) were subsequently made by Frankel and Chinn (1993) and Cavaglia et al. (1994). While Froot and Frankel (1989) and Frankel and Chinn (1993) conducted their empirical tests by pooling across bilateral US dollar exchange rates, Cavaglia et al. (1994) only present estimates for individual bilateral exchange

rates. For better comparability we therefore summarise their results by taking the average of the 10 US dollar exchange rate estimates (see Table III.2 for the result of the three studies).

The following three results appear to be noteworthy:

1. All but one of the  $\beta_1$  estimates are negative. This simply confirms the typical UIP anomaly findings.
2. For the time-varying risk premium to explain this result, it must be true that  $\beta_1^u > 1$ . However, Table III.2 shows that all but one are less than one and most of them are close to zero which confirms our results of Section III.3.1 according to which the variance of the risk premium is too small to explain the anomaly.
3. The most important result concerns  $\beta_1^e$  which takes values much greater than one implying that the forecast errors appear to be significantly correlated with the lagged forward premium. This result clearly contradicts the standard interpretation of rational expectations.

#### III.3.2.2.2 Evidence on the use of chartism

A central finding of the literature on expectation formation in the foreign exchange market is that the relative importance of technical versus fundamental analysis depends on the forecasting horizon. According to questionnaires conducted among foreign exchange dealers, the use of chartist analysis is applied to an important part of process of expectations' formation, especially in the short run. Taylor and Allan (1992) for example found that approximately 90 per cent of the respondents reported using some chartist input (besides fundamentals) at a horizon up to one week, with 60 per cent judging charts to be at least as important as fundamentals. At longer forecast horizons, one year or longer, the weight given to fundamentals increases, with nearly 30 per cent of the respondents relying on pure fundamentals and 85 per cent judging fundamentals to be more important than charts. By conducting a similar questionnaire survey these results have recently been confirmed by Lui and Mole (1998).

A similar picture emerges from studies using exchange rate expectations from survey data. At short horizons (typically up to one month) respondents tend to forecast by extrapolating recent trends, while at long horizons (typically three months and more) they tend to forecast a return to some long-run normal value of the exchange rate (Frankel and Froot, 1990, Takagi, 1991). "This

suggests the possibility that the foreign exchange market in the short run reflects an element of ‘noise trading’, trading that is based on factors other than ‘fundamentals’”(Takagi, 1991, p. 182).

### III.3.3 A monetary policy behaviour explanation for the UIP anomaly

A third explanation of the puzzling regression evidence is that the estimates of  $\beta_1$  may be biased by the failure to estimate (III.5) simultaneously with a second relationship between the interest rate differential and the change in the exchange rate. This point has been overlooked in much of the discussion of the empirical evidence on UIP, in particular in the pioneering paper of Fama (1984). Early references to the endogeneity of the interest rate differential can be found in Boyer and Adams (1988) and Isard (1988), but the decisive contribution to this issue was made by McCallum (1994a). Tests of the UIP condition normally regress the ex-post exchange rate change on the interest rate differential whereby the latter is assumed to be given exogenously and in particular independent from the disturbance term. This assumption is in particular critical in the case of the fundamentalist chartist model in which the persistent deviations of the spot rate from the UIP implied fundamental path have an important impact on macro variables like inflation and output, hence inducing the central bank to react with the interest rate. If, however, the disturbance to UIP and the interest rate differential are correlated (and hence simultaneously determined) the OLS estimator of  $\beta_1$  will be biased and inconsistent.

We can clarify this point by formulating the probability limit of  $\beta_1$  in terms of the interest rate differential. Replacing the forward premium with the interest rate differential in equation (III.43) and substituting  $\text{Cov}[E_t s_{t+k} - s_t, u_{t,t+k}^s]$  for  $\text{Cov}[i_{t,k} - i_{t,k}^f, u_{t,t+k}^s] - \text{Var}[u_{t,t+k}^s]$  gives the following expression for  $\beta_1$ :

$$\begin{aligned}
 \beta_1 &= 1 - \frac{\text{Cov}[i_{t,k} - i_{t,k}^f, u_{t,t+k}^s]}{\text{Var}[i_{t,k} - i_{t,k}^f]} - \frac{\text{Cov}[i_{t,k} - i_{t,k}^f, \eta_{t,t+k}]}{\text{Var}[i_{t,k} - i_{t,k}^f]} = \\
 \text{(III.47)} \quad &= 1 - \text{Corr}[i_{t,k} - i_{t,k}^f, u_{t,t+k}^s] \sqrt{\frac{\text{Var}[u_{t,t+k}^s]}{\text{Var}[i_{t,k} - i_{t,k}^f]}} - \text{Corr}[i_{t,k} - i_{t,k}^f, \eta_{t,t+k}] \sqrt{\frac{\text{Var}[\eta_{t,t+k}]}{\text{Var}[i_{t,k} - i_{t,k}^f]}}.
 \end{aligned}$$

This underscores the point that the unbiasedness hypothesis will hold as long as the risk premium and the forecast error are uncorrelated with the interest rate differential – and this would be true

even if, under the assumption of perfectly rational expectations, the risk premium fulfilled the basic requirement derived in Section III.3.1.2 for  $\beta_1$  to be negative (namely that it has a high variance). Thus, equation (III.47) reveals the following points:

1. The estimator will be smaller than one only if there is a positive correlation of the domestic interest rate with the disturbances to UIP.
2. If only one of the disturbances to UIP is relevant, the variance of this disturbance must exceed that of the interest differential for  $\beta_1$  to be negative (since the correlation coefficient has a maximum value of one).
3. If both disturbances jointly occur (what seems to be very likely given the results in Section III.3.2.2.1), the second condition is not binding anymore since both covariance terms may add up to a value greater than one.

Correlation between  $u_{t,t+k}^s$  and/or  $\eta_{t,t+k}$  on the one hand, and  $i_{t,k} - i_{t,k}^f$  on the other hand might arise if monetary policies are implemented in a manner that leads the nominal interest rate differential to respond to the current exchange rate. Suppose, for example, that the central bank in each country tends to tighten monetary policy whenever its currency depreciates (i.e.  $f_s > 0$ ):

$$(III.48) \quad i_{t,k} - i_{t,k}^f = f_s s_t + \zeta_t$$

where  $\zeta_t$  captures other factors affecting the interest rate differential. Note that this example is simpler than that given by McCallum (1994a), for the fact that there is no inertia in interest rate movements (interest rate smoothing would reinforce point 2 of the above interpretation of equation (III.47)). For simplicity, we assume further that UIP is only subject to a single disturbance, say  $u_{t,t+k}^s$ . Substituting (III.48) into the risk-premium adjusted UIP condition yields

$$(III.49) \quad E_t s_{t+k} = (1 + f_s) s_t + \zeta_t + u_{t,t+k}^s.$$

Applying the method of undetermined coefficients in conjunction with the minimal state variable approach (McCallum, 1983) gives the rational expectations solution for the exchange rate:

$$(III.50) \quad s_t = -\frac{1}{1 + f_s} (\zeta_t + u_{t,t+k}^s).$$

Assuming that  $\zeta_t$  and  $u_{t,t+k}^s$  are uncorrelated white noise processes then implies that  $E_t s_{t+k} = 0$ , so that the UIP equation can be written as

$$(III.51) \quad i_{t,k} - i_{t,k}^f = \frac{1}{1+f_s} (\zeta_t + u_{t,t+k}^s).$$

At this point we can calculate the probability limit of  $\beta_1$ . Substituting (III.51) into (III.47) and simplifying the resulting expression yields

$$(III.52) \quad \beta_1 = 1 - (1+f_s) \frac{\text{Var}[u_{t,t+k}^s]}{\text{Var}[u_{t,t+k}^s] + \text{Var}[\zeta_t]}$$

which is generally smaller than one. In particular, if  $\zeta_t = 0$ ,  $\beta_1$  equals the negative policy parameter  $f_s$ . In other words, if the central bank exclusively reacts to contemporaneous movements in the exchange rate, the UIP anomaly can be explained by policy behaviour, irrespective of the variance of the risk premium.

If, however, the central bank additionally reacts to variables other than the exchange rate, the sign of  $\beta_1$  cannot be predicted anymore. From central bank practice we know that this policy assumption is much more realistic than that of a central bank adjusting interest rates solely in response to exchange rate movements. Maybe McCallum's policy response hypothesis for the explanation of the UIP puzzle should not be taken too literally. It should be clear that even though central banks rarely follow such policy rules, there is always an implicit response to exchange rate movements when a central bank follows, for example, a standard Taylor-type rule according to which it responds to inflation and output movements. But it should also be clear that without (risk premium or expectational) disturbances to UIP that provoke changes in the spot rate, a deviation of  $\beta_1$  from unity would not occur. To sum up, this explanation of the UIP puzzle which McCallum himself regards as a parable can be evaluated as follows: "The basic idea of the parable is that the estimated slope coefficient is a composite parameter reflecting policy behaviour as well as the behaviour of market participants" (McCallum, 1994b, p. 15).

### ***III.3.4 Implications of the UIP puzzle for the conduct of monetary policy***

In the introduction of a recently published textbook on exchange rate economics Sarno and Taylor (2002, p. 2) summarise the state of our knowledge about the behaviour of private agents in the foreign exchange market as follows: “Regardless of – or indeed perhaps because of – the increasing sophistication of the econometric techniques employed and of the increasing quality of the data sets utilised, one conclusion emerges from this literature relatively uncontroversially: the foreign exchange market is not efficient in the sense that both risk neutrality and rational expectations appear to be rejected by the data.”

Given this result, it is astonishing that today there are still some economists who are engaged in macroeconomic modelling of open economies and who totally reject the possibility that there is any disturbance to UIP, implying that the link between interest rates and the exchange rate is fully deterministic (see e.g. Coenen and Wieland, 2002a, Gali and Monacelli, 2002, and Gaspar and Issing, 2002 for some recent examples). It must be admitted, however, that these studies represent the exception rather than the rule. The majority of economists take the empirical evidence on UIP into account and incorporate the risk premium explanation of the UIP puzzle into their models. McCallum (2000, pp. 887) puts this as follows: “Most analysts (including myself) would normally include UIP as one component of an open-economy macroeconomic model – despite the existence of mountains of empirical evidence that are, at least on the surface, strongly inconsistent with UIP on a quarter-to-quarter basis. (...) It is well known that to be consistent with the data, UIP relations must include a discrepancy term, typically referred to as the risk premium.” Other prominent examples for the risk premium approach are Taylor (1993b), Svensson (2000) and Batini et al. (2001) (see also Section II.3.2). By contrast, the incorporation of non-rationality is only considered by some few economists (see for example Dennis, 2000, and Leitemo and Söderström, 2001).

The problem with the risk premium explanation, however, was that it is not able to explain the extent of the UIP anomaly alone (Section III.3.1). For this reason, we presented an alternative strand of explanations that is based on the rejection of the foreign exchange market efficiency hypothesis (Section III.3.2). After having discussed some approaches to alternatives to rational expectations on the micro level, we derived a macroeconomic exchange rate equation that takes into account non-rationality on the part of international investors. An empirical evidence in favour of these approaches is only given partially on the level of the

process of expectations' formation, but not for the exchange rate equation as a whole. Thus, the exchange rate model given by equation (III.41) should not be understood as a 'better' exchange rate model than UIP, but as some 'tentative' approach to introduce elements that are supported by the data. With 'tentative' we stress again that these approaches do not yet provide a satisfactory and fully-fledged model of exchange rate determination. On the level of macroeconomic modelling, they can only be viewed as a proposal to better describe the behaviour of international investors, which are supported by the data in isolation (survey data, use of chartism), but which have not yet produced any reliable relationship between the exchange rate on the one hand, and the interest rate or other macroeconomic variables on the other hand. Nevertheless, we will implement these approaches into our quantitative analysis of the next Chapter, but we will treat them as some alternative exchange rate models to UIP which are only true with an unknown probability.

To summarise, our definition of exchange rate uncertainty is based on two observations: first, the poor empirical evidence on the validity of an unbiased UIP condition, and second, the existence of some tentative approaches to explain the origin of the failure of unbiased UIP. The effects of this uncertainty about the true model of exchange rate determination under market determined exchange rates on the performance of monetary policy is then the crucial issue of the next Chapter.

## **Chapter IV:**

### **Monetary Policy under Market Determined Exchange Rates and Exchange Rate Uncertainty**

In Chapter II we have shown that economists who base their argumentation on standard open economy macro models typically advocate market determined exchange rates, and in particular independently floating exchange rates, as dominant exchange rate regime for two reasons: they promote economic stability and they guarantee monetary autonomy. Implicitly using our classification scheme of monetary/exchange rate strategies set-up in Chapter I, Taylor (2001, p. 263) is a prime example of this view: “For a country that chooses not to ‘permanently’ fix its exchange rate through a currency board, or a common currency, or some kind of dollarisation, the only alternative monetary policy that can work well in the long run is one based on the trinity of (i) a flexible exchange rate, (ii) an inflation target, and (iii) a monetary policy rule.” Item (i) defines the role of the exchange rate as being purely determined by the market; item (ii) specifies an explicit inflation target as the nominal anchor of the strategy; and item (iii) defines the way in which monetary policy decisions are implemented.

The conviction of the superiority of market determined exchange rates grounds in particular on the assumption that the exchange rate is determined on an efficient foreign exchange market with forward-looking and rational behaviour on the part of the international financial markets’ participants. Uncovered interest parity defines a known and reliable relationship between changes in the central bank’s operating target and the exchange rate so that in addition to the interest rate channel a second important transmission channel of monetary impulses – the exchange rate channel – can be exploited by the central bank. In Chapter III we took a closer look at the empirical findings on the determination of the exchange rate. The conclusion that can be drawn from the literature is that especially in the short and medium run (which is the most relevant for the conduct of monetary policy) the behaviour of exchange rates cannot be explained and predicted by any of the existing models. In particular, the parity conditions typically used in theoretical analyses – UIP and PPP – do not find much empirical support. These findings raise the question of how the conduct of monetary policy in such an environment of uncertainty about the determination of exchange rates is affected. Thus, the motivation of this Chapter is (i) to explore how the introduction of exchange rate uncertainty as one of the stylised facts of market

determined exchange rates impacts on the performance of monetary policy, and (ii) to provide – based on these results – a rationale for the observed fear of floating.

The remainder of this Chapter is structured as follows. In the first Section we begin by setting up a typical small-scale open economy model used by central banks for the derivation and evaluation of their monetary policy decisions. The basic assumption is that the central bank has perfect knowledge about the way in which the market determines the exchange rate. In Section IV.2 we modify our baseline model by introducing six types of uncertainty about the true determination of the exchange rate. Section IV.3 finally quantifies the impact of exchange rate uncertainty on the performance of monetary policy under market determined exchange rates.

## **IV.1 Monetary policy under independently floating and indirect managed floating**

In Section IV.1.1 we present the structure of the baseline model. In the baseline model, the exchange rate is determined via UIP on an efficient foreign exchange market with risk averse agents. Section IV.1.2 shortly describes the instruments with which central banks control short-term interest rates. In Section IV.1.3 we develop the theoretical background for the evaluation of monetary policy rules in macroeconomic models. In particular, we provide the rationale for using simple policy rules instead of optimal policy rules. In Section IV.1.4 we then specify the simple policy rules that are used throughout the remaining part of the Chapter.

### ***IV.1.1 The baseline open economy model***

#### *IV.1.1.1 Specification of the model equations*

The baseline model is a modified version of the backward-looking Neo-Keynesian Ball (1999b) model for open economies. We have opted for the purely backward-looking specification of the inflation and output equation to get dynamics that match those of available economic data most consistently, thereby deliberately abstaining from any optimising foundations (see the discussion in Chapter II). An additional aspect that contributed to this decision was stressed by Rudebusch and Svensson (1999) who also used a purely backward-looking model, albeit for a closed economy. In their view, a backward-looking specification of the behavioural relationships is appropriate in particular if the inflation targeting strategy has only been recently introduced, implying that the public is still learning about the new monetary policy regime. As has been

shown in the introductory Chapter I, most of the countries that we are focussing on introduced inflation targeting no earlier than the 1990s.

The baseline model consists of the following equations (see Section II.3, and in particular Section II.3.1.3, for a detailed description):

$$(IV.1) \quad \pi_{t+1} = \pi_t + \gamma_y y_t + \gamma_q (q_t - q_{t-1}) + \varepsilon_{t+1}^\pi$$

$$(IV.2) \quad y_{t+1} = \beta_y y_t - \beta_i (i_t - \pi_t) + \beta_q q_t + \varepsilon_{t+1}^y$$

$$(IV.3) \quad i_t = i_t^f + E_t s_{t+1} - s_t + u_t^s$$

$$(IV.4) \quad s_t - s_{t-1} \equiv q_t - q_{t-1} - \pi_t^f + \pi_t.$$

The nominal interest rate  $i_t$  serves as the operating target of monetary policy. The real exchange rate  $q_t$ , the nominal exchange rate  $s_t$  and the output gap  $y_t$  are expressed in logarithms. The rate of inflation  $\pi_t$  and the nominal interest rate  $i_t$  are measured in per cent. All parameters are assumed to be positive. The supply shock  $\varepsilon_{t+1}^\pi$  and the demand shock  $\varepsilon_{t+1}^y$  are i.i.d. with mean zero. The open economy Phillips curve equation (IV.1) and the open economy IS relation (IV.2) are identical to the specifications in the original Ball (1999b) model. Note that we defined the real interest rate as the difference between the nominal interest rate  $i_t$  and the *current* rate of inflation  $\pi_t$  (instead of *expected* inflation for the next period  $E_t \pi_{t+1}$  as is common in forward-looking models; see Chapter II). Ellingsen and Söderström (2001) showed that this definition of the real interest rate is consistent with a forward-looking definition of the real interest rate if the Phillips curve is purely backward-looking.

As has been shown in Chapter II, the baseline Neo-Keynesian model assumes UIP as the central relationship for the determination of the exchange rate.<sup>36</sup> The UIP disturbance and the foreign interest rate are modelled as AR(1) processes

$$(IV.5) \quad u_t^s = \rho_s u_{t-1}^s + \varepsilon_t^s$$

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<sup>36</sup> This is exactly the point where the modification of the Ball (1999b) model appears. We replaced the static relationship between the real interest rate and the real exchange rate that was originally assumed by Ball (1999b) (see below in Section IV.2.2.2 equation (IV.27)) by a forward-looking UIP condition (IV.3).

$$(IV.6) \quad i_t^f = \rho_f i_{t-1}^f + \varepsilon_t^f$$

where the persistence parameters  $0 < \rho_s < 1$  and  $0 < \rho_f < 1$ . The shocks are zero-mean i.i.d. For simplicity the foreign inflation rate  $\pi_t^f$  has been set to zero. Thus,  $i_t^f = r_t^f$  and equation (IV.3) can be rewritten as

$$(IV.7) \quad i_t = r_t^f + E_t s_{t+1} - s_t + u_t^s.$$

To close the model a relationship between the nominal exchange rate and the real exchange rate is needed which is assumed by the identity in (IV.4).

#### IV.1.1.2 Calibration of the baseline model

For the quantitative analysis we have to calibrate the model. Given the time lags in equations (IV.1) to (IV.4) a period can at best be interpreted as a year. The parameter values of the Phillips curve (IV.1) and the aggregate demand equation (IV.2) were chosen in accordance with Ball (1999b). They are summarised in Table IV.1.

**Table IV.1: Calibration of the Phillips curve and the IS equation**

Phillips curve		IS equation		
$\gamma_y$	$\gamma_q$	$\beta_y$	$\beta_i$	$\beta_q$
0.4	0.2	0.8	0.6	0.2

The variance of the i.i.d. shocks  $\varepsilon_{t+1}^s$ ,  $\varepsilon_{t+1}^\pi$  and  $\varepsilon_{t+1}^y$  is normalised to unity. As the original Ball (1999b) specification of the exchange rate equation (see Section IV.2.2.2 below) neglects any influence of the foreign real interest rate on the exchange rate, we set the variance of  $\varepsilon_{t+1}^f$  as well as the persistence parameter  $\rho_f$  to zero. This simplification equally applies to all other exchange rate specifications discussed in Section IV.2.2 so that each type of model is hit by the same number of shocks (exchange rate shock, supply shock, demand shock).

In order to match the empirically found anomaly of the UIP condition the autocorrelation coefficient of the shock is chosen so as to persist over several periods. Thus, in the baseline

model, we somewhat arbitrarily set the degree of persistence of the UIP shock to 0.3.<sup>37</sup> However, as we will show below, the quantitative results are quite robust against variations of the UIP persistence as long as the degree of persistence remains low (i.e. smaller than 0.5).

#### *IV.1.2 The interest rate as operating target under market determined exchange rates*

In the following we will present the mechanics of how central banks typically control interest rates. The relevant market for targeting short-term interest rates is the domestic money market where commercial banks fund their credit supply to the private sector (see the demand lines in Figure IV.1). From this activity the commercial banks' aggregate demand for base money  $B^D$  is usually described as follows:

$$(IV.8) \quad B^D = f_1(i, Y, \varepsilon^B)$$

where the private sector's aggregate demand  $Y$  is the proxy for its credit demand and  $\varepsilon^B$  is the random disturbance which summarises other influences to the demand for base money, in addition to changes in interest rates or income. As the central bank is a monopolist for the supply of base money (which is the major input factor for the commercial banks' credit supply) it simply provides the amount of base money  $B_0$  that is necessary to realise the desired optimal interest rate  $i^{opt}$  (see Figure IV.1) (see Bofinger, 2001, chapters 3 and 10 for a detailed discussion):

$$(IV.9) \quad B = f_1(i^{opt}, Y, \varepsilon^B).$$

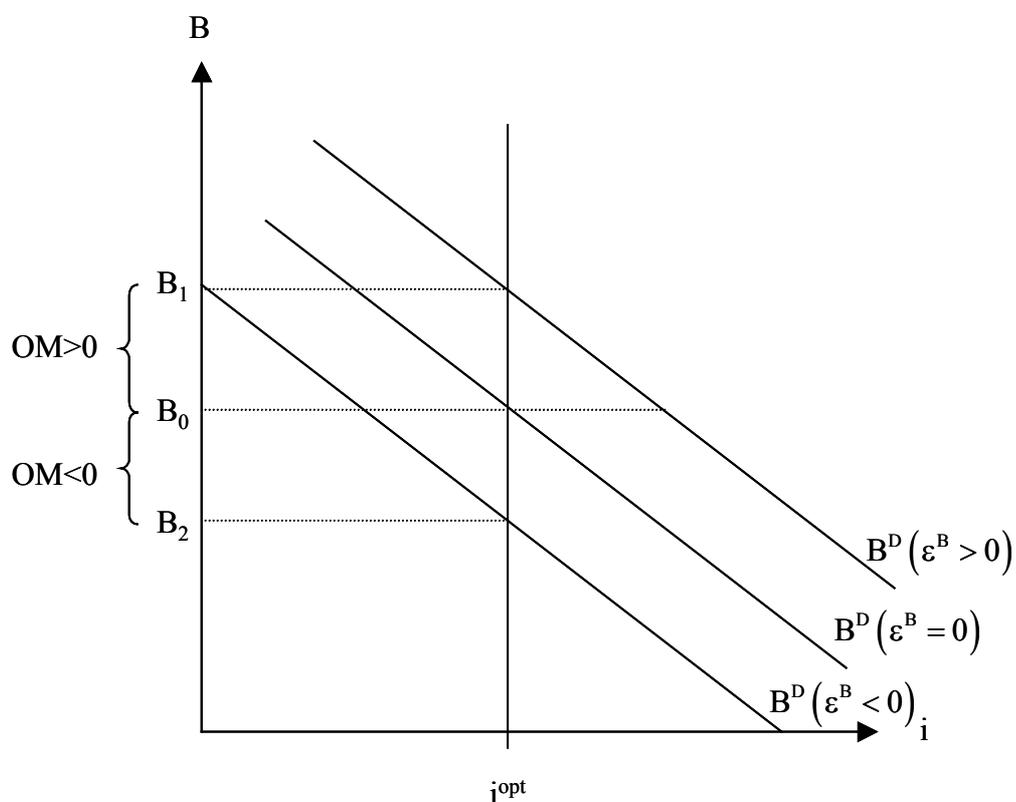
The effectiveness of targeting interest rates as described above crucially depends on two factors. First, as already mentioned, the central bank needs to be a monopolistic net supplier of base money. Second, as base money is also exchanged on the inter-bank market, implying that commercial banks clear temporary imbalances among each other without recourse to the central bank, the central bank needs an efficient set of instruments to control interest rates on the inter-bank market. In practice, we can find two variants: Some countries prefer active intervention of the central bank in the money market via open market operations. Others rely on 'automatic'

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<sup>37</sup> A persistence parameter of 0.3 signifies a decay for UIP deviations caused by a risk premium shock of 70 per cent per period, implying a half-life for UIP shocks of 0.6 periods.

stabilisation (i.e. the central bank remains passive) by an interest rate band with two unlimited standing facilities establishing the upper (lending facility) and the lower limit (absorption facility) of the band.<sup>38</sup> In fact, many countries use a mixture of both. In any case, the central bank adjusts its net domestic assets (NDA) in response to disturbances in the commercial banks' aggregate demand for base money with a view to realising the desired money market interest rate. If  $B^D$  shifts to the right, the central bank either injects base money by conducting additional open market operations ( $OM > 0$ , see Figure IV.1) or the commercial banks use the central bank's lending facility. As a result of this, domestic assets (DA) in the central bank's balance sheet will rise (see Figure IV.2). If  $B^D$  shifts to the left, the central bank has to reduce the supply of base money. This can either be done by reducing domestic assets (lowering the liquidity provided by open market operations or repayment of lending facilities) or by expanding domestic liabilities (DL) through the use of the absorption facility. As we will see below, the absorption facility will become a crucial instrument for a central bank that is engaged in foreign exchange market interventions.

**Figure IV.1: Intervention in the domestic money market**



<sup>38</sup> Because these are both standing facilities, no commercial bank has any reason to pay another bank a higher rate for overnight cash than the rate at which it could borrow from the central bank; similarly, no commercial bank has

**Figure IV.2: A stylised central bank balance sheet**

assets	liabilities
NFA	B
DA	
	DL

An important limitation to the control of the domestic inter-bank market is the lower zero bound on nominal interest rates (see Section IV.3.3 below for a discussion of the causes and the macroeconomic consequences). The reason why nominal interest rates cannot fall below zero is that the alternative to investing in short-term bonds is simply to hold cash at zero interest rates. Thus, once the money market rate becomes zero, any additional supply of base money provided by the central bank would simply increase the private sector's cash balances since the demand for interest bearing base money  $B^D$  becomes infinitely elastic.<sup>39</sup>

### ***IV.1.3 Policy rules under inflation targeting and market determined exchange rates***

From now on we will treat the instruments of monetary policy as being outside the model. Whenever monetary policy targets a certain level of the short-term nominal interest rate, implicitly is assumed that the central bank injects liquidity so as to achieve the desired level. Thus, the appropriate quantity of base money could be determined recursively from the relevant base money demand equation (IV.9). Throughout the paper it is further assumed that the central bank implements its interest rate policy within the framework of *flexible* inflation targeting. Under flexible inflation targeting the objective of monetary policy is not only to stabilise the inflation rate around a given inflation target, but also to put some weight on stabilising the real economy as represented by the output gap (Svensson, 1999). The objectives are summarised by a so-called period loss function that is quadratic and given by

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any reason to lend overnight cash at a rate lower than the rate at which it can deposit with the central bank.  
<sup>39</sup> Orphanides and Wieland (2000) show for Japanese data from 1970 to 1995 that increasing base money (measured as a fraction of nominal GDP) by one percentage point is associated with a decline in the short-term nominal interest rate of about four percentage points. Increases in base money in the latter half of the 1990s, when the nominal interest rate was close to zero, had no further effect on the rate of interest.

$$(IV.10) \quad L_t = \lambda_\pi (\pi_t - \pi^T)^2 + \lambda_y y_t^2$$

where  $\lambda_\pi$  and  $\lambda_y$  are the preferences of the central bank with respect to the target variables.<sup>40</sup> For simplicity we set the inflation target  $\pi^T$  to zero. In a dynamic context these objectives are expressed as an intertemporal loss function  $J_\tau$  which can be computed in each period  $\tau$  and which consists of the expected sum of discounted current and future period losses  $L_t$ :

$$(IV.11) \quad J_\tau = E_\tau \left[ \sum_{t=0}^{\infty} \delta^t L_{\tau+t} \right].$$

$\delta$  denotes the discount factor ( $0 < \delta < 1$ ). As has been shown by Woodford (2002b), this loss criterion can be viewed as a second-order Taylor approximation to the lifetime utility function of a representative household. By scaling the intertemporal loss function (IV.11) by a factor  $(1 - \delta)$  it can further be shown that when  $\delta$  approaches unity, the scaled intertemporal loss approaches the weighted sum of the unconditional variances of inflation and the output gap (Svensson, 2002b):

$$(IV.12) \quad \lim_{\delta \rightarrow 1} (1 - \delta) J_\tau = \lambda_\pi \text{Var}[\pi_t] + \lambda_y \text{Var}[y_t].$$

For the implementation of monetary policy the decision maker can choose – at least on a theoretical level – between two procedures. On the one hand, he could rely his decision upon the results of optimal control theory by exploiting all the information available about the economic model, the nature of the stochastic shocks borne by the economy, and the policy makers' preferences. The monetary policy problem in period  $\tau = 0$  is then to find a path for the operating target (that is, the short-term interest rate)<sup>41</sup> that minimises the intertemporal loss

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<sup>40</sup> If we set  $\lambda_y$  to zero, only inflation enters the period loss function. This case is called *strict* inflation targeting. It is important to note however that a non-zero  $\lambda_y$  does not induce any inflation bias, since the implicit output target is taken to be potential output and therefore consistent with the natural rate hypothesis (that is also underlying the Phillips curve relation). Thus, the central bank is assumed to be only concerned about the stability of output, and not – as in the case of inflation – about both, the stability and the level. While the long-run level of output is exogenously given for the central bank, the long-run level of inflation (that is, the inflation target) can be set autonomously by the central bank. Of course a non-zero  $\lambda_y$  increases the short-run variability of inflation around its target in favour of a more stable path of output (see Svensson, 1999, for further details on this issue).

<sup>41</sup> In stochastic control theory this path is often called a contingency plan.

$$(IV.13) \quad \min_{i_t} E_0 \left[ \sum_{t=0}^{\infty} \delta^t (\lambda_{\pi} \pi_t^2 + \lambda_y y_t^2) \right]$$

subject to the structure and the state of the economy at all dates. The model of the economy (equations (IV.1) to (IV.4) in our case) is usually summarised by the so-called state-space representation of the economy

$$(IV.14) \quad \begin{pmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{pmatrix} = A \begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} + B i_t + \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix}$$

where  $x_t$  is a  $(n_1 + n_2) \times 1$  vector of state variables consisting of an  $n_1 \times 1$  vector  $x_{1,t}$  of predetermined (backward looking) variables and an  $n_2 \times 1$  vector  $x_{2,t}$  of forward looking variables.  $i_t$  is the central bank's operating target, and  $\varepsilon_{t+1}$  is a column vector of  $(n_1 + n_2)$  exogenous i.i.d. shock with zero means and a constant covariance matrix  $\Sigma_{\varepsilon}$ . A and B are matrices containing the structural coefficients. For the baseline model the state-space representation is derived in Appendix IV.A.a.

On the other hand, instead of following an optimal policy rule, he could commit to a simple policy rule according to which  $i_t$  only responds to a very limited subset of state variables. In the literature one can typically find two advantages of a commitment to a simple policy rule (see e.g. Svensson, 2002b):

- first, the simplicity of the rule makes commitment technically feasible and renders monetary policy practicable;
- second, simple rules may be relatively robust to various types of uncertainty.

It is obvious that for the purpose of this Chapter the second advantage is the centre of the following discussion. Nonetheless we will begin by explaining the practicability aspect of simple rules in some detail as it helps to clarify the basic conceptual approaches to the theoretical implementation of monetary policy.

#### *IV.1.3.1 Simple versus optimal rules: A question of practicability and monitorability*

From the point of view of optimal-control theory the problem of the monetary policy maker can be solved by an unrestricted optimisation procedure which will result in an endogenous reaction

function for the current setting of the operating target. As the optimisation is unrestricted the optimal policy rule will be a function of all current and lagged predetermined variables, and hence, all the information available at date  $\tau$  (which is set to zero to indicate the initial period) (see Appendix IV.B for details):

$$(IV.15) \quad \dot{i}_t = F^d \cdot x_{1,t}$$

where  $x_{1,t}$  is an  $n_1 \times 1$  of predetermined state variables and  $F^d$  a  $1 \times n_1$  vector of so-called reaction coefficients. Once the optimal  $F^d$  vector is found the entire future state-contingent evolution of endogenous variables as of date  $\tau = 0$  including the interest rate are specified.

The superscript <sup>d</sup> of the F vector refers to the discretionary optimisation method that was adopted by the central bank so far. However, as a number of authors have pointed out, in the presence of forward looking behaviour (captured by the variables contained in the  $x_{2,t}$  vector), discretionary optimisation generally results not only in an inflation bias (provided that there is a positive output gap target in the central bank's loss function, see Kydland and Prescott (1977) and Barro and Gordon (1983)) but also in a stabilisation bias due to an inefficient interest rate response to shocks (Svensson, 1997b). Under discretion the central bank re-optimises its interest rate path every period taking the expectations of the private sector as given. As an alternative the central bank could commit to a once-and-for-all policy rule. By doing so, it would internalise the effects of its own interest rate decision on the expectations of the private sector. The resulting optimal instrument rule would not only be a function of the predetermined variables but also of the Lagrange multipliers  $\psi_{2,t}$  which are related to the forward-looking variables in the  $x_{2,t}$  vector (see Appendix IV.B for details):

$$(IV.16) \quad \dot{i}_t = F^c \cdot \begin{pmatrix} x_{1,t} \\ \psi_{2,t} \end{pmatrix}.$$

Independent of whether the central bank optimises under discretion or under commitment it should be clear that in a real world scenario (where the number of state variables is in principle unlimited) the optimal reaction function would be very complex. This complexity would lead to two major problems which make optimal policy instrument impracticable. On the one hand, it

would hamper the internal decision making process within the central bank. A complex reaction function cannot serve as a navigation system which allows monetary policy decisions to be taken even under difficult situations in a reliable and fast way (Bofinger, 2001, chapter 8).<sup>42</sup> On the other hand, it would make monitoring and verifiability of the monetary policy decisions on the part of the public impossible. This is especially important under commitment where a specific mechanism is needed by which the central bank can be bound to follow the optimal reaction function in the future (Svensson, 2002b).

For the reasons mentioned, optimal policy rules can at best be used as a benchmark for the evaluation process in a theoretical environment. For practical monetary policy, however, policy rules which are simple to implement and simple to monitor play a crucial role. Such simple rules only react to a small subset of economic variables

$$(IV.17) \quad i_t = F^s \cdot \begin{pmatrix} X_{1,t} \\ X_{2,t} \end{pmatrix}$$

where  $F^s$  is a restricted vector of reaction coefficients. Typically, the  $F$  vector is restricted to the variables in the period loss function, but it could also be extended to variables which are not even necessary to solve for the unrestricted optimal policy above. Once the decision on the variables to which the interest rates should react is taken, the question emerges on how to determine the related coefficients in  $F^s$ . We will return to this issue in Section IV.1.4. But at this stage it should already be obvious that – however the simple rule has been determined – there is no single simple rule per se so that a selection criterion is needed to choose among the variety of possible simple rules.<sup>43</sup>

The standard approach to evaluate the performance of the simple rules is to calculate the loss resulting from the loss function (IV.11) that the policy under consideration causes. For this calculation we have to derive the rule-dependent laws of motion of the state variables and to calculate the unconditional variances of the goal variables. Inserting the variances into equation (IV.12) then gives the unconditional loss of the policy rule (see Appendix IV.B for details). If

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<sup>42</sup> Especially under commitment, there is a feedback to the interest rate from variables with no economic interpretation.

<sup>43</sup> On the variety of possible simple rules see the Taylor (1999b) book, in particular the contribution of Rudebusch and Svensson (1999).

this procedure is repeated for all the simple rules considered, a ranking in terms of loss can be set-up to select the best-performing rules. Numberless studies have shown that the performance of simple rules with reasonably chosen parameters is surprisingly close to that of fully optimal policies (see e.g. the papers in Taylor, 1999b). For a forward-looking model Currie and Levine (1992) even showed that under specific circumstances a commitment to an optimal simple rule produces a lower loss than an optimal interest rate rule resulting from a discretionary optimisation (the loss resulting from an optimal interest rate rule under commitment is of course first-best).

To sum up, the first main advantage of a commitment to simple policy rule is that for a given model of the economy a well-defined simple rule comes rather close to the unconstrained optimum under commitment. This welfare loss, however, is outweighed by the facts that such a simple rule is the only practicable solution for the monetary policy maker, and that the essential monitoring of a commitment can only be guaranteed if the commitment technology (i.e. the policy rule) can be easily understood by the public. Both these aspects are not covered by the loss function defined in (IV.11), and hence do not play any role for the unconstrained optimisation.

#### *IV.1.3.2 Simple versus optimal rules: A question of robustness*

The second major advantage of simple rules compared with complex optimal rules is that they are often found to be quite robust against various types of uncertainty concerning the underlying model. In standard control theory the decision maker treats the model in (IV.14) as known and true. In particular he knows the parameters contained in the matrices A and B as well as the elements of the state vector  $x_t$ . On the basis of this knowledge he can calculate the optimal coefficients of the F vector which prescribe a value for the control variable  $i_t$  at each instant.

If, however, the process of decision making is subject to uncertainty the control problem has to be approached from another perspective. The decision maker now aims at designing policy rules that are insensitive to various kinds of uncertainties (see below in Section IV.2). Instead of assuming that the policy maker knows the true model of the economy it is now assumed that (IV.14) is only an approximation of the true model. The suspicion that the model could be misspecified then imparts a preference for robustness, that is, reasonable performance of a rule across a range of models. To formalise this approach, the approximating model only serves as a

baseline model around which the central bank analyses the performance of a set of policy rules that were found to perform well in the baseline model.

Given this uncertainty, the basic rationale for using simple policy rules stems from the finding that optimal unrestricted rules from one model in general perform much worse than the simple rules when simulated in other models (see e.g. Levin et al., 1999). This result makes intuitive sense, because in order to do better than a simple rule in one model, the optimal rule exploits properties of that model that are model specific. When the optimal rule is then tested out in another model, those properties are likely to be different and the optimal rule does not work well. Since for the purpose of the present Chapter uncertainty about the true (exchange rate) model will be a central issue, the implementation of monetary policy will be discussed in terms of simple policy rules henceforth.

#### ***IV.1.4 Simple policy rules in the baseline model***

##### *IV.1.4.1 The structure of simple policy rules under independently floating and indirect managed floating*

The following analysis will be done for seven simple policy rules which only differ from each other in the variables that the central bank responds to (see Table IV.2 for a summary). In Chapter I we defined independently floating exchange rates as a regime in which the monetary authority sets short-term interest rates exogenously and independently of any exchange rate developments. Policy rule R1 is typical for such a policy since the central bank's operating target only responds to movements in the domestic goal variables inflation and output.

Under indirect managed floating the central bank not only reacts to contemporaneous movements in inflation and output, but also to movements in some measure of the exchange rate. There is a multitude of possible formulations of such rules (see e.g. Batini et al., 2001), depending on whether one refers to the real or the nominal exchange rate, to the level or to changes in the exchange rate, or to contemporaneous or to lagged movements of the exchange rate (see policy rules R2 to R7).

**Table IV.2: A battery of simple policy rules**

		structure of the rule
independently floating	R1	$i_t = f_\pi \pi_t + f_y y_t$
indirect managed floating	R2	$i_t = f_\pi \pi_t + f_y y_t + f_q q_t$
	R3	$i_t = f_\pi \pi_t + f_y y_t + f_{q(-1)} q_{t-1}$
	R4	$i_t = f_\pi \pi_t + f_y y_t + f_{\Delta q} \Delta q_t$
	R5	$i_t = f_\pi \pi_t + f_y y_t + f_{\Delta s} \Delta s_t$
	R6	$i_t = f_\pi \pi_t + f_y y_t + f_q q_t + f_{q(-1)} q_{t-1}$
	R7	$i_t = f_\pi \pi_t + f_y y_t + f_s s_t$

#### IV.1.4.2 Determination of the response coefficients of the simple rules

For the choice of the parameters of the simple rules two approaches are common in the literature: ‘Taylor’ rules with non-optimised coefficients and optimal simple rules. The Taylor rules encompass the mainstream of the literature on simple policy rules. The response coefficients are typically chosen independently of the underlying model, based on a rough description of the interest rate setting behaviour of a central bank. They owe their name to Taylor (1993a) who proposed a policy rule with the structure of R1 and the coefficients  $f_\pi = 1.5$  and  $f_y = 0.5$ . These are round figures argued to approximately characterise the U.S. monetary policy between 1987 and 1992.<sup>44</sup>

In contrast to Taylor rules optimal simple rules are rules that minimise the policy maker’s intertemporal loss function on a restricted state variable set

$$(IV.18) \quad \min_{i_t \langle f_\pi, f_y, f_q, f_{q(-1)} \rangle} E_0 \left[ \sum_{t=0}^{\infty} \delta^t \left( \lambda_\pi \pi_t^2 + \lambda_y y_t^2 \right) \right]$$

<sup>44</sup> Besides the original Taylor (1993a) rule other popular rules are the rule proposed by Ball (1999a) according to which the interest rate should be adjusted more aggressively in response to changes in output ( $i_t = 1.50\pi_t + 1.00y_t$ ) or a Taylor rule for the open economy proposed by Svensson (2000) where the central bank additionally reacts to changes in the real exchange rate ( $i_t = 1.50\pi_t + 0.50y_t + 0.45\Delta q_t$ ).

subject to the state-space representation of the model as in equation (IV.14). As their performance is much closer to that of optimal rules, we decided on this approach in order to determine the response coefficients.

The rules that we consider in this Section have been optimised for the baseline specification of the open economy model in terms of *all* their parameter settings for given preferences ( $\lambda_\pi = \lambda_y = 1$ ) and the given structure of the rule assumed in Table IV.2.<sup>45</sup> The sets of coefficients were computed by using a grid search over a reasonable range of values with a grid of 0.01. Table IV.3 provides the results for the optimised coefficients and the related loss in absolute and relative terms. The latter expresses the loss in per cent of the loss from the optimal unrestricted policy under commitment which amounts to 4.92. It shows that the independently floating policy rule R1 performs on average 2.8 per cent worse than the optimal unrestricted rule. With regard to the equally weighted goal variables inflation and output this result means that the variance of both variables is on average 2.8 per cent higher. The coefficients on  $\pi_t$  and  $y_t$  are somewhat larger than 1.5 and 0.5 which are the coefficients of the original Taylor (1993a) rule but this result is in line with many other simulation studies (see e.g. Rudebusch and Svensson, 1999, and other papers in Taylor, 1999b). In particular, with  $f_\pi > 1$  the so-called Taylor principle holds which states that in response to a rise in inflation nominal interest rates should rise sufficiently to increase real rates (Taylor, 1999a).

Under indirect managed floating, the central bank additionally reacts with the interest rate to exchange rate movements. Adding the current movement of the real exchange rate to the interest rate rule (R2) reduces the loss by one percentage point. The central bank reacts more aggressively on deviations of the inflation rate and the output gap from their target levels, and it raises nominal interest rates when the real exchange rate depreciates. If the lagged real exchange rate is added (R3) instead of the current exchange rate, the central bank lowers the nominal interest rate in response to a real depreciation in the previous period. While the value of the loss function is relatively close to that resulting from R2, the composition of the loss has changed in favour of inflation. In R4 and R5 the interest rate reacts to the change in the exchange rate. On

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<sup>45</sup> We italicised the word *all* to emphasise the difference to a similar study by Leitimo and Söderström (2001). These authors optimised the two coefficients of a R1-type rule which were kept unchanged when they added various exchange rate variables to the policy rule. With the fixed coefficients  $f_\pi$  and  $f_y$  they then determined the optimum weights on the exchange rate. Unsurprisingly, they finally came to the conclusion that by “including the

first sight, R5 seems to be quite different from R4 since the nominal exchange rate enters the rule. However, with equation (IV.4) it is possible to replace  $\Delta q_t$  with  $\Delta s_t - \pi_t$  and to reformulate R5 as

$$(IV.19) \quad i_t = (f_{\pi}^{R4} - f_{\Delta q}^{R4})\pi_t + f_y^{R4}y_t + f_{\Delta s}^{R4}\Delta s_t.$$

Thus, with  $f_{\pi}^{R5} = f_{\pi}^{R4} - f_{\Delta q}^{R4}$ ,  $f_y^{R5} = f_y^{R4}$  and  $f_{\Delta s}^{R5} = f_{\Delta q}^{R4}$  R4 and R5 lead to equivalent results in terms of the dynamics of the system, and hence in terms of the loss function. For this reason, we only calculated the optimal parameters for R4. We then derived the parameters for R5 on the basis of (IV.19). Compared to the policy rules that only react to the level of the real exchange rate, R4 and R5 perform somewhat better so that the loss is only 0.38 per cent higher than that of the optimal unrestricted rule. If we allow for a separate weighting of the current and the lagged real exchange rate (R6) we get the best result in terms of the loss function. Note that the improvement of the last three rules mainly stems from a reduction of the variance of the inflation rate.

**Table IV.3: Performance of optimised rules in the baseline model**

structure of the rule	absolute loss	relative loss	Var( $\pi_t$ )	Var( $y_t$ )
R1: $i_t = 1.90\pi_t + 1.25y_t$	5.05	102.68	2.68	2.38
R2: $i_t = 2.23\pi_t + 1.56y_t + 0.27q_t$	5.00	101.68	2.68	2.32
R3: $i_t = 1.88\pi_t + 1.35y_t - 0.16q_{t-1}$	5.01	101.86	2.63	2.38
R4: $i_t = 2.17\pi_t + 1.69y_t + 0.26\Delta q_t$	4.94	100.38	2.60	2.33
R5: $i_t = 1.91\pi_t + 1.69y_t + 0.26\Delta s_t$	4.94	100.38	2.60	2.33
R6: $i_t = 2.29\pi_t + 1.78y_t + 0.36q_t - 0.23q_{t-1}$	4.93	100.20	2.62	2.31

Note: The relative loss refers to the loss from optimal unrestricted policy under commitment.

As for policy rule R7 according to which the nominal interest rate responds to the level of the nominal exchange rate the optimisation resulted in a coefficient on the exchange rate of zero

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exchange rate variables in the policy rule (...) there are only marginal decreases in the value of the loss function" (Leitemo and Söderström, 2001, p. 15).

( $f_s = 0$ ). Thus, the policy rule is identical with R1. This result is not very surprising given the non-stationarity of the nominal exchange rate in open economy macro models.

#### *IV.1.4.3 On the relevance of responding to exchange rate movements*

It should be noted that responding to exchange rate movements is very different from targeting the exchange rate. The latter makes the exchange rate an intermediate target, whereas the former treats the exchange rate as one further piece of information to be weighed when setting interest rates.<sup>46</sup> Expressed in this way, it should be obvious that a central bank can only gain by responding to all information that helps them meet its final target and achieve better economic outcomes. However, as has already been mentioned in Chapter II, the literature on monetary policy rules in open economies only attach a minor importance to the possibility of interest rate feedback to exchange rate movements. Quantitative work by Ball (1999b), Svensson (2000), Batini et al. (2001) and Leitimo and Söderström (2001) only find – in accordance with our results shown in Table IV.3 – a small improvement in terms of the loss function when an indirect managed floating policy rule is used in the simulations. In his multi-country study, Taylor (1999c) even found a worsening of the performance of such rules for some model specifications (and some countries). In an overview, he finally comes to the conclusion that “research to date indicates that monetary policy rules that react directly to the exchange rate, as well as to inflation and output, do not work much better in stabilizing inflation and real output and sometimes work worse than policy rules that do not react directly to the exchange rate” (Taylor, 2001, p. 267).<sup>47</sup>

The economic rationale behind this result can be directly derived from the exchange rate model underlying the New-Keynesian / Neo-Keynesian open economy models. According to UIP the current exchange rate moves in response to current and future expected movements in the domestic and foreign nominal interest rate as well as disturbances to UIP (see equation (II.28)). Let us assume for a moment that the foreign interest rate is constant and that there is no disturbance to UIP. Thus, the only remaining determinant of the exchange rate is the domestic nominal interest rate, and hence the operating target of the central bank. From this it directly follows that the contemporaneous movement of the nominal exchange rate contains no extra

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<sup>46</sup> We presented the interest rate policy rule for strategies with an exchange rate intermediate target (i.e. fixed exchange rates) in Section II.3.4.

<sup>47</sup> It should be stressed again that these results obtained from quantitative simulations are at odds with the empirical observation summarised in Chapter I according to which in small open emerging market economies indirect managed floating plays an important role.

information for the decision making process of the central bank. Thus, under such a setting policy rules R1 and R2 would be identical, with no feedback from  $q_t$  on  $i_t$  (see Table IV.4). As a result, if the exchange rate is not an independent source of disturbance, there is no additional informational value to be had from also responding to the exchange rate itself. In the case of UIP disturbances, the informational content of the current real exchange rate can even be quantified. Table IV.3 shows that the use of R2 instead of R1 lowers the loss by exactly 1 per cent.

**Table IV.4: Optimised policy rules under a perfectly holding UIP condition and constant foreign interest rates**

structure of the rule	absolute loss	relative loss 1	relative loss 2	Var( $\pi_t$ )	Var( $y_t$ )
R1: $i_t = 1.91\pi_t + 1.27y_t$	4.93	101.17	100.64	2.62	2.31
R2: $i_t = 1.91\pi_t + 1.27y_t + 0 \cdot q_t$	4.93	101.17	100.64	2.62	2.31
R3: $i_t = 1.85\pi_t + 1.35y_t - 0.20q_{t-1}$	4.88	100.30	99.78	2.57	2.31
R4: $i_t = 2.12\pi_t + 1.61y_t + 0.22\Delta q_t$	4.88	100.30	99.78	2.57	2.31
R5: $i_t = 1.90\pi_t + 1.61y_t + 0.22\Delta s_t$	4.88	100.30	99.78	2.57	2.31
R6: $i_t = 2.40\pi_t + 1.89y_t + 0.45q_t - 0.24q_{t-1}$	4.88	100.30	99.78	2.57	2.31
$i_t = 1.79\pi_t + 1.39y_t + 0.18i_{t-1}$	4.88	100.30	99.78	2.57	2.31

Note: Relative loss 1 (2) expresses the loss from the simple policy rule as a percentage of the loss from optimal unrestricted policy under commitment (discretion).

The improvement of the performance when the central bank responds to the lagged exchange rate (R3 to R6 which all produce an identical outcome) cannot be explained by informational advantages, but by gains from commitment. As has already been mentioned in Section IV.1.3 such gains occur in models with forward-looking behaviour by improving the short-run trade-off between output and inflation. For a closed economy Woodford (1999) showed that under commitment the interest rate response in the case of supply shocks is more gradual compared to that associated with discretionary policy.<sup>48</sup> Specifically, he showed that in order to manipulate

<sup>48</sup> In contrast to this, if demand shocks occur (i.e. if complete stabilisation of each of the goal variables is simultaneously possible) there is no difference in the optimal responses under discretion and under commitment (see also Clarida et al., 1999). In open economy models, this result does not hold in general. A positive demand shock, followed by an increase in the interest rate, results in an exchange rate appreciation, which in isolation contributes to lower inflation. Thus, in open economy models there is also a trade off between inflation and output stabilisation when demand shocks occur.

private sector expectations optimal policy under commitment almost always involves responses to lagged states of the economy (the so-called ‘history-dependence’ of optimal policy under commitment). On the level of simple policy rules this gain from commitment can be realised in approximation by interest rate rules which are not only a function of current output and inflation, but also of the lagged interest rate. In an open-economy setting this so-called interest rate smoothing behaviour can be replicated by responding to a lagged exchange rate term.<sup>49</sup> With  $f_{q(-1)} < 0$  an appreciation in  $t-1$  leads to an increase in the interest rate in  $t$ . As UIP perfectly holds, the appreciation in  $t-1$  has been triggered by an increase in the interest rate in  $t-1$ . Thus, responding to  $q_{t-1}$  is identical to responding to  $i_{t-1}$ . This is also confirmed by the results shown in Table IV.4 according to which R3 produces the same economic outcome as the interest rate smoothing policy rule presented in the last row of the Table.

**Table IV.5: Optimised policy rules under a perfectly holding UIP condition, constant foreign interest rates and a modified Phillips curve relation**

structure of the rule	absolute loss	relative loss 1	relative loss 2	Var( $\pi_t$ )	Var( $y_t$ )
R1: $i_t = 1.57\pi_t + 1.01y_t$	3.78	102.10	98.18	2.13	1.65
R2: $i_t = 1.57\pi_t + 1.01y_t + 0 \cdot q_t$	3.78	102.10	98.18	2.13	1.65
R3: $i_t = 1.55\pi_t + 1.01y_t - 0.03q_{t-1}$	3.78	102.10	98.18	2.13	1.65
R4: $i_t = 1.59\pi_t + 1.05y_t + 0.03\Delta q_t$	3.78	102.10	98.18	2.13	1.65
R5: $i_t = 1.56\pi_t + 1.05y_t + 0.03\Delta s_t$	3.78	102.10	98.18	2.13	1.65
R6: $i_t = 1.48\pi_t + 0.94y_t - 0.07q_t - 0.03q_{t-1}$	3.78	102.10	98.18	2.13	1.65

Note: Relative loss 1 (2) expresses the loss from the simple policy rule as a percentage of the loss from optimal unrestricted policy under commitment (discretion).

As has been stressed by Leitimo et al. (2002) who use a model that is identical to our baseline model, the reason for inertia in our baseline model is that inflation is affected by the change in the exchange rate. In an alternative specification, where only the level of the exchange rate enters the inflation equation

<sup>49</sup> Note that in our baseline model the only forward-looking agents are the foreign exchange market participants, whereas price setters and consumers are assumed to fully backward-looking.

$$(IV.20) \quad \pi_{t+1} = \pi_t + \gamma_y Y_t + \gamma_q Q_t + \varepsilon_{t+1}^\pi$$

the additional gain from using an inertial policy rule disappears and indirect managed floating is indeed identical to independently floating (see Table IV.5).

## IV.2 Uncertainty about how the market determines the exchange rates

A central result of Chapter III was that the short- and medium-run behaviour of exchange rates is not very well understood in practice. In particular the empirical evidence on the two parity conditions – purchasing power parity and uncovered interest parity – which not only constitute a major building block for monetary and portfolio balance models of exchange rate determination but also for standard open economy macro models is not very supportive in systems of market determined exchange rates. This finding introduces an important uncertainty for the monetary policy maker who has to take decisions in an open economy environment where the exchange rate influences inflation and output. Thus, when setting up an economic model on the basis of which one implements monetary policy, one has to be aware of the fact that this model is not a true description of private agents' behaviour. This concerns in particular domestic (foreign) firms selling goods to the foreign (domestic) market and international investors shifting funds from one currency into another.

In the present study we assume that the pricing behaviour of firms, and hence the degree of pass-through, is known by the monetary policy maker. Thus, deviations from PPP do not introduce any uncertainty into the decision-making process (for a discussion of the impact of an uncertain degree of pass-through on the conduct of monetary policy see Adolfson, 2001, 2002, and Hunt and Isard, 2003). The focus rather is on uncertainty originating from the international financial markets.

The behavioural deviations of international investors from the efficient markets hypothesis has been explained in detail in Chapter III. In this Chapter we concentrate on how these possible deviations and the resulting uncertainty about the true behaviour enter an open economy macro model. One possibility is to model the empirical deviations from UIP as though they are a structural shock process, interpretable as time-varying risk premium (see Section IV.2.2.1). This is the line mostly taken in open economy macroeconomics as it corresponds particularly to the standard approach to explaining the UIP puzzle by an international asset pricing model with risk

averse agents. Another strand of research concentrates on models that respond to the rejection of UIP by replacing it with an alternative exchange rate equation that continues to posit a relationship between interest rates and exchange rates. And this relationship is above all based on empirical findings which yield somewhat more stable results than UIP estimations (see Sections IV.2.2.2 and IV.2.2.3). As an alternative to the efficient market hypothesis, many studies allow for deviations from the rational expectations hypothesis by introducing the processes of backward-looking expectations (see Sections IV.2.2.4 and IV.2.2.5). Finally, we introduce a purely random exchange rate behaviour that excludes any macroeconomic determinant other than its own lagged value (see Section IV.2.2.6). Before defining the various types of exchange rate uncertainty, however, we take a short look at uncertainty in monetary policy in general.

### ***IV.2.1 Uncertainty in monetary policy***

It is unanimously recognised today that the control of monetary policy is carried out in a context of great uncertainty. In the standard approach to analysing monetary policy (i.e. setting-up a model of the economy, specifying an objective for the monetary policy maker, and determining how monetary policy should respond to disturbances to the economy) uncertainty occurs in two respects: uncertainty about what happens in the future and uncertainty about the current description of the economy.

The first type of uncertainty refers to the stochastic nature of the course of an economy. Under the assumption that the policy maker possesses perfect knowledge about the model describing the macroeconomic relationships, he is nonetheless unable to predict future events. Suppose the following general model of an economy

$$(IV.21) \quad x_{t+1} = Ax_t + Bi_t + \varepsilon_{t+1}$$

where  $x_t$  is a vector of state variables,  $i_t$  is the operating target of monetary policy, and A and B are matrices of structural coefficients. In this model, the stochastic future disturbances enter in the form of *additive shocks*  $\varepsilon_{t+1}$  which are independently and identically distributed with known stochastic properties (in particular, with zero mean and a constant variance). On a technical level, it can be shown that, for the choice of optimal policy rule for  $i_t$ , the outcome under uncertainty is identical with that occurring under a central bank that is assumed to be completely certain

about how the economy is developing. This so-called certainty equivalence principle (or sometimes separation principle) follows from the particular structure of the optimisation problem according to which the central bank's objective function is quadratic, the model of the economy is linear, and the expected future value of the disturbances is zero (for a technical treatment of the certainty equivalence principle see Sargent (1997) and Ljungqvist and Sargent (2000), for a less formal presentation see Batini et al. (1999)).<sup>50</sup>

The second type of uncertainty that refers to the current description of the economy can be further divided into two categories: uncertainty about the model used by the monetary policy maker and uncertainty about the data on the basis of which decisions are taken (see Batini et al., 1999, Goodhart, 1999, and Poole, 1998, for general reviews on this subject). In contrast to the case of additive shocks, now the formulation of monetary policy is affected by the degree and the type of uncertainty with which the central banks are confronted.

#### *IV.2.1.1 Model uncertainty*

No central bank is endowed with full knowledge of how the economy functions. Milton Friedman's long and variable lags for the transmission of monetary policy actions are probably one of the mostly cited arguments to demonstrate the little knowledge about the content of the 'black box'. This so-called model uncertainty concerns in particular two aspects: the specification of the macroeconomic model and the estimation of the parameters of a specified model.

##### *IV.2.1.1.1 Model uncertainty arising from a potential misspecification*

A fundamental difficulty underlying a large fraction of issues concerning the conduct of monetary policy stems from the lack of professional agreement concerning the appropriate specification of a model suitable for the analysis of monetary policy. This uncertainty about the true structure of the economy, or *the functional form of the economy*, enters the model given by equation (IV.21) through the lack of agreement about the composition of the vector of state

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<sup>50</sup> It is important to note that the certainty equivalence principle only holds for the solution of an unconstrained optimal control problem. In order to find a rule from a constrained optimisation (an optimal *simple* rule) a non-linear optimisation algorithm has to be applied. The solution is not certainty equivalent anymore as it depends, among other things, on the second moments (the covariance matrix) of the disturbances (Currie and Levine, 1992). This is in fact the reason why we applied the simpler (but certainly less efficient) grid search method in Section IV.1.4.

variables  $x_t$ . In various papers McCallum (1988, 1997, 1999) proposed to approach this uncertainty by searching for a policy rule that possesses robustness in the sense of yielding reasonably desirable outcomes in policy simulation experiments conducted with a wide variety of models. Recent applications of this approach include Taylor (1999c), Levin et al. (1999, 2002) and Rudebusch (2002) who compare the performance of policy rules over a wide range of structurally different model specifications. In the majority of cases the differences refer to the lag structure of the variables, the degree of forward-looking behaviour of private agents and the omission or the inclusion of particular variables. As has already been mentioned in Section IV.1.3.2, one of the central results of the aforementioned studies is that in particular simple policy rules are quite robust against uncertainty about the true structure of the economy.

#### IV.2.1.1.2 Model uncertainty arising from the estimation of the model parameters

Apart from the correct specification of the model, uncertainty occurs with respect to the parameters of the model which are estimated on samples of small size and, hence, are prone to errors of estimation. Thus, instead of defining uncertainty over a multitude of classes of models, parameter uncertainty usually occurs in the context of a single model. Now the policy maker is assumed to know that the model equations are true on average on an ex ante basis, but he is uncertain about the values of the parameters in any particular period. This uncertainty about the relationship between the variables in the economy enters equation (IV.21) as follows:

$$(IV.22) \quad x_{t+1} = A_{t+1}x_t + B_{t+1}i_t + \varepsilon_{t+1}.$$

The parameter matrices  $A_{t+1}$  and  $B_{t+1}$  are now stochastic with a given probability distribution with  $A$  and  $B$  being the matrices of the parameter means and  $\Sigma_A$  and  $\Sigma_B$  the related variance-covariance matrices. An arbitrary  $a_{t+1}$  element of  $A_{t+1}$  then takes the following form:

$$(IV.23) \quad a_{t+1} = a + \eta_{t+1}^a$$

where  $a$  is the mean (the point estimate) and  $\eta_{t+1}^a$  is white noise with a given variance (the standard error of the estimation). As the stochastic parameter  $a_{t+1}$  is multiplied by an element of the state vector  $x_t$  this kind of uncertainty is often labelled *multiplicative* uncertainty (in order to emphasise the difference to additive uncertainty just discussed).

This approach goes back to a seminal paper of Brainard (1967) who assumed that the parameters are drawn from independent normal distributions which are known by the policy-makers. He determined the optimal policy rule by a standard Bayesian decision theoretic approach where, given the prior distribution over the uncertain parameters of the model, the expected intertemporal loss is minimised. One of his main results was that multiplicative parameter uncertainty provides a rationale for a cautious and gradualist approach to policy-making as with a higher standard error of estimation the optimal feedback parameters become smaller. This is what Blinder (1997) called ‘Brainard conservatism’. Some recent papers on this approach to parameter uncertainty include Wieland (2000), Sahuc (2001) and Söderström (2002).<sup>51</sup>

The assumption, however, that the prior distribution of the uncertain parameters is known to the decision maker has recently been criticised by various authors (see Giannoni, 2002, Hansen and Sargent, 2000, Onatski and Stock, 2002, and Stock, 1999). As an alternative, they propose a robust control approach in which optimal policy is chosen to minimise the maximal loss (i.e. the loss resulting from the worst-case scenario) over all possible model scenarios. It follows that the choice criterion does not involve any weighting of the models. The foundations of this approach can be found in Knight (1921) who defines uncertainty as a situation in which no prior probability distribution exists.

It is important to note that in contrast to McCallum’s view on uncertainty and robustness both, the Bayesian and the robust control approach seek to determine a policy rule on the assumption that the central bank and the private agents share the same doubts about the true model. McCallum’s view is based on the assumption that the central bank does not know the true behaviour of private agents. For this reason it tests a broad range of possible specifications which may additionally serve to some extent as a protection against failures of the Lucas-critique type. McCallum (1999, p. 1491) writes: “That critique is best thought of not as a methodological imperative regarding model building strategies, but as reminder of the need to use policy-invariant relations in simulation studies and especially as a source of striking examples in which policy invariance is implausible. The construction of a policy-invariant model faces a major difficulty, however, in the above-mentioned absence of professional agreement about model

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<sup>51</sup> This last paper questions the conventional wisdom of the Brainard principle. Brainard (1967) was in particular concerned with the uncertainty of the quantitative impact of the *instrument* on the target variables, thereby ignoring other parameters of the economy.

specification. Thus it would seem sensible to consider a variety of models in the hope that one will be reasonably well specified – and therefore immune to the critique – and search for a rule that will perform satisfactorily in all of them.”

#### *IV.2.1.2 Data uncertainty*

Even if the central bank knew the true model of the economy, there would nonetheless remain a significant degree of uncertainty regarding the real time data which describes *the current state of the economy*. Decisions of policy makers often have to rely on data that is provisional and prone to revision, and some concepts of calculating data (i.e. data which cannot be directly observed by the central bank) is the subject of dissension between economists. Applied to the model of the economy given by (IV.21) the policy maker only observes (or measures) a noisy contemporaneous estimate of (parts of) the state vector

$$(IV.24) \quad x_{t,t} = x_t + \eta_t^x .$$

Accordingly, the measurement errors arise from the variance of the vector of white noise shocks  $\eta_t^x$ . In practice, the variables that are mostly affected by this kind of uncertainty are the output gap (Rudebusch, 2001, 2002), the inflation rate (Rudebusch, 2001), and, in the open economy, the equilibrium real exchange rate (Leitemo and Söderström, 2001).

### *IV.2.2 Types of exchange rate uncertainty*

#### *IV.2.2.1 Exchange rate uncertainty 1: Time-varying and persistent risk premium shocks*

##### *IV.2.2.1.1 Specification of the model equations*

The standard way of modelling deviations from strict UIP in open-economy macro models is to include a foreign exchange risk premium  $u_t^s$  that follows an AR(1) process

$$(IV.25) \quad E_t s_{t+1} - s_t + u_t^s = i_t - i_t^f$$

$$(IV.26) \quad u_t^s = \rho_s u_{t-1}^s + \varepsilon_t^s .$$

In the simulations of this Chapter we opted for the ‘UIP cum persistent risk premium’ exchange rate specification as our baseline model. There are two reasons for this decision. First, UIP relies on arbitrage arguments which ‘should be true’. Even though we know that arbitrage is often subject to limits (see Chapter III), it is nonetheless one of the basic building blocks of economic decision making. Questioning the validity of UIP without rejecting the underlying arbitrage mechanism then has to rely on mistaken expectations. However, rational expectations are still the predominant paradigm in macroeconomics today. Second, from this follows that in almost all open economy macro models UIP serves as the principal constituent of describing exchange rate behaviour (see for example the models presented in Buitert, 1990, McCallum, 1996, and Svensson, 2000). Moreover, UIP is also a constituent of virtually all contemporary exchange rate models, as has been pointed out in Chapter III. McCallum (1994a, p. 109) summarises the analytical importance of the UIP condition as follows: “[T]he main fact to be kept in mind is that it appears as a key behavioral relationship in virtually all of the prominent current-day models of exchange rate determination. These include not only small models used in theoretical analysis, but also a number of the more ambitious and carefully specified of today’s array of multicountry econometric models – those used by international organizations as well as individual open-economy policy analysts.”

Due to this popularity within the economic profession the exchange rate specification in our baseline model is similar to that of numerous other studies. In particular, we assumed a known and constant  $\rho_s$ , taking a value of 0.3. However, the empirical determination of the degree of persistence often leads to mixed results. Table IV.6 summarises the UIP specifications that can be found in various quantitative studies for the open economy.

Thus, as a first type of exchange rate uncertainty we allowed for variations of  $\rho_s$ . Note that the structure of the model under exchange rate uncertainty 1 is similar to that of the baseline model. The source of uncertainty solely arises from the estimation of an important model parameter. Thus, while exchange rate uncertainty 1 can be attributed to the type of uncertainty that we called parameter uncertainty in Section IV.2.1, the other types of exchange rate uncertainty to be presented in Sections IV.2.2.2 to IV.2.2.6 refer to structural model uncertainty since we present alternative exchange rate equations that replace UIP.

**Table IV.6: Persistence of UIP shocks in the literature**

	frequency	$\rho_s$	annualised $\rho_s$
Dennis (2000)	a	0	0
Adolfson (2002)	a	0.8	0.8
Batini and Nelson (2000b)	q	0.753 (estimated for UK)	0.32
Batini et al. (2001)	q	0.261 (estimated for UK with survey data)	0.005
Taylor (1993b)	q	0.5 (calibrated equally for all countries)	0.0625
Leitemo and Söderström (2001)	q	0.3 (calibrated at conventional values)	0.008
Svensson (2000)	q	0.8 (calibrated)	0.41

Note: The formula for transforming the quarterly persistence parameters into annual parameters is

$$\rho_s^{\text{annual}} = \exp(4\rho_s^{\text{quarterly}}).$$

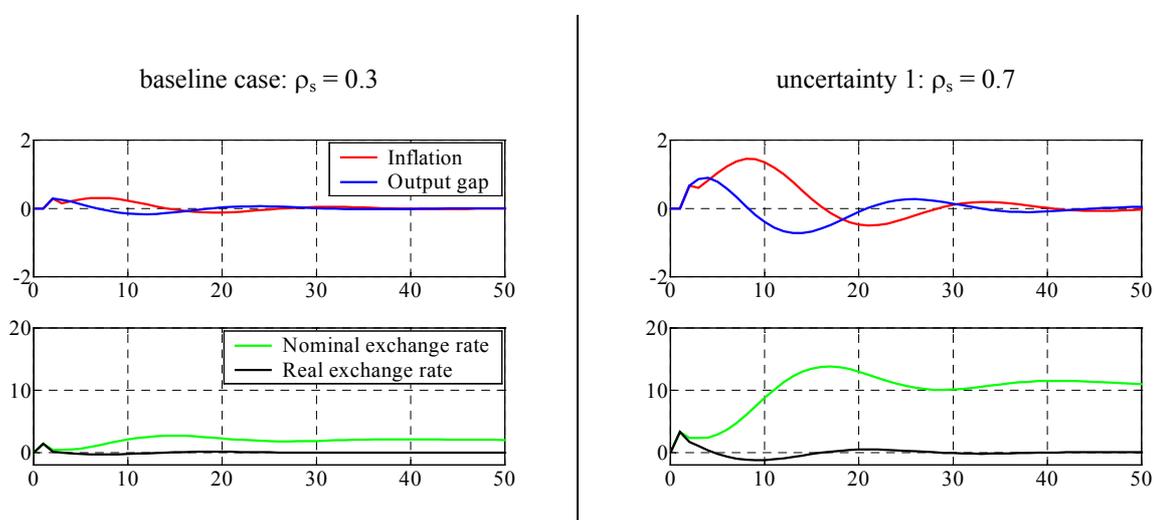
#### IV.2.2.1.2 Calibration and dynamics of exchange rate uncertainty 1

Table IV.6 showed that the degree of uncertainty about the true persistence parameter is high so that in our simulations we finally allowed for variations of  $\rho_s$  in a range from 0 to 0.99. The dynamics of the baseline model and of the related uncertainty are illustrated in Figure IV.3. In order to show how shocks to the risk premium impact on inflation, output and the exchange rate we assume for simplicity that the monetary policy authority conducts a neutral monetary policy which is defined by a constant real interest rate. This has the advantage that the impact of shocks on macroeconomic variables is undiluted since there is no feedback from the instrument. Technically speaking one could call such a system an unregulated system.

In the left panel we depicted the dynamic effects of a unit shock to the UIP equation in the baseline case with  $\rho_s = 0.3$ . Initially the exchange rate depreciates both in real and in nominal terms. The impact on the output gap and the inflation rate occurs with a one period lag. While the output gap rather quickly returns to zero, the inflation rate exhibits a high degree of persistence which is even fostered by the positive output gap (and slowed down by the appreciating real exchange rate). After the initial depreciation, the real exchange rate path turns

around and the real exchange rate appreciates. Due to the forward-looking behaviour of the foreign exchange market participants  $q_t$  falls as long as the inflation rate is expected to rise and it even undershoots its long run equilibrium given by the zero line.<sup>52</sup> The appreciation then launches a disinflationary process. The nominal exchange rate depreciates as long as the inflation rate exceeds the change in the real exchange rate. However, as opposed to the other variables, it does not return to its initial level. This non-stationarity is illustrated by the green line in Figure IV.3. The right panel shows the same unit shock, but with  $\rho_s = 0.7$ . In principle, the dynamics are the same as in the left panel. Only the extent to which system variables are affected is much more pronounced compared to the case with a lower degree of risk premium persistence.

**Figure IV.3: Risk premium shocks**



#### IV.2.2.2 Exchange rate uncertainty 2: The original Ball (1999b) model for open economies

##### IV.2.2.2.1 Specification of the model equations

As an alternative to UIP, Ball (1999b) proposed a static relationship between the real exchange rate  $q_t$  and the real interest rate (which is defined as the difference between the nominal interest rate  $i_t$  and the current rate of inflation  $\pi_t$ ) of the following form:

$$(IV.27) \quad q_t = -\alpha_i (i_t - \pi_t) + \varepsilon_t^q.$$

<sup>52</sup> This can be shown with equation (IV.79) which can be rewritten as  $E_t q_{t+1} - q_t = r_t - (E_t \pi_{t+1} - \pi_t) - u_t^s$  after setting  $\pi_t^f = r_t^f = 0$ . Since  $r_t$  is constant and zero and  $u_t^s$  is positive and mean reverting, an expected increase in the rate of inflation accelerates the appreciation process.

It captures the idea that a rise in the interest rate makes domestic assets more attractive, leading to an appreciation of the domestic currency. Albeit simplified, his approach is mainly based on empirical findings on reduced-form exchange rate equations (see Section IV.2.2.3).  $\varepsilon_t^q$  is assumed to be a i.i.d. white noise shock.

Compared to the baseline model we replaced the UIP equation (IV.3) with equation (IV.30). The remaining equations are identical to those in the baseline model:

$$(IV.28) \quad \pi_{t+1} = \pi_t + \gamma_y y_t + \gamma_q (q_t - q_{t-1}) + \varepsilon_{t+1}^\pi$$

$$(IV.29) \quad y_{t+1} = \beta_y y_t - \beta_i (i_t - \pi_t) + \beta_q q_t + \varepsilon_{t+1}^y$$

$$(IV.30) \quad q_t = -\alpha_i (i_t - \pi_t) + \varepsilon_t^q$$

$$(IV.31) \quad s_t - s_{t-1} \equiv q_t - q_{t-1} - \pi_t^f + \pi_t.$$

The formulation of the model in state-space form is shown in Appendix IV.A.b.

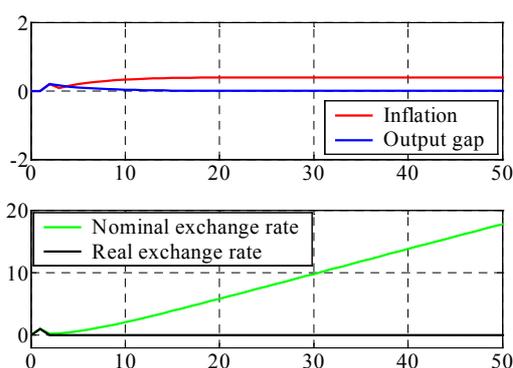
#### IV.2.2.2.2 Calibration and dynamics of exchange rate uncertainty 2

The Phillips curve and the IS equation were calibrated as in the baseline model. Concerning the exchange rate equation Ball (1999b) assumed an interest rate elasticity of the real exchange rate of 2 indicating that a one percentage point rise in the interest rate causes a 2 per cent appreciation. The origin of this value is discussed in more detail in Section IV.2.2.3. As in the discussion of exchange rate uncertainty 1 we even increase the degree of uncertainty in our simulations by not only altering the exchange rate specification (from UIP to equation (IV.30)) but by allowing the parameter  $\alpha_i$  to vary within a range from 0 to 4.

Figure IV.4 presents the dynamic effects of a disturbance to exchange rate equation (IV.30) with a monetary policy that keeps the real interest rate constant.  $\varepsilon_{t+1}^q$  is assumed to be a i.i.d. unit white noise shock. In period 1, the shock leads to a depreciation of the real exchange rate by one per cent which is completely offset in the next period.<sup>53</sup> The output gap and the inflation rate react with a one period lag. The output gap rises by 0.2 ( $= \beta_q$ ) and gradually returns in the

subsequent periods to its initial level. The inflation rate also rises by 0.2 ( $= \gamma_q$ ), but then falls back due to the real appreciation over the second period, and finally rises again as long as the output gap is positive. This implies that the nominal exchange rate pursues a permanent depreciation path. As opposed to the self-stabilising forward looking rational expectations scenario of uncertainty 1, the unregulated backward-looking model is not able to return to equilibrium (or target) levels by itself, and hence, underlines the need for a policy intervention.

**Figure IV.4: Shocks to the exchange rate equation**



### IV.2.2.3 Exchange rate uncertainty 3: The empirical approach of Ryan and Thompson (2000)

#### IV.2.2.3.1 Specification of the model equations

In empirical models for small open economies researchers often found structural reduced-form equations of the exchange rate to be superior to UIP. In a recent study for Australia, Ryan and Thompson (2000, p. 13) summarise this result as follows: “A standard, forward-looking international arbitrage condition is conspicuous in its absence but has repeatedly failed to replicate the observed behaviour of the Australian dollar. Instead, a lagged real interest rate differential has consistently proved more successful.” Thus, in their quantitative simulations they replace UIP by

$$(IV.32) \quad \Delta q_{t+1} = -\alpha_r (r_t - r_t^f) - \alpha_q q_t + \varepsilon_{t+1}^{\Delta q}$$

which can be solved for  $q_{t+1}$ :

<sup>53</sup>  $\alpha_i$  was set to 2. Since the real interest rate is constant, the dynamics are however unaffected by the value of  $\alpha_i$ .

$$(IV.33) \quad q_{t+1} = (1 - \alpha_q)q_t - \alpha_r(r_t - r_t^f) + \varepsilon_{t+1}^{\Delta q}.$$

Accordingly, the current real exchange rate is determined by its own lagged realisation and the lagged real interest rate differential.  $r_t$  is the domestic real interest rate and  $r_t^f$  the foreign real rate.  $\varepsilon_{t+1}^{\Delta q}$  is a white noise disturbance. Similar to the Ball (1999b) approach higher domestic interest rates lead to an appreciation of the currency, however with a one period lag. Additionally, the backward-looking elements in (IV.33) favour a more gradual adjustment as opposed to (IV.27).

Under exchange rate uncertainty 3 the model has the following structure:

$$(IV.34) \quad \pi_{t+1} = \pi_t + \gamma_y y_t + \gamma_q (q_t - q_{t-1}) + \varepsilon_{t+1}^{\pi}$$

$$(IV.35) \quad y_{t+1} = \beta_y y_t - \beta_i (i_t - \pi_t) + \beta_q q_t + \varepsilon_{t+1}^y$$

$$(IV.36) \quad \Delta q_{t+1} = -\alpha_r (r_t - r_t^f) - \alpha_q q_t + \varepsilon_{t+1}^{\Delta q}$$

$$(IV.37) \quad s_t - s_{t-1} \equiv q_t - q_{t-1} - \pi_t^f + \pi_t.$$

The Phillips curve and the IS relation are identical with the baseline model. The UIP equation has been replaced by equation (IV.32). Similar to the baseline model the foreign real interest rate follows an AR(1) process

$$(IV.38) \quad r_t^f = \rho_r r_{t-1}^f + \varepsilon_t^f$$

where  $\varepsilon_t^f$  is a white noise disturbance. The formulation of the model in state-space form is shown in Appendix IV.A.c.

#### IV.2.2.3.2 Calibration and dynamics of exchange rate uncertainty 3

The parameters that have to be determined for a quantitative analysis of uncertainty 3 are the interest rate elasticity  $\alpha_r$  and the exchange rate elasticity  $\alpha_q$  of the change in the real exchange rate. Ryan and Thompson (2000) estimated a macroeconomic model of the Australian economy

on the basis of a single equation framework. For a period from 1985:Q1 to 1998:Q4 they arrive at the following specification for the real exchange rate equation:

$$(IV.39) \quad \Delta q_t = -0.392(r_{t-1} - r_{t-1}^f) - 0.413q_{t-1} + 0.411tot_{t-1} + 1.263\Delta tot_{t-1} + \varepsilon_t^{\Delta q}$$

where  $tot$  is the terms of trade. Beechey et al. (2000) who estimated a model of the Australian economy similar to that of Ryan and Thompson (2000) (with an estimation period ending in 1999:Q3) find the following parameters:

$$(IV.40) \quad \Delta q_t = -0.590(r_{t-1} - r_{t-1}^f) - 0.484q_{t-1} + 0.473tot_{t-1} + 1.290\Delta tot_{t-1} + \varepsilon_t^{\Delta q}.$$

Both studies base their estimation equations on a macroeconomic model for Australia that was developed by de Brouwer and O'Regan (1997). These authors get the following estimates:

$$(IV.41) \quad \Delta q_t = -0.36dum_{t-1}(r_{t-1} - r_{t-1}^f) - 0.63(1 - dum_{t-1})(r_{t-1} - r_{t-1}^f) - \\ -0.32q_{t-1} + 0.33tot_{t-1} + 1.32\Delta tot_{t-1} + \varepsilon_t^{\Delta q}$$

where  $dum$  is a variable that takes a value of one for 1980:Q3 to 1984:Q4 and zero otherwise. The total estimation period ranges from 1980:Q3 to 1996:Q3.

The results of the three studies make clear that the elasticities are subject to a considerable degree of uncertainty. Note that in all estimations the interest rates are expressed in per cent per annum while the change of the real interest rate refers to a quarter of a year. Thus, if we want to equalise the length of the underlying periods, the interest rate elasticity has to be multiplied by four which yields a value between  $-2.52$  and  $-1.44$  for the abovementioned empirical studies.<sup>54</sup> These are the values that Ball (1999b) had in mind when he set  $\alpha_r$  in his model to 2. The parameter  $\alpha_q$  roughly ranges between 0.3 and 0.5. Thus, in accordance with the previous Sections, exchange rate uncertainty 3 not only refers to the possibility that the UIP condition of the baseline model is not the true exchange rate equation, but also to uncertain parameters within this alternative specification. We allowed  $\alpha_r$  to vary between 0 and 4, and  $\alpha_q$  between 0 and 1.

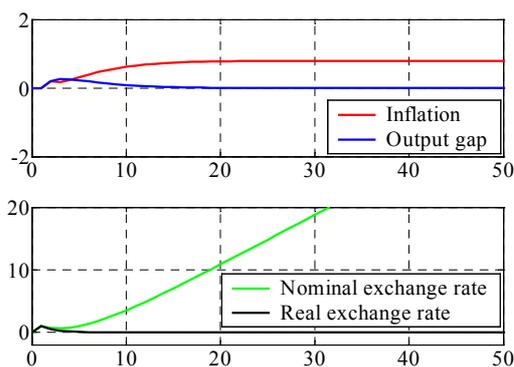
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<sup>54</sup> Recall that our model does not explicitly refer to any specific frequency. Because of the scarce lag structure it could at best be interpreted as an annual model (see Section IV.1.1.2).

For the reasons outlined in Section IV.1.1.2 the variance of  $\varepsilon_t^f$  and the persistence parameter  $\rho_f$  were set to zero.

The dynamics of a unit shock to the exchange rate equation (IV.36) is shown in Figure IV.5. For the impulse-responses we set  $\alpha_r = 2$  and  $\alpha_q = 0.5$ . It is quite obvious that the dynamics of uncertainty 3 are similar to those of the original Ball (1999b) specification. The major difference stems from the increased persistence of the exchange rate shock (due to the parameter  $\alpha_q$ , see equation (IV.33)). As a consequence, the output gap reverts more slowly to zero which in turn causes a higher increase of the inflation rate. The nominal exchange rate finally depreciates faster than before.

**Figure IV.5: Shocks to the exchange rate equation**



#### IV.2.2.4 Exchange rate uncertainty 4: Mixed expectations I (Dennis, 2000)

##### IV.2.2.4.1 Specification of the model equations

The problem with the empirical approaches of the last two Sections is that they fully reject the hypothesis of the exchange rate as an asset price since rational expectations are no longer part of the determinants of the current exchange rate. An attempt to simultaneously capture the features found in data based models on the one hand and the requirements implied by rationality and efficient market considerations on the other hand is to introduce mixed expectations. Dennis (2000) uses the following modified UIP condition:

$$(IV.42) \quad s_t = \nu E_t s_{t+1} + (1 - \nu) s_{t-1} - i_t + i_t^f + \varepsilon_t^s.$$

The parameter  $\nu$  defines the degree of forward-looking and rational behaviour and  $\varepsilon_t^s$  is a white noise disturbance. If  $\nu$  approaches unity, expectations are predominantly forward-looking. If  $\nu$  approaches zero, expectations are predominantly static and backward-looking. In fact, (IV.42) is a simplified version of the chartist-fundamentalist model presented in Chapter III. Instead of using an elaborate moving average trading rule, the chartists in the specification of Dennis (2000) simply forecast the exchange rate in  $t+1$  by its realisation in  $t-1$ .

Compared with the baseline model we only replaced the UIP equation with equation (IV.45):

$$(IV.43) \quad \pi_{t+1} = \pi_t + \gamma_y y_t + \gamma_q (q_t - q_{t-1}) + \varepsilon_{t+1}^\pi$$

$$(IV.44) \quad y_{t+1} = \beta_y y_t - \beta_i (i_t - \pi_t) + \beta_q q_t + \varepsilon_{t+1}^y$$

$$(IV.45) \quad s_t = \nu E_t s_{t+1} + (1 - \nu) s_{t-1} - i_t + i_t^f + u_t^s$$

$$(IV.46) \quad s_t - s_{t-1} \equiv q_t - q_{t-1} - \pi_t^f + \pi_t.$$

Again the foreign interest rate follows an AR(1) process

$$(IV.47) \quad i_t^f = \rho_f i_{t-1}^f + \varepsilon_t^f$$

where  $\varepsilon_t^f$  is a white noise disturbance.  $\pi_t^f$  has been set to zero. Thus,  $i_t^f = r_t^f$  and equation (IV.45) can be rewritten as

$$(IV.48) \quad s_t = \nu E_t s_{t+1} + (1 - \nu) s_{t-1} - i_t + r_t^f + u_t^s.$$

Additionally, we modelled the shock to the exchange rate equation as an AR(1) process:

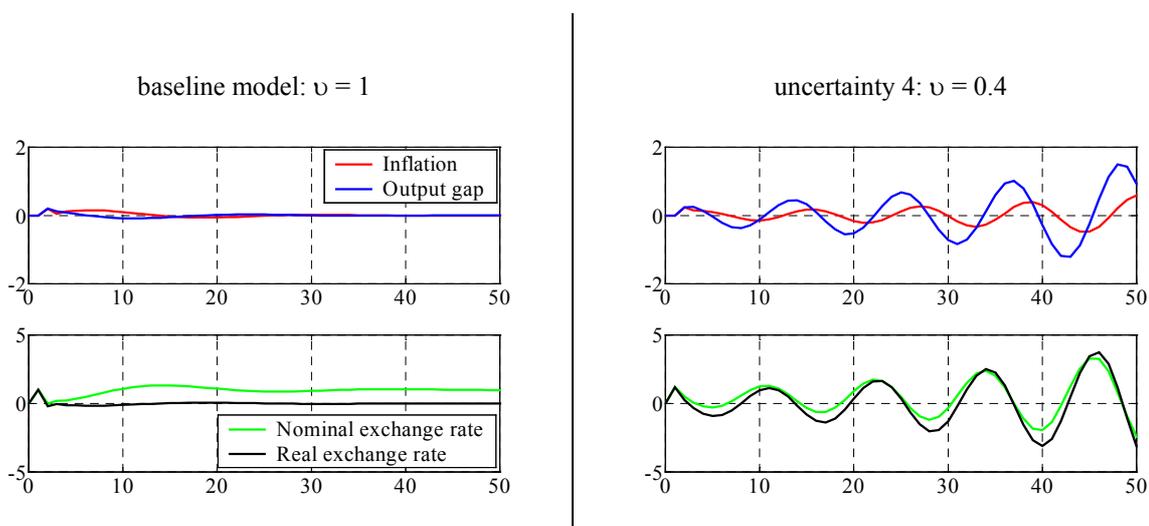
$$(IV.49) \quad u_t^s = \rho_s u_{t-1}^s + \varepsilon_t^s$$

where  $\varepsilon_t^s$  is zero mean i.i.d. The formulation of the model in state-space form is shown in Appendix IV.A.d.

## IV.2.2.4.2 Calibration and dynamics of exchange rate uncertainty 4

Again shocks to the foreign interest rate  $\varepsilon_t^f$  are ignored in our simulations. Shocks to the exchange rate equation are assumed to be white-noise ( $\rho_s = 0$ ) with a variance of 1. Uncertainty occurs with respect to the degree of backward-looking behaviour ( $1 - \nu$ ) in the foreign exchange market. Dennis (2000) only considered the extreme cases of  $\nu = 1$  and  $\nu = 0$ . In our simulations, however, we allowed  $\nu$  to vary over the entire spectrum from 1 to 0.

**Figure IV.6: Shocks to the exchange rate equation**



The left panel of Figure IV.6 shows the dynamics of a unit exchange rate shock with fully rational expectations ( $\nu = 1$ ) and neutral monetary policy ( $r_t$  is constant). This case is similar to that of the baseline model discussed in Section IV.2.2.1.2 except for the assumption that the shock exhibits no persistence. In the right panel we set  $\nu = 0.4$ . On the one hand a high degree of unregulated backward-looking behaviour destabilises the system. On the other hand it amplifies the oscillations of the system variables. Both can be explained by separating the backward-looking (static) component from the exchange rate equation. For  $\nu = 0$  equation (IV.95) becomes

$$(IV.50) \quad q_t = q_{t-1} - 2\pi_t - r_t + r_t^f + u_t^s.$$

While according to the Phillips curve equation (IV.43)  $\pi_t$  rises after a depreciation of the real exchange rate with a factor below one, the increase of the inflation rate triggers an immediate

appreciation that is two times higher than  $\pi_t$ . Thus, the more  $\upsilon$  decreases, the more the destabilising effect prevails and the higher the oscillations of the system.

#### IV.2.2.5 Exchange rate uncertainty 5: Mixed expectations II (Leitemo and Söderström, 2001)

##### IV.2.2.5.1 Specification of the model equations

A somewhat more elaborate specification of backward-looking behaviour can be found in Leitemo and Söderström (2001). Instead of static expectations for the backward-looking part of the expectations, they assumed agents to form expectations adaptively. UIP then becomes

$$(IV.51) \quad s_t = \upsilon E_t s_{t+1} + (1 - \upsilon) \mathbf{E}_t s_{t+1} - i_t + i_t^f + \varepsilon_t^s$$

where  $\mathbf{E}$  is the adaptive expectations operator and  $\varepsilon_t^s$  a white noise disturbance. The parameter  $\upsilon$  again defines the degree of forward-looking behaviour on the international financial markets. If expectations are purely adaptive ( $\upsilon = 0$ ) agents update their exchange rate expectations gradually in the direction of the observed exchange rate

$$(IV.52) \quad \mathbf{E}_t s_{t+1} = (1 - \xi) s_t + \xi \mathbf{E}_{t-1} s_t$$

where  $0 < \xi < 1$  measures the rate of updating. By backward-substitution (IV.52) can be solved for  $\mathbf{E}_t s_{t+1}$

$$(IV.53) \quad \mathbf{E}_t s_{t+1} = (1 - \xi) \sum_{\theta=0}^t \xi^\theta s_{t-\theta}$$

according to which the expected exchange rate is defined as a weighted average of previously observed exchange rates.

Under exchange rate uncertainty 5 the open economy model consists of the following equations:

$$(IV.54) \quad \pi_{t+1} = \pi_t + \gamma_y y_t + \gamma_q (q_t - q_{t-1}) + \varepsilon_{t+1}^\pi$$

$$(IV.55) \quad y_{t+1} = \beta_y y_t - \beta_i (i_t - \pi_t) + \beta_q q_t + \varepsilon_{t+1}^y$$

$$(IV.56) \quad s_t = \upsilon E_t s_{t+1} + (1 - \upsilon) \mathbf{E}_t s_{t+1} - i_t + i_t^f + u_t^s$$

$$(IV.57) \quad \mathbf{E}_t s_{t+1} = (1 - \xi) s_t + \xi \mathbf{E}_{t-1} s_t$$

$$(IV.58) \quad s_t - s_{t-1} \equiv q_t - q_{t-1} - \pi_t^f + \pi_t$$

where the exchange rate disturbance and the foreign interest rate follow an AR(1) process

$$(IV.59) \quad u_t^s = \rho_s u_{t-1}^s + \varepsilon_t^s$$

$$(IV.60) \quad i_t^f = \rho_f i_{t-1}^f + \varepsilon_t^f.$$

$\varepsilon_t^s$  and  $\varepsilon_t^f$  are white noise shocks. With  $\pi_t^f = 0$  we get  $i_t^f = r_t^f$ . Thus, equation (IV.56) can be rewritten as

$$(IV.61) \quad s_t = \upsilon E_t s_{t+1} + (1 - \upsilon) \mathbf{E}_t s_{t+1} - i_t + r_t^f + u_t^s.$$

The formulation of the model in state-space form is shown in Appendix IV.A.e.

#### IV.2.2.5.2 Calibration and dynamics of exchange rate uncertainty 5

Similar to the other types of uncertainty,  $\varepsilon_t^f$  is set to zero. Shocks to the exchange rate equation are assumed to be white-noise ( $\rho_s = 0$ ) with a variance of 1. Uncertainty occurs with respect to the degree of rationality  $\upsilon$  and the rate  $\xi$  with which agents with adaptive expectations revise their expectations about the future exchange rate. Again  $\upsilon$  was allowed to vary between 0 and 1. Reasonable parameters for  $\xi$  were chosen on the basis of a study by Frankel and Froot (1987). Using survey data on exchange rate expectations for the US dollar against five major currencies they found statistically significant values of  $\xi$  ranging from 0.05 to 0.09. We somewhat extended the range and allowed  $\xi$  to take values between 0 and 0.15.

The transmission of an unregulated unit exchange rate shock to the variables of the model is shown in Figure IV.7. The upper left panel reproduces the baseline model without persistence in the exchange rate shock ( $\upsilon = 1$  and  $\xi = 0$ ). In the upper right panel we set  $\upsilon = 0.15$  and  $\xi = 0$  which simplifies equation (IV.57) to purely static expectations ( $\mathbf{E}_t s_{t+1} = s_t$ ). In order to give an

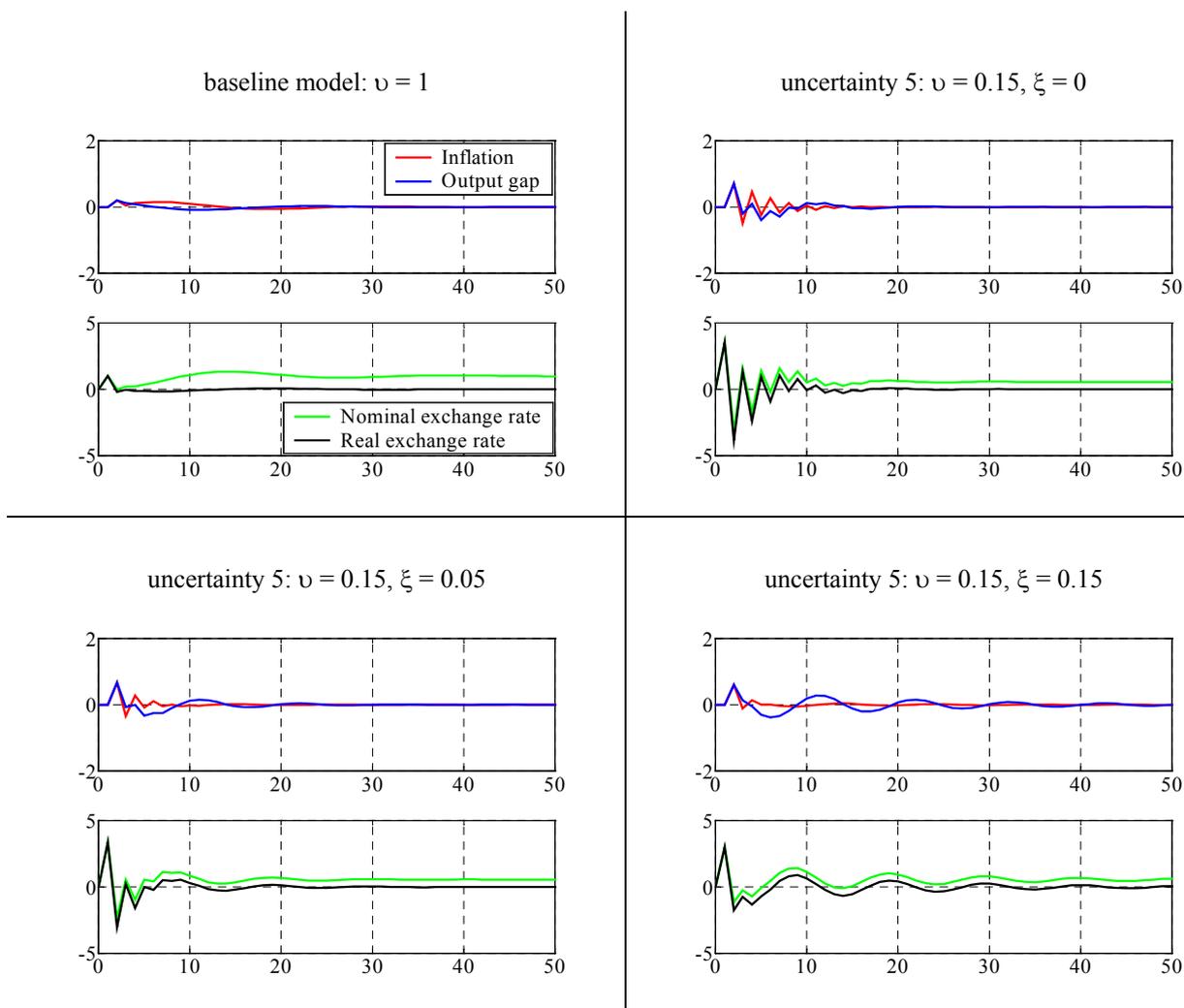
intuit explanation for the alternating behaviour of the exchange rate it is helpful to insert  $\xi = 0$  into equation (IV.106) (see Appendix IV.A.e). Solving for the expected exchange rate change yields

$$(IV.62) \quad E_t \Delta q_{t+1} = -\gamma_q \Delta q_t + \frac{(1-\nu)}{\nu} \pi_t - \gamma_y y_t + \frac{1}{\nu} (r_t - r_t^f - u_t^s).$$

The corresponding equation in the baseline model ( $\nu = 1$ ) is given by (IV.81) (see Appendix IV.A.a):

$$(IV.63) \quad E_t \Delta q_{t+1} = -\gamma_q \Delta q_t - \gamma_y y_t + r_t - r_t^f - u_t^s.$$

**Figure IV.7: Shocks to the exchange rate equation**



Thus, without going too much into detail, a comparison of both equations shows that the lower  $\upsilon$  the higher the impact of the current inflation rate on the expected exchange rate change. With  $\upsilon = 0.15$  the inflation coefficient becomes 5.67. Thus, a rise of the inflation rate due to the depreciation of the exchange rate in the pervious period (see the Phillips curve (IV.54)) causes a far more than proportional appreciation over the subsequent period. The lower left panel simulates an exchange rate shock with  $\upsilon = 0.15$  and  $\xi = 0.05$ , and in the lower right panel we further increased  $\xi$  to 0.15. Independently of the value of  $\xi$  the nominal exchange rate converges the same long-run equilibrium (0.55 for our calibration). However, with a growing rate of updating  $\xi$  the oscillations in the exchange rate process are propagated.

#### *IV.2.2.6 Exchange rate uncertainty 6: The real exchange rate as a random variable*

##### IV.2.2.6.1 Specification of the model equations

In one of the most widely cited papers in the international economics literature Messe and Rogoff (1983) demonstrated that a whole range of fundamentals-based nominal exchange rate models (flexible-price monetary models with and without current account effects, and a sticky-price monetary model) were unable to outperform a simple random walk in an out-of-sample forecasting exercise. Some years later, in Messe and Rogoff (1988) they regressed changes in the real exchange rates on real interest rate differentials to forecast the real exchange rates of three currencies against the dollar. Again they found that the forecasts from the random walk have lower root-mean-square error than those from their regressions in the majority of the post-sample fit experiments. However, as has been shown in Chapter III, the pure random walk of the real exchange rate (i.e.  $\alpha_q = 1$ ) has recently been rejected by studies using long-span data sets in favour of an AR(1) process with a high degree of persistence  $\alpha_q$ . Based on these findings which are still uncontested today (see e.g. Kilian and Taylor, 2003) we posit the following behavioural relationship of the real exchange rate

$$(IV.64) \quad q_{t+1} = \alpha_q q_t + \varepsilon_{t+1}^q.$$

Accordingly, the real exchange rate only depends on its own lagged value and a white noise disturbance  $\varepsilon_{t+1}^q$ . In particular, no other macroeconomic variables, such as the domestic interest rate, have an influence on the exchange rate.

By using (IV.64) instead of the UIP condition the open economy model simplifies to the following equations:

$$(IV.65) \quad \pi_{t+1} = \pi_t + \gamma_y y_t + \gamma_q (q_t - q_{t-1}) + \varepsilon_{t+1}^\pi$$

$$(IV.66) \quad y_{t+1} = \beta_y y_t - \beta_i (i_t - \pi_t) + \beta_q q_t + \varepsilon_{t+1}^y$$

$$(IV.67) \quad q_{t+1} = \alpha_q q_t + \varepsilon_{t+1}^q$$

$$(IV.68) \quad s_t - s_{t-1} \equiv q_t - q_{t-1} - \pi_t^f + \pi_t,$$

where  $\varepsilon_{t+1}^q$  is a white noise shock. The formulation of the model in state-space form is shown in Appendix IV.A.f.

#### IV.2.2.6.2 Calibration and dynamics of exchange rate uncertainty 6

We allowed for additional uncertainty by assuming  $\alpha_q$  to take values between zero and unity. For reasons of non-stationarity, however, the pure random walk scenario in which  $\alpha_q = 1$  has to be excluded from the range of possible values. Thus, we only approximated the random walk by defining the real exchange rate as a stationary AR(1) process with an autocorrelation coefficient approaching unity.

**Figure IV.8: Shocks to the exchange rate equation**

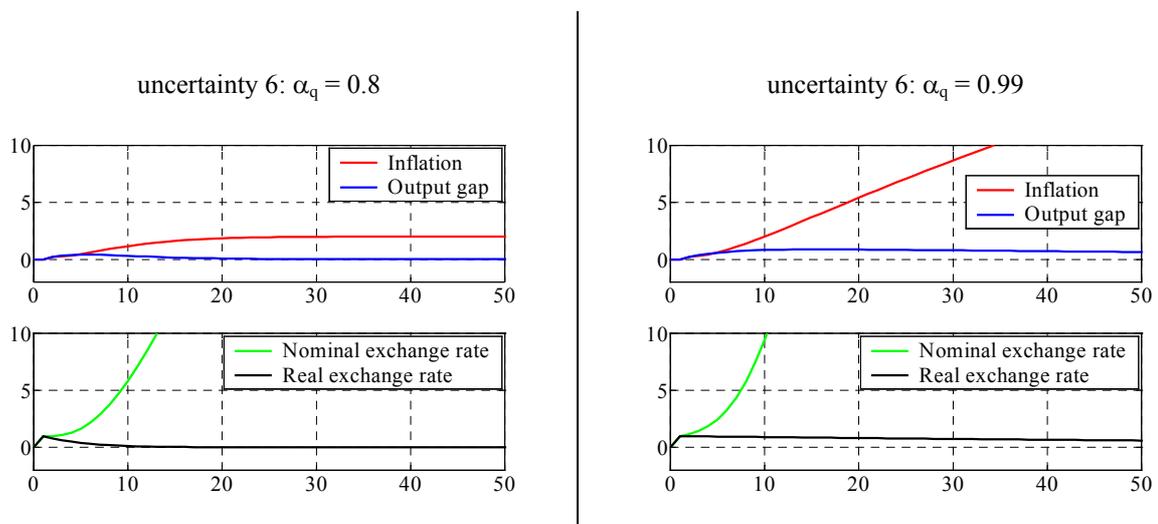


Figure IV.8 shows the impact of a unit exchange rate shock on the variables of the model under a constant real interest rate. The left panel depicts the impulse-response with  $\alpha_q = 0.8$  whereas the right panel simulates the near-random-walk case ( $\alpha_q = 0.99$ ). The latter points out the problem of non-stationarity. If the real exchange rate did not exhibit any convergence to its initial level, the rate of inflation would end in an exploding process. Besides the high persistence of the exchange rate shock, the dynamics of uncertainty 6 are quite similar to those of uncertainty 2 and 3.

### *IV.2.3 Summary*

In order to clarify the information, in this Section we summarise Sections IV.2.2.1 to IV.2.2.6. The six alternative exchange rate specifications are

- an uncovered interest parity condition that is subject to risk premium shocks with an uncertain degree of persistence (baseline model, U1)
- the specification used in the original Ball (1999b) model where the real exchange rate reacts to contemporaneous movements in the real exchange rate (U2)
- the empirical approach of Ryan and Thompson (2000) where a lagged interest rate differential determines the change in the real exchange rate (U3)
- an uncovered interest parity with mixed expectations (I) where part of the economic agents simply take the last periods value of the exchange rate as their expectation of its next period value (U4)
- an uncovered interest parity with mixed expectations (II) where part of the economic agents form their expectations about the future exchange rate adaptively (U5)
- a random behaviour of the real exchange rate without any determinant other than its own lagged value (U6).

Table IV.7 summarises the concrete exchange rate specifications as well as the ranges of variation of the uncertain coefficients. All the shocks in U2 to U6 were defined to be white noise. Furthermore, in case the foreign interest rate figures in the exchange rate equation it was set to zero.

**Table IV.7: Summary of the different exchange rate specifications**

exchange rate uncertainty		exchange rate specification	variation of
U1	UIP and risk premium	$E_t s_{t+1} = s_t + i_t - i_t^f + u_t^s$ with $u_t^s = \rho_s u_{t-1}^s + \varepsilon_t^s$	$\rho_s \in [0; 1[$
U2	original Ball (1999b)	$q_t = -\alpha_i (i_t - \pi_t) + \varepsilon_t^q$	$\alpha_i \in [0; 4]$
U3	Ryan and Thompson (2000) approach	$\Delta q_t = -\alpha_r (r_{t-1} - r_{t-1}^f) - \alpha_q q_{t-1} + \varepsilon_t^{\Delta q}$	$\alpha_r \in [0; 4]$ $\alpha_q \in [0; 1]$
U4	mixed expectations (I)	$s_t = \nu E_t s_{t+1} + (1-\nu) s_{t-1} - i_t + i_t^f + u_t^s$	$\nu \in ]0; 1]$
U5	mixed expectations (II)	$s_t = \nu E_t s_{t+1} + (1-\nu) \mathfrak{E}_t s_{t+1} - i_t + i_t^f + u_t^s$ with $\mathfrak{E}_t s_{t+1} = (1-\xi) s_t + \xi \mathfrak{E}_{t-1} s_t$	$\nu \in ]0; 1]$ $\xi \in [0; 0.15]$
U6	random behaviour	$q_t = \alpha_q q_{t-1} + \varepsilon_t^q$	$\alpha_q \in [0; 1[$

### IV.3 Monetary policy under exchange rate uncertainty

In the previous Section we presented various approaches to replacing strict UIP with other exchange rate specifications that are mainly supported by empirical findings. The question that we are going to answer in this Section is: Is the conduct of monetary policy affected by the uncertainty about the true exchange rate behaviour? Or, to be more precise, do the simple policy rules that the monetary policy maker derived from the baseline model in Section IV.1<sup>55</sup> yield reasonably good outcomes over the different exchange rate specifications presented in Section IV.2? If the answer turned out to be positive, then the high degree of exchange rate uncertainty that we can observe in regimes of market determined exchange rates would not be a cause for concern for the policy makers. The commitment to such a so-called robust policy rule would insulate the economy from the negative consequences of both, exchange rate shocks and uncertain transmission of interest rate impulses via the exchange rate channel. If, however, the performance of the policy rules largely depends on the concrete exchange rate specification (which is subject to uncertainty), then the role of market determined exchange rates for monetary policy has to be assessed from a different angle.

The outcome of the policy rules under exchange rate uncertainty is evaluated on two levels. The first level (Section IV.3.2) compares the performance in terms of the variability of the goal

<sup>55</sup> To be precise, we analyse the performance of the six policy rules presented in Table IV.3 of Section IV.1.4.2.

variables – and hence in terms of the loss function – of each of the policy rules (i) with the performance of the same policy rule in the baseline model (isolated performance) and (ii) with the performance of the other policy rules in the same uncertainty scenario (competitive performance). While comparison (i) is interesting in relation to the question of whether exchange rate uncertainty leads to a welfare loss in general, comparison (ii) will provide a rationale for the observed popularity of regimes of indirect managed floating.

The second level (Section IV.3.3) discusses the impact of exchange rate uncertainty on the volatility of the central bank's operating target. In particular, we focus on the relationship between exchange rate uncertainty and the probability that the nominal interest rate reaches the zero lower bound. If the nominal interest rate is bound at zero, this may have an important feedback on the stabilising properties of interest rate policy rules, and hence again on the performance in terms of the loss function.

### *IV.3.1 Determinacy of the policy rules in other model specifications*

Before calculating the losses generated by each policy rule under different model specifications we have to address the fundamental question of whether the policy rules are associated with a determinate equilibrium in each exchange rate specification or not. If a rule fails to ensure determinacy, then the economy may follow either a number of different equilibrium paths or an unstable and explosive path. If, however, the policy rule results in a determinate equilibrium, there exists a unique stationary path for the variables of the dynamic system (Woodford, 2002a).

The existence and uniqueness of a solution to a dynamic system can be examined using a method proposed by Blanchard and Kahn (1980). By inserting the policy rule (IV.17) into our model (IV.14) we get:

$$(IV.69) \quad \begin{pmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{pmatrix} = (A + BF^s) \begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix} = \tilde{A} \begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix}$$

where  $x_{1,t}$  is an  $n_1 \times 1$  vector of predetermined (backward looking) variables and  $x_{2,t}$  an  $n_2 \times 1$  vector of forward looking variables. Define  $q$  the number of eigenvalues of  $\tilde{A}$  outside the unit circle, i.e.

**Table IV.8: Regions of indeterminacy**

uncertainty	policy rule	regions of indeterminacy		
U1	R1 – R6	-		
U2	R2, R3, R6	-		
	R1	$\alpha_i \in [2.2; 4]$		
	R4/R5	$\alpha_i \in [1.4; 4]$		
U3	R1	$\alpha_q = 0.2, \alpha_q = 0.4$	$\alpha_r \in [2.4; 4]$	
		$\alpha_q = 0.6, \alpha_q = 0.8$	$\alpha_r \in [2.3; 4]$	
	R2	$\alpha_q = 0.2$	$\alpha_r \in [2.5; 4]$	
		$\alpha_q = 0.4$	$\alpha_r \in [2.3; 4]$	
		$\alpha_q = 0.6$	$\alpha_r \in [2.2; 4]$	
		$\alpha_q = 0.8$	$\alpha_r \in [2.1; 4]$	
	R3	$\alpha_q = 0.2$	$\alpha_r \in [3.0; 4]$	
		$\alpha_q = 0.4$	$\alpha_r \in [3.1; 4]$	
		$\alpha_q = 0.6$	$\alpha_r \in [3.3; 4]$	
		$\alpha_q = 0.8$	$\alpha_r \in [3.4; 4]$	
	R4/R5	-		
	R6	$\alpha_q = 0.8$	$\alpha_r \in [3.7; 4]$	
	U4	R1 – R6	-	
U5	R1	$\xi = 0$	$\upsilon \in [0; 0.32]$	
		$\xi = 0.05$	$\upsilon \in [0; 0.29]$	
		$\xi = 0.1$	$\upsilon \in [0; 0.26]$	
		$\xi = 0.15$	$\upsilon \in [0; 0.22]$	
	R2	$\xi = 0$	$\upsilon \in [0; 0.20]$	
		$\xi = 0.05$	$\upsilon \in [0; 0.16]$	
		$\xi = 0.1$	$\upsilon \in [0; 0.12]$	
		$\xi = 0.15$	$\upsilon \in [0; 0.08]$	
	R3	$\xi = 0$	$\upsilon \in [0; 0.21]$	
		$\xi = 0.05$	$\upsilon \in [0; 0.17]$	
		$\xi = 0.1$	$\upsilon \in [0; 0.14]$	
		$\xi = 0.15$	$\upsilon \in [0; 0.10]$	
	R4 – R6	-		
	U6	R1 – R6	-	

$$(IV.70) \quad |\lambda_i| > 1, i = 1, 2, \dots, q$$

then there is

- a unique solution if  $q = n_2$
- no solution if  $q > n_2$
- a multiplicity of solutions if  $q < n_2$ .

Table IV.8 summarises the results for the six policy rules in each model specification. In U1, U4 and U6 each of the rules guarantees a unique equilibrium. In U2 policy rules R1 and R4 destabilise the economy for an  $\alpha_i$  exceeding 2.2 and 1.4 respectively.<sup>56</sup> This signifies an important limitation to these two rules. Since Ball (1999b) set  $\alpha_i$  to 2.0 in his calibration, we put this value in the middle of the spectrum of possible values for  $\alpha_i$ . If we assume some kind of normal distribution around 2.0, for R1 there is a high probability that it falls into the region of indeterminacy; and for R4 this probability even exceeds 50 percent. The same limitation applies to R1 and R2 in U3. R3 only destabilises the economy for values of  $\alpha_r$  larger than 3. Policy rules R4 to R6 lead to a unique equilibrium (with the one exception indicated in the Table). For the mixed expectations scenario represented by U5 policy rules R1, R2 and R3 only destabilise the economy for a high degree (about 70 percent and more) of adaptive expectations. As a general rule it can be said that the higher the rate of updating represented by  $\xi$ , the more extended the region of determinacy. R4 to R6 finally leads to a unique equilibrium for all uncertain parameters.

### ***IV.3.2 The performance of monetary policy rules under exchange rate uncertainty***

#### *IV.3.2.1 The isolated performance of the policy rules under exchange rate uncertainty*

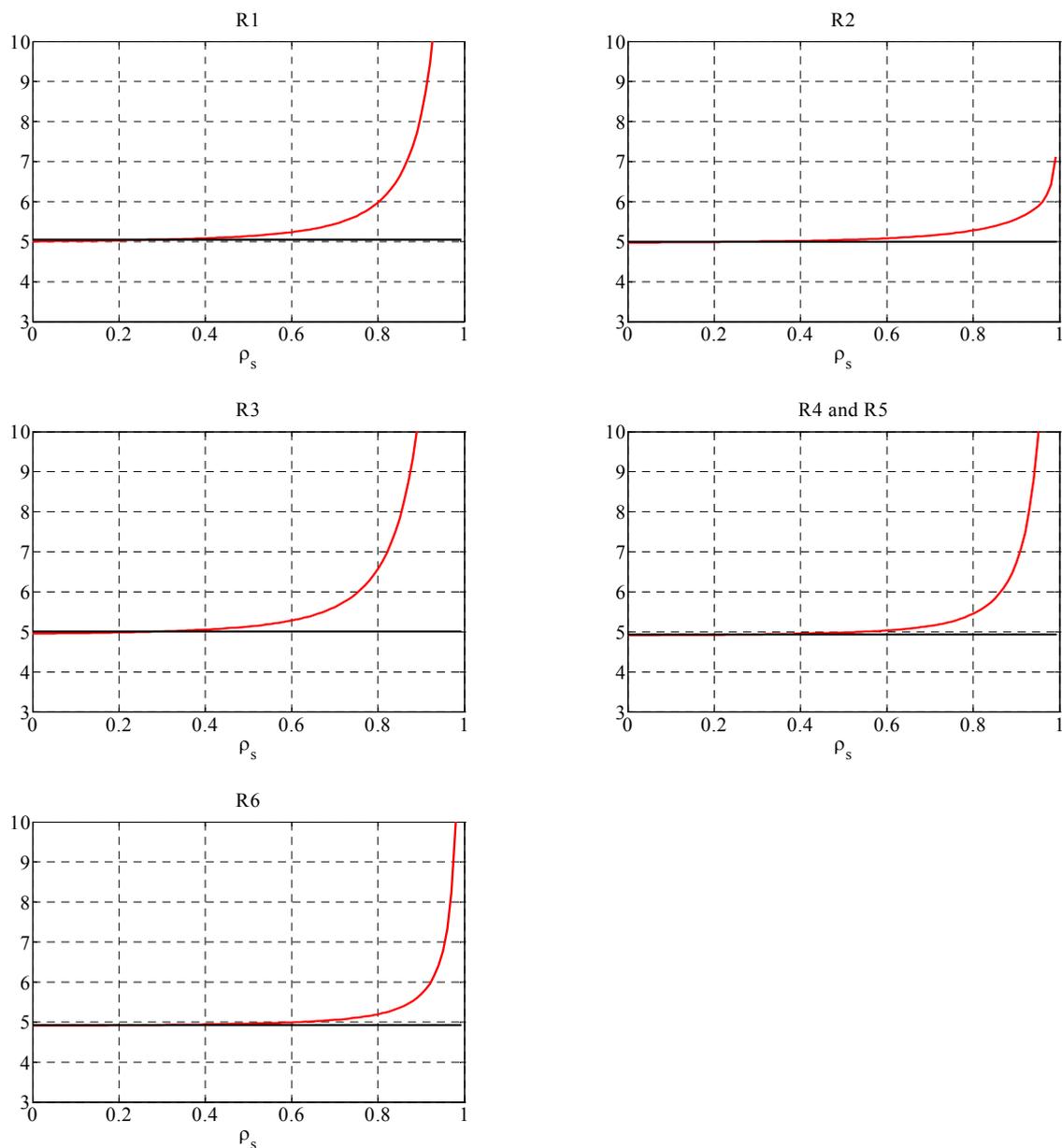
The performance of a policy rule is typically measured in terms of the unconditional loss that results from the policy rule when simulated in a model. The analysis of the isolated performance of a policy rule aims at comparing the performance of a particular policy rule in the baseline model with the performance of the same policy rule in the six uncertainty scenarios defined above. The question that we are going to answer in this Section is whether the uncertainty about

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<sup>56</sup> See Appendix IV.C on the simulations of simple policy rules under U2.

the true exchange rate specification leads to a welfare loss – measured by a higher value of the loss function – once the central bank has decided for a particular policy rule. Figure IV.9 to Figure IV.14 show the loss curves of each of the six policy rules in the six uncertainty scenarios. As a reference value the black horizontal line in each chart represents the loss of the policy rule under consideration that would occur if the baseline model was true. We come to the following results:

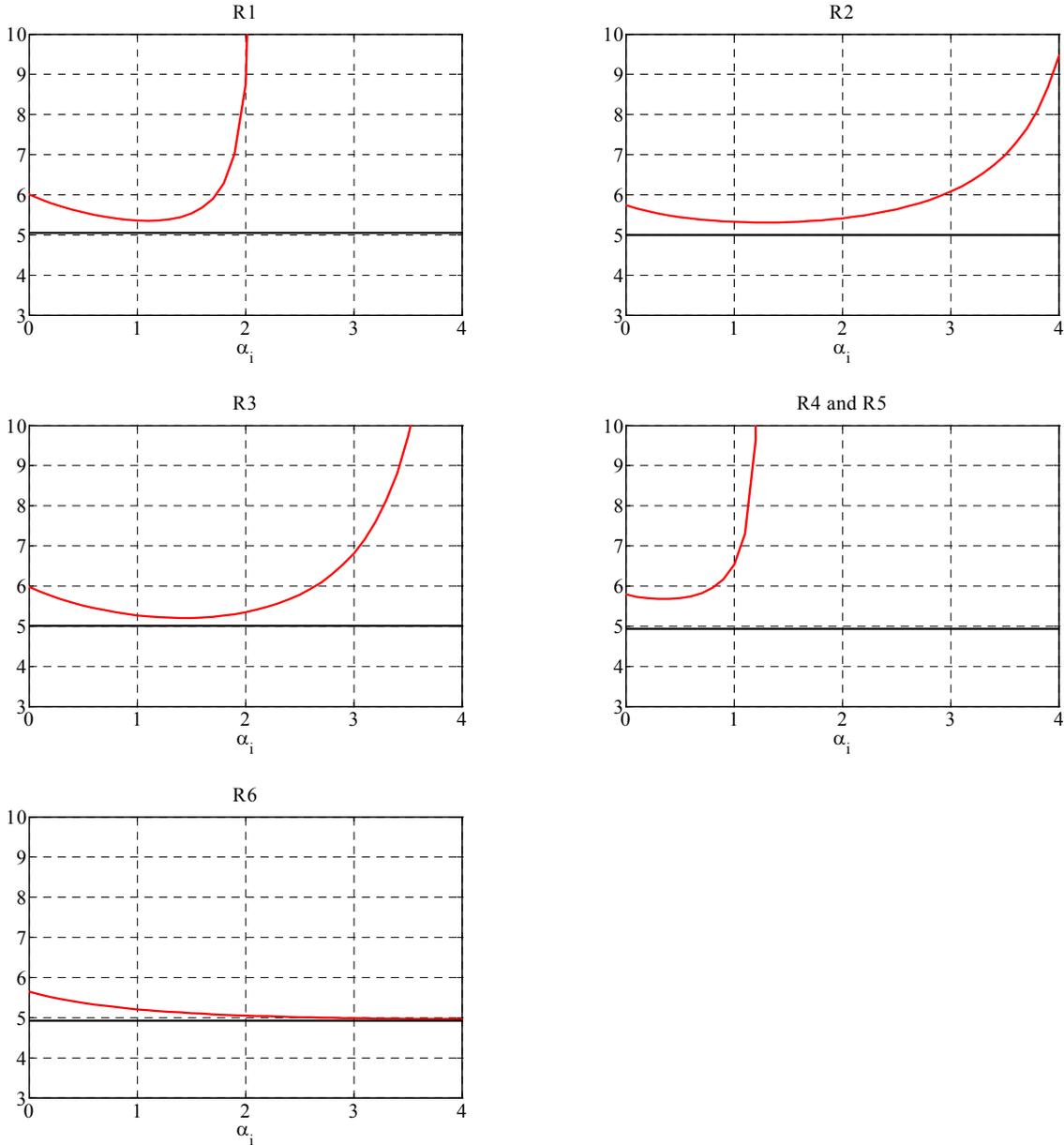
**Figure IV.9: Exchange rate uncertainty 1**

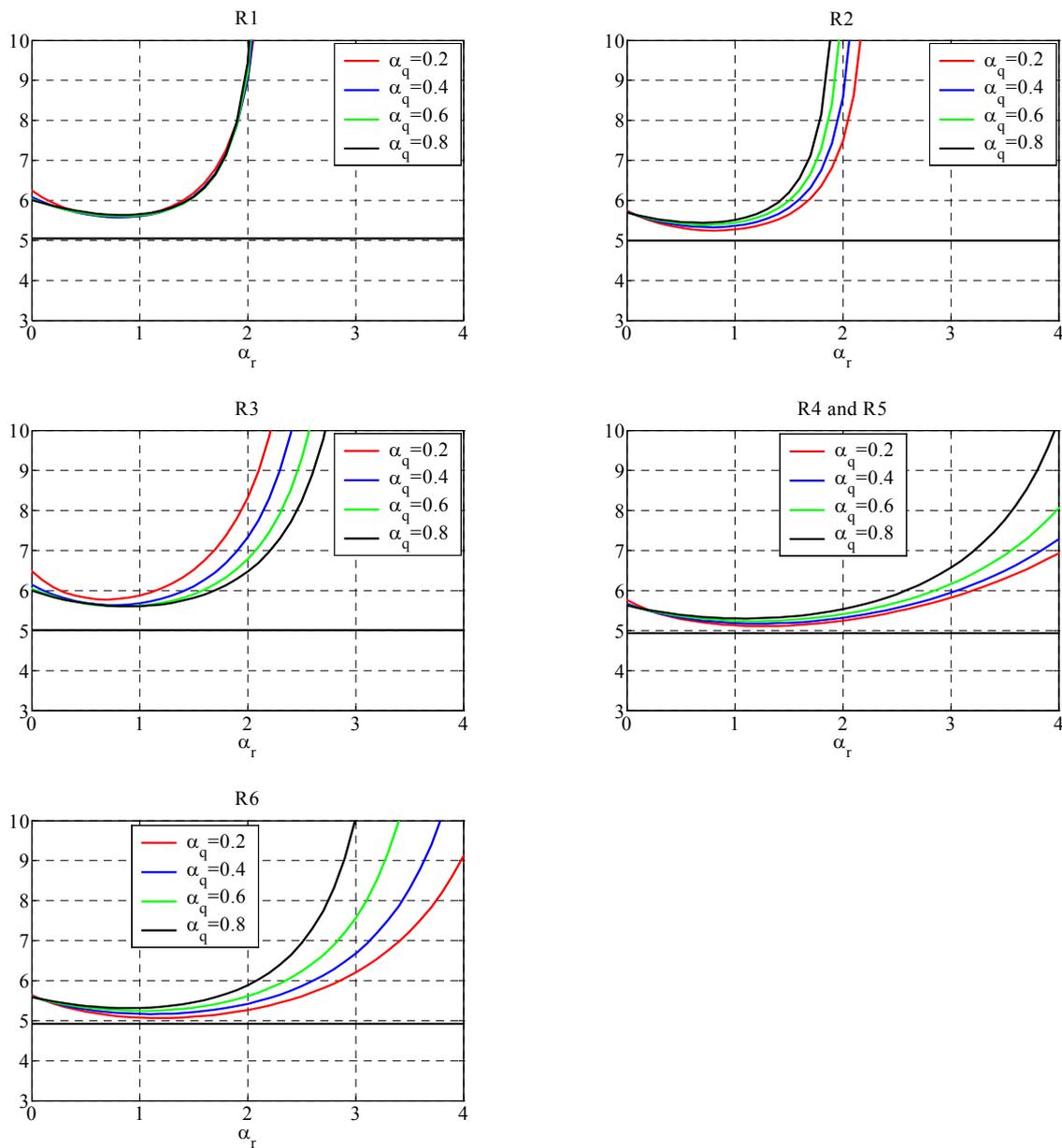


First, with a growing risk premium persistence (U1; see Figure IV.9), the loss increases. While variations of  $\rho_s$  between 0 and 0.5 do not have a major impact on the value of the loss function,

a  $\rho_s$  approaching unity makes the loss grow progressively. All the rules then result in a loss higher than that in the baseline model.

Figure IV.10: Exchange rate uncertainty 2



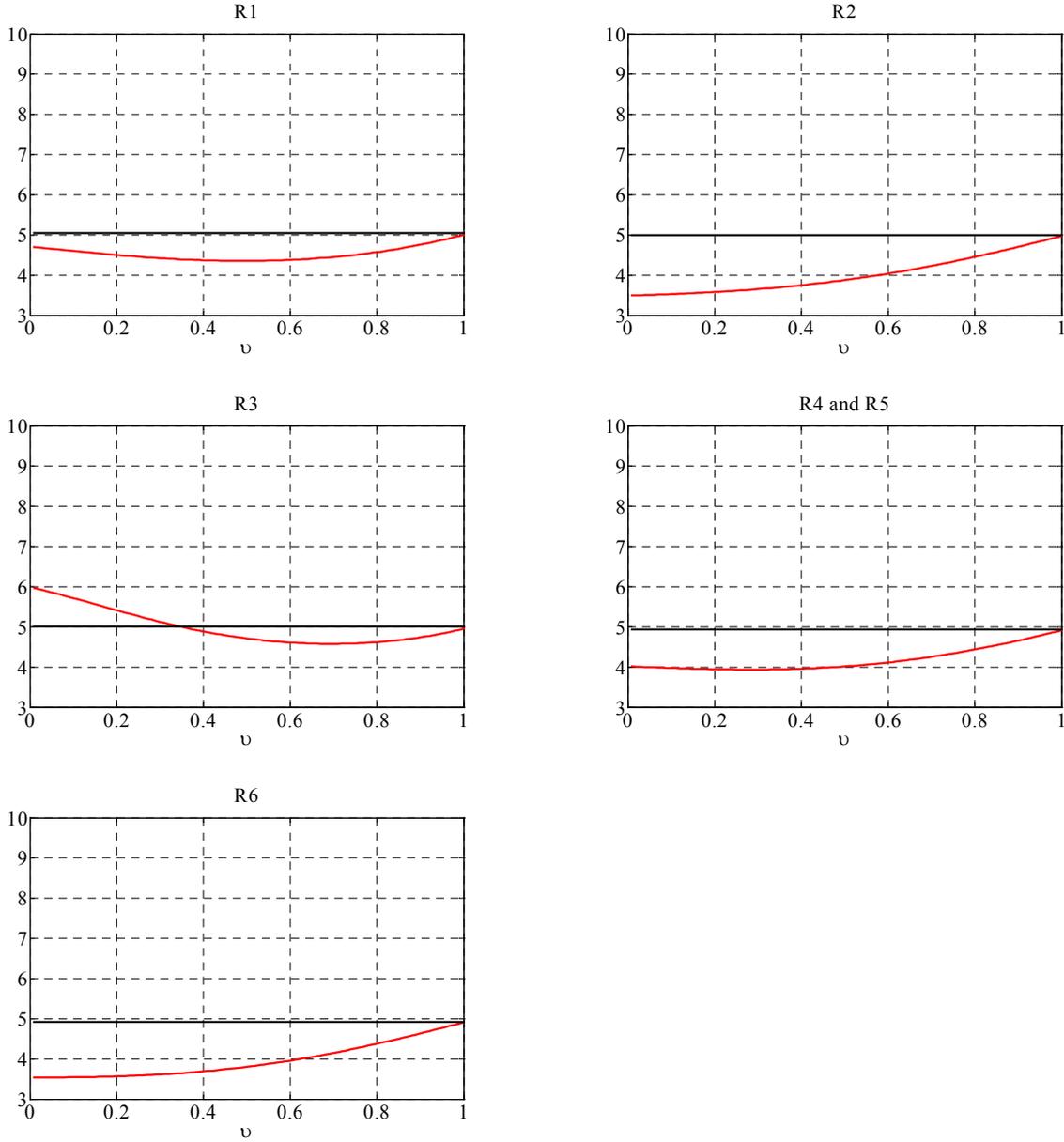
**Figure IV.11: Exchange rate uncertainty 3**

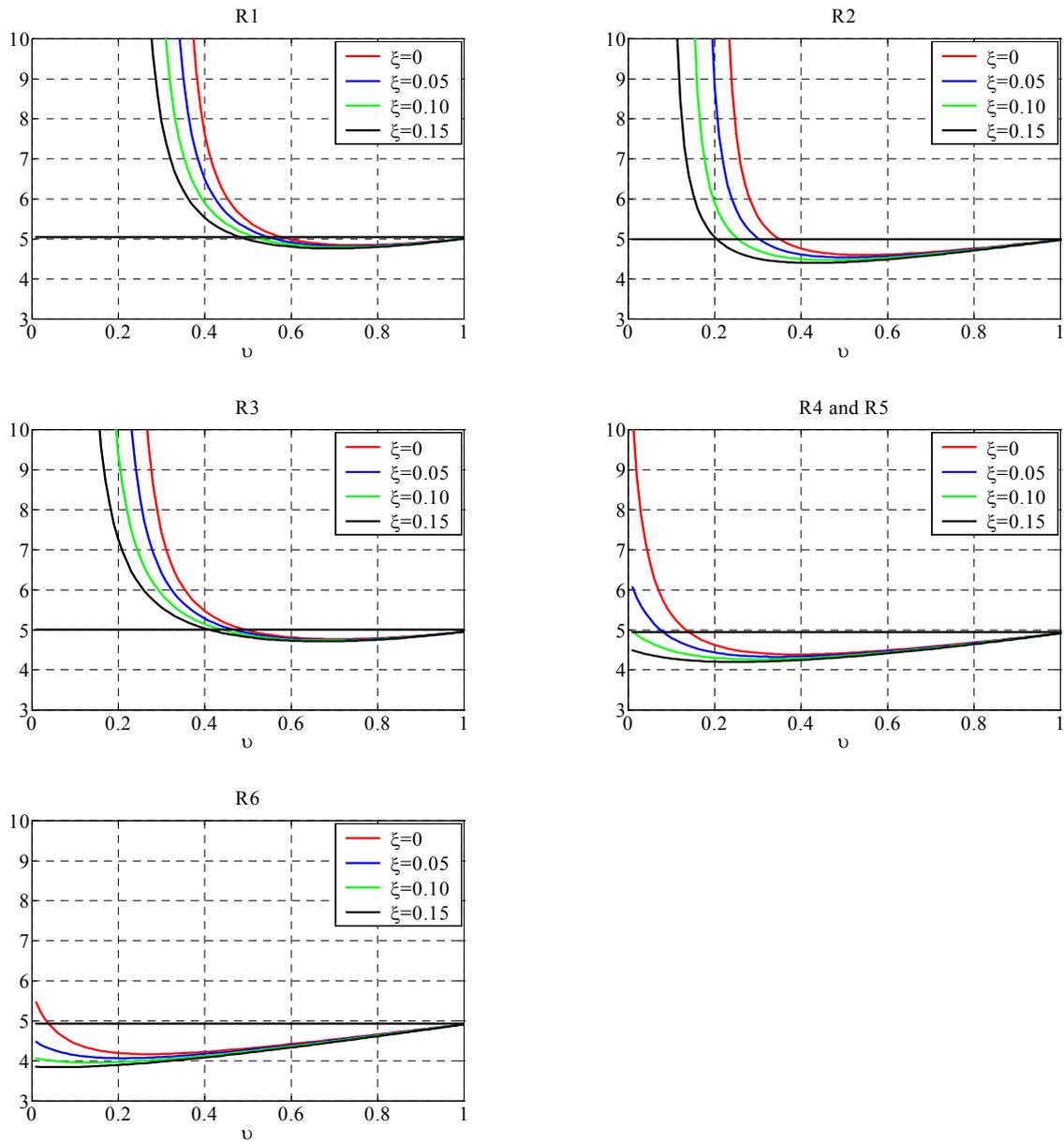
Second, the empirical approaches to the determination of the real exchange rate (U2 and U3; see Figure IV.10 and Figure IV.11, respectively) produce U-shaped loss curves. The loss reaches its minimum for an interest rate elasticity of the real exchange rate somewhere between zero and two. With a growing  $\alpha_{i/r}$  the loss increases much faster than with a falling  $\alpha_{i/r}$ . Thus, the curves have an asymmetric shape which also reflects the results obtained in the previous Section according to which some of the rules destabilise the economy for high  $\alpha_{i/r}$  (see Table IV.8). A notable exception is the outcome of R6 under U2. The resulting loss seems to be almost immune

against uncertainty about  $\alpha_i$ . An explanation for this result can be found if we remind ourselves that U2 corresponds to the original Ball (1999b) model (for  $\alpha_i = 2$ ). Ball found that the following policy rule performed optimally within his simple open economy model:  $i_t = 2.51\pi_t + 1.93y_t + 0.43q_t - 0.30q_{t-1}$ . Apart from the fact that his feedback parameters are all somewhat higher, there is a great similarity between his rule and R6. Notwithstanding the good performance of R6 under U2, all the rules (including R6) produce a higher loss under U2 and U3 compared with their outcome under certainty. Additionally, under U3, a rising coefficient  $\alpha_q$  (i.e. a lower autocorrelation coefficient of the real exchange rate, see equation (IV.33)) increases the loss from R2, R4, R5 and R6, and reduces the loss from R3. R1 seems to be quite robust against changes in  $\alpha_q$ .

Third, up to a critical mass the introduction of mixed expectations (U4 and U5; see Figure IV.12 and Figure IV.13, respectively) reduces the loss resulting from the policy rules relative to the fully rational baseline case ( $\upsilon = 1$ ). The concrete results, however, depend on both, the policy rule and the exchange rate specification. Thus, we first take a look at U4. The performance of policy rules R2 and R6 becomes better the higher the degree of static (and hence backward-looking) expectations. In contrast to this, the loss curves of the other rules have a minimum which is at  $\upsilon = 0.5$  for R1,  $\upsilon = 0.7$  for R3, and  $\upsilon = 0.3$  for R4 and R5. Nonetheless, with the exception of R3, the loss remains lower than under certainty. An examination of U5 shows that for all policy rules a rising rate of updating adaptive expectations  $\xi$  reduces loss. For a growing degree of adaptive expectations (i.e. a lower  $\upsilon$ ) the behaviour of the loss curve of R1, R2 and R3 differs from that of R4, R5 and R6. The first group reaches a minimum loss at an  $\upsilon$  somewhere between 0.4 and 0.7 which is somewhat below the value of the loss of the respective rule under certainty. If  $\upsilon$  is further reduced, the loss resulting from these rules quickly explodes. In contrast to this, the loss from the last three rules remains below the baseline loss for almost all values of  $\upsilon$ . Only if  $\upsilon$  approaches zero, and  $\xi$  is low, the loss somewhat exceeds the baseline loss.

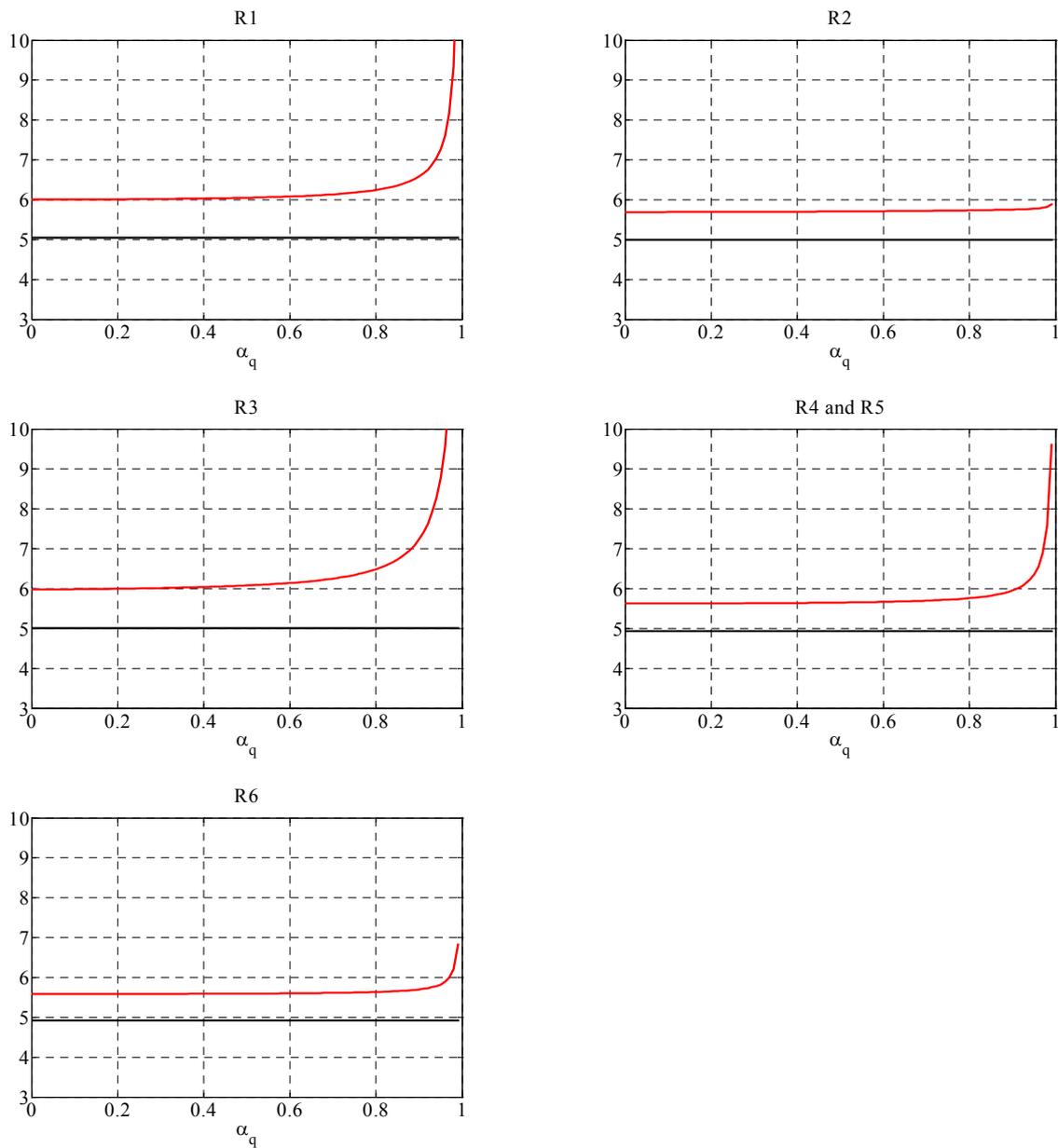
Figure IV.12: Exchange rate uncertainty 4



**Figure IV.13: Exchange rate uncertainty 5**

Finally, with regard to a purely random real exchange rate (U6; see Figure IV.14), loss increases with a growing  $\alpha_q$ . Except for R2 and R6, the loss becomes very high for a pure random walk.

For all rules loss is higher under U6 than under certainty.

**Figure IV.14: Exchange rate uncertainty 6**

In short, the following results should be recorded:

1. The occurrence of U1, U2 and U3 increase the loss from all simple rules (compared to the loss from the baseline specification).
2. The introduction of backward looking behaviour into the UIP equation (mixed expectations) initially improves the performance of the simple rules.
3. With a growing degree of backward looking behaviour (in particular under adaptive expectations) the loss increases significantly (R6 as a notable exception!).

4. A near random walk of the real exchange rate leads to a loss that is significantly higher than in the baseline scenario.

#### *IV.3.2.2 The competitive performance of the policy rules under exchange rate uncertainty*

Section IV.1.4 showed that the performance of optimised simple rules in our baseline specification of the open economy model improves when some weight is put on the exchange rate in the policy rule. However, the improvement is only small compared to the outcome of the independently floating policy rule R1. This result seems to confirm the reluctance of many economists towards making policy rules more complicated by including exchange rate variables.

While a basic assumption underlying the analysis in Section IV.1 was that the central bank knows the behaviour of the private agents with certainty, now the central bank is assumed to operate in a world of uncertainty. So far we have looked at the isolated performance of each policy rule in each exchange rate specification. The result was that once the central bank has committed to specific policy rule there is high probability that welfare deteriorates as the variance of the goal variables is likely to increase significantly. The purpose of this Section is to find among the set of rules the policy rule which always guarantees the policy maker the best outcome, even though he is uncertain about the actual private agents' behaviour. Thus, for each exchange rate specification the policy rules have to compete with each other. The policy rule that performs best across a range of structural models is then called a robust policy rule.

In the literature on model uncertainty one can typically find two methods on how to evaluate the competitive performance of simple interest rate rules across several structural models. Levin et al. (1999) took simple interest rate rules with parameters that were optimised in a baseline model for different preferences of the central bank towards inflation and output and compared the outcome of these rules in terms of the variances of the goal variables and the value of the loss function in structurally different models. The baseline model is defined as the model that the policy maker deems to be more likely than the alternative specifications. Leitemo and Söderström (2001) applied the same proceeding in their open economy study.

The second method differs from the first mainly in its treatment of the optimised policy rule. While in the first approach the policy maker must rely on a particular parameterisation of a rule (with given numerical coefficients resulting from the optimisation in the baseline model) and

then consider the performance of that given fixed rule across various models, Rudebusch (2001) optimises a simple rule for each model specification. He then calculates the performance of each rule within the rule-generating model and compares the results of one model with those of other specifications. In Rudebusch (2002) he also assesses the performance of various structurally different optimised interest rate rules by setting up a ranking in terms of loss within each model under consideration. However, in the same paper he admits that “these results do not capture the model uncertainty faced by a policy maker” and that “the performance of a fixed rule across models is in the essence of the model robustness criterion championed by McCallum (1999)” (Rudebusch, 2002, p. 417). The same criticism has been pronounced by Stock (1999, p. 254) who argues that “the essence of policy robustness is whether a specific quantitative rule performs well under a model *other than that used to develop the policy.*”

We decided in favour of the first method as our goal is to show how uncertainty about the true exchange rate determination on the financial markets affects monetary policy that has committed itself to follow a time-invariant simple interest rate rule. In contrast to the approach of Levin et al. (1999), however, we did our analysis for one specific preference structure of the monetary policy maker, namely  $\lambda_\pi = \lambda_y = 1$ . The results are presented in Figure IV.15 which shows for each exchange rate specification the loss from all the policy rules in a single chart. The parameter  $\alpha_q$  in U3 was set to 0.5, and  $\xi$  equals 0.075 in U5.

We defined a policy rule to be robust when it performs reasonably well across a range of models. Significant differences in the performance of the rules only occur for a large risk premium persistence (U1), a high interest rate elasticity of the exchange rate (U2 and U3), a high degree of backward-looking expectations (U4 and U5) and a near-random-walk behaviour of the real exchange rate (U6). In Table IV.9 we set up a ranking of the best and second best performing policy rule for each model specification. It shows that R6 performs very well under all types of exchange rate uncertainty. R2, R4 and R5 also seem to produce relatively good results. However, R2 performs worst under U3; and so do R4 and R5 under U2.

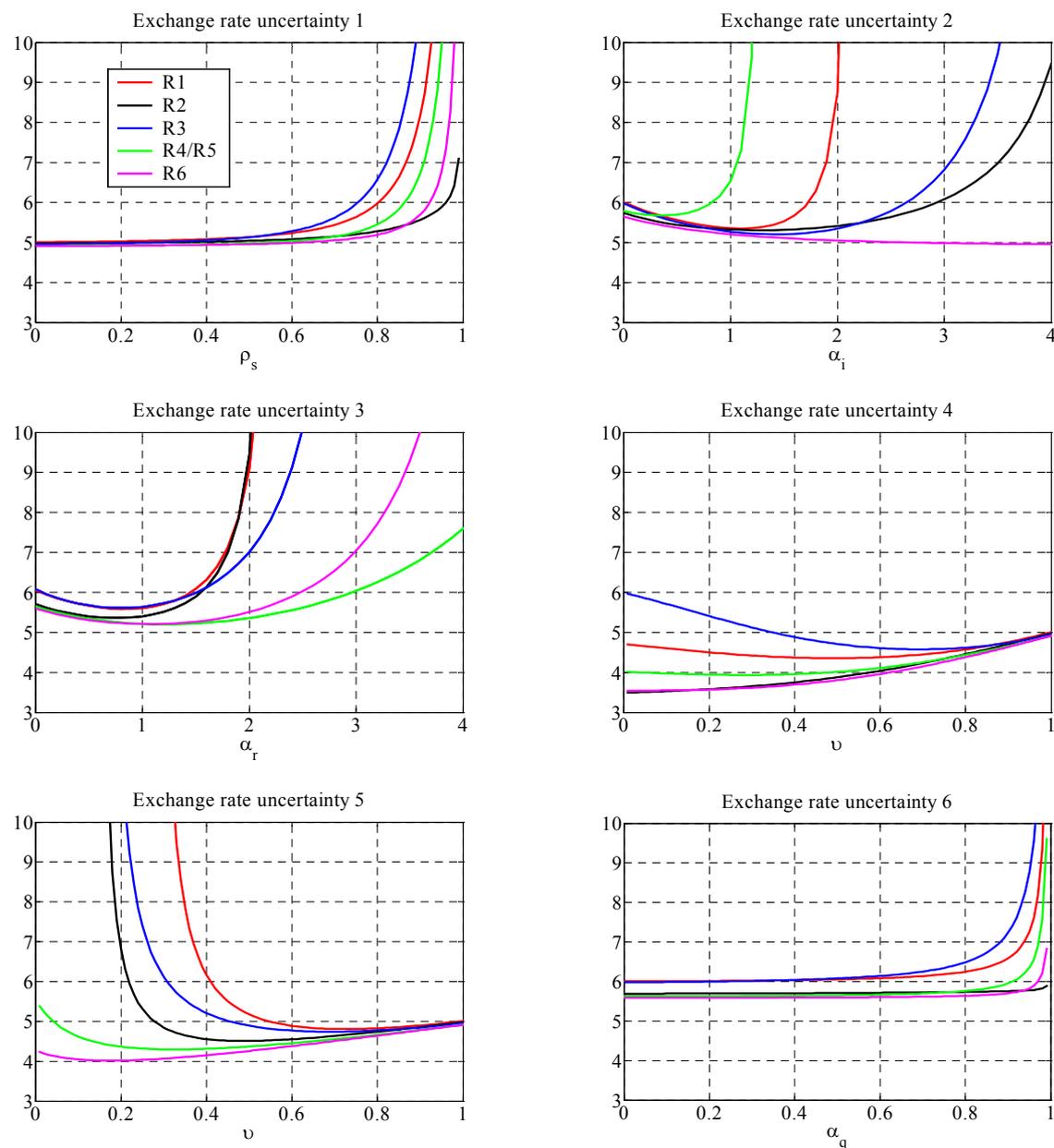
In short, we get the following results:

1. The independently floating policy rule R1 according to which the central bank sets  $i_t$  independent of any exchange rate developments performs badly under market determined

exchange rates with exchange rate uncertainty (second worst in all exchange rate specifications, except U5 in which it performs worst).

2. Policy rule R6 which is a specific variant of indirect managed floating performs very well in all types of exchange rate uncertainty (three times second best, three times first best).
3. The remaining indirect managed floating policy rules lead to a very mixed performance which makes them not suitable for isolating the policy maker from the consequences of exchange rate uncertainty.

**Figure IV.15: Competitive performance of the policy rules**



**Table IV.9: Ranking of the optimised simple rules**

Exchange rate uncertainty	U1	U2	U3	U4	U5	U6
Best performing policy rule	R2	R6	R4 + R5	R2 + R6	R6	R2
Second best performing policy rule	R6	R2	R6	R4 + R5	R4 + R5	R6

A final, but important issue that should be addressed when evaluating the performance of policy rules under a range of uncertainty scenarios is the question of whether the parameters that lead to differences in the performance of the rules are plausible (or realistic) or not. For U1 significant differences only occur for a risk premium persistence exceeding 0.6. A short look back to Table IV.6 shows that such high (annualised) values for  $\rho_s$  are rather an exception in the literature.<sup>57</sup> Turning to the empirical approaches represented by U2 and U3 the parameters for which the performance of the rules shows important differences are much more realistic. Remember that the values for  $\alpha_i$  and  $\alpha_r$  that Ball (1999b), Ryan and Thompson (2000) and the other authors had in mind when calibrating their models were around 2 (see Sections IV.2.2.2 and IV.2.2.3). Quantifying a plausible degree to which expectations are backward-looking (U4 and U5) is somewhat difficult as empirical work is not available. However, as significant differences already occur for values of  $\upsilon$  equal to 0.8 and lower (meaning that at least 20 per cent of the international investors do not form expectations rationally) we deem the contribution of U4 and U5 to the central bank's choice of a robust policy rule as highly relevant. The same applies to U6 where differences in the performance between R2, R4, R5 and R6 only appear for a high  $\alpha_q$ . Note that a value of  $\alpha_q$  approaching unity simulates the random walk behaviour of the real exchange rate often found in the empirical literature.

### ***IV.3.3 Exchange rate uncertainty and interest rate volatility***

#### *IV.3.3.1 Two dimensions of interest rate volatility*

The previous discussion concentrated on the consequences of exchange rate uncertainty for the central bank's final targets inflation and output. As an additional issue we have to examine whether there is a relationship between target stabilisation on the one hand and instrument volatility on the other hand. The origin of this possible relationship is obvious. If exchange rate

<sup>57</sup> A persistence parameter of 0.9 signifies a decay for UIP deviations caused by a risk premium shock of 10 per cent per period (which we interpreted as a year), implying a half-life for UIP shocks of 6.6 periods.

uncertainty translates into a higher volatility of output and inflation, then the need to stabilise increases which in turn can have a negative feedback on the instrument.

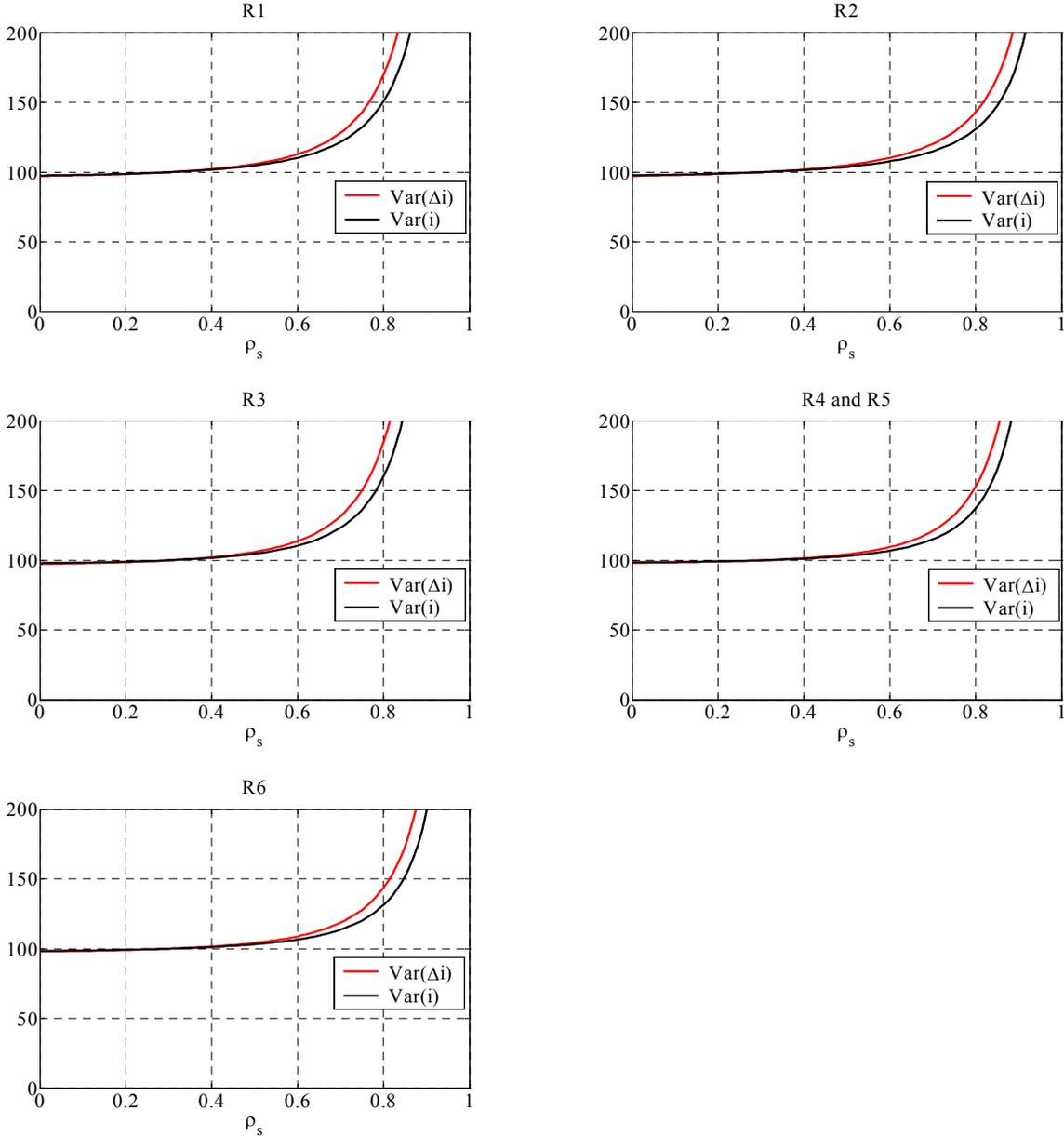
When discussing the consequences of volatile interest rates we have to distinguish between two separate issues. The first is the concern that frequent interest rate changes could have a negative impact on the stability of the financial system as well as on the influence of short-term interest rates on long-term interest rates. Thus, central banks are assumed to pursue a policy of interest rate smoothing which involves an only gradual interest rate adjustment towards the desired position (see e.g. Cukierman, 1991, and Goodhart, 1996). Empirically, the degree of interest rate smoothing is approximated by the variance of changes of the interest rate ( $\text{Var}[i_t - i_{t-1}]$ ). The second issue is related to the stability of interest rates, that is the average deviation of the level of the interest rate from its long-run equilibrium measured by  $\text{Var}[i_t - \bar{i}]$ . While the range in which interest rate can move is theoretically unlimited at the upper end, there is an important asymmetry concerning an expansionary monetary policy: Central banks can only lower the nominal interest rates to zero (see Section IV.1.2). This so-called zero lower bound on nominal interest rates implies a restriction on the ability of the monetary policy maker to implement an unconstrained stabilisation policy. Consider a situation with a negative output gap and deflation. The real interest rate (zero nominal interest rate plus the rate of deflation) may still be higher than the level required to stimulate the economy out of recession and deflation. If additionally, an unfavourable sequence of shocks follows, the real interest rate which is still too high may drive the economy further into a spiral of deflation and depression (the well-known liquidity trap).

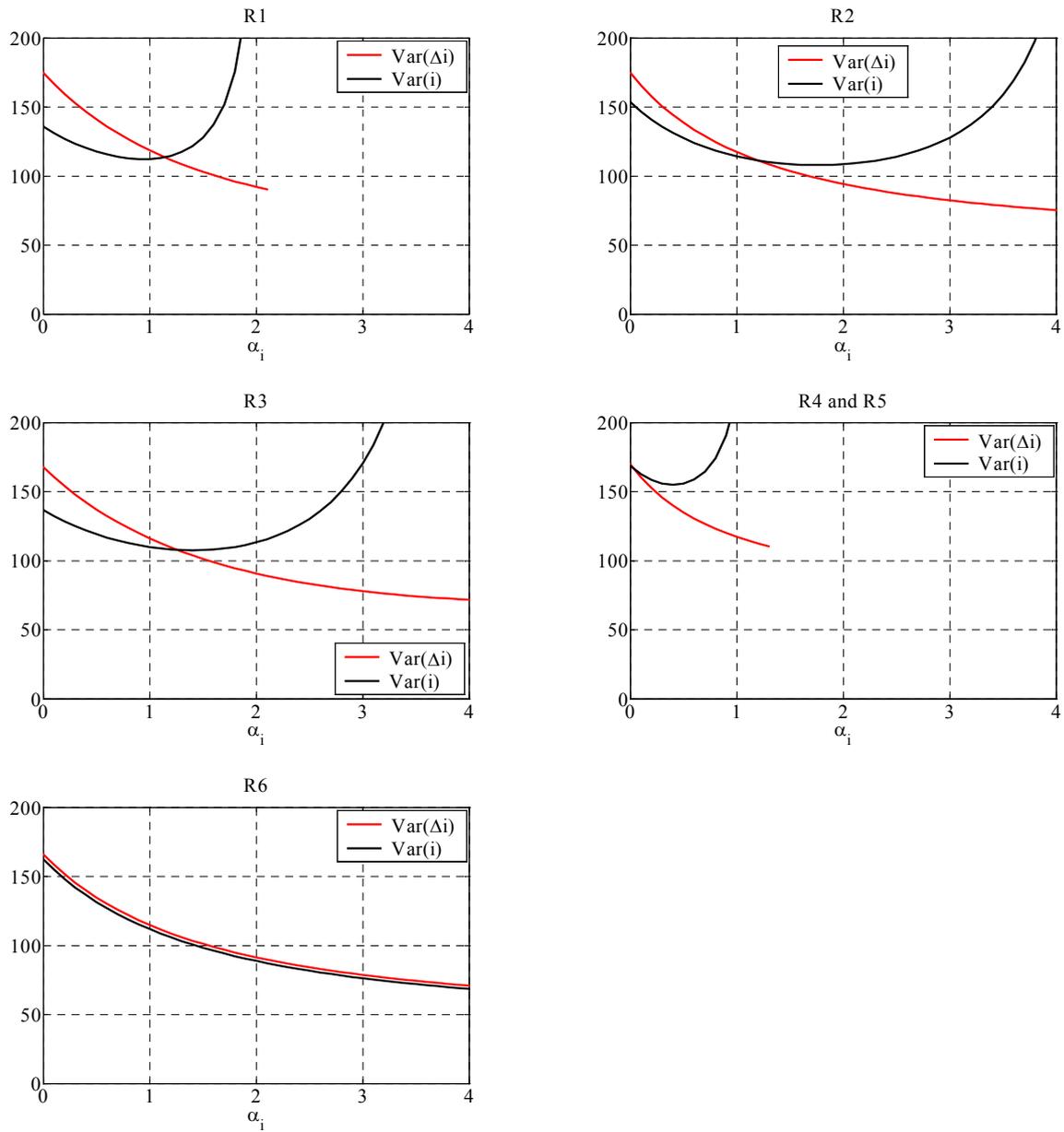
Before turning to the question on how the two dimensions of interest rate volatility possibly modify our results obtained from the robustness analysis, we will first take a look at the unconditional variances realised under each type of uncertainty. For all types of exchange rate uncertainty Figure IV.16 to Figure IV.21 depict  $\text{Var}(\Delta i) = \text{Var}[i_t - i_{t-1}]$  and  $\text{Var}(i) = \text{Var}[i_t - \bar{i}]$  resulting from each policy rule as percent of the variances resulting from the same rule in the baseline model.<sup>58</sup>

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<sup>58</sup> Note that  $\text{Var}[i_t - \bar{i}] = \text{Var}[i_t]$  as long as  $\bar{i} = \text{const.}$

Figure IV.16: Interest rate volatility under exchange rate uncertainty 1



**Figure IV.17: Interest rate volatility under exchange rate uncertainty 2**

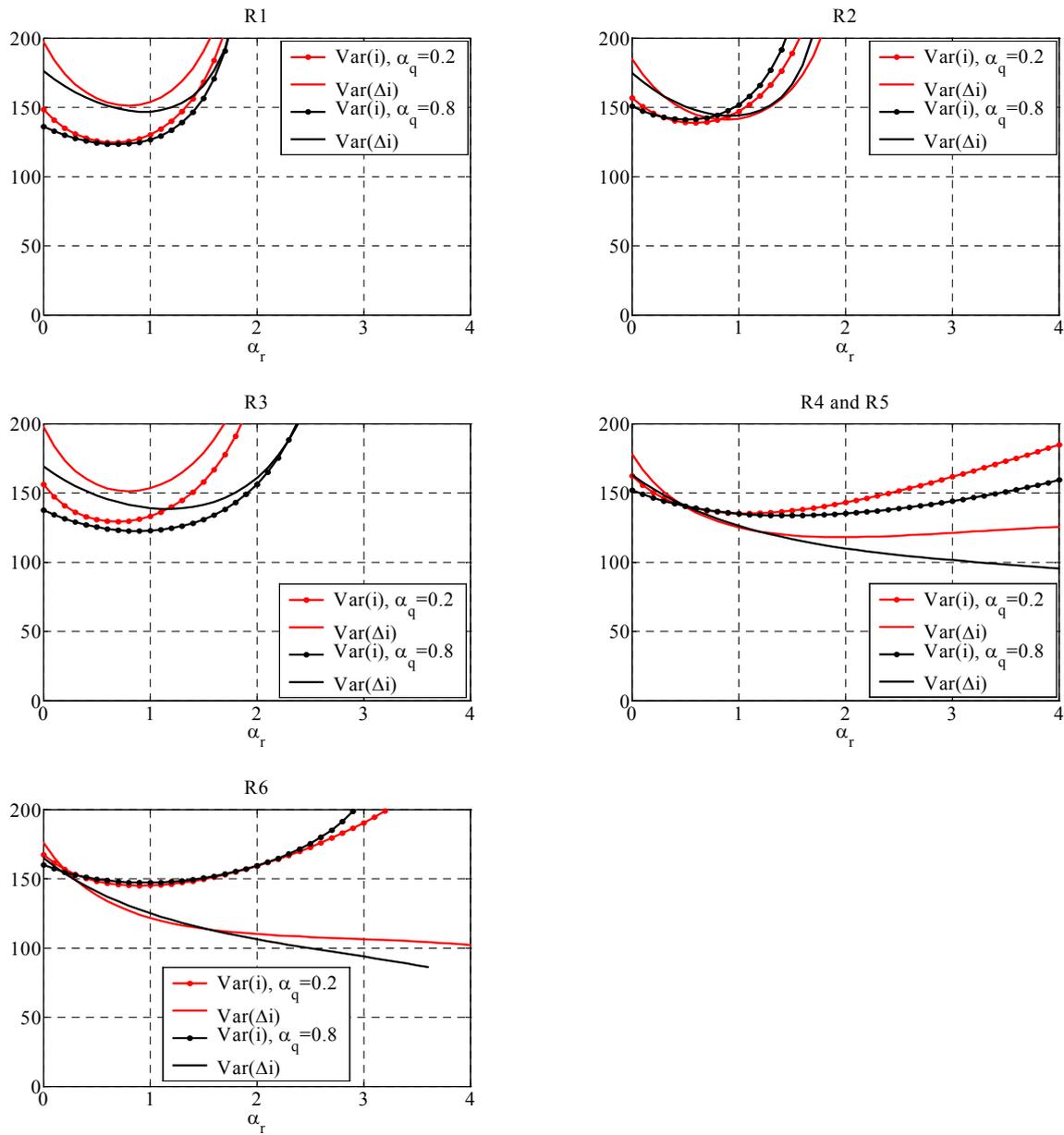
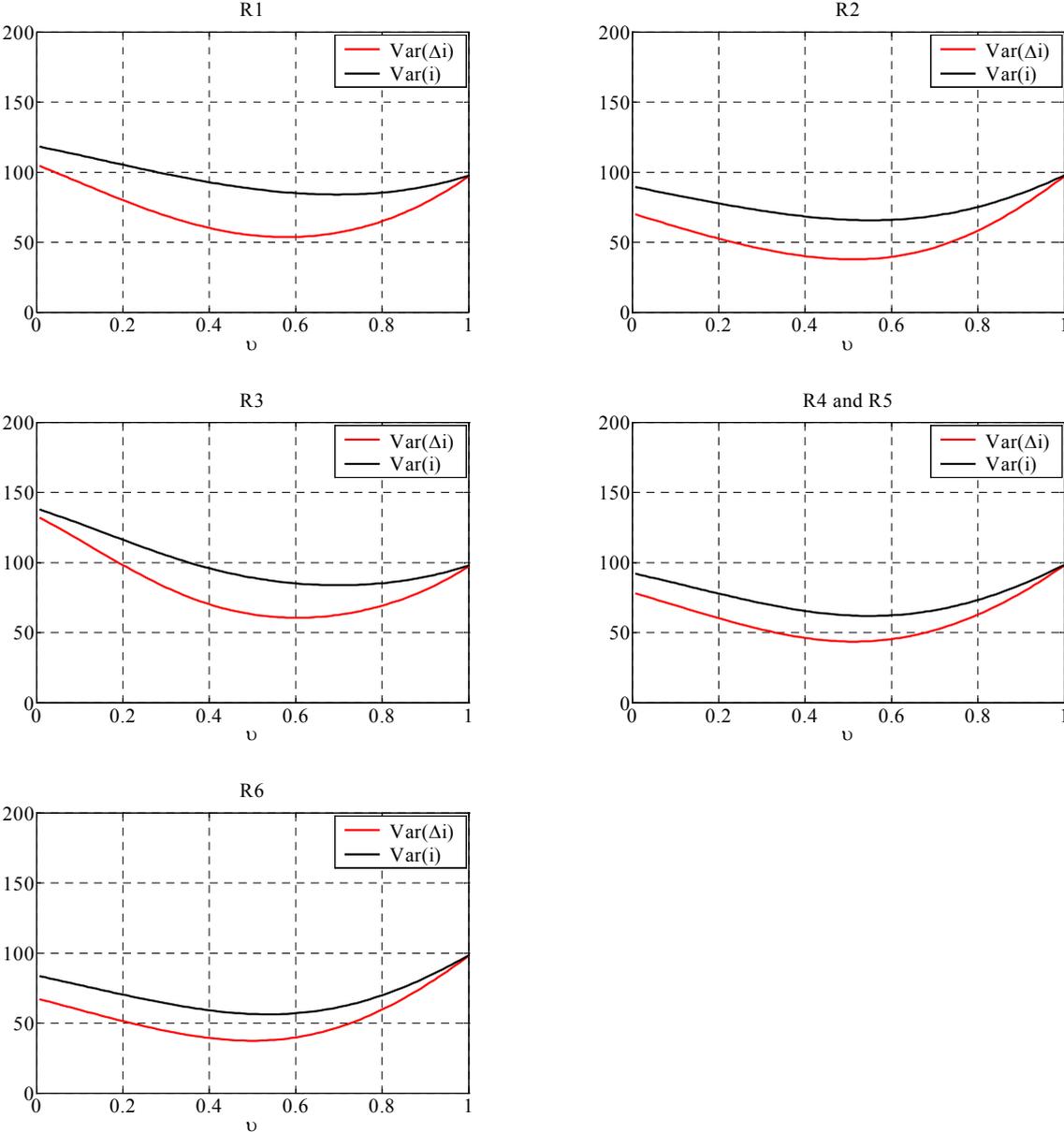
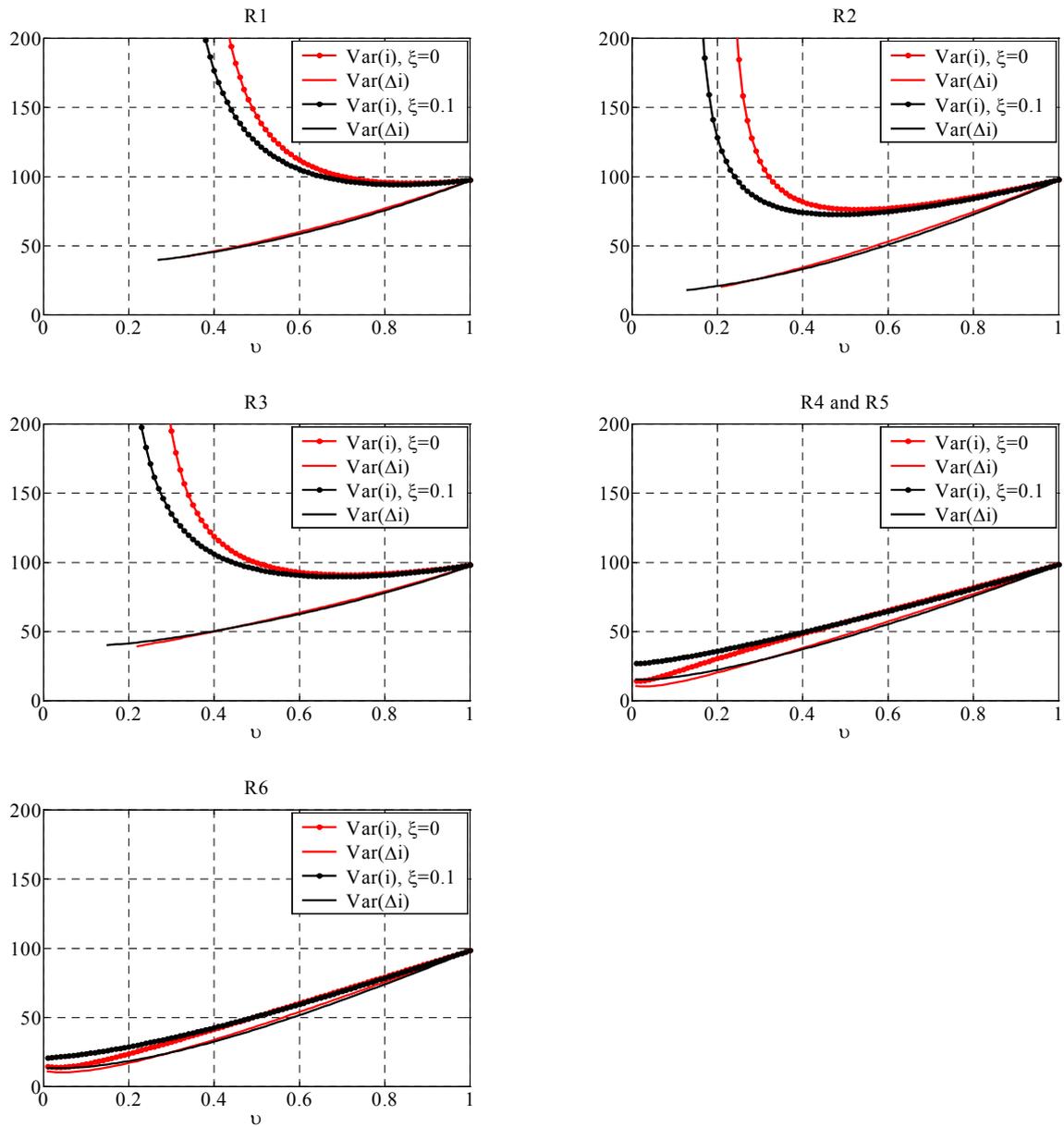
**Figure IV.18: Interest rate volatility under exchange rate uncertainty 3**

Figure IV.19: Interest rate volatility under exchange rate uncertainty 4



**Figure IV.20: Interest rate volatility under exchange rate uncertainty 5**

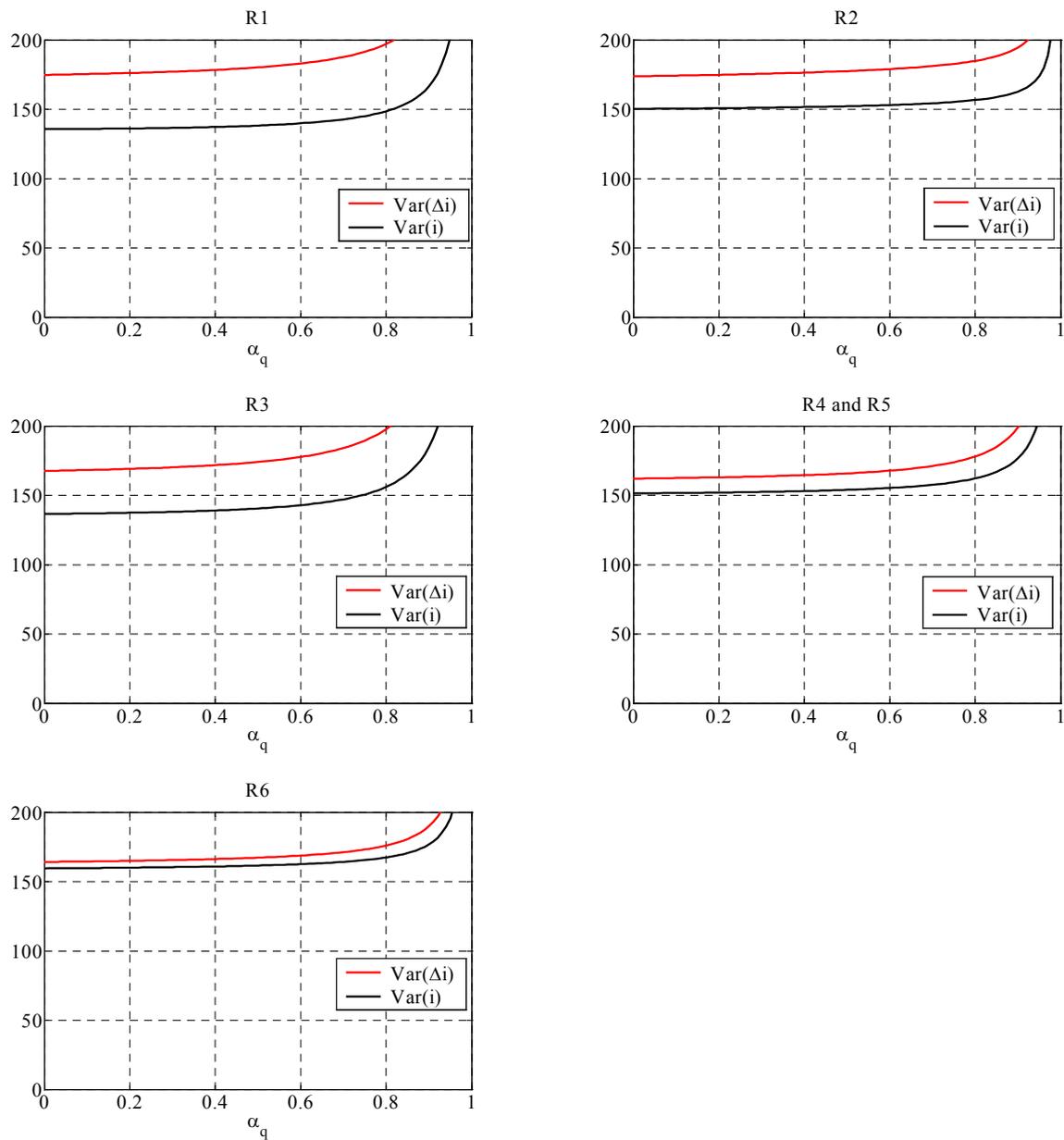
**Figure IV.21: Interest rate volatility under exchange rate uncertainty 6**

Figure IV.16 shows that an increase in the risk premium ( $U1$ ) increases the volatility of nominal interest rates for all rules. Note, however, that for values of  $\rho_s$  up to 0.5 the increase is rather limited. If  $\rho_s$  reaches 0.9 the volatility doubled for all policy rules.

Concerning  $U2$  (see Figure IV.17) as a general rule it can be said that an increasing  $\alpha_i$  smoothes the course of the nominal interest rate ( $\text{Var}(\Delta i)$  falls). For values of  $\alpha_i$  exceeding 2 (stable results only for R2, R3 and R6) the variance of  $\Delta i$  falls below that in the baseline specification,

implying smoother interest rates. In contrast to this, the variance of  $i_t$  forms a U-shaped curve, with all variances greater than in the baseline specification. The exception is R6 where  $\text{Var}(i)$  steadily decreases with a growing  $\alpha_i$ .

Under U3 the interest rate volatility exceeds that resulting from the baseline case for all policy rules (see Figure IV.18). The volatility curves are U-shaped, except for the  $\text{Var}(\Delta i)$ -curves under R4/R5 and R6 which fall steadily over the parameter span plotted. With a higher degree of persistence  $\alpha_q$  of the real exchange rate (the black lines)  $\text{Var}(\Delta i)$  falls for all policy rules, while  $\text{Var}(i)$  only falls for R1, R3, R4 and R5.

U4 generally reduces interest rate volatility compared to the baseline model (see Figure IV.19). The exceptions are  $\text{Var}(i)$  for policy rules R1 and R3 ( $\nu < 0.3$ ) and  $\text{Var}(\Delta i)$  for policy rule R3 ( $\nu < 0.2$ ). All the volatility curves are U-shaped with a minimum at values of  $\nu$  between 0.5 and 0.7.

Under U5 the  $\text{Var}(i)$ -curve is asymmetrically U-shaped for R1, R2 and R3 with relative variances falling slightly below 100 up to a certain degree of backward looking behaviour and then rising quickly to very high levels (see Figure IV.20). In contrast to this it steadily falls for R4/R5 and R6, all of which are policy rules responding to the current and the lagged exchange rate. With a higher rate of updating  $\xi$   $\text{Var}(i)$  is lower for R1, R2 and R3, and somewhat higher for R4/R5 and R6. For all policy rules  $\text{Var}(\Delta i)$  is lower than under fully rational expectations, and the nominal interest rate becomes steadily smoother the higher the weight of adaptive expectations. The rate of updating  $\xi$  seems to have only a minor impact on  $\text{Var}(\Delta i)$ .

Random behaviour of the real exchange rate (U6; see Figure IV.21) increases the variance of both, the interest rate and the change in the interest rate significantly. For  $\alpha_q$  approaching unity (the real exchange rate as a pure random walk) the variances grow progressively.

To sum up, it can be said that there is a substantial risk that the volatility of interest rates rises in the event of alternative exchange rate scenarios. This is true in particular for the risk premium explanation of the UIP anomaly, the empirical approaches and the near random walk model. Of

course there is also the complementary risk that the volatility falls. This is true for mixed expectations with an intermediate degree of backward-looking behaviour. What do these results now mean for the underlying question of this Section? Remember that the purpose was to investigate whether or not exchange rate uncertainty affects the conduct of monetary policy. As in Section IV.3.2 the performance of a specific monetary policy rule is measured in terms of the loss function. In equation (IV.12) we defined the intertemporal loss as the weighted sum of the unconditional variances of inflation and the output gap. From this definition and from the introduction to the current Chapter it follows that there is no direct impact of interest rate volatility on the performance of the policy rules.

One way to take into account the possibly adverse affects of interest rate volatility would have been to include additional terms in the loss function such as  $\text{Var}[i_t - i_{t-1}]$  and  $\text{Var}[i_t - \bar{i}]$ . The literature on policy rules often follows this approach, at least with regard to the ‘observable’ objective of interest rate smoothing (see e.g. Rudebusch and Svensson, 1999). The problem of this approach, however, is that loss functions like

$$(IV.71) \quad J_0 = \lambda_\pi \text{Var}[\pi_t] + \lambda_y \text{Var}[y_t] + \lambda_{\Delta i} \text{Var}[i_t - i_{t-1}]$$

where  $\lambda_{\Delta i}$  is a positive weight for the interest rate smoothing objective are rather specified ad hoc instead of being derived from a solid foundation.

This is different if we assume that a central bank follows an interest rate stabilisation objective. Woodford (2002b) replaces the constraint that the nominal interest rate must be non-negative in every period with a constraint upon its variability. By requiring that the mean interest rate  $\bar{i}$  has to at least  $k$  standard deviations above the theoretical zero lower bound (where  $k$  has to be large enough so that negative interest rates occur only infrequently), this approach provides a rationale for including interest rate stabilisation as an extra target into the loss function. The idea behind this is that there is an equivalence between a constraint and a modified loss function. The best-known example is the use of an Lagrangian to solve a constrained optimisation problem.<sup>59</sup>

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<sup>59</sup> In general, imposing an inequality constraint results in a non-linear programming problem. The constraint imposed by Woodford (2002b) circumvents this difficulty by replacing a more intuitive formulation like  $i_t \geq 0$  with a requirement in terms of the second moments of the nominal interest rate. He shows that with such a constraint the solution methods of linear quadratic control can still be applied.

Woodford (2002b) showed that the standard loss function as presented by equation (IV.12) then becomes

$$(IV.72) \quad J_0 = \lambda_\pi \text{Var}[\pi_t] + \lambda_y \text{Var}[y_t] + \lambda_i \text{Var}[i_t - \bar{i}]$$

which introduces an important trade-off between inflation/output gap stabilisation and interest rate stabilisation.

By including additional objectives in the loss function we would have to re-optimize our simple rules which we calculated for a central bank that only pursues an inflation and output objective. Instead of doing so we left our loss function unchanged and looked for other effects of volatile nominal interest rates in our models. While a reduction in interest rate volatility (expressed by either of the variances above) as well as an increase in  $\text{Var}[i_t - i_{t-1}]$  has no costs or benefits within our model specifications, an increase of the  $\text{Var}[i_t - \bar{i}]$  directly impacts on the ability of the central bank to follow its stabilisation policy according to the policy rule that it committed to. And it is exactly this zero lower bound constraint on nominal interest rates that we are focussing on in the following.

#### *IV.3.3.2 The zero lower bound on nominal interest rates*

The literature on the zero lower bound and its consequences addresses, among other things, the problem against the background of finding an inflation target that renders such an event unlikely (see e.g. McCallum, 2001, Orphanides and Wieland, 1998, and Reifschneider and Williams, 2000). The source of a significant decline in nominal interest rates is a sequence of unfavourable shocks that hit the economy. Most of the literature usually discusses negative supply shocks or negative demand shocks (both of which exert a deflationary pressure on the economy) as main triggers of such an interest rate policy. In an open economy, however, a large and prolonged appreciation of the domestic currency can also cause a binding zero lower bound. Regardless of the source, the consequences of the zero lower bound can be devastating. If the central bank is unable to counteract the effect of large deflationary shocks, the economy might be pushed into a deflationary spiral where expected inflation falls, real interest rates rise, aggregate demand and expected inflation fall even further, real rates rise by even more, and so on.

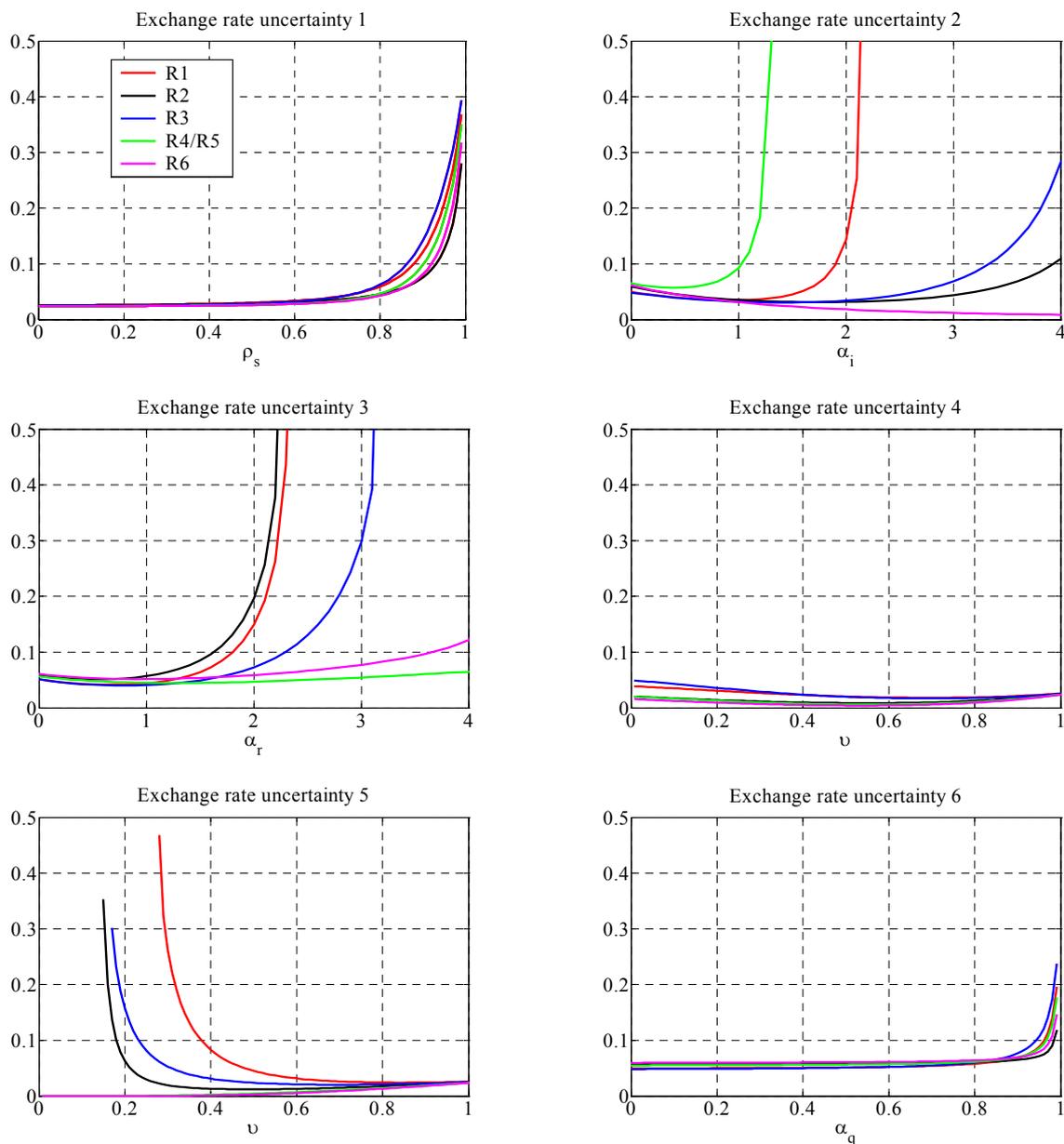
In order to quantify the importance of the zero lower bound constraint in our open economy models we begin our examination with a calculation of the probability that negative nominal interest rates occur. For a given model, this probability will of course depend upon the neutral nominal interest rate  $\bar{i}$  which is defined as the sum of the target inflation rate  $\pi^T$  and the long run average of the real interest rate  $\bar{r}$ . Up to now we were only interested in the second moments of the goal variables and the instrument. Thus, for simplicity we set the means of all our variables equal to zero in the previous simulations. Since the shocks perturbing our models are normally distributed around zero and since the model equations are linear, the instrument is also normally distributed around zero and with a variance that is shown for each rule and each exchange rate specification in Figure IV.16 to Figure IV.21. An important property of the normal distribution is its preservation under linear transformation. Thus, by defining some non-zero values for  $\pi^T$  and  $\bar{r}$  (and hence for  $\bar{i}$ ) we only shift the bell curve to the right without modifying its shape which is determined by the variance of  $i_t$ . In accordance with McCallum (2001) we set the economy's average real interest rate to 3 percent and its inflation target to 2 percent. The probabilities of reaching the zero lower bound are depicted in Figure IV.22.

It is clear that the results presented in Figure IV.22 are only a transformation of the  $\text{Var}(i)$  lines shown in Figure IV.16 to Figure IV.21. Nonetheless they illustrate in a simple way the problems for the conduct of monetary policy that are related to excessive needs of stabilising interest rate changes. In the baseline case, the probability that the nominal interest rate reaches the zero lower bound lies between 2.5 per cent (R4/R5 and R6) and 2.8 per cent (R1), implying that in 100 years there are on average somewhat less than three years in which negative interest rates would be required.

Concerning the uncertain degree of persistence of the UIP shock (U1) the probability that interest rates become negative rises with the true parameter  $\rho_s$ . Under U2 and U3, the probability of reaching the zero lower bound is higher than in the baseline case, except for policy rule 6 in uncertainty scenario 2 in conjunction with a value of  $\alpha_i$  exceeding 1.5. If expectations are formed statically (U4) the probability remains relatively low, regardless of the policy rule and the value of  $\nu$ . Under adaptive expectations (U5) the outcome crucially depends on the policy rule. While R1, R2 and R3 produce a high probability with  $\nu$  approaching zero, the probability falls to zero for R4/R5 and R6. If the exchange rate behaves according to U6, the

probability of reaching the zero lower bound is always higher than in the baseline case and rises very quickly for  $\alpha_q$  approaching unity.

**Figure IV.22: Probability of reaching the zero lower bound**



### IV.3.3.3 Impact of the zero lower bound on the central bank's target variables

In the above calculations the central bank was still able to reduce nominal interest rates below zero – we simply calculated the probability that the central bank has to do so. In this Section we go one step further and analyse the feedback of the zero lower bound constraint on the ability of the central bank to stabilise the economy. In particular, we calculate the variances of the goal

variables under a binding zero lower bound. For an unconstrained interest rate policy the variances of the target variables were computed using the analytical formulae derived in Appendix IV.B. However, the imposition of the zero lower bound constraint on the interest rate policy rule which can be formalised as

$$(IV.73) \quad i_t = \max \left[ 0, \bar{i} + F^s \cdot \begin{pmatrix} X_{1,t} \\ X_{2,t} \end{pmatrix} \right]$$

introduces an important nonlinearity into the system. As a consequence these formulae cannot be applied anymore. There are solution algorithms for non-linear rational expectations models (see e.g. Boucekkine, 1995), but given the purpose of the present Section their implementation would be too costly.

In accordance with Reifschneider and Williams (2000), we therefore opted for a more pragmatic approach and imposed the non-negativity constraint on the model by including an additive disturbance to the level of the interest rate. The disturbance is set equal to zero if the unconstrained policy rule prescribes an interest rate greater than zero, and set equal to the absolute value of the unconstrained interest rate if the rule dictates a negative value. With this approach the model remains ‘artificially’ linear so that the burdensome non-linear algorithms are circumvented.<sup>60</sup> To get the variances of the goal variables, we performed stochastic simulations of the models to generate artificial time series of the system variables. From this data we computed distributional statistics that are shown in italics in Table IV.10. To obtain reliable estimates of the effect of the zero bound on the variances of  $\pi_t$  and  $y_t$  the length of simulated time series was set to 1000 periods which we repeated 10000 times.

In order to avoid the economy becoming trapped in a deflationary spiral we defined a maximum number of successive periods with nominal interest rates stuck at zero as a stop criterion for each simulated time series. We experimented with two stop criteria: after three years of zero interest

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<sup>60</sup> An important drawback of the method proposed by Reifschneider and Williams (2000) is that the private sector does not take into account that the nominal interest rates cannot fall below zero when forming its expectations rationally. Ideally, the model would be solved under the assumption that the private sector would factor in the probability that the bound might bind. By modelling the zero lower bound similar to a disturbance term, model-consistent expectations which are computed under the assumption that certainty equivalence holds, set future shocks equal to their expected value of zero (see the M-matrices in equations (IV.125), (IV.150) and (IV.158)). This problem, however, equally emerges with more sophisticated non-linear solution algorithms (see Orphanides and Wieland, 1998).

rates and after five years (shown in the column 'Max'). The column 'Traps' then shows the number of liquidity traps that occurred during the 10000 repeated simulations. By increasing the maximum number of zero interest rates, the frequency of liquidity traps decreases significantly. This shows that in many cases, the economy is still able to rescue itself out of the trap even though monetary policy is constrained by the zero lower bound.

Table IV.10 summarises the simulation results for R1 in the baseline model and under exchange rate uncertainty 1 and 2. We do not present the results for other uncertainty scenarios or other policy rules for the following reasons. First, the method chosen to simulate the effects of the zero lower bound does not take into account that the private sector factors in the probability that interest rates cannot fall below zero when forming its expectations (see also footnote 60 on page 162). Thus, the simulation misses an important element of rational expectations models. Second, the calculation of the empirical variances only works quite well for relatively low probabilities that the economy gets trapped (e.g. the baseline model and U1 for  $\rho_s \leq 0.7$ ). But even though under U2 (to take the example shown in Table IV.10) the probability of reaching the lower zero bound is comparable to that of the baseline model (at least for values of  $\alpha_i$  up to 1.5), the probability of being trapped is almost 100 per cent which dramatically increases the impact of this constraint on the empirical variances of inflation and output under this exchange rate specification. In particular, we noted very high standard deviations around the mean values shown in the Table, despite the high number of repeated simulations. Thus, the results presented in Table IV.10 should be interpreted with caution, and they should be understood as a rough (though presumably exaggerated) approximation of the feedback of the zero lower bound on the performance of policy rules under market determined exchange rates and exchange rate uncertainty.

Despite these important limitations we will briefly discuss the impact of the zero lower bound on the ability of the policy maker to stabilise the economy. The following points can be made: First, as has been expected, a binding zero lower bound leads to an increase of the loss. Second, the higher we set the maximum number of subsequent periods with zero interest rates, the more significant the feedback is on the variances of inflation and output. At the same time, the number of cases in which the economy gets trapped declines. From this follows (at least for U1 with  $\rho_s \leq 0.7$ ) that in a number of cases the economy is able to escape itself from a liquidity trap even though the central bank is unable to lower nominal interest rates sufficiently.

**Table IV.10: Feedback effects of the zero lower bound of R1 on  $\pi_t$  and  $y_t$  under U1 and U2**

		Max	Traps	Var( $\pi_t$ )	Var( $y_t$ )	Loss
baseline	unconstrained	-	-	2.68	2.38	5.05
	<i>constrained</i>	3	4426	2.86	2.30	5.16
		5	1299	3.06	2.39	5.45
U1: $\rho_s = 0.5$	unconstrained	-	-	2.74	2.40	5.14
	<i>constrained</i>	3	5096	2.97	2.31	5.29
		5	1741	3.37	2.48	5.85
U1: $\rho_s = 0.7$	unconstrained	-	-	2.98	2.47	5.44
	<i>constrained</i>	3	7973	3.47	2.36	5.83
		5	4124	5.53	3.18	8.70
U1: $\rho_s = 0.9$	unconstrained	-	-	5.49	2.69	8.18
	<i>constrained</i>	3	9998	10.3	4.68	15.0
		5	9999	47.0	21.4	68.4
U2: $\alpha_i = 0.5$	unconstrained	-	-	3.33	2.23	5.56
	<i>constrained</i>	3	9928	13.9	11.3	25.2
		5	9720	195	208	403
U2: $\alpha_i = 1.0$	unconstrained	-	-	3.06	2.30	5.36
	<i>constrained</i>	3	10000	28.3	29.2	57.5
		5	10000	967	1186	2152
U2: $\alpha_i = 1.5$	unconstrained	-	-	2.95	2.58	5.53
	<i>constrained</i>	3	10000	68.5	79.0	148
		5	10000	1723	2273	3997
U2: $\alpha_i = 2.0$	unconstrained	-	-	3.59	5.16	8.75
	<i>constrained</i>	3	10000	161	206	367
		5	10000	4833	6338	11671

#### IV.4 Summary of the results

There are two lessons that can be drawn from the analysis of monetary policy under market determined exchange rates and exchange rate uncertainty:

1. exchange rate uncertainty translates into a high risk that a central bank fails to pursue a successful stabilisation policy – irrespective of the policy rule chosen;
2. exchange rate uncertainty provides a rationale for indirect managed floating.

The first lesson has important implications for the performance of a central bank's monetary policy. Due to exchange rate uncertainty the exchange rate is not only treated as endogenous variable, but also as an important source of shocks, which on the one hand is likely to provoke a more activist stabilisation policy, and which on the other hand implies an uncertain transmission of interest rate impulses via the exchange rate channel. Four of the alternative exchange rate models used in the quantitative analysis definitively increase the value of the loss function compared to a world of certainty in which UIP with known statistical properties of the disturbance term determines the exchange rate. Under mixed expectations the results are not that clear cut. An intermediate degree of backward-looking behaviour definitively improves the performance of all policy rules. If backward-looking behaviour prevails, the result crucially depends on the policy rule followed by the central bank. Additionally, the limited ability to stabilise the economy that stems from the zero lower bound on nominal interest rates may also contribute to a higher variance of the goal variables, and hence a higher welfare loss.

The second lesson according to which, under market determined exchange rates, the quest for robustness of monetary policy implies indirect managed floating, and hence a response of the policy maker to exchange rate movements, is in sharp contrast to the literature on policy rules in open economies. Most of the studies conducted in this field only attach a minor importance to the possibility of interest rate feedback to the exchange rate movements. The study of Leitimo and Söderström (2001), for example, which is similar in topic to our study, comes to the conclusion that as long as there is no extreme parameterisations of the uncertainty scenario (which mainly corresponds to U5) independently floating policy rules seem to be an efficient and robust guide for monetary policy in an open economy. In comparison with their analysis we increased the degree of exchange rate uncertainty to account for the little knowledge about the true exchange rate behaviour by extending the set of possible exchange rate specifications. We showed that even with quite realistic parameters underlying the uncertainty scenarios the independently floating policy rule and some of the indirect managed floating policy rules perform poorly in terms of the loss they produce. Only the policy rule which prescribes an important exchange rate feedback (R6) performs reasonably well over the various exchange rate specifications. Not only the loss in terms of the variability of inflation and output remains low

compared to the other policy rules, but also the probability that stabilisation is restricted by the zero lower bound on nominal interest rates remains in a reasonable range. Nevertheless, just as the other policy rules under market determined exchange rates, also the indirect managed floating policy rule R6 bears the risk that inflation and output might be negatively affected by the unpredictability of the true exchange rate behaviour (lesson 1). This undesirable result may be viewed as an explanation for further political measures, in particular direct interventions in the foreign exchange market, which are discussed in the following Chapter.

## Appendices to Chapter IV

### IV.A The state-space representation of the models

The models of this Chapter can be generalised to the following state-space representation

$$(IV.74) \quad A_0 x_{t+1} = A_1 x_t + B_0 i_t + \varepsilon_{t+1}, \text{ or}$$

$$(IV.75) \quad A_0 \begin{pmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{pmatrix} = A_1 \begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} + B_0 i_t + \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix}$$

where  $x_t$  is a  $(n_1 + n_2) \times 1$  vector of state variables consisting of an  $n_1 \times 1$  vector  $x_{1,t}$  of predetermined (backward looking) variables and an  $n_2 \times 1$  vector  $x_{2,t}$  of forward looking variables.  $i_t$  is the central bank's instrument, and  $\varepsilon_{t+1}$  is a column vector of  $(n_1 + n_2)$  exogenous i.i.d. shock with zero means and a constant covariance matrix  $\Sigma_\varepsilon$ .  $A_0$ ,  $A_1$  and  $B_0$  are matrices containing the structural coefficients. Premultiplying (IV.75) with  $A_0^{-1}$  yields a more conventional form of the model

$$(IV.76) \quad \begin{pmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{pmatrix} = A \begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} + B i_t + \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix}$$

where  $A = A_0^{-1} A_1$  and  $B = A_0^{-1} B_0$ . Note that

$$(IV.77) \quad A_0^{-1} \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix} = \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix}$$

since  $A_0$  is block diagonal with an identity matrix as its upper left block  $(1:n_1, 1:n_1)$  and the lower block of  $\varepsilon_{t+1}$   $(n_1+1, n_1+n_2)$  is zero.

For each specification of exchange rate uncertainty we proceed as follows:

1. we eliminate the non-stationary variables (in particular  $s_t$ ) from the system equations;

2. we specify the matrices and vectors of the state space representation of each model;
3. we set-up the goal vector.

The first step allows us to apply the numerical algorithms (see Appendix IV.B) to solve our models and to calculate the unconditional variances of the variables of interest. If the state vector of a dynamic system contains non-stationary variables, it is unclear whether the solution of the system is stable or not. The second step - the transformation of the system equations into state-space form - simply provides a computationally manageable form. In particular, the Matlab routines of Söderlind (1999) can be applied for the numerical calculations.<sup>61</sup> The third step summarises the objectives of the monetary policy maker into a single vector. It is defined as a linear combination of the state vector and the instrument:

$$(IV.78) \quad z_t = C_x x_t + C_i i_t.$$

#### IV.A.a The state-space representation of the baseline model and exchange rate uncertainty 1

In order to eliminate the non-stationary nominal exchange rate in the UIP equation (IV.3) we first have to replace  $E_t s_{t+1} - s_t$  in (IV.7) with the updated identity (IV.4). After taking expectations at  $t$  and solving for  $E_t q_{t+1}$  we get

$$(IV.79) \quad E_t q_{t+1} = q_t + E_t \pi_{t+1}^f - E_t \pi_{t+1} + i_t - r_t^f - u_t^s.$$

Defining the expected rate of inflation as

$$(IV.80) \quad E_t \pi_{t+1} = \pi_{t+1} - \varepsilon_{t+1}^\pi = \pi_t + \gamma_y y_t + \gamma_q (q_t - q_{t-1})$$

and setting  $E_t \pi_{t+1}^f = 0$ , the UIP condition finally becomes

$$(IV.81) \quad E_t q_{t+1} = (1 - \gamma_q) q_t + \gamma_q q_{t-1} - \pi_t - \gamma_y y_t + i_t - r_t^f - u_t^s.$$

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<sup>61</sup> The basic Matlab codes on the basis of which the numerical simulations have been performed can be downloaded from Söderlind's website (<http://www.hhs.se/personal/psoderlind/Software/Software.htm#MatLabScripts>). The specific codes used for the simulations of the present thesis are available from the author upon request.

The state vector is then composed by an  $(n_1 \times 1)$  vector of  $n_1 = 6$  predetermined variables which is given by  $x_{1,t} = (r_t^f \quad u_t^s \quad \pi_t \quad y_t \quad q_{t-1} \quad i_{t-1})^T$  and an  $(n_2 \times 1)$  vector of  $n_2 = 1$  forward looking variables which is given by  $x_{2,t} = (q_t)$  as. The vector of disturbances to the predetermined variables  $\varepsilon_{1,t+1}$  is defined by  $(\varepsilon_{t+1}^f \quad \varepsilon_{t+1}^s \quad \varepsilon_{t+1}^\pi \quad \varepsilon_{t+1}^y \quad 0 \quad 0)^T$ . The system matrices of the state-space representation of the model are composed as follows:

$$(IV.82) \quad A_0 = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix},$$

$$(IV.83) \quad A_1 = \begin{pmatrix} \rho_f & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \rho_s & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & \gamma_y & -\gamma_q & 0 & \gamma_q \\ 0 & 0 & \beta_i & \beta_y & 0 & 0 & \beta_q \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -\gamma_y & \gamma_q & 0 & 1 - \gamma_q \end{pmatrix} \text{ and}$$

$$(IV.84) \quad B_0 = (0 \quad 0 \quad 0 \quad -\beta_i \quad 0 \quad 1 \quad 1)^T.$$

The nominal exchange rate path (which is not part of the state vector anymore) is simply derived by the identity (IV.4) by assuming an initial value of the nominal exchange rate of zero. The inclusion of  $i_{t-1}$  in the state vector finally stems from the fact that in Section IV.3 we are not only interested in the variance of  $y_t$  and  $\pi_t$  (the traditional goal variables), but also in the variance of  $\Delta i_t$  which is not a state variable per se.<sup>62</sup> Thus, we define the vector of goal variables  $z_t$  as follows:

<sup>62</sup> It is important to note, however, that the weight on  $\Delta i_t$  in the loss function (see equations (IV.117) and (IV.118) in Appendix IV.B) is always set to zero. Thus, we only created the new variable  $\Delta i_t$  in order to be able to calculate its unconditional variance under each exchange rate specification (see Section IV.1.4 and IV.3.3).

$$(IV.85) \quad z_t = \begin{pmatrix} \pi_t \\ y_t \\ \Delta i_t \end{pmatrix} = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 \end{pmatrix} \begin{pmatrix} r_t^f \\ u_t^s \\ \pi_t \\ y_t \\ q_{t-1} \\ i_{t-1} \\ q_t \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} i_t.$$

#### IV.A.b The state-space representation of exchange rate uncertainty 2

As the shocks to equations (IV.28) and (IV.29) occur in different period than the shock to the exchange rate equation (IV.30) we have to define  $\varepsilon_t^q$  as a further state variable in period t. Thus, when setting-up the state space representation of the model we have to replace  $q_t$  in (IV.28) and (IV.29) with (IV.30). This gives the following model-consistent modifications of the Phillips curve and the IS equation:

$$(IV.86) \quad \pi_{t+1} = (1 + \gamma_q \alpha_i) \pi_t + \gamma_y y_t - \gamma_q q_{t-1} - \gamma_q \alpha_i i_t + \gamma_q \varepsilon_t^q + \varepsilon_{t+1}^\pi$$

$$(IV.87) \quad y_{t+1} = (\beta_i + \beta_q \alpha_i) \pi_t + \beta_y y_t - (\beta_i + \beta_q \alpha_i) i_t + \beta_q \varepsilon_t^q + \varepsilon_{t+1}^y.$$

The state vector  $x_t$  is then composed of  $x_{1,t} = (\varepsilon_t^q \quad \pi_t \quad y_t \quad q_{t-1} \quad i_{t-1})^T$  which is a  $(n_1 \times 1)$  vector of  $n_1 = 5$  predetermined variables. As the original Ball (1999b) model is purely backward-looking the number of forward-looking variables  $n_2$  is zero. The vector of disturbances to the predetermined variables  $\varepsilon_{1,t+1}$  is defined by  $(\varepsilon_{t+1}^q \quad \varepsilon_{t+1}^\pi \quad \varepsilon_{t+1}^y \quad 0 \quad 0)^T$ . To summarise, the system can be written as follows:

$$(IV.88) \quad \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_{t+1}^q \\ \pi_{t+1} \\ y_{t+1} \\ q_t \\ i_t \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 \\ \gamma_q & 1 + \gamma_q \alpha_i & \gamma_y & -\gamma_q & 0 \\ \beta_q & \beta_i + \beta_q \alpha_i & \beta_y & 0 & 0 \\ 1 & \alpha_i & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} \varepsilon_t^q \\ \pi_t \\ y_t \\ q_{t-1} \\ i_{t-1} \end{pmatrix} + \begin{pmatrix} 0 \\ -\gamma_q \alpha_i \\ -\beta_i - \beta_q \alpha_i \\ -\alpha_i \\ 1 \end{pmatrix} i_t + \begin{pmatrix} \varepsilon_{t+1}^q \\ \varepsilon_{t+1}^\pi \\ \varepsilon_{t+1}^y \\ 0 \\ 0 \end{pmatrix}.$$

The vector of goal variables is finally defined by

$$(IV.89) \quad z_t = \begin{pmatrix} \pi_t \\ y_t \\ \Delta i_t \end{pmatrix} = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} \varepsilon_t^q \\ \pi_t \\ y_t \\ q_{t-1} \\ i_{t-1} \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} i_t.$$

As in the baseline model the non-stationary nominal exchange rate is derived ‘off-system’ on the basis of (IV.31).

#### IV.A.c The state-space representation of exchange rate uncertainty 3

As the model is purely backward-looking the state vector only consists of  $n_1 = 6$  predetermined variables and is given by  $x_t = x_{1,t} = (r_t^f \quad \pi_t \quad y_t \quad q_t \quad q_{t-1} \quad i_{t-1})^T$ . The vector of disturbances to the predetermined variables  $\varepsilon_{1,t+1}$  is defined by  $(\varepsilon_{t+1}^f \quad \varepsilon_{t+1}^\pi \quad \varepsilon_{t+1}^y \quad \varepsilon_{t+1}^{\Delta q} \quad 0 \quad 0)^T$ . Thus, in state-space form the model can be summarised as:

$$(IV.90) \quad \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} r_{t+1}^f \\ \pi_{t+1} \\ y_{t+1} \\ q_{t+1} \\ q_t \\ i_t \end{pmatrix} = \begin{pmatrix} \rho_f & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & \gamma_y & \gamma_q & -\gamma_q & 0 \\ 0 & \beta_i & \beta_y & \beta_q & 0 & 0 \\ \alpha_r & \alpha_r & 0 & 1 - \alpha_q & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} r_t^f \\ \pi_t \\ y_t \\ q_t \\ q_{t-1} \\ i_{t-1} \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ -\beta_i \\ -\alpha_r \\ 0 \\ 1 \end{pmatrix} i_t + \begin{pmatrix} \varepsilon_{t+1}^f \\ \varepsilon_{t+1}^\pi \\ \varepsilon_{t+1}^y \\ \varepsilon_{t+1}^{\Delta q} \\ 0 \\ 0 \end{pmatrix}.$$

The vector of goal variables is defined by

$$(IV.91) \quad z_t = \begin{pmatrix} \pi_t \\ y_t \\ \Delta i_t \end{pmatrix} = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} r_t^f \\ \pi_t \\ y_t \\ q_t \\ q_{t-1} \\ i_{t-1} \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} i_t.$$

#### IV.A.d The state-space representation of exchange rate uncertainty 4

Similar to the procedure in the baseline model, before setting up the state space form of the model the non-stationary nominal exchange rate has to be replaced by stationary system variables. This can be achieved by rearranging (IV.48) as follows

$$(IV.92) \quad \upsilon(E_t s_{t+1} - s_t) - (1 - \upsilon)(s_t - s_{t-1}) = i_t - r_t^f - u_t^s$$

and by replacing the current exchange rate change and the expected nominal exchange rate change with equation (IV.46) and an updated expectational equation (IV.46). After solving the resulting equation for  $\upsilon E_t q_{t+1}$  we get

$$(IV.93) \quad \upsilon E_t q_{t+1} = q_t - (1 - \upsilon)q_{t-1} - \upsilon(E_t \pi_{t+1} - E_t \pi_{t+1}^f) + (1 - \upsilon)(\pi_t - \pi_t^f) + i_t - r_t^f - u_t^s.$$

Defining the expected rate of inflation as

$$(IV.94) \quad E_t \pi_{t+1} = \pi_{t+1} - \varepsilon_{t+1}^\pi = \pi_t + \gamma_y y_t + \gamma_q (q_t - q_{t-1})$$

and setting  $E_t \pi_{t+1}^f = 0$  and  $\pi_t^f = 0$ , exchange rate equation (IV.93) finally becomes

$$(IV.95) \quad \upsilon E_t q_{t+1} = (1 - \upsilon \gamma_q) q_t + (\upsilon - 1 + \upsilon \gamma_q) q_{t-1} + (1 - 2\upsilon) \pi_t - \upsilon \gamma_y y_t + i_t - r_t^f - u_t^s.$$

For the state space representation of the model we define the vector of predetermined variables as  $x_{1,t} = (r_t^f \quad u_t^s \quad \pi_t \quad y_t \quad q_{t-1} \quad i_{t-1})^T$ . The only forward looking variable is the real exchange rate so that  $x_{2,t} = (q_t)$ . The vector of disturbances to the predetermined variables  $\varepsilon_{1,t+1}$  is defined by  $(\varepsilon_{t+1}^f \quad \varepsilon_{t+1}^s \quad \varepsilon_{t+1}^\pi \quad \varepsilon_{t+1}^y \quad 0 \quad 0)^T$ . The matrices  $A_0$ ,  $A_1$  and  $B$  are then given by

$$(IV.96) \quad A_0 = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & v \end{pmatrix},$$

$$(IV.97) \quad A_1 = \begin{pmatrix} \rho_f & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \rho_s & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & \gamma_y & -\gamma_q & 0 & \gamma_q \\ 0 & 0 & \beta_i & \beta_y & 0 & 0 & \beta_q \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & 1-2v & -v\gamma_y & v-1+v\gamma_q & 0 & 1-v\gamma_q \end{pmatrix} \text{ and}$$

$$(IV.98) \quad B_0 = (0 \ 0 \ 0 \ -\beta_i \ 0 \ 1 \ 1)^T.$$

Likewise, the goal variables can be written as

$$(IV.99) \quad z_t = \begin{pmatrix} \pi_t \\ y_t \\ \Delta i_t \end{pmatrix} = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 \end{pmatrix} \begin{pmatrix} r_t^f \\ u_t^s \\ \pi_t \\ y_t \\ q_{t-1} \\ i_{t-1} \\ q_t \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} i_t.$$

#### IV.A.e The state-space representation of exchange rate uncertainty 5

For the purpose of eliminating the non-stationary nominal exchange rate we first have to transform the adaptive expectations variable into real terms. Defining the level of the real exchange rate  $q_t$  and the level of its adaptive expectations  $\epsilon_{t-1}q_t$  as

$$(IV.100) \quad q_t = s_t + p_t^f - p_t$$

$$(IV.101) \quad \epsilon_{t-1}q_t = \epsilon_{t-1}s_t + p_t^f - p_t$$

and using these two equations in equation (IV.57), it can be rewritten as

$$(IV.102) \quad \epsilon_t q_{t+1} = (1 - \xi)q_t + \xi \epsilon_{t-1} q_t + \pi_{t+1}^f - \pi_{t+1}.$$

$p_t$  and  $p_t^f$  denote the domestic and the foreign price level. Their first differences yield the domestic and the foreign rate of inflation. With  $\pi_t^f = 0$  equation (IV.102) simplifies to

$$(IV.103) \quad \epsilon_t q_{t+1} = (1 - \xi)q_t + \xi \epsilon_{t-1} q_t - \pi_{t+1}.$$

The same proceeding applies to the adjusted UIP equation (IV.56).  $s_t$  is replaced by  $q_t - p_t^f + p_t$  (see (IV.100)).  $E_t s_{t+1}$  can be transformed into  $E_t q_{t+1}$  after updating (IV.100) and taking expectations. Using an updated equation (IV.101)  $\epsilon_t s_{t+1}$  is replaced with  $\epsilon_t q_{t+1} - p_{t+1}^f + p_{t+1}$ . Inserting finally equation (IV.102) and solving it for  $v E_t q_{t+1}$  gives

$$(IV.104) \quad v E_t q_{t+1} = [v + (1 - v)\xi]q_t - (1 - v)\xi \epsilon_{t-1} q_t + v E_t \pi_{t+1}^f - v E_t \pi_{t+1} + i_t - r_t^f - u_t^s.$$

Defining the rational expectations of the future inflation rate by

$$(IV.105) \quad E_t \pi_{t+1} = \pi_{t+1} - \varepsilon_{t+1}^\pi$$

and using the right hand side of the Phillips curve equation (IV.54) to replace  $\pi_{t+1}$  then yields:

$$(IV.106) \quad v E_t q_{t+1} = [v + (1 - v)\xi - v\gamma_q]q_t + v\gamma_q q_{t-1} - (1 - v)\xi \epsilon_{t-1} q_t - v\pi_t - v\gamma_y y_t + i_t - r_t^f - u_t^s.$$

To set up the system we defined an  $(n_1 \times 1)$  vector of  $n_1 = 7$  predetermined variables as

$x_{1,t} = (r_t^f \quad u_t^s \quad \pi_t \quad y_t \quad q_{t-1} \quad \epsilon_{t-1} q_t \quad i_{t-1})^T$  and an  $(n_2 \times 1)$  vector of  $n_2 = 1$  forward looking

variables as  $x_{2,t} = (q_t)$ . The vector of disturbances to the predetermined variables  $\varepsilon_{1,t+1}$  is given by  $(\varepsilon_{t+1}^f \quad \varepsilon_{t+1}^s \quad \varepsilon_{t+1}^\pi \quad \varepsilon_{t+1}^y \quad 0 \quad 0 \quad 0)^T$ . The matrices  $A_0$ ,  $A_1$  and  $B$  are then given by

$$(IV.107) \quad A_0 = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \nu \end{pmatrix},$$

$$(IV.108) \quad A_1 = \begin{pmatrix} \rho_f & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \rho_s & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & \gamma_y & -\gamma_q & 0 & 0 & \gamma_q \\ 0 & 0 & \beta_i & \beta_y & 0 & 0 & 0 & \beta_q \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & \xi & 0 & 1-\xi \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -\nu & -\nu\gamma_y & \nu\gamma_q & -(1-\nu)\xi & 0 & \nu+(1-\nu)\xi-\nu\gamma_q \end{pmatrix} \text{ and}$$

$$(IV.109) \quad B_0 = (0 \quad 0 \quad 0 \quad -\beta_i \quad 0 \quad 0 \quad 1 \quad 1)^T.$$

The vector of goal variables can be written as:

$$(IV.110) \quad z_t = \begin{pmatrix} \pi_t \\ y_t \\ \Delta i_t \end{pmatrix} = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \end{pmatrix} \begin{pmatrix} i_t^f \\ u_t^s \\ \pi_t \\ y_t \\ q_{t-1} \\ \varepsilon_{t-1} q_t \\ i_{t-1} \\ q_t \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} i_t.$$

#### IV.A.f The state-space representation of exchange rate uncertainty 6

As the model is purely backward-looking the state vector only consists of  $n_1 = 5$  predetermined variables and is given by  $x_t = x_{1,t} = (\pi_t \ y_t \ q_t \ q_{t-1} \ i_{t-1})^T$ . The vector of disturbances to the predetermined variables  $\varepsilon_{1,t+1}$  is defined by  $(\varepsilon_{t+1}^\pi \ \varepsilon_{t+1}^y \ \varepsilon_{t+1}^q \ 0 \ 0)^T$ . Thus, in state-space form the model can be summarised as:

$$(IV.111) \quad \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \pi_{t+1} \\ y_{t+1} \\ q_{t+1} \\ q_t \\ i_t \end{pmatrix} = \begin{pmatrix} 1 & \gamma_y & \gamma_q & -\gamma_q & 0 \\ \beta_i & \beta_y & \beta_q & 0 & 0 \\ 0 & 0 & \alpha_q & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} \pi_t \\ y_t \\ q_t \\ q_{t-1} \\ i_{t-1} \end{pmatrix} + \begin{pmatrix} 0 \\ -\beta_i \\ 0 \\ 0 \\ 1 \end{pmatrix} i_t + \begin{pmatrix} \varepsilon_{t+1}^\pi \\ \varepsilon_{t+1}^y \\ \varepsilon_{t+1}^q \\ 0 \\ 0 \end{pmatrix}.$$

The vector of goal variables is defined by

$$(IV.112) \quad z_t = \begin{pmatrix} \pi_t \\ y_t \\ \Delta i_t \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} \pi_t \\ y_t \\ q_t \\ q_{t-1} \\ i_{t-1} \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} i_t.$$

## IV.B Optimisation, simple rules, dynamics and unconditional variances in discrete-time stochastic rational expectations models<sup>63</sup>

To perform the numerical calculations in this Chapter we need four ingredients

1. the model of the economy in state-space representation:

$$(IV.113) \quad \begin{pmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{pmatrix} = A \begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} + B i_t + \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix}.$$

2. a vector of goal variables:

$$(IV.114) \quad z_t = C_x x_t + C_i i_t$$

3. an intertemporal loss function at time  $\tau = 0$ :

$$(IV.115) \quad J_0 = E_0 \left[ \sum_{t=0}^{\infty} \delta^t L_t \right]$$

4. the unconditional variance-covariance matrix of the disturbance vector  $\varepsilon_{1,t+1}$ :

$$(IV.116) \quad \Sigma_{\varepsilon_1}.$$

The different models and goal vectors have already been specified in Appendix IV.A. For a complete representation of the monetary policy maker's problem we further need to transform the loss function into matrix notation. The period loss function  $L_t$  is given by

$$(IV.117) \quad L_t = z_t^T K z_t$$

where  $K$  is diagonal matrix of preference parameters. For all our model specifications  $K$  takes the following form

$$(IV.118) \quad K = \begin{pmatrix} \lambda_{\pi} & 0 & 0 \\ 0 & \lambda_y & 0 \\ 0 & 0 & \lambda_{\Delta i} \end{pmatrix}$$

where  $\lambda_{\pi} = \lambda_y = 1$  and  $\lambda_{\Delta i} = 0$ . By inserting (IV.114) into (IV.117) the period loss function can be written in standard form as

$$\begin{aligned}
(IV.119) \quad L_t &= \begin{pmatrix} x_t^T & i_t^T \end{pmatrix} \begin{pmatrix} C_x^T \\ C_i^T \end{pmatrix} K \begin{pmatrix} C_x & C_i \end{pmatrix} \begin{pmatrix} x_t \\ i_t \end{pmatrix} = \\
&= x_t^T C_x^T K C_x x_t + x_t^T C_x^T K C_i i_t + i_t^T C_i^T K C_x x_t + i_t^T C_i^T K C_i i_t = \\
&= x_t^T Q x_t + x_t^T U i_t + i_t^T U^T x_t + i_t^T R i_t = \\
&= x_t^T Q x_t + 2x_t^T U i_t + i_t^T R i_t
\end{aligned}$$

where

$$(IV.120) \quad Q = C_x^T K C_x$$

$$(IV.121) \quad U = C_x^T K C_i$$

$$(IV.122) \quad R = C_i^T K C_i.$$

Thus, the policy maker's intertemporal loss function can be written as

$$(IV.123) \quad J_0 = E_0 \left[ \sum_{t=0}^{\infty} \delta^t L_t \right] = E_0 \left[ \sum_{t=0}^{\infty} \delta^t \left( x_t^T Q x_t + 2x_t^T U i_t + i_t^T R i_t \right) \right].$$

The policy problem is to choose a time path for the instrument  $i_t$  to engineer time paths of the target variables  $z_t$  given by (IV.114) that minimise the loss function (IV.123), subject to the constraints on private sector behaviour implied by (IV.113). The value of the intertemporal loss function is then calculated on the basis of the policy rule dependent dynamics of the system and the unconditional variance-covariance matrix (IV.116).

#### IV.B.a Optimal policy under commitment

Under commitment the policy maker internalises the effects of his decision rule on expectations. His objective is assumed to be the minimisation of (IV.123) subject to (IV.113). This would be straightforward but for the fact that (IV.113) has the expected value of  $x_{2,t+1}$  on the left hand side rather than the actual values, and at any given time  $t$  the values of  $x_{2,t}$  are not predetermined. We can replace  $E_t x_{2,t+1}$  by  $x_{2,t+1} - \varepsilon_{2,t+1}$  where  $\varepsilon_{2,t+1}$  is by construction the innovation in  $x_{2,t+1}$ , and

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<sup>63</sup> This Appendix draws on work of Backus and Driffill (1986), Currie and Levine (1992), and Söderlind (1999).

its value is unconstrained except by the requirement that it should be uncorrelated with any variables dated  $t$  or earlier. It is not exogenously given, but it is a function of  $\varepsilon_{1,t+1}$ . The central bank's optimisation problem is represented by the Lagrangian

$$(IV.124) \quad \mathcal{L} = E_0 \left[ \sum_{t=0}^{\infty} \delta^t \left( x_t^T Q x_t + 2x_t^T U u_t + u_t^T R u_t + 2\psi_{t+1}^T (A x_t + B u_t + \varepsilon_{t+1} - x_{t+1}) \right) \right]$$

where  $\varepsilon_{t+1} = (\varepsilon_{1,t+1}, \varepsilon_{2,t+1})$  and  $\psi_{t+1}$  is a  $((n_1 + n_2) \times 1)$  vector of Lagrange multipliers. The solution of the optimisation problem is given by the dynamic equations

$$(IV.125) \quad k_{1,t+1} = \begin{pmatrix} x_{1,t+1} \\ \psi_{2,t+1} \end{pmatrix} = M^c k_{1,t} + \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix} = M^c k_{1,t} + \varepsilon_{k1,t+1}, \text{ and}$$

$$(IV.126) \quad k_{2,t} = \begin{pmatrix} x_{2,t} \\ i_t \\ \psi_{1,t} \end{pmatrix} = N^c k_{1,t}$$

where  $\psi_{j,t}$  is the vector of Lagrange multipliers associated with  $x_{j,t}$ . The exact derivation of the  $M^c$  and  $N^c$  matrices is shown in detail in Söderlind (1999). Equation (IV.125) corresponds to equation (1.14) and equation (IV.126) to equation (1.15) of this paper. The optimal feedback rule is then given by

$$(IV.127) \quad i_t = F^c \cdot \begin{pmatrix} x_{1,t} \\ \psi_{2,t} \end{pmatrix}$$

where  $F^c$  corresponds to row  $n_2 + 1$  of the  $N^c$  matrix.

On the basis of (IV.125) the covariance matrix of  $k_{1,t+1}$  satisfies

$$(IV.128) \quad \Sigma_{k1} = M^c \Sigma_{k1} M^{cT} + \Sigma_{\varepsilon k1}$$

where

$$(IV.129) \quad \Sigma_{\varepsilon k1} = \begin{pmatrix} \Sigma_{\varepsilon 1} & \mathbf{0}_{n1 \times n2} \\ \mathbf{0}_{n2 \times n1} & \mathbf{0}_{n2 \times n2} \end{pmatrix}.$$

$\Sigma_{k1}$  can finally be obtained from

$$(IV.130) \quad \text{vec}(\Sigma_{k1}) = [\mathbf{I}_{n^2} - \mathbf{M}^c \otimes \mathbf{M}^c]^{-1} \text{vec}(\Sigma_{\varepsilon k1}).$$

By inserting (IV.125) into (IV.126) we get

$$(IV.131) \quad \mathbf{k}_{2,t+1} = \mathbf{N}^c (\mathbf{M}^c \mathbf{k}_{1,t} + \varepsilon_{k1,t+1}).$$

With  $\mathbf{k}_{t+1}$  defined as vector that results from stacking  $\mathbf{k}_{1,t+1}$  and  $\mathbf{k}_{2,t+1}$

$$(IV.132) \quad \mathbf{k}_{t+1} = \begin{pmatrix} \mathbf{k}_{1,t+1} \\ \mathbf{k}_{2,t+1} \end{pmatrix},$$

we get the following expression for  $\mathbf{k}_{t+1}$

$$(IV.133) \quad \mathbf{k}_{t+1} = \begin{pmatrix} \mathbf{I}_{(n1+n2)} \\ \mathbf{N}^c \end{pmatrix} \mathbf{k}_{1,t+1} = \mathbf{H} \mathbf{k}_{1,t+1}.$$

The covariance matrix of  $\mathbf{k}_{t+1}$  (or  $\mathbf{k}_t$ ) is then given by

$$(IV.134) \quad \Sigma_k = \mathbf{H} \Sigma_{k1} \mathbf{H}^T.$$

As the goal variables  $z_t$  follow

$$(IV.135) \quad z_t = \mathbf{C}_x \mathbf{x}_t + \mathbf{C}_i \mathbf{i}_t = (\mathbf{C}_x \quad \mathbf{C}_i) \begin{pmatrix} \mathbf{x}_t \\ \mathbf{i}_t \end{pmatrix} = \mathbf{C}_c \begin{pmatrix} \mathbf{x}_t \\ \mathbf{i}_t \end{pmatrix}$$

their covariance matrix can be calculated from

$$(IV.136) \quad \Sigma_z = C_c \Sigma_{x,i} C_c^T.$$

$\Sigma_{x,i}$  is a submatrix of  $\Sigma_k$  that is obtained by deleting the columns and rows belonging to the Lagrange multipliers  $\psi_{1,t}$  and  $\psi_{2,t}$ . The value of the intertemporal loss function is finally given by

$$(IV.137) \quad J_0 = \text{diag}(\Sigma_z)^T \text{diag}(K)$$

where the  $\text{diag}$  operator defines a vector containing the elements of the main diagonal of a matrix.

#### IV.B.b Optimal policy under discretion

If the central bank is optimising in a discretionary way, then at each period of time it optimises taking the state of the economy defined by the predetermined variables  $x_{1,t}$  as well as the private sector's expectations as given. The central bank thus no longer internalises the effects of its decisions on expectations. Since  $x_{1,t}$  is the only predetermined variable,  $x_{2,t}$  is supposed to be a linear function of  $x_{1,t}$ :

$$(IV.138) \quad x_{2,t} = N^d x_{1,t}.$$

Private agents form expectations about  $x_{2,t+1}$  accordingly:

$$(IV.139) \quad E_t x_{2,t+1} = N^d E_t x_{1,t+1}.$$

Based on these preliminary considerations we can reformulate the central bank's period loss function only in terms of the predetermined variables. First, we take expectations of (IV.113)

$$(IV.140) \quad \begin{pmatrix} E_t x_{1,t+1} \\ E_t x_{2,t+1} \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix} \begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} + \begin{pmatrix} B_1 \\ B_2 \end{pmatrix} i_t$$

where the matrices A and B were partitioned conformably with  $x_{1,t}$  and  $x_{2,t}$ . We then replace  $E_t x_{2,t+1}$  with (IV.139) and solve for  $x_{2,t}$  and  $E_t x_{1,t+1}$ :

$$(IV.141) \quad \begin{aligned} x_{2,t} &= (A_{22} - N^d A_{12})^{-1} (N^d A_{11} - A_{21}) x_{1,t} + (A_{22} - N^d A_{12})^{-1} (N^d B_1 - B_2) i_t = \\ &= D x_{1,t} + G i_t, \end{aligned}$$

$$(IV.142) \quad \begin{aligned} E_t x_{1,t+1} &= A_{11} x_{1,t} + A_{12} x_{2,t} + B_1 i_t = \\ &= (A_{11} + A_{12} D) x_{1,t} + (B_1 + A_{12} G) i_t = \\ &= A^* x_{1,t} + B^* i_t. \end{aligned}$$

Inserting (IV.141) into (IV.119) finally yields

$$(IV.143) \quad \begin{aligned} L_t &= \begin{pmatrix} x_{1,t}^T & D^T x_{1,t}^T + G^T i_t^T \end{pmatrix} \begin{pmatrix} Q_{11} & Q_{12} \\ Q_{21} & Q_{22} \end{pmatrix} \begin{pmatrix} x_{1,t} \\ D x_{1,t} + G i_t \end{pmatrix} + \\ &+ 2 \begin{pmatrix} x_{1,t} \\ D x_{1,t} + G i_t \end{pmatrix} \begin{pmatrix} U_1 \\ U_2 \end{pmatrix} i_t + i_t^T R i_t = \\ &= x_{1,t}^T Q^* x_{1,t} + 2 x_{1,t}^T U^* i_t + i_t^T R^* i_t, \end{aligned}$$

where Q and U were partitioned conformably with  $x_{1,t}$  and  $x_{2,t}$ . The asterisked matrices are given by

$$(IV.144) \quad Q^* = Q_{11} + D^T Q_{21} + Q_{12} D + D^T Q_{22} D,$$

$$(IV.145) \quad U^* = Q_{12} G + D^T Q_{22} G + U_1 + D^T U_2,$$

$$(IV.146) \quad R^* = G^T Q_{22} G + G^T U_2 + U_2^T G + R.$$

With equations (IV.142) and (IV.143) at hand, the problem of the monetary policy maker is transformed to a standard backward-looking optimisation problem. Instead of using the maximum principle approach (as in the case of commitment) this type of problem is typically solved by a dynamic programming approach which exploits the recursive nature of the time separable intertemporal loss function (IV.115). We first rewrite the value of our modified intertemporal loss function at time t for given  $x_{1,t}$ :

$$(IV.147) \quad J_t(x_{1,t}) = E_t \left[ \sum_{s=0}^{\infty} \delta^s \left( x_{1,t+s}^T Q x_{1,t+s} + 2x_{1,t+s}^T U i_{t+s} + i_{t+s}^T R i_{t+s} \right) \right].$$

Next, due to Bellman's principle of optimality, the optimisation problem can be reformulated as

$$(IV.148) \quad \begin{aligned} J_t(x_{1,t}) &= x_{1,t}^T V_t x_{1,t} + \omega_t = \\ &= \min_{i_t} \left\{ L_t + \delta E_t \left[ x_{1,t+1}^T V_t x_{1,t+1} + \omega_{t+1} \right] \right\} = \\ &= \min_{i_t} \left\{ \begin{aligned} &x_{1,t}^T Q x_{1,t} + 2x_{1,t}^T U i_t + i_t^T R i_t + \\ &+ \delta E_t \left[ \left( A^* x_{1,t} + B^* i_t + \varepsilon_{1,t+1} \right)^T V_{t+1} \left( A^* x_{1,t} + B^* i_t + \varepsilon_{1,t+1} \right) + \omega_{t+1} \right] \end{aligned} \right\} \end{aligned}$$

where  $V_t$  is a positive semidefinite matrix and  $\omega_t$  a scalar, both yet to be determined by iterating on the value function. By using standard methods it can be shown that the optimal discretionary policy is calculated as a rule for the interest rate which is a linear function of the predetermined variables:

$$(IV.149) \quad i_t = F^d x_{1,t}.$$

Given this interest rate rule the reduced form of the model can be written as

$$(IV.150) \quad x_{1,t+1} = M^d x_{1,t} + \varepsilon_{1,t+1}$$

$$(IV.151) \quad x_{2,t} = N^d x_{1,t}.$$

As in the case of commitment we refer to Söderlind (1999) for the exact derivation of the  $F^d$ ,  $M^d$  and  $N^d$  matrices (see equations (1.24), (1.27) and (1.25) of this paper).

The covariance matrix of  $x_{1,t}$  can be calculated on the basis of (IV.150) as

$$(IV.152) \quad \text{vec}(\Sigma_{x_1}) = \left[ I_{n^2} - M^d \otimes M^d \right]^{-1} \text{vec}(\Sigma_{\varepsilon_1}).$$

Since the goal variables  $z_t$  follow

$$\begin{aligned}
z_t &= C_x x_t + C_i i_t = \\
&= (C_{x1} \quad C_{x2}) \begin{pmatrix} x_{1t} \\ x_{2t} \end{pmatrix} + C_i F^d x_{1,t} = \\
\text{(IV.153)} \quad &= (C_{x1} \quad C_{x2}) \begin{pmatrix} x_{1t} \\ N^d x_{1,t} \end{pmatrix} + C_i F^d x_{1,t} = \\
&= (C_{x1} + C_{x2} N^d + C_i F^d) x_{1,t} = \\
&= C_d x_{1,t}.
\end{aligned}$$

where  $C_x$  is partitioned conformably with  $x_{1,t}$  and  $x_{2,t}$  the covariance matrices of  $x_{2,t}$  and  $z_t$  are given by

$$\text{(IV.154)} \quad \Sigma_{x2} = N^d \Sigma_{x1} N^{dT} \text{ and}$$

$$\text{(IV.155)} \quad \Sigma_z = C_d \Sigma_{x1} C_d^T.$$

The value of the intertemporal loss function can be calculated on the basis of equation (IV.137).

#### IV.B.c (Optimal) simple policy rules

A commitment of the policy maker to a simple policy rule is most generally given by

$$\text{(IV.156)} \quad i_t = F^s x_t$$

where the elements in  $F^s$  are restricted in some specified way. Substituting for  $i_t = F^s x_t$  in equation (IV.113) gives

$$\text{(IV.157)} \quad \begin{pmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{pmatrix} = (A + BF) \begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t+1} \\ 0_{n_2 \times 1} \end{pmatrix}$$

which can be solved by an adequate decomposition of the matrix  $(A + BF)$ . It can be shown that the dynamics of the system evolve according to

$$\text{(IV.158)} \quad x_{1,t+1} = M^s x_{1,t} + \varepsilon_{1,t+1} \text{ and}$$

$$(IV.159) \quad x_{2,t} = N^s x_{1,t}.$$

See equations (1.17) and (1.18) in Söderlind (1999).

The goal variables  $z_t$  then follow

$$(IV.160) \quad \begin{aligned} z_t &= C_x x_t + C_i i_t = \\ &= (C_{x1} \quad C_{x2}) \begin{pmatrix} x_{1t} \\ x_{2t} \end{pmatrix} + C_i \begin{pmatrix} F_1^s & F_2^s \end{pmatrix} \begin{pmatrix} x_{1t} \\ x_{2t} \end{pmatrix} = \\ &= (C_{x1} \quad C_{x2}) \begin{pmatrix} x_{1t} \\ N^s x_{1,t} \end{pmatrix} + C_i \begin{pmatrix} F_1^s & F_2^s \end{pmatrix} \begin{pmatrix} x_{1t} \\ N^s x_{1,t} \end{pmatrix} = \\ &= (C_{x1} + C_{x2} N^s + C_i F_1^s + C_i F_2^s N^s) x_{1,t} = \\ &= C_s x_{1,t} \end{aligned}$$

where  $C_x$  and  $F^s$  are partitioned conformably with  $x_{1,t}$  and  $x_{2,t}$ .

The covariance matrix of  $x_{1,t}$  can be calculated on the basis of (IV.158) as

$$(IV.161) \quad \text{vec}(\Sigma_{x1}) = [I_{n1^2} - M^s \otimes M^s]^{-1} \text{vec}(\Sigma_{\varepsilon1}).$$

The covariance matrices of  $x_{2,t}$  and  $z_t$  are then given by

$$(IV.162) \quad \Sigma_{x2} = N^s \Sigma_{x1} N^{sT} \quad \text{and}$$

$$(IV.163) \quad \Sigma_z = C_s \Sigma_{x1} C_s^T.$$

The value of the intertemporal loss function finally results from the following equation (which corresponds to equation (IV.137)):

$$(IV.164) \quad J_0 = \text{diag}(\Sigma_z)^T \text{diag}(K).$$

An optimal simple rule is defined as a policy rule of the form (IV.156) that minimises  $J_0$  subject to the model of the economy – just as regular optimal control problems – plus a constraint on the

number of arguments in the reaction function. Thus the monetary authority's problem can be stated as

$$(IV.165) \quad \min_{i_t \langle f_\pi, f_y, f_q, f_{q(-1)} \rangle} E_0 \left[ \sum_{t=0}^{\infty} \delta^t (\lambda_\pi \pi_t^2 + \lambda_y y_t^2) \right]$$

subject to

$$(IV.166) \quad \begin{pmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{pmatrix} = A \begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} + B i_t + \begin{pmatrix} \varepsilon_{1,t+1} \\ \mathbf{0}_{n_2 \times 1} \end{pmatrix}$$

where the restriction on the elements of  $F$  is shown in brackets below the min operator. We solved this constrained optimisation problem by using a grid search method. The non-zero elements of  $F^s$  were allowed to vary within a pre-specified reasonable range using a grid of 0.01. For each  $F^s$  vector we then calculated  $J_0$ . The  $F^s$  vector with the lowest loss finally gave the optimal simple rule.

### IV.C Simple policy rules under U2

In Appendix IV.A.b we derived the state-space representation of the model containing the exchange rate specification of Ball (1999b). As it can be seen from equation (IV.88), the state vector of the model does not include the contemporaneous real exchange rate. If, however, one aims at assessing the performance of simple rules which react to this variable, like R2, R4, R5 and R6, we have to make use of the contemporaneous relationship between the real exchange rate and the nominal interest rate in this model:

$$(IV.167) \quad q_t = -\alpha_i (i_t - \pi_t).$$

The rules that need to be transformed have the following structure:

$$(IV.168) \quad i_t = f_\pi \pi_t + f_y y_t + f_q q_t$$

$$(IV.169) \quad \dot{i}_t = f_\pi \pi_t + f_y y_t + f_{\Delta q} \Delta q_t$$

$$(IV.170) \quad i_t = f_\pi \pi_t + f_y y_t + f_{\Delta s} \Delta s_t$$

$$(IV.171) \quad i_t = f_\pi \pi_t + f_y y_t + f_q q_t + f_{q(-1)} q_{t-1}.$$

We have to replace  $q_t$  in equation (IV.168) with  $-\alpha_i (i_t - \pi_t)$  and solve the resulting equation for  $i_t$ :

$$(IV.172) \quad i_t = \frac{f_\pi + f_q \alpha_i}{1 + f_q \alpha_i} \pi_t + \frac{f_y}{1 + f_q \alpha_i} y_t.$$

Interest rate rule (IV.172) is thus the equivalent rule to (IV.168) in the original Ball (1999b) model. The same proceeding can be applied to rule (IV.169) which yields

$$(IV.173) \quad i_t = \frac{f_\pi + f_{\Delta q} \alpha_i}{1 + f_{\Delta q} \alpha_i} \pi_t + \frac{f_y}{1 + f_{\Delta q} \alpha_i} y_t - \frac{f_{\Delta q}}{1 + f_{\Delta q} \alpha_i} q_{t-1}.$$

For transforming rule (IV.170) we additionally have to replace  $s_t$  with  $s_{t-1} + q_t - q_{t-1} + \pi_t$ . By doing so we finally get the equivalent interest rate rule to equation (IV.170) in the original Ball (1999b) model:

$$(IV.174) \quad i_t = \frac{f_\pi + f_{\Delta s}(1 + \alpha_i)}{1 + f_{\Delta s}\alpha_i} \pi_t + \frac{f_y}{1 + f_{\Delta s}\alpha_i} y_t - \frac{f_{\Delta s}}{1 + f_{\Delta s}\alpha_i} q_{t-1}.$$

Rule (IV.171) is transformed in the same way as rule (IV.168) and (IV.169). We get

$$(IV.175) \quad i_t = \frac{f_\pi + f_q\alpha_i}{1 + f_q\alpha_i} \pi_t + \frac{f_y}{1 + f_q\alpha_i} y_t - \frac{f_{q(-1)}}{1 + f_q\alpha_i} q_{t-1}.$$

## **Chapter V:**

### **A Monetary Policy Strategy of Direct Managed Floating**

In this Chapter we will provide a rationale for the second type of a central bank's reaction to fear of floating. While in the previous Chapter indirect managed floating turned out to be a robust monetary policy strategy under purely market determined exchange rates, we now introduce direct and sterilised foreign exchange market interventions as an additional policy tool in a strategy of direct managed floating. In particular, we will show that the motive for these interventions and their effectiveness can only be explained on the basis of the failures of a perfectly holding UIP condition.

According to the classification scheme of monetary and exchange rate strategies set up in Chapter I, the characteristics of direct managed floating are as follows. Concerning (i) the role of the exchange rate, under direct managed floating the exchange rate is controlled by the central bank through direct interventions in the foreign exchange market. Unlike in systems of purely market determined exchange rates the movements in the exchange rate are not predominantly market determined, but policy determined. Concerning (ii) the implementation of monetary policy, under direct managed floating the central bank has a double operating target: the nominal exchange rate and the nominal short-term interest rate. The interest rate is controlled – like in systems of purely market determined exchange rates – through direct interventions in the domestic money market. Unlike in systems of pre-announced crawling pegs or fixed exchange rates the central bank targets an exchange rate path that is not pre-announced. The independence of the two operating targets is guaranteed by sterilisation of the foreign exchange market interventions which distinguishes a direct managed float from (idealised) systems of pre-announced crawling pegs or fixed exchange rates in which the interest rate is subordinated to the exchange rate target. Concerning (iii) the nominal anchor, the primary goal of monetary policy is a preannounced target rate of inflation. As neither the exchange rate path nor the short-term interest rate are pre-announced, they cannot serve as a nominal anchor. Thus, in this respect, direct managed floating is similar to inflation targeting strategies under market determined exchange rates.

The remainder of this Chapter is structured as follows. In the first Section we will begin by taking a closer look at the central bank's additional operating target, the nominal exchange rate.

While the mechanics and the effectiveness of interventions in the domestic money market to target a short-term nominal interest rate are uncontroversial and identical to strategies with a single operating target (see Section IV.1.2), the effectiveness of sterilised foreign exchange market interventions to target a level of the nominal exchange rate has to be seen in a close context to the question of how the exchange rate is determined. We present a range of intervention channels and we critically discuss the related empirical literature. In Section V.2 we develop a policy rule for the two operating targets of a direct managed floating central bank and we show how the central bank adjusts its operating targets in response to shocks. Section V.3 finally compares the strategy of direct managed floating with the strategies of independently floating and indirect managed floating.

## **V.1 The exchange rate as operating target under direct managed floating**

An important difference to a central bank's intervention in the domestic money market is that in the foreign exchange market the central bank no longer acts as a monopolist. It rather appears as an additional customer on the inter-bank foreign exchange market (besides non-financial corporations and institutional investors) who carries out trades with market makers or brokers through buying and selling orders (see Section V.1.2.3.2 below). Thus, in order to understand how additional supply of or demand for foreign exchange following a central bank intervention affects the exchange rate, we have to discuss the channels by which the equilibrium exchange rate is determined in general (i.e. independent of who creates additional demand or supply). And this discussion is typically done in the context of various models of exchange rate determination. For each of the channels that are presented in the following Sections we proceed as follows. We begin by presenting the underlying model of exchange rate determination. We then describe how interventions are supposed to affect the exchange rate. In order to answer the crucial question whether interventions in the foreign exchange market are effective we finally summarise the empirical evidence related with each channel.

### ***V.1.1 Non-sterilised interventions and the 'monetary channel' of exchange rate determination***

Non-sterilised interventions involve a one-for-one change in the central bank's net foreign assets and the monetary base. Thus, they are simply a variant of a central bank's interest rate policy that can be distinguished from conventional open market operations only in the type of asset being

exchanged for base money. The change in base money leads to a change in the short-term interest rate, and hence to a modified exchange rate path. This effect can be demonstrated by solving the UIP equation of our baseline model presented in Section IV.1.1 for  $s_t$ :

$$(V.1) \quad s_t = E_t \sum_{j=0}^{\infty} (i_{t+j}^f - i_{t+j} + u_{t+j}^s).$$

Accordingly, a one-time rise in domestic interest rates in time  $t$  ( $j = 0$ ) leads to an appreciation of the contemporaneous spot rate, everything else being equal. In sum, non-sterilised interventions do not provide an additional and independent instrument for a central bank under independently floating exchange rates.

As the term ‘monetary channel’ in the title of this Section already indicates, the literature usually discusses the effects of this type of non-sterilised interventions within the framework of monetary models of exchange rate determination. Thus, instead of focusing on the intervention’s impact on short-term interest rates, the supply of a broad monetary aggregate (such as M1) is affected by a change in the monetary base  $B$  via the money-multiplier relationship. Since monetary models of the exchange rate start from the definition of the exchange rate as the relative price of two monies, changes in the domestic money supply, relative to the foreign money supply, lead to a change in the exchange rate (see Section II.2 for a presentation of the monetary model). However, as is the case in most modern dynamic monetary models, our model totally neglects the role of monetary aggregates in the determination of output, prices, and the exchange rate. Thus, the effects of non-sterilised interventions via the monetary channel are exclusively captured by movements in the short-term interest rate.

Astonishingly, the effectiveness of the monetary channel under floating exchange rates is rarely questioned. In contrast, many authors argue like Marston (1988, p. 97): “There is virtually unanimous agreement among economists that non-sterilised intervention can affect exchange rates, just as more conventionally defined monetary policy can undoubtedly affect exchange rates” (see also Edison, 1993, p. 8, and Sarno and Taylor, 2001a, p. 841, for similar statements). This is in particular astonishing in view of the poor empirical evidence for a stable relationship between short-term interest rates and exchange rate changes via UIP or between changes in a monetary aggregate and exchange rate changes as predicted by the monetary model of exchange

rate determination (see for example the survey article on exchange rate economics of one of the above authors, namely Taylor, 1995).

Nonetheless, it should be mentioned that, with regard to the assignment of the operating targets made in Section I.3.2, the monetary channel constitutes a central channel of monetary policy under absolutely fixed exchange rates, in particular in a currency board arrangement. This can easily be shown with the help of a stylised currency board balance sheet (see Figure V.1). In pure currency board systems the monetary authority does not have any domestic credit instruments at its disposal. Hence, the only source of base money creation are changes in the NFA which cannot be sterilised. As soon as the domestic short-term interest rate deviates from the ‘policy rule’ given by equation (II.30) (see Section II.3.4), capital flows put pressure on the fixed exchange rate. The monetary authority has to intervene in the foreign exchange market in order to keep the exchange rate unchanged. Capital inflows, for example, lead to an increase in NFA, and hence to B, which in turn lowers short-term domestic interest rates, and hence the source of the capital inflows (see Berensmann, 2002, for a detailed analysis).

**Figure V.1: A stylised currency board balance sheet**

assets	liabilities
NFA	B

**V.1.2 Sterilised interventions**

It should be clear from the last Section that the monetary channel of foreign exchange market interventions subordinates the interest rate instrument to the exchange rate instrument. Thus, in order to have an independent exchange rate instrument, the effects of foreign exchange market interventions on base money have to be sterilised. Before we discuss the channels through which sterilised interventions are supposed to work, the next Section presents the mechanics of sterilisation on the basis of some simple balance sheet identities.

### *V.1.2.1 Sterilisation of foreign exchange market interventions*

In broad terms sterilisation can be defined as any off-setting measure by the central bank in response to changes in the NFA so as to leave the monetary policy instrument unaffected. In this context the term ‘instrument’ has been somewhat loosely used. This stems from the fact that the earlier literature in which central banks were assumed to control the supply of a monetary aggregate usually made no difference between base money (B) and broad money (M) (see e.g. Argy and Kouri, 1974). It was simply assumed that there was a stable relationship between these two aggregates via the money multiplier.

As we focus solely on short-term interest rates as monetary policy instrument (or, to be precise, as operating target), the mechanics of sterilisation are quite straightforward. As each sale or purchase of foreign exchange leads to an equivalent change of the foreign component of base money (the net foreign assets, NFA)

$$(V.2) \quad I = \Delta NFA$$

and thus to a change of total base money

$$(V.3) \quad \Delta NFA + \Delta NDA = \Delta B,$$

the short-term interest rate would deviate from its optimum value (see Figure V.2 for a presentation of a sterilised intervention in T-accounts). To avoid this, each purchase (sale) of foreign exchange has to be offset by a corresponding decrease (increase) of net domestic assets ( $\Delta NDA$ )

$$(V.4) \quad \overset{!}{\Delta B = 0} \Rightarrow \Delta NDA = -\Delta NFA$$

so that in the end the foreign exchange market intervention leaves the domestic short-term interest rates constant. In practice, the sterilisation can be accomplished either by an opposite change in domestic assets ( $\Delta DA = -\Delta NFA$ , sterilisation 1 in the lower left panel of Figure V.2) or by a corresponding change in domestic liabilities ( $\Delta DL = \Delta NFA$ , sterilisation 2 in the lower right panel of Figure V.2). In the first case an official purchase, for example, of foreign exchange can be offset through a corresponding open market sale of domestic assets by the central bank or

by a repayment of the lending facilities previously used by the commercial banks. In the second case the increase in foreign assets is neutralised by a placement of excessive commercial banks' funds at the central bank (via the deposit facility) or through sales of domestic currency-denominated short-term securities by the central bank.

**Figure V.2: The mechanics of a sterilised foreign exchange market intervention**

<i>before intervention</i>		<i>after intervention, before sterilisation</i>	
assets	liabilities	assets	liabilities
NFA	B	NFA	B
DA		I = $\Delta$ NFA	
	DL	DA	$\Delta$ B
			DL

<i>after intervention, with sterilisation (option 1)</i>		<i>after intervention, with sterilisation (option 2)</i>	
assets	liabilities	assets	liabilities
NFA	B	NFA	B
I = $\Delta$ NFA		I = $\Delta$ NFA	
DA	DL	DA	DL
$-\Delta$ DA			$\Delta$ DL

Since the short-term interest rate remains unchanged the question arises of how the change in the net foreign assets impacts on the exchange rate. In the following we will discuss a range of intervention channels which are all based on specific models of exchange rate determination.

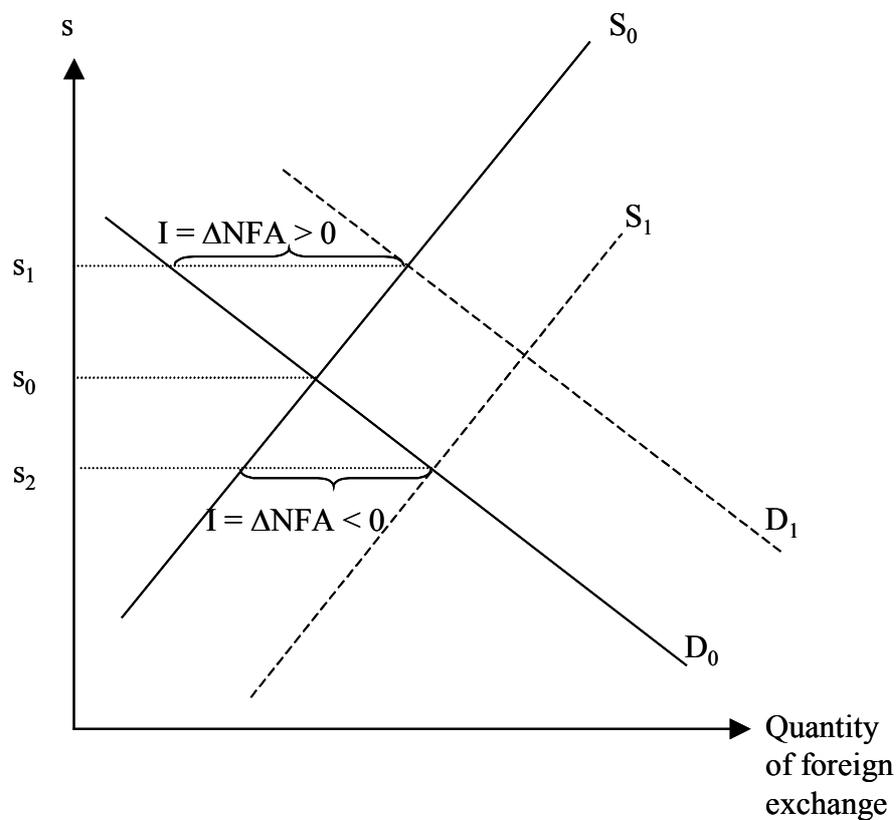
#### *V.1.2.2 Immediate effects of sterilised interventions through the balance of payments flow channel*

Prior to the 1970s, the dominant approach to exchange rate determination was to view the exchange rate as the equilibrium price of flows of foreign exchange passing through the foreign exchange market. The primary source of flow demand for and flow supply of foreign exchange are current account and capital account transactions that are recorded in the balance of payments. Probably the most influential application of this approach to the determination of the exchange

rate is the Mundell-Fleming model. Although the primary aim of this model was not to explain exchange rate movements, the balance of payments equilibrium is only guaranteed by changes in the exchange rate. Thus, foreign exchange was largely thought to be a medium of exchange for executing international transactions instead of a store of value which was considered as the primary function of foreign exchange under the subsequent asset market approach to exchange rate determination (see Section II.1 for a presentation of the Mundell-Fleming model).

Interventions that are assumed to operate on the basis of this balance of payments view alter the flow supply of foreign exchange relative to the demand for foreign exchange. The idea behind this channel is that the central bank intervenes in order to accommodate temporary imbalances on the foreign exchange market that result in short-run deviations of the exchange rate from its long-term flow equilibrium. Additional demand for ( $I > 0$ ) or supply of ( $I < 0$ ) foreign exchange by the central bank temporarily affects the flow equilibrium in the foreign exchange market (see Figure V.3).

**Figure V.3: The flow channel of foreign exchange market interventions**



It is normally uncontested that sterilised interventions exert an immediate effect on the exchange rate simply by the flow it creates. However, as such an intervention does not fundamentally change the determinants of the flow demand for foreign exchange, the demand curve would shift back to its initial position ( $D_0$ ). Consequently, in order to keep the exchange rate at  $s_1$ , the central bank has to keep on intervening as long as the temporary supply disturbance has disappeared. Thus, the success of interventions through that channel ultimately hinges on the central bank's potential to create a temporary shift of the flow equilibrium that results in an exchange rate  $s_1$  or  $s_2$ . Kenen (1987) refers to this kind of intervention policy as a 'brute-force policy' as continuing flow interventions are required to prevent market forces from reverting the exchange rate back to  $s_0$ . By arguing this way, he implicitly assumes that the central bank provokes a temporary stock disequilibrium on the international asset market.

If we believe in the asset market approach to exchange rate determination, then we have to apply a stock supply/demand framework. Macroeconomic flow approaches are only relevant for determining the equilibrium market price of a perishable good or service because such items exist only over short intervals of time.<sup>64</sup> The fact that we used UIP as the behavioural relationship of international investors makes it clear that we view the exchange rate as the price of financial assets – which are infinitely durable and which can be transferred but not destroyed. According to UIP investors are assumed to decide on the (stock) composition of their portfolios so that expected (and eventually risk-adjusted) returns on short-term, interest-bearing assets denominated in different currencies are equal. As sterilised interventions based on the balance of payments flow approach only alter the current spot rate (say from  $s_0$  to  $s_1$ ), an initial stock equilibrium on the international financial markets given by

$$(V.5) \quad \dot{i}_t = i_t^f + E_t s_{t+1} - s_0 + u_t^s$$

turns into a stock disequilibrium

$$(V.6) \quad \dot{i}_t > i_t^f + E_t s_{t+1} - s_1 + u_t^s$$

which triggers capital (in)flows and hence a reverting pressure on the domestic exchange rate.

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<sup>64</sup> The label 'macroeconomic' flow approach was used to distinguish it from the microstructure flow approach which will be introduced in the next Section.

This example shows that there is an important relationship between the stock and the flow perspective. Obviously, foreign exchange is used as both a medium of exchange and a store of value, so an overall equilibrium in the foreign exchange market requires a balance in both flow and stock aspects of the market (see Levich, 2001, appendix 6.1, for a simple model). Thus, the discussion of the balance of payments flow channel provides a useful insight into the basic issues of determining the exchange rate. We will come back to the flow approach below when we discuss foreign exchange market interventions on the level of the microstructure theory of exchange rates.

The central message of the Section is that if we want to have a persistent effect on the level of the exchange rate we have to change the behaviour of international investors. In our view there are at least three channels based on the asset market (and hence stock) approach to the determination of the exchange rate by which sterilised foreign exchange market interventions have a persistent impact on the exchange rate: the portfolio balance channel, the signalling (or expectations) channel and the noise trading (or coordination) channel. All channels have the common factor that the central bank changes important behavioural patterns of financial market participants.

### *V.1.2.3 The portfolio-balance channel of sterilised interventions and the portfolio-balance model of exchange rate determination*

#### V.1.2.3.1 The traditional macroeconomic approach

The idea of this channel is derived from the portfolio-balance models of exchange rate determination. This class of models is based on a two-country-two-currency world with two composite private sectors. International investors are supposed to hold two interest bearing assets in their portfolios: domestic government bonds denominated in domestic currency, and foreign government bonds denominated in foreign currency. The remainder is held as non-interest bearing domestic money so that the total wealth of the investor is defined as the sum of the three assets.<sup>65</sup> Since imperfect substitutability between domestic and foreign assets and risk aversion of

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<sup>65</sup> In a more generalised version of the portfolio-balance model investors additionally hold non-interest bearing foreign money so that the investors' portfolios contain four assets (Branson and Henderson, 1985). For empirical purposes the assumption is often made that currency substitution is irrelevant, thus reducing the number of

the investors is assumed, the uncovered interest parity condition has to be adjusted by a risk premium. In the UIP equation the risk premium  $u_t^s$  is defined as the rationally expected excess return that a domestic investment must offer in order to induce international investors to willingly hold the existing supply of domestic and foreign assets. Thus if  $u_t^s < 0$  ( $u_t^s > 0$ ) the expected return on the foreign country's asset which is measured by  $i_t^f + E_t \Delta s_{t+1}$  is greater (smaller) than that on the home country's asset which is measured by  $i_t$  because foreign assets are viewed as more (less) risky than home assets. According to the portfolio balance approach, the demand for any of the financial assets depends on the total wealth of the investor and the expected return on domestic and foreign bonds. The stock supply of the financial assets is determined by the interaction of monetary policies, budget deficits, and central bank interventions in the foreign exchange market. In the short-run, in the absence of any official intervention, it is assumed to be constant so that any exogenous change in the demand for foreign bonds results in an adjustment of the exchange rate. Thus, the exchange rate is the equilibrium price on the stock market for interest bearing and imperfectly substitutable assets (see Hallwood and MacDonald, 2000, chapter 11, for a textbook treatment).

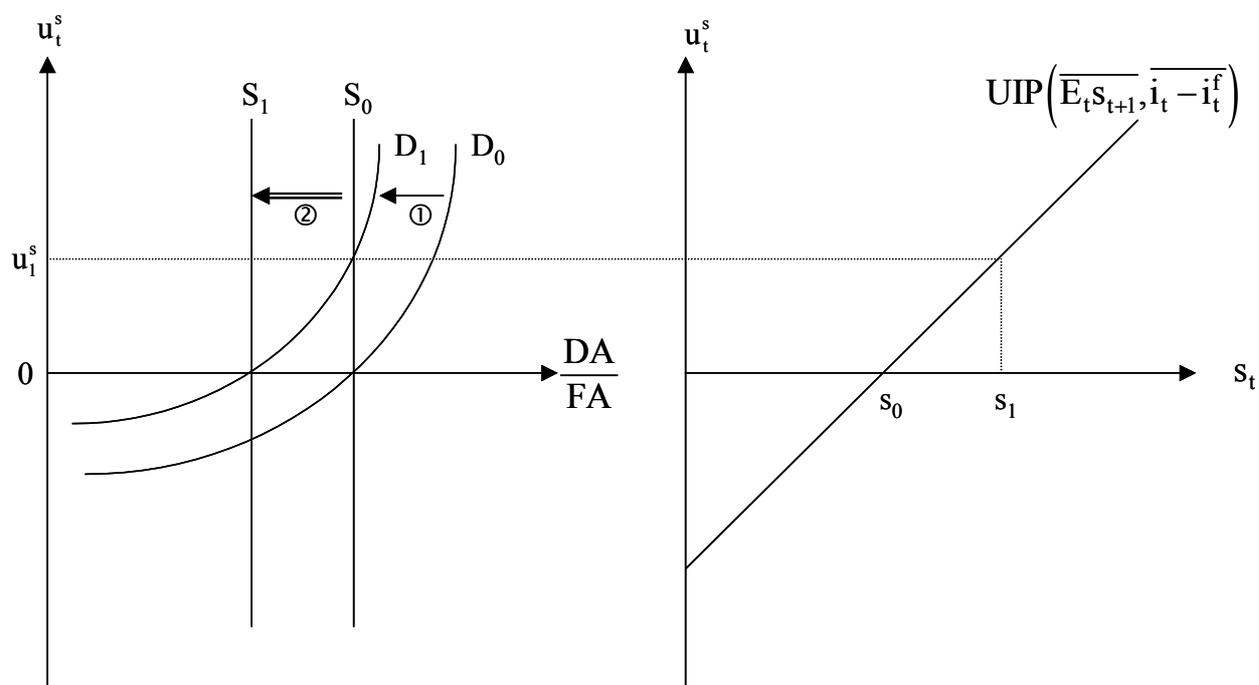
Under the aforementioned assumptions, asset holders will not be indifferent to the currency composition of their portfolios. Thus, if interventions are assumed to work through a portfolio-balance channel they affect the exchange rate by inducing investors to rebalance their portfolios. As an example, Figure V.4 illustrates a situation in which the initial equilibrium on the international financial market ( $D_0, S_0, s_0$ ) is disturbed by a positive exogenous risk premium shock ( $u_1^s$ ). The change in the investor's degree of risk aversion shifts the demand for domestic assets (DA) relative to foreign assets (FA) to the left ( $\textcircled{D}, D_1$ ). Since the relative supply is given by  $S_0$ , an adjustment of the structure of the portfolio is not possible. Thus, private investors will force an increase in the expected yield of the domestic asset relative to the foreign asset. For given exchange rate expectations  $\overline{E_t s_{t+1}}$  and a given interest differential  $\overline{i_t - i_t^f}$ , the spot exchange rate rises (depreciates) from  $s_0$  to  $s_1$ :

$$(V.7) \quad \begin{aligned} \overline{i_t - i_t^f} &= \overline{E_t s_{t+1}} - s_0 = \\ &= \overline{E_t s_{t+1}} - s_1 + u_1^s. \end{aligned}$$

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potential assets to three. Note that the complete model nevertheless contains four assets as domestic residents and

**Figure V.4: The portfolio-balance channel of sterilised foreign exchange market intervention**



Assume that the central bank's objective is to prevent its currency from depreciating to  $s_1$ . With sterilised foreign exchange market interventions (purchase of domestic assets against foreign assets) it changes the relative supply of assets (②) and hence, the stock of domestic relative to foreign assets that the private sector has to hold in its portfolio ( $S_1$ ). However, the imperfect substitutability assumption implies that investors are only willing to hold the changed asset stock if the risk premium and with it the spot rate (given again the interest rate differential  $\overline{i}_t - \overline{i}_t^*$ <sup>66</sup> and the exchange rate expectations  $\overline{E}_t s_{t+1}$ <sup>67</sup>) changes. The reason why the risk premium must fall in the case of a sterilised sale of foreign assets by the domestic central bank is that asset holders must be compensated by a higher expected return on foreign assets in order to induce them to buy the decreased relative supply of domestic relative to foreign assets. Thus, instead of viewing the disturbances to UIP as purely exogenous, the portfolio balance approach suggests the following decomposition of  $u_t^s$  (McCallum, 2000)

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foreigners are regarded simultaneously.

<sup>66</sup> Above all the domestic interest rate remains unchanged because of the sterilisation of the sale of foreign assets.

<sup>67</sup> As already mentioned in Chapter III, the risk premium explanation of the forward discount bias hinges on the assumption that market participants have rational expectations. Thus, the portfolio-balance channel of sterilised interventions applies only to UIP deviations that result from shocks to the risk aversion.

$$(V.8) \quad u_t^s = \lambda [da_t - (fa_t - s_t)] + v_t^s$$

where  $da_t$  and  $fa_t$  are logs of domestic and foreign assets held by the public and  $v_t^s$  is an exogenous auto-correlated risk premium shock. If UIP is hit by a positive exogenous risk premium shock  $v_t^s$  (①), sterilised purchases of domestic assets against foreign assets by the central bank ( $da_t$  falls whereas  $fa_t$  rises) offset the resulting change in the spot rate from  $s_0$  to  $s_1$  by counteracting (②) the change in the risk premium.

In the empirical literature it is common practice to verify the portfolio channel by estimating an (inverted<sup>68</sup>) asset-demand function which is derived from a mean-variance optimisation. The risk premium which is defined as the rationally expected deviation from UIP is modelled as function of the portfolio composition  $x_t$  (either domestic assets to foreign assets, foreign assets to total wealth, or domestic assets to total wealth) which is assumed to change in response to sterilised interventions:

$$(V.9) \quad i_t - i_t^f - E_t s_{t+1} + s_t = f(x_t).$$

Most studies in the 1980s that were based on this approach led to rather disappointing results.<sup>69</sup> While researchers typically concluded that risk premia exist and that they vary through time, they have not succeeded in relating these changes to relative asset supplies. With near unanimity, researchers have found the relationship to be either statistically insignificant or quantitatively unimportant. If there was significant evidence, the effects on the exchange rate were too weak in order to attribute any importance to this channel (see for example Almekinders, 1995, Dominguez and Frankel, 1993b, Edison, 1993, and Sarno and Taylor, 2001a, for comprehensive overviews).

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<sup>68</sup> According to the portfolio balance model of exchange rates the relative demand for assets is – among other things – a function of the risk premium. By inverting the asset demand function we can express the risk premium as a function of the aggregate supplies of assets (see equation (V.9)).

<sup>69</sup> We do not review the results in detail since they are rather unison and well-documented in the reviews quoted at the end of this paragraph.

According to Dominguez and Frankel (1993b) all these studies were confronted with two major problems, both of which are related to measurement difficulties. The first involves specifying the intervention variable. As shown on the right hand side of equation (V.9) the intervention activity is captured by the variation of relative asset supplies where adequate data sets are hardly available, and if so, only on a monthly or quarterly base (see for example the studies by Gosh, 1992, Obstfeld, 1983, and Rogoff, 1984).

The second difficulty refers to the measurement of exchange rate expectations. All the weak results of the studies based on the portfolio-balance channel were produced via application of the rational expectations approach. Recall that the risk premium explanation of UIP deviations critically hinges on the assumption that exchange markets are rational in the sense of using all available information and of not making systematic forecast errors. Thus, the market's failure to exploit all profitable interest opportunities must reflect a risk premium, not market inefficiencies. In contrast to the rational expectations studies which simply took ex post changes in the exchange rate as an unbiased measure of expected exchange rate changes Dominguez and Frankel (1993a) introduced the survey data approach where expectations are directly derived from private exchange market participants. By constructing measures of the risk premium on the basis of survey data on expectations they come to the conclusion "that the consensus view in the early 1980's, that intervention policy is largely ineffective, is no longer supported by the data" (Dominguez and Frankel, 1993a, p. 1366). In contrast to the mixed results obtained by previous studies their results indicate that interventions had a statistically significant effect on the risk premium.

We will come back to the process of expectations' formation and to the implications of alternatives to the efficient markets hypothesis for a central bank's intervention policy below in Section V.1.2.5. We will show that market inefficiencies open an alternative channel for foreign exchange market interventions. Before getting there, however, we cast doubt on the typical conclusion made by most economists that due to the mixed evidence of the portfolio channel there is no room for an efficient additional central bank instrument. In our view, the criticism that is pronounced against the portfolio balance channel of sterilised interventions is of a rather myopic nature. Recall that the basic assumption of this channel is that in the absence of interventions the exchange rate is determined according to the portfolio balance model described at the beginning of this Section. A short look however at the empirical literature on exchange rate models shows that the evidence in favour of portfolio balance models is weak. Frankel and

Rose (1995, p. 1697), for example, summarise the findings as follows: “Early empirical tests of the portfolio-balance model (...) were not particularly successful, even in-sample. The outlook did not much improve when researchers did a more careful job of measuring asset supplies.” In particular, as is the case in all fundamentals-based exchange rate models, coefficients in the exchange rate equations are subject to structural instabilities. For this reason, Hallwood and MacDonald (2000, p. 246) conclude: “Although the extant econometric evidence is perhaps not encouraging (...), casual empiricism suggests that the approach may, at least at certain times, be a useful framework for analysing the determination of the exchange rate.” Thus, in accordance with these findings, the empirical results for the portfolio balance channel of interventions vary with the underlying estimation period. The question now arises of why interventions that change a fundamental determinant of the exchange rate should lead to different and in particular better results than other sources of changes in the fundamentals (like a central bank’s open market policy or a government’s bond issue). Or, to put it differently, 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, and in particular it is inconsistent with the conclusions drawn in the context of the monetary channel. As mentioned above, it is generally argued that non-sterilised interventions unquestionably work through that channel while at the same time the monetary model of exchange rate determination is rejected in the literature – like the portfolio balance models.

“Another argument for the relatively lesser importance of the portfolio balance channel is that the typical size of intervention operations is a very tiny fraction of total foreign exchange market turnover” (Sarno and Taylor, 2001a, p. 862).<sup>70</sup> According to surveys of the Bank for International Settlements global turnover in traditional foreign exchange market segments (spot transactions, outright forwards, and foreign exchange swaps) grew from 600 billions of US dollars in 1989 per day to 1200 billions of US dollars per day in 2001 (Galati, 2001). With the US dollar being involved in between 40 and 45 percent of these transactions, the average absolute amount of US dollars used in foreign exchange market intervention by the Fed in the mark/dollar market between 1991 and 1999 was only 0.3 billions of US dollars. Although this argument seems to be convincing at first sight, there is again an important inconsistency if it is applied in the context of the macroeconomic view of the portfolio balance channel. As already mentioned in the previous Section, the sole determinants of the exchange rate in macroeconomic asset market models are

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<sup>70</sup> For a similar view see Almekinders (1995, p. 79) and Ramaswamy and Samiei (2000, p. 9).

relative stocks of assets. Thus, there is no room for explaining trading volumes since analyses on the macro level only capture the developments in the exchange rate from one stock equilibrium to another. Instead of arguing on the basis of trading volumes, it is more consistent to relate the intervention activity to average sizes of outstanding government debt. Humpage (1991, p. 15) puts this as follows: “The total stock of publicly held U.S. government securities, for example, was nearly \$2.3 trillion at the end of 1989. U.S. intervention amounted to \$22 million that year, a record volume, but it was less than 1 percent of the total stock of publicly held U.S. securities. Even if dollar interventions of the other 10 major industrial countries are included, the total amount represents only about 3 percent of publicly held debt.” Although he uses these figures to argue against the efficiency of the portfolio balance channel of sterilised interventions, it should be clear that taking the US as an example involves, on the one hand, a central bank that is among the quantitatively least engaged central banks in the foreign exchange market (see Bofinger and Wollmershäuser, 2001, for the calculation of an index of intervention activity), and, on the other hand, the biggest public debt securities market of the world (see the domestic debt securities tables published in the statistical annex of the ‘BIS Quarterly Review: International Banking and Financial Market Developments’). We will come back to the importance of the volume and the intensity of foreign exchange market interventions below in Section V.1.3.2.

#### V.1.2.3.2 The microstructure approach

In recent years, the criticism of the portfolio balance approach to the determination of the exchange rate seems to be challenged by the use of real-time data on a microstructure level. “Instead of starting with a set of macroeconomic relations (...) which are used to solve for the exchange rate (...), the microstructure literature analyzes the behavior and interaction of individual decisionmaking units in the foreign-exchange market. Simply put, the microstructure literature is concerned with the details of the mechanics of foreign-exchange trading, whereas the macroeconomic approach typically dismisses the details as unimportant” (Sarno and Taylor, 2001b, pp. 1). One strand of the literature on the microstructure view of the exchange rate highlights the role of order flow for the explanation of exchange rate behaviour. Order flow is defined as the net of buyer-initiated and seller-initiated orders in the inter-bank foreign exchange market (see below for institutional details). The basic idea is that order flow communicates information that is not common knowledge. This information needs to be aggregated by the market, and microstructure describes how that aggregation is achieved (see Lyons, 2001b, for a textbook treatment).

The advantages of the microstructure approach are twofold. On the one hand the measurement difficulties that are particularly related with macroeconomic portfolio-balance models can be overcome by the microstructure approach. “Macro fundamentals in exchange rate equations may be so imprecisely measured that order-flow provides a better ‘proxy’ of their variation” (Evans and Lyons, 2001a, p. 5). Instead of measuring *asset supplies* or making assumptions about how the market forms expectations about future fundamentals, shifts in *public demand* for foreign currency assets are the basic determinants of the exchange rate. The shifts themselves can be exactly measured by the order flow that occurs in the inter-bank foreign exchange market.

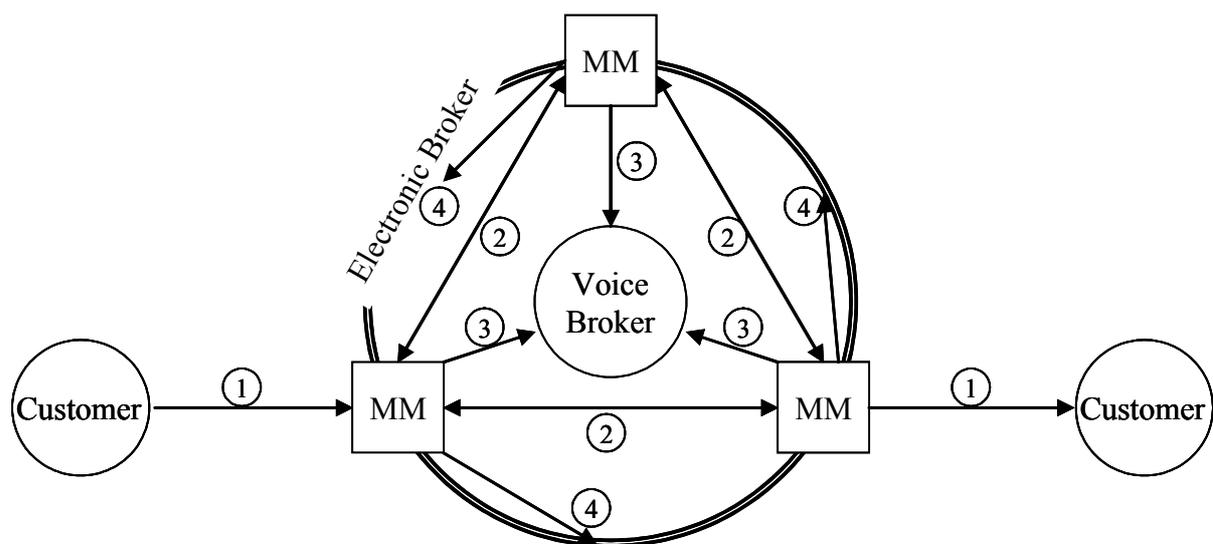
On the other hand the microstructure approach provides a rationale for the remarkably high trading volume that can be observed in the foreign exchange market and that is incompatible with the macro approach. Frankel and Froot (1990, p. 92) describe the underlying logic of the latter as follows: “When a new piece of information becomes available, if all investors process the information in the same way and are otherwise identical, no trading needs to take place. The price of the asset should simply jump to its new value.” Thus, the macro view implicitly assumes a Walrasian auctioneer who first collects preliminary orders and who then uses them to find the market-clearing price. Accordingly, the auctioneer’s price adjustment is immediate and no trading needs to occur in transition (see also Evans and Lyons, 2001a). Frankel and Froot (1990, p. 92) continue: “To explain the volume of trading, some heterogeneity of investors is required.” And indeed, the foreign exchange market is characterised by a high degree of heterogeneity concerning the access of the market’s participants to fundamental information. To understand this we have to take a deeper look at the specific structure of the global foreign exchange market.

In contrast to many other markets, the foreign exchange market has to be understood as a complex system with three major groups interacting with each other: market makers (MM), brokers, and customers (for a general text dealing with the nature of markets see Goodhart (1989, chapter I); for a recent survey of the structure of the foreign exchange market see Sarno and Taylor (2001b)).

Generally speaking, the spot foreign exchange market is a decentralised multiple-dealer market with continuous trading. Foreign exchange dealers are *market-makers*. They guarantee the

immediacy<sup>71</sup> of the market by continuously standing ready to give two-way quotes to another dealer at request. In order to do so, market makers need to act as principals, with purchases and sales on their own accounts, and thus with varying inventory of foreign exchange over time. When there is a temporary excess supply in the market, the dealer will buy at his announced bid price, thus increasing his inventory of the currency being sold, and when there is a temporary excess demand, the dealer will sell out of his inventory at his ask price, independently of whether he is willing to hold the respective position or not. Thus, direct inter-dealer trade (indicated by the encircled ② in Figure V.5) is best described by the formula ‘trading begets trading’ which arises from the repeated passage of inventory imbalances among dealers. As a central result, pricing is continuous over time and the trading volume at the foreign exchange market is extremely high.

**Figure V.5: Structure of the foreign exchange market**



*Brokers* facilitate trades between dealers (indirect inter-dealer trade) either through radio-networks (the so-called traditional voice brokers) or through electronic communication networks (the so-called electronic brokers) (see Bjønnes and Rime, 2000, for a detailed discussion). They only collect two-way quotes from many dealers and match the lowest ask and the highest bid price. More generally, a broker is best described as an auctioneer who serves as a clearing house. With a view to the trading volume, brokered transactions only occur if both parties (demand and

<sup>71</sup> Immediacy is the characteristic that both buyers and sellers have the opportunity to deal as and when they want.

supply) are willing to take the respective position. Together with the market makers they establish the inter-bank foreign exchange market.

The final category of participants in the foreign exchange market are the *customers* of the market-making banks. Corporate customers can be divided into non-financial firms (exporters and importers) and financial firms (institutional investors). The customer's demand for and supply of currency represent portfolio shifts coming, for example, from changing hedging demands, changing transactional demands, or changing risk preferences (and hence from the customer's activities in international trade and investment). They deal only with market makers and they never go through brokers as the access to the inter-bank market is available only at some fixed costs which are prohibitive for low-transactions volumes. Central banks can also be viewed as customers. They intervene in the foreign exchange market by selling foreign exchange to and buying foreign exchange from market-making banks.

With these three groups in mind, it is now possible to describe the mechanism of price discovery and hence, information dissipation in the foreign exchange market. Generally speaking, the inter-dealer trade has to be understood as a mechanism that maps new information (additional demand and additional supply from outside the inter-dealer market, that is from customers) to prices. The crucial point now is that these initial customer orders ① are not publicly known, with the exception of the dealer who was contacted by the customer.<sup>72</sup> This new information is communicated to the remaining dealers via inter-dealer order flow. The inter-dealer trade itself is characterised by different degrees of transparency, depending on the way the trade is carried out:

- Direct trades between market makers ② are typically unknown except to the two parties in trade. Thus, in order to disperse the new information to all dealers, a multiplicity of direct inter-dealer trades is necessary which sums up to the huge amount of foreign exchange turnover.
- In indirect trades with voice brokers ③, a small subset of trades is communicated to the market via intercom. In general, voice brokers have open telephone lines to many trading desks, so that a market maker dealing in a specific currency can hear over squawk boxes continuous oral reports of the activity of brokers in that currency, the condition of the market, the number of transactions occurring, and the rates at which trading is taking place, though traders do not hear the names of the two banks in the transaction or the

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<sup>72</sup> See Figure V.5 for the encircled numbers.

specific volume of the trade (Federal Reserve Bank of New York, 1998). Thus, trades only take place when two dealers within the subset are found that are willing to transact at the new equilibrium price. None the less, part of the new information (especially the transaction price) is communicated to the subset of dealers by the broker.<sup>73</sup>

- In indirect trades on electronic broker systems ④, however, all trades are communicated to the dealers via computer screens. It is the most transparent form of inter-dealer trade as every dealer has access to the systems.

Accordingly, the total inter-dealer trade is simply a mechanism to turn private information into public information. The more transparent the way the inter-dealer trade is carried out, the more informative the trades are assumed to be (Bjønnes and Rime, 2000). Inter-dealer trading which is quantified by the observable order flow can therefore be understood as a means by which market makers ‘sell’ each other information about their transactions with outside customers. They capture the informational rent associated with receiving the private information from customer orders. Thus, “order flow conveys information about dispersed fundamentals because it contains the trades of those who analyse/observe those fundamentals. It is a transmission mechanism” (Lyons, 2001a, p. 2). If fundamental information is not publicly known, non-zero order flow will continue to occur. In sharp contrast to the Walrasian auctioneer based macro approach, the foreign exchange market does not immediately jump from one equilibrium to another. As a decentralised multiple-dealer market the foreign exchange market can rather be viewed as a complex system that is characterised by a permanent disequilibrium (Chakrabarti, 2000).

Evans and Lyons (2001a, 2002b) developed a theoretical model that incorporates the above institutional elements and that yields a testable exchange rate equation. In the following we will present the basic features of the so-called *portfolio shifts model*.

The model assumes that a period (usually a day) is divided into three stylised trading rounds. In the first round dealers trade with the customers (① in Figure V.5). Each of the  $N$  dealers, indexed by  $i$ , receives stochastic customer orders  $C_{i,t}^1$ . All dealers’ customer orders sum up to the aggregate public demand  $C_t^1$ . The superscript indicates the round in which the orders are assumed to occur. The bid and ask rates the dealers quote to their customers depend on the

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<sup>73</sup> For the reasons on why a market maker contacts a broker instead of another market maker see Luca (2000, chapter 10) and Levich (2001, chapter 3).

information that is available to the dealers in round 1. Below we will specify this information as interest rate differential. For the moment however we will concentrate on the influence of the new information resulting from the customer orders that is only observed by the contacted dealer.

In round 2 the risk averse dealers trade among themselves to share the risk related with holding positions they would not hold otherwise (② in Figure V.5).<sup>74</sup> This is the round in which order flow comes into play. A period's net inter-dealer order flow is defined as

$$(V.10) \quad X_t = \sum_{i=1}^N T_{i,t}^2$$

where  $T_{i,t}^2$  denotes the round-2 net inter-dealer trade initiated by dealer  $i$ . Evans and Lyons (2001a) show that for each individual dealer the optimal strategy is to realise a trading volume that is proportional to the customer orders he receives in round 1:

$$(V.11) \quad T_{i,t}^2 = \alpha C_{i,t}^1.$$

The coefficient  $\alpha$  is positive and equal to all dealers. If all inter-dealer trades are executed at the end of the period, the dealers have learnt about the total position the public needs to absorb from order flow  $X_t$

$$(V.12) \quad X_t = \alpha C_t^1.$$

The crucial point of the portfolio shifts model is that the dealer-customer trades (round 1) which are not observable on a market-wide level are gradually reflected in inter-dealer trades (round 2) which are observed market-wide. Once observed, this information is impounded in the exchange rate in round 3 when dealers are assumed to trade again with the customers (① in Figure V.5). Dealers know that the public needs to be induced to reabsorb the initial aggregate portfolio shift

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<sup>74</sup> An important drawback of the Evans and Lyons (2001a, 2002b) model is that brokered trading is not captured by the model. Only about 60 percent of the inter-bank trading volume is direct (i.e. between market makers). The remaining part are indirect (brokered) trades (see Evans and Lyons, 2001a, footnote 15).

$C_t^1$  since the dealers themselves do not hold any interest-bearing overnight positions.<sup>75</sup> From this follows that  $C_t^3 = -C_t^1$  so that each dealer ends the day with no net position. However, the public's total demand in round 3,  $C_t^3$ , is not perfectly elastic. As the public is not indifferent with regard to the composition of their portfolio, it requires a price adjustment to clear the market. This finally produces a testable relation between the observable inter-dealer order flow and the subsequent adjustment of the exchange rate:

$$(V.13) \quad \Delta s_t = \alpha_1 (i_{t-1} - i_{t-1}^f) + \alpha_2 X_t + \varepsilon_t$$

where  $\Delta s_t = s_t - s_{t-1}$  spans the period from the end of round 3 of the previous day (which is equal to the beginning of today's round 1 since foreign exchange trading is continuous) to the end of today's round 3. If the end-of-period public demand were perfectly elastic (i.e. the customers' aggregate risk-bearing capacity is infinite), order flow would still convey information about the portfolio shift, but the shift would not affect the end-of-period exchange rate (i.e.  $\alpha_2 = 0$ ). Thus, imperfect substitutability of different-currency assets and risk aversion of the public requires a coefficient  $\alpha_2$  to be positive and significantly different from zero. The inclusion of the interest rate differential turns the portfolio shifts model into a hybrid model combining both, microstructure elements (institutional features, non-public information about fundamentals) and macro elements (public information about fundamentals, specifically interest rates).<sup>76</sup>

Evans and Lyons (2001a, 2002b) estimated the model with daily data from May to August 1996 for the DM/US-\$ spot rate. The coefficient  $\alpha_2$  was found to be statistically significant with the correct sign. Accordingly, \$1 billion of net dollar purchases appreciate the dollar by 0.54 percent. The explanatory power of this regression was due to order flow: regressing the change in the exchange rate only on the interest rate differential produces an  $R^2$  statistic of below 1 percent and a coefficient  $\alpha_1$  that is insignificant (hence, the typical UIP result for UIP estimations; see Chapter III). Adding order flow increases  $R^2$  to 64 percent. In two related papers Evans and Lyons (2001b, 2002a) present a somewhat more refined intra-day model. Working

<sup>75</sup> In reality, dealers hold open positions overnight, however within prudential limits set by their bank (Goodhart, 1988). A study by Yao (1998) shows that only 4 percent of the total trading volume of a representative New York based market maker can be identified as open positions.

<sup>76</sup> Equation (V.13) is very similar to the typical regression model for testing UIP, of course without the order flow term.

with higher-frequency data allows to distinguish between temporary portfolio balance effects stemming from (intra-day) inter-dealer trades and persistent portfolio balance effects stemming from the customers' (and hence the foreign exchange market's) risk aversion. The result slightly differs from that of the daily model (which was estimated for the same underlying period). According to the authors, the difference can be explained by order flow being positively auto-correlated at the hourly frequency. They find that \$1 billion of net dollar purchases now appreciate the dollar by 0.44 percent whereof 80 percent persist indefinitely.

Many economists might be tempted to ask: But what drives order flow? Admittedly, this question is of crucial importance for macroeconomists. However, it is not important for our analysis (those who are interested in this question are referred to Lyons, 2001a, 2001b). What matters for the present analysis is that portfolio shifts coming from outside the inter-bank foreign exchange market provoke exchange rate changes. This attributes an important role to central bank interventions, in particular to foreign exchange market interventions that are sterilised, conducted secretly (i.e. anonymously and unannounced) and that convey no signal of future monetary policy.<sup>77</sup> In fact, modelling a central bank's intervention that way makes them indistinguishable from other customer orders. Thus, the approach chosen by Evans and Lyons is an indirect one since interventions do not necessarily have to occur during the estimation period. It simply provides evidence for the old idea that forcing international investors to adjust their portfolios consisting of different-currency assets requires an adjustment of the exchange rate as long as investors care about the currency denomination of their assets. In contrast to the macro approach, now the asset supply is assumed to be constant. Evans and Lyons (2002a, p. 24) interpret their results as follows: "We find strong evidence of price effects from imperfect substitutability, both temporary and persistent. This contrasts with the common belief that these effects (from interventions or otherwise) are too small to be detectable. Not only are they detectable, they are also economically significant, leading us to conclude that portfolio balance theory is more applicable than many believe." A prime example for the common belief that is based on the poor evidence of the macro approach is the survey article of Sarno and Taylor (2001a, p. 862). With respect to the importance of the portfolio balance channel they point out that, if it is effective at all, its importance will diminish over time "- at least among the major industrialised countries - as international capital markets become increasingly integrated and the

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<sup>77</sup> This ensures that only portfolio-balance effects impact on the exchange rate. If interventions convey signals of future monetary policy an alternative intervention channel applies (see Section V.1.2.4).

degree of substitutability between financial assets denominated in the major currencies increases.”

Finally, it should be stressed that the argument according to which the high daily trading volume in the foreign exchange market reduces the potential power of interventions considerably is not valid anymore if one takes the microstructure of the foreign exchange market into account. The multiplier effect resulting from the market maker principle that governs the organisation of the foreign exchange market equally applies to each customer transaction, be it a private customer order or a central bank intervention (Bofinger, 2000). In the words of Baillie and Osterberg (1997, p. 913): “Hence the volume of ‘market moving’ transactions may well be considerably smaller than the \$1000 bn stated earlier and hence allows a potentially greater role for central bank intervention.”

#### *V.1.2.4 The signalling / expectations channel of sterilised interventions and the news approach to the determination of the exchange rate*

The previously presented asset market approaches to the determination of the exchange rate focused on the identification of the assets for which the exchange rate is regarded as relative price. So far, however, we totally neglected the role of expectations and the forward-looking nature of the exchange rate. If the exchange rate is viewed as the price of a durable asset then the current exchange rate should reflect the market’s expectation concerning present and future economic conditions relevant for determining the appropriate value of this durable asset. Changes in the spot rate should be largely unpredictable and reflect primarily new information that alters expectations concerning these present and future conditions. While the previously presented exchange rate models tell us how the exchange rate should respond to each news report, we now concentrate on the occurrence of news and their impact on the exchange rate without further specifying these news. In particular, the exchange rate should change only in response to new pieces of unanticipated information (the so-called news). This leads to the well-known efficient markets hypothesis underlying the news approach to the determination of the exchange rate. If foreign exchange markets were perfectly efficient, all the relevant information concerning the determinants of the currencies should be reflected in their exchange rate.

In the following we present the basic framework of an asset pricing model of the exchange rate in a fairly general way (see Levich, 2001, chapter 6, for a textbook treatment). As with other

asset prices, the exchange rate is forward-looking and a function of its own expected future value. The current spot exchange rate can thus be expressed as

$$(V.14) \quad s_t = x_t + \alpha_1 \left( E_t [s_{t+1} | \Omega_t] - s_t \right),$$

where  $x_t$  represents the fundamentals,  $E_t[\dots]$  denotes the expected rate of change of the exchange rate conditional on the information set  $\Omega$  at time  $t$ , and  $\alpha_1$  measures the elasticity of the current exchange rate with respect to expectations. Solving equation (V.14) for  $s_t$  yields the following stochastic difference equation

$$(V.15) \quad s_t = \frac{1}{1 + \alpha_1} x_t + \frac{\alpha_1}{1 + \alpha_1} E_t [s_{t+1} | \Omega_t].$$

By forward iteration, the solution of equation (V.15) is obtained which leads to the more commonly used formulation of the nominal exchange rate

$$(V.16) \quad s_t = \frac{1}{1 + \alpha_1} \sum_{j=0}^{\infty} \left( \frac{\alpha_1}{1 + \alpha_1} \right)^j E_t [x_{t+j} | \Omega_t]$$

as a discounted sum of current and expected future fundamentals conditional on currently available information.<sup>78</sup>

According to this model, every piece of additional information that is relevant for the determination of the exchange rate influences the market expectations and consequently changes the current exchange rate. Under these assumptions the sole consequence of central bank intervention  $I_t$  is to alter the information set from  $\Omega_t$  to  $\Omega'_t = \Omega_t + I_t$  by conveying inside information to the market (Watanabe, 1994). The effect on the exchange rate is then captured by

$$(V.17) \quad \Delta s_t = \frac{1}{1 + \alpha_1} \sum_{j=0}^{\infty} \left( \frac{\alpha_1}{1 + \alpha_1} \right)^j \left( E_t [x_{t+j} | \Omega'_t] - E_t [x_{t+j} | \Omega_t] \right).$$

With respect to our baseline model presented in Chapter IV we can now specify the fundamentals determining the current exchange rate. The asset market relationship is given by UIP without taking into account a risk premium in order to distinguish this intervention channel from the portfolio balance channel.<sup>79</sup> Rewriting the UIP condition as an equation for the current exchange rate without restricting the coefficients gives

$$(V.18) \quad s_t = \alpha_1 E[s_{t+k} | \Omega_t] + \alpha_2 (i_t - i_t^f),$$

where  $k$  is the maturity of the interest rate. Under strict UIP, implying unbiased efficiency,  $\alpha_1$  would be equal to 1 and  $\alpha_2$  equal to  $-1$ . The rational expectations solution to equation (V.18) is

$$(V.19) \quad s_t = \alpha_2 \sum_{j=0}^{\infty} \alpha_1^j E[(i_{t+j} - i_{t+j}^f) | \Omega_t].$$

As the current interest rate is assumed to remain unchanged due to sterilisation of the foreign exchange market interventions, the current exchange rate is the result of investor's portfolio decisions that are taken on the ground of expectations about future interest rates (i.e.  $j > 0$ ). Thus, for central bank interventions to be effective, it is assumed that the central bank possesses resources and knowledge not available to the public, the so-called inside informations. The literature basically distinguishes between two types of informational asymmetries.

First, as Mussa (1981, p. 15), one of the first to describe the expectational effects of interventions, writes: "A central bank can use its knowledge of its own future policy to guide its speculations in foreign exchange and, if the need arises, can use its control over monetary policy to guarantee the success of its speculations." According to this hypothesis operations in the foreign exchange market by the central bank may be used to signal future changes in monetary policy instruments (i.e. changes in  $i_{t+j}$  for  $j > 0$ ). Sterilised intervention is more effective than a simple announcement, because by buying (selling) foreign assets the central bank stakes its own

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<sup>78</sup> The solution presented in equation (V.16) is only valid for  $\alpha_1/(1+\alpha_1) < 1$ . If it is greater than unity, we have to add a second term to equation (V.16) which is often referred to as a rational bubble.

capital in support of the future policy and hence “can purchase credibility” (Mussa, 1981, p. 17). If the market participants believe the signals provided by the intervention, they will influence exchange rates by betting with the central bank. Thus, the credibility of the signal results from the reputational costs associated with false signals. These costs are the loss of both, reputation and international reserves resulting from interventions in the wrong direction. We refer to this kind of expectations channel as the policy signalling channel.

Within the setting of our rational expectations model, however, it is not clear why the private sector should have informational disadvantages concerning the future interest rate policy as long as the central bank continues to commit to a publicly known policy rule and as long as all agents (including the central bank) agree on the model describing the behavioural relationships of the economy.<sup>80</sup> Thus, many economists rely on an alternative rationale for interventions within the framework of the news model of exchange rates and view interventions as a means “to improve the flow of information in disorderly markets” (Rosenberg, 1996, p. 306). It is assumed that central banks can judge the current development of the exchange rate as primarily driven by non-rational behaviour (speculative bubbles and herding) with the consequence that fundamental information is not correctly incorporated in the exchange rate. Therefore central banks intervene in order to give the market a signal about its view of the correct exchange rate (Eijffinger and Grujters, 1992). Thus, markets are viewed as weak-form efficient, while central banks are assumed to possess superior information. This branch of the expectations channel is often referred to as the market efficiency channel.

However, in our view, this last interpretation of the expectations channel is not consistent with the underlying news approach to the determination of the exchange rate which basically assumes foreign exchange market efficiency. Certainly, collective irrational behaviour of the market is an important issue for understanding the misalignments of freely floating exchange rates. Thus, in Section V.1.2.5 we will consider an intervention channel that exploits the properties of exchange

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<sup>79</sup> Under such circumstances, investors are indifferent between these two assets only if the expected return on foreign bonds equals the domestic interest rate. In contrast to the portfolio channel, expectations affect the exchange rate even if domestic and foreign bonds are perfect substitutes.

<sup>80</sup> Humpage (1991, p. 17) ‘saves’ the policy signalling channel as follows: “In attempting to explain the signaling mechanism, many economists have argued that the importance of intervention centers not on its ability to herald policy changes, but on its ability to cement governments’ commitment to those policy changes. Even when governments announce an optimal policy today, they can face incentives to renege on that policy tomorrow. Markets, of course, realize this and factor into their expectations the likelihood that policy makers will not follow through on their pronouncements. Policies allowing no opportunity for backing down, consequently, can have very different effects than similar policies that permit renegeing.”

rates that are driven by chartist behaviour. In this Section we will rather concentrate on the first interpretation of the expectations channel of sterilised foreign exchange market interventions – the policy signalling channel – which assumes a fully efficient foreign exchange market.

One popular approach to test empirically the signalling hypothesis is to directly estimate the news character of current intervention on the exchange rate. Based on equation (V.17) one can derive the following estimation equation which takes into account two sources of new information:

$$(V.20) \quad \Delta s_t = \alpha_0 + \alpha_1 x_t + \alpha_2 I_t + \varepsilon_t^s.$$

$x_t$  denotes fundamental news, while intervention activity is captured by  $I_t$ . Thus, the basic technique of this approach is to directly estimate the influence of current interventions on the exchange rate, over and above the contribution of the current fundamental. Due to the importance of the informational content of interventions, the signalling approach offers the opportunity to compare the impact of different forms of interventions. Most studies differentiated between secret and public interventions<sup>81</sup> (Dominguez and Frankel, 1993b, Fischer and Zurlinden, 1999, Zurlinden, 1996), initial and subsequent interventions<sup>82</sup> (Dominguez and Frankel, 1993b, Eijffinger and Gruijters, 1992, Fischer and Zurlinden, 1999, Humpage, 1988, Ito, 2002, Zurlinden, 1996) or coordinated and unilateral interventions<sup>83</sup> (Dominguez, 1990, Dominguez and Frankel, 1993b, Eijffinger and Gruijters, 1992, Humpage and Osterberg, 1992). Unfortunately, the results vary considerably. The studies of Dominguez and Frankel (1993b), Fischer and Zurlinden (1999) and Ito (2002) provide strong statistical evidence supportive of the

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<sup>81</sup> This group of empirical work compares the effects of reported and non-reported interventions on the exchange rate. One basic message of the signalling channel is that only publicly known (and thus announced by the central bank) interventions can affect the expectations of private agents and therefore have an influence on the exchange rate as described in the asset pricing model.

<sup>82</sup> The idea behind this distinction is that the news effect plays a dominant role in the determination of the exchange rate. If interventions are clustered, i.e. several intervention operations are conducted consecutively in a short period of time, then the signalling hypothesis suggests that only those interventions can alter current exchange rates that are providing new information. In contrast to subsequent interventions, the initial intervention is supposed to have that announcement effect, and thus the news content of initial interventions is supposed to be larger than the news content of the subsequent interventions. Accordingly, the effectiveness of initial interventions is expected to be higher.

<sup>83</sup> An intervention is said to be coordinated or concerted if at least two central banks intervene on the same day in the same direction, i.e. in support of or against the same currency. An outcome of the signalling channel should be that coordinated interventions affect the exchange rate more effectively than unilateral interventions. The underlying rationale is that concerted interventions are assumed to convey multiple coordinated signals which increases the probability that the signal is true.

effectiveness of sterilised interventions through the signalling channel. In particular, they found that initial interventions that are made public and that are coordinated with interventions of other central banks are most effective. In contrast to this, the other studies are far from conclusive. Depending on the underlying sub-period and the intervening central bank, coefficients of the intervention variable are sometimes correctly signed and significant, sometimes insignificant, and sometimes significant and wrongly signed.

An extension of the direct approach to estimating the effects of interventions on the exchange rate was introduced by Baillie and Humpage (1992). Instead of using traditional OLS estimates, they took account of the fact that the variance of short-term exchange rate changes is variable over time<sup>84</sup> and therefore used a GARCH-model on the basis of daily exchange rate data. This method allows the investigator to examine the effect of interventions on both, the conditional volatility and the level of the exchange rate. The literature using this method almost exploded in recent years due to the better availability of high frequency data (see Aguilar and Nydahl, 2000, Baillie and Osterberg, 1997, Beine et al., 2002, Chang and Taylor, 1998, Dominguez, 1998, Morana and Beltratti, 2000, Osterberg and Humes, 1995). Most of the studies conclude that the effects of interventions on the level of the exchange rate are insignificant and that intervention activity typically increases the volatility.<sup>85</sup>

Recently, three types of criticism have been pronounced against the time series approach of the above studies. First, they can only capture the short-term (day-to-day or even intra-day) effects (or non-effects) of the intervention on the exchange rate. However, as Baillie et al. (2000, p. 414) put it, “in general, little is known about the duration of price discovery in the foreign exchange market following an intervention.” Second, the lower the frequency of the data, the higher the probability that the estimations are biased due to simultaneity as the causes and the effects of the intervention become blurred. To avoid this, researchers either use high frequency (tick-by-tick) data which is subject to the first criticism, or they lag intervention relative to the exchange rate

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<sup>84</sup> This observation (which goes back to Hsieh, 1989) violates the central assumption of every OLS estimation according to which the residuals  $\varepsilon_t$  have to be normally distributed with a constant variance (i.e. homoscedastic). Hsieh found evidence that the distribution of daily exchange rate changes is characterised by heteroskedasticity and leptokurtosis (i.e. large changes are followed by large changes, and small changes by small changes). GARCH models therefore take account of the persistence in the effects of shocks in period  $t$  onto the conditional variance in later periods.

<sup>85</sup> It is often argued that a purpose of central bank interventions is to calm disorderly markets – besides targeting a level for the exchange rate (see e.g. Almekinders and Eijffinger, 1996, and Frenkel and Stadtmann, 2001). Thus, it may be of interest to measure the impact of interventions on the volatility of the exchange rate. However, the

which may introduce a specification error (see Almekinders and Eijffinger, 1994, and Humpage, 1999). Finally, Fatum (2000, pp. 5) recognised that while “exchange rates are typically highly volatile on a day-to-day basis, intervention tends to come in sporadic clusters – viewed in this light it may seem less surprising that time series based studies tend not to find strong evidence for a systematic link between exchange rate movements and intervention operations.”

Thus, a new strand of empirical literature emerged that focused on singular intervention episodes rather than on a time series approach. A common feature of this literature is that the appropriate measure of successful intervention is not the daily or hourly instantaneous impact on the exchange rate while the intervention activity is ongoing, but the cumulative effect after its completion. Catte et al. (1994) who were among the first to implement this approach found in their descriptive study that all of the intervention episodes under investigation (G3 interventions between 1985 and 1991) were effective. Using a statistically more refined event study approach typically employed in the finance literature, Fatum (2000) and Fatum and Hutchison (2002c) (for mark/US dollar interventions), Fatum and Hutchison (2002a) (for euro/US dollar interventions) and Fatum and Hutchison (2002b) (for yen/US dollar interventions) found strong evidence in favour of short-term effectiveness (i.e. up to 15 days following the intervention event) of sterilised interventions. Estimating a binary choice (logit) model Humpage (1999, 2000) and Fatum (2002), moreover, found that the probability of success increases when intervention operations are coordinated.

A fundamentally different approach to test the signalling hypothesis is to measure the ability to forecast movements in the future monetary policy variables. Instead of directly testing the impact of interventions on the exchange rate (on the basis of equations (V.17) and (V.20)), now the effectiveness of interventions is indirectly investigated by using equation (V.19) as the starting point. If a central bank aims at signalling, for example, a more contractionary policy in the future, it buys domestic currency today. Therefore, the expectations of future tighter monetary policy make the domestic currency appreciate, even though the current monetary effects of the intervention are sterilised by the central bank. The majority of studies (Fatum and Hutchison, 1999, Kaminsky and Lewis, 1996, Klein and Rosengren, 1991, Lewis, 1995a) comes to rather mixed and inconclusive results – although the methods they used were quite different. Above all, the “evidence suggests an interpretation of the typical finding in the literature that the

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definition of direct managed floating given in Chapter I clearly defines the objective of the central bank as

effectiveness of intervention appears to depend upon the sample period” (Kaminsky and Lewis, 1996, p. 308). Contrary to this conventional wisdom, Watanabe (1994) found that in the majority of cases under investigation intervention policy was consistent with the subsequent interest rate policy. Interestingly, he studied the intervention policy of the Bank of Japan, whereas the other papers focused on US monetary policy.

We will finish the discussion of the signalling channel with some critical remarks. First, as has already been pointed out by Obstfeld (1990), Gosh (1992) and Reeves (1997), sterilised interventions should no longer be considered as independent monetary policy tool, if the information revealed contains own future policy intentions. If the signals transmitted by the central bank shall retain credibility in the future (what is a central requirement for the signalling channel to be effective; see e.g. Dominguez, 1998), central banks should avoid renegeing on prior policy announcements. This suggests that initially sterilised interventions have to be ultimately monetised. Notwithstanding this credibility aspect, if sterilised interventions only worked through this channel, one has to ask why the liquidity effect caused by the variation of the foreign exchange reserves should be compensated by sterilisation at all when it will be backed sooner or later by monetary policy steps ‘in the same direction’.<sup>86</sup> Moreover, the credibility requirement for the effectiveness of the signalling channel may also lead to problems in the context of coordinated interventions. A very common strategy of central banks is to ‘lean against the wind’ irrespective of the actual course of monetary policy. If, for example, a central bank actually pursues a policy of monetary contraction, it may well be involved in a concerted intervention to weaken its own currency in order to break a current trend away from what central banks deem appropriate. Such a contradiction in policy intentions certainly does not enhance the credibility needed for interventions to be effective within the framework of the signalling channel. Note that, unlike the signalling channel, the balance of payments flow channel and portfolio balance channel make no prediction as to the direction of future changes in the monetary policy.

Besides being credible, a further requirement for interventions to be effective is that the signals of the central bank have to be unambiguous. If the signalling channel is taken seriously, then the

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targeting an exchange rate path, and hence a level for each point in time.

<sup>86</sup> See footnote 80 for a possible, albeit not convincing, explanation. There are certainly better commitment technologies for a central bank (e.g. the pursuance of a simple policy rule; see Chapter IV) compared to sterilised foreign exchange market interventions.

question emerges of why many actual intervention operations in the foreign exchange market are secret (the so-called 'secrecy puzzle'; see Dominguez and Frankel, 1993b, and Sarno and Taylor, 2001a). A hidden intervention cannot provide any news to private agents, and thus, expectations about future exchange rate determinants, and hence the current exchange rate, cannot be adjusted.

The third type of criticism refers to the underlying exchange rate model. Dominguez (1998) emphasises that a basic assumption related with this approach is that foreign exchange markets need to be fully efficient in the sense that the current exchange rates reflect all the relevant information available. Thus, each econometric model based on asset price relations like (V.17) involves a joint hypothesis: the efficiency of the foreign exchange market and the effectiveness of the intervention policy. Most economists (in particular those using time series analyses) argued that their results indicate that interventions cannot be viewed as an effective policy tool, thereby assuming that the foreign exchange market efficiently maps new information into prices. From this point of view it is perfectly consistent to investigate the immediate effects of interventions on the exchange rate by using daily or intra-daily data. However, if one rejects the efficient markets hypothesis, it is not allowed to draw any conclusions with regard to the effectiveness of interventions on the basis of models that basically rely on this assumption. So the crucial question emerges if it is permissible to question the validity of the efficient markets hypothesis. This is certainly not the place to address this question in detail. However, it should be clear from Chapter III that inefficiencies (in the sense of collective non-rationality) play a dominant role in explaining the various exchange rate anomalies. With respect to the news model of the exchange rate De Grauwe and Grimaldi (2001, pp. 459) state: "There is increasing evidence that the efficient market hypothesis fails as a theory. For example it has been shown that most of the movements of the exchange rate cannot be associated with news (...). Unanticipated shocks in the fundamental variables explain only a small fraction of the unanticipated changes in the exchange rates. Typically over forecast horizons of up to one year, news in output, inflation, and interest rates explains less than 5% of the movements of the exchange rate. About 95% of the latter is attributable to the news in the exchange rate itself" (see also the literature cited there). In a recent empirical study Galati and Ho (2001) come to qualitatively similar results. In particular, they point out that the influence of news on exchange rates exhibits considerable time variation. Thus, in accordance with the line of arguments of the previous fundamentals-based exchange rate channels, it is not surprising that the results of time-series based studies of interventions are rather inconclusive, given the inappropriateness of the

news model. Baillie and Osterberg (2000, p. 365), who take shocks to monetary aggregates as an example for the driving force of exchange rate movements, come to a similar conclusion: “The lack of success of the signalling hypothesis does not seem particularly surprising given the monetary model’s apparent failure to predict exchange rate movements. If money has little direct role in the short term exchange rate changes, then it is also unclear why signalling monetary policy should matter.”

#### *V.1.2.5 The noise trading / coordination channel of sterilised interventions and the inefficient foreign exchange markets hypothesis*

In the discussion of the macroeconomic portfolio balance channel and the signalling channel we criticised the weak empirical results in favour of these two channels for the underlying exchange rate models which are based on the efficient markets hypothesis and which are widely rejected in the empirical literature. In both channels, interventions were assumed to influence the course of the exchange rate by altering a fundamental determinant of the exchange rate (either the risk premium in the case of the portfolio balance channel, or the expected future interest rate in the case of the signalling channel). If, however, fundamental determinants are weakly related to exchange rate movements, an alternative intervention channel should be discussed which is based on an exchange rate model that does not rely upon the hypothesis of an efficient foreign exchange market, but that incorporates the sources of inefficiencies, such as noise trading and chartism.

The so-called ‘noise trading’ channel of sterilised foreign exchange market interventions which was developed by Hung (1997) (based on two earlier working papers: Hung, 1991a, 1991b) provides central banks with a means of exploiting the behaviour of short run technical-oriented traders who dominate especially the world’s most liquid currency markets (see Chapter III): “The hypothesis maintains that (...) central banks can use well-designed intervention strategies to induce noise traders to buy or sell a currency in such a way that the otherwise temporary effect of sterilized intervention is longer-lasting” (Hung, 1997, p. 782). In particular, it provides an explanation for the secrecy puzzle and the volatility puzzle which emerged from the signalling channel of sterilised foreign exchange market interventions. Hung (1997, p. 780) states: “In cases where intervention is intended to reverse the direction of the exchange rate moving with strong momentum, authorities may use volatility-enhancing intervention to manage the exchange rate level, although normally they may prefer to reduce exchange rate volatility.” The higher

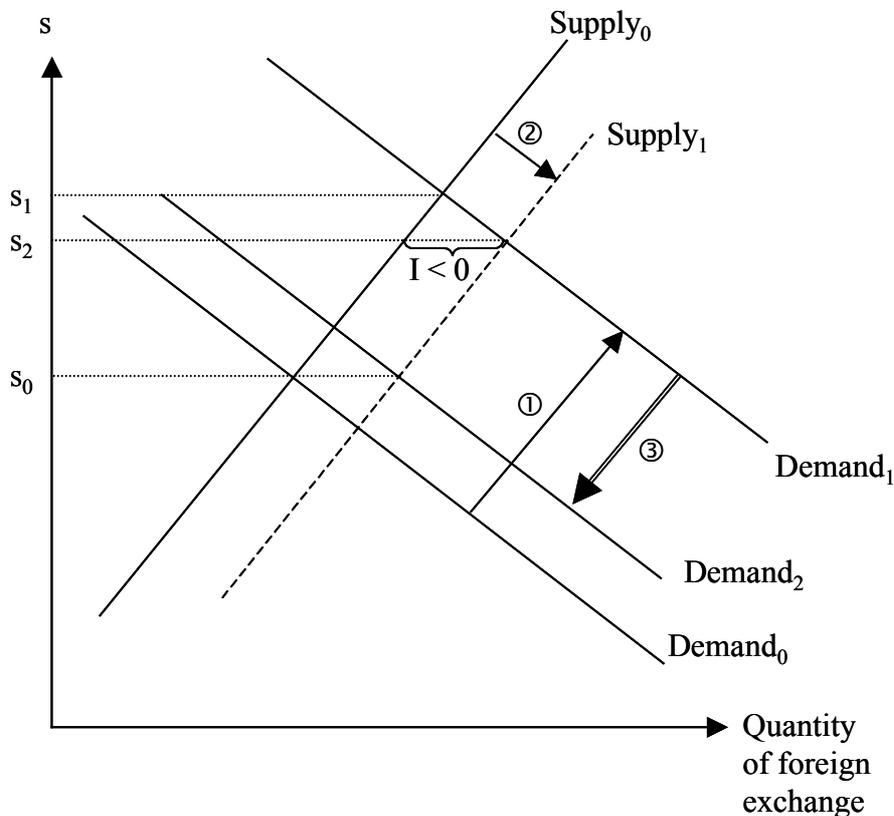
volatility is viewed to be a reflection of the market's increased uncertainty about the sustainability of the prevailing trend. Hung assumes that the more ambiguous the signals that are spread by the central bank's intervention (secrecy of the intervention), the higher the uncertainty of the market participants (volatility of the exchange rate) who may think that the market momentum is changing of its own accord.

Another way of interpreting sterilised interventions in this context is through their role of remedying the coordination failure of the foreign exchange market when it is subject to irrational speculative bubbles brought on by non-economic factors such as chartism or technical analysis. This so-called 'coordination' channel has already been discussed implicitly in Dominguez and Frankel (1993b). In their analogy for foreign exchange market interventions, they liken the role of intervention to the role played by herd dogs among cattle. "On those rare occasions when a stampede gets under way because each panicked steer is following its neighbors, the herd can potentially wander quite far from the proper course. The dogs can be useful in heading off a stampede: if a few of them succeed in turning around a few key steers in a highly visible manner, the rest of the herd may turn to follow" (Dominguez and Frankel, 1993b, p. 139). In a related study Dominguez and Frankel (1993c, p. 343) come to the following conclusion: "Our own inclination is to believe that expectations only tend to be extrapolative in occasional periods: speculative bubble environments, when the foreign exchange market loses its moorings and forecasters forget about fundamentals. Of course, these are precisely the periods in which central bankers might be most interested in using the tool of intervention."

Figure V.6 graphically illustrates the noise trading / coordination channel. Suppose that for technical reasons (chartism) the demand for foreign exchange steadily rises (①) so that the domestic currency depreciates from  $s_0$  to  $s_1$ . Suppose further that if the spot rate reached  $s_2$ , it would break a technically important point recommending the noise trader to sell foreign exchange from that time on. From this clearly follows the strategy of the central bank: Through intervention it has to create a temporary increase in the supply of foreign exchange (②) which causes an appreciation to  $s_2$  (this re-allocates an important role to the balance of payments flow channel which was criticised in Section V.1.2.2 because of its temporary nature). If chartists perceive that the prevailing trend has been broken and that a trend reversal has been formed, noise traders may unwind their positions and take on new positions, betting on the intervention-inspired reversal. Such shifts in noise traders' positions will tend to perpetuate the effect of the

initial intervention operation and contribute to the reversal in trend desired by the monetary authorities (③).

**Figure V.6: The noise trading channel of sterilised foreign exchange market intervention**



The theoretical background for a chartist-fundamentalist foreign exchange market was presented in Chapter III. A main result was that deviations from fundamental values can persist for a considerable length of time as it is individually rational in such circumstances for each market participant not to bet against the market. In the following, we will extend the chartist-fundamentalist model by introducing a central bank as an additional player in the foreign exchange market. Without central bank interventions, we showed that the exchange rate evolves according to

$$(V.21) \quad s_{t+1} = s_t + \nu\theta^f (s_t^{\text{fund}} - s_t) + (1-\nu)\theta^c \left( s_t - \frac{1}{n+1} \sum_{i=0}^n s_{t-i} \right) + \varepsilon_{t+1}$$

which is similar to equation (III.41). With interventions, (V.21) becomes

$$(V.22) \quad s_{t+1} = s_t + \nu \theta^f (s_t^{\text{fund}} - s_t) + (1 - \nu) \theta^c \left( s_t - \frac{1}{n+1} \sum_{i=0}^n s_{t-i} \right) + I_t + \varepsilon_{t+1}$$

where  $I_t$  reflects the effect of the intervention in time  $t$  on the exchange rate in time  $t+1$ . We specifically modelled an intervention rule according to which the central bank only buys foreign exchange when the value of its currency is below its fundamental value (overvaluation) and it only sells foreign currency when the value of its currency is above its fundamental value (undervaluation). The single intervention is assumed to temporarily move the exchange rate by five per cent.<sup>87</sup> In summary, the intervention variable is defined by

$$(V.23) \quad I_t = \begin{cases} +0.05s_t, & \text{if } s_t < s_t^{\text{fund}} \\ -0.05s_t, & \text{if } s_t > s_t^{\text{fund}}. \end{cases}$$

In fact, a sterilised intervention through the noise trading / coordination channel implicitly increases the weight  $\nu$  of the fundamentalists in equation (V.21) which was defined as the percentage of private market participants with stabilising rational expectations. Thus, central banks can overcome the collective action problem by using sterilised foreign exchange market interventions to support the private fundamentalists and to accelerate the trend reversal.

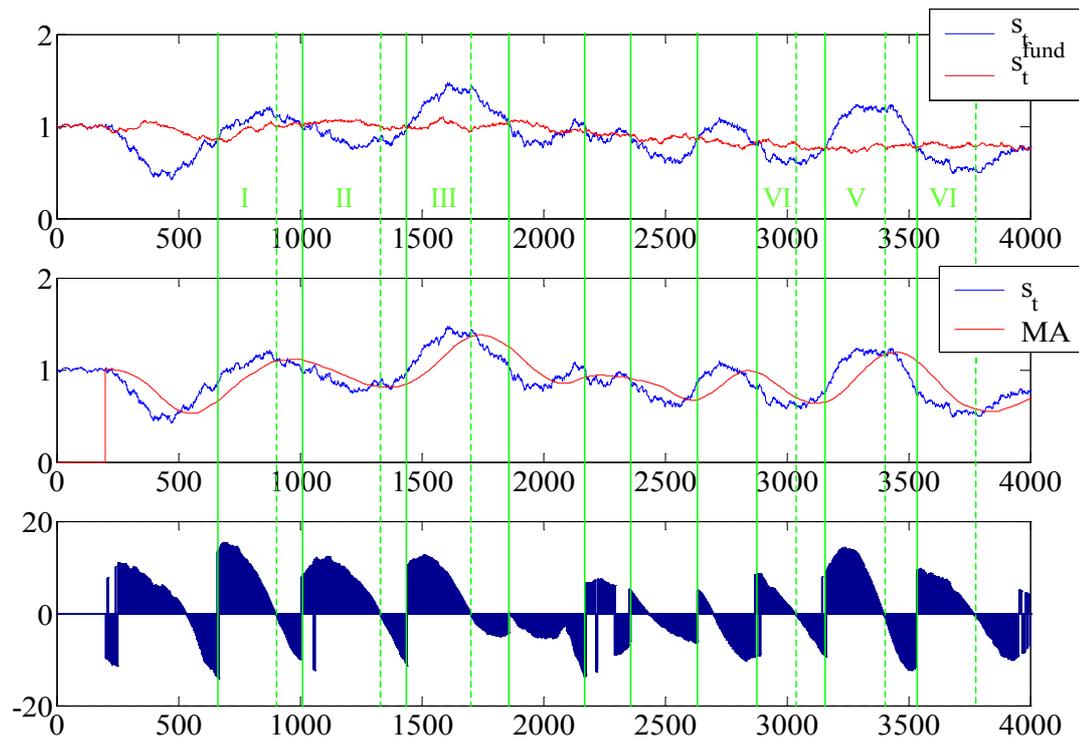
The results of the simulation are shown in Figure V.7. The upper two panels are identical with Figure III.2 in Section III.3.2.1.2 (see here also for the calibration of the model). The lower panel shows the effectiveness curve of interventions in the chartist-fundamentalist model which depicts the effects of a single intervention in time  $t$ . The effect is measured by the reduction in the misalignment from  $t$  to  $t+1000$  (in comparison with the situation without intervention) in per cent. The solid green vertical lines mark the period in which the actual exchange rate breaks the red fundamental line (see the upper panel). Interventions that take place shortly before these points are clearly destabilising as they accelerate an already existing trend of the currency, thereby creating some kind of overshooting. By contrast, interventions that take place after these points are very successful in reducing the degree of misalignment. The dashed green vertical

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<sup>87</sup> For those who believe that this effect is too high, just think back to the intervention to support the yen on June 17, 1998. Within a few hours the currency moved from around 144 to 136 yen per US-\$ which corresponds to a dollar depreciation of more than five per cent. This intervention was coordinated between the Japanese authorities and the US Federal Reserve, with a sale of US-\$ by the Japanese authorities amounting to 1670 millions of US-\$ (i.e.  $\frac{2}{3}$  of the total), and a sale of US-\$ by the Federal Reserve amounting to 833 millions of US-\$ (i.e.  $\frac{1}{3}$  of the total) (see also Figure V.9 below for the Japanese interventions).

lines mark the period in which the effect of the interventions turns from positive to negative. They roughly coincide with the periods in which the actual exchange rate breaks the red moving average line (see the middle panel). The maxima of the blue effectiveness curve coincide with the maximum distance of the actual exchange rate from its moving average.

**Figure V.7: Interventions in the chartist-fundamentalist model**



To sum up, interventions in the chartist-fundamentalist model appear to be successful if

- the exchange rate trend (misalignment) is sufficiently large (in the middle of our simulation period between  $t \approx 1700$  and  $t \approx 2300$  where  $s_t$  is relatively close to both,  $s_t^{\text{fund}}$  and MA, the pattern of the effectiveness curve is very unstable),
- the current spot exchange rate is either above both, the fundamental value of the currency and its moving average, or the current spot exchange rate is below both, the fundamental value of the currency and its moving average (see the areas in Figure V.7 marked by roman numerals),
- the distance of the current spot exchange rate from its moving average reaches a maximum.

The coordination view of interventions recalls strongly the old discussion that a central bank acts as a stabilising speculator. If a central bank intervenes in the foreign exchange market, Friedman (1953) suggests that it should measure the success of its intervention by its profitability, as a private speculator would. According to Friedman, speculation in foreign exchange markets is generally stabilising (see Chapter I) as long as speculators buy when the price is low and sell when the price is high. Figure V.6 shows that the central bank creates additional supply of foreign exchange by buying its own currency which is relatively cheap ( $s$  is high). If the intervention is successful the relative price of the domestic currency rises ( $s$  falls). In the end, the central bank makes a profit as it sold the assets (the foreign assets) which it expected to fall in price.

Thus, one way to get some (though not conclusive<sup>88</sup>) evidence on the effectiveness of intervention according to the coordination channel is to calculate the profitability of a central bank's interventions. Recent research on this topic, however, has discovered two seemingly contradictory empirical facts. On the one hand, a number of studies have found that central bank interventions are profitable – or at least, do not make systematic losses (Leahy, 1995, Sjöo and Sweeney, 2001, Sweeney, 1997). On the other hand, there is striking evidence that technical trading rules can earn economically significant excess returns in the foreign exchange market, in particular on days when central banks intervene (LeBaron, 1999, Szakmary and Mathur, 1997). Neely (1998) reconciles the technical trading results with the profit calculations for central banks by showing that profits from intervention occur over a longer time horizon than profits from technical trading rules. In a similar vein, Saacke (2002) estimated the profitability of Fed and Bundesbank interventions for the period from 1979 to 1994. He concluded that the “seeming contradiction turned out to be due to (a) intervention profits and trading rule profitability being measured over different horizons and (b) after interventions, exchange rates moving contrary to central banks' intentions in the short run, but in agreement with their intentions in the long run” (Saacke, 2002, p. 474). Thus, in the short-run, intervention often generates losses and technical traders profit against the central bank, but in the longer-run the central bank will make profits, indicating a long-run effectiveness of sterilised foreign exchange market interventions.

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<sup>88</sup> In the early years after Friedman published his influential article, authors like Baumol (1957) and Johnson (1967) produced theoretical examples of profitable speculation that is destabilising. It is clear that a central bank that behaves similar to a chartist would both, contribute to a further destabilisation, and make profits in the short-run. In the longer-run, however, the central bank would lose on average (see Section 3.2.1 of Chapter III for the discussion of divergent time horizons in the noise trader literature). As in our view central banks are not primarily

Another indication of the importance of the coordination channel was presented by Bofinger and Schmidt (2002). Drawing upon the results of the purely descriptive study of Catte et al. (1994), they determined the long trends of the DM/US-\$ and yen/US-\$ exchange rate by estimating a Markov-Switching model. They then took a closer look at the turning points of the exchange rate time series and the foreign exchange market interventions of the three central banks. They come to the result that “a comparison of the intervention activities with the evaluated turning points indicates that no major turning point in both exchange rate time series was attained without any central bank interventions” (Bofinger and Schmidt, 2002, p. 37). Thus, central banks appear to act as an important trend setter in the foreign exchange market, with interventions being an important means to determine the timing of the turning points (see also Figure V.9 and Figure V.10 below for a graphical presentation of the Japanese case).

### ***V.1.3 A summary of the intervention channels***

#### *V.1.3.1 The intervention-response function*

In Chapter IV we set up a fairly general model of an open economy (see equations (IV.1) to (IV.4) of the baseline model) which can be applied to systems of floating exchange rates as well as to systems of absolutely fixed exchange rates. While Section IV.1.2 shortly described the mechanics of a central bank’s intervention in the domestic money market in order to control short-term interest rates, the purpose of this Section was to show how foreign exchange market interventions can be implemented as monetary policy instrument in this model. In particular, we showed that the UIP condition serves as core relationship for the explanation of persistent effects of foreign exchange market interventions on the exchange rate. Table V.1 summarises the channels through which interventions are assumed to influence the spot exchange rate.

The direction of intervention is prescribed by deviations of the exchange rate from UIP. It may be of use to recall here that a UIP compatible path makes international investors indifferent between domestic and foreign investments and thus prevents them from speculation, provided that their expectations are compatible with the targeted exchange rate of the central bank. In Chapter III we presented a UIP condition that took into account non-rational behaviour of

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interested in maximising its profit, but in stabilising its final targets, the possibility that a central bank deliberately destabilises the value of its currency by interventions can be excluded.

foreign exchange market participants (see equation (III.36)). We extend this condition by the risk premium explanation of the UIP puzzle (see equation (III.29)) so that the overall UIP becomes

$$(V.24) \quad \upsilon E_t \Delta s_{t+1} + (1-\upsilon) \epsilon_t \Delta s_{t+1} + u_t^s = i_t - i_t^f.$$

**Table V.1: Summary of the intervention channels**

	direct influence on	indirect influence on	sterilised	remark
monetary channel	$i_t$	$s_t$	no	based on EMH
balance of payments flow channel	$s_t$	-	yes	based on b.o.p., temporary (asset market disequilibrium)
portfolio balance channel	$u_t^s = \rho_s u_{t-1}^s + \varepsilon_t^s$	$s_t$	yes	based on EMH
signalling / expectations channel	$E_t s_{t+1}$ or $i_{t+j}$ with $j > 0$	$s_t$	yes	based on EMH
noise trading / coordination channel	$\epsilon_t s_{t+1}$	$s_t$	yes	based on noise and chartism (EMH fails)

Let us assume that at time  $t$ , the central bank targets an exchange rate path  $\Delta s_{t+1}^T = (s_{t+1}^T - s_t^T)$  that equals the current interest rate differential ( $i_t - i_t^f$ ) so that ex post in  $t+1$  there should have been no opportunity to realise excess returns. The volume of intervention in the foreign exchange market which is needed to achieve  $\Delta s_{t+1}^T$  is characterised by the following intervention response function:

$$(V.25) \quad I_t = \Delta NFA_t = f_2 \left( \Delta s_{t+1}^T - \upsilon E_t \Delta s_{t+1} - (1-\upsilon) \epsilon_t \Delta s_{t+1} - u_t^s \right)$$

where  $f_2(0)$  is equal to zero and where the first derivative  $f_2'$  is always positive.<sup>89</sup> Theoretically,  $I_t$  can adopt values ranging from a critical negative value ( $NFA_t^c - NFA_{t-1}$ ) to infinity (we will

<sup>89</sup> For simplicity, we assume that the mean of the risk premium is zero. This is equal to saying that investors are risk neutral over the long-term. In the case of a non-zero mean (which is certainly the case for most emerging market economies) the central bank targets an exchange rate path that equals the current interest rate differential minus

come back to this important asymmetry in the case of foreign exchange sales below in Section V.1.4). Under the assumption that the central bank targets the rationally expected and therefore fundamentally correct exchange rate path ( $\Delta s_{t+1}^T = E_t \Delta s_{t+1}$ ) equation (V.25) simplifies to

$$(V.26) \quad I_t = \Delta NFA_t = f_2 \left( (1 - \nu) (\Delta s_{t+1}^T - \epsilon_t \Delta s_{t+1}) - u_t^s \right).$$

In principle, the central bank may be confronted with three situations. First, if the central bank's targeted exchange rate path equals the private sector's expected exchange rate change plus the actual risk premium, there is no need for the central bank to intervene in the foreign exchange market.

In the second case, private investors expect to make a profit from an investment in the domestic currency which leads to *capital inflows*. The sum of the private sector's expectations about the future exchange rate path and the required risk premium are more than compensated by the given actual interest differential and the given actual spot rate:

$$(V.27) \quad i_t - i_t^f = \Delta s_{t+1}^T > \nu E_t \Delta s_{t+1} + (1 - \nu) \epsilon_t \Delta s_{t+1} + u_t^s.$$

In a world of direct managed floating the central bank intervenes in the foreign exchange market in order to absorb the excess supply of foreign exchange ( $I_t > 0$ ). This guarantees that the central bank achieves the desired exchange rate path  $\Delta s_{t+1}^T$ . At the same time, it is able to keep the interest rate at its level  $i_t$  because of the immediate sterilisation of the accumulated foreign reserves.

The third case is characterised by *capital outflows* which can be described as follows:

$$(V.28) \quad i_t - i_t^f = \Delta s_{t+1}^T < \mu \cdot E_t \Delta s_{t+1} + (1 - \mu) \cdot \epsilon_t \Delta s_{t+1} + u_t^s.$$

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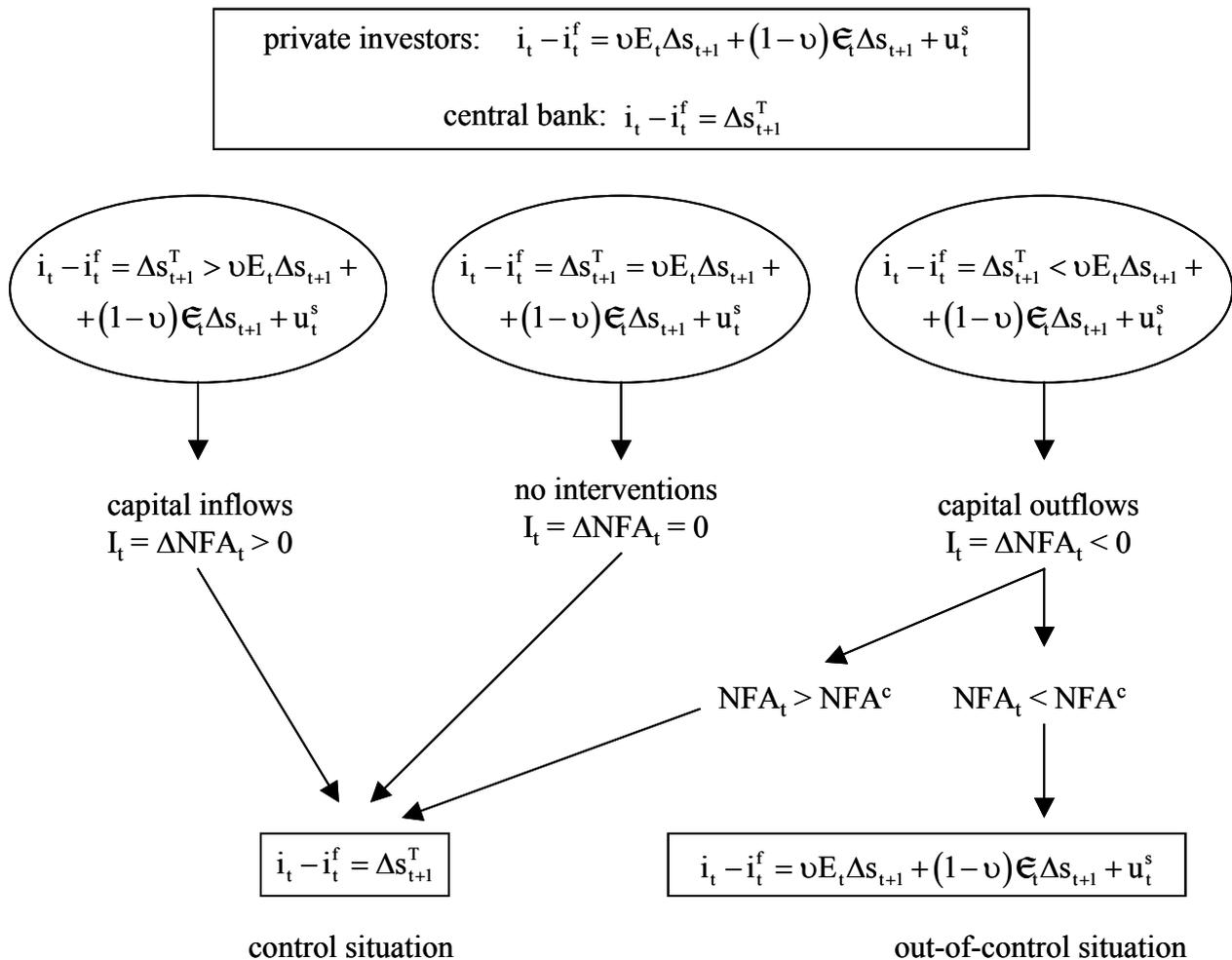
the mean of the risk premium that is required by private investors. Interventions then only occur when the risk premium deviates from its mean (and, of course, still in the case of collective non-rationality). We will come back to the problems related with permanent non-zero risk premia in Section V.1.4.2.

The actual interest rate differential does not compensate for the expected exchange rate change and the required risk premium, and hence, international investors prefer the foreign investment. As the central bank's objective is to realise  $\Delta s_{t+1}^T$ , it has to sell foreign assets in order to satisfy the excess demand for foreign exchange ( $I_t < 0$ ).

Under normal conditions the central bank is able to realise its target path for the exchange rate which equals the path of the rational and forward-looking investor, in all three cases. Thus, the UIP condition becomes:

$$(V.29) \quad i_t - i_t^f = \Delta s_{t+1}^T = E_t \Delta s_{t+1}.$$

**Figure V.8: The central bank's intervention response function  $f_2$**



We call this the 'control situation'. There is only one, but a very important situation – as we will see below in the next Section – in which the central bank loses control over its operating targets:

the capital outflow case with foreign reserves falling below a critical threshold  $NFA^c$ . In this situation which we call ‘out-of-control situation’, the central bank is no longer able to target the exchange rate through sterilised sales of foreign exchange since it runs out of sufficient reserves. It rather has to adjust its interest rates in order to stop the capital outflow. This adjustment can be achieved by either reducing the domestic part of the monetary base, or by non-sterilised foreign exchange market interventions (if there are still foreign reserves left) which lower the foreign part of the monetary base. Independently of how domestic interest rates are raised, the UIP condition in the out-of-control situation becomes

$$(V.30) \quad i_t - i_t^f = \upsilon E_t \Delta s_{t+1} + (1 - \upsilon) \epsilon_t \Delta s_{t+1} + u_t^s.$$

Figure V.8 summarises again the major relationships underlying the external equilibrium of our strategy.

### V.1.3.2 On the relevance of the five intervention channels

Which of the five channels through which interventions are modelled to affect the exchange rate are finally relevant for a strategy of direct managed floating? According to equation (V.25) interventions are carried out each time the aggregate net order flow of private market participants deviates from the order flow that is needed to realise the spot exchange rate that is in line with the targeted path. The targeted path is consistent with the fundamental path of the exchange rate. By fundamental path we mean the exchange rate path that would result from an efficient foreign exchange market with a stable degree of risk aversion of the private sector, and hence, from UIP with a constant (for simplicity zero; see footnote 89 on page 227) risk premium. Possible reasons for deviations from the underlying UIP are noisy expectations on the part of the market participants and/or shocks to their propensity to bear risk. The relevant intervention channels are therefore the *balance of payments flow channel*, the *noise trading / coordination channel* and the *portfolio balance channel*. The monetary channel and – in our view as well – the signalling channel do not provide the central bank with an independent monetary policy tool as interventions are – though possibly with some lag – closely related with interest rate changes. Thus, in the following they will not be discussed anymore in the context of a strategy of direct managed floating.

Even though the balance of payments flow channel only exerts a temporary effect on the exchange rate, we already mentioned in Section V.1.2.5 that for the noise trading / coordination channel of sterilised interventions to be triggered (and with it, a sustainable impact of the intervention on the exchange rate) only a temporary shift in the level of the exchange rate is needed. The balance of payments flow channel and the noise trading / coordination channel are therefore closely interrelated.

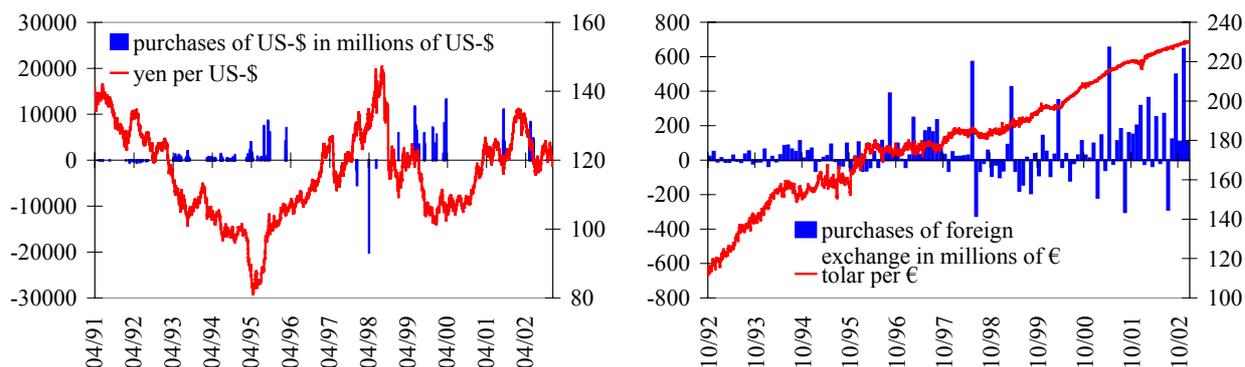
An important difference between the portfolio balance channel and the noise trading / coordination channel is that according to the latter significant deviations from the fundamental value of the currency have to occur before interventions become efficient. By contrast, the former is already effective immediately after the exchange rate leaves the fundamental path due to disturbances of the risk premium. In the following, we will illustrate this difference with two country studies.

On the one hand, there are very liquid foreign exchange markets like that of the Japanese yen. The central bank (or to be more precise, the Japanese Ministry of Finance) only intervenes infrequently and in clusters. A particular feature of the Japanese exchange rate policy is that interventions take place when the exchange rate remarkably deviates from PPP and UIP – thereby fulfilling a basic prerequisite of interventions through the noise trading / coordination channel (see the left panels of Figure V.9, Figure V.10 and Figure V.11 for the Japanese case).

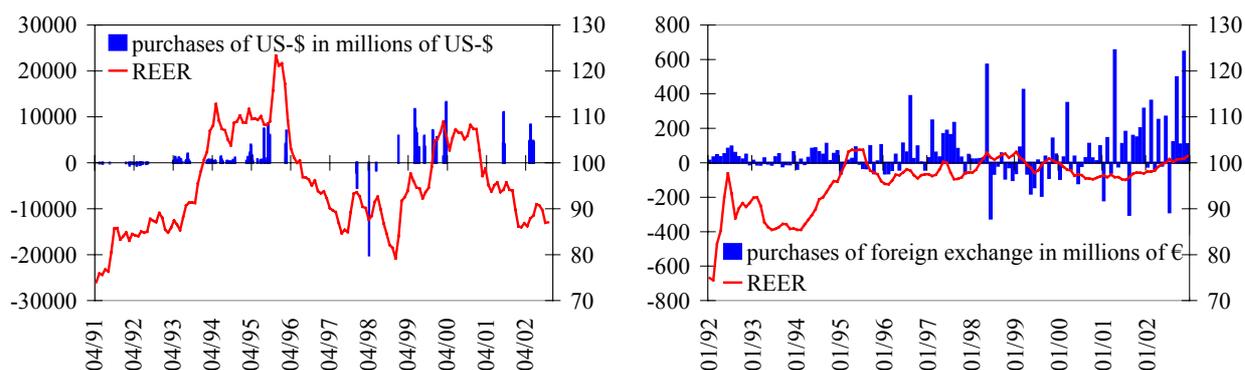
On the other hand, there are very thin foreign exchange markets like that of the Slovenian tolar, in which central banks basically target the exchange rate through portfolio shifts effects. The Bank of Slovenia is continuously engaged in the foreign exchange market and it tightly manages the course of the tolar. Thus, the occurrence of misalignments (large swings in the REER) or inefficiencies (pronounced excess returns) is prevented from the outset (see the right panels of Figure V.9, Figure V.10 and Figure V.11 for the Slovenian case).<sup>90</sup>

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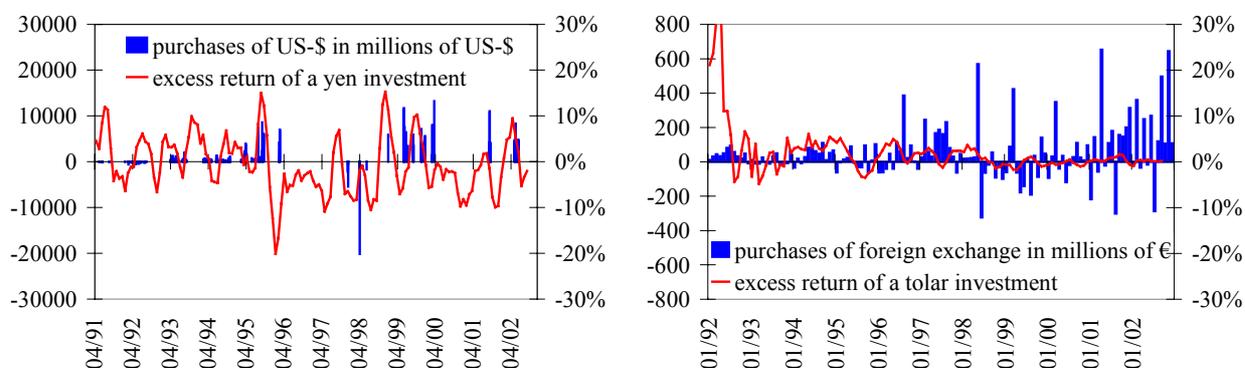
<sup>90</sup> Note that in the early years of economic transition (1992-1994) significant deviations from PPP and UIP also occurred in Slovenia which was mainly due to instabilities arising from the problems related to the separation process from former Yugoslavia.

**Figure V.9: Foreign exchange market interventions and the targeted exchange rate**

Note: The interventions are depicted on the left scale. Japanese official intervention data is published on the website of the Japanese Ministry of Finance. The Slovenian interventions are proxied by monthly changes in foreign reserves minus gold which are published by the IMF in its International Financial Statistics. Daily yen/US-\$ exchange rates are published by the Federal Reserve. Daily tolar/€ exchange rates are taken from databases of Datastream and the Deutsche Bundesbank. Euro exchange rates prior to 1999 have been converted from DM/tolar rates.

**Figure V.10: Foreign exchange market interventions and deviations from PPP**

Note: The REER which is depicted on the right scale is an index of the real effective exchange rate on the basis of relative consumer prices. An increase in the REER is a real appreciation. The Japanese data is calculated and published by the IMF in its International Financial Statistics. The Slovenian data is taken from the Monthly Bulletin of the Bank of Slovenia.

**Figure V.11: Foreign exchange market interventions and deviations from UIP**

Note: The excess return is depicted on the right scale. It measures ex post deviations from UIP with a time horizon of 3 months. The interest rates used to calculate the excess return are 3-month deposit rates which are published in the International Financial Statistics of the IMF.

Having mentioned the liquidity of the underlying foreign exchange market, another important difference between the intervention channels emerges. While the balance of payments flow channel and the portfolio balance channel (as well as the monetary channel) are often classified as direct channels through which interventions may have an immediate effect on exchange rates, the noise trading / coordination channel (and also the signalling channel) is an indirect channel. Rosenberg (1996, p. 294) explains as follows: “The direct channels stress the importance of the volume and intensity of the intervention operations themselves, while the indirect channels stress the importance of market responses to the intervention operations and how private investor expectations and positions may be altered.”<sup>91</sup>

The volume of the intervention, however, can not be assessed in isolation from the liquidity of the underlying foreign exchange market: the larger and the more liquid the market, the smaller the direct effect of a given amount of foreign exchange used for the intervention. In Bofinger and Wollmershäuser (2001) we proposed a summary measure to proxy the relative intervention activity of a country. We calculated the sum of absolute changes ( $S^{abs}$ ) in the central banks level of foreign reserves (Res) over the last  $n=12$  months as a fraction of the country’s degree of openness which is defined as the arithmetic mean of imports (Im) and exports (Ex):

$$(V.31) \quad S^{abs}(n)_t = \sum_{i=0}^n \left| \frac{Res_{t-i}}{\frac{Ex_{t-i} + Im_{t-i}}{2}} - \frac{Res_{t-i-1}}{\frac{Ex_{t-i-1} + Im_{t-i-1}}{2}} \right|.$$

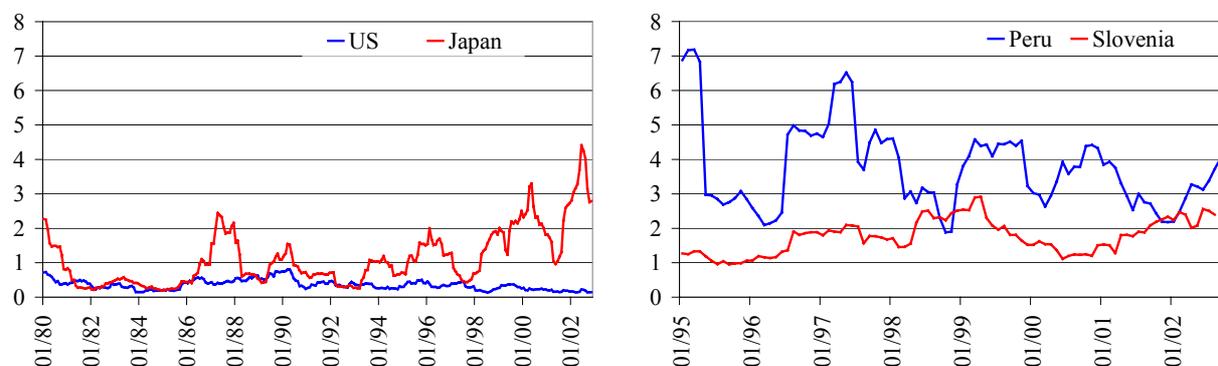
By taking absolute values, our focus was on the question whether a central bank intervenes or not. Thus, we did not discriminate between sales and purchases of foreign exchange reserves. Figure V.12 shows the intervention activity of two large industrialised economies (the US and Japan) and two small open emerging market economies (Peru and Slovenia). While the US intervention activity is relatively low throughout the whole period 1975-2002, the Japanese

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<sup>91</sup> Within the framework of the signalling channel, the question whether the amount of the sale or the purchase of foreign currency matters for the effects on the exchange rate, cannot be answered unambiguously. On the one hand, it is argued that only the information that is transmitted by the central bank is relevant. On the other hand, as it was expressed by Mussa (1981), the central bank’s operation aims at buying credibility and thus the investors’ confidence that the signal is true. In this case, one can argue that the more a central bank spends, the more it can buy (which is equal to say the higher the potential costs of lost reputation) and the more successful the intervention will be.

intervention measure reveals again the infrequent and clustered activity of the Japanese authorities. By contrast, the two emerging market economies show a permanently higher intervention activity.

**Figure V.12: Intervention activity**



Note: The two charts depict  $S^{\text{abs}}$  on the basis of data that was taken from the International Financial Statistics of the IMF.

With the normalisation of the reserve changes to the size of the countries' external sector we take into account the differences in the countries' total economic size, and hence in the size of the foreign exchange markets. Of course, a better way to measure the size and the liquidity of the foreign exchange market would be to directly look at the turnover of the market under consideration. The relevance of this flow figure directly follows from the microstructure approach of the portfolio balance channel and the balance of payments flow channel. Unfortunately, as the data on foreign exchange market turnover which is collected by the Bank for International Settlements is only available every three years, an informative indicator of relative intervention activity cannot be calculated. As an alternative, we could have normalised the changes in reserves by the amount of publicly held domestic government securities. The relevance of this stock figure directly follows from the macro level of the portfolio balance channel. Here again, the data which is also collected by the Bank for International Settlements is available at a quarterly frequency only since 1994.

Nevertheless, we take a short look at the two alternatives to the size of the external sector (see Table V.2, Table V.3 and Table V.4). The figures in the Tables show that the size of the external sector significantly overestimates the size and the liquidity of the foreign exchange market (irrespective of whether proxied by foreign exchange market turnover or by the amount of publicly held domestic government securities) of the small open emerging market economies

compared to that of the US or Japan. Thus, the relative intervention activity is even more pronounced in Slovenia and Peru than revealed by Figure V.12.

**Table V.2: Size of the external sector (Ex+Im)/2: 04/2001**

	Japan	US	Peru	Slovenia
in billions of US dollars	32.30	80.80	0.56	0.79
in percent of US	39.98	100.00	0.70	0.98

Source: International Financial Statistics

**Table V.3: Foreign exchange turnover of local currency net of local inter-dealer double-counting (daily averages): 04/2001**

	Japan	US	Peru	Slovenia
in billions of US dollars	109.71	236.44	0.22	0.09
in percent of US	46.40	100.00	0.09	0.04

Source: Bank for International Settlement (2002), Table E.7

**Table V.4: Domestic government debt securities (amounts outstanding): 03/2001**

	Japan	US	Peru	Slovenia
in billions of US dollars	3753.40	4248.40	1.70	0.02
in percent of US	88.35	100.00	0.04	0.00

Source: BIS Quarterly Review (International Banking and Financial Market Developments), Table 16A; Slovenian data: Bulletin of Government Finance, Ministry of Finance, Republic of Slovenia

To sum up, the average intervention activity in small open economies like Peru and Slovenia is remarkably higher and more continuous compared with the intervention activity of the US and Japan. At the same time, the turnover of the Peruvian and Slovenian currencies as well as the stock of domestic bonds is only a tiny fraction of the respective figures of the US and Japan. From this it follows that in Peru and Slovenia (standing for small open emerging market economies in general) portfolio shifts effects seem to be the dominant channel for sterilised interventions, whereas market sentiment considerations play the dominant role for the intervention policy of the Japanese and the US authorities. Note, however, that this does not mean that portfolio effects do not play any role in the Japanese case. A look at Table V.5 shows that in contrast to the US, the frequency and the average volume of Japanese interventions is

much higher. Thus, direct effects also seem to have played a non-negligible role for Japanese interventions.<sup>92</sup>

**Table V.5: Summary statistics on official intervention data**

intervening central bank	market of intervention	period	number of days with interventions	average intervention volume in billions of US dollars
Federal Reserve	mark/dollar	1980-1990	423	0.1
Federal Reserve	mark/dollar	1991-1998	31	0.3
Federal Reserve	euro/dollar	1999-2002	1	1.3
Federal Reserve	yen/dollar	1991-2002	22	0.4
Bank of Japan	yen dollar	1991-2002	215	1.4

Source: Central bank websites

#### ***V.1.4 The limits of foreign exchange market interventions***

##### *V.1.4.1 Quantitative limits*

The last Section has already shown that targeting the nominal exchange rate by foreign exchange market interventions may be subject to an important limitation. Theoretically, a central bank's sterilised purchases of foreign exchange are not restricted by any quantitative limits. It buys foreign assets from a broker or a market maker in exchange for net domestic assets. In contrast to this, sales of foreign exchange are clearly limited by the central bank's stock of foreign currency denominated assets. As long as its reserves exceed a critical threshold,  $NFA^c$ , the central bank can credibly achieve the desired path through sterilised sales. But as soon as the current stock of foreign reserves is perceived as too low by the market, foresighted investors anticipate the upcoming exhaustion of reserves and the consequent depreciation of the currency, and hence sell domestic currency. Thus, capital outflows will accelerate and the central bank finally loses its intervention instrument. This idea of a hard budget constraint on the control of the exchange rate is quite similar in spirit to the theory of currency crisis under fixed exchange rates developed by Krugman (1979). However, it should be stressed again that this constraint is asymmetric and that

<sup>92</sup> The volume of intervention of the Federal Reserve on September 22, 2000 to support the euro is exceptional in the US intervention history. Neither the US interventions in the yen/dollar market, nor those in the mark/dollar market have ever reached this amount.

it only applies to prolonged capital outflow episodes. Capital inflows, and thereby appreciating pressure on the domestic currency can be fully absorbed by the central bank. Thus, even if one does not believe in any of the discussed asset market approaches to the effectiveness of sterilised foreign exchange market interventions, the required ‘brute force’ policy in the framework of the balance of payments flow channel can be indefinitely realised – at least – in times of an appreciating domestic currency.

Besides the possible limitations concerning the stock of foreign assets in the central bank’s balance sheet one might be further tempted to argue that in the case of capital inflows there is also an important quantitative limit set by the stock of domestic assets. Recall that in order to sterilise the purchase of foreign assets the central bank has to withdraw liquidity from the banking system. This can either be done by reducing the stock of domestic assets (i.e. the central bank’s lending to the domestic banking system) or by expanding the central bank’s liabilities to the banking system (i.e. by allowing the commercial banks to deposit interest bearing excessive funds at central bank) (see Figure V.2 in Section V.1.2.1 for a stylised central bank balance sheet). While the reduction of the central bank’s claims against the banking system is obviously limited by stocks of domestic assets, there is no such boundary on the liability side of the balance sheet. Thus, theoretically, the central bank’s liabilities to the domestic banking system can be increased infinitely, provided that commercial banks have access to an unlimited deposit facility. And indeed, many central banks in small open emerging market economies which are engaged in sterilised foreign exchange market interventions have balance sheets with extensive negative NDA positions.

#### *V.1.4.2 Limits due to budgetary costs*

A second aspect which might impose a constraint on the control of the exchange rate is the costs resulting from the sterilisation of changes in the net foreign assets. In order to explain the origin of these so-called sterilisation costs ( $C_t^S$ ) it is helpful to imagine the composition of the balance sheet of a central bank as a portfolio consisting of interest-bearing assets and liabilities in domestic and foreign currency. The act of sterilisation therefore represents nothing else than a change from foreign interest-bearing assets to domestic interest-bearing assets (in the case of a constant balance sheet total) or from foreign interest-bearing assets to domestic liabilities which are remunerated at a domestic interest rate (in the case of a varying balance sheet total). In this Section we will show exemplarily for the case of an appreciating currency and the related central

bank's purchase of foreign currency under which conditions sterilisation costs may occur. The opposite can be derived in an analogous manner.

The sterilisation costs that are supposed to occur in period  $t$  (defined per unit of domestic currency that is supplied in interventions in period  $t-1$ ) are made up of two components: the interest rate costs (or earnings) ( $C_t^i$ ) and the valuation losses (or returns) from foreign exchange reserves ( $C_t^V$ ):

$$(V.32) \quad C_t^S = C_t^i + C_t^V .$$

The interest rate component of sterilisation is determined by the difference between the foreign and the domestic interest rate:

$$(V.33) \quad C_t^i = i_{t-1} - i_{t-1}^f .$$

This is due to the fact that a sterilised intervention that tries to prevent an appreciation leads to an increase in foreign assets and a decrease in domestic assets; in the case of a deposit facility or the issuance of notes, domestic liabilities increase. Thus, the central bank loses income from domestic assets (or has to pay interest on domestic liabilities) while it receives additional income from a higher amount of foreign assets. It is obvious that sterilised interventions are associated with interest costs (returns) if the domestic interest rate is higher (lower) than the foreign interest rate.

The valuation costs (returns) per unit of sterilisation depend on the percentage change of the exchange rate which we express by the difference of the log of the nominal exchange rate:

$$(V.34) \quad C_t^V = -(s_t - s_{t-1}) = -\Delta s_t .$$

If the domestic currency depreciates, the value of foreign exchange reserves in terms of the domestic currency increases. The central bank makes a profit from sterilised intervention.

Both cost components can be combined in order to define conditions under which sterilised interventions are free of charge:

$$(V.35) \quad C_t^S = 0 = i_{t-1} - i_{t-1}^f - (s_t - s_{t-1}),$$

which leads to the ex post formulation of the interest parity condition:

$$(V.36) \quad (s_t - s_{t-1}) = i_{t-1} - i_{t-1}^f.$$

In other words, the costs of sterilised intervention are zero if a central bank targets the exchange rate along a path that is determined by the interest rate differential. This guarantees at the same time that there are no profit opportunities for short-term oriented investors whom invest in the domestic currency. If the domestic interest rate is higher than the foreign interest rate the advantage is fully compensated by a depreciation of the domestic currency. Thus the condition of zero costs for sterilised interventions is the mirror image of the condition that the mix of exchange rate and interest policy should not provide profit opportunities for short-term oriented investors. In fact, the profits of these investors are to a large extent nothing else but the sterilisation costs paid by the central bank.<sup>93</sup>

The situation is somewhat more complicated if there is a permanent risk premium ( $u_t^s$ ) that is different from zero. Thus, the UIP equation becomes:

$$(V.37) \quad (s_t - s_{t-1}) + u_{t-1}^s = i_{t-1} - i_{t-1}^f.$$

In this case the total costs of sterilisation are:

$$(V.38) \quad C_t^S = u_{t-1}^s.$$

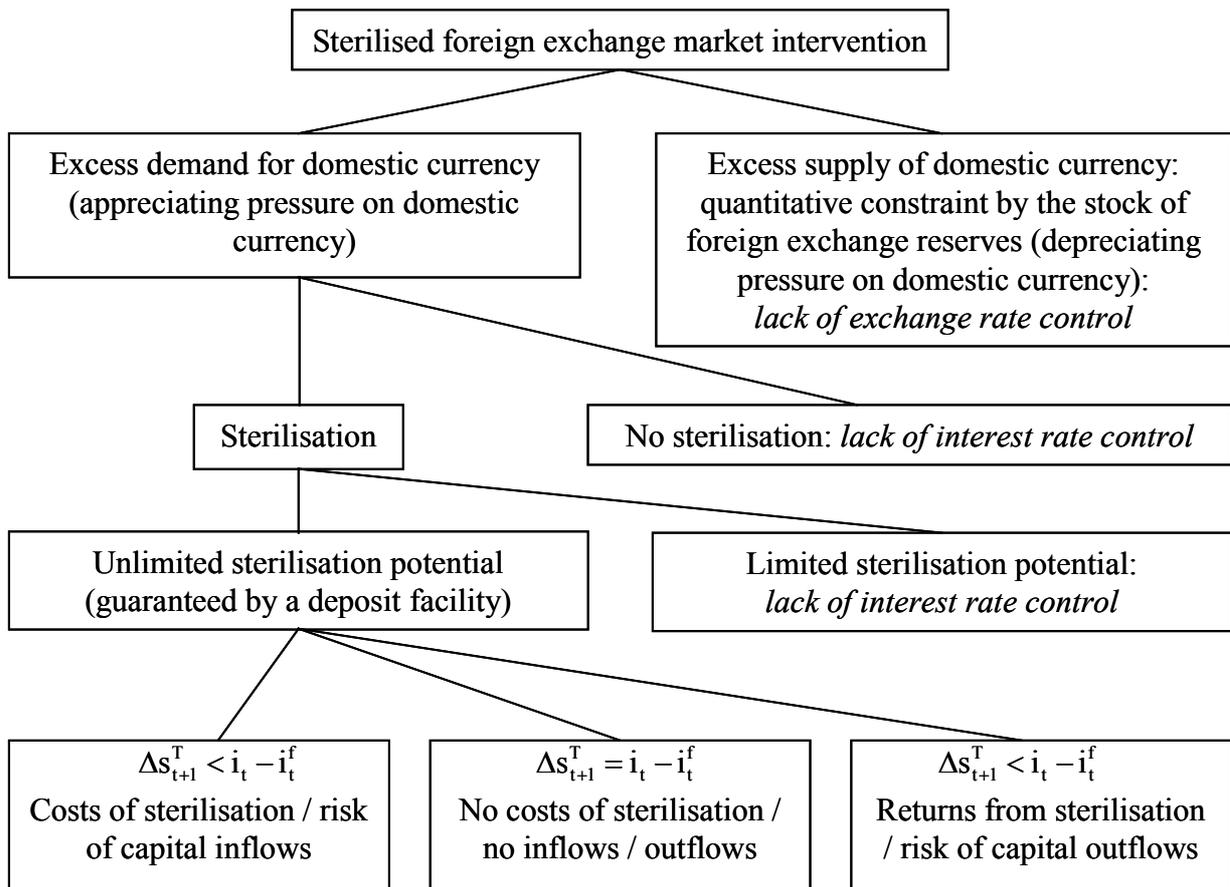
Thus, exchange rate targeting becomes more difficult, if the exchange rate path that is chosen is associated with a high risk premium.

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<sup>93</sup> As far as domestic commercial banks receive deposits denominated in the domestic currency and grant credits in the foreign currency, they also pay for the profits of short-term oriented investors.

Figure V.13 summarises the critical issues that are related with sterilised foreign exchange market interventions.

**Figure V.13: Scope and limits of sterilised foreign exchange market interventions**



### V.1.5 Some concluding remarks on the effectiveness of sterilised interventions

A central requirement for the successful implementation of a strategy of direct managed floating is the effectiveness of foreign exchange market interventions that leave the interest rate instrument unchanged. However, the empirical literature on sterilised interventions is anything but conclusive about this issue. Having already criticised many of these studies in Sections V.1.2.2 to V.1.2.5 for various reasons, two of the most important points are worth repeating.

The first criticism concerns the studied foreign exchange market. Most of the empirical studies (investigating in particular the portfolio balance channel and the signalling channel) were conducted on the basis of official US interventions in the mark/dollar market. As has been shown

in Section V.1.3.2, researchers thereby selected the central bank which is least active in the foreign exchange market (interventions on rare occasions and with relatively small amounts) and the foreign exchange market which is by far the most liquid in the world (measured by daily turnover and the size of the bonds market). On the basis of these results, they often conclude that sterilised foreign exchange market interventions do not provide central banks in general with an efficient policy tool.

The second criticism concerns the efficient market hypothesis. Most econometric tests of intervention channels (monetary, portfolio balance, signalling) are based on a joint hypothesis of efficient foreign exchange markets and effective sterilised foreign exchange interventions. While exchange rate economists regularly come to the result that models of exchange rate determination based on the former are not able to predict the movements in the exchange rate, one should not be surprised that the attempts to explain the effectiveness of interventions on the basis of the same models are not very satisfying. Most economist, however, treat the assumption of efficient foreign exchange markets as axiomatic and conclude on the basis of the mixed empirical results from the intervention studies that they are not very supportive of the effectiveness of sterilised interventions.

Apart from these two, in our opinion, important and rarely mentioned types of criticism a final remark is devoted to the sterilisation issue. It should be stressed again that sterilised interventions are not aimed at creating a disequilibrium on the international financial markets. In many papers dealing with fixed exchange rate systems under internationally mobile capital sterilisation was primarily discussed as a means to maintain artificially high yields. Calvo et al. (1996, p. 134), for example, argue as follows: “Presumably, funds are being attracted into the country by the promise of higher expected interest rates. But if the capital inflow is sterilised, this will prevent the interest rate differential from narrowing, and may thus induce further capital inflows.” This perpetuation of policy-induced capital inflows and the related increase in the volume of sterilisation led most economists to argue that the sterilisation instrument is ineffective under perfect capital mobility. Additionally, it entails an import risk for the monetary policy maker. Since the interest rate differential is artificially kept above what the market would perceive as an equilibrium under constant exchange rates (i.e.  $i_t > i_t^f + u_t^s$ ), sterilisation costs incur. These costs are often regarded as quasi-fiscal costs of the government that are supposed to constitute an upper boundary for a central bank’s ability to control the fixed exchange rate (see Calvo et al.

(1993) for estimates of magnitudes of such quasi-fiscal costs under fixed exchange rates; see Grilli (1986) for a model of currency crisis that is in the spirit of Krugman (1979) with a private sector anticipating the limited capacity or willingness of the government to bear the costs). Thus, in our opinion, sterilisation of foreign exchange market interventions is a policy tool that is non-compliant with systems of fixed exchange rates. Since the domestic interest rate is fully determined by the interest rate of the anchor country, in credible fixed rate systems the sole instrument is non-sterilised interventions (see the discussion of the monetary channel of interventions and its application to currency board arrangements in Section V.1.1). With regard to systems of direct managed floating exchange rates this critique however does not apply provided that sterilised interventions are used in the way described above.

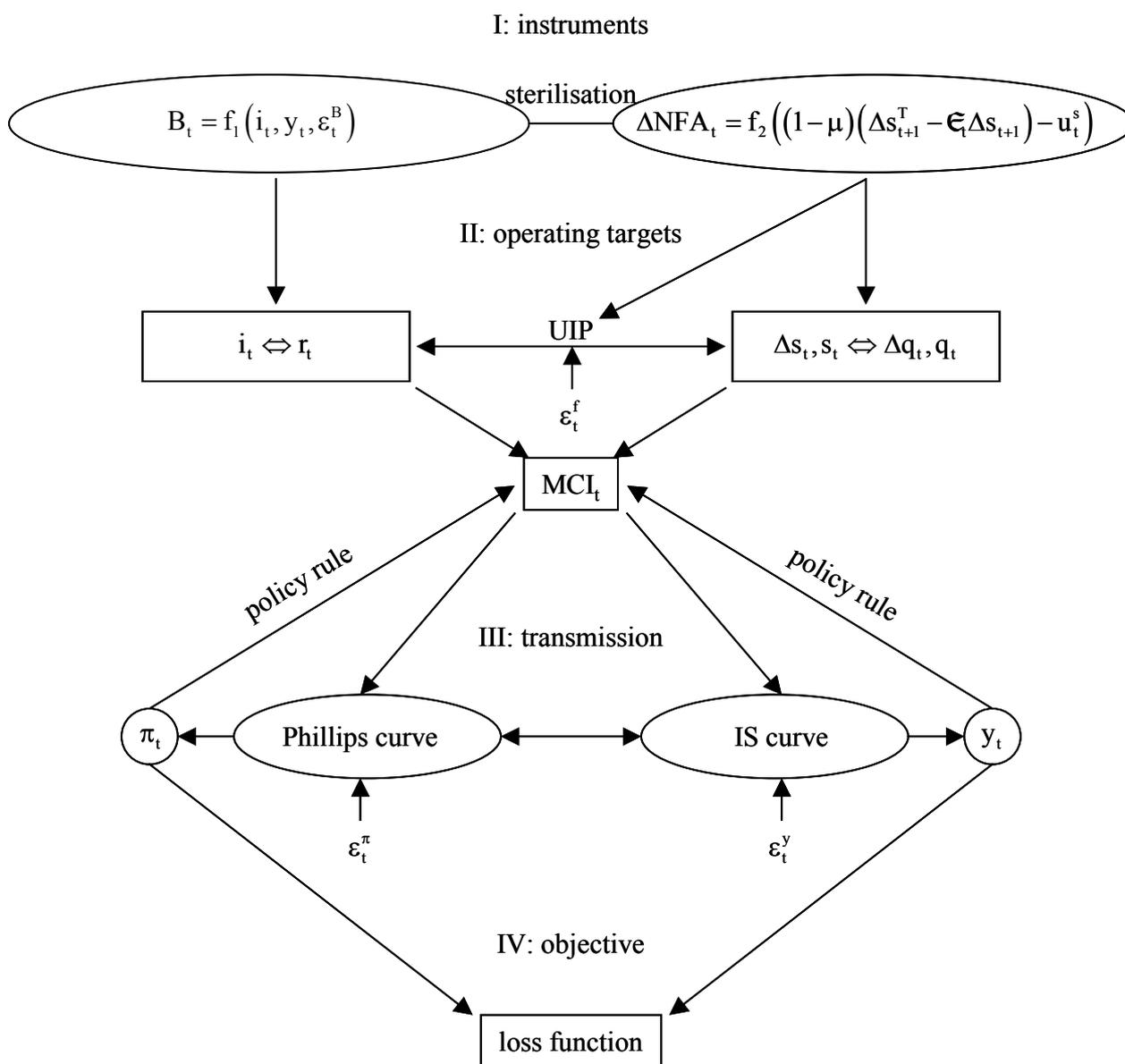
Thus, we fully agree with Mayer (1982, p. 12) who argues as follows: “As regards the potential rôle of official intervention in the exchange markets, it is clear that there would be very little room for such intervention in the ideal scenario of nearly perfect foresight on the part of exchange market participants. Since, under these conditions, any diversion of the spot and forward exchange rates from their ‘optimal response pattern’ [the UIP path, T.W.] would give rise to practically unlimited speculative capital flows, efforts by the authorities to prevent the spot rate from accommodating the change in interest rate differentials would entail reserve losses (or gains) on a scale that would soon force them to abandon such policy.” In a similar vein, Dominguez and Frankel (1993b, p. 139) again use the analogy between interventions and herd dogs: “It is clear that a few dogs, who after all are smaller in size and fewer in numbers than the steers, probably could not sustain overall control of the herd for long without the sense of direction provided by the cowhands and would have little idea what to do with such control if they had it. This makes the point that intervention operations – which, after all, are small compared with the private market – probably could not sustain control of the foreign exchange market for long without the sense of direction provided by monetary policy and might be used to pursue inconsistent policy goals even if such control could be sustained.”

## **V.2 Monetary policy under direct managed floating**

In the last Section we have shown that central banks are able to independently control two operating targets, a short-term interest rate and the exchange rate. For the reasons outlined the UIP condition serves as an important guideline for the paths of the two operating targets. However, it should be clear that theoretically the number of combinations is unlimited. For each

level of domestic interest rates (given the foreign interest rate) a different target path of the exchange rate follows. Thus, in this Section we develop a second restriction for the setting of the central bank's two operating targets by defining a policy rule according to which the operating targets have to be adjusted in response to a small set of macroeconomic information variables.

**Figure V.14: Monetary policy under direct managed floating**



In principle, the proceeding is quite similar to that of a central bank that pursues a strategy with a single interest rate operating target as for example presented in Chapter IV. We first showed that under normal circumstances a central bank is able to perfectly control each level of the short-term nominal interest rate. We then developed a policy rule that tells the monetary policy maker which interest rate level he should target. Unlike in the case of interest rate policy rules,

however, the policy framework for direct managed floating has to be based on the simultaneous use of the exchange rate and the interest rate as independent operating targets of monetary policy. Figure V.14 gives an overview of the basic relationships of the strategy.<sup>94</sup>

While levels I and II of the strategy (instruments and operating targets) have already been discussed in Section V.1 the focus of this Section is on levels III and IV. In the first step we will summarise the two operating targets by a comprehensive measure that we call a monetary conditions index (MCI). We will concentrate our analysis on two possible formulations of the MCI: a real MCI which is defined as

$$(V.39) \quad \text{MCI}_t = r_t - \psi q_t$$

and a nominal MCI which is given by

$$(V.40) \quad \text{MCI}_t = i_t - \psi \Delta s_t$$

where  $\psi$  reflects the relative importance of the exchange rate term for measuring monetary conditions.

The advantage of the nominal MCI is straightforward as it directly measures the observable setting of the monetary policy instruments  $i_t$  and  $s_t$ . Including the lagged nominal exchange rate instead of its level stems from the non-stationary properties of the level of  $s_t$ . If a stationary variable and a non-stationary variable are linearly combined to an index, the variable with the higher order of integration will tend to dominate fluctuations in the MCI and hence will lead to a biased information content of the index (Eika et al., 1996). For this reason McCallum (2000) refers to (V.40) as a dimensionally coherent definition of an MCI. The problem with different orders of integration vanishes if the MCI is defined in real terms. Since both  $r_t$  and  $q_t$  are non-stationary variables, the MCI is non-stationary as well. A problem with the real MCI may however emerge if one doubts that the real interest rate and the real exchange rate can be viewed as operating targets. In Section IV.1.2 and Section V.1 we have shown that their nominal

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<sup>94</sup> In Figure V.24 below (see Section V.3) we present a similar diagram for monetary policy with a single operating target under market determined exchange rates.

counterparts are directly controllable through interventions in the domestic money market and in the foreign exchange market. Also, for the real variables to be directly controllable we have to make some further assumptions. According to the Fisher relationship the real interest rate which enters the aggregate demand equation (see equation (V.45) below) as a basic determinant is usually defined as

$$(V.41) \quad r_t = i_t - E_t \pi_{t+1}.$$

Expectations about the future inflation rate are determined by the Phillips curve. Under the assumption of a purely backward-looking Phillips curve Ellingsen and Söderström (2001) have shown that it is consistent to express aggregate demand as a function of the ex post real interest rate which is given by<sup>95</sup>

$$(V.42) \quad r_t = i_t - \pi_t.$$

Thus, in period  $t$ , the real interest rate is fully determined by the operating target  $i_t$  and the observable rate of inflation  $\pi_t$ . In a similar vein, the real exchange rate is solely defined by variables that are known by the actors of our open economy model. From equation (V.47) (see below)  $q_t$  is given by

$$(V.43) \quad q_t = s_t - s_{t-1} + q_{t-1} + \pi_t^f - \pi_t.$$

To sum up, targeting the nominal interest rate and the nominal exchange rate implies control over the real interest rate and the real exchange rate. Thus, both the nominal MCI and the real MCI can be regarded as operating targets of a direct managed floating central bank.

In the second step, we will derive a policy rule in terms of the MCI that minimises the central bank's loss function by taking into account the economy's basic transmission channels of monetary impulses to the goal variables. As in Chapter IV the model of the economy is given by the following equations:

$$(V.44) \quad \pi_{t+1} = \pi_t + \gamma_y y_t + \gamma_q (q_t - q_{t-1}) + \varepsilon_{t+1}^\pi$$

$$(V.45) \quad y_{t+1} = \beta_y y_t - \beta_i (i_t - \pi_t) + \beta_q q_t + \varepsilon_{t+1}^y$$

$$(V.46) \quad i_t = i_t^f + E_t s_{t+1} - s_t + u_t^s$$

$$(V.47) \quad s_t - s_{t-1} \equiv q_t - q_{t-1} - \pi_t^f + \pi_t.$$

Again  $\pi_t^f$  is set to zero so that  $i_t^f = r_t^f = \rho_f r_{t-1}^f + \varepsilon_t^f$ . Compared with a single interest rate operating target framework, however, under a direct managed float the UIP equation (V.46) enters the model with a modified shock term to reflect the effects of sterilised foreign exchange market interventions. While in Chapter IV one way to capture the purely market determined outcome of unexpected exchange rate movements was to model an autoregressive UIP disturbance according to  $u_t^s = \rho_s u_t^s + \varepsilon_t^s$ , in Section V.1.3 of this Chapter we summarised the situation in which a central bank that follows the intervention rule (V.25) has control of the exchange rate by equation (V.29), i.e. a perfectly holding UIP condition. Thus, the open economy model given by equations (V.44) to (V.47) has to be adjusted by assuming that

- there are no persistent deviations from UIP, i.e.  $\rho_s$  is equal to zero;
- $\text{Var}[\varepsilon_t^s]$  is small in comparison with the values it takes under purely market determined exchange rates.

Below we will show that the results obtained from the analysis of the direct managed floating strategy are quite robust against variations of the variance of the UIP disturbance – provided that the values of the variance are kept small. Thus, for the sake of simplicity, we will set the variance to zero. Nevertheless it is worth mentioning that the practical relevance of non-zero variances even for central banks practicing a direct managed float should not be underestimated. In this case the central bank is assumed not to be concerned about some (day-to-day) volatility in the movement of the exchange rate. If the exchange rate is determined by UIP, we have already shown (see Chapter II) that the exchange rate path that is expected by the privates (and eventually targeted by the central bank) in time  $t-1$  may be subject to unanticipated changes in time  $t$  for the following three reasons:

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<sup>95</sup> We therefore refrained from explicitly formulating aggregate demand in terms of the expected real interest rate in all our open economy models in Chapter IV and in this Chapter. This is common practice in all purely backward-

- unanticipated changes of the central bank's interest rate instrument ( $i_t$ )
- shocks stemming from the foreign country (as summarised by  $i_t^f$ )
- disturbances to UIP ( $\varepsilon_t^s$  which is under the control of the direct managed floating central bank).

While the first two reasons alone would make the exchange rate path quite foreseeable due to central banks' practice of interest rate smoothing (i.e. central banks alter interest rates only in small steps and try to avoid frequent sign changes when altering the interest rate; see also Chapter IV), the accepted degree of temporary disturbances to UIP contributes towards maintaining some uncertainty on the part of foreign investors. The problem related to perfectly foreseeable exchange rate path is that it can easily lead market participants to underestimate the degree of foreign exchange risk and encourage one-way bets. Thus, it is often recommended that a central bank should not "attempt to even out all short-term volatility in the exchange rate, because such volatility serves to sharpen participants' awareness of risk" (Goldstein, 2002, p. 43).

It should finally be noted that in accordance with Chapter IV the economics of controlling the operating targets do not explicitly enter the model. Thus, it is assumed that a central bank is able to fully control  $i_t$  and  $s_t$  with its instruments.<sup>96</sup>

### ***V.2.1 The role of MCIs in monetary policy***

Generally an MCI is defined as the weighted sum of variables  $P_\omega$  directly affected by monetary policy actions (Mayes and Virén, 2000):

$$(V.48) \quad MCI_t = \sum_{\omega} \psi_{\omega} (P_{\omega,t} - P_{\omega,0}).$$

The degree of restriction of variable  $P_\omega$  in period  $t$  is measured as percent deviation from its neutral value which was realised, by assumption, in some base period  $t = 0$ .<sup>97</sup> The weights  $\psi_\omega$

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looking models (see e.g. Rudebusch and Svensson, 1999).

<sup>96</sup> For an approach to integrate the instruments of monetary policy into a standard open economy macro model, see Coenen and Wieland (2002b). Note however that in this paper only non-sterilised interventions in the foreign exchange market are considered as an alternative to interventions in the domestic money market.

used for constructing MCIs represent the relative impact of the variables  $P_{\omega}$  on the final targets of the monetary policy authority and thus, they are normally derived on the basis of a macroeconomic model. We will come back to the issue of calculating the appropriate weights below in Section V.2.2. In most applications the variables entering the MCI are a short-term interest rate and some measure of the exchange rate. Since the MCI is an index it is quite common to normalise the weight of one variable (usually that of the interest rate) to unity so that the weight of the other variable becomes a relative weight ( $\psi = \psi_q/\psi_r$  and  $\psi = \psi_{\Delta s}/\psi_i$  in the case of the MCIs presented in equation (V.39) and (V.40) above).

During the 1990s several central banks (e.g. Canada, New Zealand, Sweden and Norway; see Eika et al., 1996, Freedman, 1994, Nadal-De Simone et al., 1996) and international institutions (e.g. the IMF) constructed such an index and regularly reported on its evolution. Because the interest rate and the exchange rate have an important impact on a central bank's final targets in an open economy and since both are assumed to be tightly interlinked on the international financial markets the appeal of the MCI is understandable. In the following we will briefly summarise the use of the MCI by two of its formerly leading advocates, the Bank of Canada and the Reserve Bank of New Zealand. We will show that in a monetary policy environment in which the exchange rate is purely determined by the market the MCI mixes up two variables that are situated on two fundamentally different stages of the transmission process. The related problems mainly contributed to the loss of the MCI's attractiveness in recent years.

In Canada the MCI was officially used as an operating target since the early 1990s (Freedman, 1994). However, unlike in the definition of an operating target given in Chapter I (operating targets are variables that the central bank influences directly by its monetary policy instruments) the Canadian authorities did not directly control both the interest rate and the exchange rate, but only the interest rate. Thus, when the central bank needs to change monetary conditions directly, it adjusts its interest rates, which in turn is assumed to affect the exchange rate in some systematic way – usually via uncovered interest parity. Freedman (1994, p. 467) gives the following example: “If short-term interest rates rose by 1 percentage point and the increase was expected to last one quarter, and if the expected exchange rate remained unchanged, the

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<sup>97</sup> Note that in the case of our MCIs presented in equations (V.39) and (V.40) the neutral values are zero. This is due to the fact that in the definition of the initial conditions of the dynamic system we set all variables – somewhat arbitrarily – to zero (see in contrast to this the analysis of the zero lower bound on nominal interest rates in Chapter IV). Moreover, all the variables defining the MCI are mean stationary.

exchange rate would appreciate by 0.25 percent.” The overall restriction exerted by the tightening of interest rates is measured by the weighted sum of both the increase in the interest rate and the appreciation of the exchange rate. Thus, when the MCI is employed under market determined exchange rates (independently or indirect managed floating) its characterisation as an operating target of monetary policy may be misleading. Stevens (1998, p. 36) puts this as follows: “An MCI is a sort of hybrid of the policy *instrument*, and one (important) part of, what economists call, the *transmission* mechanism for policy. Monetary policy does not control the exchange rate directly; the exchange rate is a result of changes in the instrument (among a host of other factors).”<sup>98</sup> In a similar vein the European Central Bank writes: “MCIs mix variables which are not of the same nature. Aggregating the nominal short-term interest rate, which is controlled by the central bank, and the exchange rate which may respond to many influences other than monetary policy decisions, does not result in a meaningful indicator of the monetary policy stance of the ECB” (ECB, 2002, p. 25).

If the exchange rate and the interest rate were indeed tightly linked by UIP, the hybrid nature of the MCI would not be a cause for concern. However, given the topic of the present study, it is clear that UIP does not describe the behaviour of financial market participants and that the link between interest rates and exchange rates is subject to a high degree of uncertainty under market-determined exchange rates. The problems related to a non-stable relationship between the interest rate and the exchange rate can be exemplified by the experiences of the Reserve Bank of New Zealand which introduced the use of the MCI in June 1997. The practice of the Reserve Bank of New Zealand had probably taken the concept the furthest, adopting a practice of announcing a ‘desired’ level of the MCI and its future path within a narrow indicative band, conditional on the information available at the time, which they judge as most likely to be consistent with the achievement of their inflation target over time. But soon the limits of this strategy were revealed: “Such narrow bands did not adequately allow for the short-term ‘noise’ in the exchange rate, and we also greatly underestimated the extent of the quarter-to-quarter shifts in desired monetary conditions that were likely to be required. Use of these tight indicative bands around the MCI intra-quarter greatly increased the day-to-day and week-to-week responsiveness of interest rates to day-to-day exchange rate movements. It also led to interest rates rising quite sharply intra-quarter, as the exchange rate began to trend sharply downwards”

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<sup>98</sup> Note that many economists (as the one just cited) do not distinguish between operating targets and instruments as operating targets are supposed to be perfectly controllable with the central bank’s instruments. Strictly speaking, what they call an instrument is an operating target.

(Reserve Bank of New Zealand, 2000, item 36). The experience portrayed in this quotation confirms our results obtained in Chapter IV where we have shown that in the case of an alternative modelling of financial market behaviour there is a high probability that interest rates become very volatile.

On the academic level, the idea to use an MCI as an operating target for monetary policy under market-determined exchange rates was in particular promoted by Ball (1999b). Instead of the UIP condition he uses a rather simple structure for the international linkages of an open economy by simply assuming a negative relationship between the real exchange rate and the domestic real interest rate which can be disturbed by random shocks (see also Chapter IV):

$$(V.49) \quad q_t = -\alpha_i (i_t - \pi_t) + \varepsilon_t^q.$$

Using equation (V.44) and (V.45) as Phillips curve and aggregate demand curve and assuming a traditional intertemporal loss function he derives an optimum monetary policy rule for a central bank in an open economy which he expressed in terms of an MCI as ‘policy instrument’.<sup>99</sup> He correctly states that “the rationale for using an MCI is that it measures the overall stance of policy, including the stimulus through both  $r$  and  $e$  [the real interest rate and the real exchange rate in his notation; T.W.]. Policy makers shift the MCI when they want to ease or tighten” (Ball, 1999b, p. 131). But subsequently he specifies his policy rule as follows: “When there are shifts in the  $e/r$  relation – shocks in equation (3) [our equation (V.49); T.W.] –  $r$  is adjusted to keep the MCI at the desired level.” In other words, even though he accepts the central role of the exchange rate for monetary policy in an open economy, he grounds his theory on an exchange rate system with purely market-determined exchange rates in which the only instrument of monetary policy is the interest rate. Thus, the way he (as well as the Bank of Canada and the Reserve Bank of New Zealand) uses the MCI is in principle identical with an indirect managed floating policy rule (see Chapter IV) where the operating target  $i_t$  reacts to movements of a range of endogenous variables, including some measure of the exchange rate.

To sum up, at the end of the 1990s the concept of the MCI lost a great part of its initial attractiveness. The Reserve Bank of New Zealand abandoned publishing an MCI in March 1999

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<sup>99</sup> See again footnote 98 on the distinction between operating targets and instruments in the monetary policy literature.

and concentrated its policy statements on a short-term interest rate. While the Bank of Canada continues to publish an MCI, its role in taking monetary policy decisions was reduced to that of many other indicators in recent years. It should be stressed again that the way we use the MCI in this Chapter fundamentally differs from that just described. Under direct managed floating both the interest rate and the exchange rate serve as operating targets. Thus, combining both to an aggregate measure again yields an operating target that can be perfectly controlled (within the limits mentioned in Section IV.1.2 and Section V.1.4) by the central bank.

### ***V.2.2 The MCI as composite operating target under direct managed floating***

Before deriving the central bank's policy rule the objective of the policymaker has to be defined. As in Chapter IV the problem of the monetary policy authority is to minimise in each period  $\tau$  an intertemporal loss function  $J_\tau$

$$(V.50) \quad J_\tau = E_t \left[ \sum_{t=0}^{\infty} \delta^t L_{\tau+t} \right]$$

with a period loss function given by

$$(V.51) \quad L_t = \lambda_\pi \pi_t^2 + \lambda_y y_t^2.$$

The preferences of the central bank with respect to the target variables  $\lambda_\pi$  and  $\lambda_y$  are assumed to take equal values ( $\lambda_\pi = \lambda_y = 1$ ). One major difference to the analysis presented in Chapter IV is the introduction of a composite operating target. While under market determined exchange rates the policy rule is formulated in terms of a short-term interest rate, under direct managed floating the policy rule has to be defined in terms of an MCI. Thus, we have to transform the constraint under which (V.50) will be minimised into a constraint in which the MCI serves as a control variable.

### V.2.2.1 Introducing the MCI as control variable<sup>100</sup>

Recall that the problem under market determined exchange rates was to find an interest rate path that minimises the intertemporal loss subject to the structure and the state of the economy given by

$$(V.52) \quad x_{t+1} = Ax_t + Bi_t + \varepsilon_{t+1}$$

or – somewhat more detailed – by

$$(V.53) \quad \begin{pmatrix} r_{t+1}^f \\ u_{t+1}^s \\ \pi_{t+1} \\ y_{t+1} \\ q_t \\ i_t \\ E_t q_{t+1} \end{pmatrix} = \begin{pmatrix} \rho_f & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \rho_s & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & \gamma_y & -\gamma_q & 0 & \gamma_q \\ 0 & 0 & \beta_i & \beta_y & 0 & 0 & \beta_q \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -\gamma_y & \gamma_q & 0 & 1-\gamma_q \end{pmatrix} \begin{pmatrix} r_t^f \\ u_t^s \\ \pi_t \\ y_t \\ q_{t-1} \\ i_{t-1} \\ q_t \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \\ -\beta_i \\ 0 \\ 1 \\ 1 \end{pmatrix} i_t + \begin{pmatrix} \varepsilon_{t+1}^f \\ \varepsilon_{t+1}^s \\ \varepsilon_{t+1}^\pi \\ \varepsilon_{t+1}^y \\ 0 \\ 0 \\ 0 \end{pmatrix}.$$

A and B are matrices containing the structural coefficients and  $x_t$  is the vector of state variables (see Appendix IV.A.a). The interest rate  $i_t$  which has been served so far as a control variable was isolated from the other system variables. If the purpose is to introduce a new control variable, we have to replace the old control variable  $i_t$  with an expression containing the new control variable. In this Section we present the concrete proceedings only for the real MCI. The transformation of the state-space representation for the nominal MCI as operating target is shown in Appendix V.A.

In the first step we take the definition of the real MCI (given by (V.39)) and we replace the real interest rate with  $i_t$  and  $E_t \pi_{t+1}$  according to the Fisher equation:

$$(V.54) \quad \begin{aligned} \text{MCI}_t &= r_t - \psi q_t = \\ &= i_t - E_t \pi_{t+1} - \psi q_t. \end{aligned}$$

<sup>100</sup> The transformation of the system into a system with the MCI as a control variable draws on appendix F of the

Then, the expected future inflation rate can be expressed as a function of the state variables  $x_t$  and the interest rate  $i_t$ :<sup>101</sup>

$$(V.55) \quad \begin{aligned} E_t \pi_{t+1} &= \pi_{t+1} - \varepsilon_{t+1}^\pi = \\ &= A_3 x_t + B_3 i_t. \end{aligned}$$

$A_i$  is a  $1 \times n$  row vector (where  $n = n_1 + n_2 = 6 + 1 = 7$ ) containing the elements of the  $i$ -th row of matrix  $A$ .  $B_i$  is a scalar taking the value of the  $i$ -th row of the column vector  $B$ . Note that in our case  $B_3$  is equal to zero so that  $E_t \pi_{t+1} = A_3 x_t$ . In a similar vein, the real exchange rate can be expressed as

$$(V.56) \quad q_t = A_5 x_t + B_5 i_t$$

where again  $B_5$  is equal to zero so that  $q_t = A_5 x_t$ . Solving (V.54) for  $i_t$  and inserting (V.55) and (V.56) into the resulting equation yields the following expression:

$$(V.57) \quad i_t = MCI_t + (A_3 + \psi A_5) x_t.$$

We can now rewrite the state-space representation of our economy by substituting  $i_t$  in (V.52) for (V.57):

$$(V.58) \quad \begin{aligned} x_{t+1} &= A x_t + B \left[ MCI_t + (A_3 + \psi A_5) x_t \right] + \varepsilon_{t+1} = \\ &= \underbrace{\left[ A + B(A_3 + \psi A_5) \right]}_{A^{MCI}} x_t + B MCI_t + \varepsilon_{t+1}. \end{aligned}$$

This finally gives a state-space form of the model's equations with an MCI as control variable:

$$(V.59) \quad x_{t+1} = A^{MCI} x_t + B MCI_t + \varepsilon_{t+1}.$$

Similarly, we can derive a modified equation for the vector of target variables  $z_t$ . Recall that with  $i_t$  as control variable  $z_t$  was given by

$$(V.60) \quad z_t = C_x x_t + C_i i_t.$$

Inserting (V.57) into (V.60) and rearranging it yields

$$(V.61) \quad z_t = \underbrace{[C_x + C_i (A_3 + \psi A_5)]}_{C_x^{MCI}} x_t + C_i MCI_t.$$

### V.2.2.2 Numerical determination of the coefficients of the policy rule

The central bank's problem is solved by assuming the central bank follows a simple policy rule in terms of the MCI:

$$(V.62) \quad MCI_t = f_\pi \pi_t + f_y y_t$$

Similar to the proceeding in Chapter IV the operating target is adjusted in response to a small set of observable variables, namely the actual inflation rate and the actual output gap. In order to determine the response coefficients in the policy rule we performed a constrained optimisation for both the real MCI (given by (V.39)) and the nominal MCI (given by (V.40)). In any case, searching for an optimal simple policy rule involves three unknown values: the optimum weighting of the exchange rate term in the MCI ( $\psi$ ) and the optimum response coefficients ( $f_\pi$  and  $f_y$ ). Since analytical solutions of the central bank's problem may be very complex and in many cases even not computable we approached the problem by numerical simulation.<sup>102</sup> Therefore we have to calibrate the model (see Table V.6). The parameters of the Phillips curve and the IS (aggregate demand) equation are identical to those in Chapter IV. In contrast to the simulations of Chapter IV however the foreign interest rate is modelled as an autoregressive

<sup>101</sup> Equation (V.55) shows again that in period  $t$  the expected future rate of inflation  $E_t \pi_{t+1}$  is fully pre-determined. We implicitly used this fact in the introduction to Section V.2 (see equations (V.41) and (V.42)).

<sup>102</sup> The mathematics for calculating the optimised coefficients, the related variances and the loss is identical with the case of an interest rate as operating target, and hence already described in Appendix IV.B.c.

process with a positive and non-zero persistence parameter  $\rho_f$ . For simplicity the variance of the i.i.d. shocks  $\varepsilon_t^\pi$ ,  $\varepsilon_t^y$  and  $\varepsilon_t^f$  is normalised to unity.

**Table V.6: Calibration of the model**

Phillips curve		IS equation			UIP equation	
$\gamma_y$	$\gamma_q$	$\beta_y$	$\beta_i$	$\beta_q$	$\rho_f$	$\rho_s$
0.4	0.2	0.8	0.6	0.2	0.3	0

When determining the optimal simple policy rule it is important to bear in mind that its derivation cannot be based on the certainty-equivalence principle (see Section IV.2.1). Thus, the weight  $\psi$  and the coefficients  $f_\pi$  and  $f_y$  depend – among other things – on the variances of the shock terms. While the real shocks ( $\varepsilon_t^\pi, \varepsilon_t^y$ ) as well as the shocks from abroad ( $\varepsilon_t^f$ ) are assumed to be policy-independent, the UIP shocks are not. According to our ‘technical’ definition of direct managed floating at the beginning of Section V.2 sterilised foreign exchange market interventions enter the model by avoiding any persistent deviation from UIP (i.e.  $\rho_s = 0$ ) and by eventually allowing for some stochastic white noise shock (i.e. some short term volatility in the exchange rate). Thus, in order to find out whether the degree to which the spot exchange rate is managed, has an influence on the structure of the optimal simple rule we calculated the weight  $\psi$  and the coefficients  $f_\pi$  and  $f_y$  for both MCI rules (the real MCI rule,  $MCI_t = r_t - \psi q_t$ , and the nominal MCI rule,  $MCI_t = i_t - \psi \Delta s_t$ ) for values of the variance of the UIP shock ranging from zero to one (see Table V.7 and Table V.8).

Accordingly, the optimised coefficients of the real MCI rule are independent of the variance of the UIP shock (at least within  $0 \leq \text{Var}[\varepsilon_t^s] \leq 1$ ). The real exchange rate enters the MCI with a weight of 0.14 implying that a one percentage point increase in the real interest rate exerts the same degree of monetary restriction as an appreciation of the real exchange rate by  $1/0.14 = 7.14$  per cent. Given the response coefficients the MCI has to rise in the case of an increase in inflation and/or output. The results are somewhat different for the nominal MCI rule. For variances of the UIP shock exceeding 0.6 the weighting of the exchange rate in the MCI increases from 0.26 to 0.27. At the same threshold value of  $\text{Var}[\varepsilon_t^s]$  the reaction coefficient for the output gap rises to 1.71. Since we assume that the central banks accommodates the majority

of UIP disturbances we decided for a nominal MCI rule with the parameters  $\psi = 0.26$ ,  $f_\pi = 1.91$  and  $f_y = 1.69$ .

**Table V.7: Optimised coefficients, variances and loss of the real MCI rule**

$\text{Var}[\varepsilon_t^s]$	$\psi$	$f_\pi$	$f_y$	$\text{Var}[\pi_t]$	$\text{Var}[y_t]$	loss	relative loss
0.0	0.14	1.27	1.34	2.62	2.31	4.93	100.33
0.1	0.14	1.27	1.34	2.63	2.31	4.93	100.33
0.2	0.14	1.27	1.34	2.63	2.31	4.94	100.33
0.3	0.14	1.27	1.34	2.63	2.31	4.94	100.33
0.4	0.14	1.27	1.34	2.63	2.31	4.94	100.33
0.5	0.14	1.27	1.34	2.64	2.31	4.94	100.33
0.6	0.14	1.27	1.34	2.64	2.31	4.95	100.33
0.7	0.14	1.27	1.34	2.64	2.31	4.95	100.33
0.8	0.14	1.27	1.34	2.64	2.31	4.95	100.33
0.9	0.14	1.27	1.34	2.65	2.31	4.95	100.34
1.0	0.14	1.27	1.34	2.65	2.31	4.96	100.34

Note: The relative loss refers to the loss from optimal unrestricted policy under commitment.

**Table V.8: Optimised coefficients, variances and loss of the nominal MCI rule**

$\text{Var}[\varepsilon_t^s]$	$\psi$	$f_\pi$	$f_y$	$\text{Var}[\pi_t]$	$\text{Var}[y_t]$	loss	relative loss
0.0	0.26	1.91	1.69	2.60	2.33	4.94	100.48
0.1	0.26	1.91	1.69	2.61	2.33	4.94	100.48
0.2	0.26	1.91	1.69	2.61	2.33	4.94	100.49
0.3	0.26	1.91	1.69	2.61	2.33	4.95	100.49
0.4	0.26	1.91	1.69	2.61	2.34	4.95	100.50
0.5	0.26	1.91	1.69	2.62	2.34	4.95	100.50
0.6	0.26	1.91	1.69	2.62	2.34	4.96	100.51
0.7	0.27	1.91	1.71	2.62	2.34	4.96	100.51
0.8	0.27	1.91	1.71	2.63	2.34	4.96	100.52
0.9	0.27	1.91	1.71	2.63	2.34	4.96	100.52
1.0	0.27	1.91	1.71	2.63	2.34	4.97	100.52

Note: The relative loss refers to the loss from optimal unrestricted policy under commitment.

### V.2.2.3 A note on the optimum weighting of the exchange rate term in the MCI

In contrast to our model consistent approach for the calculation of  $\psi$  economists and central banks often propose to weight the exchange rate term in the MCI according to the relative elasticities of the exchange rate and the interest rate in the IS curve, i.e.  $\psi = \beta_q / \beta_i$  (see Dennis, 1997, Dornbusch et al., 1998, Freedman, 1994). The idea behind this one-dimensional view is that real output (or the output gap) constitutes the sole target variable of the central bank. If inflation is added as an additional monetary policy target, this way of calculating  $\psi$  remains correct as long as the only determinant of inflation is output (in our case:  $\gamma_q = 0$ , see calculations below; for the calculations of an MCI in the case of an inflation equation without exchange rate pass-through see Gerlach and Smets (2000) and Detken and Gaspar (2003)). Otherwise, the information on the monetary policy stance contained in the MCI may be flawed. Gerlach and Smets (2000, p. 1679) state: “In accordance with central bank practice, our model suggests that the optimal weight on the exchange rate depends on the elasticities of aggregate demand.(...) However, this model may be deficient in a number of ways. First, monetary policy may affect inflation through other transmission channels than the output gap, for instance through the direct effect of exchange rate changes on import prices. If so, the attractive result that the weight on the exchange rate depends solely on the elasticities of aggregate demand may no longer hold true.”

One way to cope with this problem is to define an MCI with respect to each of the central bank’s final targets (Eika et al., 1996, Nadal-De Simone et al., 1996). Suppose that the target variables are summarised by a vector  $z_t$  (see equation (V.60)). Thus, the relative exchange rate weight of the real MCI on target variable  $z_{i,t}$  is defined as the quotient of the two partial derivatives of the target variable  $z_{i,t}$  with respect to the exchange rate and the interest rate:

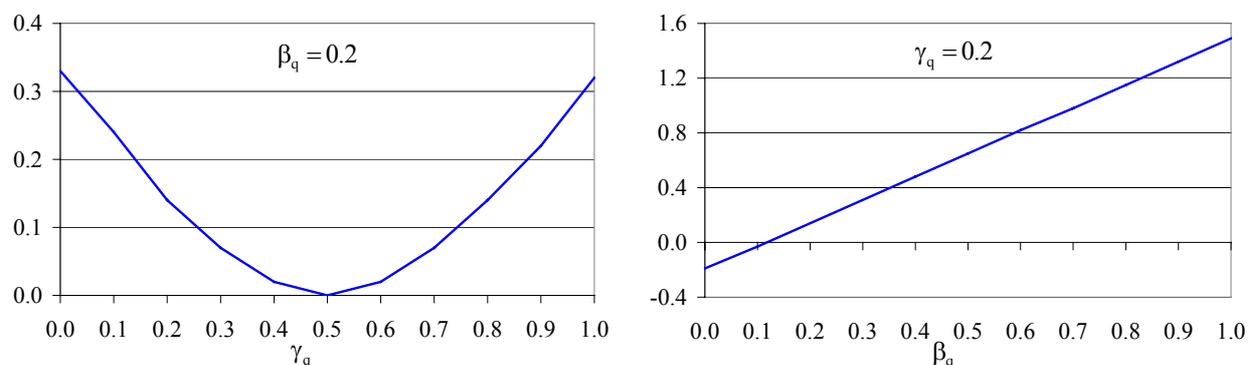
$$(V.63) \quad \psi_{zi} = \frac{\partial z_{i,t} / \partial q_t}{\partial z_{i,t} / \partial r_t}.$$

The same proceeding applies in the case of a nominal MCI. In our view, however, this approach certainly does not contribute to the basic requirement of every monetary policy strategy to be transparent and communicable. Given the two final targets  $\pi_t$  and  $y_t$  the central bank would have to publish two MCIs and situations producing contradictory results cannot be excluded.

For this reason we adopted an alternative approach in which we derived a single but fully model-consistent MCI. The weight on the real exchange rate depends on the effects of both operating targets on both of the central bank's target variables as summarised by the intertemporal loss function as well as on the policymaker's preferences (see Ball, 1999b, and Guender, 2001 for a similar approach).

In the following, we will show how the optimum exchange rate weight  $\psi$  varies with the degree of openness of the economy and with the preference parameters in the intertemporal loss function. We first take a look at the weight of the exchange rate in the real MCI. For a given exchange rate elasticity of aggregate demand ( $\beta_q = 0.2$ ) the optimum weight  $\psi$  only reaches  $\beta_q / \beta_i = 0.33$  if there is no additional exchange rate channel in the model (i.e. for  $\gamma_q = 0$ ). However, as the left panel of Figure V.15 shows the direct impact of exchange rate changes on inflation is an important determinant of  $\psi$ . For a growing  $\gamma_q$  the weight initially falls until it reaches its minimum ( $\psi = 0$ ) for  $\gamma_q = 0.5$  and then increases again. If, on the other hand,  $\gamma_q$  is held constant  $\psi$  grows linearly with the exchange rate elasticity of aggregate demand (see the right panel of Figure V.15).

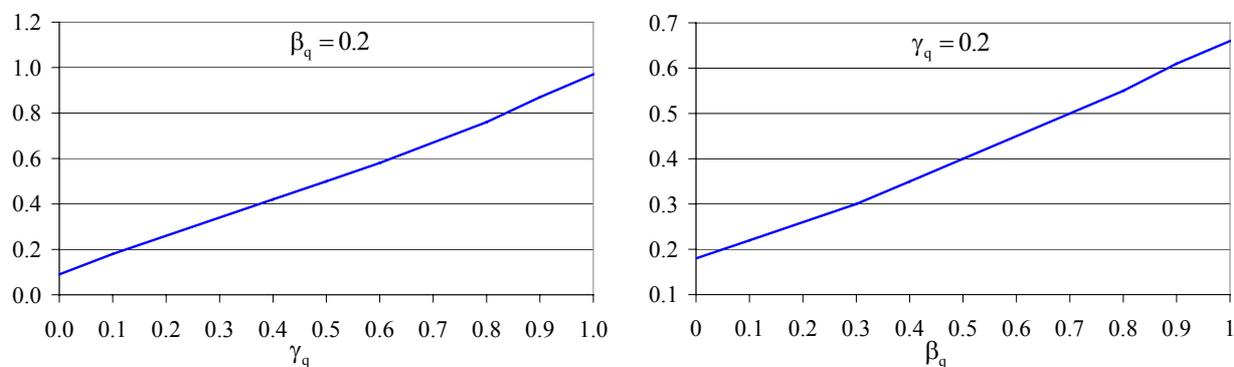
**Figure V.15: Optimum MCI weights for a varying degree of openness (real MCI)**



Under a nominal MCI rule  $\psi$  depends linearly on both, the exchange rate elasticity in the Phillips curve and the exchange rate elasticity of aggregate demand (see Figure V.16). However, when  $\gamma_q$  goes to zero the MCI weight does not become  $\beta_q / \beta_i = 0.33$  (but 0.09). This is due to the fact that in contrast to the real MCI now the lag structure of the MCI is different compared with the lag structure of aggregate demand (see also Stevens (1998) on this point who argues that

for more realistic models with a more detailed lag structure the simple rule thumb  $\psi = \beta_q / \beta_i$  in the case of a Phillips curve without exchange rate term does not apply anymore).

**Figure V.16: Optimum MCI weights for a varying degree of openness (nominal MCI)**



Even though it seems to be important to take into account all the relevant transmission channels of the exchange rate when calculating the exchange rate weight in the MCI the additional loss that occurs if one simply assumes  $\psi$  to take a value of  $\beta_q / \beta_i = 0.33$  is rather limited. The variances of the goal variables and the losses shown in Table V.9 are expressed in relation to the outcome resulting from an unrestricted MCI weight (see Table V.7 and Table V.8). We calculated these values by setting  $\psi$  to 0.33 and by optimising over the response coefficients  $f_\pi$  and  $f_y$ .

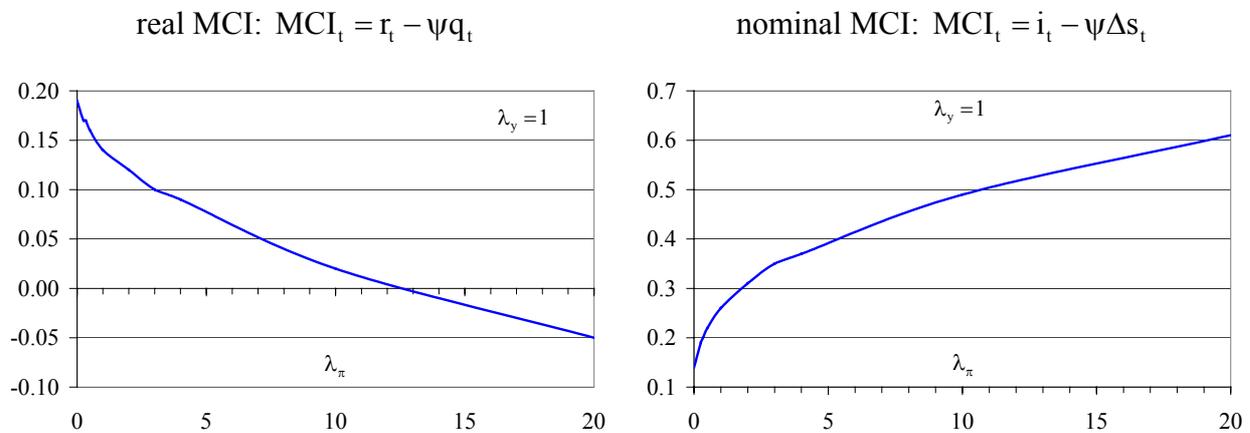
**Table V.9: Loss if  $\psi$  is set to  $\beta_q / \beta_i$**

	$f_\pi$	$f_y$	$\text{Var}[\pi_t]$	$\text{Var}[y_t]$	loss
real MCI	1.51	1.57	100.16	100.59	100.36
nominal MCI	1.91	1.80	99.44	100.96	100.16

Besides the exchange rate elasticities of output and inflation, an additional determinant of  $\psi$  is the relative preferences of the central bank towards its final targets. For a given preference  $\lambda_y$  Figure V.17 depicts  $\psi$  for values of  $\lambda_\pi$  ranging from zero ('output junkie') to twenty ('inflation nutter'). In the case of a real MCI (left panel) the exchange rate weight in the MCI steadily falls and even becomes negative for a strict inflation targeting central bank. This result is quite similar to the analytically solved MCI problem of Guender (2001). In the case of a nominal MCI (right panel) the exchange rate weight in the MCI steadily grows with the degree of strict inflation

targeting. Thus the more the central bank is concerned about the variance of inflation the more the rate of nominal depreciation impacts on the restriction of monetary policy.

**Figure V.17: Optimum MCI weights for varying preferences of the central bank**



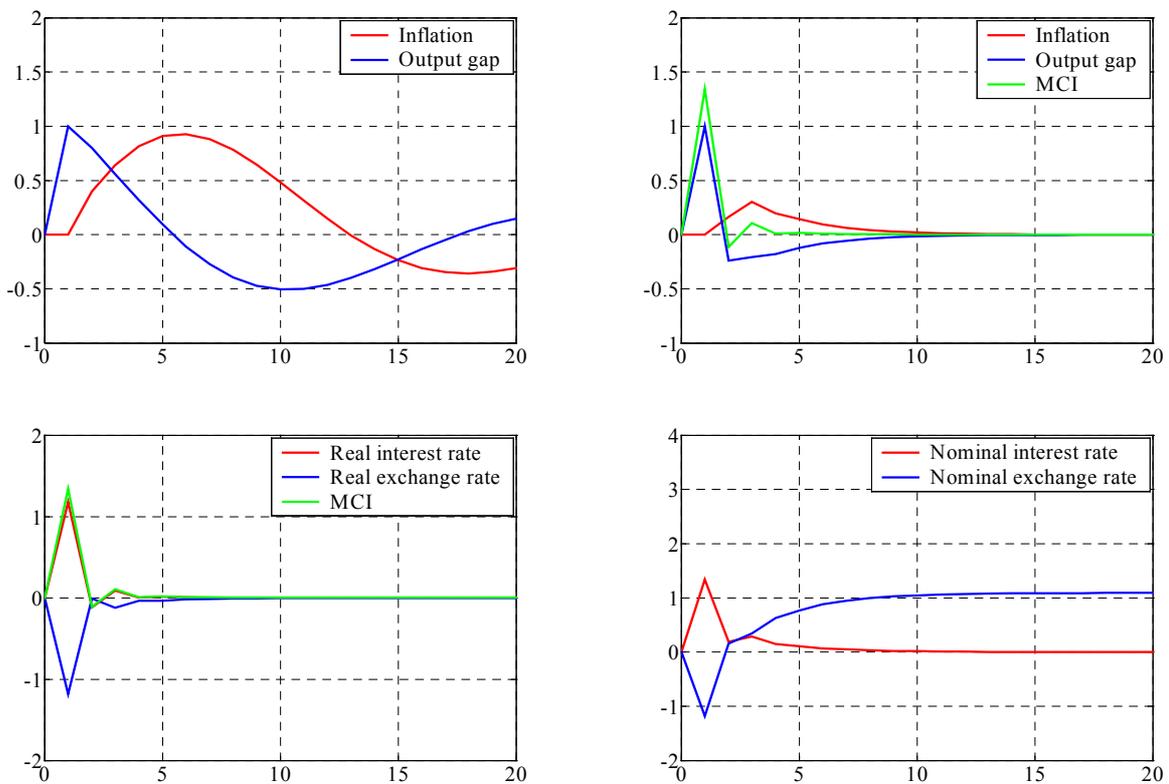
### V.2.3 Direct managed floating in action

The setting of the two operating targets within the direct managed floating framework can be demonstrated if we analyse the dynamics following the occurrence of each of the three possible shocks that may hit the economy: a positive demand shock, an inflationary supply shock and a shock in the form of an increase of the foreign real interest rate. The following Figures depict the impulse-response of the variables of interest over 20 periods. The shocks are assumed to hit the economy in period 1. In each case the size of the shock is one standard deviation. To demonstrate the necessity of a policy reaction the upper left panel of Figure V.18, Figure V.20 and Figure V.22 depict the development of inflation and output under the assumption that there is no policy reaction. For simplicity the absence of monetary policy is simulated by a constant real interest rate. The three charts show that in such a scenario the shocks would cause large and persistent oscillations in inflation and output, and hence significant costs in terms of the loss function.

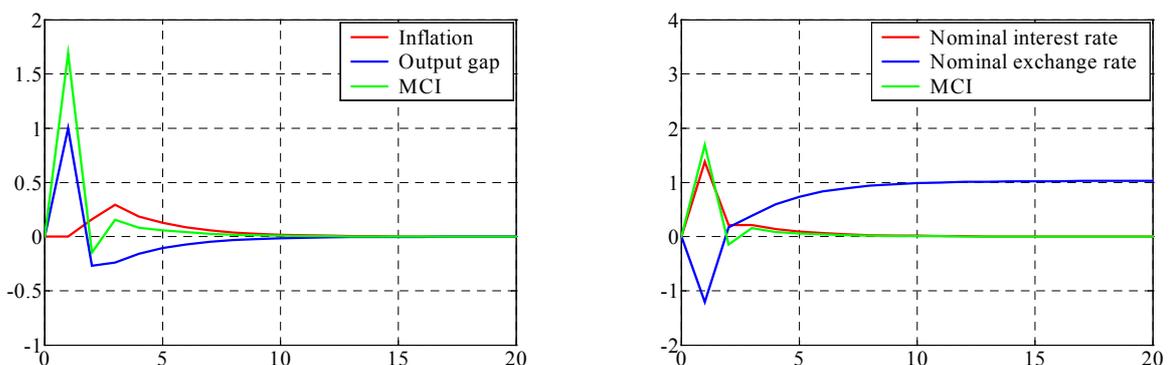
Figure V.18 shows that in the case of a real MCI rule a positive demand shock calls for a restrictive MCI in period 1. In an open economy framework this is mainly achieved by an increase of the domestic real and nominal interest rate. Since the foreign real interest rate has remained unchanged, UIP requires that the domestic currency follows a depreciation path beginning in period 1. This is realised by an immediate real and nominal appreciation of the domestic currency which exerts an additional degree of monetary restriction in period 1 (see the

lower charts in Figure V.18 for the path of the operating targets). From period 2 on the overall degree of restriction more or less returns to zero. The nominal interest rates gradually return to its neutral level while the nominal exchange rate converges to a new equilibrium level. The effects of both the nominal depreciation and the decrease in nominal interest rates tend to be neutralised by the positive but declining domestic rate of inflation so that their real counterparts  $q_t$  and  $r_t$  quickly return to zero. The policy response of a central bank following a nominal MCI rule is almost identical (see Figure V.19).

**Figure V.18: Demand shock (real MCI)**

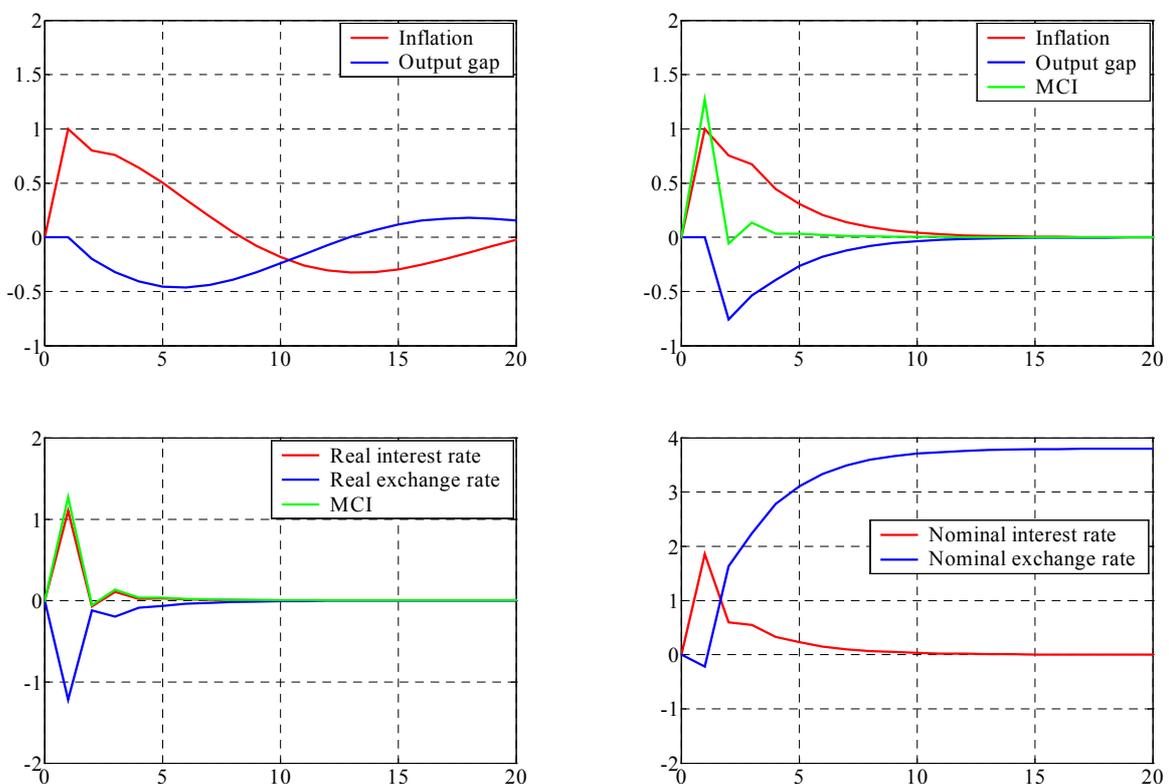


**Figure V.19: Demand shock (nominal MCI)**

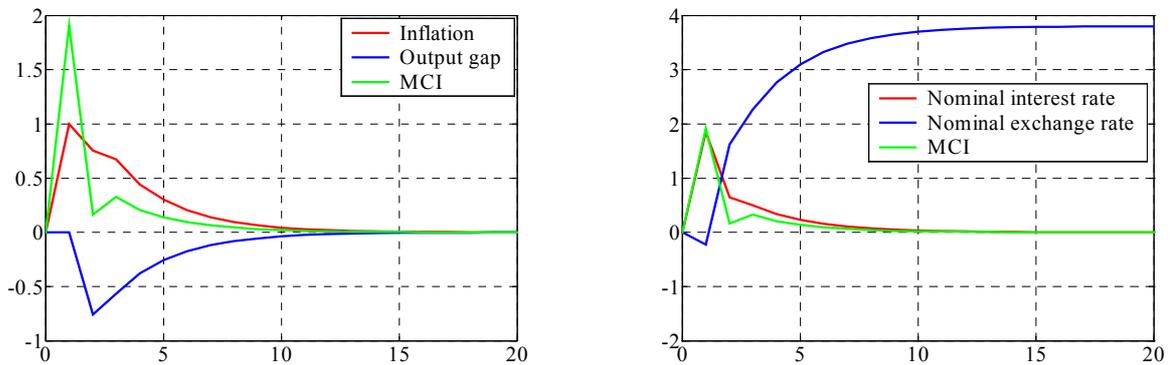


In the situation of an inflationary supply shock the model shows that an almost similar tightening of monetary conditions is required – at least in the case of a real MCI rule (see Figure V.20). Unlike in the event of a positive demand shock however the nominal interest rate hike is more pronounced and comes along with a much smaller initial nominal appreciation. Nonetheless the UIP condition is perfectly met since the expected depreciation is much higher. Again the real interest rate and the real exchange rate quickly return to zero. Thus, the more pronounced movements in the nominal operating targets are neutralised by a much higher and in particular more persistent rise in the rate of inflation. Similar to the well-known result for closed economy models (see e.g. Clarida et al., 1998) the positive supply shock faces the central bank with an important short run trade-off between output and inflation. Instead of almost perfectly offsetting the effects of the demand shock the central bank now creates a significant negative output gap in order to bring down inflation. Since the negative output gap persists over several periods the inflation rate is reduced almost automatically, albeit slowly, without any significant additional monetary restriction. In the case of a nominal MCI rule the initial increase in the MCI is somewhat more pronounced (see Figure V.21). The rest of the dynamics is again quite similar to those of the real MCI rule.

**Figure V.20: Supply shock (real MCI)**

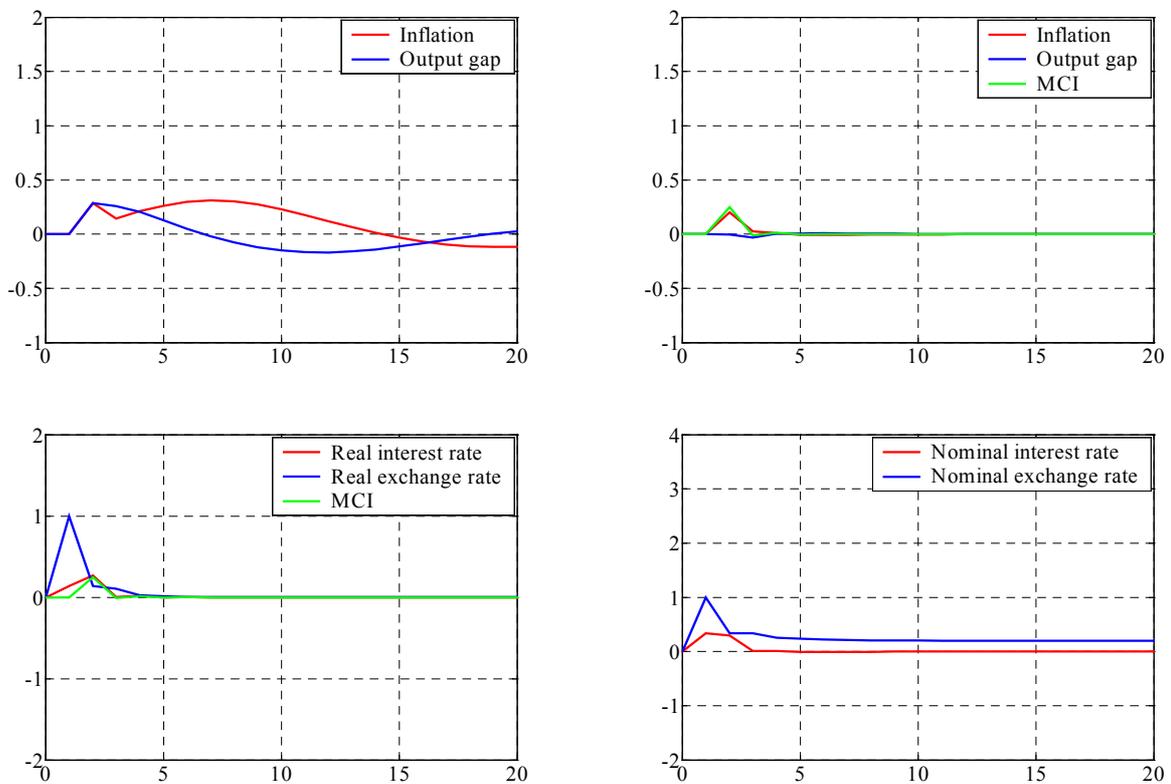


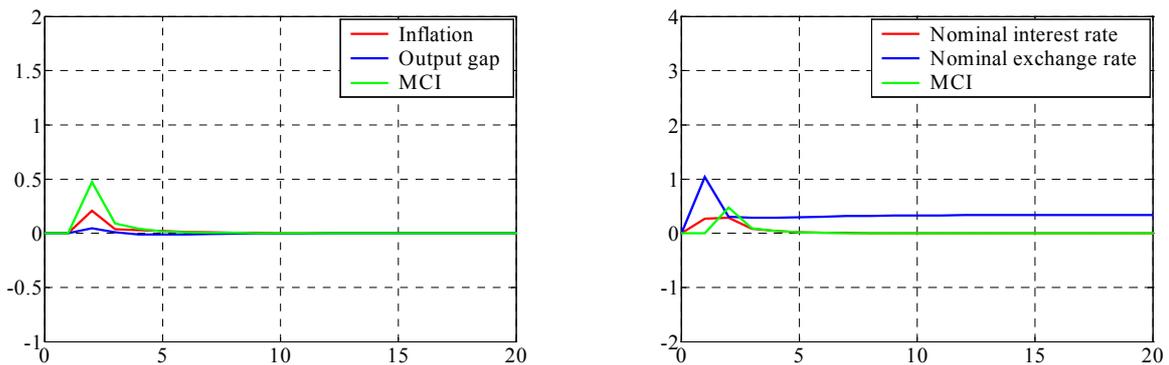
**Figure V.21: Supply shock (nominal MCI)**



In an open economy changes in the foreign interest rate can be also treated as a shock. Here we assume that the foreign interest rate is increased by one standard deviation. Initially the shock induces the central bank to adjust its policy mix – i.e. the combination of the two operating targets – without changing the overall monetary conditions in period 1 (see Figure V.22 for the real MCI rule and Figure V.23 for the nominal MCI rule).

**Figure V.22: Foreign interest rate shock (real MCI)**



**Figure V.23: Foreign interest rate shock (nominal MCI)**

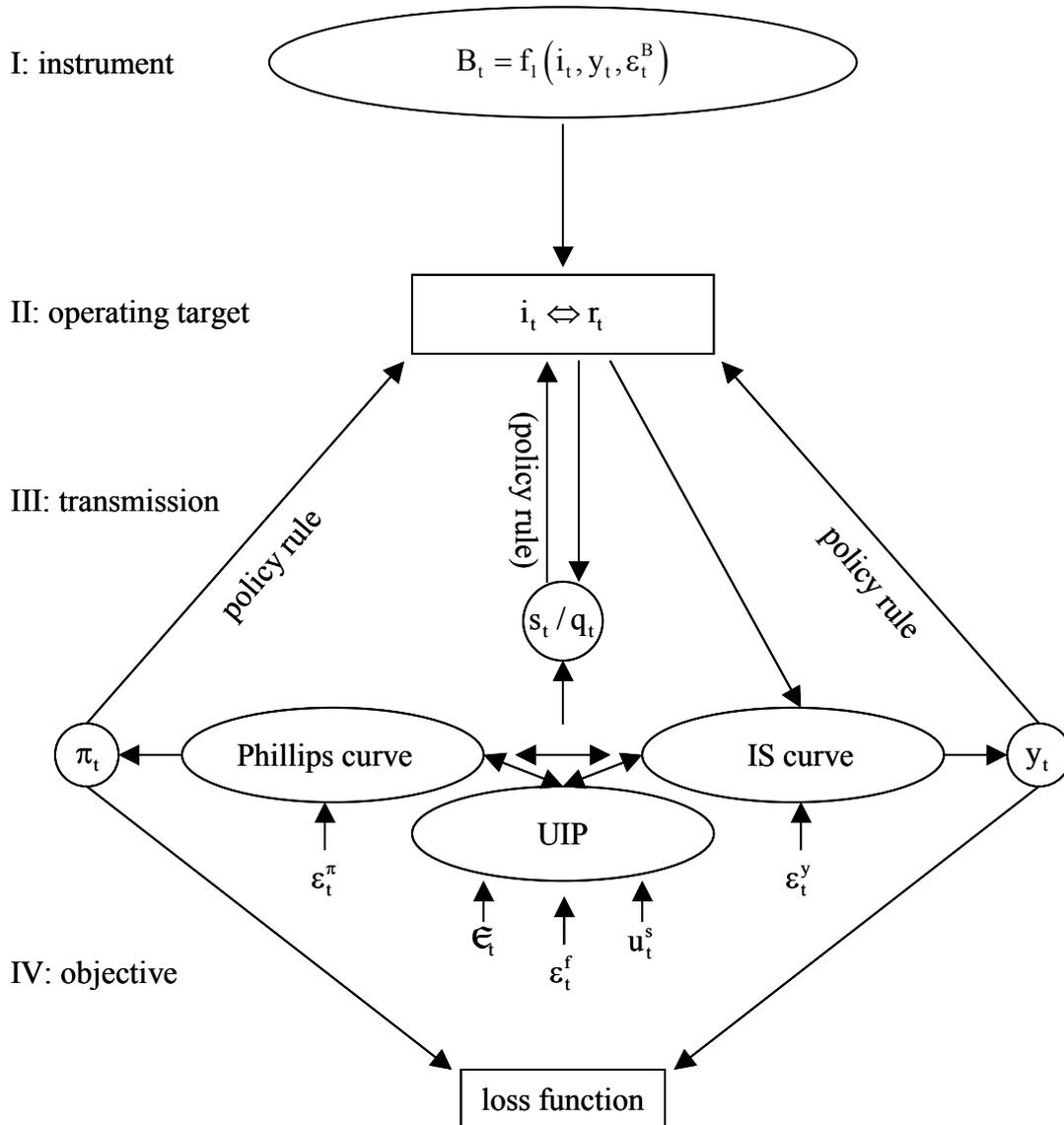
This can be reconciled with UIP if the domestic real interest rate is increased, but less than the foreign rate and if at the same time the exchange rate is depreciated. While the two components of this change of the policy mix nearly offset each other with respect to their effect on output, the real depreciation (caused by a nominal depreciation) directly leads to an increase in inflation in period 2. From this it follows that the MCI rises in period 2 in order to counteract the inflationary pressure. However this contraction in monetary policy has again almost no feedback on output, so it can be concluded that the consequences of foreign interest rate shocks can be compensated relatively well with the policy rules just described.

### V.3 Direct managed floating in comparison with independently and indirect managed floating

In the last Section we developed the theoretical framework for a strategy of direct managed floating. The crucial difference to strategies of independently floating and indirect managed floating exchange rates was the way in which the exchange rate is determined. While under independently floating and indirect managed floating the exchange rate is purely market determined, a direct managed floating central bank additionally makes use of a second policy instrument, namely sterilised foreign exchange market interventions, in order to target the path of the nominal exchange rate. Instead of being the guideline for the central bank's simultaneous targeting of the interest rate and the exchange rate (see Section V.1.3), the UIP condition becomes a basic element of the transmission process if the central bank leaves the exchange rate to the market. In Figure V.24 we summarise the basic structure of a monetary policy strategy under market determined exchange rates. The interest rate which serves as a single operating target responds to inflation and output and eventually – under indirect managed floating – to an

exchange rate term. As has been shown in Chapters III and IV, the UIP condition introduces a high degree of uncertainty for the policy maker which we modelled by expectational anomalies  $\epsilon_t$  and risk premium shocks  $u_t^s$ .

**Figure V.24: Monetary policy under market determined exchange rates**

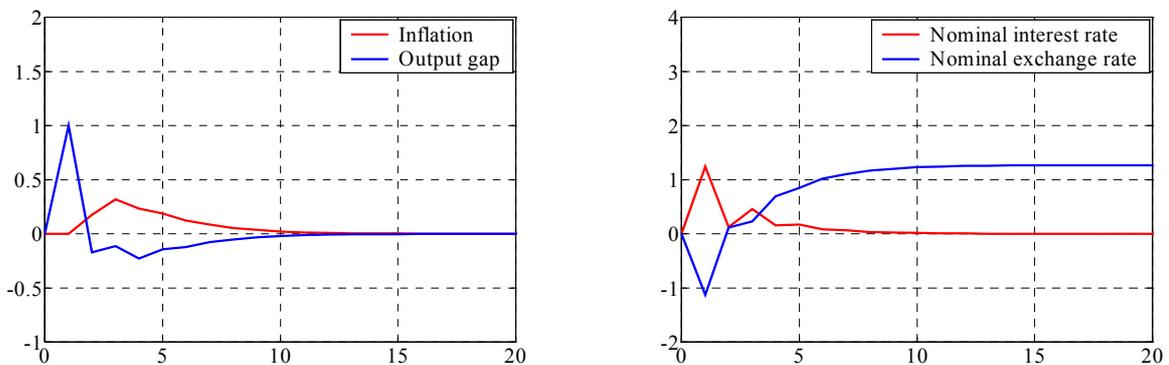


### *V.3.1 A comparison of the consequences of shocks under independently/indirect managed floating and direct managed floating*

One might be tempted to ask the difference of the monetary policy response under independently floating and indirect managed floating on the one hand and direct managed floating on the other hand. The answer crucially depends on the nature of the shocks hitting the economy. In the case of domestic demand, domestic supply and foreign interest rate shocks the dynamics of the

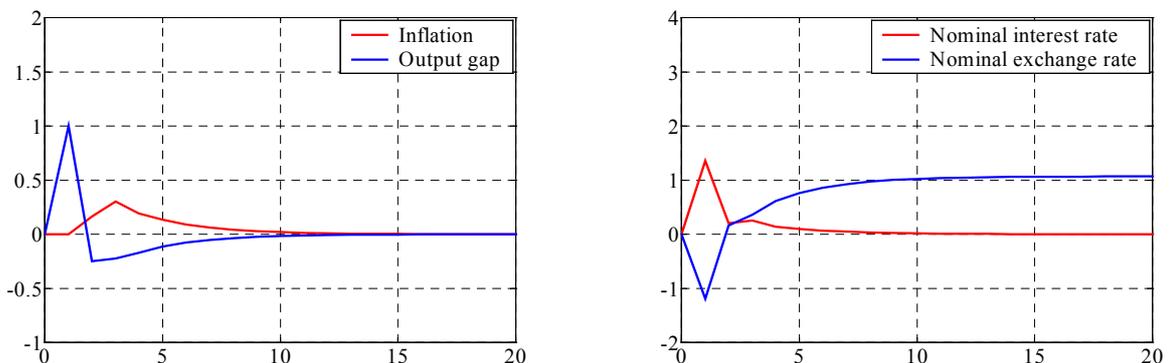
economy following the policy intervention are quite similar. This is shown in Figure V.25 to Figure V.30 which depict the impulse responses for an independently floating and an indirect managed floating central bank. The response coefficients were calculated on the basis of a constrained optimisation as described in Chapter IV. As usual, the central bank is assumed to have equal preferences towards output and inflation. Note that the coefficients of the policy rule for an independently floating central bank slightly differ from those of policy rule R1 in Chapter IV which is due to the additional foreign interest rate shock that has been set to zero in Chapter IV. By contrast, the optimal coefficients of the indirect managed floating policy rule (the structure of which corresponds to that of the robust policy rule R6) are unaffected by the inclusion of this additional shock.

**Figure V.25: Demand shock under independently floating**

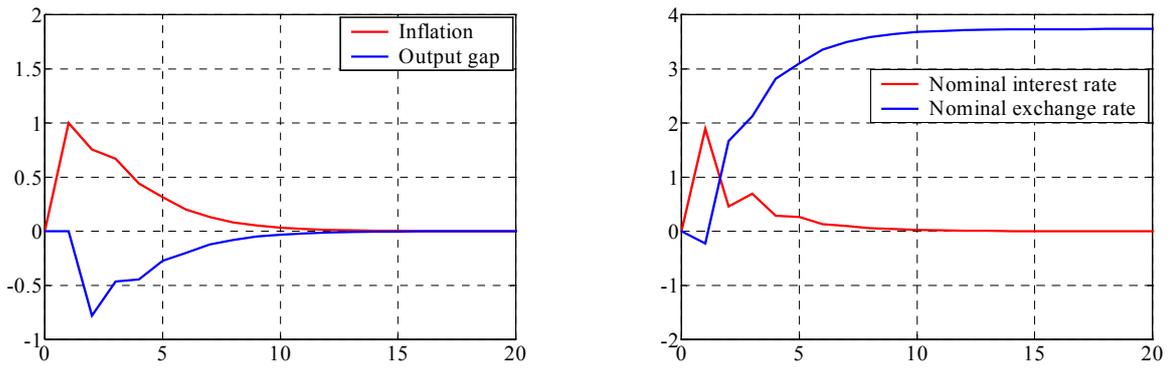


Note: The optimal independently floating policy rule is  $i_t = 1.89\pi_t + 1.24y_t$ .

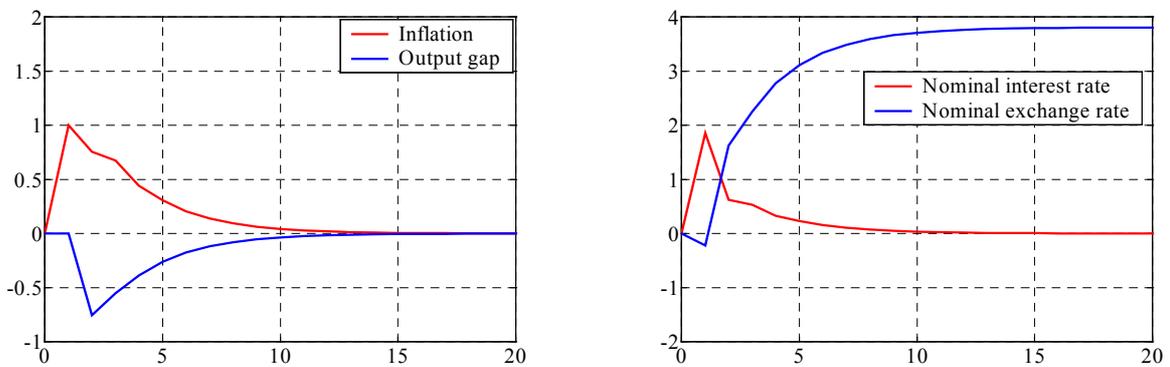
**Figure V.26: Demand shock under indirect managed floating**



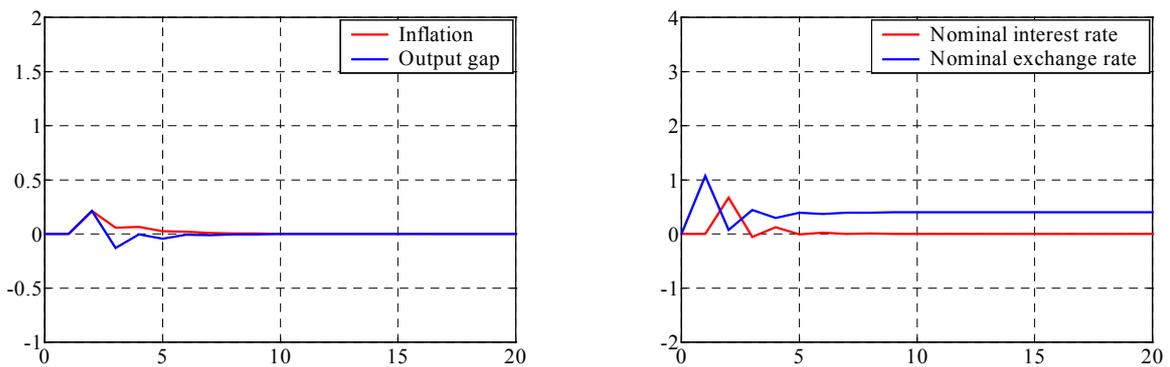
Note: The optimal indirect managed floating policy rule is  $i_t = 2.29\pi_t + 1.78y_t + 0.36q_t - 0.23q_{t-1}$ .

**Figure V.27: Supply shock under independently floating**

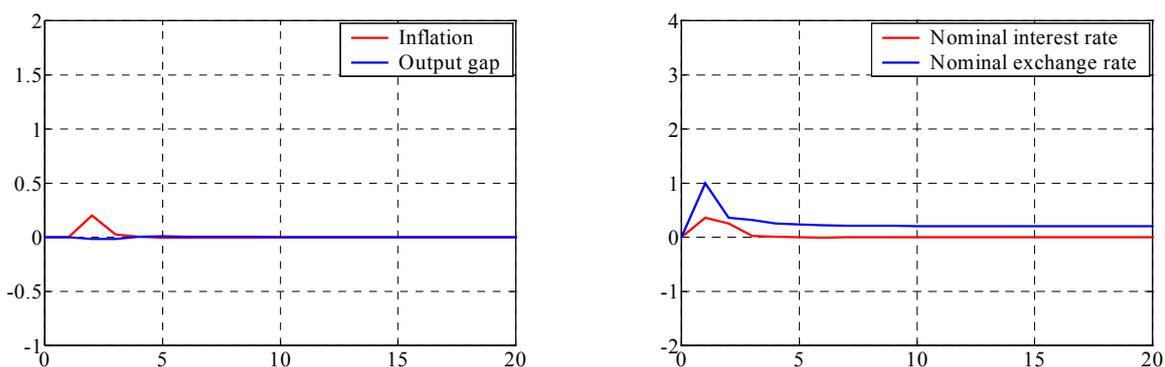
Note: The optimal independently floating policy rule is  $i_t = 1.89\pi_t + 1.24y_t$ .

**Figure V.28: Supply shock under indirect managed floating**

Note: The optimal indirect managed floating policy rule is  $i_t = 2.29\pi_t + 1.78y_t + 0.36q_t - 0.23q_{t-1}$ .

**Figure V.29: Foreign interest rate shock under independently floating**

Note: The optimal independently floating policy rule is  $i_t = 1.89\pi_t + 1.24y_t$ .

**Figure V.30: Foreign interest rate shock under indirect managed floating**

Note: The optimal indirect managed floating policy rule is  $i_t = 2.29\pi_t + 1.78y_t + 0.36q_t - 0.23q_{t-1}$ .

Since  $\varepsilon_t^y$ ,  $\varepsilon_t^\pi$  and  $\varepsilon_t^f$  are independently distributed, the interest rate path and the nominal exchange rate path perfectly fulfil the UIP condition. If there are no unexpected exchange rate movements in the form of disturbances to UIP, then the direct managed floating central bank sees no need for sterilised foreign exchange market interventions. The intervention response function given by equation (V.25) takes a value of zero. Thus, the exchange rate can be viewed as being purely market determined. From this it follows that the central bank's policy rule could be equally expressed as

$$(V.64) \quad r_t = 1.27\pi_t + 1.34y_t + 0.14q_t$$

or

$$(V.65) \quad i_t = 1.91\pi_t + 1.69y_t + 0.26\Delta s_t$$

which results from solving the real/nominal MCI policy rule given by equation (V.62) for the interest rate. It is obvious that these two policy rules are quite similar in their structure to the indirect managed floating policy rules R2 and R5 in Chapter IV.

The difference between direct managed floating and independently/indirect managed floating basically appears in the case of UIP shocks. While the direct managed floating central bank absorbs these shocks with its foreign exchange market policy instruments, the independently/indirect managed floating central bank implicitly/explicitly reacts to the resulting exchange rate movements with its interest rates. From Chapter IV we know that not only the fact that UIP disturbances may occur, but particularly the high degree of uncertainty that surrounds these shocks poses a problem for the central bank. In contrast, however, to our analysis in Chapter IV

we keep the analysis simple by only considering uncertainty about the persistence of the shocks to the risk premium.

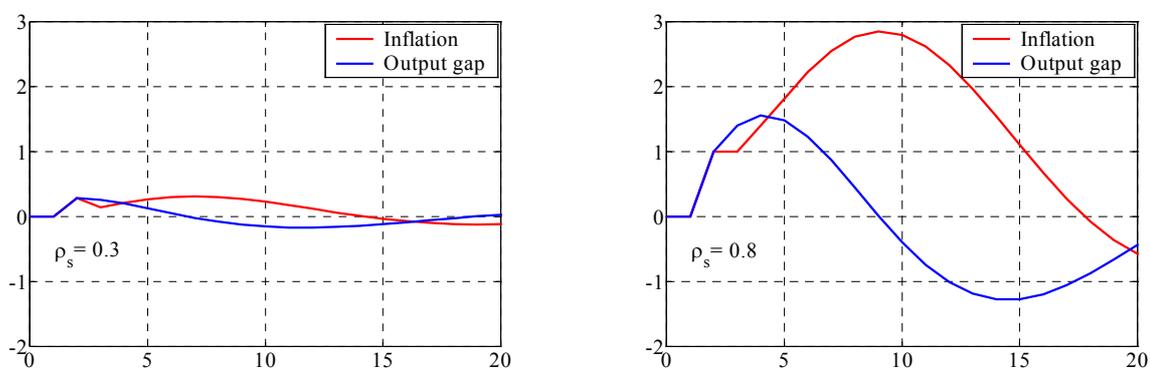
Again we assume that the central banks deems a value of  $\rho_s$  equal to 0.3 to be most likely. Thus it follows a policy rule that was optimised on the basis of this information. Uncertainty is modelled as an unexpected increase in the risk premium to 0.8. Since the direct managed floating central bank is assumed to perfectly absorb all kinds of disturbances to UIP we set the variance and the persistence of the UIP shock to zero (see Table V.10 for the parameters).

**Table V.10: UIP shock parameters under different strategies**

	direct managed floating	independently floating		indirect managed floating	
		certain	uncertain	certain	uncertain
$\text{Var}[\varepsilon_t^s]$	0	1	1	1	1
$\rho_s$	0	0.3	0.8	0.3	0.8

In a first step Figure V.31 illustrates the impact of a unit UIP shock with  $\rho_s = 0.3$  (left panel) and  $\rho_s = 0.8$  (right panel) on output and inflation under the assumption that the real interest rate remains unchanged (i.e. in the absence of any policy reaction). A positive UIP shock causes the domestic currency to depreciate, and by this stimulates output and accelerates inflation. With an increase in the risk premium the oscillations of the target variables become more pronounced.

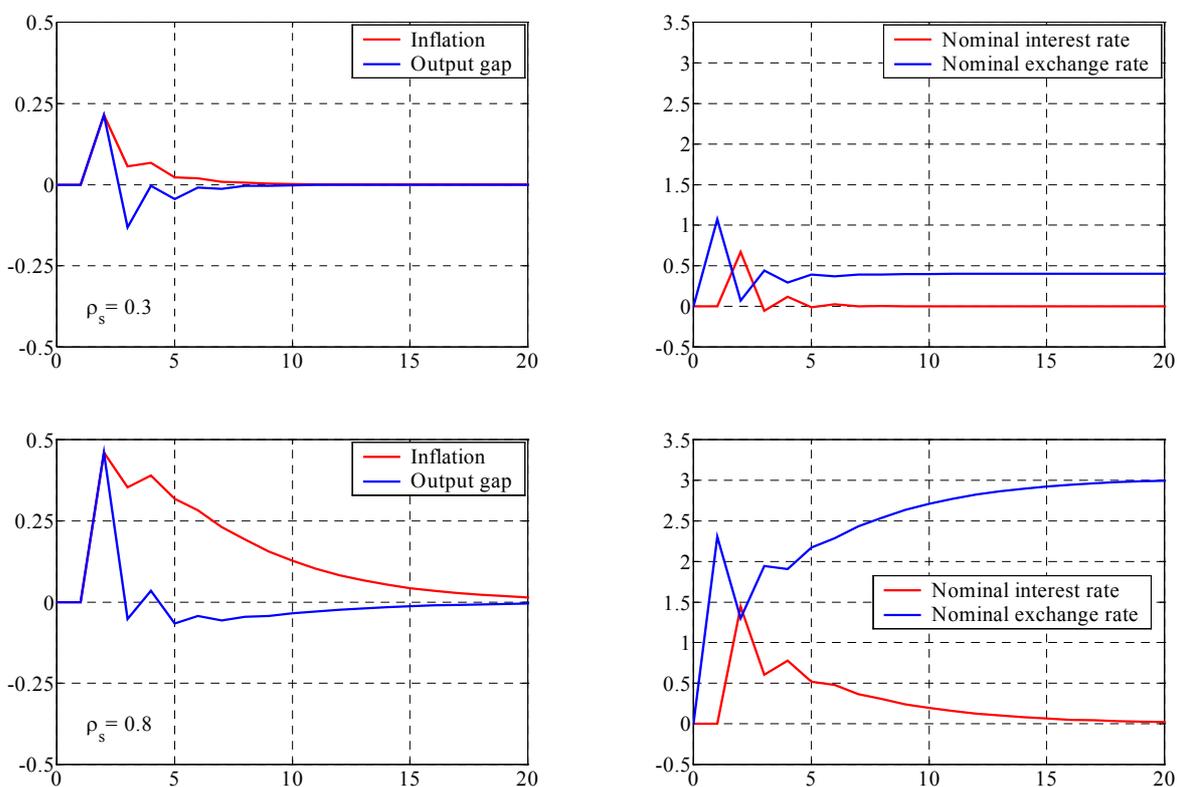
**Figure V.31: Impact of persistent UIP shocks in the absence of monetary policy**



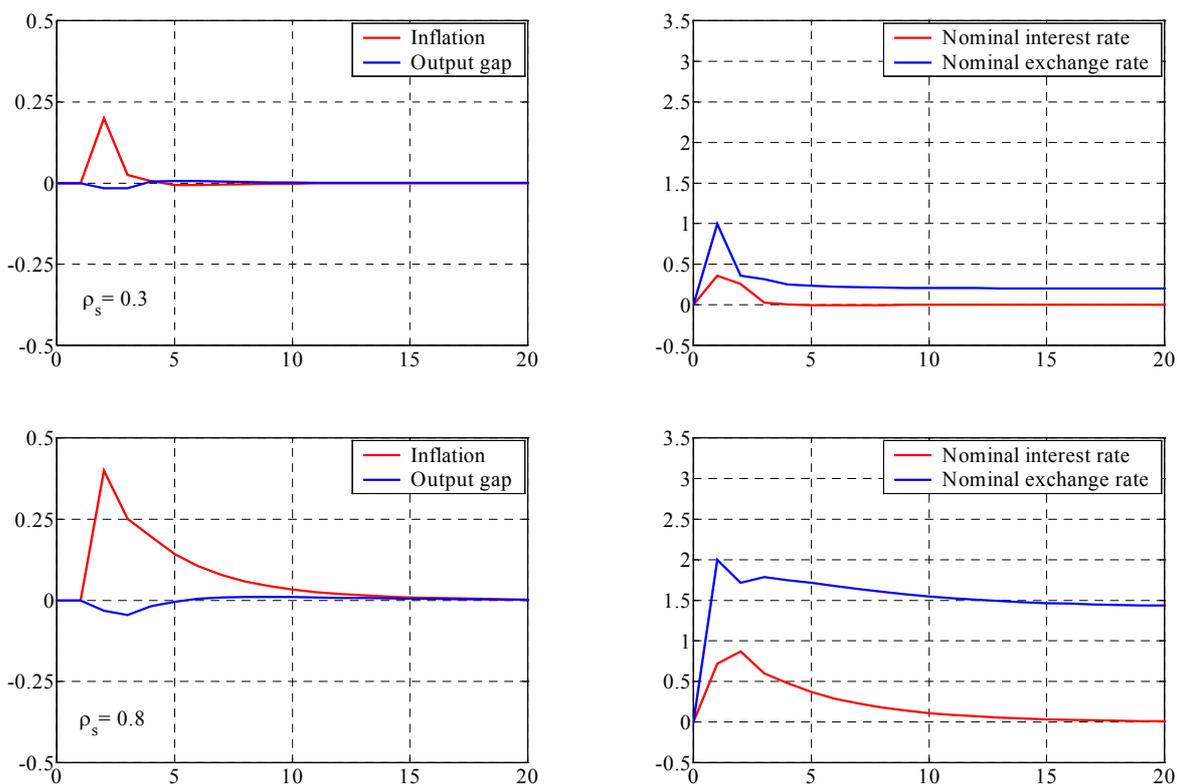
An independently floating central bank reacts to this shock by raising nominal interest rates to counteract the expansionary effects of the depreciation (see Figure V.32). The output gap is

sharply reduced to negative levels which helps to bring back inflation to its target level. The cost resulting from this shock stem primarily from a persistent deviation of inflation from its target level. The interest rate response of the indirect managed floating central bank is much less pronounced (see Figure V.33). In the case of a highly persistent UIP shock the advantage of this rule is revealed: due to the specific structure of the interest rate rule the central bank already adjusts its interest rates in period 1. Consequently, the interest rate path is more gradual (see the discussion on the relationship between interest rate smoothing and indirect managed floating in Section IV.1.4.3) and losses in terms of the output gap can be avoided almost altogether. While inflation still exceeds its target for several periods, it returns much faster compared with the situation shown in Figure V.32.

**Figure V.32: Persistent UIP shocks under independently floating**



Note: The optimal independently floating policy rule is  $i_t = 1.89\pi_t + 1.24y_t$ .

**Figure V.33: Persistent UIP shocks under indirect managed floating**

Note: The optimal indirect managed floating policy rule is  $i_t = 2.29\pi_t + 1.78y_t + 0.36q_t - 0.23q_{t-1}$ .

### ***V.3.2 A welfare comparison of independently/indirect managed floating with direct managed floating***

In the discussion of the preceding Figures an important point was made concerning the trade-off between inflation and output. While economists today widely agree upon the fact that there is no such trade-off in the long-term (see e.g. Taylor, 1998, for a recent paper), this conclusion is no more apparent in the short-term. A short look back to our Phillips curve in equation (V.44) gives a straightforward explanation: it is perfectly accelerationist. In other words there is no possibility that output can be raised permanently above its trend growth rate without accelerating rates of inflation. Thus, in the long-term the Phillips curve is vertical, though in the short-term an important trade-off exists between the variances of inflation and output leading to a ‘second order’ Phillips curve which is not vertical anymore but convex to the origin (Taylor, 1979a). In order to bring back, say, a positive inflation to its target level after a shock the central bank temporarily dampens economic activity by raising interest rates (such a situation is best illustrated in the case of a supply shock; see Figure V.20, Figure V.21, Figure V.27 and Figure V.28). Thus, it deliberately accepts an increase in the variance of the output gap in order to

reduce the variance of inflation. The central bank's concrete decision about the desired combination of inflation variance and output variance crucially depends on the relative weight the policymakers put on inflation versus output stabilisation in their intertemporal loss function. Varying the preferences from one end of the spectrum (full inflation stabilisation) to the other end (full output stabilisation) and calculating for each preference type the set of efficient combinations of inflation variance and output variance defines the so-called policy frontier.

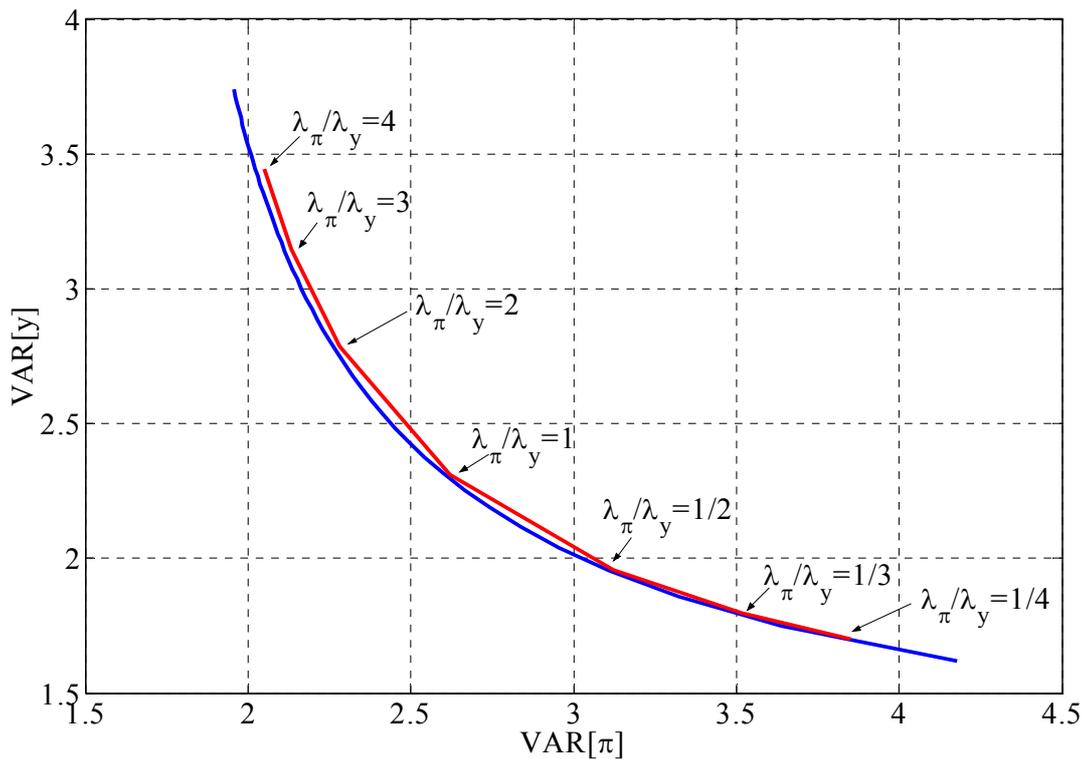
The term policy frontier already indicates that the attainable combinations are a function of the policy rule chosen by the central bank. Thus, in order to compare the performance of several classes of policy rules, we computed the policy frontier for each policy rule by tracing out the minimum weighted unconditional variances at different relative preferences for inflation versus output gap variance. Technically speaking, for each of the simple policy rules we performed the following optimisation

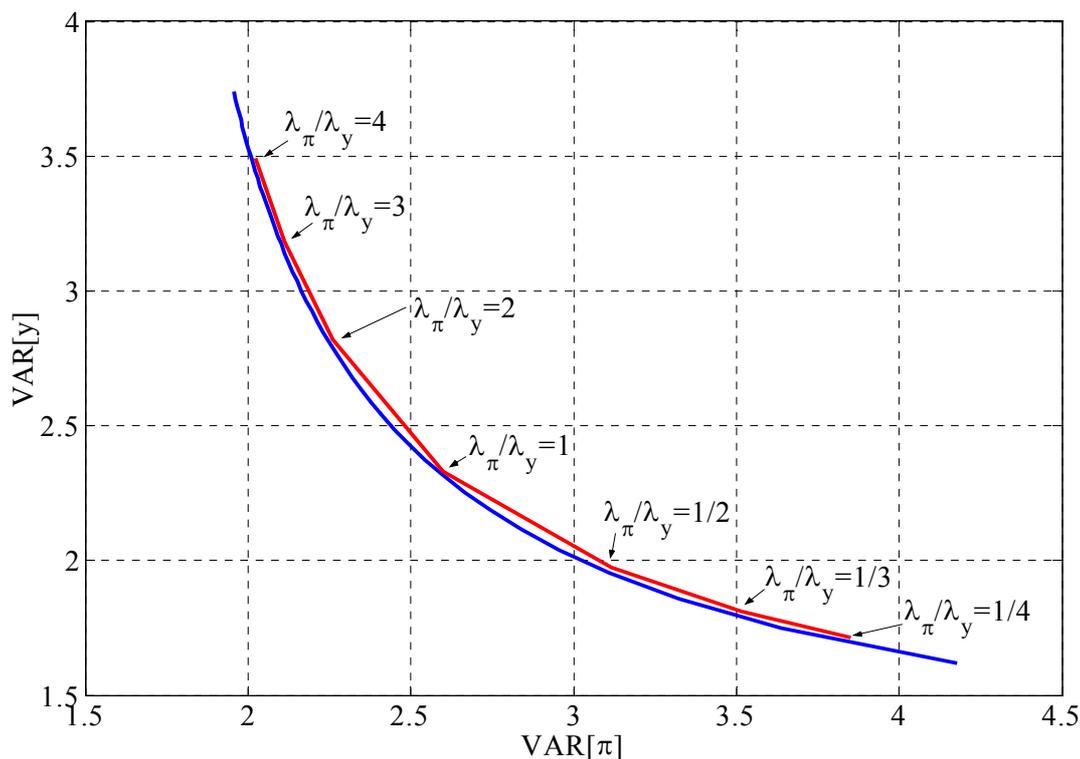
$$(V.66) \quad \min_{\langle F^s \rangle} J_0 = \min_{\langle F^s \rangle} \{ \lambda_\pi \text{Var}[\pi_t] + \lambda_y \text{Var}[y_t] \}$$

with  $\lambda_\pi/\lambda_y \in \{1/4, 1/3, 1/2, 1, 2, 3, 4\}$ .  $F^s$  is the vector containing the coefficients of the policy rules for the real and the nominal MCI. The optimised parameters of the two policy rules are summarised in Table V.11. The red line in Figure V.34/Figure V.35 shows the trade-off between the variance of inflation and output resulting from the real/nominal MCI policy rule. By construction, at points on the policy frontier, it is not possible to reduce the variance of inflation without increasing the variance of the output gap. Thus, for a given structure of the policy rule the frontier represents an efficiency locus. The blue line represents the unrestricted optimal policy frontier calculated on the basis of an optimisation under commitment over a grid for  $\lambda_\pi/\lambda_y$  from 0.2 to 5 in increments of 0.1. By definition the policymakers cannot attain any combination that is closer to the origin than the blue line. The proximity of the red direct managed floating frontiers to the blue baseline frontier confirms the results shown in the last column of Table V.7 and Table V.8 according to which the loss produced by the MCI rules only slightly exceeds the loss resulting from optimal unrestricted policy under commitment. Moreover, the Figures show that the nominal MCI rule seems to be preferable in the case of a high preference for inflation stability whereas the opposite applies to the real MCI rule. The improvement, however, is rather small.

**Table V.11: MCI policy rules**

$\lambda_\pi/\lambda_y$	real MCI			nominal MCI		
	$\psi$	$f_\pi$	$f_y$	$\psi$	$f_\pi$	$f_y$
4	0.09	2.01	1.46	0.37	2.77	2.06
3	0.10	1.84	1.43	0.35	2.56	1.98
2	0.12	1.62	1.40	0.31	2.29	1.85
1	0.14	1.27	1.34	0.26	1.91	1.69
1/2	0.16	0.98	1.30	0.22	1.61	1.56
1/3	0.17	0.83	1.27	0.20	1.47	1.49
1/4	0.17	0.73	1.24	0.19	1.39	1.46

**Figure V.34: Policy frontiers under direct managed floating (real MCI)**

**Figure V.35: Policy frontiers under direct managed floating (nominal MCI)**

To make a comparison with the attainable trade-off under independently/indirect managed floating exchange rates we optimised the interest rate rules for different pairs of preference parameters under the assumption that the policymakers are certain about the statistical properties of UIP shocks (i.e. for  $\rho_s = 0.3$ ). The resulting coefficients for the policy rules are shown in Table V.12. We then traced out the policy frontiers of the independently floating central bank (see Figure V.36) and the indirect managed floating central bank (see Figure V.37) for both the certainty and the uncertainty case. The blue line represents the frontier under direct managed floating. In accordance with the results obtained in Chapter IV the independently floating central bank that follows an exclusively domestically oriented policy rule clearly performs worse than the indirect managed floating central bank in an environment with uncertain exchange rate movements.<sup>103</sup> Compared to the strategy of direct managed floating both independently floating and indirect managed floating result in a higher variance of the goal variables – irrespective of

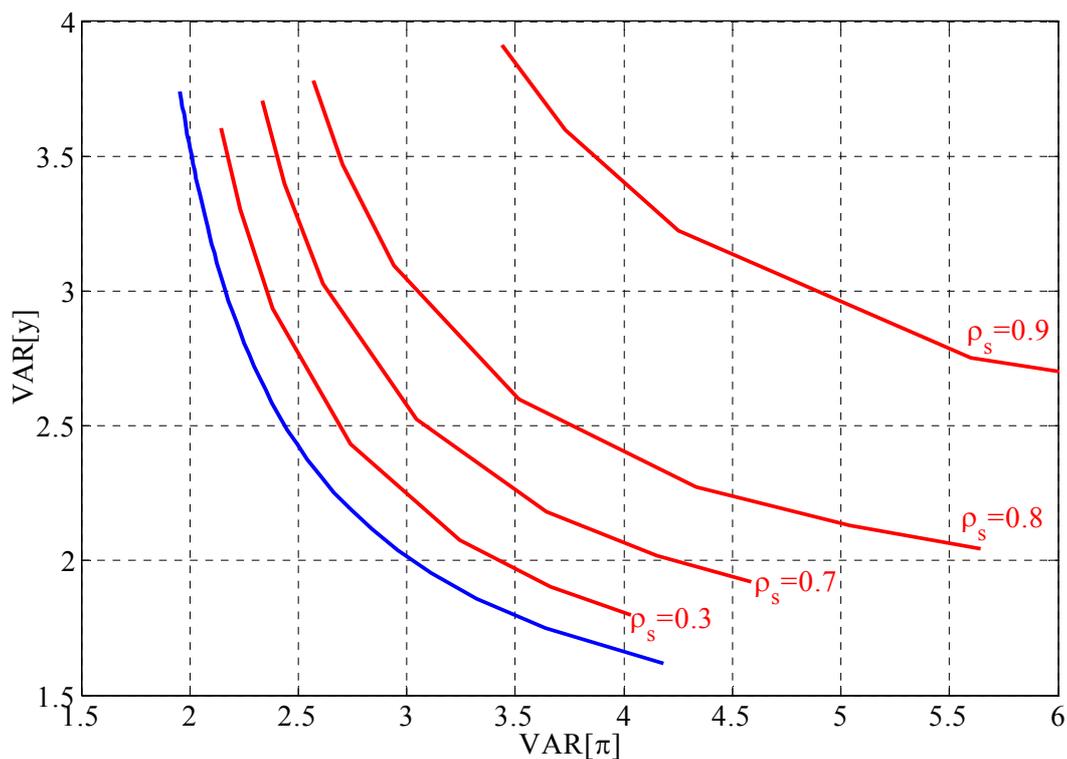
<sup>103</sup> If  $\rho_s$  takes a value of 0.9 under an independently floating central bank the variance of inflation rises up to 11.3 for  $\lambda_\pi/\lambda_y = 1/4$  while the variance of the output gap slightly falls to 2.4. We don't show that part of the policy frontier to make the results more comparable with the other strategies shown in Figure V.34, Figure V.35 and Figure V.37.

the central bank's relative preferences. It is interesting to see however that for a central bank putting a high weight on output stabilisation the benefit from intervening in the foreign exchange market decreases considerably for a indirect managed floating central bank – even in the case of a high degree of exchange rate uncertainty.

**Table V.12: Policy rules under independently floating and indirect managed floating**

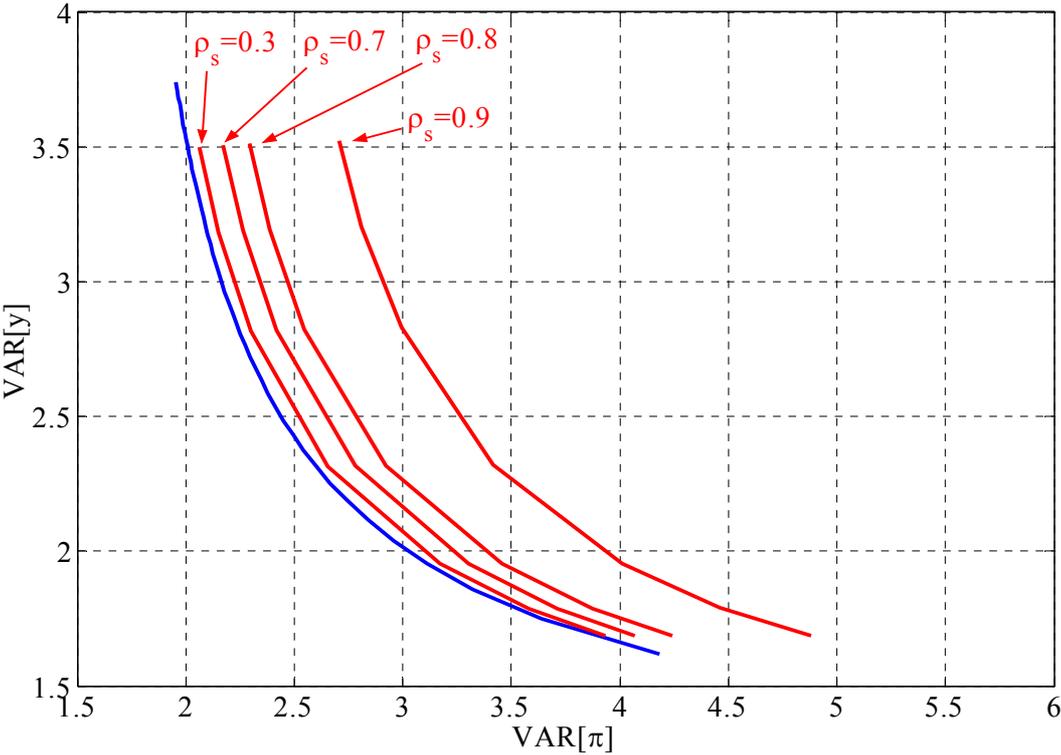
$\lambda_\pi/\lambda_y$	$i_t = f_\pi \pi_t + f_y y_t$		$i_t = f_\pi \pi_t + f_y y_t + f_q q_t + f_{q(-1)} q_{t-1}$			
	$f_\pi$	$f_y$	$f_\pi$	$f_y$	$f_q$	$f_{q(-1)}$
4	2.54	1.36	3.19	2.11	0.4	-0.38
3	2.39	1.33	2.97	2.02	0.39	-0.34
2	2.19	1.29	2.70	1.93	0.38	-0.30
1	1.89	1.24	2.29	1.78	0.36	-0.23
1/2	1.66	1.21	1.97	1.67	0.35	-0.18
1/3	1.54	1.19	1.82	1.63	0.35	-0.16
1/4	1.47	1.19	1.72	1.59	0.34	-0.14

**Figure V.36: Policy frontiers under independently floating with consideration of exchange rate uncertainty**



The costs of market determined exchange rates (either in independently floating or in indirect managed floating systems) consist in the social loss – expressed in terms of output and inflation volatility – that is caused by the unpredictability of the true relationship between interest rates and exchange rates on the international financial markets. Direct managed floating clearly provides a better outcome than purely market determined exchange rates. Of course this result only holds if foreign exchange market interventions do not cause any additional costs. But as long as the central bank implements its direct managed floating strategy according to the rules presented in Section V.1 of this Chapter (in particular the zero-cost-condition derived in Section V.1.4.2) the benefit provided by this strategy is indeed a ‘free lunch’.

**Figure V.37: Policy frontiers under indirect managed floating with consideration of exchange rate uncertainty**



## Appendix to Chapter V

### V.A State-space representation of the model with a nominal MCI as control variable

In Section V.2 we defined the nominal MCI as

$$(V.67) \quad \text{MCI}_t = i_t - \psi \Delta s_t .$$

Using the definition of the real exchange rate (see equation (V.47)) we can rewrite the MCI as follows:

$$(V.68) \quad \text{MCI}_t = i_t - \psi (q_t - q_{t-1} + \pi_t) .$$

Solving (V.68) for  $i_t$

$$(V.69) \quad i_t = \text{MCI}_t + \psi (q_t - q_{t-1} + \pi_t)$$

gives an expression containing variables (namely  $q_{t-1}$  and  $\pi_t$ ) that are not part of the original vector  $x_{t+1}$ :

$$(V.70) \quad x_{t+1} = Ax_t + Bi_t + \varepsilon_{t+1}$$

$$(V.71) \quad \begin{pmatrix} r_{t+1}^f \\ u_{t+1}^s \\ \pi_{t+1} \\ y_{t+1} \\ q_t \\ i_t \\ E_t q_{t+1} \end{pmatrix} = \begin{pmatrix} \rho_f & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \rho_s & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & \gamma_y & -\gamma_q & 0 & \gamma_q \\ 0 & 0 & \beta_i & \beta_y & 0 & 0 & \beta_q \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -\gamma_y & \gamma_q & 0 & 1-\gamma_q \end{pmatrix} \begin{pmatrix} r_t^f \\ u_t^s \\ \pi_t \\ y_t \\ q_{t-1} \\ i_{t-1} \\ q_t \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \\ -\beta_i \\ 0 \\ 1 \\ 1 \end{pmatrix} i_t + \begin{pmatrix} \varepsilon_{t+1}^f \\ \varepsilon_{t+1}^s \\ \varepsilon_{t+1}^\pi \\ \varepsilon_{t+1}^y \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Thus, we extend the system by two identities (the italicised variables and coefficients show the modification compared to (V.71)) to

$$(V.72) \quad \begin{pmatrix} r_{t+1}^f \\ u_{t+1}^s \\ \pi_{t+1} \\ y_{t+1} \\ q_t \\ i_t \\ \pi_t \\ q_{t-1} \\ E_t q_{t+1} \end{pmatrix} = \begin{pmatrix} \rho_f & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \rho_s & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & \gamma_y & -\gamma_q & 0 & 0 & 0 & \gamma_q \\ 0 & 0 & \beta_i & \beta_y & 0 & 0 & 0 & 0 & \beta_q \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -\gamma_y & \gamma_q & 0 & 0 & 0 & 1-\gamma_q \end{pmatrix} \begin{pmatrix} r_t^f \\ u_t^s \\ \pi_t \\ y_t \\ q_{t-1} \\ i_{t-1} \\ \pi_{t-1} \\ q_{t-2} \\ q_t \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \\ -\beta_i \\ 0 \\ 1 \\ 0 \\ 0 \\ 1 \end{pmatrix} i_t + \begin{pmatrix} \varepsilon_{t+1}^f \\ \varepsilon_{t+1}^s \\ \varepsilon_{t+1}^\pi \\ \varepsilon_{t+1}^y \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

that can be summarised by

$$(V.73) \quad \tilde{x}_{t+1} = \tilde{A}\tilde{x}_t + \tilde{B}i_t + \tilde{\varepsilon}_{t+1}.$$

Expressing the endogenous variables in (V.69) as a function of the state vector  $x_t$  then gives

$$(V.74) \quad i_t = MCI_t + \psi(\tilde{A}_5\tilde{x}_t - \tilde{A}_8\tilde{x}_t + \tilde{A}_7\tilde{x}_t) = MCI_t + \psi(\tilde{A}_5 - \tilde{A}_8 + \tilde{A}_7)\tilde{x}_t$$

where  $\tilde{A}_i$  is a  $1 \times n$  row vector containing the elements of the  $i$ -th row of matrix  $\tilde{A}$ . We can now rewrite the state-space representation of our economy by substituting  $i_t$  in (V.72) for (V.74):

$$(V.75) \quad \begin{aligned} \tilde{x}_{t+1} &= \tilde{A}\tilde{x}_t + \tilde{B}\left[MCI_t + \psi(\tilde{A}_5 - \tilde{A}_8 + \tilde{A}_7)\tilde{x}_t\right] + \tilde{\varepsilon}_{t+1} = \\ &= \left[\tilde{A} + \psi\tilde{B}(\tilde{A}_5 - \tilde{A}_8 + \tilde{A}_7)\right]\tilde{x}_t + \tilde{B}MCI_t + \tilde{\varepsilon}_{t+1} = \\ &= \tilde{A}^{MCI}\tilde{x}_t + \tilde{B}MCI_t + \tilde{\varepsilon}_{t+1}. \end{aligned}$$

The vector of target variables which is originally given by

$$(V.76) \quad \tilde{z}_t = \tilde{C}_x\tilde{x}_t + C_i i_t$$

becomes

$$(V.77) \quad z_t = \left[ \tilde{C}_x + \psi C_i (\tilde{A}_5 - \tilde{A}_8 + \tilde{A}_7) \right] \tilde{x}_t + C_i i_t$$

after inserting (V.74) into (V.76). Note that due to the extension of the state vector from  $x_t$  to  $\tilde{x}_t$  the matrix  $\tilde{C}_x$  has the following form:

$$(V.78) \quad \tilde{C}_x = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \end{pmatrix}.$$

## Chapter VI: Conclusion

After the experience with the currency crises of the 1990s, a broad consensus has emerged among economists that such shocks can only be avoided if countries that decided to maintain unrestricted capital mobility adopt either purely floating exchange rates or very hard pegs (currency boards, dollarisation). As a consequence of this view which has been enshrined in the so-called impossible trinity all intermediate currency regimes are regarded as inherently unstable. As far as the economic theory is concerned, this view has the attractive feature that it not only fits with the logic of traditional open economy macro models, but also that for both corner solutions (independently floating exchange rates with a domestically oriented interest rate policy; hard pegs with a completely exchange rate oriented monetary policy) solid theoretical frameworks have been developed. Above all the IMF statistics seem to confirm that intermediate regimes are indeed less and less fashionable by both industrial countries and emerging market economies. However, in the last few years an anomaly has been detected which seriously challenges this paradigm on exchange rate regimes. In their influential cross-country study, Calvo and Reinhart (2000) have shown that many of those countries which had declared themselves as ‘independent floaters’ in the IMF statistics were actually heavily reacting to exchange rate movements, either in the form of an interest rate response, or by intervening in foreign exchange markets. Thus, in most cases ‘floating’ means ‘managed floating’.

The findings of Calvo and Reinhart are, however, nothing new in the modern history of exchange rate policy. After 10 years of experience with the post-Bretton Woods floating rate system, in a study of the Bank for International Settlements, Mayer (1982) – after having diagnosed that the level of foreign exchange market interventions sometimes even dwarfed the amount of intervention that had to be undertaken under the Bretton Woods fixed rate system – came to the following conclusion: “From the point of view of pure economic theory, official intervention is of course not very attractive. It cannot be nicely fitted into models; and it means the substitution of discretion and judgement for simple and automatic formulae that appear to provide neat and simple answers to any problem. However, the case for official intervention and other exchange rate policies is purely a reflection of the imperfections and ‘messiness’ of the real world. The achievement in the main industrial countries of a more stable and predictable economic and monetary environment would certainly be a most important step towards reducing

external constraints and the need for official intervention. In the present world of the ‘second-best’, however, ‘first-best’ policies such as ‘pure’ floating may only yield ‘third-best’ results” (Mayer, 1982, p.47). At that time, the reason for the large gyrations in exchange rates was still assumed to be found in an unstable macroeconomic environment. 20 years later, however, it is fair to say that there is a consensus among economists that the causes for the puzzling exchange rate movements lie rather in behavioural anomalies of private agents who are the main participants at transactions on the international financial markets. Apart from this insight, the point made by Mayer that managed floating is incompatible with macroeconomic theory is still valid today. Given this status quo, the present study can be understood as an attempt

- to find a rationale for an interest rate response of central banks to movements in the market determined exchange rate (what we defined as indirect managed floating), and
- to include foreign exchange market interventions as an additional tool of a central bank (what we defined as direct managed floating)

on the basis of standard Neo-Keynesian open economy macro model that is widely used today for monetary policy analysis. The key ingredient for our analysis is that we allow for substantial deviations from foreign exchange market efficiency, and hence from uncovered interest parity, which is rarely questioned in standard models – despite its poor empirical evidence.

In short, we come to the following conclusions:

1. With a high degree of exchange rate uncertainty (Mayer’s world of ‘second-best’) monetary policy under independently floating exchange rates only yields ‘third-best’ results. Due to exchange rate uncertainty the exchange rate is not only treated as endogenous variable, but also as an important source of shocks, which on the one hand is likely to provoke a more activist stabilisation policy, and which on the other hand implies an uncertain transmission of interest rate impulses via the exchange rate channel of monetary policy.
2. An indirect managed floating policy rule with an interest rate response to contemporaneous and lagged movements in the real exchange rate turned out to be very robust against the high degree of exchange rate uncertainty. A robust policy rule was defined as a policy rule that performs reasonably well – in terms of the loss it produces – over a range of possible exchange rate specifications other than uncovered interest parity. Thus, under indirect managed floating the central bank takes the ‘second-best’ world (market determined exchange rates with a high degree of exchange rate uncertainty) as given and achieves the best possible (‘second-best’) results.

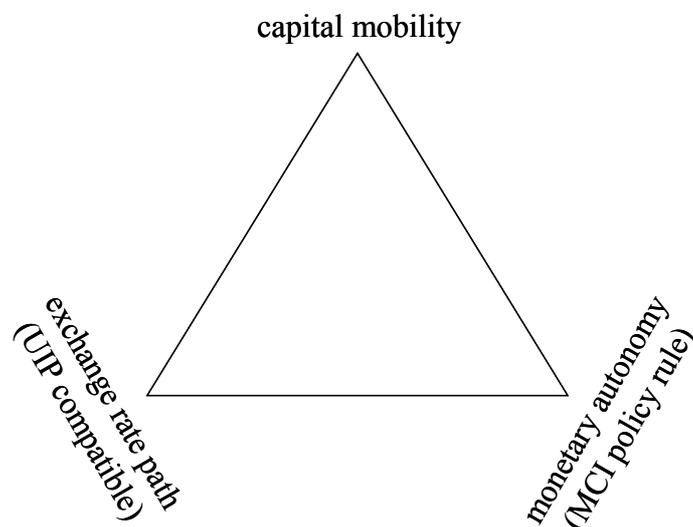
3. Direct managed floating can be understood as a strategy that aims at returning the ‘second-best’ world into a ‘first-best’ world by means of direct central bank interventions in the foreign exchange market. Interventions are triggered each time the private market deviates from uncovered interest parity so that the uncertainty about the transmission of monetary impulses via the exchange rate channel and the systematic unpredictability of exchange rate movements disappear. As, in addition to that, interventions are sterilised, the central bank retains full control of the short-term interest rate.

The third point holds an important message. In the introductory Chapter we criticised the current thinking about the choice of exchange rate regimes for being dominated by the paradigm of the impossible trinity which postulates that a country cannot simultaneously maintain exchange rate stability, monetary autonomy, and capital mobility. The major flaw of this paradigm is that it says nothing about the possibility of adopting some sort of intermediate regime: “There is nothing in existing theory, for example, that prevents a country from pursuing a managed float in which half of every fluctuation in demand for its currency is accommodated by intervention and half is allowed to be reflected in the exchange rate” (Frankel, 1999, p. 7). Our discussion has shown that the solution to the impossible trinity is not a halfway house between half-stability and half-independence. Instead, an integrated approach is required where the adequate interest rate path and the adequate exchange rate path are determined simultaneously. Thus, direct managed floating provides a solution to the impossible trinity and allows to convert it into a possible trinity with the following three corners (see Figure VI.1): capital mobility, an autonomously determined monetary conditions index and an exchange rate path which follows the interest rate differential and which can be controlled as long as the reserves are above a critical level. Above all, direct managed floating provides a comprehensive solution to the problem of capital inflows which many economists regard as an inherent flaw of intermediate regimes.

Even though indirect managed floating and direct managed floating seem to be fundamentally different intermediate exchange rate regimes – at least concerning the role of the exchange rate – in practical monetary policy, this distinction is often blurred. Central banks do not only follow one or the other strategy, but most times a mixture of both. This is in particular evident from the very simple fact that following an MCI rule without foreign exchange market interventions is similar – from a point of view of control theory – to following an interest rate rule with a feedback from some measure of the exchange rate. As has been shown by the intervention-response function, the additional policy tool of sterilised foreign exchange market interventions

is only used under specific circumstances. If the market correctly determines the current exchange rate, direct managed floating is almost identical with indirect managed floating.

**Figure VI.1: The possible trinity**



It should be clear, however, that direct managed floating is not a panacea. The most serious flaw of this strategy is the asymmetric control over the exchange rate: a central bank's ability to avoid an unwanted depreciation is limited by the stock of its exchange reserves (and the availability of balance of payments credits). Thus, a central bank could always be confronted with a situation of a major crisis of confidence which forces it to accept a depreciation that exceeds its exchange rate target path by far. An example for such a crisis is the depreciation of the Indonesian rupiah in the course of the Asian crisis from 2 500 rupiah per US dollar in July 1997 to over 15 000 rupiah per US dollar in mid-July 1998. To defend its currency, the Bank of Indonesia sold 5 billions of US dollars within a few months. In the more recent past, Uruguay had to give up its direct managed float because of very strong capital outflows which were triggered by severe financial spillovers following the collapse of the Argentine currency board. Between March 2002 and September 2002 the Uruguayan peso depreciated by almost 100 % (from 15 to 29 peso per US dollar), and the Banco Central del Uruguay sold 80 % of its foreign reserves in an attempt to stop the fall of the currency.

If a country loses control over the exchange rate, it has to rely its monetary policy implementation exclusively on the setting of the nominal interest rate, and thus falls back on an indirect managed float. In order to maintain a given degree of monetary restriction, this would

require a very strong increase in the interest rate. As the MCI is constructed under the assumption of a perfect substitutability of the interest rate and the exchange rate lever, such a policy switch would not be problematic. In reality, this substitutability is questionable, above all if the required degree of substitution is very high. While the exchange rate mainly affects the international sector of the economy (exporters and import substitution), the interest rate affects the whole economy. A policy shift leading to a strong real depreciation and a very high real interest rates implies an extremely restrictive impulse for the domestic sectors of the economy (the banking system because of its maturity transformation, the services and the construction sector, and the government which is often heavily indebted and often also in a foreign currency). As the Asian crisis has shown, such an overly restrictive effect on the domestic sectors of the economy can transform a currency crisis into a financial sector crisis.

Thus, under direct managed floating countries remain vulnerable to crises of confidence which can be generated simply by contagion effects. Some IMF credit facilities (the Supplemental Reserve Facility and – as a precautionary device – the Contingent Credit Line) provide countries with financial resources that are not subject to the usual limits but are based on the actual financing needs. However, a surcharge of 300 up to 500 basis points is applied for such funds and the member country has to repay these credits within 2 ½ years at the very latest. Given the rather strict eligibility criteria for the Contingent Credit Line (CCL)<sup>104</sup> one could ask whether countries that are qualified for CCL could be completely or partially dispensed from the repayment of such credits if a clear contagion effect can be diagnosed.

The asymmetry problem of direct managed floating was also addressed in Bofinger and Wollmershäuser (2002). In this paper, we discuss the compatibility of direct managed floating with the institutional framework of the Exchange Rate Mechanism II (ERM II), which is currently regarded as the adequate framework for the path towards membership in the European Monetary Union (EMU). While some of the constituent elements of the ERM II are well suited for a policy of direct managed floating (in particular, the wide bands around the central rates that provide much flexibility, and the requirement that parity changes have to be mutually agreed, thereby preventing that competitive devaluations take place), the rules for intramarginal

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<sup>104</sup> See IMF (2000, p. 67): “(...) the eligibility criteria confine potential candidates for a CCL to those members implementing policies considered unlikely to give rise to a need to use IMF resources; whose economic performance – and progress in adhering to relevant internationally accepted standards – has been assessed positively by the IMF in the latest Article IV consultation and thereafter; and which have constructive relations with private sector creditors with a view to facilitating appropriate private sector involvement.”

interventions, the financing of interventions through provision of credit facilities and the design of the exit option provide relatively little support for a policy of direct managed floating vis-à-vis the euro. While the ‘very short-term financing facility’ (VSTF) is “in principle automatically available and unlimited in amount” in the case of marginal interventions (see Article 7 of the ERM II agreement<sup>105</sup>), it can also be used for intramarginal interventions, but it requires an agreement of the ECB, and the cumulative amount made available for such interventions is limited to a ceiling, which is laid down for each ERM II member country. In addition, it is expected that the debtor central bank makes “appropriate use” of its own reserves (Article 8 of the agreement). It is obvious that for a strategy of direct managed floating which is institutionally embedded in a  $\pm 15\%$  exchange rate band, intramarginal interventions are much more important than interventions at the margins. Under an effective exchange rate management, the latter should only provide a safety net. We therefore suggested some modifications for the ERM II rules, in particular the automatic access of ERM II members to the VSTF in the case of intramarginal interventions and an enhancement of the credit ceilings, which would make the scheme equally attractive for the accession countries and the present EMU members.

An interesting additional application of direct managed floating emerged in recent years with Japanese monetary policy being trapped at the zero lower interest rate bound since the mid 1990s. As has been argued in Chapters IV and V, both operating targets, the nominal interest rate and the nominal exchange rate, are subject to an important asymmetry. On the one hand, the nominal interest rate cannot fall below zero. Thus, central banks having the interest rate as operating target run the risk of not being able to guarantee the adequate degree of monetary expansion with the interest rate. On the other hand, interventions in the foreign exchange market aimed at appreciating the domestic currency (halting a depreciation of the domestic currency) are limited by the stock of foreign reserves. Thus, central banks having the exchange rate as operating target run the risk of not being able to guarantee the adequate degree of monetary contraction with the exchange rate. Since the conduct of monetary policy with a single operating target is therefore always constrained in one or the other direction, the combined use of both operating targets, the interest rate and the exchange rate, is complementary so that the central bank is neither constrained on the contractionary side, nor on the expansive side. McCallum

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<sup>105</sup> Agreement of 1 September 1998 between the European Central Bank and the national central banks of the Member States outside the euro area laying down the operation procedures for an exchange rate mechanism in stage three of Economic and Monetary Union, see Official Journal of the European Communities C 345, 13.11.1998, pp. 6.

(2000, 2001), for example, recommends switching to the nominal exchange rate as policy instrument whenever the economy is stuck at the zero bound. In particular, he assumes the exchange rate to be controllable via the portfolio-balance channel. In the case of a deflation and recession, the central bank stands ready to buy foreign currency which results in a depreciation of the domestic currency, and hence in a stabilisation of the economy.

An interesting area for future work on direct managed floating would be to conduct the analysis on the level of the instruments, namely base money and net foreign assets. Instead of implicitly assuming the operating targets to be controllable by the central bank (within the limits just mentioned), policy rules could be formulated in terms of the instruments. A first attempt in this direction has been recently presented by Coenen and Wieland (2002b) who endogenise both, the nominal interest rate and the risk premium. The latter is assumed to be controllable by the central bank through changes in the amount of outstanding domestic government debt of which domestic base money is an important component. Thus, by controlling the risk premium with changes in domestic base money, interventions are modelled to be non-sterilised, and the underlying strategy is in fact an indirect managed float.

On the empirical side, further research is required to adequately take into account the simultaneous use of the interest rate and the exchange rate as operating target under a direct managed float. One strand of the empirical literature concentrates on the interest rate as operating target of monetary policy and examines the impact of interest rate shocks on macroeconomic variables (like output, inflation, and the exchange rate) or tries to find out to which variables the monetary authority reacts (see our short survey in Section I.2.3). Another strand of the literature investigates the effects of sterilised interventions on the exchange rate in isolation from any macro model (see our survey in Section V.1.2). As one of the first studies attempting to combine both instruments, Kim (2003) presents a unifying framework based on a structural VAR model in which he jointly analyses the effects of sterilised foreign exchange market interventions and interest rate setting policies. He comes to the result that “modeling foreign exchange policy explicitly seems to be crucial for the studies on monetary policy and exchange rate behaviors” (Kim, 2003, p. 357). As his analysis focused on the monetary-exchange rate policy of the Federal Reserve which is one of the least interventionist central banks of the world, it would certainly be interesting to apply his approach to central banks that are much more engaged in the foreign exchange market.

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## LEBENS LAUF

### Timo Wollmershäuser

- Nationalität: deutsch
  - Geburtstag und -ort: 28. April 1972 in Rothenburg ob der Tauber
  - Familienstand: ledig
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- 1991: Abitur am Reichsstädtgymnasium Rothenburg
- Okt.'92 - Sept.'93: Studium der Physik an der Universität Würzburg (abgebrochen)
- Okt.'93 - Sept.'94: Studium des Wirtschaftsingenieurwesens an der TU Karlsruhe
- Okt.'94 - Juli '96: Studium der Volkswirtschaftslehre an der Universität Würzburg
- Aug.'96 - Aug.'97: Auslandsstudium an der Universität Paris I (Panthéon-Sorbonne)  
Abschluss: Diplôme d'Université in einem Europa-Studiengang mit dem Schwerpunkt Ökonomie
- Sept.'97 – Nov.'99: Fortsetzung des Studiums der Volkswirtschaftslehre an der Universität Würzburg  
Abschluss: Diplom-Volkswirt
- Dez. '99 – Juni '03: wissenschaftlicher Mitarbeiter am Lehrstuhl von Prof. Dr. Peter Bofinger, Universität Würzburg
- seit Juli '03: wissenschaftlicher Mitarbeiter am ifo Institut für Wirtschaftsforschung, Abteilung Konjunktur und Finanzmärkte