Essays in Industrial Organization: Intermediation, Marketing, and Strategic Pricing

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Zusammenfassung

Die vorliegende Dissertation beschäftigt sich mit ausgewählten Unternehmensstrategien, die insbesondere mit der Entwicklung neuer Informationstechnologien verbreitet Anwendung finden.

In der Einleitung wird die Motivation dargelegt und kurz auf Definitionsmöglichkeiten des Begriffs "zweiseitiger Markt" eingegangen sowie eine knappe Zusammenfassung der nachfolgenden Essays gegeben.

Der erste Essay beschäftigt sich mit dem Einfluss von Produktinformationen auf die Preis- und Werbeentscheidung des Anbieters eines Erfahrungsgutes dessen Qualität potenzielle Käufer vor dem Kauf nicht kennen. In zwei Modellen, welche sich insbesondere in der vorherrschenden Rolle von Werbung unterscheiden, wird analysiert, wie sich die Verfügbarkeit von zusätzlichen Informationen, welche allerdings möglicherweise irreführend sein können, auf die von der tatsächlichen Produktqualität abhängige Preissetzung und Werbeinvestition auswirkt.

Im ersten Modell, in welchem unterstellt wird, dass sowohl Werbung als auch andere Produktinformationen auf die Existenz von Produkten aufmerksam machen, stellt sich heraus, dass der vom Anbieter gewählte Preis positiv mit der tatsächlichen Qualität zusammenhängt, allerdings unter gewissen Umständen ein Anbieter eines Produkts niedriger Qualität profitabel einen hohen Preis setzen kann. Der Zusammenhang zwischen Produktqualität und Werbung hängt von der vorliegenden Parameterkonstellation ab.

Im zweiten Modell wird – anders als zuvor – angenommen, dass die Preissetzungsentscheidung indirekt Informationen bzgl. der Produktqualität vermitteln kann, d.h. einige Konsumenten den Preis als Signal interpretieren, während andere Konsumenten ihre Einschätzung über Produktqualität direkt aus evtl. verfügbaren anderen Informationen beziehen. Einerseits ergibt sich unter bestimmten Umständen das aus der Signalisierungsliteratur bekannte Ergebnis, dass sich trotz asym-

metrischer Information dieselben Preise wie unter vollständiger Information einstellen können. Andererseits zeigt sich, dass sich bei möglicherweise irreführender Produktinformation weitere Preissetzungsmuster ergeben können. Darüber hinaus wird unterstellt, dass Unternehmen durch unbeobachtbare Marketinginvestitionen Einfluss auf Produktinformationen nehmen können, was im Extremfall dazu führen kann, dass ein hoher Preis niedrige Produktqualität signalisiert, wobei bei diesem Preis nur ein Teil der Konsumenten einen Kauf in Betracht zieht.

Im zweiten Essay werden Handelsplattformen untersucht, welche die spezielle Eigenschaft haben, dass deren Betreiber nicht nur Verkäufern die Möglichkeit einräumen, Käufern über die Plattform Produkte anzubieten, sondern auch selbst Produkte als Händler vertreiben können. Es wird zunächst aufgezeigt, dass im unterstellten Rahmen unter den bisher von der Literatur schwerpunktmäßig behandelten klassischen zweistufigen Tarifen das Problem besteht, dass der drohende Wettbewerb zwischen Plattformbetreiber und Verkäufern die Plattform unattraktiv macht. Produkte, auf die der Plattformbetreiber erst durch Beitritt von anderen Verkäufern aufmerksam wird, werden somit möglicherweise nicht angeboten, da sich zu wenige Verkäufer der Plattform anschließen. Es wird jedoch aufgezeigt, dass umsatzabhängige Gebühren dazu führen, dass der Plattformbetreiber seltener in Wettbewerb mit Händlern tritt, und deren Einsatz daher profitabel sein kann. Dies liefert eine neue Erklärung dafür, warum insbesondere Handelsplattformen tatsächlich umsatzabhängige Gebühren verlangen.

Der dritte Essay beschäftigt sich wiederum mit Handelsplattformen, betont aber, dass Verkäufer parallel auch weitere Vertriebskanäle nutzen können. Nachdem im gegebenen Rahmen mögliche Ursachen dafür aufgezeigt wurden, dass Verkäufer in verschiedenen Vertriebskanälen unterschiedliche Preise setzen, wird die Tarifentscheidung des Plattformbetreibers und deren Einfluss auf die Nutzung der verschiedenen Vertriebswege untersucht. Insbesondere wird die Wirkung von sog. Nichtdiskriminierungsregeln analysiert, welche in der Realität zu beobachten, aber wettbewerbspolitisch umstritten sind. Es wird identifiziert, unter welchen Umständen der Plattformbetreiber die Preissetzung von Verkäufern mit einer solchen Regel einschränkt, welche ihm insbesondere erlaubt, die Nutzung der verschiedenen Vertriebswege direkt zu kontrollieren. Darüber hinaus wird gezeigt, dass diese Regeln im gegebenen Rahmen sowohl positive als auch negative Folgen haben können.

Summary

This dissertation deals with certain business strategies that have become particularly relevant with the spread and development of new information technologies.

The introduction explains the motivation, discusses different ways of defining the term "two-sided market", and briefly summarizes the subsequent essays.

The first essay examines the effects of product information on the pricing and advertising decision of a seller who offers an experience good whose quality is unknown to consumers prior to purchase. It comprises of two theoretical models which differ with respect to their view on advertising. The analysis addresses the question how the availability of additional, potentially misleading information affects the seller's quality-dependent pricing and advertising decision.

In the first model, in which both advertising and product reviews make consumers aware about product existence, the seller's optimal price turns out to be increasing in product quality. However, under certain circumstances, also the seller of a low-quality product prefers setting a high price. Within the given framework, the relationship between product quality and advertising depends on the particular parameter constellation.

In the second model, some consumers are assumed to interpret price as a signal of quality, while others rely on information provided by product reviews. Consequently, and differently from the first part, pricing may indirectly inform consumers about product quality. On the one hand, in spite of asymmetric information on product quality, equilibria exist that feature full information pricing, which is in line with previous results presented by the signaling literature. On the other hand, potentially misleading product reviews may rationalize further pricing patterns. Moreover, assuming that firms can manipulate product reviews by investing in concealed marketing, equilibria can arise in which a high price signals low product quality. However, in these extreme cases, only a few (credulous) consumers consider buying the product.

The second essay deals with trade platforms whose operators not only allow sellers to offer their products to consumers, but also offer products themselves. In this context, the platform operator faces a hold-up problem if he sets classical two-part tariffs (on which previous literature on two-sided markets focussed) as potential competition between the platform operator and sellers reduces platform attractiveness. Since some sellers refuse to join the platform, products whose existence is not known to the platform operator in the first place and which can only be established by better informed sellers may not be offered at all. However, revenue-based fees lower the platform operator's incentives to compete with sellers, increasing platform attractiveness. Therefore, charging such proportional fees can be profitable, what may explain why several trade platforms indeed do charge proportional fees.

The third essay examines settings in which sellers can be active both on an intermediary's trade platform and in other sales channels. It explores the sellers' incentives to set different prices across sales channels within the given setup. Afterwards, it analyzes the intermediary's tariff decision, taking into account the implications on consumers' choice between different sales channels. The analysis particularly focusses on the effects of a no-discrimination rule which several intermediaries impose, but which appears to be controversial from a competition policy view. It identifies under which circumstances the intermediary prefers restricting sellers' pricing decisions by imposing a no-discrimination rule, attaining direct control over the split-up of customers on sales channels. Moreover, it illustrates that such rules can have both positive and negative effects on welfare within the given framework.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Research in industrial organization has a long history.[1] Especially with the increased use of formal game-theoretic concepts, a great variety of substantial insights on market forces and effects of market imperfections such as asymmetric information have been established by theoretical research.

As this research has derived many important policy implications, it has significantly impacted policy making. Furthermore, as parts of the research in industrial organization also offer remarkable management implications, intersecting with research in marketing and management science, it may also have directly affected firm behavior. Consequently, the evolutions of competition policy, market conduct, and research in industrial organization are interdependent. Moreover, within a changing environment, firms are likely to develop new strategies, adapting their behavior, which challenges both practitioners and researchers.

One of the central developments during the last decades is the spread of new information technologies. This technological change opens up new trade opportunities, facilitating e-commerce which has already taken a considerable share of (retail) sales.[2] Moreover, the spread of the Internet and related technologies also affects traditional markets, firstly by introducing a new level of competition, and secondly by

[1]For a comprehensive survey on the development of industrial organization and its roots, cf. e.g. De Jong and Shepherd (2007).

[2]Referring to turnover (i.e., total revenues due to sales of goods and services), Eurostat (2012, p. 351) reports that "e-commerce accounted for around 14% of turnover among enterprises with at least ten persons employed in the EU-27 [...] in 2009". Focussing on the demand side, Statistisches Bundesamt (2012a) indicates that 74% of the German Internet users bought or ordered products or services online in 2012.

providing consumers more detailed information on product attributes, prices, or alternative offers. These changes in both market and information structure gradually translate into a change in consumers' and firms' behavior.

Although some business practices and behavioral patterns that evolve within the changing environment can be assessed by reinterpreting existing results, applicability of theoretical models that are fitted to established market structures, imposing certain assumptions on the informational structure and focussing on "traditional" business models, is limited.

More specifically, while the advent of the world wide web makes information easily accessible, it may also raise credibility concerns as the identity of information providers often cannot be assessed. As most consumers have access to the Internet,[3] and a great fraction of them indeed frequently investigates product information prior to making buying decisions, consulting various online resources,[4] the technological change may result in consumers being better informed. Hence, asymmetric information problems may be less severe than before. However, consumers can also be misled by deceptive information. Hence, models that presume consumers being completely uninformed or that focus on features that perfectly inform consumers (e.g. reliable product reviews) do not match with contemporary market characteristics.

Furthermore, with the rise of new information technologies, online platforms which bring together different user groups have become popular. On the one hand, such platforms offer a new way of information transmission between users who post messages and users who read these messages, constituting one mechanism which may lead to more informed consumers. On the other hand, several platforms bring together sellers and potential buyers, constituting new sales channels (or "marketplaces") that facilitate transactions between sellers and buyers. During the past decade, several influential studies focussed on the economics of platforms, analyzing "two-sided markets". However, as many of these studies provide frameworks which are supposed to match several kinds of platforms at once, they may fail to explain the effects of certain features that are only specific to some platforms.

[3]In 2011, more than 75% of all German households had access to the Internet, cf. Statistisches Bundesamt (2012b, p. 175).

[4]83% of the respondents to a survey conducted in 2011 among German households who use the Internet claimed that they search for information on products and services on the Internet, cf. Statistisches Bundesamt (2012b, p. 205).

This dissertation takes account of a selection of the recent developments indicated above. It aims at meeting specific properties of a changed environment, matching updated market circumstances. Furthermore, it deals with strategies which evolved within this environment and whose effects have not been covered by previous research. It consists of three essays which are all based on theoretical models, analyzing the impact of certain changes or trends that have been facilitated by the spread of new information technologies. The results are particularly relevant for a better understanding of certain practices within e-commerce settings, but also have implications on traditional markets.

The first essay (chapter 2) deals with a firm's pricing and marketing decision when selling a good whose quality is unknown to consumers prior to purchase. Differently from previous studies, I assume that the firm takes into account consumers having access to noisy third-party product information (such as product reviews on the Internet) which seems realistic, given evidence on consumers frequently using such information sources and on demand indeed being sensible to this kind of information.

My analysis distinguishes between two different scenarios: in a first part, I focus on settings in which advertising predominantly informs about product existence. Third-party product information may inform consumers about both product existence and product quality, but it is assumed to be noisy, i.e., sometimes also being misleading. In absence of any price signaling considerations, prices often differ across product qualities as third-party product information induces a "segregating" effect: a firm that offers a product of high quality is likely to charge a higher price than a firm that offers a product of low quality. However, as product information can be misleading, a firm that offers a low-quality product may also prefer to charge a high price under certain circumstances. The relationship between advertising and true product quality turns out to be ambiguous.

In a second part, I consider third-party product information not only being noisy, but also being manipulable by certain investments in concealed marketing. In particular, these investments could reflect firms participating in online discussions about their products or costs of influencing third parties, leading to improved quality ratings. Furthermore, I allow for consumers who interpret prices as a signal of quality. Besides well-established pricing patterns – a high price may signal high quality with a segment of consumers who are informed about product quality – other pricing patterns can evolve, in particular if review-sensitive consumers are credulous, not being aware of the firm's manipulation decision.

In particular, both parts illustrate that results which have been gained under assumptions that meet more traditional market structures remain valid under certain circumstances, but accounting for properties of present market conditions (firms facing noisy product information) may also uncover new effects, leading to changed results.

Both the second essay (chapter 3) and the third essay (chapter 4) deal with platforms that facilitate trade between sellers and potential buyers. In general, markets in which firms serve two different groups of customers are sometimes referred to as "two-sided markets", and the firms that are active in these markets may be called "two-sided platforms". However, it is important to distinguish between settings in which firms serve different groups of customers with demand of one group being relatively independent of the demand of other groups, and settings in which firms offer products or services with demand being interdependent. While analyzing a single product or a single customer group as a separate "market" may be appropriate in the former case, analyzing groups separately is likely to result in false conclusions in the latter case.[5] In particular, Wright (2004), Schiff (2008), and King (2013) illustrate that conventional "one-sided" logic may often be misleading in presence of certain interdependencies.

Although researchers widely agree on demand interdependencies calling for special attention, there seems to be no consensus on a single definition of "two-sidedness" so far. For the case of platforms charging transaction-based fees, Rochet and Tirole (2006) characterize markets as being two-sided if the number of transactions varies with the split-up of a given aggregate fee level on customer groups. Armstrong (2006) focusses on the presence of network effects or cross-group externalities under which the number of a firm's customers from one group affects the utility that customers from the other group receive from using the platform.

Without giving a clear-cut definition, but having in mind existence of interdependencies or externalities between groups, Rysman (2009, p. 127) argues that "[t]he interesting question is often not whether a market can be defined as two-sided

[5] Products or customer groups might also be linked by cost interdependencies.

[...] but how important two-sided issues are in determining outcomes of interest". Hagiu and Wright (2011) discuss further variants of defining two-sidedness, arguing that the existing definitions may be both under- and over-inclusive. They propose to define the term "multi-sided platform" as "an organization that creates value primarily by enabling direct interactions between two (or more) distinct types of affiliated customers".[6]

Depending on the definition that is applied, a trade platform may constitute a special case of a two-sided platform. On the one hand, if the platform operator does not impose a restriction on sellers' pricing decisions, the platform fee structure often features neutrality, i.e., the split-up of a certain overall transaction-based fee does *not* affect trade volume, as sellers internalize both seller fees and buyer fees when setting their prices. On the other hand, a trade platform may create significant value by bringing together sellers and buyers, in particular if (i) trade does not arise in absence of the platform, or (ii) the platform offers additional services or lowers search costs, leading to a more efficient matching process. Ultimately, given that a trade platform may satisfy all proposed definitions under certain circumstances, it seems reasonable to consider it as "two-sided" when assessing its market position, not neglecting potential interdependencies or non-neutrality of its tariff system from the outset.

Assuming that sellers can reach potential buyers only through a platform, the second essay (chapter 3) deals with a platform operator's tariff decision when he can serve demand himself, competing with sellers who are active on his platform. Understanding this "dual mode" of intermediation – offering a platform and selling products as a merchant at the same time – is particularly relevant as operators of trade platforms typically face competitive advantages over third-party sellers: firstly, platform operators can easily observe information on demand and profitability of selling certain products, and secondly, they can shape competition by choosing their tariff system. However, if sellers anticipate that a platform operator can do "cherry-picking", offering profitable products himself, this threat of competition makes the platform less attractive: sellers may refuse to join the platform and gains from trade remain unrealized as the platform operator may not be aware of certain product markets if they are not disclosed by (more specialized) sellers.

[6]Hagiu and Wright (2011, p. 7).

Setting up a framework that allows for endogenous seller pricing, we[7] show that the platform operator faces a certain hold-up problem: committing to not becoming active in sellers' markets can be profitable to him. In particular, we analyze the effect of different tariff systems on the platform operator's incentives to compete with sellers. We show that classical two-part tariffs (which most of the literature on two-sided markets focusses on) do not affect the platform's incentives to compete with sellers and, hence, cannot enhance platform attractiveness. In contrast, proportional (revenue-based) fees affect the operator's trade-off between serving markets himself and remaining a "pure" platform operator by changing the opportunity costs of competition. Hence, charging proportional fees is indeed profitable under many circumstances, which offers a novel explanation for the frequent use of these fees by several prominent platform operators.

The third essay (chapter 4) examines a setting in which sellers can reach consumers both directly and through a platform, first of all focussing on sellers' incentives to set different prices across these two sales channels. However, interestingly, certain trade platforms impose no-discrimination rules (sometimes also called "price parity rules" or "most-favored treatment clauses"), asking sellers who are active on their respective platform not to offer better sales conditions elsewhere.

Although firms in other industries sometimes use similar clauses which have been analyzed by previous literature, the discussion of clauses that are imposed by a platform operator, restricting pricing decisions of third-party sellers, is much less developed.[8] Therefore, my analysis aims at providing insights on no-discrimination rules in intermediated markets, fostering this discussion.

In my framework, the two sales channels differ in perceived transaction costs and consumers' valuations. Furthermore, I presume a specific channel-importance effect which is induced by consumers imperfectly searching for matching products: each consumer has a "native" sales channel in which he starts searching for products. Consumers only consider buying products that are present in their respective native

[7] Chapter 3 is based on joint research with Johannes Muthers, which is indicated by the use of the plural pronoun "we" throughout the second essay and this paragraph of the introduction.

[8] Aguzzoni et al. (2012) offer a recent assessment of the economic literature on "price relationship agreements", indicating that there is no study that examines such agreements in intermediated markets. For more details, cf. my literature review in chapter 4.

channel. Hence, the initial distribution of consumers on sales channels also affects sellers' pricing decisions.

As I allow for an endogenous redistribution of consumers on sales channels which depends on price differences across channels and the buyer fee charged by the platform, imposing a no-discrimination rule gives the platform operator direct control over the split-up of consumers on sales channels. In particular, under a no-discrimination rule, sellers' prices reflect their average transaction costs, resulting in a cross-subsidization across sales channels. In contrast, if the platform operator does not impose a no-discrimination rule, each seller's prices reflect cost differences between channels and the channel-importance effect. Hence, the platform operator may not be able to extract rents from sellers without achieving a suboptimal channel split-up. When deciding whether to impose a no-discrimination rule, he trades off the benefits from having full control with the costs that are due to a fee restriction which captures sellers' incentives to specialize on direct sales under a no-discrimination rule. I identify both settings in which the platform's decision on imposing a no-discrimination rule matches with the socially desirable outcome, and settings in which a ban on no-discrimination rules would be beneficial.

Although the last two essays explicitly refer to business practices of online platforms, parts of the reasoning also apply to traditional marketplaces or franchising and licensing agreements. However, the analyzed practices are based on certain actions being observable, presuming a certain extent of transparency which is more likely to be achieved within an e-commerce context.[9]

[9] In particular, it is essential that the platform operator can monitor sellers' pricing decisions.

Chapter 2

Advertising, Pricing, and Third-Party Product Information

2.1 Introduction

When consumers consider buying a newly introduced product, they are often imperfectly informed about its quality. Therefore, it is natural that they try to infer product quality (and, hence, their valuation) prior to purchase, using sources which may differ in the kind and accuracy of information provided.

On the one hand, consumers can try to indirectly[1] infer information on product quality from observable seller decisions, in particular pricing or informative advertising.[2] In general, consumers can indirectly learn about product or seller characteristics ("types") whenever a specific choice of action is profitable for one seller type while other types do not have incentives to imitate this specific behavior. On the other hand, consumers may rely on direct information provided by the seller or other sources, e.g. product ratings offered by third parties, product reviews written by other (more experienced) consumers, or explicit recommendations.[3] Especially

[1]The distinction between direct and indirect information goes back to Nelson (1970, 1974) who also differentiates between search goods and experience goods, depending on whether relevant characteristics can be assessed prior to purchase or not. My analysis focusses on experience goods.

[2]Bagwell (2007) offers a comprehensive survey of the literature on advertising and distinguishes different views on advertising, namely the complementary view, the persuasive view, and the informative view. The first part of my study focusses on the informative view.

[3]In the following, I refer to these sources as "third-party product information".

the spread of the Internet and related technologies nowadays allows consumers to easily access these kinds of third-party product information. Indeed, several recent studies provide evidence that consumers frequently make use of this opportunity before buying products.[4] Therefore, it is essential to gain a better understanding of the impact of third-party product information on firms' pricing and marketing decisions, which this study focusses on.

Third-party product information has specific properties: firstly, mainly depending on its origin, content can be completely reliable and very helpful, but also misleading, providing unhelpful, biased, or wrong information. Secondly, its origin may be difficult to assess particularly if it is obtained from anonymous sources. Thirdly, any type of information always informs about existence or availability of a product, irrespective of the claim regarding quality or other characteristics.

Early literature on third-party information focusses on firms' responses to availability of a single reliable review, assuming information never being misleading or biased (e.g. due to reputational concerns of professional reviewers). As nowadays information on almost every kind of product is easily accessible, it seems likely that firms do not react to every single opinion, but proactively anticipate products being discussed and reviews becoming available after introduction of a new product. Furthermore, the likelihood of information being misleading or biased seems no longer negligible, in particular as statements can be made public anonymously or reputational concerns do not matter for (seemingly) non-professional reviewers.

Consequently, this study examines the interdependencies between a firm's pricing/marketing decisions and third-party product information ("reviews"),[5] analyzing a monopoly framework which allows for anticipation of potentially biased reviews when consumers try to infer product quality. The theoretical framework consists of two parts which focus on different (polar) views regarding the underlying pricing and marketing objectives of the seller.

[4] For example, Nielsen (2010) states that 57% of the respondents of an (international) Internet survey consider reviews before buying products; 40% of online shoppers claimed that they would not buy electronic devices without consulting reviews first. Fittkau & Maaß Consulting (2011) analyzes a German survey and provides detailed information about the use of different information sources prior to purchase; furthermore, cf. footnote 4. For more specific (economic) evidence, cf. the literature review below.

[5] For simplicity of notation, from now on I use the term "review" as representative for any kind of third-party product information.

In the first part, the seller neglects the potential effect of his pricing and marketing (advertising) decision on quality perception and consumers do not try to infer quality from price or received advertisements. Product reviews are assumed to be independent of the seller's decisions. Both advertising and reviews make consumers aware about product existence; furthermore, when observing a review, consumers learn about product quality. Accordingly, this part focusses on the effects of precision and availability of third-party product information on (type-dependent) seller decisions, namely pricing and existence advertising.

In the second part, the seller decides on price and marketing expenditures with the "objective" to affect consumers' quality perception. Consumers are assumed to be informed about product existence, but try to infer product quality from (manipulable) reviews or the seller's pricing decision. In contrast to studies which consider advertising as a signal, I assume that consumers cannot observe the seller's marketing expenses. However, investing in marketing affects the review distribution in favor of the seller (e.g. as the seller provides effort to manipulate opinion forums or to create a certain media bias).

Both parts aim at investigating the impact of availability of reviews on the relationship between advertising, pricing, and product quality. The first part presumes a substitutive effect between product reviews and advertising as both provide information on product existence. However, for a given quality level, the optimal amount of advertising may also be increasing in review availability as reviews also inform about (high) product quality, triggering purchases. The relationship between price and advertising level turns out to be ambiguous. Hence, although the high-quality firm always sets a (weakly) higher price than the low-quality type in the given framework, a low-quality firm may choose a higher advertising level than a high-quality firm. Finally, the effects of both review availability and the probability for reviews being misleading on pricing and advertising decisions are illustrated under the assumption that consumers update their beliefs according to Bayes' rule. In contrast to previous studies that focus on reactions on published product reviews and highlight that it might be optimal not to adjust prices, I find that optimal prices often differ across qualities. Hence, it seems reasonable to analyze prices as potential signals of product quality.

In the second part, I assume that some consumers are overconfident, fully trusting any review outcome. Existence of these (mis-)informed consumers allows the remaining consumers to interpret price as a signal of quality since pricing incentives differ across qualities as the review technology induces different sales probabilities. In line with previous literature on price signaling with a fraction of informed consumers, a high price may signal high quality if (non-manipulated) reviews are likely to indicate true product quality. However, given that the fraction of overconfident consumers credulously takes the review outcome for granted, a low-quality firm may also choose to manipulate the review outcome, specializing on selling to these overconfident consumers at a high price. In this case, the high-quality firm may choose to set a lower price than the low-quality firm, serving all consumers at a price that allows the non-credulous consumers to infer true product quality. Hence, a relatively low price may signal high quality – even in absence of repeat purchases and with production costs being equal across qualities.

Related literature

In the following, I provide a review of the literature most closely related to my work. I proceed as follows: firstly, I survey the (empirical) literature on the relationship between third-party product information, advertising, pricing, and demand. The literature seems to be compatible with the views that both advertising and third-party product information provide information on product existence, and that advertising may create a media bias, achieving news coverage in favor of advertisers' products. Secondly, I focus on theoretical studies that examine the effect of independent (and completely reliable) product information on firms' pricing and advertising decisions. Thirdly, I introduce two theoretical studies which discuss "promotional chat on the Internet" as a specific form of review manipulation (being in line with anecdotal evidence, another empirical study confirms their view that firms utilize manipulation opportunities in the given context). Finally, I sketch the literature on asymmetric information and prices (and advertising) as signals of product quality.

My work builds on the stylized facts that are emphasized by the empirical contributions (third-party information often informs about product existence but may be misleading or biased with respect to the indicated quality level). Examining a firm's proactive pricing and advertising decision under asymmetric information when anticipating potentially biased product reviews, it extends the existing theoretical literature which is surveyed below. Furthermore, it constitutes a link between the previous work on firms' (advertising) responses to reliable product reviews, studies on review manipulation, and the literature on price as a signal of quality.

Empirical insights: third-party information, seller decisions, and demand

In their seminal study, Archibald, Haulman, and Moody (1983) examine the effect of published quality ratings on the relationship between retail prices, advertising expenditures, and quality of running shoes. Assuming that the quality ratings of the leading running magazine (Runner's World) reflect true product quality, they find that a positive relationship between quality and advertising is much more likely in presence of third-party information; however, they do not report significant price adjustments after publication of product ratings.

Following up on this influential work, recent studies reassess the relationship between third-party product information, seller decisions, and product demand. In particular, several empirical studies deal with the effect of reviews on the demand for wine (which constitutes a prominent example of an experience good). For example, Hilger, Rafert, and Villas-Boas (2011) argue that reviews (or "ratings") affect demand by providing information about both product existence and quality. However, they find that demand for products with bad reviews is lower than demand for similar unrated products. Demand for products with average and high scores is higher than demand without any rating. They conclude that "not all publicity is good publicity".

In a related study, Friberg and Groenqvist (2012) find that both neutral reviews and advertising have a (small) positive effect on demand, which is consistent with the view that both inform about product existence. They report that bad reviews have basically no effect on demand. A possible explanation is that the negative effect of a review that reports low quality is offset by the additional awareness of product existence.

Berger, Sorensen, and Rasmussen (2010) illustrate that negative publicity can have a positive (overall) effect on demand for books due to increased product awareness. They find that negative reviews decrease demand for established products, but increase demand for previously unknown products. Here, the awareness effect overcompensates the effect of negative information about quality.

Dubois and Nauges (2010) examine the effect of expert reviews on prices of experience goods ("en primeur" wine). Using a structural empirical approach that allows to control for unobservable wine quality, they find a (jointly) positive relationship between prices and both wine quality and high expert grades. In particular, this result is in line with price signaling product quality.

Media bias

Several studies deal with the question if advertising biases product reviews or leads to more (favorable) media coverage. For example, De Smet and Vanormelingen (2011) report that in their survey among Belgian journalists about 25% of the respondents indicated that advertisers try to steer newspaper content. Analyzing Belgian newspapers, De Smet and Vanormelingen (2012) find that advertisers indeed receive higher news coverage (spending money on advertising in a newspaper positively affects the number of articles in which the advertiser is mentioned in the same newspaper within the same month).

Gambaro and Puglisi (2010) find that (a sample of) Italian newspapers react more strongly to company-specific events the larger the advertisement revenues received from that company are: buying more advertisements results in significantly more coverage in the respective newspaper. Similarly, Rinallo and Basuroy (2009) find a strong positive influence of Italian fashion companies' advertising spending on coverage in newspapers and magazines from international publishers.

Reuter (2009) analyzes wine ratings in the U.S. Different from the studies mentioned before, he only finds a very low bias created by advertising in the two major national wine publications. In contrast, examining personal finance publications, Reuter and Zitzewitz (2006) find a robust positive correlation between recommendations of mutual funds and past advertising expenditures of the respective mutual funds families. Furthermore, they detect that investors indeed respond to media mentions, i.e., recommendations result in a significant increase in fund size, although their actual predictive ability seems weak.

Ellman and Germano (2009), Blasco, Pin, and Sobbrio (2012) and Germano and Meier (2013) offer theoretical frameworks dealing with commercial media bias, highlighting effects that arise if media firms consider the impact of their content on advertisers' sales in order to achieve high advertising revenues. However, these studies focus on media outlets' content decisions and sellers' advertising investments, abstracting from product market choices, in particular sellers' pricing decisions.

Theory: independent third-party product information

Chen and Xie (2005) analyze firms' optimal responses to third-party product reviews in a duopoly model with horizontal and vertical product differentiation. They introduce several dimensions of consumer heterogeneity (taste-dependent reservation prices, "taste-driven" vs. "quality-driven" product choice, loyal consumers vs. price-sensitive switchers) and explain how the optimal price and advertising reactions depend on the sizes of the respective consumer groups and true product quality. In their framework, advertising provides existence information, conveys horizontal product characteristics, and imperfectly informs about product quality, while reviews perfectly inform a certain fraction of consumers about both product existence and all product characteristics. Chen and Xie focus on scenarios where firms' prices are independent of actual product quality in absence of reviews. If prices change after publication of a review, consumers do not try to infer product quality even if price adaption depends on true quality. Furthermore, Chen and Xie assume that reviews always provide accurate information, neglecting that they might be misleading. Within the empirical part of their analysis, Chen and Xie report no significant price changes and ambiguous (partly insignificant) changes in advertising levels after a review becomes available.

In a subsequent study, Chen and Xie (2008) analyze the interdependencies between a monopoly seller's pricing and information content strategy (i.e., partial or full disclosure of product characteristics) and word-of-mouth communication between heterogenous consumers. Chen and Xie do not include any advertising costs in this framework. Nevertheless, besides analyzing the optimal response to reviews, they also argue that a monopolist may want to adapt his strategy when *anticipating* reviews, i.e., they discuss "proactive" seller behavior.

Jiang and Wang (2008) study the optimal price response to publication of third-party product information. Firstly, they find that a better rating always increases price and profit of a monopoly firm. Secondly, analyzing competition between a high-quality and a low-quality firm, they illustrate that a higher ranking of the high-quality firm's product increases product differentiation and, hence, relaxes competition. In contrast, a higher ranking of the low-quality firm's product has a negative effect on both firms' profits due to fiercer competition. However, Jiang and Wang abstract from advertising.

Manipulable third-party product information

Mayzlin (2006) analyzes a duopoly model of vertical differentiation. Firms can engage in "promotional chat", manipulating word-of-mouth communication between informed and uninformed consumers about which product is superior. Depending on how much messages firms post (stating that their product is superior), they incur costs. Prices for both products are exogenously given and assumed to be equal. Mayzlin finds that under certain circumstances an equilibrium exists where the high-quality firm manipulates less than the low-quality firm. However, chat remains informative since the number of truthful messages (sent by the high-quality firm and informed consumers) remains greater than the number of misleading messages sent by the low-quality firm.

In a related but more general study, Dellarocas (2006) deals with a similar issue. He finds that participation of firms in online discussions about product quality can benefit consumers: it increases informativeness of online forums if firms' manipulation activities are monotonically increasing in their respective true quality. If opinion forums are relatively informative without being influenced, firms would be better off if they could not engage in manipulation. However, Dellarocas abstracts away prices. Finally, he points out that consumers might not be fully rational or cannot anticipate manipulation strategies, contrary to the assumption taken in his framework.

Mayzlin, Dover, and Chevalier (2012) examine online review manipulation empirically. Utilizing differences in the review technologies of different travel websites, they report a significant (but modest) level of manipulation.[6]

Signaling unobservable product quality

In his seminal study, Akerlof (1970) highlights the adverse selection problem caused by asymmetric information about product quality, demonstrating that it may induce a complete market breakdown. Subsequent work discusses different means to overcome asymmetric information problems. In particular, Nelson (1974) argues

[6]However, according to the operator of one of the leading German travel websites, attempts to defraud range from 18% to 35% of all posted reviews (cf. Stiftung Warentest, 2010). Interestingly, within the management literature, studies explicitly examine how firms should optimally exploit the susceptibility of online communities to manipulation, cf. e.g. Miller, Fabian, and Lin (2009).

that advertising spending may be indirectly informative about product quality, but he does not provide a formal model. Building on Nelson's argument, Schmalensee (1978) shows that advertising may indicate product quality, but advertising levels can also mislead buyers as low-quality firms may invest more in advertising than high-quality firms. However, his results rely on the assumption that consumers follow a rule of thumb (higher advertising levels correspond to a higher likelihood of high quality, independent of actual firm behavior).

Kihlstrom and Riordan (1984) find that advertising can be understood as a signal of quality with rational behavior of consumers (regarding their beliefs about the advertising-quality relationship) in equilibrium. Nevertheless, Kihlstrom and Riordan assume that consumers do not infer quality from prices. Milgrom and Roberts (1986) illustrate that a combination of introductory price and marketing expenditures can signal product quality in presence of repeat purchases. They conclude that "advertising may signal quality, but price signaling will also typically occur, and the extent to which each is used depends [...] on the difference in costs across qualities".[7]

Building on this development, several studies have discussed prices (and advertising) as signals of quality. Most of them are based on at least one of the following assumptions: (i) quality-dependent costs, (ii) repeat purchases, or (iii) presence of informed consumers. The basic intuition behind these three "segregating" factors can be understood as follows: firstly, if a firm's costs depend on true product quality, profit-maximizing prices are supposed to differ under complete information. Hence, under incomplete information, the low-quality firm usually has to choose a suboptimal price-quantity combination when imitating the high-quality firm, and imitation is less attractive. Secondly, with repeat purchases, consumers who bought the product in the first period are assumed to be informed about quality in subsequent periods. Hence, a high-quality firm faces incentives to reduce its initial price to benefit from an increased willingness-to-pay in later periods, in contrast to a low-quality firm. Consequently, in this context, a low (initial) price may signal high quality. However, thirdly, when assuming that some consumers are informed about true product quality, a low-quality firm faces less incentives to set a high price than a high-quality firm as informed consumers would refuse to buy at prices which are only justified for a high-quality product. Hence, a high price may signal high quality.

[7] Milgrom and Roberts (1986, p. 819).

Analyzing a monopolistic framework,[8] Bagwell and Riordan (1991) show that a high price indeed signals high quality when production costs differ across qualities and some consumers are informed, highlighting that the (upward) price distortion of the high-quality type decreases in the number of informed consumers. Linnemer (2002) offers an extension, allowing for the use of dissipative advertising. He argues that under certain circumstances a firm may prefer the combination of a high (but less distorted) price and additional advertising investments in order to signal high quality. Hahn (2004) also builds a model based on the third factor, with some consumers being informed but costs being constant across quality levels. In contrast to Mahenc (2004) who illustrates that a sufficiently high fraction of informed consumers can eliminate the adverse selection problem with elastic demand, Hahn assumes inelastic demand but allows for advertising. In his framework, prices cannot signal quality with a small fraction of informed consumers, but investments in (dissipative) advertising allow to achieve a separating equilibrium with full-information pricing.

In contrast to the studies mentioned above, Moraga-Gonzalez (2000) assumes that advertising directly reveals product quality; accordingly, a seller can choose how many consumers are informed about product quality by investing in informative advertising. Hence, advertising never occurs in a separating equilibrium. As Moraga-Gonzalez presumes (ex-ante) homogenous consumers, a separating equilibrium cannot evolve.

Combining the views that advertising informs about product existence[9] and that observation of price and advertising expenses may (jointly) signal quality, Zhao (2000) allows for a dual role of advertising: "raising awareness and signaling quality". Given this assumption, Zhao illustrates that the combination of a high price and a low advertising level (compared to the low-quality firm's level) can signal high product quality.

Kennedy (1994) argues that word-of-mouth communication among consumers

[8]All models of prices signaling quality cited in the text presume a monopolistic seller. For an analysis of signaling in competitive environments, cf. e.g. Hertzendorf and Overgaard (2001), Daughety and Reinganum (2008), Yehezkel (2008), Janssen and Roy (2010), and Mirman and Santugini (2013).

[9]This view goes back to Ozga (1960) and has been formalized before (cf. e.g. Grossman & Shapiro, 1984, for an analysis of existence advertising under imperfect competition).

may support effective price signaling in a similar way as repeat purchases: a low introductory price signals high quality.

While the literature mentioned so far and concerned with advertising as a signal takes the extreme assumption of advertising expenses being perfectly observable for consumers, Hertzendorf (1993) and Hakenes and Peitz (2010) analyze advertising as a noisy signal, i.e., consumers observe advertisements only with a certain probability and cannot assess advertising expenses. Following up Zhao (2000), Hakenes and Peitz examine the interplay between directly and indirectly informative advertising. Focussing on repeat purchases and abstracting from price signaling, they find that a low-quality firm sets a lower advertising level than a high-quality firm. Hertzendorf allows for price signaling, highlighting that (noisy) advertising will only be used if price does not signal quality; under certain assumptions, the high-quality firm chooses a higher advertising level than the low-quality firm.

Outline

Given the various insights on the relationship between different kinds of advertising, pricing, and product quality provided by the literature surveyed above, I reassess this relationship for two specific kinds of advertising (or, more generally, marketing investments) with potentially misleading product reviews.

In the first part (section 2.2), advertising informs about product existence. In addition, consumers may receive product reviews, indicating product quality, but also informing about product existence. However, consumers do not interpret price (or advertising) as a signal of quality.

In the second part (section 2.3), consumers cannot observe the firm's investments in marketing (advertising), and the only effect of these investments consists in achieving more favorable product reviews (e.g. due to a media bias or the firm anonymously participating in online discussions). However, motivated by the positive price-quality relationship detected in the first part, I now allow for consumers interpreting price as a signal of quality.

Each of the two parts closes with a discussion of the respective main insights. Finally, I offer a conclusion in section 2.4. All proofs are relegated to the appendix.

2.2 Information on product existence and quality

In this section, I set up a basic model to analyze the impact of future reviews on a firm's decisions on informative advertising and pricing. Advertising provides direct information about product existence but does not inform about quality.

2.2.1 Framework

I consider a monopolist who introduces a single experience good to the market: prior to purchase, the product's true quality is unobservable to consumers. I assume that quality is assigned by nature and can take on two levels: with probability q the product is of high quality H, and with probability $1-q$ it is of low quality L. The monopolist faces linear production costs with marginal costs normalized to zero (irrespective of product quality).[10]

There is a unit mass of consumers, each of them willing to buy at most one unit of the product. Consumers are ex-ante uninformed about both product quality and product existence. If they become aware of the monopolist's offer, their valuation depends on (unknown) product quality. If consumers knew that the product was of high quality, their willingness to pay would be v_H, and if they knew that it was of low quality, their willingness to pay would be $v_L \in [0, v_H)$.

The monopolist can advertise to inform consumers about product existence using the following advertising technology: he reaches a fraction $\alpha < 1$ at costs of $C(\alpha)$, where C is increasing and convex in α with $C'(0) = 0$.[11]

Besides advertisements, consumers may receive product information (a review) immediately after introduction of the monopolist's product.[12] First of all, this re-

[10] Within the discussion, I also consider type-dependent marginal costs as an extension.

[11] Building on the informative view on advertising, decreasing returns to advertising are a typical assumption.

[12] This "review" may also be interpreted as the result of word-of-mouth communication created by (exogenous) early adopters. For a discussion on consumers' motives for reviewing products, cf. e.g. Hennig-Thurau, Gwinner, Walsh, and Gremler (2004), Chen, Fay, and Wang (2011), and Moe and Schweidel (2013). Furthermore, firms may create additional incentives through referral reward programs or member-get-member campaigns, cf. e.g. Biyalogorsky, Gerstner, and Libai (2001), Kornish and Li (2010), Ryu and Feick (2007), Schmitt, Skiera, and Van den Bulte (2011), or Verlegh, Pruyn, and Peters (2003). However, I abstract from such activities within this first

view may help consumers to assess product quality: it indicates either high product quality h or low product quality l.[13] I also allow for cases in which the indicated quality does not correspond to the true quality. However, I assume that a review is always informative and unbiased in the following sense: the probability of a positive review indicating quality h when true quality is low (L) equals the probability of a negative review that indicates quality l when true quality is high (H); both are denoted by $\beta < 0.5$ and are not affected by any of the firm's decisions.

The probability of a review being available (irrespective of whether quality is indicated correctly) is given by μ. Each consumer's willingness to pay after receiving a review that indicates quality $j \in \{h, l\}$ is denoted by v_j, with $v_h > v_l$.[14]

Furthermore, observing a review can also initiate consumers who did not receive any advertisement to buy the product as it also informs about product existence. I assume that a fraction γ of consumers considers buying the product if they do not receive any advertisement but a review.

I assume that consumers do not have access to any other sources of information than reviews and advertisements. In particular, in this part, consumers are assumed not to interpret price or received advertisements as signals of product quality. Furthermore, advertisements cannot be targeted at specific consumers; the monopolist cannot discriminate between consumers who consider buying the product after receiving a review and consumers who do not buy without receiving an advertisement.

In summary, if a review is available, a fraction $\alpha + (1 - \alpha) \cdot \gamma$ of consumers is informed about product existence and considers buying the product. All of them observe the review outcome $j \in \{h, l\}$ which implies a willingness to pay of v_j. If no review is available (n), a fraction α of consumers is informed about product existence, but product quality remains unknown and willingness to pay is given by $v_n \equiv q \cdot v_H + (1 - q) \cdot v_L$.

part, and although I allow for investments in (probabilistic) review manipulation in the second part of my study, such practices seem to be different since payments are made contingent on *successful* customer acquisition and would not be paid for uncertain recommendations.

[13] Capital letters denote true product quality while lowercases refer to the quality level which is indicated by the review.

[14] Given consumer's willingness to pay under full information, i.e., v_H and $v_L < v_H$, it seems natural to define v_h and v_l according to Bayes' rule (as defined in equations (2.6) and (2.7)). In the following analysis, I use the "general" notations v_l and v_h; section 2.2.3 provides a numerical illustration based on Bayesian updating.

Timing

The timing is given as follows:

1. Product quality $Q \in \{L, H\}$ is realized and observed by the monopolist.
2. The monopolist takes his advertising and pricing decision.
3. The outcome of the product review $i \in \{h, l, n\}$ is realized (either indicating high quality (h), low quality (l), or no review available (n)).
4. Consumers take their buying decision contingent upon price, realization of review, and received advertisement.

Note that I assume both price and advertising level to be fixed before reviews become available and to remain constant after realization of product reviews.[15]

Both the monopolist and consumers are assumed to be risk neutral, maximizing their expected profit/surplus.

2.2.2 Analysis

Given the probabilities introduced above and true product quality, the monopolist's expected profit depends on his price p and his advertising level α. Defining

$$D_i(p) = \begin{cases} 1, & p \leq v_i \\ 0, & p > v_i \end{cases},$$

where $i \in \{h, l, n\}$ indicates the review outcome, the high-quality firm's expected profit can be written as

$$\Pi_H^e(p, \alpha) = \{(1-\mu) \cdot \pi_n(p, \alpha) + \mu \cdot (1-\beta) \cdot \pi_h(p, \alpha) + \mu \cdot \beta \cdot \pi_l(p, \alpha)\} \cdot p - C(\alpha),$$

where

$$\pi_n(p, \alpha) = \alpha \cdot D_n(p)$$

denotes the level of demand if no review is available, and

$$\pi_j(p, \alpha) = (\alpha + (1-\alpha) \cdot \gamma) \cdot D_j(p), \ j \in \{h, l\}$$

[15] This seems reasonable as short-run adjustment of a firm's marketing policy directly in response to reviews may be difficult. Furthermore, empirical evidence suggests that firms may not adjust prices (and advertising levels) after publication of reviews, also cf. my literature review.

is defined as the level of demand if a review is available and indicates quality $j \in \{h, l\}$. Using the same definitions, the low-quality firm's expected profit can be written as

$$\Pi_L^e(p,\alpha) = \{(1-\mu)\cdot \pi_n(p,\alpha) + \mu \cdot (1-\beta)\cdot \pi_l(p,\alpha) + \mu \cdot \beta \cdot \pi_h(p,\alpha)\} \cdot p - C(\alpha).$$

Table 2.1 illustrates the underlying expected demand, depending on true product quality, advertising level, and price.[16] The mass of consumers who are aware of the firm's offer and consider buying the product after receiving a review is denoted by $A(\alpha,\gamma) \equiv \alpha + (1-\alpha)\cdot\gamma$.

Price	Expected demand of firm H	Expected demand of firm L
v_h	$\mu \cdot (1-\beta)\cdot A(\alpha,\gamma)$	$\mu \cdot \beta \cdot A(\alpha,\gamma)$
v_n	$(1-\mu)\cdot\alpha + \mu\cdot(1-\beta)\cdot A(\alpha,\gamma)$	$(1-\mu)\cdot\alpha + \mu\cdot\beta\cdot A(\alpha,\gamma)$
v_l	$(1-\mu)\cdot\alpha + \mu\cdot A(\alpha,\gamma)$	$(1-\mu)\cdot\alpha + \mu\cdot A(\alpha,\gamma)$

Table 2.1: Underlying expected demand of high-quality firm and low-quality firm

Given expected profit $\Pi_H^e(p,\alpha)$, the high-quality firm's optimal advertising level α_H has to fulfill

$$\{(1-\mu)\cdot D_n(p)+\mu\cdot(1-\beta)\cdot(1-\gamma)\cdot D_h(p)+\mu\cdot\beta\cdot(1-\gamma)\cdot D_l(p)\}\cdot p = C'(\alpha_H) \quad (2.1)$$

for any given price p, i.e., the marginal expected revenue (left-hand side of equation (2.1)) must equal the marginal advertising costs.[17] Similarly, the low-quality firm's optimal advertising level α_L is characterized by

$$\{(1-\mu)\cdot D_n(p)+\mu\cdot\beta\cdot(1-\gamma)\cdot D_h(p)+\mu\cdot(1-\beta)\cdot(1-\gamma)\cdot D_l(p)\}\cdot p = C'(\alpha_L). \quad (2.2)$$

Before analyzing the monopolist's pricing behavior under the special case of a quadratic advertising cost function, I state some general comparative static results that indicate how the optimal advertising level at a given price (in particular, at a price $p \in \{v_l, v_n, v_h\}$) is affected by the properties of product reviews.

Proposition 2.1 (Substitutive effect of product reviews on advertising). *At any given price, an increase in γ results in a lower optimal advertising level.*

[16] Expected demand is fully characterized by the levels that are taken on at the three (undominated) prices v_h, v_n, and v_l.

[17] First order conditions (w.r.t. α) are sufficient for optimality as $C(\alpha)$ is convex.

This result is rather straightforward as the parameter γ captures the awareness effect of reviews (i.e., how many consumers become informed about product existence and consider buying the product after receiving a review), which measures substitutability between advertising and reviews as information about product existence. The higher γ, the more consumers buy without receiving any advertisement, and, hence, the lower the marginal revenue from advertising.

Proposition 2.2 (Effect of review availability on advertising)**.**
If the monopolist charges a price below v_h, his optimal advertising level decreases if the availability of reviews μ increases. If he charges a price of $p = v_h$, the optimal advertising level increases in μ if $\gamma < 1$.

Firstly, if the monopolist charges a low price $p = v_l$, his advertising level decreases in μ solely due to the substitutive effect that is captured by γ. Secondly, if he charges a price of v_n, he also loses buyers if the review indicates low quality, but he does not gain from reviews indicating high quality. Therefore, his marginal revenue decreases if the probability of availability of (negative) reviews increases. Finally, if he charges a high price v_h, he only serves demand if the review indicates high quality. Consequently, advertising becomes more profitable if the probability for a (positive) review increases.[18] However, if $\gamma = 1$, all consumers consider buying the product after observing a review, even without receiving any advertisement. Hence, if the monopolist charges a high price, the optimal advertising level equals zero in case of $\gamma = 1$.

Proposition 2.3 (Effect of misleading reviews on advertising)**.**
If the monopolist charges a fixed price above v_l, the error probability β has a strictly negative effect on the high-quality firm's advertising level and a strictly positive effect on the low-quality firm's level. At a fixed price $p \leq v_l$, an increase in β has no effect on the advertising level.

In the latter case ($p \leq v_l$), the only (direct) effect of reviews is informing about product existence as consumers buy whenever they are aware of the firm's offer, regardless of whether the review indicates quality correctly. However, if consumers consistently take into account β when forming their beliefs (e.g. according to Bayes'

[18]As the error probability β does not exceed 0.5, the positive effect of review availability dominates the negative effect.

rule), a higher β implies a higher v_l. If the monopolist does not adapt his price, β does not affect his advertising decision in this case (if he increases his price accordingly, his optimal advertising level also increases). For any given price above v_l, β decreases the buying probability if true product quality is high and increases it if quality is low as the review becomes more likely to delude consumers.

If the monopolist charges a high price of v_h, and β negatively affects this price, the overall effect on advertising is negative in case of quality H, but it may also become negative in case of quality L as the negative effect on consumers' willingnesses to pay may overcompensate the positive (direct) effect of β on sales probability (depending on the prior probability q and the difference $v_H - v_L$).

Lemma 2.1 (Comparison of advertising incentives at a given price)**.**
At any given price $p \in \{v_n, v_h\}$, the high-quality firm's optimal advertising level strictly exceeds the low-quality firm's optimal level if $\mu > 0$ and $\gamma < 1$. At $p = v_l$, the low-quality firm advertises as much as the high-quality firm.

As reviews are assumed to be informative ($\beta < 0.5$), expected demand of the high-quality firm exceeds the low-quality firm's level of expected demand at any reasonable given price. The marginal expected revenue from advertising is strictly higher for the high-quality firm at prices where negative reviews lead to strictly less sales ($p > v_l$). At $p = v_l$, consumers who are informed about product existence always buy, indiscriminate of the quality indicated by a review. Therefore, reviews have the same effect on both the high-quality and the low-quality firm's expected demand, and advertising decisions are independent of true product quality.

I derive the monopolist's pricing decision under the following Assumption:

Assumption 2.1 (Sufficiently large quadratic advertising costs)**.**
The advertising cost function is given by $C(\alpha) = \frac{k}{2} \cdot \alpha^2$, with $k > v_h$.

The first part of this Assumption (quadratic cost function) allows tractable comparisons of the profits at different prices under the optimal advertising levels, and the latter part guarantees interior solutions for α under any parametrization.[19]

As only the three prices that equal the potential willingnesses to pay, i.e., v_l, v_n,

[19]The subsequent results are qualitatively robust against changes in the specification of the (convex) advertising cost function.

and v_h, are not strictly dominated by slightly higher prices, I compute the firm's profit for each of these prices, using the corresponding optimal advertising levels.

Lemma 2.2 (Optimal advertising levels of high-quality firm)**.**
Define $a_l^H \equiv 1-\gamma\cdot\mu$, $a_n^H \equiv (1-\mu)+(1-\gamma)\cdot\mu\cdot(1-\beta)$, *and* $a_h^H \equiv (1-\gamma)\cdot\mu\cdot(1-\beta)$. *Then, the high-quality firm's optimal advertising level at price* $v_i \in \{v_l, v_n, v_h\}$ *is given by* $a_i^H \cdot \frac{v_i}{k}$.

As $a_h^H - a_n^H = -(1-\mu) < 0$, and $a_n^H - a_l^H = -(1-\gamma)\cdot\beta\cdot\mu < 0$, the high-quality firm's advertising level decreases in price if the three prices are close to each other. This is the case if v_l and v_h are based on Bayesian updating and the probability β of reviews indicating the wrong quality is rather large, or if the difference between the full-information willingnesses to pay, $v_H - v_L$, is small.

However, the change in the coefficients a_i^H (which capture the probability that consumers consider buying due to received advertisements and are willing to buy at the given price) may also be overcompensated by the opposite change in prices (margins) v_i. Hence, for sufficiently large differences between the willingnesses to pay, the optimal advertising level either increases or is no longer monotone in price.

A similar logic applies to the low-quality firm's advertising levels which are characterized by the following Lemma:

Lemma 2.3 (Optimal advertising levels of low-quality firm)**.**
Define $a_l^L \equiv 1-\gamma\cdot\mu$, $a_n^L \equiv (1-\mu)+(1-\gamma)\cdot\mu\cdot\beta$, *and* $a_h^L \equiv (1-\gamma)\cdot\mu\cdot\beta$. *Then, the low-quality firm's optimal advertising level at price* $v_i \in \{v_l, v_n, v_h\}$ *is given by* $a_i^L \cdot \frac{v_i}{k}$.

Given the optimal advertising levels, I calculate the firm's expected profit for each price, depending on true product quality. With quadratic advertising costs, expected profit of the high-quality firm at prices $v_i \in \{v_n, v_h\}$ can be calculated as

$$\Pi_H^*(v_i) = \left\{\left(a_i^H\right)^2 \cdot \frac{v_i}{2k} + \gamma\cdot\mu\cdot(1-\beta)\right\}\cdot v_i,\ i \in \{n, h\},$$

and expected profit of the low-quality firm equals

$$\Pi_L^*(v_i) = \left\{\left(a_i^L\right)^2 \cdot \frac{v_i}{2k} + \gamma\cdot\mu\cdot\beta\right\}\cdot v_i,\ i \in \{n, h\}.$$

If the firm charges a price of v_l, the profit in case of quality $Q \in \{L, H\}$ is

$$\Pi_Q^*(v_l) = \left\{\left(a_l^Q\right)^2 \cdot \frac{v_l}{2k} + \gamma\cdot\mu\right\}\cdot v_l.$$

As already mentioned above, at $p = v_l$ the review only has an awareness effect, and indicated quality itself does not affect sales. Therefore, the error probability β does not enter directly into the latter profit (but indirectly if v_l changes in β).

A high-quality firm prefers targeting only correctly informed consumers by charging a price of v_h over selling to both uninformed and correctly informed consumers by charging a price of v_n if

$$\frac{v_h}{v_n} > \frac{\left(a_n^H\right)^2 \cdot v_n + \gamma \cdot \mu \cdot (1-\beta) \cdot 2k}{\left(a_h^H\right)^2 \cdot v_h + \gamma \cdot \mu \cdot (1-\beta) \cdot 2k}. \tag{2.3}$$

Defining

$$B_1 \equiv (1-\gamma)^2 \cdot (1-\beta)^2 \cdot \left(\frac{v_h}{v_n}\right)^2 - \{1-(1-\gamma)\cdot(1-\beta)\}^2, \tag{2.4}$$

and

$$B_2 \equiv 1-(1-\gamma)\cdot(1-\beta) + \gamma\cdot(1-\beta)\cdot k \cdot \frac{v_h - v_n}{v_n^2}, \tag{2.5}$$

I can state the following result:

Lemma 2.4 (High-quality firm prefers v_h over v_n)**.**
Given definitions (2.4) and (2.5), the high-quality firm prefers v_h over v_n if and only if
(i) $B_1 > 0 \wedge \mu > -\frac{B_2}{B_1} + \sqrt{\frac{1}{B_1} + \left(\frac{B_2}{B_1}\right)^2}$, or (ii) $B_1 < 0 \wedge \mu > -\frac{B_2}{B_1} - \sqrt{\frac{1}{B_1} + \left(\frac{B_2}{B_1}\right)^2}$, or (iii) $B_1 = 0 \wedge \mu > \frac{1}{2\cdot B_2}$.

The intuition behind this result is rather simple: targeting consumers who received a positive review (i.e., charging v_h) is more profitable if and only if the likelihood of a review being available, i.e., μ, is sufficiently large. As $\beta < 0.5$, a higher μ always implies a higher probability of consumers buying the product at a high price.

The following Lemmas are based on similar pairwise comparisons of the above profits.

Lemma 2.5 (High-quality firm prefers v_n over v_l)**.**
The high-quality firm prefers v_n over v_l if and only if $\beta < B_3 - \sqrt{B_3^2 - B_4}$, where $B_3 \equiv 1 + \frac{1-\mu}{(1-\gamma)\cdot\mu} + \frac{k\cdot\gamma}{(1-\gamma)^2\cdot\mu\cdot v_n}$, and $B_4 \equiv \left(1 + \frac{1-\mu}{(1-\gamma)\cdot\mu}\right)^2 \cdot \left(1 - \frac{v_l^2}{v_n^2}\right) + \frac{2\cdot k\cdot\gamma\cdot(v_n - v_l)}{(1-\gamma)^2\cdot\mu\cdot v_n^2}$.

Consumers are willing to pay only v_l if they receive a review which indicates low product quality. Therefore, given a positive probability μ for receiving a review, the error probability β impairs the expected mass of consumers who buy at a price v_n. Hence, the high-quality firm only prefers the higher price v_n if β is relatively small.[20]

Lemma 2.6 (High-quality firm prefers v_h over v_l).
The high-quality firm prefers v_h *over* v_l *if and only if* $\beta < B_5 - \sqrt{B_5^2 - B_6}$*, where* $B_5 \equiv 1 + \frac{k\cdot\gamma}{(1-\gamma)^2\cdot\mu\cdot v_h}$*, and* $B_6 \equiv 1 - \left(1 + \frac{1-\mu}{(1-\gamma)\cdot\mu}\right)^2 \cdot \frac{v_l^2}{v_h^2} + \frac{2\cdot k\cdot\gamma\cdot(v_h - v_l)}{(1-\gamma)^2\cdot\mu\cdot v_h^2}$.

The inequality given in this Lemma can also be written as

$$\beta < 1 - \frac{\sqrt{\left(\frac{k\cdot\gamma}{1-\gamma}\right)^2 + 2\cdot k\cdot\gamma\cdot\mu\cdot v_l + (1-\gamma\cdot\mu)^2\cdot v_l^2} - \frac{k\cdot\gamma}{1-\gamma}}{\mu\cdot(1-\gamma)\cdot v_h}.$$

This condition is most demanding (threshold for the error probability β relatively low) for small values of μ and a relatively large level of v_l. Conversely speaking, the high-quality firm prefers charging a high price if availability of a review is very likely, v_h is relatively large compared to v_l, and/or the probability for a misleading review β is small. This is because otherwise both the probability for selling at a high price v_h and the reduction in the margin, $v_h - v_l$, are rather small, and, hence, serving more customers at a low price would be more profitable.

Lemma 2.7 (Low-quality firm prefers v_h over v_n).
The low-quality firm prefers v_h *over* v_n *if and only if* $|\beta + B_7| > \sqrt{B_7^2 + B_8}$*, where* $B_7 \equiv \frac{k\cdot\gamma\cdot(v_h - v_n) - (1-\mu)\cdot(1-\gamma)\cdot v_n^2}{\mu\cdot(1-\gamma)^2\cdot(v_h^2 - v_n^2)}$*, and* $B_8 \equiv \left(\frac{1-\mu}{\mu\cdot(1-\gamma)}\right)^2 \cdot \frac{v_n^2}{v_h^2 - v_n^2}$.

On the one hand, as consumers buy at a price of v_h only if they receive a review that indicates high quality, the low-quality firm only profits from charging v_h if the probability for a misleading review is sufficiently high. Hence, charging v_h is only profitable if both the probability for availability of a review, i.e., μ, and the error probability β are sufficiently large. On the other hand, in particular if v_h and v_n are close to each other, it is no longer profitable to sell to a smaller mass of customers at a slightly higher margin, and charging v_n becomes more profitable.[21]

[20] Note that v_h and v_l also depend on β if they follow Bayes' rule. The next section offers a numerical illustration with Bayesian updating.

[21] In particular, if v_h is calculated according to Bayes' rule, taking into account β, β should take an intermediate level for the condition to be fulfilled as v_h approaches v_n (resulting in $B_7 < 0$) for reviews becoming uninformative ($\beta \to 0.5$).

Lemma 2.8 (Low-quality firm prefers v_n over v_l).
If $\beta < \frac{v_l}{v_n}$, the low-quality firm prefers v_n over v_l if and only if $\mu < B_9 - \sqrt{B_9^2 - B_{10}}$, where $B_9 \equiv \frac{(1-(1-\gamma)\cdot\beta)\cdot v_n^2 - k\cdot\gamma\cdot(\beta\cdot v_n - v_l) - \gamma\cdot v_l^2}{(1-(1-\gamma)\cdot\beta)^2\cdot v_n^2 - \gamma^2\cdot v_l^2}$, and $B_{10} \equiv \frac{v_n^2 - v_l^2}{(1-(1-\gamma)\cdot\beta)^2\cdot v_n^2 - \gamma^2\cdot v_l^2}$.

Note that the first condition in this Lemma just claims that v_l takes on a "reasonable" level, given the error probability β; it is always fulfilled if v_l is calculated according to Bayes' rule. Then, for the low-quality firm, charging v_n is more profitable than charging v_l if availability of a review is relatively unlikely (μ small) and/or the additional margin $v_n - v_l$ is relatively large – otherwise, it is more profitable to target all consumers who are informed about product existence at a low price of v_l.

Lemma 2.9 (Low-quality firm prefers v_h over v_l).
The low-quality firm prefers v_h over v_l if and only if $\beta > \sqrt{B_{11}^2 + B_{12}} - B_{11}$, where $B_{11} \equiv \frac{\gamma\cdot k}{\mu\cdot(1-\gamma)^2\cdot v_h}$, and $B_{12} \equiv \frac{(1-\gamma\cdot\mu)^2\cdot v_l^2 + \gamma\cdot\mu\cdot 2k\cdot v_l}{\mu^2\cdot(1-\gamma)^2\cdot v_h^2}$.

When charging a price of v_h, the firm only profits if consumers receive a positive review. The low-quality type only prefers to specialize on sales based on misleading reviews if the error probability is relatively high. Taking a closer look on the condition for β, it turns out that it can be fulfilled even if v_h and v_l follow Bayes' rule, cf. the following section.[22]

Before offering a graphical illustration of the above conditions and the implied advertising and pricing decisions for a certain parameter constellation, I state a more general result, comparing the price setting decisions across firm types.

Proposition 2.4 (High-quality firm sets higher price than low-quality firm).
The low-quality firm never sets a higher price than the high-quality firm, but the high-quality firm may set a strictly higher price than the low-quality firm.

Both firm types face the same linear production cost function (normalized to zero) and the same advertising technology. Hence, they only differ in product quality. As long as reviews are informative ($\beta < 0.5$) and available with a positive probability ($\mu > 0$), the high-quality firm faces higher incentives to increase its price as a favorable review is more likely for this type than for the low-quality type.

[22]In particular, the low-quality firm prefers to set a price of v_h for moderate levels of β, a high level of μ, a skewed type distribution characterized by a low q, and $v_H - v_L$ relatively large.

Although Lemma 2.1 indicates that the high-quality firm also faces higher advertising incentives at any given price, optimal advertising levels do not exhibit a similar "monotonicity" property: since advertising levels may decrease in price (cf. the discussion of Lemma 2.2) the low-quality firm may advertise more than the high-quality firm if the latter charges a strictly higher price:

Corollary 2.1 (Relationship between product quality and advertising).
The relationship between product quality and advertising is ambiguous: under certain parametrizations, the high-quality firm advertises less than the low-quality firm.

The following numerical example also demonstrates this particular outcome.

2.2.3 A numerical illustration with Bayesian updating

In this section, I illustrate the impact of the probabilities μ (for a review being available) and β (for an available review being misleading) on firm's type-dependent choices of price and advertising level for the parameter constellation

$$\gamma = 0.2,\ q = 0.2,\ v_H = 5,\ v_L = 0.2,\ k = 5.$$[23]

I presume that the willingness to pay after receiving a review, i.e., v_h or v_l, is calculated based on Bayes' rule, given the prior probability q for high quality and the error probability β:

$$v_h = \frac{(1-\beta)\cdot q}{(1-\beta)\cdot q + \beta\cdot(1-q)}\cdot v_H + \frac{\beta\cdot(1-q)}{(1-\beta)\cdot q + \beta\cdot(1-q)}\cdot v_L, \tag{2.6}$$

$$v_l = \frac{\beta\cdot q}{(1-\beta)\cdot(1-q) + \beta\cdot q}\cdot v_H + \frac{(1-\beta)\cdot(1-q)}{(1-\beta)\cdot(1-q) + \beta\cdot q}\cdot v_L. \tag{2.7}$$

Figure 2.1 illustrates the firm's pricing decision. For parameter constellations within the dark gray area, the firm prefers to set a high price of v_h. The light gray area refers to combinations under which the firm sets an intermediate price of v_n, while for all other constellations (white area) a low price of v_l maximizes expected profits.

[23] For less skewed type distributions (higher q) and/or smaller differences between the willingnesses to pay v_H and v_L, the basic pricing decision remains qualitatively unchanged. However, the low-quality firm might never set a high price of v_h, unlike under the given parametrization.

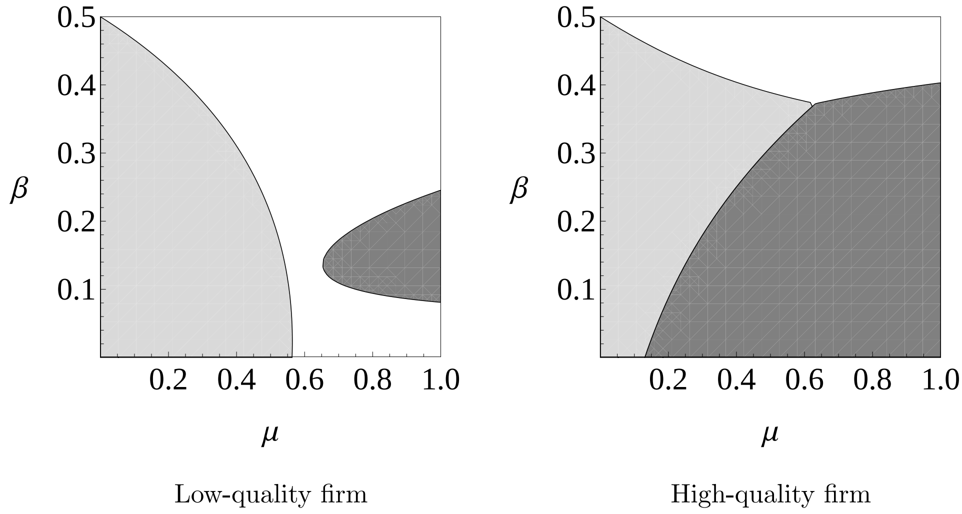

Figure 2.1: Illustration of type-dependent pricing decisions

For small values of μ, i.e., reviews hardly being available and consumers usually being uninformed, the firm prefers charging the intermediate price v_n which reflects the "average" willingness to pay, given consumers' ex-ante beliefs (unless β is close to 0.5, i.e., reviews are uninformative). For large values of μ and a relatively small error probability β, reviews exhibit their segregating effect: the low-quality firm charges a low price of v_l, and the high-quality firm charges a high price of v_h. If reviews are likely to be available (μ sufficiently large) but very noisy (large level of β close to 0.5), both firm types prefer charging a low price, serving consumers irrespective of the review outcome; for such levels of β, the difference between the three potential prices is relatively small, and the gains from a higher margin at a higher price do not offset the expected loss due to consumers being less likely to buy at such a higher price.

Given the skewed type distribution ($q = 0.2$) and the large difference between v_H and v_L, the low-quality firm faces strong incentives to set a high price if reviews are likely to be available (μ large) and sometimes misleading (moderate to intermediate level of β). In this special case (already mentioned in the analysis), a misleading review is sufficiently likely to occur while the high price v_h still remains sufficiently large to be more profitable than other prices.

Finally, note that Figure 2.1 reconfirms Proposition 2.4 as the shaded areas indicating the pricing decisions of the low-quality type are smaller and/or lighter than the respective regions for the high-quality type: whenever the low-quality firm prefers a higher price, the high-quality firm also does.

Figure 2.2 depicts the underlying optimal advertising levels for an error probability of $\beta = 0.1$. The high-quality firm's advertising decision is described by the dashed line, and the low-quality firm's advertising level is characterized by the solid line. Note that the points of discontinuity coincide with the levels of μ at which the respective firm type is indifferent between two price levels, cf. the borders of the shaded areas in Figure 2.1.

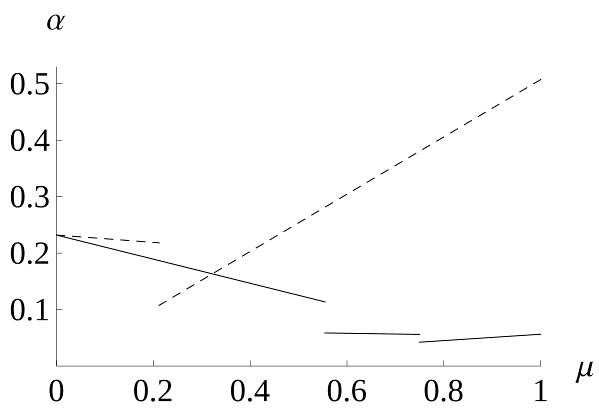

Figure 2.2: Illustration of optimal advertising levels ($\beta = 0.1$)

For small levels of μ, both firm types set a price of v_n, the high-quality firm advertises more than the low-quality firm,[24] and the optimal advertising level decreases in μ due to the substitutive effect between advertising and reviews as existence information and reviews potentially indicating low quality (cf. Proposition 2.2).

For levels of $\mu > 0.212$, the high-quality firm prefers charging a high price of v_h while the low-quality firm keeps charging $p = v_n$ (as long as $\mu < 0.554$). For levels of μ around 0.25, the low-quality type advertises more than the high-quality type. However, at a price of $p = v_h$, the high-quality firm's advertising level is increasing in μ (in particular as γ is relatively small) and exceeds the low-quality firm's advertising level again for higher levels of μ. Hence, as indicated by Corollary 2.1, the relationship between product quality and advertising is ambiguous, in particular due to price differences between types varying with parameter constellations.

[24]Note that both firm types face the same expected profit function if $\mu = 0$ (no reviews available), resulting in identical optimal advertising levels. However, for higher values of μ, the high-quality firm advertises strictly more than the low-quality firm at a price of v_n, cf. Lemma 2.1.

2.2.4 Discussion

Firstly, previous empirical literature suggests a substitutive effect between product reviews and advertising as both create awareness about product existence. Secondly, a review may provide useful information on product quality, creating a "segregating" effect as the high-quality firm is more likely to face a favorable review than the low-quality firm. Although previous theoretical literature already included these effects and also allowed for imperfect competition, review information was restricted not to be misleading. Furthermore, previous studies highlighted scenarios in which the high-quality firm and the low-quality firm set the same price, analyzing the optimal response on certain review outcomes.

In contrast, within the monopoly framework introduced so far, I focus on the effects of *future* product reviews (products are likely to be discussed shortly after their introduction, either by "professional" reviewers or early adopters) rather than reactions on past reviews. Furthermore, I relax the assumption on reviews never being misleading, allowing for a firm anticipating future *noisy* information about product quality when choosing its initial price and advertising level.

Assuming that reviews remain informative, the high-quality firm always faces a higher level of expected demand than the low-quality firm at any given price, resulting in a higher optimal advertising level if both firm types charge the same price. However, the relationship between price and optimal advertising level might not be monotone, and the relationship between review availability and the optimal advertising level depends on price. Hence, although the high-quality firm never sets a lower price than the low-quality firm, the low-quality firm's optimal advertising level may be higher than the high-quality firm's level as the optimal prices differ across qualities for certain parameter constellations.

While the formal conditions given in Lemmas 2.4 to 2.9 indicate whether the firm prefers a certain price over another price, depending on true product quality, review availability, and the probability for reviews being misleading, section 2.2.3 summarizes these findings, illustrating the impact of true product quality and review technology on the firm's optimal pricing (and advertising) decisions.[25] In particular, the firm's price choice does not differ across qualities if reviews are unlikely to be

[25] Although the illustration is based on a specific parameter constellation, the main qualitative insights also remain valid under different parametrizations.

available (segregating effect is very weak) or likely to be misleading. If reviews are relatively likely to be available, the high-quality firm prefers to charge a high price unless the error probability is very high. Nevertheless, with reviews being likely to be available, it might also be optimal for the low-quality firm to charge a high price under certain parameter constellations (particularly characterized by a small to intermediate level of the error probability, a large difference between consumers' full-information valuations and a skewed initial type distribution). However, higher review availability usually creates incentives for a price decrease in case of low product quality and a price increase in case of high product quality (starting from an intermediate price which is optimal for both types in absence of reviews).

Although the probability for reviews being available intuitively explains the segregating effect, i.e., the high-quality firm facing stronger incentives to charge a high price than the low-quality firm, my analysis indicates that the probability for reviews being misleading strongly affects the extent of this segregating effect, and, in addition, can explain the low-quality firm charging a high price even if reviews are always available.

As I focus on a firm anticipating future reviews, my analysis also provides an explanation for a positive relationship between introductory price and product quality even if reviews are actually not available (i.e., the actual review realization being non-availability despite an intermediate probability for reviews being available).

This positive price-quality relationship is due to the firm's expected profits fulfilling an "increasing-differences" property with respect to prices (cf. Proposition 2.4). Besides reviews being informative, this result relies on production costs being equal across firm types. In particular, if the high-quality firm did not only produce a high-value product, but also faced lower production costs than the low-quality firm, the monotone relationship between quality and optimal price would no longer hold. This can be understood as follows: if the low-quality firm faces higher marginal costs, this reduces its margin at any given price, increasing incentives to charge a higher price compared to the previous situation with low (zero) marginal costs. Hence, the low-quality firm sets a higher price than the high-quality firm under certain parameter constellations, in particular if the error probability and the difference in production costs are relatively large. However, high production costs also reduce the marginal revenue from advertising at any given price, impairing advertising incentives and resulting in lower advertising levels.

Finally, at least two caveats remain: firstly, given that the firm's price choice depends on true quality, it might be reasonable to consider price signaling, i.e., consumers potentially inferring quality from the firm's pricing decision. Secondly, given the anecdotal and empirical evidence on reviews sometimes not only being (randomly) noisy but biased due to certain actions or investments of the firm, a (stylized) endogenous decision on such manipulation practices seems interesting, in particular in combination with an endogenous pricing decision, extending the insights gained in the theoretical literature so far.

2.3 Manipulable information with price as a quality signal

In this part, I set up a (modified) framework which allows for prices signaling product quality. In order to simplify the analysis, I now assume that all consumers are informed about product existence, but product quality is unknown prior to purchase. However, the monopolistic seller can still invest in marketing (e.g. advertising campaigns); motivated by the evidence and the related theoretical studies mentioned above, these investments are assumed to alter the type-dependent probability distribution which determines availability and/or indicated quality level of a product review. Some consumers (credulously) respond to product reviews while others do not have access to this kind of information or do not trust reviews. This latter segment of consumers interprets price as a signal, being aware of the monopolist's opportunity to influence product reviews and other consumers' decision making processes. However, in contrast to previous literature which presumes that advertising investments and prices jointly signal product quality, I assume that consumers cannot observe the firm's marketing investments.[26]

In the following, I firstly introduce the framework. Within the analysis, I start by explaining a simple benchmark case in which (non-manipulated) reviews are perfectly informative. Afterwards, I focus on certain equilibria with "undistorted"

[26]For example, DRPR (2012) indicates that several prominent firms (including Deutsche Bahn and Mercedes-Benz) indeed invested in concealed marketing campaigns, manipulating online communication. Harmon (2004) and Blasco and Sobbrio (2012) provide further anecdotal evidence on sellers' providing effort to attain favorable reviews and news coverage.

prices. Although I do not strive for a detailed analysis of all potential equilibria, my results illustrate that several type-dependent pricing decisions can be rationalized (depending on the actual parameter constellation) by a firm's anticipating manipulable product reviews when prices are interpreted as signals of quality.[27] In particular, a high-quality firm may set a lower price than a low-quality firm, even in absence of repeat purchases.

2.3.1 Framework

As in the previous setup, a monopolist sells a single experience good of unknown quality $Q \in \{L, H\}$ (assigned by nature with a probability q for high quality H), facing linear production costs normalized to zero. The seller now takes a binary decision on marketing investments: either he spends a fixed amount of $A > 0$, or he does not invest in marketing. Investing A affects the probability distribution which determines the review outcome (defined below) in favor of the seller.

All consumers are informed about product existence, but not about the product's true quality. As before, I assume that there is a unit mass of consumers. Under perfect information, consumers would be willing to pay v_H for one unit of the high-quality product and $v_L \in [0, v_H)$ for one unit of the low-quality product.

As consumers cannot observe true product quality prior to purchase, they base their buying decisions upon the observation of a product review and the price that is set by the monopolist. Consumers are assumed to be heterogeneous: on the one hand, a fraction γ is review-sensitive;[28] these consumers are credulous (or overconfident) in the sense that they always trust the review outcome, taking the quality indicated by the review (if received) for granted. In particular, they do not consider reviews being biased (e.g. as they are not aware of the seller's manipulation opportunity).[29] On the other hand, the remaining fraction of $1 - \gamma$ solely interprets

[27] Note that many firms indeed consider signaling as one of the main objectives of their pricing strategies, cf. e.g. Rao and Kartono (2009).

[28] Note that the notation "γ" is used slightly different in the first part, although γ there also captures the size of the segment of "review-sensitive" consumers.

[29] Examining consumer decision-making in retail investment services, Chater, Huck, and Inderst (2010) find that the majority of consumers mostly or completely trust the advice that they receive, ignoring that most advisors face conflicts of interest and may provide biased recommendations.

price as a signal of quality, not taking into account the realized review outcome.[30] I assume that these consumers cannot observe whether the seller invests in manipulative marketing activities, too. However, they are aware of the seller's opportunity to influence product reviews and the other segment of consumers acting credulously in response to reviews.

Consequently, review-sensitive consumers from segment γ are willing to pay a high price of v_H if they receive a positive review that indicates high quality (h). In reverse, they are willing to pay at most v_L if they observe a negative review that indicates low quality (l). If they receive no review at all (or an ambiguous review which does not assert a specific quality level), they build expectations on true quality by using the prior probability q; I presume that they have a willingness to pay of $v_n \equiv q \cdot v_H + (1-q) \cdot v_L$ in this case. The remaining consumers (belonging to the fraction of $1-\gamma$) are willing to pay v_n in a pooling equilibrium (i.e., if both seller types set the same price). In a separating equilibrium, these consumers correctly identify the product's true quality through the observed price. Thus, their willingness to pay corresponds to the one under perfect information.

Without any attempts of the seller to influence the review outcome (i.e., not investing in marketing activities), the probabilities of the three possible review outcomes h, l, and n depend on true product quality as follows: if true product quality is high (H), the probability of a (warrantable) positive review is q_H while the probability of a negative review is zero. Consequently, with a probability of $1-q_H$ there is no clear indication of quality (no review). In contrast, the probability of availability of a review that correctly indicates low quality (i.e., if product quality is low) is denoted by q_L. I assume that in this case (quality L) the probability of a positive review is zero, and, therefore, the probability of the neutral outcome is $1-q_L$.

As the seller has the opportunity of manipulating the distribution that determines the review outcome, I need to specify how the unbiased distribution changes due to the seller's investment of A. I assume that the seller of a high-quality product obtains a positive review for sure if he invests A. An investment in manipulative marketing by the low-quality seller changes the review distribution as follows: negative reviews are completely prevented (probability q_L is reduced to zero), the probability of attaining a positive review becomes $q_{h,L}$, and the probability of a neutral (or no)

[30] In order to simplify the analysis, I do not include consumers who react to both sources of information simultaneously, excluding processing of multiple signals.

review changes to $1 - q_{h,L}$.[31]

I assume that all consumers receive one common review. However, the probabilities just defined can also be interpreted as fractions of (review-sensitive) consumers if each consumer receives one review and review outcomes differ across consumers according to the specified distribution.

In summary, investing A encourages truthful positive reviews in case of a high-quality product. In contrast, in case of a low-quality seller, such investments result in a bias of the review outcome, spuriously improving the evaluation of product quality. Thus, the opportunity of manipulating reviews constitutes a special kind of moral hazard problem.

The timing of the game corresponds to the timing in the previous framework (given at the end of section 2.2.1). However, in the final stage, consumers decide whether to buy the product only based on review outcome and/or price (depending on the segment they belong to), but not on (unobservable) marketing investments.[32] As before, the seller cannot discriminate between consumers from different segments.

2.3.2 Analysis

2.3.2.1 Equilibrium concept

Within the following analysis, I solve the game for Perfect Bayesian Nash Equilibria.[33] Given the assumptions on consumer behavior and non-observability of the monopolist's investment decision, it seems reasonable to use the following specification of this concept:

[31] These probability changes are relatively extreme but simplify the analysis. With a less extreme impact, manipulation would be less attractive to the seller; however, my results remain qualitatively unchanged as long as the low-quality firm can achieve a positive review with a probability greater than q_H, cf. the discussion of the "most extreme" Proposition 2.8.

[32] I abstract from any reputational concerns of the seller or the (exogenous) reviewing party. In particular, this seems reasonable for previously unknown firms who offer a single "durable" product (no repeat purchases) and reviews that are posted anonymously (e.g. online consumer reviews). For an analysis of (non-anonymous) experts facing conflicts of interests, cf. e.g. Bourjade and Jullien (2010), Durbin and Iyer (2009), and Inderst and Ottaviani (2009).

[33] Note that within the given framework, the concept of Perfect Bayesian Nash Equilibrium is equivalent to the concept of Sequential Equilibrium, cf. e.g. Fudenberg and Tirole (1991).

– Given consumers' beliefs, the seller chooses a strategy from his strategy space

$$\{((p_L, \alpha_L), (p_H, \alpha_H)) \mid p_L, p_H \in [0, \infty);\ \alpha_L, \alpha_H \in \{0, A\}\}$$

which maximizes his expected profit for each type $Q \in \{L, H\}$.

– Review-sensitive (credulous) consumers from segment γ pursue the following inherent strategy: buy the product if and only if the observed price p does not exceed v_i, where $i \in \{l, n, h\}$ refers to the review outcome, $v_l = v_L$, and $v_h = v_H$.[34]

– Consumers from segment $1 - \gamma$ (who interpret price as a signal) decide as follows: buy the product if and only if the price p charged by the firm fulfills

$$p \leq \lambda(p|p_L, p_H) \cdot v_H + (1 - \lambda(p|p_L, p_H)) \cdot v_L$$

with belief $\lambda(p|p_L, p_H)$ (probability attributed to high-quality type) as specified below.

– For equilibrium prices $p \in \{p_L, p_H\}$, beliefs of consumers from segment $1 - \gamma$ fulfill the following criteria:

  – if $p_L \neq p_H$, $\lambda(p_H|p_L, p_H) = 1$, and $\lambda(p_L|p_L, p_H) = 0$;
  – if $p_L = p_H = p$, $\lambda(p|p_L, p_H) = q$.

– For $p \notin \{p_L, p_H\}$, $\lambda(p|p_L, p_H)$ captures out-of-equilibrium beliefs which may take any arbitrary probability.[35]

Given homogeneity within the two consumer segments and each consumer taking a binary buying decision, it turns out to be useful to define the highest out-of-equilibrium ("deviation") price at which consumers from segment $1 - \gamma$ decide to buy. Defining a set

$$S_d(\lambda(\cdot), p_L, p_H) \equiv \{p \mid p \leq \lambda(p|p_L, p_H) \cdot v_H + (1 - \lambda(p|p_L, p_H)) \cdot v_L,\ p \notin \{p_L, p_H\}\}$$

[34] Less "overconfident" (but non-Bayesian) consumers could also use a rule of thumb with $v_h \in (v_n, v_H)$, cf. the potential extension mentioned in the discussion.

[35] During the following analysis, I will specify conditions on out-of-equilibrium beliefs and sometimes exclude certain "implausible" constellations.

for given prices p_L, p_H, and a belief-function $\lambda(\cdot)$,[36] this price can be specified as

$$p_d(\lambda(\cdot), p_L, p_H) \equiv \begin{cases} \max S_d(\lambda(\cdot), p_L, p_H) & \text{if } S_d(\lambda(\cdot), p_L, p_H) \neq \emptyset, \\ v_L, & \text{else.} \end{cases}$$

In particular, if the probability that consumers attribute to the high-quality type does not exceed the prior probability q at any out-of-equilibrium price $p \notin \{p_L, p_H\}$, the price $p_d(\lambda(\cdot), p_L, p_H)$ cannot exceed v_n.[37]

2.3.2.2 Benchmark case and basic manipulation principles

Before discussing potential equilibria which include manipulation of reviews, it seems useful to explain the basic underlying signaling principle with unbiased, perfectly informative reviews.

Lemma 2.10 (Full-information pricing with perfectly informative reviews)**.** *If reviews are perfectly informative ($q_L = q_H = 1$), full-information pricing (i.e., $p_L = v_L$ and $p_H = v_H$) constitutes an equilibrium if $1 - \frac{v_L}{v_H} \leq \gamma$ and the costs A of review manipulation are prohibitively high.*

If $q_H = q_L = 1$, the segment γ of review-sensitive (credulous) consumers is perfectly informed about product quality (without manipulation). Consequently, the high-quality type would never invest A as the review indicates high quality for sure. For sufficiently high values of A (i.e., if changing the review distribution is very costly) the low-quality type also refuses from investing A although the investment would avoid disclosing the true quality level to the segment of credulous consumers.[38] If the size γ is sufficiently large (measured by the relative difference of consumers' valuation for different qualities), the low-quality firm neither imitates the high-quality firm nor charges any other price which would both result in losing

[36] In the following, I drop the belief argument for convenience of notation.

[37] More generally, $p_d(\lambda(\cdot), p_L, p_H)$ does not exceed v_n if $\lambda(p|p_L, p_H) < \frac{p - v_L}{v_H - v_L}$ for prices $p > v_n$. Hence, as $\frac{v_n - v_L}{v_H - v_L} = q$, consumers may be even more "optimistic" at prices above v_n, attributing a higher probability to the high-quality type than the prior probability q, while still refusing to buy.

[38] A sufficient condition for manipulation not being profitable would be $A > \gamma \cdot (v_H - v_L)$.

all buyers from the informed segment γ.[39]

Given the assumptions on the review technology and the impact of the seller's potential manipulation activity, some basic facts on the type-dependent manipulation decision can be stated (given the seller's respective price in a potential equilibrium):

Lemma 2.11 (Seller's decision on manipulating reviews)**.**

(i) Manipulating reviews is never profitable when charging a low price of v_L.

(ii) A high-quality seller never manipulates reviews when charging a price $p_H \leq v_n$.

(iii) A low-quality seller always manipulates reviews when charging a price $p_L > v_n$.

Firstly, at a price of v_L, all consumers buy, regardless of the review outcome. Secondly, given the unbiased distribution from which the review outcome is drawn, all review-sensitive consumers buy if the true quality is high (the review never indicates low quality) and price does not exceed v_n.[40] Thirdly, the low-quality seller has to invest in review manipulation if he charges a price strictly above v_n: credulous consumers from segment γ only buy after receiving a positive review (which happens with zero probability without manipulation), while the remaining consumers who interpret price as a signal never buy at such prices (neither in a pooling equilibrium nor in a separating equilibrium).

Beyond these cases, the seller explicitly compares the gains from manipulating reviews with its costs. If the high-quality seller invests A, he acquires an additional consumer mass of $\gamma \cdot (1 - q_H)$, generating additional revenues of $\gamma \cdot (1 - q_H) \cdot p_H$ (depending on his price $p_H > v_n$). By investing A, the low-quality seller prevents negative reviews. Hence, if $p_L \leq v_n$, he supplies an additional mass of $\gamma \cdot q_L$ consumers, increasing his revenue by $\gamma \cdot q_L \cdot p_L$.

2.3.2.3 Informative pricing: separating equilibria

First of all, it seems useful to describe the set of reasonable candidate prices. Firstly, prices above v_H and prices below v_L cannot be optimal for any seller type: no

[39] Given $q_L = 1$ and A being prohibitively high, the low-quality firm's best way to deviate is imitating the high-quality firm, regardless of out-of-equilibrium beliefs.

[40] Note that manipulation does not change imitation incentives of the other type as the two consumer segments are assumed to be disjunct.

consumer buys at prices above v_H, and at any price strictly below v_L, an infinitesimal price increase results in a higher margin without losing any buyers, regardless of true product quality. Secondly, given the behavior of the review-sensitive consumers belonging to segment γ, prices slightly above v_L or slightly above v_n seem little attractive unless out-of-equilibrium beliefs are very extreme. This can be understood as follows: starting with a price of v_n, any increase in price results in a discrete loss of expected demand from review-sensitive consumers. For prices slightly above v_L, the same principle applies to the the low-quality type's expected profit. Unless consumers who interpret price as a signal attribute a very low probability to the high-quality type at one of the price candidates, but a very high probability at prices slightly above the respective candidate (out-of-equilibrium), this reasoning explains why prices slightly above v_L or v_n are not profitable.

In the following, I focus on equilibrium candidates where the firm charges one of the "focal" prices v_L, v_n, or v_H (depending on its type),[41] starting with separating equilibria in which price reveals true product quality.

The pricing pattern introduced in Lemma 2.10, i.e., full-information pricing, may also arise as an equilibrium under less extreme parameter constellations than in the benchmark case. I analyze this equilibrium candidate under the belief restriction

$$\lambda(p|p_L = v_L, p_H = v_H) < \frac{p - v_L}{v_H - v_L} \quad \text{for} \quad p \in (v_n, v_H),$$

i.e., beliefs are such that $p_d(\cdot)$ does not exceed v_n (as argued at the end of section 2.3.2.1), and consumers who interpret price as a signal are not too optimistic and would not buy if they observed a price between v_n and v_H.[42]

[41]Note that most models that analyze price signaling assume (elastic) demand being continuous with an "endogenous" discontinuity due to the potential loss of demand from a fraction of perfectly informed consumers. In my model, expected demand exhibits more points of discontinuity, taking the form of a step function (due to the review technology and homogenous willingnesses to pay under full information) that suggests certain "focal" prices.

[42]In particular, this assumption is compatible with the idea behind several equilibrium refinements: the high-quality firm would never benefit from charging a price between v_n and v_H, even under the most favorable beliefs, as it could not attract any additional buyers by lowering its price (starting from v_H). Therefore, it seems reasonable that consumers do not attribute high probabilities to the high-quality type if they observe prices between v_n and v_H.

Defining

$$\pi_{LH}^{im} \equiv \max\{(1-\gamma)\cdot v_H,\ (1-\gamma\cdot(1-q_{h,L}))\cdot v_H - A\}$$

as the low-quality firm's profit from imitating the high-quality firm's pricing,

$$\pi_{Ln}^{dev} \equiv \max\{\gamma\cdot(1-q_L)\cdot v_n,\ \gamma\cdot v_n - A\}$$

as the low-quality firm's profit from deviating by setting a price of v_n, and

$$\pi_{Ld}^{dev} \equiv \max\{(1-\gamma\cdot q_L)\cdot p_d(\cdot),\ p_d(\cdot) - A\}$$

as the low-quality firm's profit from deviating by setting a price of $p_d(\cdot)$ for given beliefs, I can state the following result:

Proposition 2.5 (Separating 1: full-information pricing)**.**
If the following incentive compatibility constraints hold, there exists a separating equilibrium (with beliefs such that $p_d(\cdot) \leq v_n$) in which the high-quality firm sets a price of v_H and the low-quality firm sets a price of v_L:

$$\max\{(1-\gamma\cdot(1-q_H))\cdot v_H,\ v_H - A\} \geq \max\{p_d(\cdot),\ \gamma\cdot v_n\}, \tag{2.8}$$

$$v_L \geq \max\{\pi_{LH}^{im},\ \pi_{Ln}^{dev},\ \pi_{Ld}^{dev}\}. \tag{2.9}$$

The low-quality type does not manipulate reviews and supplies the whole market. The high-quality firm invests in manipulative marketing (to supply all consumers) if

$$\gamma\cdot(1-q_H)\cdot v_H > A.$$

Under the given incentive compatibility constraints, the high-quality firm neither charges a price of v_n (serving review-sensitive consumers), nor a price of $p_d(\cdot) \leq v_n$ (serving all consumers). The high-quality firm's constraint (2.8) is most likely to be fulfilled if γ and/or the costs of review manipulation are small. However, the low-quality firm's incentives to imitate the high-quality firm's pricing are decreasing in γ (similar to the logic illustrated in the benchmark case, cf. Lemma 2.10). Nevertheless, in contrast to the reasoning in the benchmark case with perfectly informative reviews, an increase in γ increases attractiveness of another deviation option for the low-quality firm: specializing on sales to credulous consumers from segment γ by charging a price of v_n. Consequently, if the probability q_L for unbiased reviews indicating low quality or the costs of review manipulation are small, this equilibrium is most likely to exist for *intermediate* levels of γ, but may fail to exist for very large levels. Moreover, for relatively optimistic out-of-equilibrium beliefs, i.e., $p_d(\cdot)$ close to v_n, and low manipulation costs A, the equilibrium fails to exist since then the low-quality firm's constraint (2.9) fails to hold as π_{Ld}^{dev} exceeds v_L.

While in the equilibrium that features full-information pricing a specialization on sales to review-sensitive consumers by the low-quality firm needs to be ruled out, an equilibrium may also be based on the low-quality firm serving only credulous consumers at an inappropriately high price.[43]

Proposition 2.6 (Separating 2: high-quality firm sets v_H, low-quality firm sets v_n)**.** *If the constraints*

$$\max\{(1-\gamma\cdot(1-q_H))\cdot v_H,\ v_H - A\} \geq \gamma\cdot v_n \tag{2.10}$$

and

$$\max\{\gamma\cdot(1-q_L)\cdot v_n,\ \gamma\cdot v_n - A\} \geq \max\{\pi_{LH}^{im},\ \pi_{Ld}^{dev},\ v_L\} \tag{2.11}$$

hold, there exists a separating equilibrium with beliefs such that $p_d(\cdot) \leq \gamma\cdot v_n$ in which the high-quality firm charges v_H and the low-quality firm (at most) serves review-sensitive consumers, charging a price of v_n. The high-quality firm invests in marketing if $\gamma\cdot(1-q_H)\cdot v_H > A$, while the low-quality firm manipulates reviews if $\gamma\cdot q_L\cdot v_n > A$.

In this equilibrium, the high-quality firm sells to both consumers who interpret price as a signal and consumers who received a positive review, while the low-quality firm only serves demand from review-sensitive consumers (who only buy if the review fails to reveal that the product is of low quality). Accordingly, beliefs of consumers from segment $1-\gamma$ are given by $\lambda(v_H|p_L = v_n, p_H = v_H) = 1$ and $\lambda(v_n|p_L = v_n, p_H = v_H) = 0$, while their out-of-equilibrium beliefs need to fulfill

$$\lambda(p|p_L = v_n, p_H = v_H) < \frac{p - v_L}{v_H - v_L} \quad \text{for} \quad p \in (\gamma\cdot v_n, v_H), p \neq v_n, \tag{2.12}$$

[43]Note that the incentive compatibility constraints of the two equilibria characterize disjunct parameter sets, i.e., the two equilibria described by Propositions 2.5 and 2.6 never coexist (also cf. Lemma 2.13).

i.e., consumers who interpret price as a signal attribute a relatively low probability to the high-quality type at prices above $\gamma \cdot v_n$.[44]

Condition (2.10) reflects the high-quality firm's incentive compatibility constraint. It is fulfilled if the costs A of review manipulation are sufficiently small or if the non-manipulated review distribution is such that (truthful) disclosure of high quality is very likely; otherwise, the high-quality firm would prefer imitating the low-quality type, specializing on review-sensitive consumers. Although the high-quality firm's incentives to deviate increase in the size of the review-sensitive segment γ, γ has to be relatively large for the low-quality firm's incentive compatibility constraint (2.11) to hold. Furthermore, for a specialization on (misled) review-sensitive consumers to be profitable, the probability q_L for reviews reporting low quality must be relatively low or manipulation must be relatively easy (i.e., A has to be relatively low), while the prior probability for high quality needs to be sufficiently high (resulting in a relatively high level of v_n).

Before explaining under which conditions another (more extreme) equilibrium can arise in which the low-quality firm always manipulates reviews, exploiting credulous consumers by charging a high price of v_H, while the high-quality firm prefers to charge a price of v_n, I examine another candidate equilibrium in which all consumers are served and both firm types do not invest in manipulative marketing.

Defining the low-quality firm's profit of imitating the high-quality type as

$$\pi_{Ln}^{im} \equiv \max\{(1-\gamma \cdot q_L) \cdot v_n,\ v_n - A\},$$

the following result can be stated:

Proposition 2.7 (Separating 3: high-quality firm sets v_n, low-quality firm sets v_L)**.** *Under the constraints*

$$v_n \geq \max\{\gamma \cdot q_H \cdot v_H,\ \gamma \cdot v_H - A\} \tag{2.13}$$

and

$$v_L \geq \max\{\pi_{Ln}^{im},\ \gamma \cdot q_{h,L} \cdot v_H - A\}, \tag{2.14}$$

[44] Note that the additional restriction on out-of-equilibrium beliefs for prices $p \in (\gamma \cdot v_n, v_n)$ neither violates the reasoning of basic equilibrium refinement methods (non-profitability of a certain action under the most favorable beliefs just for one type results in a high probability attributed to the other type) nor is implied by the basic refinement methods as both types may benefit from charging prices between $\gamma \cdot v_n$ and v_n.

there exists a separating equilibrium with beliefs such that $p_d(\cdot) \leq v_n$ in which the high-quality firm charges a price of v_n, the low-quality firm charges a price of v_L, and neither of both types invests in marketing.

The main intuition behind this equilibrium is similar to the logic applied in the separating equilibrium that features full-information pricing (characterized by Proposition 2.5). However, now, the high-quality firm does not set its full-information price, but serves all consumers with certainty without investing in marketing. On the one hand, this result can be driven by out-of-equilibrium beliefs which attribute sufficiently low probabilities to the high-quality type at prices above v_n.[45] On the other hand, charging v_n is also one of the two most profitable ways of deviating in the equilibrium given in Proposition 2.5 in which beliefs are more favorable for the high-quality type.[46]

The high-quality firm's incentive compatibility constraint (2.13) is most likely to be fulfilled for high levels of A and a low probability q_H of a review indicating high quality without being manipulated, or for a low size γ of review-sensitive consumers (who may also buy at prices above v_n). Under both conditions, charging a high price is relatively unattractive as expected demand is low. For the low-quality firm's incentive compatibility constraint (2.14) to hold, both γ and the probability for disclosure of low quality, i.e., q_L, must not be too small as otherwise imitation of the high-quality firm is most profitable. Furthermore, the costs of review manipulation have to be relatively high (and $q_{h,L}$ relatively small) in order to mitigate incentives to charge higher prices facilitated by manipulated reviews. Taken together, γ should take an intermediate level, A and q_L should be large, while q_H must not be too large for this equilibrium to exist.

The following equilibrium is based on the low-quality firm's utilizing the opportunity of review manipulation, specializing on sales to credulous consumers. Under

[45]The described pricing pattern can also constitute an equilibrium with less restrictive out-of-equilibrium beliefs, i.e., $p_d(\cdot) > v_n$. The corresponding incentive compatibility constraints can be found in the appendix within the proof of Proposition 2.7.

[46]In contrast to the previously described equilibria, the equilibria characterized in Propositions 2.5 and 2.7 can coexist under certain parameter constellations. While consumers are better off if the high-quality firm charges v_n (all consumers are served with certainty), the high-quality type's equilibrium profit may be higher or lower than under full-information pricing.

the conditions stated in Proposition 2.8, the low-quality firm charges a higher price than the high-quality firm that sells to both consumer segments; a high price signals low quality.[47]

Proposition 2.8 (Separating 4: high price signals low quality).
If both

$$v_n \geq \max\{\gamma \cdot q_H \cdot v_H,\ \gamma \cdot v_H - A\} \tag{2.15}$$

and

$$\gamma \cdot q_{h,L} \cdot v_H - A \geq \max\{\pi_{Ln}^{im},\ v_L\} \tag{2.16}$$

hold, there exists a separating equilibrium with beliefs such that $p_d(\cdot) \leq v_n$ in which the high-quality firm charges a price of v_n and the low-quality firm charges a price of v_H. The low-quality firm invests in manipulative marketing.

In equilibrium, the low-quality firm serves demand of the review-sensitive segment γ with probability $q_{h,L}$ for a (manipulated) review indicating high quality in case of true quality being low; the high-quality firm supplies all consumers with certainty, given beliefs $\lambda(v_n|p_L = v_H, p_H = v_n) = 1$ and $\lambda(v_H|p_L = v_H, p_H = v_n) = 0$.

Rewriting the low-quality firm's incentive compatibility constraint (2.16) as the combination of the conditions

$$\gamma \cdot q_{h,L} \geq \frac{v_n}{v_H} \quad \text{and} \quad A \leq \min\{\gamma \cdot (q_{h,L} \cdot v_H + q_L \cdot v_n) - v_n,\ \gamma \cdot q_{h,L} \cdot v_H - v_L\}$$

illustrates that both γ and $q_{h,L}$ have to be sufficiently large (measured by v_n, which is increasing in the prior probability q) while the costs of review manipulation, i.e., A, have to be relatively small for the equilibrium to exist.[48] Moreover, the (unbiased) probability q_L for a review correctly indicating low-quality must not be too small in order to prevent the low-quality type from imitating the high-quality type.

Comparing both types' incentive compatibility constraints, another necessary condition for equilibrium existence turns out to be $q_{h,L} \geq q_H$, i.e., the probability

[47] Again, the proposition focusses on the case in which out-of-equilibrium beliefs are such that $p_d(\cdot) \leq v_n$; the opposite case is mentioned in the appendix within the proof of Proposition 2.8. In both cases, the equilibrium never coexists with one of the separating equilibria derived in the previous propositions.

[48] For example, for the parameter constellation $v_H = 3$, $v_L = 1$, $q = 0.25$, $\gamma = 0.5$, $q_H = q_L = 0.5$, the equilibrium exists if the low-quality firm can achieve perfect manipulation ($q_{h,L} = 1$) at costs $A \leq \frac{3}{8}$.

of an unbiased review correctly indicating high quality must not be larger than the probability of a biased review erroneously indicating high quality, as otherwise imitation of the other type's pricing would be profitable to one of the types.

The following result delimits the set of further equilibrium candidates:

Lemma 2.12 (High-quality firm never charges a low price of v_L)**.**
Unless out-of-equilibrium beliefs are such that consumers who interpret price as a signal refuse to buy at all prices between v_L and v_n, the high-quality firm never charges a price of v_L in any equilibrium.

Under the given condition, the high-quality firm can always increase its price (starting from the candidate price v_L) without losing any customers. Hence, given any equilibrium candidate in which the high-quality firm sets a price of v_L, the high-quality firm faces incentives to increase its price above v_L.[49]

Consequently, there are no other separating equilibria that involve strategies based on the three "focal" prices, at least under the given condition on consumers' beliefs.

As argued before, several equilibria involving other prices (e.g. slightly above v_n) can only be supported by extreme (implausible) out-of-equilibrium beliefs. Although there may be also other (less implausible) equilibria, for example based on the high-quality firm reducing its full-information price in order to make imitation less attractive to the low-quality type,[50] the given propositions illustrate the main impact of (manipulable) reviews on the feasibility of prices effectively signaling product quality.

[49] Note that the high-quality firm faces stronger incentives to charge a price slightly above v_L than the low-quality firm if beliefs are such that consumers from segment $1 - \gamma$ buy at these prices (the low-quality firm loses a discrete mass of (expected) demand from segment γ or needs to invest in review manipulation when increasing its price above v_L). Hence, beliefs violating the given condition seem implausible.

[50] For example, the high-quality firm charging $v_H - \varepsilon$ and the low-quality firm charging v_L may constitute an equilibrium in which the low-quality firm faces less incentives to imitate the high-quality firm compared to the full-information pricing equilibrium discussed in Proposition 2.5.

2.3.2.4 Pooling equilibria

While the previous section focussed on separating equilibria in which consumers can infer true product quality from the firm's pricing decision, this section is dedicated to pooling equilibria in which both firm types set the same price. While review-sensitive consumers (segment γ) exclusively base their buying decision on the review outcome, the remaining consumers who interpret price as a signal are willing to pay v_n in equilibrium, reflecting the initial type distribution. Hence, the most natural equilibrium candidate is characterized by both types charging a price of v_n:

Proposition 2.9 (Pooling 1: both firm types charge intermediate price)**.**
Both firm types charging a price of v_n constitutes an equilibrium with beliefs such that $p_d(\cdot) \leq v_n$ if

$$v_n \geq \max\{\gamma \cdot q_H \cdot v_H,\ \gamma \cdot v_H - A\} \tag{2.17}$$

and

$$\max\{(1 - \gamma \cdot q_L) \cdot v_n,\ v_n - A\} \geq \max\{\gamma \cdot q_{h,L} \cdot v_H - A,\ v_L\}. \tag{2.18}$$

The high-quality type never invests in marketing, while the low-quality type manipulates reviews if $\gamma \cdot q_L \cdot v_n > A$.

For the high-quality firm's incentive compatibility constraint (2.17) to hold, γ has to be relatively small or reviews indicating high quality must be sufficiently unlikely (small value of q_H) while review manipulation is very costly (high level of A), as otherwise the high-quality firm prefers specialization on sales to review-sensitive consumers at a high price.

With respect to γ, a similar reasoning applies to the low-quality firm's incentives: if γ (and q_L) were relatively large while review manipulation is attractive (i.e., the costs A are relatively small and the probability for a manipulated review indicating high quality, $q_{h,L}$, is sufficiently large), the firm would deviate by charging a high price, manipulating reviews. Furthermore, if the expected number of correctly informed consumers $\gamma \cdot q_L$ was relatively large and the costs of review manipulation high, charging a low price of v_L would be profitable to the low-quality type. Consequently, in line with the intuition of the basic idea of price signaling with a segment of informed consumers, the number of review-sensitive ("informed") consumers must not be too large for this pooling equilibrium to exist.[51] Furthermore, both firm types do not face strong incentives to deviate if the prior probability for high quality is relatively large, since then v_n is relatively close to v_H.

Besides the "generic" pooling equilibrium described in the previous proposition, with a sufficiently large segment of (credulous) review-sensitive consumers another atypical pooling equilibrium may arise in which consumers who interpret price as a signal refuse to buy:

Proposition 2.10 (Pooling 2: firm only serves review-sensitive consumers)**.** *Both firm types charging a price of v_H constitutes an equilibrium with out-of-equilibrium beliefs such that $p_d(\cdot) \leq v_n$ if*

$$\max\{\gamma \cdot v_H - A,\ \gamma \cdot q_H \cdot v_H\} \geq \max\{p_d(\cdot),\ \gamma \cdot v_n\} \tag{2.19}$$

and

$$\gamma \cdot q_{h,L} \cdot v_H - A \geq \max\{\pi_{Ld}^{dev},\ \pi_{Ln}^{dev},\ v_L\}. \tag{2.20}$$

The low-quality firm manipulates reviews, while the high-quality firm invests in marketing only if $\gamma \cdot (1 - q_H) \cdot v_H > A$.

In this equilibrium, beliefs fulfill $\lambda(v_H | p_L = v_H, p_H = v_H) = q < 1$. Hence, only review-sensitive consumers buy – conditional on receiving a review indicating high product quality. Therefore, the low-quality firm needs to invest in review manipulation. For its incentive compatibility constraint (2.20) to hold, review manipulation has to be highly effective (large level of $q_{h,L}$ and low costs A). Furthermore, the initial probability for high quality (which positively affects v_n) should be relatively low, as otherwise serving review-sensitive consumers at a price of v_n is more profitable than sales that rely on receiving a positive review. For small levels of A, also the high-quality firm's constraint (2.19) is likely to be fulfilled. Nevertheless, it is even more profitable for the high-quality firm not to manipulate reviews if the probability for truthful disclosure of its quality, i.e., q_H, is relatively large.

[51] For a brief discussion on the role of out-of-equilibrium beliefs on existence of this equilibrium, see the modified incentive compatibility constraint given in the appendix within the proof of Proposition 2.9.

Having established these two pooling equilibria, it seems useful to discuss whether further pooling equilibria can arise. Firstly, given Lemma 2.12, both firm types charging a price of v_L can only be supported by relatively extreme out-of-equilibrium beliefs. Secondly, pooling equilibria based on the firm charging a price between v_n and v_H cannot exist: at these prices, only review-sensitive consumers are served; under the given review technology, both firm types face incentives to increase their price up to v_H (without losing any expected demand). Thirdly, under certain out-of-equilibrium beliefs, pooling equilibria involving prices between v_L and v_n can exist. However, all these equilibria are driven by out-of-equilibrium beliefs that exhibit a certain discrepancy: all consumers from segment $1-\gamma$ would also buy at a higher price (not exceeding v_n) if both firm types charged such a higher price in equilibrium. Hence, from the firm's perspective, these equilibria are "dominated" by the pooling equilibrium described in Proposition 2.9.

2.3.2.5 Coexistence of different equilibria

Taking a closer look at the parameter restrictions implied by the incentive compatibility constraints stated in the previous propositions, I arrive at the following result:

Lemma 2.13 (Coexistence of equilibria)**.**
Unless at least two of the low-quality firm's incentive compatibility constraints (originating from different Propositions) jointly hold with equality, the following findings are true:

(i) For certain parameter constellations, the "atypical" pooling equilibrium characterized in Proposition 2.10 and the "inverse" separating equilibrium characterized in Proposition 2.8 coexist, but each of these two equilibria never coexists with any of the other equilibria given in Propositions 2.5, 2.6, 2.7, and 2.9.

(ii) The separating equilibria characterized in Propositions 2.5 and 2.6 never coexist.

(iii) The separating equilibrium characterized in Proposition 2.7 never coexists with the pooling equilibrium characterized in Proposition 2.9.

The given findings hold as long as the low-quality firm is not indifferent between different strategies – otherwise, two directly opposed conditions may jointly hold.

Firstly, the pooling equilibrium with both firms charging a high price of v_H, specializing on sales to credulous consumers, can never coexist with any of the other "regular" equilibria, as both firms could choose this specialization option in any equilibrium, regardless of consumers' beliefs, but for existence of the respective equilibrium, this option must not be profitable. Similarly, the "inverse" separating equilibrium which is based on the low-quality firm's specialization on sales to credulous consumers cannot coexist with any of the other "regular" equilibria as again such a specialization must not be profitable to the low-quality firm in those equilibria. However, depending on consumers' beliefs, the "atypical" equilibria may coexist.

Secondly, the full-information pricing equilibrium and the second separating equilibrium (the high-quality firm charging a price of v_H, the low-quality firm charging a price of v_n) cannot coexist, as in the latter equilibrium serving all customers at a low (full-information) price of v_L must not be profitable to the low-quality firm.

Thirdly, similarly to the previous argument, both firms charging an intermediate price of v_n can constitute an equilibrium only if the low-quality firm does not prefer to charge its full-information price, which conflicts with non-profitability of imitating the high-quality firm in the separating equilibrium that is characterized in Proposition 2.7.

However, apart from these insights on the incompatibility of the conditions for existence of certain (dissimilar) equilibria, other equilibria might coexist, depending on consumers' (out-of-equilibrium) beliefs. Although belief-based refinement methods oftentimes allow ruling out certain equilibria, the presence of review-sensitive consumers in combination with reviews being noisy (and manipulable) restrains these techniques.[52]

2.3.3 Discussion

Motivated by the previous finding that a firm facing noisy reviews may charge prices that are varying with product quality (in absence of any signaling considerations), this part allows for prices signaling quality when a firm faces both consumers

[52]In particular, under highly favorable out-of-equilibrium beliefs, deviating from certain equilibrium strategies may be profitable to *both* types or neither of them. Hence, there seems to be no uncontroversial way to restrict out-of-equilibrium beliefs.

who are review-sensitive and consumers who interpret price as a signal of quality and mistrust reviews. Furthermore, it allows for firms manipulating the (noisy) review outcome. Without any manipulation attempts, reviews either correctly indicate true product quality or are not available at all (the latter outcome may also be interpreted as an ambiguous review which does not clearly indicate one of the two extreme quality levels), while investing in review manipulation changes the review distribution in favor of the seller.

Considering that certain information sources (such as online reviews) are susceptible to (concealed) manipulation but also frequently consulted by many consumers when trying to assess product quality, it seems reasonable to assume that these review-sensitive consumers are sometimes informed about true product quality, but sometimes also misled by product reviews. This fact changes the firm's pricing incentives, partly in line with the signaling literature which illustrates that presence of a certain fraction of (correctly) informed consumers may facilitate prices effectively signaling quality. However, it also may explain why firms invest in concealed marketing activities as discussed by the extant theoretical studies. Bringing together these two strands of literature – studies on strategic manipulation of internet forums (which have abstracted away the firm's pricing decision so far) and studies on signaling with a segment of perfectly informed consumers –, the given stylized framework helps rationalizing several pricing and manipulation patterns.

Firstly, while without reviews being misleading full-information pricing constitutes a separating equilibrium if the fraction of review-sensitive (informed) consumers is sufficiently large (cf. Lemma 2.10), the respective incentive compatibility constraints become more demanding if reviews can be misleading. In particular, full-information pricing may no longer constitute an equilibrium if the difference between consumers' willingnesses to pay for different qualities is relatively large and many consumers are review-sensitive, as then a specialization on sales to these consumers (building on reviews which fail to reveal true product quality) may be more profitable to the low-quality firm than serving all consumers at a low price.

Secondly, depending on the review technology, other equilibria may arise. In the separating equilibria introduced above, the high-quality firm always serves consumers who interpret price as a signal of quality. However, applying a similar reasoning as the deviation considerations in case of the full-information pricing equilibrium, the low-quality firm may refuse to serve these consumers, specializing on sales to credulous (review-sensitive) consumers in equilibrium. Under relatively extreme conditions (review manipulation has to be highly effective at little costs), the low-quality firm charging a high price and the high-quality firm charging an intermediate price constitutes a separating equilibrium – a high price signals low quality. Under similar conditions, both firms specializing on sales to credulous consumers may constitute a pooling equilibrium. However, these "extreme" equilibria in which those consumers who interpret price as a signal refuse to buy at a high price never coexist with anyone of the other "regular" equilibria.

Given the two "irregular" equilibria, it should be mentioned that they rely on the presence of review-sensitive consumers who are overconfident (or credulous), taking an inherent buying decision based on the review outcome regardless of the firm's (unobservable) manipulation decision. Therefore, it might seem interesting to consider an extension with these consumers being less overconfident. In particular, review-sensitive consumers might apply a rule of thumb, taking into account that a positive review might be misleading. Such a behavior may result in a modified willingness to pay $\widetilde{v}_h$ after observing a positive review, lying somewhere between v_n and v_H (assuming that the rule of thumb is based on some moderate error probability). However, as long as $\widetilde{v}_h$ is calculated by a general rule of thumb which does not incorporate the firm's actual equilibrium decisions, the analysis remains basically (qualitatively) unchanged if v_H is exchanged by $\widetilde{v}_h$.

2.4 Conclusion

Given the development of information technologies, nowadays allowing easy access on manifold kinds of information on products and their alleged quality, and the evidence on consumers' use of these opportunities to collect information prior to purchase of a product, firms are likely to take third-party product information into account when making their pricing and marketing decisions. However, firms may also be aware of product reviews sometimes being misleading or potentially biased. On the one hand, they might passively account for features of the review technology when choosing strategic variables such as price or advertising level. On the other hand, they might also avail themselves of the opportunity of actively manipulating consumers' opinions, e.g. by participating in (online) discussions about product quality, or by hoping for favorable media coverage in response to certain donations or advertising investments.

However, existing studies on product reviews focus on firms' responses on perfectly reliable review information, not allowing for reviews being potentially misleading, firms anticipating review information, or product reviews facilitating price signaling. The extant work on strategic manipulation of consumers' product opinions allows for product reviews (or discussions) being biased, but abstracts away pricing decisions, while the literature that interprets prices as signals of product quality has examined firms' pricing decisions in presence of a segment of perfectly informed consumers. My work aims at bridging the gap between these strands of literature, providing new insights into the interdependencies between product reviews and a firm's pricing and marketing decisions.

Assuming that both advertising and product reviews inform about existence of otherwise unknown products and neglecting any signaling considerations, the first part of my study examines the impact of noisy product reviews on the relationship between true product quality and the firm's advertising and pricing decision. It turns out that prices often differ across qualities (in particular due to the "segregating" effect of product reviews). However, with reviews sometimes being misleading, a low-quality firm may prefer to set a high price under certain circumstances, even with consumers rationally updating their beliefs about product quality in response to receiving a review. The firm's advertising incentives depend on the underlying review technology; in particular, I find that the relationship between advertising and true product quality is ambiguous within the given framework.

Motivated by the result that optimal prices are likely to differ across qualities (in contrast to the cases highlighted by previous literature on product reviews), the second part allows for prices signaling product quality, although in a slightly modified framework. On the one hand, with product reviews being relatively reliable, the presence of review-sensitive consumers facilitates price signaling, similar to the results gained within the signaling literature. However, if review-sensitive consumers credulously respond to noisy review outcomes, the conditions under which full-information pricing can be supported in a separating equilibrium are more demanding. Furthermore, other equilibria can arise in which the low-quality firm specializes on sales to review-sensitive consumers or the high-quality firm lowers its full-information price not to suffer from reviews failing to reveal true product quality. Moreover, with reviews being manipulable through a certain investment by the firm, atypical pricing patterns can arise: both firms may charge a high price in a pooling equilibrium, specializing on sales to credulous consumers only, or a high price may signal low quality if the low-quality firm exploits its manipulation option. However, depending on susceptibility of certain media to misleading manipulation, a program against concealed marketing activities could also have negative effects: manipulation in favor of high-quality firms may be beneficial as it helps supporting desirable outcomes, leading to more accurate reviews and better informed consumers.

Taken together, both parts illustrate that existing results – gained under the assumption that reviews are perfectly informative – are robust against changes in the review technology, but only to a certain degree: similar pricing and advertising patterns can arise even if reviews can sometimes be misleading (prices being independent of product quality or full-information pricing). However, accounting for reviews being noisy uncovers and rationalizes several other patterns in both frameworks and helps identifying the impact of the review technology on a firm's decisions.

2.5 Appendix

Proof of Proposition 2.1

Given expected demand in Table 2.1, it is easy to see that an increase in γ always results in a decrease in marginal expected revenue from advertising (as $A(\alpha, \gamma) = \alpha + (1 - \alpha) \cdot \gamma$). For convex advertising cost functions, the marginal costs of advertising increase in the level of advertising. Hence, an increase in γ causes a decrease in the optimal advertising level, regardless of true product quality (formally, this fact follows directly from applying the implicit function theorem on the first order conditions w.r.t. α).

Proof of Proposition 2.2

At a price of $p = v_h$, the marginal expected revenue from advertising equals $\mu \cdot (1 - \beta) \cdot (1 - \gamma) \cdot v_h$ in case of high quality and $\mu \cdot \beta \cdot (1 - \gamma) \cdot v_h$ in case of low quality (cf. left-hand side of equations (2.1) and (2.2), respectively). Hence, it is increasing in μ, and the optimal advertising level is increasing in μ.

For $p = v_n$, the derivative of the marginal expected revenue from advertising w.r.t. μ equals $(-1 + (1 - \beta) \cdot (1 - \gamma)) \cdot v_n$ for the high-quality firm, and $(-1 + \beta \cdot (1 - \gamma)) \cdot v_n$ for the low-quality firm. For $p = v_l$, the respective derivative equals $(-1 + (1 - \gamma)) \cdot v_l$ (cf. equations (2.1) and (2.2)). Consequently, the derivative of the marginal expected revenue from advertising w.r.t. μ is always negative for $p \in \{v_n, v_l\}$, and an increase in review availability μ results in a decrease of the optimal advertising level.

Proof of Proposition 2.3

Along the same lines of the previous proofs, the effect of the error probability β follows directly from applying the implicit function theorem on the first order conditions (2.1) and (2.2) w.r.t. α for any fixed price.

Proof of Lemma 2.1

The fact that the high-quality firm advertises more at any given price follows directly from the first order conditions (or, from Table 2.1 which illustrates expected demand levels): at a high price $p \in (v_n, v_h]$, the marginal expected revenue is higher for the high-quality firm since $\beta < 0.5$ (a positive review is more likely in case of high quality). Consequently, also the marginal expected revenue at any price $p \in (v_l, v_n]$ is higher (consumers buy only if they received no review or a positive review). At a low price of $p \leq v_l$, consumers always buy if they are informed about product existence, regardless of indicated (or true) product quality. Therefore, both firm types face the same advertising incentives at $p \leq v_l$.

Proofs of Lemma 2.2 and Lemma 2.3

The optimal advertising levels follow directly from the first order conditions (2.1) and (2.2), taking into account that Assumption 2.1 implies $C'(\alpha) = k \cdot \alpha$.

Proof of Lemma 2.4

Condition (2.3) for v_h resulting in a higher profit than v_n, i.e.,

$$\frac{v_h}{v_n} > \frac{\left(a_n^H\right)^2 \cdot v_n + \gamma \cdot \mu \cdot (1-\beta) \cdot 2k}{\left(a_h^H\right)^2 \cdot v_h + \gamma \cdot \mu \cdot (1-\beta) \cdot 2k},$$

is equivalent to $B_1 \cdot \mu^2 + 2 \cdot B_2 \cdot \mu - 1 > 0$, with

$$B_1 = (1-\gamma)^2 \cdot (1-\beta)^2 \cdot \left(\frac{v_h}{v_n}\right)^2 - \{1-(1-\gamma)\cdot(1-\beta)\}^2,$$

and

$$B_2 = 1-(1-\gamma)\cdot(1-\beta) + \gamma \cdot (1-\beta) \cdot k \cdot \frac{v_h - v_n}{v_n^2}.$$

If $B_1 > 0$, the inequality can be rewritten as $\left(\mu + \frac{B_2}{B_1}\right)^2 > \frac{1}{B_1} + \left(\frac{B_2}{B_1}\right)^2$. As $\mu \geq 0$ and $B_2 > 0$, this condition is fulfilled if

$$\mu > -\frac{B_2}{B_1} + \sqrt{\frac{1}{B_1} + \left(\frac{B_2}{B_1}\right)^2}.$$

If $B_1 < 0$, the initial condition is equivalent to $\left(\mu + \frac{B_2}{B_1}\right)^2 < \frac{1}{B_1} + \left(\frac{B_2}{B_1}\right)^2$, or

$$\mu \in \left(-\frac{B_2}{B_1} - \sqrt{\frac{1}{B_1} + \left(\frac{B_2}{B_1}\right)^2},\; -\frac{B_2}{B_1} + \sqrt{\frac{1}{B_1} + \left(\frac{B_2}{B_1}\right)^2}\right).$$

It can be shown that the upper bound exceeds 1. Hence, as $\mu \leq 1$, the relevant condition is

$$\mu > -\frac{B_2}{B_1} - \sqrt{\frac{1}{B_1} + \left(\frac{B_2}{B_1}\right)^2}.$$

Proof of Lemma 2.5

The high-quality firm prefers charging v_n over charging v_l if

$$\left\{(1-\mu\cdot(\gamma+\beta\cdot(1-\gamma)))^2\cdot\frac{v_n}{2k}+\gamma\cdot\mu\cdot(1-\beta)\right\}\cdot v_n > \left\{(1-\gamma\cdot\mu)^2\cdot\frac{v_l}{2k}+\gamma\cdot\mu\right\}\cdot v_l.$$

Multiplying this inequality by $\frac{2k}{\mu^2\cdot(1-\gamma)^2\cdot v_n^2}$ and rearranging yields

$$\beta^2-2\beta\cdot\frac{\mu\cdot(1-\gamma)-\gamma\cdot\mu^2\cdot(1-\gamma)+\gamma\cdot\mu\cdot\frac{k}{v_n}}{\mu^2\cdot(1-\gamma)^2} > -\frac{(1-\gamma\cdot\mu)^2+\gamma\cdot\mu\cdot 2k\cdot\frac{v_n-v_l}{v_n^2}-(1-\gamma\cdot\mu)^2\cdot\frac{v_l^2}{v_n^2}}{\mu^2\cdot(1-\gamma)^2},$$

which is equivalent to $(\beta-B_3)^2 > B_3^2-B_4$, where

$$B_3=\frac{\mu\cdot(1-\gamma)-\gamma\cdot\mu^2\cdot(1-\gamma)+\gamma\cdot\mu\cdot\frac{k}{v_n}}{\mu^2\cdot(1-\gamma)^2},$$

and

$$B_4=\frac{(1-\gamma\cdot\mu)^2\cdot\left(1-\frac{v_l^2}{v_n^2}\right)+\gamma\cdot\mu\cdot 2k\cdot\frac{v_n-v_l}{v_n^2}}{\mu^2\cdot(1-\gamma)^2}.$$

As B_3 exceeds 1 and $\beta < 0.5$, the only relevant condition is $\beta < B_3-\sqrt{B_3^2-B_4}$.

Proof of Lemma 2.6

The high-quality firm prefers charging v_h over v_l if

$$\left\{((1-\gamma)\cdot\mu\cdot(1-\beta))^2\cdot\frac{v_h}{2k}+\gamma\cdot\mu\cdot(1-\beta)\right\}\cdot v_h > \left\{(1-\gamma\cdot\mu)^2\cdot\frac{v_l}{2k}+\gamma\cdot\mu\right\}\cdot v_l.$$

Multiplying this inequality by $\frac{2k}{\mu^2\cdot(1-\gamma)^2\cdot v_h^2}$ and rearranging yields

$$\beta^2-2\beta\cdot\left(1+\frac{\gamma\cdot k}{\mu\cdot(1-\gamma)^2\cdot v_h}\right) > \frac{(1-\gamma\cdot\mu)^2}{\mu^2\cdot(1-\gamma)^2}\cdot\frac{v_l^2}{v_h^2}-1-\frac{2k\cdot\gamma\cdot(v_h-v_l)}{\mu\cdot(1-\gamma)^2\cdot v_h^2},$$

which is equivalent to $(\beta-B_5)^2 > B_5^2-B_6$, where

$$B_5=1+\frac{\gamma\cdot k}{\mu\cdot(1-\gamma)^2\cdot v_h},$$

and

$$B_6=-\frac{(1-\gamma\cdot\mu)^2}{\mu^2\cdot(1-\gamma)^2}\cdot\frac{v_l^2}{v_h^2}+1+\frac{2k\cdot\gamma\cdot(v_h-v_l)}{\mu\cdot(1-\gamma)^2\cdot v_h^2}.$$

As $B_5>1$ and $\beta<0.5$, the relevant condition turns out to be $\beta < B_5-\sqrt{B_5^2-B_6}$.

Proof of Lemma 2.7

The low-quality firm prefers charging v_h over charging v_n if

$$\left\{((1-\gamma)\cdot\mu\cdot\beta)^2\cdot\frac{v_h}{2k}+\gamma\cdot\mu\cdot\beta\right\}\cdot v_h > \left\{((1-\mu)+(1-\gamma)\cdot\mu\cdot\beta)^2\cdot\frac{v_n}{2k}+\gamma\cdot\mu\cdot\beta\right\}\cdot v_n.$$

Multiplying by $2k$ and rearranging leads to

$$(1-\gamma)^2\cdot\mu^2\cdot(v_h^2-v_n^2)\cdot\beta^2+2\beta\cdot\left(\gamma\cdot\mu\cdot k\cdot(v_h-v_n)-(1-\mu)\cdot(1-\gamma)\cdot\mu\cdot v_n^2\right)>(1-\mu)^2\cdot v_n^2.$$

Dividing this expression by $(1-\gamma)^2\cdot\mu^2\cdot(v_h^2-v_n^2)$ yields

$$\beta^2+2\beta\cdot\frac{\gamma\cdot k\cdot(v_h-v_n)-(1-\mu)\cdot(1-\gamma)\cdot v_n^2}{(1-\gamma)^2\cdot\mu\cdot(v_h^2-v_n^2)}>\frac{(1-\mu)^2\cdot v_n^2}{(1-\gamma)^2\cdot\mu^2\cdot(v_h^2-v_n^2)},$$

which is equivalent to $(\beta+B_7)^2>B_7^2+B_8$, or $|\beta+B_7|>\sqrt{B_7^2+B_8}$, where

$$B_7=\frac{\gamma\cdot k\cdot(v_h-v_n)-(1-\mu)\cdot(1-\gamma)\cdot v_n^2}{(1-\gamma)^2\cdot\mu\cdot(v_h^2-v_n^2)},$$

and

$$B_8=\frac{(1-\mu)^2\cdot v_n^2}{(1-\gamma)^2\cdot\mu^2\cdot(v_h^2-v_n^2)}.$$

As B_7 can take positive and negative values, the condition cannot be reduced any further.

Proof of Lemma 2.8

The low-quality firm prefers charging v_n over charging v_l if

$$\left\{((1-\mu)+(1-\gamma)\cdot\mu\cdot\beta)^2\cdot\frac{v_n}{2k}+\gamma\cdot\mu\cdot\beta\right\}\cdot v_n > \left\{(1-\gamma\cdot\mu)^2\cdot\frac{v_l}{2k}+\gamma\cdot\mu\right\}\cdot v_l.$$

Multiplying by $2k$ and rearranging yields

$$\begin{aligned}&\left(-2\mu+\mu^2+2\cdot(1-\mu)\cdot(1-\gamma)\cdot\mu\cdot\beta+(1-\gamma)^2\cdot\mu^2\cdot\beta^2\right)\cdot v_n^2\\ &\quad+2k\cdot\gamma\cdot\mu\cdot(\beta\cdot v_n-v_l)-\left(-2\gamma\cdot\mu+\gamma^2\cdot\mu^2\right)\cdot v_l^2+v_n^2-v_l^2 \;>\; 0.\end{aligned}$$

Another rearranging leads to

$$\begin{aligned}&\mu^2\cdot\{(1-\beta\cdot(1-\gamma))^2\cdot v_n^2-\gamma^2\cdot v_l^2\}\\ -2\mu\cdot\{(1-(1-\gamma)\cdot\beta)\cdot v_n^2-k\cdot\gamma\cdot(\beta\cdot v_n-v_l)&-\gamma\cdot v_l^2\}>-(v_n^2-v_l^2),\end{aligned}$$

which is equivalent to

$$\mu^2-2\mu\cdot\frac{(1-(1-\gamma)\cdot\beta)\cdot v_n^2-k\cdot\gamma\cdot(\beta\cdot v_n-v_l)-\gamma\cdot v_l^2}{(1-\beta\cdot(1-\gamma))^2\cdot v_n^2-\gamma^2\cdot v_l^2}>-\frac{v_n^2-v_l^2}{(1-\beta\cdot(1-\gamma))^2\cdot v_n^2-\gamma^2\cdot v_l^2}.$$

With $B_9 = \frac{(1-(1-\gamma)\cdot\beta)\cdot v_n^2 - k\cdot\gamma\cdot(\beta\cdot v_n - v_l) - \gamma\cdot v_l^2}{(1-(1-\gamma)\cdot\beta)^2\cdot v_n^2 - \gamma^2\cdot v_l^2}$, and $B_{10} = \frac{v_n^2 - v_l^2}{(1-(1-\gamma)\cdot\beta)^2\cdot v_n^2 - \gamma^2\cdot v_l^2}$, this condition is equivalent to

$$(\mu - B_9)^2 > B_9^2 - B_{10}$$

(the denominator of B_9 is positive as $v_l \leq v_n$, $\gamma \leq 1$, and $\beta \leq 0.5$).

For $\beta < \frac{v_l}{v_n}$, B_9 exceeds 1 (this is shown below), and the only relevant part of this condition is

$$\mu < B_9 - \sqrt{B_9^2 - B_{10}}.$$

B_9 can be rewritten as follows:

$$B_9 = 1 + \frac{(1-\gamma)\cdot\beta\cdot v_n^2 - (1-\gamma)^2\cdot\beta^2\cdot v_n^2 - k\cdot\gamma\cdot(\beta\cdot v_n - v_l) - \gamma\cdot v_l^2 + \gamma^2\cdot v_l^2}{(1-(1-\gamma)\cdot\beta)^2\cdot v_n^2 - \gamma^2\cdot v_l^2}.$$

Hence, B_9 exceeds 1 if

$$(1-\gamma)\cdot\beta\cdot v_n^2 - (1-\gamma)^2\cdot\beta^2\cdot v_n^2 - k\cdot\gamma\cdot(\beta\cdot v_n - v_l) - \gamma\cdot v_l^2 + \gamma^2\cdot v_l^2 > 0,$$

which is equivalent to

$$v_n\cdot\beta\cdot\{(1-\gamma)\cdot v_n\cdot(1-(1-\gamma)\cdot\beta) - k\cdot\gamma\} + v_l\cdot\gamma\cdot\{k - (1-\gamma)\cdot v_l\} > 0,$$

or

$$\frac{\beta\cdot\{k\cdot\gamma - (1-\gamma)\cdot v_n\cdot(1-(1-\gamma)\cdot\beta)\}}{\gamma\cdot\{k-(1-\gamma)\cdot v_l\}} < \frac{v_l}{v_n}$$

(assuming $\gamma \neq 0$, the denominator is always positive, cf. Assumption 2.1).

As $1-(1-\gamma)\cdot\beta > \gamma$, this condition is fulfilled if

$$\frac{\beta\cdot\{k\cdot\gamma - (1-\gamma)\cdot v_n\cdot\gamma\}}{\gamma\cdot\{k-(1-\gamma)\cdot v_l\}} < \frac{v_l}{v_n} \;\Leftrightarrow\; \beta < \frac{v_l}{v_n}\cdot\frac{k-(1-\gamma)\cdot v_l}{k-(1-\gamma)\cdot v_n}.$$

Consequently, a sufficient condition for $B_9 \geq 1$ is given by $\beta \leq \frac{v_l}{v_n}$. This condition is always fulfilled if v_l is calculated based on Bayes' rule, i.e.,

$$v_l = \frac{\beta\cdot q}{(1-\beta)\cdot(1-q)+\beta\cdot q}\cdot v_H + \frac{(1-\beta)\cdot(1-q)}{(1-\beta)\cdot(1-q)+\beta\cdot q}\cdot v_L.$$

This can be seen as follows: The condition $\beta \leq \frac{v_l}{v_n}$ is most demanding for $v_L = 0$. Setting v_L equal to zero results in

$$\frac{v_l}{v_n} = \frac{\frac{\beta\cdot q}{(1-\beta)\cdot(1-q)+\beta\cdot q}\cdot v_H}{q\cdot v_H} = \frac{\beta}{(1-\beta)\cdot(1-q)+\beta\cdot q} \geq \beta.$$

For $\beta = 0$, $\frac{v_l}{v_n}$ equals 0. For $\beta = 0.5$, $\frac{v_l}{v_n}$ equals 1. For $q < 0.5$, $\frac{v_l}{v_n}$ is strictly convex and strictly exceeds β for $\beta > 0$. If $q = 0.5$, $\frac{v_l}{v_n}$ is linear. For $q > 0.5$, $\frac{v_l}{v_n}$ is strictly concave in β (strictly negative monotone second derivative w.r.t. β). Hence, it always exceeds β.

Proof of Lemma 2.9

Charging v_h is more profitable to the low-quality firm than charging v_l if and only if

$$\left\{((1-\gamma)\cdot\mu\cdot\beta)^2\cdot\frac{v_h}{2k}+\gamma\cdot\mu\cdot\beta\right\}\cdot v_h > \left\{(1-\gamma\cdot\mu)^2\cdot\frac{v_l}{2k}+\gamma\cdot\mu\right\}\cdot v_l.$$

Multiplying by $\frac{2k}{\mu^2\cdot(1-\gamma)^2\cdot v_h^2}$ yields

$$\beta^2+2\beta\cdot\frac{\gamma\cdot k}{\mu\cdot(1-\gamma)^2\cdot v_h} > \frac{(1-\gamma\cdot\mu)^2\cdot v_l^2+\gamma\cdot\mu\cdot 2k\cdot v_l}{\mu^2\cdot(1-\gamma)^2\cdot v_h^2},$$

which is equivalent to

$$(\beta+B_{11})^2 > B_{11}^2+B_{12},$$

where $B_{11}=\frac{\gamma\cdot k}{\mu\cdot(1-\gamma)^2\cdot v_h}$, and $B_{12}=\frac{(1-\gamma\cdot\mu)^2\cdot v_l^2+\gamma\cdot\mu\cdot 2k\cdot v_l}{\mu^2\cdot(1-\gamma)^2\cdot v_h^2}$. As $\beta\geq 0$, the relevant condition is $\beta>\sqrt{B_{11}^2+B_{12}}-B_{11}$.

Proof of Proposition 2.4

The following table illustrates the expected profits of both firm types for all relevant price levels:

Price	Exp. profit of high-quality firm	Exp. profit of low-quality firm
v_h	$\left\{\left(a_h^H\right)^2\cdot\frac{v_h}{2k}+\gamma\cdot\mu\cdot(1-\beta)\right\}\cdot v_h$	$\left\{\left(a_h^L\right)^2\cdot\frac{v_h}{2k}+\gamma\cdot\mu\cdot\beta\right\}\cdot v_h$
v_n	$\left\{\left(a_n^H\right)^2\cdot\frac{v_n}{2k}+\gamma\cdot\mu\cdot(1-\beta)\right\}\cdot v_n$	$\left\{\left(a_n^L\right)^2\cdot\frac{v_n}{2k}+\gamma\cdot\mu\cdot\beta\right\}\cdot v_n$
v_l	$\left\{\left(a_l^H\right)^2\cdot\frac{v_l}{2k}+\gamma\cdot\mu\right\}\cdot v_l$	$\left\{\left(a_l^L\right)^2\cdot\frac{v_l}{2k}+\gamma\cdot\mu\right\}\cdot v_l$

The advertising coefficients a_i^Q (cf. Lemmas 2.2 and 2.3) are as follows:

i	a_i^H	a_i^L
h	$(1-\gamma)\cdot\mu\cdot(1-\beta)$	$(1-\gamma)\cdot\mu\cdot\beta$
n	$(1-\mu)+(1-\gamma)\cdot\mu\cdot(1-\beta)$	$(1-\mu)+(1-\gamma)\cdot\mu\cdot\beta$
l	$1-\gamma\cdot\mu$	$1-\gamma\cdot\mu$

As $\beta<0.5$, the difference between two advertising coefficients of the high-quality firm for a higher and a lower price, i.e., $a_i^H-a_j^H$ with $v_i>v_j$, is (weakly) greater than the difference between the corresponding two coefficients of the low-quality firm, $a_i^L - a_j^L$. Furthermore, even if the differences between advertising coefficients are equal across types, the difference between two levels of the high-quality firm's expected profit (again, profit at a relatively high price minus profit at a lower price) exceeds the difference between the corresponding levels of the low-quality firm's expected profit (as $1 - \beta > \beta$). Therefore, for every choice between two prices, the high-quality firm prefers to set the higher price whenever the low-quality firm does.

Proof of Lemma 2.10

In the proposed separating equilibrium, the high-quality firm's expected profit equals v_H (review-sensitive consumers are perfectly informed and the remaining consumers correctly infer quality from their price observation, i.e., all consumers buy), and the low-quality firm's profit equals v_L. Hence, the high-quality firm does not face any incentives to deviate. The low-quality firm would deviate, imitating the high-quality firm, if $(1-\gamma) \cdot v_H \geq v_L$ (charging a high price and serving deluded consumers who try to infer quality from prices and ignore the review outcome is more profitable than serving all consumers at a low price). This condition is equivalent to $\gamma \leq 1 - \frac{v_L}{v_H}$. As reviews are assumed to be perfectly informative, for the low-quality firm any other deviation is less profitable than imitating the high-quality firm.

Proof of Lemma 2.11

The Lemma directly follows from the assumptions on the type-dependent distributions that determine the review outcome.

Proof of Proposition 2.5

Similar as in the benchmark case (Lemma 2.10), beliefs fulfill $\lambda(v_H|v_L, v_H) = 1$ and $\lambda(v_L|v_L, v_H) = 0$, i.e., in equilibrium consumers from segment $1 - \gamma$ correctly infer product quality and buy at both equilibrium prices.

The incentive compatibility constraint (2.8) ensures that the high-quality firm neither deviates by charging the highest out-of-equilibrium price compatible with all consumers buying nor finds it profitable to serve only review-sensitive consumers at a price of v_n; other ways of deviating always result in lower expected profits.

The second constraint (2.9) guarantees that it is more profitable for the low-quality firm to serve all consumers at the full-information price v_L than (i) imitating the high-quality firm, (ii) deviating by serving review-sensitive consumers at a price of v_n, and (iii) deviating by charging the highest out-of-equilibrium price at which consumers from segment $1-\gamma$ decide to buy. Under the given demand structure, other ways of deviating are less profitable.

Proof of Proposition 2.6

The high-quality firm's incentive compatibility constraint can be written as

$$\max\{(1-\gamma\cdot(1-q_H))\cdot v_H,\ v_H - A\} \geq \max\{p_d(\cdot),\ \gamma\cdot v_n\},$$

while the low-quality firm's constraint is given by

$$\max\{\gamma\cdot(1-q_L)\cdot v_n,\ \gamma\cdot v_n - A\} \geq \max\{\pi_{LH}^{im},\ \pi_{Ld}^{dev},\ v_L\}.$$

The high-quality firm's constraint coincides with the constraint given in Proposition 2.5, although the price level captured by $p_d(\cdot)$ (which depends on out-of-equilibrium beliefs) may differ.

Building on the notation introduced before stating Proposition 2.5, the second constraint ensures that the low-quality firm prefers serving review-sensitive consumers who received no review (or a neutral review) over (i) imitating the high-quality firm, (ii) deviating by serving the highest out-of-equilibrium price at which consumers from segment $1-\gamma$ would buy, and (iii) serving all consumers at the full-information price v_L.

The low-quality firm's constraint implies $\gamma\cdot v_n \geq p_d(\cdot)$: firstly, if the low-quality type invests A in equilibrium, the constraint implies

$$\gamma\cdot v_n - A \geq \pi_{Ld}^{dev} \geq p_d(\cdot) - A.$$

Secondly, if the low-quality type does not invest A in equilibrium, the constraint implies

$$\gamma\cdot(1-q_L)\cdot v_n \geq \pi_{Ld}^{dev} \geq (1-\gamma\cdot q_L)\cdot p_d(\cdot),$$

which is equivalent to

$$\left(1-\frac{1-\gamma}{1-\gamma\cdot q_L}\right)\cdot v_n \geq p_d(\cdot).$$

As the left-hand side of this inequality is smaller than $(1-(1-\gamma))\cdot v_n$, the condition implies $\gamma\cdot v_n \geq p_d(\cdot)$.

Given this necessary condition (which implicitly constrains out-of-equilibrium beliefs, cf. condition (2.12)), the right-hand side of the first constraint can be simplified and becomes $\gamma \cdot v_n$, yielding condition (2.10).

Proof and extension of Proposition 2.7

If out-of-equilibrium beliefs are such that $p_d(\cdot) \leq v_n$, condition (2.13) captures the high-quality firm's incentive compatibility constraint. In equilibrium, the high-quality firm serves all consumers with certainty. Hence, it can only gain by increasing its price. Given that $p_d(\cdot) \leq v_n$, the best way to deviate is charging v_H (as demand remains constant for all prices $p \in (v_n, v_H]$). Condition (2.14) captures the low-quality firm's constraint: serving all consumers at a price of v_L has to be more profitable than imitating the high-quality type and charging a high price while investing in review manipulation; all other ways of deviating are less profitable.

With out-of-equilibrium beliefs such that $p_d(\cdot) > v_n$, i.e., there exists a price $p > v_n$ at which

$$\lambda(p|p_L = v_L, p_H = v_n) \geq \frac{p - v_L}{v_H - v_L},$$

the pricing pattern induces an equilibrium if

$$v_n \geq \max\{(1 - \gamma \cdot (1 - q_H)) \cdot p_d(\cdot),\ p_d(\cdot) - A,\ \gamma \cdot q_H \cdot v_H,\ \gamma \cdot v_H - A\},$$

and

$$v_L \geq \max\{(1 - \gamma) \cdot p_d(\cdot),\ (1 - \gamma \cdot (1 - q_{h,L})) \cdot p_d(\cdot) - A,\ \pi^{im}_{Ln},\ \gamma \cdot q_{h,L} \cdot v_H - A\}.$$

Similar to the opposite case with $p_d(\cdot) \leq v_n$, these conditions are likely to be fulfilled for high costs A, intermediate levels of γ, low probabilities q_H and $q_{h,L}$ for reviews indicating high quality, and a high probability q_L for reviews (correctly) indicating low quality.

Proof and extension of Proposition 2.8

Note that condition (2.15) coincides with condition (2.13) since the same logic as in the previous proof applies to the incentives of the high-quality firm. Nevertheless, the low-quality firm now chooses a high price of v_H. If $p_d(\cdot) \leq v_n$, the most profitable ways of deviating are serving all consumers by charging v_L and imitating the high-quality firm's pricing.

If out-of-equilibrium beliefs are such that $p_d(\cdot) > v_n$, the incentive compatibility constraints are as follows:

$$v_n \geq \max\{(1-\gamma\cdot(1-q_H))\cdot p_d(\cdot),\ p_d(\cdot)-A,\ \gamma\cdot q_H\cdot v_H,\ \gamma\cdot v_H - A\},$$

and

$$\gamma\cdot q_{h,L}\cdot v_H - A \geq \max\{(1-\gamma)\cdot p_d(\cdot),\ (1-\gamma\cdot(1-q_{h,L}))\cdot p_d(\cdot)-A,\ \pi^{im}_{Ln},\ v_L\}.$$

The high-quality firm's constraint coincides with the constraint given in the previous proof of Proposition 2.7. Similarly, the additional terms on the right-hand side of the low-quality firm's constraint (i.e., the expected profit levels from charging a price of $p_d(\cdot)$) correspond to the additional terms in the respective previous constraint.

Proof of Lemma 2.12

Under the given condition, there exists a price $\widetilde{p} \in (v_L, v_n)$ at which consumers from segment $1-\gamma$ decide to buy. If true product quality is high, the willingness to pay of consumers from segment γ is at least v_n under the given review technology. Hence, regardless of the type of equilibrium candidate, all consumers buy if the high-quality firm charges a price of $\widetilde{p}$, and charging $\widetilde{p}$ is more profitable than charging v_L.

Proof and extension of Proposition 2.9

With out-of-equilibrium beliefs such that $p_d(\cdot) \leq v_n$, it is never profitable to charge a price different from the "focal" prices v_n, v_L, and v_H: firstly, in equilibrium, all consumers from segment $1-\gamma$ decide to buy at a price of v_n, and demand from review sensitive consumers remains unchanged when changing the price from v_n to any price $p \in (p_d(\cdot), v_n)$. Secondly, demand remains unchanged when changing the (deviation) price from v_H to any price $p \in (v_n, v_H)$, but expected profit decreases. Consequently, the only reasonable ways of deviating involve prices v_L (for the low-quality firm) and v_H, which is reflected by the two incentive compatibility constraints (2.17) and (2.18) (note that constraint (2.17) coincides with constraints (2.13) and (2.15)).

For out-of-equilibrium beliefs such that $p_d(\cdot) > v_n$, the incentive compatibility constraint of the high-quality firm coincides with the constraint given in the proof of Proposition 2.8, and the low-quality firm's constraint reads

$$\max\{(1-\gamma\cdot q_L)\cdot v_n,\ v_n - A\}$$
$$\geq \max\{(1-\gamma)\cdot p_d(\cdot),\ (1-\gamma\cdot(1-q_{h,L}))\cdot p_d(\cdot) - A,\ \gamma\cdot q_{h,L}\cdot v_H - A,\ v_L\}.$$

Hence, under this alternative assumption on out-of-equilibrium beliefs, the equilibrium is less likely to exist in particular for very small levels of γ (for which the equilibrium always exists under the condition on beliefs given in the proposition). However, for $p_d(\cdot)$ only slightly above v_n, incentives to deviate are relatively small for (non-degenerated) parameter values $q_L, q_{h,L}, q_H \in (0,1)$ and $A > 0$, and the equilibrium exists also for $p_d(\cdot) > v_n$ if it exists in the opposite case (i.e., if $p_d(\cdot) \leq v_n$) which the Proposition focusses on.

Proof of Proposition 2.10

Under the given condition on out-of-equilibrium beliefs, it cannot be profitable to charge any price $p \in (v_n, v_H)$ as expected demand remains on the same level as in the case of a price of v_H. Furthermore, it can never be profitable to set any price between v_L and v_n except for $p_d(\cdot)$: expected demand from review-sensitive consumers does not change (compared to the level at a price of v_n), and the only reasonable price in this interval is the highest price compatible with the remaining consumers buying.

Proof of Lemma 2.13

(i) As $\pi_{LH}^{im} \geq \gamma \cdot q_{h,L} \cdot v_H - A$, conditions (2.9) and (2.20) cannot hold jointly (unless both are fulfilled with equality) since the right-hand side of condition (2.20) exceeds v_L. Similarly, as the right-hand side of condition (2.20) exceeds the left-hand side of condition (2.11), these conditions are also incompatible. Furthermore, conditions (2.14) and (2.20) as well as conditions (2.18) and (2.20) are incompatible, respectively.

The "inverse" separating equilibrium cannot coexist with any other but the "atypical" pooling equilibrium since conditions (2.9), (2.11), (2.14), and (2.18) are incompatible with condition (2.16).

(ii) The separating equilibria characterized in Propositions 2.5 and 2.6 cannot coexist since the right-hand side of condition (2.9) exceeds the left-hand side of condition (2.11), but the right-hand side of condition (2.11) exceeds the left-hand side of condition (2.9).

(iii) The separating equilibrium characterized in Proposition 2.7 cannot coexist with the pooling equilibrium characterized in Proposition 2.9: a similar logic as given in (ii) applies to conditions (2.14) and (2.18).

Chapter 3

Platforms, Potential Competition, and Proportional Fees

3.1 Introduction[1]

Sellers frequently use marketplaces (or trade platforms) to reach consumers. Before they can offer their products on a particular platform, sellers often have to sink platform-specific investment costs, such as development costs. In turn, a platform operator who wants to attract sellers has to guarantee sellers some return on their investment by leaving them a positive margin on sales. However, as the platform operator easily observes sales and, thus, can identify profitable products, he is tempted to cut the respective sellers out, collecting (parts of) their margins just after they established their products on his platform. This generates a particular hold-up problem for platform operators who can offer products themselves.

For example, Amazon is a retailer and, at the same time, provides a platform for sellers to access their customers – the Amazon Marketplace.[2] Similarly, Apple and Google provide their own applications next to third-party applications in their online stores. Using the language of Hagiu (2007), these intermediaries combine the *merchant mode* and the *platform mode*. Therefore, we call this policy "operating under a *dual mode*": for some products, intermediaries act as classical retailers, buying from suppliers and setting prices (merchant mode), while they also allow external sellers access to consumers on their platform for some fee (platform mode).

[1]This chapter is based on joint research with Johannes Muthers, also cf. footnote 7 on page 6.

[2]According to Amazon's reports, sales by third-party sellers reached 36% of unit sales in 2011.

Interestingly, Amazon primarily charges proportional (revenue-based) fees to sellers who use the Amazon Marketplace.[3] Similarly, Apple and Google charge software providers proportional fees for selling their applications in the AppStore and on Google Play.[4] Likewise, proportional fees are usually included in franchising arrangements, where the franchisor offers the franchisee a business model (platform) to reach consumers.[5] Furthermore, revenue-based payments are integral parts of patent licensing agreements.[6]

In these examples, the platform operator (franchisor, patentee) is also a potential competitor to sellers (franchisees, licensees) as he often can serve demand himself. Indeed, the dual mode can be more profitable to him than a pure merchant mode or a pure platform mode for several reasons. Firstly, enabling third-party sellers to reach consumers can be more profitable than acting as a pure merchant since more specialized sellers may be better informed about product demand than the intermediary. Opening the platform increases the variety of products. Secondly, when production costs differ between sellers and the intermediary, acting as a merchant in addition to operating a platform can be profitable as the intermediary can utilize his own cost advantage, or, when sellers are more efficient, appropriate a share of their cost advantage.

In this essay, we analyze a framework with a monopoly intermediary who provides a platform and can be a merchant at the same time. The intermediary can do cherry-picking, selling profitable goods himself after observing sellers' offers. However, this potential competition makes the platform less attractive to sellers in the first place. By choosing a platform tariff, the intermediary shapes competition between himself and sellers, trading off his gains from cherry-picking against platform attractiveness.

We focus on the case in which sellers have to sink investment costs before offering a new product on the platform. Sellers are better informed about product demand than the intermediary. Production costs can differ between sellers and the

[3]Besides a small membership fee and a fixed per-transaction fee, Amazon charges sellers a proportional fee of about 15% (depending on product category).

[4]Apple and Google charge software developers a proportional fee of 30%.

[5]Cf. e.g. Blair and Lafontaine (2010, p. 62ff.).

[6]Bousquet, Cremer, Ivaldi, and Wolkowicz (1998) report that more than 75% of the licensing contracts (in a sample from the France Telecom research center) contain revenue-based royalties.

intermediary, i.e., market conditions are ex ante unknown. In this framework, we firstly analyze "classical" two-part tariffs consisting of fixed (membership) fees and per-transaction fees. Secondly, we examine tariffs that include proportional (per-revenue) fees.

While the extant economic literature concerned with the pricing of (two-sided) platforms has focussed on linear and classical two-part tariffs, our analysis departs from this classical approach. In line with the studies of Shy and Wang (2011) and Z. Wang and Wright (2012), we thereby account for the fact that proportional fees are often observed in reality. While Shy and Wang (2011) show that proportional fees mitigate double marginalization problems and Z. Wang and Wright (2012) explain that they can be used as a means of price-discrimination, we find that proportional fees allow the intermediary to commit not to compete with sellers, thereby increasing the attractiveness of the platform.

Focussing on classical two-part tariffs first, we find that the intermediary prefers per-transaction fees over membership fees. In contrast to previous results (e.g. Armstrong, 2006), he is no longer indifferent between both kinds of fees as transaction-based fees create a competitive advantage when the intermediary becomes active as a merchant. Regarding platform attractiveness, we find that an intermediary using classical two-part tariffs enters sellers' markets to undercut their prices whenever he has lower costs. This is to the detriment of the platform's attractiveness to sellers; in particular, if the intermediary is always more efficient than sellers, sellers will be undercut with certainty. Hence, sellers do not join the platform and products are not disclosed. In that case the intermediary would always profit from committing himself not to enter product markets. We find that contracts which include proportional fees allow an intermediary to do so: by increasing the opportunity costs of competition, the use of proportional fees makes it less attractive for an intermediary to compete with sellers as a merchant.

Introducing a dual mode of intermediation into the platform literature, our work sheds light on the different impacts of membership fees, per-transaction fees, and proportional fees on market outcomes. It provides a novel explanation why proportional fees are commonly observed in reality.

Related literature

Our work is most closely related to the literature on platform pricing/two-sided markets and to the research on an intermediary's choice of the optimal intermediation mode.

To the best of our knowledge, the only studies that directly address the question whether an intermediary should take an active role as a (pure) merchant, buying products himself and reselling them to buyers, or a more passive role as a (pure) platform, enabling other sellers to reach potential buyers, are Hagiu (2007) and Hagiu and Wright (2013). Hagiu (2007) finds that under many circumstances a monopoly intermediary prefers the 'merchant mode' to the 'platform mode'. However, he also identifies several factors that affect the intermediary's choice towards the platform mode, e.g. consumers' demand for variety or asymmetric information about product quality between the intermediary and sellers.[7] Hagiu and Wright (2013) illustrate that an intermediary's decision on which intermediation mode to choose may also be driven by a trade-off between coordinating marketing activities as a merchant (taking into account potential externalities across products) and benefiting from sellers internalizing more precise information on individual demand as a platform. We extend both analyses by explicitly allowing for endogenous seller pricing when the intermediary can become active as a merchant while offering a platform at the same time.

Similar to our work, Jiang, Jerath, and Srinivasan (2011) examine the case of an intermediary who both offers a platform and can serve demand himself (dual mode), crowding out sellers. In their framework, the intermediary has to incur fixed costs to enter a market. Better informed sellers fear that the intermediary serves markets with high demand himself to avoid double marginalization. However, by choosing a low service level, sellers can pretend to offer a product whose demand does not suffice to cover the intermediary's fixed costs. Accordingly, the setting also includes moral hazard. Although proportional fees would tackle both the double marginalization problem and the hold-up problem that arises due to screening, Jiang et al. analyze pure per-unit fees only.

[7]Differently from our model, Hagiu assumes that the merchant has to buy products from a seller who would otherwise sell them on the intermediary's platform (at an exogenous price).

During the last decade, several seminal studies on platform pricing/two-sided markets have been published (cf. e.g.[8] Rochet & Tirole, 2006; Armstrong, 2006). They focus on intermediaries featuring the 'platform mode' and analyze tariff choices in presence of (indirect) network effects under various circumstances. Most studies on platform pricing focus on membership fees, per-transaction fees, or two-part tariffs as a combination of both. Furthermore, they usually abstract away explicit payments between the two sides of a market or price setting by sellers. Accordingly, proportional (revenue-based) fees are not discussed.

However, there are several important exceptions who do examine proportional fees. Shy and Wang (2011) analyze a model of a payment card network. They find that profits of the card network are higher under proportional fees than under per-transaction fees as the network faces a double marginalization problem which is mitigated by proportional fees. In their framework, sellers earn lower profits under proportional fees, but consumers are better off and social welfare is higher than under per-transaction fees. Miao (2011) extends the model of Shy and Wang (2011). Allowing for an endogenous number of sellers, he shows that the use of proportional fees results in less seller participation. Consequently, consumer surplus and social welfare may be lower under proportional fees. Z. Wang and Wright (2012) examine the case of an intermediary who facilitates trade of products that differ in both costs and valuations. They illustrate that a combination of a per-transaction fee and a fee which linearly depends on price can achieve the same profit as third-degree price discrimination, even if the intermediary is uninformed about product attributes.

Hagiu (2006) studies commitment of two-sided platforms to a tariff system. In contrast to previous studies (which assume that sellers and buyers take their decisions on joining a platform simultaneously), Hagiu analyzes a sequential time structure: he assumes that all sellers arrive at the platform before the first buyer does. He shows that a platform prefers to commit to the access price charged to buyers instead of setting or adapting it after sellers joined the platform under certain circumstances. Although Hagiu does not mention how commitment could be achieved, he points out that platform commitment is an important issue.

[8]Jullien (2012) offers a comprehensive up-to-date survey on two-sided (B2B) platforms, including a general introduction to two-sided markets.

Hagiu (2009) analyzes a platform's tariff decision when sellers compete and consumers value variety. In an extension, he explains that charging variable (proportional) fees can mitigate the aforementioned commitment problem.[9]

Within the literature on patent licensing, there has been a debate on different tariff systems for many years (cf. e.g. Kamien & Tauman, 1986; X. H. Wang, 1998; Sen, 2005). Nevertheless, those studies are only slightly related to our analysis as they usually do not focus on incentives to invest in innovations and as most of them focus on fixed and per-transaction fees.

Our work may also be seen as a contribution to the literature on franchising:[10] by allowing for a dual mode of intermediation and analyzing a framework of asymmetric information on demand between sellers (franchisees) and intermediary (franchisor), we provide additional insights into a franchisor's decision on dual distribution/partial vertical integration (cf. e.g. Minkler, 1992; Scott, 1995; Hendrikse & Jiang, 2011) and on the frequent use of sales revenue royalties.

Taken together, we contribute to the economic literature firstly by introducing a "dual mode" of intermediation. Secondly, in contrast to the majority of the extant studies on two-sided markets, we explicitly account for trade between sellers and buyers, allowing for endogenous seller pricing. Thirdly, we show that an intermediary operating under the dual mode is no longer indifferent between membership fees and transaction-based fees. Fourthly, we identify a hold-up problem created by the threat of competition between the intermediary and sellers which impairs platform attractiveness. Finally, we find that platform tariffs that include proportional fees mitigate this problem, in contrast to "classical" two-part tariffs which previous literature focussed on.

[9]However, note that in Hagiu's framework transaction-based fees can create a commitment not to change the buyer fee if buyers join the platform after sellers, while we find that proportional fees relax (potential) competition between the intermediary and sellers.

[10]Blair and Lafontaine (2010) provide a sound introduction to the economics of franchising.

Outline

The remainder of this essay is organized as follows: in section 2, we set up a model of a monopoly intermediary who offers a platform to connect sellers and buyers. In section 3, we solve the model for classical two-part tariffs which consist of membership fees and per-transaction fees. In section 4, we discuss existence and conditions of the intermediary's hold-up problem, starting with the decisions that a social planer would take. Within section 5, we analyze proportional fees as part of multi-part tariffs. In section 6, we summarize our findings and discuss the results. Proofs are relegated to the appendix.

3.2 Framework

We consider a market with a monopoly intermediary who offers sellers a platform to reach potential buyers and, at the same time, can offer products himself.

There is a unit mass of sellers. For being able to list a new product on the marketplace, a seller has to incur fixed investment costs I which are sunk after investment. These costs may be interpreted as costs of developing the respective product, or as general costs of sales preparation (e.g. market research, designing an attractive product illustration, or establishing capacities to ensure immediate supply). They are distributed among sellers according to a differentiable distribution function $F(I)$ over the support $[\underline{I}, \overline{I}]$ with $\underline{I} \geq 0$. We assume products offered by different sellers to be completely independent. Hence, there is no competition between sellers. Taken together, there is a continuum of independent product markets which are characterized by their respective investment costs.[11] For selling their products, sellers incur constant marginal costs $c > 0$, incorporating all per-unit costs except for fees charged by the intermediary. In the following, we simply refer to c as (marginal) *production costs*, although c could also represent costs of purchasing the product from some wholesaler, retailing or transaction costs like payment charges, or the expected costs of product failure.

We assume that each buyer purchases at most one unit of each product. Buyers'

[11]Note that our framework also covers the situation of a single seller with unknown investment costs if $F(I)$ is interpreted as a probability instead of the share of the mass of sellers having investment costs below I.

gross utilities from consuming a unit of a good are constant across buyers and products and given by $r > c$. Accordingly, we abstract from double marginalization problems and buyer heterogeneity. Hence, the intermediary's tariff decision is neither driven by the effect of mitigating double marginalization (unlike Shy & Wang, 2011), nor by any price discrimination attempts (unlike Z. Wang & Wright, 2012).[12] There is a mass of M buyers. Buyers' (as well as sellers') outside options are normalized to zero. Hence, not joining the platform yields a zero payoff to either side. As we will assume that buyers do not have to pay a membership fee, it is a dominant strategy for buyers to join the platform.[13] Hence, for each product the demand function is given by[14]

$$D(p) = \begin{cases} M, & p \leq r \\ 0, & p > r \end{cases} .$$

The intermediary chooses a platform tariff system which can comprise different forms of payments by sellers: a membership fee A, a per-transaction fee a, or a proportional fee. For the latter a fixed share α of seller revenues accrues to the platform. All platform costs are normalized to zero.

Additionally, the intermediary can decide to compete with sellers who joined his platform, becoming active as a *merchant* in the respective product markets. In doing so, he either starts selling the same product, purchasing it from some supplier, or he imitates the product that is offered by a seller. More precisely, each product offered by the merchant is not differentiated from the corresponding seller's product.

We assume that the intermediary cannot offer a product if the respective seller did not join the platform.[15] In particular, this assumption captures the following situation: the intermediary is ex ante uninformed about existence of new products or corresponding demand. In contrast, more specialized sellers are (perfectly) in-

[12]Our results would also generalize to cases of heterogenous product categories with varying market sizes or different gross utilities across markets.

[13]We implicitly rule out trivial equilibria in which no buyer and no seller joins.

[14]We assume that the demand structure for new products is common knowledge. This seems reasonable at least within smaller product categories since the intermediary is supposed to be informed about typical market characteristics, but not about existence of specific products. Note that this might be a rationale for Amazon's discriminating practice of charging different fees across well-defined product categories.

[15] This assumption could be interpreted as a search cost advantage of sellers, cf. e.g. Minkler (1992).

formed about existence of demand for products which they may offer. By joining the intermediary's platform, they disclose information. Thereby, the intermediary can easily learn existence of demand for each specific product as platform operator. We emphasize the role of sellers' demand information as we do not include product markets in our model for which the intermediary is informed about demand.

After sellers joined the intermediary's platform, he observes his constant marginal production costs and may pick profitable products, entering markets.[16] We assume that these marginal costs ζ are drawn from a distribution represented by a differentiable distribution function $H(\zeta)$ with support $[\underline{\zeta}, \overline{\zeta}]$. A draw of ζ captures the intermediary's relative bargaining position towards suppliers or his ability in imitating sellers' products; he may have higher or lower production costs than sellers, i.e., $c \in (\underline{\zeta}, \overline{\zeta})$. We assume that the merchant's marginal costs are determined by one single draw, and, hence, are the same for all products. For entering a market that was disclosed by a seller, the intermediary faces infinitesimally small (but positive) costs $\varepsilon > 0$. This assumption is made for two reasons: firstly, the asymmetry between the intermediary's and merchants' investment costs accounts for the fact that the intermediary becomes informed about important product characteristics without bearing any costs. Once a seller disclosed demand and established her product on the platform, it is much less costly to simply imitate the product. Secondly, positive investment costs solve the tie situation that the intermediary would face if he was indifferent with respect to market entry, i.e., in cases he faces higher production costs than the respective seller, and, hence, is not willing to serve any demand.

As the intermediary attains an (exclusive) information advantage about profitable product markets compared to sellers who are active in other markets, his imitation incentives are much stronger than those ones faced by other sellers. Therefore, we do not allow for sellers imitating each other but focus on potential competition between the intermediary and each individual seller.

[16] Again, we use the term "production costs" as representative for any kind of per-transaction costs.

Timing

The timing of the game is given as follows:[17]

1. The intermediary sets the platform tariff.[18]
2. Decision on platform membership:
   i) Sellers' investment costs are realized;
   ii) Sellers & buyers decide on joining the platform.
3. Intermediary's decision on becoming merchant/imitating sellers:
   i) The intermediary's production costs are realized;
   ii) The intermediary decides whether to enter product markets.
4. In each product market that the intermediary entered he competes with the respective seller in Bertrand fashion, setting prices; otherwise, sellers take their monopoly pricing decisions.

We assume that the structure of demand as well as all costs, once realized, are common knowledge to sellers and the intermediary. Both sellers and the intermediary are assumed to maximize their expected profits, i.e., they are risk neutral.

In the following, we firstly analyze tariffs that consist of a membership fee and a per-transaction fee charged to sellers. Secondly, we elaborate on the hold-up problem which emerges under those classical two-part tariffs. Finally, we discuss the case of a proportional fee, i.e., revenue sharing between the intermediary and each seller, as a special case of three-part tariffs.

3.3 Classical two-part tariffs charged to sellers

In this section we consider classical two-part tariffs charged to sellers only. These tariffs combine a membership fee A as fixed transfer and a transaction-based per-

[17] It may be natural to include another period of sales between the second and third stage. In this period, sellers who joined the platform could be active as monopolists. However, this would not affect any of our results.

[18] We implicitly assume that the tariff is contractible, or, at least, that commitment to a tariff system is feasible. Commitment seems plausible: As the tariff system is publicly observable, a reputation for not changing it can be obtained.

unit fee a which increases each seller's perceived marginal costs. We restrict our analysis to non-negative fees: we rule out negative membership fees since they induce a moral hazard problem.[19] Similarly, negative per-unit fees would create incentives for fictitious transactions.[20]

We solve the game described before by backward induction.

3.3.1 Product pricing decisions

We firstly look at the pricing decisions in one representative product market that a seller disclosed before. The seller paid the membership fee A up front. Hence, A are sunk costs at this stage. However, the seller pays the per-transaction fee a for each unit sold which increases her marginal costs to $a + c$. We can exclude cases where $a > r - c$ as then this stage would never be reached (zero seller participation).

If the intermediary did not enter the market, the seller is a monopolist, charging a price of

$$p^{mon} = r.$$

In this case, the seller's profit (before investment costs and membership fee) equals $\pi_s^{mon} = M \cdot \{r - (c + a)\}$.

If the intermediary entered the market in stage 3, he and the seller compete à la Bertrand, with asymmetric costs. However, contrary to standard price competition, the intermediary receives a transfer of a for each unit sold by the seller.

If the intermediary undercuts the seller[21] by setting a price of

$$p_m^{comp}(a) = c + a,$$

his (merchant) profit from this market equals

$$\pi_m(a) = M \cdot ((c + a) - \zeta).$$

[19] With a negative A, sellers would list products they do not want to sell. In our setting the platform operator cannot distinguish good products from worthless ones before they are listed; hence, he would have to pay $|A|$ to the seller indiscriminate of the listing value.

[20] We abstract from the provision of free goodies (which could be interpreted as negative fees).

[21] As is standard in the literature on Bertrand competition, we rule out prices below marginal costs (which would lead to "implausible" equilibria of the pricing game) because they are not limits of undominated strategies in discrete approximations of the strategy space.

If he does not undercut the seller, the (variable) platform revenue that he receives from the seller equals

$$\pi_p(a) = M \cdot a.$$

He prefers undercutting the seller if and only if

$$\pi_m(a) > \pi_p(a) \;\Leftrightarrow\; \zeta < c. \tag{3.1}$$

Hence, if production costs turn out to be below the seller's costs ($\zeta < c$), the intermediary serves demand himself as a merchant.

If $\zeta > c$, the seller serves the market at a price of

$$p_s^{comp}(a) = \min\{\zeta + a, r\}.$$

The intermediary does not undercut $p_s^{comp}(a)$ by any amount $k > 0$ as he would lose $M \cdot a$ in platform fees while only gaining merchant profits of $M \cdot ((\zeta + a - k) - \zeta) < M \cdot a$ (assuming that $\zeta + a \leq r$). Charging prices above r is dominated as it results in zero demand. Finally, the case that both are equally efficient ($\zeta = c$) happens with zero probability as the distribution of ζ is atomless.

Lemma 3.1 (Product pricing under a classical two-part tariff).
Under a classical two part tariff (A, a), if the intermediary did not enter a market, the respective seller is a monopolist, setting a price of r. If the intermediary entered a market and has lower production costs than the seller ($\zeta < c$), he undercuts the seller by setting a price of $c + a$. If the intermediary faces higher production costs ($\zeta > c$), the seller serves demand at a price of $\min\{\zeta + a, r\}$.

Note that competitive prices increase in the per-transaction fee as the increase in seller's perceived marginal costs relaxes competition.

3.3.2 Intermediary's entry decision

In stage 3 the intermediary decides on entering markets that sellers disclosed by joining the platform, anticipating the pricing decisions just discussed.

The intermediary decides on entry contingent on his production costs. He enters markets only if he serves demand, which is the case when he has lower production costs ($\zeta < c$), as then his merchant profit exceeds his foregone platform revenues, cf. condition (3.1). If he entered without serving demand, he would lose exactly his entry costs $\varepsilon > 0$, without any gains.

Lemma 3.2 (Intermediary's entry decision under classical two-part tariffs). *Under a classical two-part tariff* (A, a)*, the intermediary enters product markets if and only if his production costs are lower than sellers' costs* $(\zeta < c)$.

Note that neither the fixed membership fee nor the per-transaction fee affects the intermediary's entry decision. This is intuitive for the membership fee, but more surprising for the per-transaction fee. The latter increases the platform revenue by a per unit. However, it also increases the competitive price and thus the merchant profit by a per unit. Hence, the per-transaction fee a does not affect the intermediary's trade-off between platform revenue and merchant profit.

3.3.3 Decisions on joining the platform

In stage 2 sellers and buyers simultaneously decide whether to join the platform.

Recall that for buyers joining is a dominant strategy. Hence, all buyers join the platform.[22] Sellers join the platform if they expect to be able to at least recoup their investment costs I. As argued before, each seller will be a monopolist in her respective product market if $\zeta > c$, but will be undercut if $\zeta < c$. Hence, each seller's expected profit from joining the platform under a two-part tariff (A, a) is given by

$$\pi_s^e(A, a, I) = Pr(\zeta > c) \cdot M \cdot \{r - (c + a)\} - I - A,$$

where $Pr(\zeta > c) = 1 - H(c)$ represents the probability that the intermediary does not enter as he is less efficient. Defining the critical level of investment costs

$$\widetilde{I}(A, a) \equiv \{1 - H(c)\} \cdot M \cdot \{r - (c + a)\} - A, \qquad (3.2)$$

we achieve the following result:

Lemma 3.3 (Decisions on joining the platform under classical two-part tariffs). *Under a classical two-part tariff* (A, a)*, all buyers join the platform. Sellers join if their investment costs are below* $\widetilde{I}(A, a)$ *as defined in (3.2). The mass of sellers joining the platform,* $F(\widetilde{I}(A, a))$*, decreases in both* A *and* a.

[22]Note that the joining decision would still be homogeneous if buyers had to pay fees as there is no buyer heterogeneity and, hence, each buyer faces the same trade-off. Consequently, there is either zero or full buyer participation, and zero participation can never occur in equilibrium as the intermediary could increase his profit by lowering fees.

Seller participation decreases in the membership fee A and in the per-transaction fee a as both fees decrease seller rents which lowers the maximum level of investment costs that sellers can cover without expecting a negative surplus from joining the platform.

In particular, since the intermediary cannot charge negative fees to sellers,

$$\underline{I} < \{1 - H(c)\} \cdot M \cdot (r - c) \;\Leftrightarrow\; \underline{I} < \widetilde{I}(0, 0) \tag{3.3}$$

is a necessary condition for positive seller participation under any classical two-part tariff; otherwise, the whole marketplace breaks down as no seller would have an incentive to join the platform, even if the intermediary charged no fees at all.

The basic intuition behind condition (3.3) is simple: if the probability of the intermediary facing lower production costs than the seller, i.e., $H(c)$, is high, each seller rarely makes product market profits as she will often be undercut by the intermediary. Hence, expected earnings from selling her product would not suffice to compensate even for the lowest investment costs $\underline{I}$. Therefore, no products would be introduced to the marketplace, and no markets would be disclosed to the intermediary.

Throughout the remaining analysis, we make the following assumption to ensure that positive seller participation can be achieved with classical two-part tariffs:

Assumption 3.1 (Positive seller participation).
If the intermediary does not charge any fees, the seller's expected monopoly profit suffices to cover the lowest level of investment costs: $\underline{I} < \{1 - H(c)\} \cdot M \cdot (r - c)$.

Furthermore, in order to ensure interior solutions, we make another (technical) assumption on the distribution of investment costs:

Assumption 3.2 (Limited seller participation).
The seller's monopoly profit does not cover the highest level of investment costs, even in absence of the threat of the intermediary entering markets: $\overline{I} \geq M \cdot (r - c)$.[23]

We elaborate on the hold-up problem that evolves from the threat of entry (captured by the probability $1 - H(c)$) in more detail within the next section.

[23] For most of the analysis it would be sufficient to assume $\overline{I} \geq \{1 - H(c)\} \cdot M \cdot (r - c)$. The given Assumption also ensures an interior solution (no full seller participation) in the extreme case of an intermediary operating under a pure platform mode, cf. equation (3.21) and Lemma 3.10.

Beforehand, we solve the model under two-part tariffs, analyzing the intermediary's tariff decision in the first stage.

3.3.4 Optimal classical two-part tariff

In stage 1 the intermediary sets the membership fee A and the per-transaction fee a.

Recall that under any two-part tariff (A, a) the intermediary will enter product markets as merchant if and only if he has lower production costs than sellers. The respective probability for ζ being below c is given by $H(c)$. Therefore, for each product listed on the marketplace, the intermediary's expected platform profit equals

$$\pi_p^e(A, a) = A + (1 - H(c)) \cdot M \cdot a, \tag{3.4}$$

and his expected per-product merchant profit (which is independent of the membership fee A) is given by

$$\pi_m^e(a) = H(c) \cdot M \cdot \{c + a - E[\zeta|\zeta < c]\}. \tag{3.5}$$

His expected overall profit is given by the sum of his platform profit $\pi_p^e(A, a)$ and his merchant profit $\pi_m^e(a)$, multiplied by the mass of sellers who joined the platform:

$$\Pi^e(A, a) = F(\widetilde{I}(A, a)) \cdot \{\pi_p^e(A, a) + \pi_m^e(a)\}. \tag{3.6}$$

We observe that if we define the merchant's expected cost advantage as

$$\Delta^e(c) \equiv H(c) \cdot \left(c - \frac{1}{H(c)} \int_{\underline{\zeta}}^{c} x dH(x) \right), \tag{3.7}$$

we can rewrite the intermediary's expected overall profit (3.6), inserting (3.4) and (3.5), as

$$\Pi^e(A, a) = F(\widetilde{I}(A, a)) \cdot \{A + M \cdot (a + \Delta^e(c))\}. \tag{3.8}$$

While the first factor, $F(\widetilde{I}(A, a))$, is decreasing in A and a (cf. Lemma 3.3), the second factor, i.e., the intermediary's expected profit per market, is increasing in both fees. Taking a closer look on the intermediary's trade-off between seller participation and per-market profit, we find:

Proposition 3.1 (Optimal classical two-part tariff).
The optimal two-part tariff consists of a zero membership fee and a positive per-transaction fee a^*. Given that $F(\cdot)$ is (weakly) concave, interior a^* are defined by the first order condition

$$f(\widetilde{I}(0,a^*)) \cdot (1 - H(c)) \cdot M \cdot (a^* + \Delta^e(c)) = F(\widetilde{I}(0,a^*)). \tag{3.9}$$

The intuition why the intermediary prefers the per-transaction fee to the membership fee is the following: while every combination of a membership fee and a per-transaction fee that generates the same level of expected platform profit $\pi_p^e(\cdot)$ induces the same rate of seller participation, the per-transaction fee additionally increases the expected merchant profit $\pi_m^e(\cdot)$ by creating a competitive advantage for the merchant, raising the competitive price. Therefore, decreasing the membership fee and simultaneously increasing the per-transaction fee such that seller participation remains unchanged increases the intermediary's profit, and the optimal tariff includes no membership fee.

3.4 Efficiency benchmarks and hold-up problem

In this section we firstly analyze the first-best outcome which a social planner would establish. Secondly, we examine the welfare-maximizing outcome with non-negative fees (second-best). Finally, we show that the intermediary always faces a hold-up problem under classical two-part tariffs.

3.4.1 Efficiency benchmarks

We consider a social planner maximizing expected welfare. He can obtain the first-best outcome by choosing the consumer price, a critical level of investment costs I^* that determines which markets will be opened up, and an allocation rule that specifies who supplies the product, given the realization of the intermediary's production costs ζ.

Lemma 3.4 (First-best outcome).
In the first-best outcome the intermediary enters and serves demand if and only if $\zeta < c$. The critical level of investment costs I^* equals $M \cdot \{r - c + \Delta^e(c)\}$, and the price is (weakly) below r.

Firstly, first best requires that all disclosed markets are served as buyers' gross utility r exceeds production costs. Secondly, demand is served by the most efficient supplier. Finally, markets are opened up whenever the expected surplus created by a market,

$$M \cdot \{r - (1 - H(c)) \cdot c - H(c) \cdot E[\zeta|\zeta < c]\} = M \cdot \{r - c + \Delta^e(c)\},$$

covers the investment costs.

If there was no information asymmetry between sellers and the intermediary, the first-best outcome could be obtained and the intermediary could extract the full surplus from sellers. In particular, a simple (customized) two-part tariff offered to each seller would implement the first-best outcome: a negative membership fee covers the seller's individual investment costs if they are below I^*, and a per-transaction fee of $r - c$ extracts the market surplus that is generated when the seller serves demand.

However, in case of asymmetric information, the intermediary will charge non-negative fees only. Therefore, the first-best outcome cannot be obtained since the critical level of investment costs $\widetilde{I}(A, a)$ will then be strictly smaller than I^*. Hence, efficient markets remain unexplored and will not be opened up. Moreover, if the social planner faces the same constraint, i.e., can only set non-negative two-part tariffs, he cannot implement first best:

Lemma 3.5 (Second-best outcome)**.**
Under the constraint that $(A, a) \geq 0$*, the welfare-maximizing tariff is* $(0, 0)$*. The intermediary serves demand if and only if his production costs do not exceed a threshold that is strictly below* c*. The critical level of investment costs is strictly below* I^**.*

Note first that efficient seller participation cannot be achieved without negative fees. In line with the theory of the second best, consequently, also allocation of production is distorted compared to the first best: although the intermediary is more efficient, he does not serve demand in order to increase expected seller rents, and, thus, seller participation. The intuition for the proof to this result is that marginally decreasing the entry threshold does not cause a reduction in productive efficiency but increases seller investment incentives.

3.4.2 Hold-up problem

A reasoning similar to the previous one on the second-best outcome also holds if the intermediary could commit not to enter markets even in cases he faces (marginally) lower costs than sellers. He would always utilize this option to increase seller participation:

Lemma 3.6 (Profitability of commitment to restricted entry).
Under any classical two-part tariff (A, a)*, the intermediary benefits from committing not to enter with costs above a threshold* $\hat{\zeta} < c$*.*

With classical two-part tariffs, the intermediary therefore faces a hold-up problem: he would like to commit to enter markets in less cases. However, as he decides on entry when sellers have already joined the platform, he will enter markets whenever he is more efficient (see Lemma 3.2). Hence, we arrive at the following result:

Proposition 3.2 (Intermediary's hold-up problem under two-part tariffs).
Under any two-part tariff consisting of a membership fee and a per-transaction fee, the intermediary faces a hold-up problem: his excessive entry behavior leads to insufficient seller investment incentives as well as poor seller participation and impedes him to open up profitable product markets.

In some cases the intermediary would even profit from a commitment never to enter (henceforth: *full* commitment). This is the case when the expected foregone profit of not entering is small, which is the case if $\Delta^e(c)$ is small. However, the intermediary would often prefer to enter markets if he is much more efficient, while committing not to enter only when his cost advantage is small.

In the following section we analyze proportional fees as parts of three-part tariffs. In particular, we compare the profitability of full commitment (i.e., commitment never to compete with sellers) and proportional fees which create a (partial) commitment not to compete with production costs ζ slightly below sellers' costs c.

3.5 Proportional fees mitigate the hold-up problem

We have shown that for any classical two-part tariff the intermediary always enters a seller's market when he has lower marginal costs than the seller.

Nevertheless, we have argued that an intermediary using only classical two-part tariffs would profit if he committed not to compete with sellers in cases he is more efficient. However, we have not explained *how* an intermediary could achieve such commitment – in fact committing not to compete seems to be hard to achieve (i) in a credible way and (ii) by legal means.[24]

We now consider an intermediary using proportional fees, i.e., tariffs that comprise revenue sharing where the intermediary earns a fraction α of the revenues that sellers realize on his platform. We find that proportional fees allow the intermediary to credibly commit not to compete with sellers even in cases he has lower marginal costs. Therefore, proportional fees help the intermediary to attract more sellers, mitigating the hold-up problem. Furthermore, we show that even if full commitment not to compete with sellers could be achieved without using proportional fees, the intermediary would prefer not to use this option under certain circumstances, while the introduction of a proportional fee is profitable to him.

In the following, we analyze three-part tariffs as combinations of classical two-part tariffs and proportional fees. We again proceed by backward induction. The key insight regarding the intermediary's entry behavior (which is decisive for the hold-up problem) will be given in subsection 3.5.2 (analysis of third stage). Furthermore, we identify conditions under which the inclusion of an additional proportional fee improves the optimal classical two-part tariff. This gives an explanation for the use of proportional fees by platforms and similar businesses.

[24]Note that platforms like Amazon often already have a reputation for acting under the dual mode, i.e., competing with sellers in a variety of existing product markets. Therefore, credible commitment on *not* competing might not be feasible. Furthermore, an announcement not to compete with other sellers may be interpreted as a horizontal collusive agreement.

3.5.1 Product pricing decisions under a three-part tariff

Along the lines of the analysis under classical two-part tariffs, we have to consider two cases to determine price setting within a (representative) product market that a seller disclosed under a three-part tariff (A, a, α).

If the intermediary did not enter the market, the seller is a monopolist and earns a profit (before investment costs and membership fee) of $M \cdot \{(1-\alpha) \cdot r - (c+a)\}$ by setting a price of

$$p^{mon} = r.$$

If the intermediary entered the market as merchant, he competes with the seller in Bertrand fashion. Nevertheless, he might prefer not to serve any demand, even if he earned a positive margin by undercutting the seller, as he would lose the transfer $a + \alpha p$ that he earns for each transaction conducted by the seller at a price of p.

As before, once entered the market, the intermediary still prefers to serve demand whenever he has lower costs than the seller. This can be seen as follows: at any price p chosen by the seller, the intermediary is tempted to undercut the seller if his merchant profit $M \cdot (p - \zeta)$ exceeds his variable platform profit $M \cdot (a + \alpha \cdot p)$. Accordingly, serving demand himself at a given price p is more profitable than acting as platform operator if

$$p - \zeta > a + \alpha p \;\Leftrightarrow\; p > \frac{\zeta + a}{1-\alpha}.$$

As the lowest price the seller can offer without obtaining a negative margin equals $\frac{c+a}{1-\alpha}$, the intermediary indeed prefers to undercut the seller by charging a price of

$$p_m^{comp}(a, \alpha) = \frac{c+a}{1-\alpha}$$

if $\zeta < c$. Then, the intermediary achieves a profit of $M \cdot \left(\frac{c+a}{1-\alpha} - \zeta\right)$.[25]

If the merchant faces higher production costs than the seller ($\zeta \geq c$), the seller serves demand at a price of

$$p_s^{comp}(a, \alpha) = \min\left\{\frac{\zeta + a}{1-\alpha}, r\right\}.$$

We summarize our findings in the following result:

[25] Again, our analysis excludes cases where $\frac{c+a}{1-\alpha} > r$ as these cannot occur (no seller participation).

Lemma 3.7 (Pricing decisions under a three-part tariff).
Under a three-part tariff (A, a, α)*, if the intermediary did not enter, the seller serves demand at a price equal to* r*. If the intermediary entered the product market as merchant, he serves demand at a price of* $\frac{c+a}{1-\alpha}$ *if and only if he has lower costs than sellers* ($\zeta < c$)*; otherwise* ($\zeta \geq c$)*, the seller serves demand at a price of* $\min\left\{\frac{\zeta+a}{1-\alpha}, r\right\}$.

Both the per-transaction fee a and the proportional fee α increase competitive prices.

3.5.2 Intermediary's entry decision under a three-part tariff

After the intermediary's production costs have been realized, he decides on entering product markets. If he faces higher production costs than a (representative) seller ($\zeta \geq c$), he does not enter the market, anticipating the decisions in stage 4: if he entered, he would not serve any demand, but incur entry costs $\varepsilon > 0$. Furthermore, entry would drive down the seller's price by $r - \frac{\zeta+a}{1-\alpha}$. Hence, if the intermediary's tariff includes a positive proportional fee α, the intermediary in addition loses parts of his platform profit by entering the market, even though he does not serve any demand.

The latter logic also applies to the case when the intermediary's production costs turn out to be below the seller's costs: if the intermediary charges a proportional fee, he incurs a direct loss from the reduction in prices which is induced by his market entry. Therefore, the intermediary prefers not to enter even if he has a (small) cost advantage. This can be formalized as follows: the intermediary prefers entry if his merchant profit from undercutting the seller,

$$\pi_m(a, \alpha) = p_m^{comp}(a, \alpha) - \zeta,$$

exceeds his variable platform profit

$$\pi_p(a, \alpha) = a + \alpha \cdot p^{mon};$$

this is the case if

$$\pi_m(a, \alpha) > \pi_p(a, \alpha) \;\Leftrightarrow\; \zeta < \frac{c+a}{1-\alpha} - \alpha \cdot r - a \equiv \widetilde{\zeta}(a, \alpha). \tag{3.10}$$

The critical threshold $\widetilde{\zeta}(a, \alpha)$ of merchant's production costs generally differs from the seller's marginal costs c. Differently from the analysis under classical two-part tariffs, his entry decision now depends on the difference of production costs, the level of production costs, and the transaction-based tariff components a and α.

Lemma 3.8 (Intermediary's entry decision under a three-part tariff).
Under a three-part tariff (A, a, α), the intermediary enters product markets if and only if $\zeta < \widetilde{\zeta}(a, \alpha)$.

For a more intuitive illustration of the intermediary's tradeoff, we define $\Delta c \equiv c - \zeta$ as the merchant's cost advantage. Then, we have $\pi_m(a, \alpha) = \Delta c + a + \alpha \cdot \left(\frac{c+a}{1-\alpha}\right)$, and condition (3.10) for entry being profitable can be written as

$$\Delta c > \alpha \cdot \left(r - \frac{c+a}{1-\alpha}\right). \tag{3.11}$$

This inequality exactly corresponds to the reasoning that we made above: if the intermediary enters the market, he incurs a loss from the price reduction caused by competition which is captured by the right-hand side. He only enters if this loss is overcompensated by his cost advantage Δc.

Taking a closer look at the right-hand side of inequality (3.11), we can state the following result:

Proposition 3.3 (Intermediary's entry decision under a three-part tariff).
Under any three-part tariff that yields positive seller participation and comprises a proportional fee $\alpha > 0$, the intermediary only enters product markets if his cost advantage exceeds a strictly positive threshold, i.e., $c - \widetilde{\zeta}(a, \alpha) > 0$.

Accordingly, under three-part tariffs that include a positive proportional fee, the intermediary always enters in fewer cases than under any classical two-part tariff. The use of proportional fees creates a credible commitment not to enter product markets for cost advantages $\Delta c < c - \widetilde{\zeta}(a, \alpha)$, and, therefore, mitigates the hold-up problem by reducing the threat of competition.

3.5.3 Sellers' joining decisions under a three-part tariff

Given the critical level of merchant's production costs $\widetilde{\zeta}(a, \alpha)$, a seller's expected profit from joining the intermediary's platform can be written as

$$\pi_s^e(A, a, \alpha, I) = Pr(\zeta \geq \widetilde{\zeta}(a, \alpha)) \cdot M \cdot \{(1 - \alpha) \cdot r - c - a\} - A - I,$$

where $Pr(\zeta \geq \widetilde{\zeta}(a, \alpha))$ denotes the probability of the intermediary not entering the respective product market, which equals $1 - H(\widetilde{\zeta}(a, \alpha))$. A seller joins the platform if her expected profit $\pi_s^e(A, a, \alpha, I)$ is positive, i.e., if her investment costs are below the critical level

$$\widetilde{I}(A, a, \alpha) \equiv \{1 - H(\widetilde{\zeta}(a, \alpha))\} \cdot M \cdot \{(1 - \alpha) \cdot r - c - a\} - A. \quad (3.12)$$

Interestingly, while $\widetilde{I}(A, a, \alpha)$ is strictly decreasing in both A and a, it is increasing in the proportional fee α under certain conditions. For $\alpha = 0$, i.e., classical two-part tariffs, seller participation increases in α if and only if

$$\frac{h(c)}{1 - H(c)} \cdot (r - c - a) > \frac{r}{r - c - a}. \quad (3.13)$$

[26]

While all tariff components, i.e., A, a, and α, strictly reduce sellers' margins from selling their products, the proportional fee α in addition reduces the intermediary's entry incentives, and, in turn, makes sellers more likely to sell their products themselves.

The results are summarized in the following Lemma:

Lemma 3.9 (Sellers' decision to join the platform under a three-part tariff). *Under a three-part tariff (A, a, α), the mass of sellers who join the platform equals $F(\widetilde{I}(A, a, \alpha))$. It decreases in A and a, but the effect of a change in α is ambiguous.*

Note that the intermediary's platform profit is increasing in α if seller participation increases in α. Furthermore, under condition (3.13), the increase in platform profits overcompensates the reduction of merchant profits, and introducing a proportional fee is profitable to the intermediary, cf. our analysis below.

[26] The condition for $\frac{\partial \widetilde{I}}{\partial \alpha}$ being positive in case of $\alpha \neq 0$ can be found in the remark on Lemma 3.9 on p. 101.

3.5.4 Intermediary's decision on the use of proportional fees

Given the results derived before, the intermediary's expected per-product platform profit under a three-part tariff (A, a, α) equals

$$\pi_p^e(A, a, \alpha) = A + M \cdot \{1 - H(\widetilde{\zeta}(a, \alpha))\} \cdot (a + \alpha \cdot r), \tag{3.14}$$

and his expected per-product merchant profit is given by

$$\pi_m^e(a, \alpha) = M \cdot H(\widetilde{\zeta}(a, \alpha)) \cdot \left\{ \frac{c + a}{1 - \alpha} - E[\zeta | \zeta < \widetilde{\zeta}(a, \alpha)] \right\}. \tag{3.15}$$

His expected overall profit equals the sum of his platform profit $\pi_p^e(A, a, \alpha)$ and his merchant profit $\pi_m^e(a, \alpha)$, multiplied by the mass of sellers who joined the platform:

$$\Pi^e(A, a, \alpha) = F(\widetilde{I}(A, a, \alpha)) \cdot \{\pi_p^e(A, a, \alpha) + \pi_m^e(a, \alpha)\}. \tag{3.16}$$

Substituting (3.14) and (3.15) into (3.16) leads to

$$\Pi^e(A, a, \alpha) = F(\widetilde{I}(A, a, \alpha)) \cdot \left\{ A + M \cdot \left[a + \alpha \cdot r + \Delta^e \left(\widetilde{\zeta}(a, \alpha) \right) \right] \right\}, \tag{3.17}$$

where

$$\Delta^e \left(\widetilde{\zeta}(a, \alpha) \right) = H(\widetilde{\zeta}(a, \alpha)) \cdot \widetilde{\zeta}(a, \alpha) - \int_{\underline{\zeta}}^{\widetilde{\zeta}(a,\alpha)} x dH(x)$$

as defined in (3.7).[27] Evaluating the partial derivative of the intermediary's profit $\Pi^e(A, a, \alpha)$ with respect to α at the optimal two-part tariff leads to the following result:

Proposition 3.4 (Proportional fees improve optimal classical two-part tariff). *The inclusion of an additional positive proportional fee strictly improves the optimal classical two-part tariff* $(0, a^*)$ *if*

$$\frac{h(c)}{1 - H(c)} \cdot (r - c - a^*) > H(c). \tag{3.18}$$

Note that the Proposition only gives a sufficient condition for proportional fees increasing the intermediary's profit. If condition (3.18) holds, a marginal substitution from a to α is profitable, starting at $\alpha = 0$. The condition is always fulfilled if seller participation increases in α (i.e., (3.18) is implied by (3.13)).

[27]Note that $\Delta^e(x)$ can only be interpreted as the merchant's expected cost advantage if $x = c$.

In the following, we show that even if full commitment never to enter sellers' markets was feasible, (i) the intermediary might prefer not to use this commitment, while at the same time (ii) introducing a proportional fee (which endogenously yields a commitment not to enter for small cost advantages) is profitable to him.

For the remaining analysis, we parameterize our model as follows:

Assumption 3.3 (Uniformly distributed investment costs).
Sellers' investment costs follow a uniform distribution with support $[0, \overline{I}]$.

Given this Assumption, we can explicitly write down the optimal two-part tariff:

Corollary 3.1 (Optimal classical two-part tariff).
With uniformly distributed investment costs, the optimal classical two-part tariff consists of a zero membership fee and a per-transaction fee

$$a^* = \max\left\{0, \frac{r - c - \Delta^e(c)}{2}\right\}. \tag{3.19}$$

In order to focus on cases in which the intermediary earns positive platform revenues, we make another assumption which ensures that the optimal per-transaction fee (3.19) is strictly positive:

Assumption 3.4 (Positive platform revenues).
The intermediary's expected cost advantage does not exceed sellers' profit margin: $\Delta^e(c) < r - c$.

Then, the intermediary's expected profit under a classical two-part tariff equals

$$\Pi^e(0, a^*) = \frac{1 - H(c)}{\overline{I}} \cdot M^2 \cdot \left(\frac{r - c + \Delta^e(c)}{2}\right)^2. \tag{3.20}$$

If the intermediary could fully commit not to enter sellers' markets, he would achieve a maximal expected profit of

$$\frac{1}{\overline{I}} \cdot M^2 \cdot \left(\frac{r - c}{2}\right)^2 \tag{3.21}$$

by setting a per-transaction fee of $a^*_{f.c.} = \frac{r-c}{2}$.[28]

Defining

$$\gamma(c) \equiv \frac{\Delta^e(c)}{r - c} \tag{3.22}$$

[28] As argued during the analysis of classical two-part tariffs, a pure platform operator is indifferent between all combinations of fees that yield the same rate of seller participation.

as the ratio of the intermediary's expected cost advantage to sellers' gross margin (which determines the extractable rent), we can state the following result:

Lemma 3.10 (Non-profitability of full commitment).
If full commitment not to enter sellers' markets was feasible with a classical two-part tariff, the intermediary would prefer not to commit if

$$\gamma(c) > \frac{1}{\sqrt{1 - H(c)}} - 1. \tag{3.23}$$

Note that Assumption 3.4 implies $H(c) < \frac{3}{4}$ as a necessary condition for condition (3.23) to hold. For a given expected cost advantage, i.e., given $\gamma(c)$ as defined in (3.22), full commitment is only profitable for large $H(c)$.[29] The intuition behind this result can be understood as follows: the hold-up problem, caused by the threat of the intermediary entering markets, is most severe if the probability for entry under a classical two-part tariff, i.e., $H(c)$, is large. Accordingly, commitment not to compete with sellers, creating additional investment incentives, becomes more attractive if $H(c)$ increases. Therefore, full commitment is profitable for high levels of $H(c)$, but for relatively low levels the intermediary prefers not to forgo his additional profit option of selling as a merchant at lower costs than sellers. Conversely speaking, it is more profitable to attract a smaller mass of sellers and retain this option instead of completely eliminating the threat of entry if $H(c)$ is small.

In order to compare the profitability of full commitment and partial commitment created by proportional fees, we rewrite condition (3.18) for an introduction of a proportional fee being profitable by inserting the optimal per-transaction fee (3.19) as

$$\gamma(c) > 2 \cdot \left(\frac{H(c)}{r - c}\right) \cdot \left(\frac{1 - H(c)}{h(c)}\right) - 1. \tag{3.24}$$

Finally, we arrive at the following result:

Proposition 3.5 (Commitment and profitability of proportional fees).
If conditions (3.23) and (3.24) hold, the introduction of a positive proportional fee strictly improves the optimal classical two-part tariff, whereas the intermediary would reject the opportunity of full commitment.

[29] Note that the shape of the cost distribution $H(\zeta)$ above c does not affect any decision as long as the corresponding probability mass $1 - H(c)$ remains constant. This is because the intermediary never enters with costs $\zeta > c$.

Differently from full commitment, the introduction of a proportional fee creates additional investment incentives for sellers without completely abandoning the merchant option. Accordingly, the condition for a proportional fee being profitable can be fulfilled while full commitment is not attractive to the intermediary.[30] In particular, both conditions hold if $H(c)$ is sufficiently small, given a fixed level of $\gamma(c)$. This shows that (partial) commitment created by the use of a proportional fee is not only more profitable than setting a classical two-part tariff, but also more profitable than full commitment (if feasible at all) under certain circumstances.

3.6 A numerical example

In this section, we consider the following parametrization of our model:

- Sellers' investment costs I are uniformly distributed between 0 and 300.
- The mass of consumers is given by $M = 20$.[31]
- The intermediary's costs ζ are uniformly distributed between 0 and 9.
- Sellers' production costs are given by $c = 6.5$.
- Consumers' willingness to pay equals $r_1 = 20$ (case 1) or $r_2 = 9$ (case 2).[32]

Under this parametrization, the intermediary faces lower costs than sellers with a probability of $H(c) = \frac{13}{18}$. Furthermore, under classical two-part tariffs, his expected cost advantage (as defined in (3.7)) is given by $\Delta^e(c) = \frac{169}{72}$. Consequently, the

[30]Note that Proposition 3.5 only gives a sufficient condition for partial commitment being more profitable. In particular, condition (3.23) is relatively demanding as we compare the profit under full commitment with the intermediary's profit *under two-part tariffs*.

[31]Note that a change in M has the same effect as rescaling the distribution of I.

[32]This specific parameter constellation which is characterized by a wide range of production costs (relative to the sellers' monopoly margin $r-c$) allows to illustrate that full commitment may not be profitable. Given the restriction that both investment costs and production costs follow a uniform distribution, this particular result only holds for a relatively small set of parameters. However, the condition for proportional fees improving classical two-part tariff is much less sensitive to the choice of parameters: with $[\underline{\zeta}, \overline{\zeta}]$ denoting the support of the uniform production cost distribution, condition (3.18) becomes $\frac{r-c}{\overline{\zeta}-\underline{\zeta}} > H(c) \cdot \{2 \cdot (1 - H(c)) - \frac{1}{2} \cdot H(c)\}$, with $H(c) = \frac{c-\underline{\zeta}}{\overline{\zeta}-\underline{\zeta}}$.

optimal classical two-part tariff is characterized by $a_1^* = \frac{r_1 - c - \Delta^e(c)}{2} = \frac{803}{144}$ in case 1 and by $a_2^* = \frac{r_2 - c - \Delta^e(c)}{2} = \frac{11}{144}$ in case 2.

Condition (3.18) for profitability of the introduction of a proportional fee is fulfilled in both cases. Condition (3.23) for full commitment not being profitable under classical two-part tariffs fails to hold in case 1, but it is fulfilled in case 2.[33] The intermediary's maximum profit under full commitment (i.e., a pure platform mode) equals $\frac{243}{4}$ in case 1 and $\frac{25}{12}$ in case 2.

Table 3.1 shows the intermediary's expected profit $\Pi^e(0, a, \alpha)$, his entry threshold $\widetilde{\zeta}(a, \alpha)$, and the corresponding level of seller participation $F(\widetilde{I}(0, a, \alpha))$ for different combinations of a per-transaction fee a and a proportional fee α for both cases.

Row #	r	a	α	$\Pi^e(0, a, \alpha)$	$\widetilde{\zeta}(a, \alpha)$	$F(\widetilde{I}(0, a, \alpha))$
1	20	5.5764	0.000	23.253	6.500	14.67 %
2	20	5.5764	0.010	23.798	6.422	14.75 %
3	20	0.0000	0.357	43.357	2.969	28.41 %
4	9	0.0764	0.000	2.1755	6.500	4.49 %
5	9	0.0764	0.010	2.1782	6.476	4.36 %
6	9	0.0000	0.019	2.1829	6.456	4.40 %

Table 3.1: Intermediary's profit and seller participation under different tariff systems

Rows 1 and 4 represent the optimal classical two-part tariff in which the entry threshold always fulfills $\widetilde{\zeta}(a, 0) = c$. In line with condition (3.23), the intermediary's respective profit under full commitment exceeds the profit level given in row 1 (case 1), but is lower than the level given in row 4 (case 2).

Rows 2 and 5 reconfirm that introducing a small additional proportional fee (of one percent) improves the optimal classical two-part tariff, reducing the intermediary's entry incentives, i.e., leading to a lower level of $\widetilde{\zeta}(a, \alpha)$. However, seller participation, measured by $F(\widetilde{I}(0, a, \alpha))$, may increase or decrease due to a higher overall fee level.[34]

[33] We have $\gamma(c) = \frac{169}{972}$ in case 1, and $\gamma(c) = \frac{169}{180} \approx 0.9389$ in case 2, while the right-hand side of condition (3.23) approximately equals 0.8974.

[34] More specifically, condition (3.13) for a proportional fee increasing seller participation is fulfilled in case 1, but it does not hold in case 2.

Finally, rows 3 and 6 illustrate that a proportional fee does not only (marginally) improve a two-part tariff – a pure proportional fee may yield even higher profits.[35]

Although the numerical analysis may suggest that pure proportional fees are optimal, in particular with both investment costs and production costs being uniformly distributed, the fact that pure proportional fees always reduce the intermediary's entry incentives indicates that they may also imply an unprofitably low entry threshold. Hence, non-degenerate three-part tariffs may outperform pure proportional fees, at least under more sophisticated cost distributions, leading to a better balance between intermediary's entry incentives and rent extraction.

3.7 Conclusion

While real world platforms use a mixture of tariff forms, including proportional (per-revenue) fees, the great majority of the economic literature on platform markets has focussed on membership fees and per-transaction fees. The extant studies on proportional platform fees highlight the reduction of the double marginalization problem and the ability to price discriminate by using a certain proportional fee. Analyzing a dual mode of intermediation, we identify the effects of the intermediary's tariff system on competition between sellers and the intermediary and on sellers' investment incentives.

Firstly, we identify a *competition-relaxing effect* of transaction-based fees. Abstracting from double marginalization, the intermediary strictly prefers transaction-based fees to membership fees. The reason is that transaction-based fees increase sellers' marginal costs and, thus, increase prices in case the intermediary competes with a seller. This effect does not occur for a pure platform, and, hence, the operator of a pure platform is indifferent between membership-based and transaction-based tariffs (in line with Armstrong, 2006).[36]

If sellers have to sink costs before joining the platform, the threat of competition leads to a hold-up problem: profitable product markets remain unexplored. Sellers' investment incentives are insufficient as sellers do not internalize the profits that the intermediary achieves due to their product. Therefore, the intermediary would

[35] Rows 3 and 6 indeed characterize the (numerically determined) optimal three-part tariff.

[36] The canonical two-sided market models like Armstrong (2006) abstract from price-setting by sellers and, thereby, also abstract from double marginalization problems.

like to commit not to compete, forgoing (parts of) his merchant profits to increase investment incentives.

However, even if credible commitment never to enter sellers' markets was feasible, it would not always be profitable. The intermediary would prefer to commit not to enter if his cost advantage is small, but he wants to exercise his merchant option in case of a large cost advantage.[37] We show that proportional (revenue-based) fees can achieve this partial commitment as they change the intermediary's opportunity costs of competition. In particular, the *commitment effect* of proportional fees is such that the intermediary only enters product markets if his cost advantage exceeds a strictly positive threshold. In contrast, under classical two-part tariffs, the intermediary enters if and only if he faces lower production costs than sellers. The reason is that the level of the per-transaction fee does not affect the intermediary's incentives to enter as a change in this platform fee results in an equal change of sellers' perceived costs, affecting merchant profits to the same extent as platform profits.

However, the commitment effect of proportional fees comes at the cost of foregoing cost advantages and a potential reduction of the competitive price. Although proportional fees mitigate the hold-up problem, their profitability depends on the distribution of the intermediary's costs relative to the sellers' costs. If the probability of the intermediary facing costs slightly below sellers' costs c is large, the introduction of a small proportional fee is always profitable as it significantly reduces the hold-up problem.[38]

Our analysis sheds light on the economics of intermediated markets, in particular markets in which the intermediary does not only organize a marketplace, but can become active in it himself. In addition, the effects we identify could also play a role in the context of franchising and licensing.

[37] As the intermediary's costs are rarely verifiable, such behavior seems not to be contractible directly.

[38] Furthermore, if the intermediary's maximal cost advantage is relatively small, the intermediary can achieve credible commitment *never* to enter sellers' markets by charging a proportional fee that implies that the entry threshold $\widetilde{\zeta}(\cdot)$ does not exceed $\underline{\zeta}$.

3.8 Appendix

Proof of Proposition 3.1

Recall that the intermediary's expected overall profit under a two-part tariff (A, a) can be written as

$$\Pi^e(A, a) = F(\widetilde{I}(A, a)) \cdot \{A + M \cdot (a + \Delta^e(c))\}, \tag{3.25}$$

with $\Delta^e(c)$ being independent of both A and a.

We show that it is always more profitable to charge a higher per-transaction fee instead of a membership fee: a 'compensated' increase in the per-transaction fee a which does not affect seller participation leads to an increase in the intermediary's per-product profit. Starting from an arbitrary tariff scheme (A, a) with $A > 0$, we firstly determine how to adapt the membership fee A such that the critical level of investment costs $\widetilde{I}(A, a)$ remains constant while changing a. Secondly, given this compensation, we show that the effect of a change in the per-transaction fee a overcompensates the effect of the corresponding adaption of the membership fee A.

(i) Given the definition

$$\widetilde{I}(A, a) \equiv \{1 - H(c)\} \cdot M \cdot \{r - (a + c)\} - A$$

from Lemma 3.3, we have $\frac{\partial \widetilde{I}(A,a)}{\partial A} = -1$. By implicit function theorem it follows that the compensation $A(a)$ has to fulfill $\frac{\partial A(a)}{\partial a} = -\frac{\partial \widetilde{I}/\partial a}{\partial \widetilde{I}/\partial A} = \frac{\partial \widetilde{I}(A,a)}{\partial a}$. Substituting $\frac{\partial \widetilde{I}}{\partial a}$ yields $\frac{\partial A(a)}{\partial a} = -M \cdot (1 - H(c))$.

(ii) Define $\pi(A, a) \equiv A + M \cdot (a + \Delta^e(c))$. Then, we obtain $\frac{\partial \pi}{\partial A} = 1$ and $\frac{\partial \pi}{\partial a} = M$. Substituting these derivatives and $\frac{\partial A(a)}{\partial a}$ into the definition of the total differential

$$d\pi = \frac{\partial \pi}{\partial A} dA + \frac{\partial \pi}{\partial a} da$$

leads to $\frac{d\pi}{da} = M \cdot H(c) > 0$, and the loss from a decrease in A is overcompensated by the corresponding increase in a as the latter creates an additional advantage for the merchant in case of competition (that occurs with probability $H(c)$).

Now, we can focus on pure per-transaction fee tariffs as the optimal membership fee is zero. Differentiating equation (3.8) with respect to a and plugging in $A = 0$ yields

$$\frac{\partial \Pi^e(0, a)}{\partial a} = M \cdot \Big\{ F(\widetilde{I}(0, a)) - f(\widetilde{I}(0, a^*)) \cdot \{1 - H(c)\} \cdot M \cdot (a^* + \Delta^e(c)) \Big\}.$$

Setting this equation to zero yields the first order condition (3.9).

If $F(\cdot)$ is weakly concave, $\Pi^e(0, a)$ is strictly concave in a. Hence, the first order condition is sufficient for a maximum.

Proof of Lemma 3.4

We already explained that the expected surplus created by a market equals $M \cdot \{r - c + \Delta^e(c)\}$. Intuitively, a market should be opened up if this expected surplus covers investment costs. More formally, it is easy to show that $I^* = M \cdot \{r - c + \Delta^e(c)\}$ maximizes expected welfare

$$W^e = F(\hat{I}) \cdot M \cdot \{r - c + \Delta^e(c)\} - \int_{\underline{I}}^{\hat{I}} I \, dF(I).$$

We can focus on the first order condition with respect to $\hat{I}$. Using the Leibniz integral rule, the condition indeed turns out to be $I^* = M \cdot \{r - c + \Delta^e(c)\}$.

Proof of Lemma 3.5

In the second-best case, the social planner faces the constraint $(A, a) \geq 0$ when maximizing the expected welfare, which is given by

$$\begin{aligned} W^e(A, a, \hat{\zeta}) =& F(\hat{I}(A, a, \hat{\zeta})) \cdot M \cdot \{H(\hat{\zeta}) \cdot (r - E[\zeta | \zeta < \hat{\zeta}]) + (1 - H(\hat{\zeta})) \cdot (r - c)\} \\ & - \int_{\underline{I}}^{\hat{I}(A,a,\hat{\zeta})} I \, dF(I), \end{aligned}$$

with $\hat{I}(A, a, \hat{\zeta}) \equiv M \cdot \{1 - H(\hat{\zeta})\} \cdot (r - (c + a)) - A$.

Firstly, for $(A, a) \geq 0$, less sellers invest than in the first-best case:

$$\hat{I}(A, a, \hat{\zeta}) < I^* \;\Leftrightarrow\; \{1 - H(\hat{\zeta})\} \cdot \{r - (c + a)\} - A < r - c + \underbrace{\Delta^e(c)}_{\geq 0}.$$

Intuitively, since investment incentives are too low, charging positive fees only reduces welfare. Formally, both $\frac{\partial W^e}{\partial A}$ and $\frac{\partial W^e}{\partial a}$ are strictly negative within the support of $F(\cdot)$, i.e., if $f(\cdot) > 0$ (which necessarily holds in the optimum):

$$\frac{\partial W^e}{\partial A} = -f(\hat{I}(A, a, \hat{\zeta})) \cdot M \cdot \underbrace{\left\{ H(\hat{\zeta}) \cdot r - \int_{\underline{\zeta}}^{\hat{\zeta}} x dH(x) + \frac{A}{M} + (1 - H(\hat{\zeta})) \cdot a \right\}}_{>0},$$

$$\frac{\partial W^e}{\partial a} = \{1 - H(\hat{\zeta})\} \cdot \frac{\partial W^e}{\partial A}.$$

Hence, for any value of $\hat{\zeta} \in (\underline{\zeta}, \overline{\zeta})$, $(A, a) = (0, 0)$ maximizes welfare, given the constraint $(A, a) \geq 0$.

It is left to show that the social planer chooses $\hat{\zeta} < c$. We can rule out that $\hat{\zeta} \geq c$ since in that case expected welfare could be improved by lowering $\hat{\zeta}$:

$$\begin{aligned}
\frac{\partial W^e}{\partial \hat{\zeta}} &= -h(\hat{\zeta}) \cdot M^2 \cdot (r - (c + a)) \cdot f(\hat{I}(A, a, \hat{\zeta})) \cdot \left\{ r - (1 - H(\hat{\zeta})) \cdot c - \int_{\underline{\zeta}}^{\hat{\zeta}} x dH(x) \right\} \\
&\quad + F(\hat{I}(A, a, \hat{\zeta})) \cdot M \cdot h(\hat{\zeta}) \cdot (c - \hat{\zeta}) \\
&\quad + M \cdot h(\hat{\zeta}) \cdot (r - (c + a)) \cdot f(\hat{I}(A, a, \hat{\zeta})) \cdot \hat{I}(A, a, \hat{\zeta}) \\
&= h(\hat{\zeta}) \cdot M \cdot (r - (c + a)) \cdot f(\hat{I}(A, a, \hat{\zeta})) \\
&\quad \times \left[\hat{I}(A, a, \hat{\zeta}) - M \cdot \left\{ r - (1 - H(\hat{\zeta}))c - \int_{\underline{\zeta}}^{\hat{\zeta}} x dH(x) \right\} \right] \\
&\quad + F(\hat{I}(A, a, \hat{\zeta})) \cdot M \cdot h(\hat{\zeta}) \cdot (c - \hat{\zeta}) \\
&= M \cdot h(\hat{\zeta}) \cdot \left\{ \left(\frac{\partial W^e}{\partial A} \right) \cdot (r - (c + a)) + F(\hat{I}(A, \hat{\zeta})) \cdot (c - \hat{\zeta}) \right\}
\end{aligned}$$

The second summand in curly brackets, $F(\hat{I}(A, \hat{\zeta})) \cdot (c - \hat{\zeta})$, is negative for $\hat{\zeta} > c$ (and 0 for $\hat{\zeta} = c$). As the first summand is negative, we have

$$\left. \frac{\partial W^e}{\partial \hat{\zeta}} \right|_{\hat{\zeta} \geq c} < 0,$$

and the optimal threshold is below c.

Proof of Lemma 3.6

The intermediary's expected overall profit under commitment not to enter with production costs above $\hat{\zeta}$ is given as follows:

$$\widehat{\Pi}^e(A, a, \hat{\zeta}) = \begin{cases} F(\hat{I}(A, a, \hat{\zeta})) \cdot \{A + M \cdot (a + \Delta^e(c, \hat{\zeta}))\}, & \hat{\zeta} \leq c \\ F(\hat{I}(A, a, \hat{\zeta})) \cdot \{A + M \cdot (a + \Delta^e(c, c))\}, & \hat{\zeta} > c \end{cases}, \tag{3.26}$$

where

$$\hat{I}(A, a, \hat{\zeta}) = M \cdot \{1 - H(\hat{\zeta})\} \cdot (r - (c + a)) - A,$$

and

$$\Delta^e(c,\hat{\zeta}) \equiv H(\hat{\zeta}) \cdot c - \int_{\underline{\zeta}}^{\hat{\zeta}} x dH(x).$$

Firstly, note that $\hat{\zeta} > c$ are dominated by $\hat{\zeta} = c$. This can be seen as follows: if $\hat{\zeta} > c$, $\hat{\zeta}$ affects the intermediary's profit only through the change in seller participation captured by $F(\cdot)$ because it is never profitable for the intermediary to enter with costs $\zeta \in (c, \hat{\zeta})$ (i.e., $\Delta^e(c,c)$ does not depend on $\hat{\zeta}$). For any $\hat{\zeta} > c$, $F(\hat{I}(A,a,c)) > F(\hat{I}(A,a,\hat{\zeta})$ holds (given Assumption 3.2 which guarantees interior levels of investment costs).

Differentiating $\widehat{\Pi}^e(A,a,\hat{\zeta})$ from below c yields

$$\left.\frac{\partial \widehat{\Pi}^e(A,a,\hat{\zeta})}{\partial \hat{\zeta}}\right|_{\hat{\zeta}\leq c} = f(\hat{I}(A,a,c)) \cdot \{-h(\hat{\zeta}) \cdot M \cdot (r-(c+a)\} \cdot \{A + M \cdot (a + \Delta^e(c,\hat{\zeta}))\} \\ + F(\hat{I}(A,a,\hat{\zeta})) \cdot \{M \cdot h(\hat{\zeta}) \cdot (c-\hat{\zeta})\}.$$

For $\hat{\zeta} = c$, the first term is negative, while the second term equals zero. Hence,

$$\left.\frac{\partial \widehat{\Pi}^e(A,a,\hat{\zeta})}{\partial \hat{\zeta}}\right|_{\hat{\zeta}=c} < 0,$$

and $c > \arg\max_{\hat{\zeta}} \widehat{\Pi}^e(A,a,\hat{\zeta})$.

Proof of Proposition 3.3

The condition $\widetilde{\zeta}(a,\alpha) < c$ is equivalent to $\frac{c+a}{1-\alpha} - \alpha r - a < c$, which can also be written as $c - (1-\alpha)\cdot\alpha\cdot r + \alpha\cdot a < (1-\alpha)\cdot c$, or $\alpha\cdot(c+a) < (1-\alpha)\cdot\alpha\cdot r$. Division by $\alpha > 0$ yields $c + a < (1-\alpha)\cdot r$, a necessary condition for positive seller participation.

Proof of Lemma 3.9

Equation (3.12) defines the critical level of investment costs under a three-part tariff as

$$\widetilde{I}(A,a,\alpha) \equiv \{1 - H(\widetilde{\zeta}(a,\alpha))\} \cdot M \cdot \{(1-\alpha)\cdot r - c - a\} - A.$$

Since $\widetilde{\zeta}(a,\alpha) \equiv \frac{c+a}{1-\alpha} - \alpha r - a = \frac{c}{1-\alpha} - \alpha r + \frac{\alpha}{1-\alpha}\cdot a$, $\widetilde{I}$ clearly decreases in A and a. Furthermore, we have

$$\frac{\partial \widetilde{I}(A,a,\alpha)}{\partial \alpha} = - M \cdot \underbrace{(1 - H(\widetilde{\zeta}(a,\alpha))) \cdot r}_{\text{change of revenue share}} + M \cdot \underbrace{h(\widetilde{\zeta}(a,\alpha)) \cdot \left(r - \frac{c+a}{(1-\alpha)^2}\right) \cdot \{(1-\alpha) \cdot r - (c+a)\}}_{\text{change of entry incentives}}.$$

This expression is positive if and only if

$$(1 - H(\widetilde{\zeta})) \cdot r < h(\widetilde{\zeta}) \cdot \left(r - \frac{c+a}{(1-\alpha)^2}\right) \cdot \{(1-\alpha) \cdot r - (c+a)\}.$$

Proof of Proposition 3.4

Firstly, we consider the merchant's expected cost advantage. We observe

$$\frac{\partial \Delta^e(\widetilde{\zeta}(a,\alpha))}{\partial \alpha} = h(\widetilde{\zeta}(a,\alpha)) \cdot \frac{\partial \widetilde{\zeta}(a,\alpha)}{\partial \alpha} \cdot \widetilde{\zeta}(a,\alpha) + H(\widetilde{\zeta}(a,\alpha)) \cdot \frac{\partial \widetilde{\zeta}(a,\alpha)}{\partial \alpha} - \left[\widetilde{\zeta}(a,\alpha) \cdot h(\widetilde{\zeta}(a,\alpha)) \cdot \frac{\partial \widetilde{\zeta}(a,\alpha)}{\partial \alpha}\right],$$

where the last term in brackets follows from the Leibniz integral rule. As the first and the last term cancel out, this simplifies to

$$\frac{\partial \Delta^e(\widetilde{\zeta}(a,\alpha))}{\partial \alpha} = H(\widetilde{\zeta}(a,\alpha)) \cdot \frac{\partial \widetilde{\zeta}(a,\alpha)}{\partial \alpha} = H(\widetilde{\zeta}(a,\alpha)) \cdot \left(\frac{c+a}{(1-\alpha)^2} - r\right).$$

Hence, the derivative of the intermediary's expected profit (3.17) is given by

$$\frac{\partial \Pi^e(A,a,\alpha)}{\partial \alpha} = F(\widetilde{I}(A,a,\alpha)) \cdot M \cdot \left[r + H(\widetilde{\zeta}(a,\alpha)) \cdot \left(\frac{c+a}{(1-\alpha)^2} - r\right)\right] + f(\widetilde{I}(A,a,\alpha)) \cdot \left(\frac{\partial \widetilde{I}(A,a,\alpha)}{\partial \alpha}\right) \cdot \left\{A + M \cdot \left[a + \alpha r + \Delta^e\left(\widetilde{\zeta}(a,\alpha)\right)\right]\right\},$$

with $\frac{\partial \widetilde{I}(A,a,\alpha)}{\partial \alpha}$ as given in the proof of Lemma 3.9. Defining

$$\pi(A,a,\alpha) \equiv \left\{A + M \cdot \left[a + \alpha r + \Delta^e\left(\widetilde{\zeta}(a,\alpha)\right)\right]\right\},$$

we find that $\frac{\partial \Pi^e(A,a,\alpha)}{\partial \alpha}$ is positive if and only if

$$\frac{F(\widetilde{I}(A,a,\alpha))}{f(\widetilde{I}(A,a,\alpha))} > \pi(A,a,\alpha) \cdot \frac{(1 - H(\widetilde{\zeta}(a,\alpha))) \cdot r + h(\widetilde{\zeta}(a,\alpha)) \cdot \left(\frac{c+a}{(1-\alpha)^2} - r\right) \cdot \{(1-\alpha) \cdot r - c - a\}}{r + H(\widetilde{\zeta}(a,\alpha)) \cdot \left(\frac{c+a}{(1-\alpha)^2} - r\right)}.$$

From Proposition 3.1, we know that the optimal per-transaction fee in case of $\alpha = 0$ is defined by

$$\{1 - H(c)\} \cdot \{\underbrace{M \cdot (a^* + \Delta^e(c))}_{=\pi(0,a^*,0)}\} = \frac{F(\widetilde{I}(0, a^*, 0))}{f(\widetilde{I}(0, a^*, 0))}.$$

Hence, by envelope theorem, $\frac{\partial \Pi^e(0,a^*,0)}{\partial \alpha} > 0$ holds at the optimal two-part tariff if

$$\begin{aligned} 1 - H(c) &> \frac{(1 - H(c)) \cdot r - h(c) \cdot \{r - c - a^*\}^2}{r - H(c) \cdot \{r - c - a^*\}} \\ \Leftrightarrow -H(c) \cdot \{r - c - a^*\} &> \frac{-h(c) \cdot \{r - c - a^*\}^2}{1 - H(c)} \\ \Leftrightarrow \qquad \frac{h(c)}{1 - H(c)} &> \frac{H(c)}{r - c - a^*}. \end{aligned}$$

Proof of Corollary 3.1

Again, from Proposition 3.1, we know that the optimal per-transaction fee (in case of an interior solution, i.e., $a^* > 0$) is defined by

$$\{1 - H(c)\} \cdot \{M \cdot (a^* + \Delta^e(c))\} = \frac{F(\widetilde{I}(0, a^*))}{f(\widetilde{I}(0, a^*))},$$

with $\widetilde{I}(0, a) = \{1 - H(c)\} \cdot M \cdot \{r - c - a\}$. As $F(I) = \frac{I}{\overline{I}}$ for $I \in [0, \overline{I}]$, the condition becomes

$$\{1 - H(c)\} \cdot \{M \cdot (a^* + \Delta^e(c))\} = \frac{\{1 - H(c)\} \cdot M \cdot \{r - c - a^*\}}{\overline{I}} \cdot \overline{I},$$

which is equivalent to

$$a^* = \frac{r - c - \Delta^e(c)}{2}.$$

Inserting this fee into the intermediary's profit (3.8) yields the expected profit (3.20).

Proof of Lemma 3.10

Comparing the intermediary's expected profit under a classical two-part tariff (with entry if costs are below c) given in (3.20) with his expected profit (3.21) under full commitment never to enter sellers' markets, full commitment is *not* profitable if

$$(1 - H(c)) \cdot \left(\frac{r - c + \Delta^e(c)}{2}\right)^2 > \left(\frac{r - c}{2}\right)^2.$$

By definition (3.22), we have $\Delta^e(c) = (r - c) \cdot \gamma(c)$. Therefore, the latter condition is equivalent to

$$\sqrt{1 - H(c)} \cdot (1 + \gamma(c)) > 1.$$

Solving this condition for $\gamma(c)$ yields condition (3.23).

Chapter 4

Intermediated versus Direct Sales and a No-Discrimination Rule

4.1 Introduction

Sellers often simultaneously use several ways of distribution or sales channels to reach consumers. Different channels are likely to differ in transaction costs. Furthermore, each consumer's willingness to pay for a specific product may depend on the channel used for purchase. Consequently, sellers usually face incentives to set different prices across channels.[1] However, if a seller joins a marketplace offered by an intermediary, the intermediary may restrict the seller's pricing decisions. More specifically, an intermediary who has (some) market power may prohibit sellers offering customers better sales conditions elsewhere, in particular selling the same product at a lower price in other sales channels, by imposing a most-favored treatment or no-discrimination clause.

For example, HRS, the leading German online hotel reservation platform, only lists hotels which agree to offer the best room rates and most favorable booking conditions on the HRS platform. Several other online travel agents (e.g. Booking.com and Expedia) limit hotels' decisions on room rates in a similar way. Furthermore, in May 2010, Amazon's European platforms introduced a price parity rule where they ask sellers who offer their products in Amazon's marketplaces not to set lower prices for these products elsewhere. A similar rule has applied to the US mar-

[1] Wolk and Ebling (2010) find that sellers indeed practice channel-based price differentiation.

ketplace (Amazon.com) for several years. Both Amazon's price parity rule and the most-favored treatment clauses imposed by HRS and other platforms of online travel agents just recently became subjects of litigation.[2]

In all cases described above, many sellers (or hotels)[3] want to be listed on a platform, in particular to reach consumers who might not search for them outside the respective platform. At the same time, they also offer products outside the platform (using their own stores/websites or accepting direct requests from potential customers). The platform charges sellers considerable fees/commissions, primarily based on transaction volume, whereas direct sales typically generate different costs. Under a no-discrimination rule (NDR), sellers' prices usually cannot reflect all cost differences. Therefore, consumers who come to know that a seller uses several sales channels do not internalize differences in costs when choosing in which channel to buy as the (zero) price difference does not signal cost advantages. This problem can become even more severe if consumers are likely to search for offers in alternative channels of the same provider after they found a matching product in one channel: if sellers are free to set different prices across channels, they can steer consumers to the most profitable channel, in contrast to the situation under a no-discrimination rule. However, competing sellers may not perfectly internalize consumers' channel preferences and the intermediary's costs when setting their prices.[4] Therefore, it is natural to ask about the consequences of no-discrimination rules on seller behavior, the split-up of consumers between channels, and the intermediary's decision on fees charged to sellers and buyers. However, to date, there is no study that explicitly addresses these consequences.[5]

[2]Cf. Office of Fair Trading (2012), injunction against HRS's most-favored treatment clause (Higher Regional Court Duesseldorf, file no. 33 O 16/12), Bundeskartellamt (2012, 2013), and appendix, p. 139.

[3]In the following, I use the terms "no-discrimination rule" (NDR) and "sellers" also as representatives for most-favored treatment clauses and hotels, respectively.

[4]Furthermore, if the platform provides useful services (e.g. detailed product information, reviews, reduction of search costs) which require investments by the intermediary but also promote direct sales, this phenomenon (which basically causes a free-riding effect) can lead to an inefficiently low level of such investments.

[5]Aguzzoni et al. (2012) offer an up-to-date review of the literature on price relationship agreements and their potential effects, indicating that there is no study that examines such agreements in intermediated markets. For more details, cf. the literature section below.

In this essay, I analyze a framework of a dominant intermediary who offers sellers a platform to reach consumers. Sellers serve horizontally differentiated products and compete with each other. Each seller can offer her respective product both directly and in the marketplace operated by the intermediary. Consumers apply a sequential decision rule: they compare products based on prices in one of the two sales channels, choose their preferred product, and then decide in which channel to buy. In particular, this assumption introduces a certain spillover effect between channels: being active in one channel can lead to additional sales in the other channel.[6] Taken together, I analyze a model that allows for an endogenous split-up of consumers between channels with competing sellers who might set different prices across channels. In this model, both consumers' and sellers' decisions are affected by the tariff chosen by the intermediary and his decision on imposing a no-discrimination rule.

Firstly, I find that without a no-discrimination rule the division of the intermediary's fee between sellers and buyers does not affect the split-up of consumers between channels: sellers fully internalize (transaction-based) fees charged to consumers when setting their prices.[7] Without a no-discrimination rule, each seller's channel-dependent prices generally differ from each other. The price difference reflects cost differences, relative importance of each channel for product choice, and differences in consumers' channel valuations, resulting in a redistribution of consumers between channels.

Secondly, if the intermediary imposes a no-discrimination rule, his tariff system is no longer neutral. Furthermore, when deciding whether to join the platform, sellers trade-off the costs of providing a certain amount of their product over the platform with the benefits of reaching additional consumers on the platform. The intermediary imposes a no-discrimination rule if his costs for processing a transaction are relatively high, if seller competition is weak, and if the initial distribution of consumers on channels is strongly skewed (in particular, if most consumers' prod-

[6]This effect (sometimes called "billboard effect") seems natural and is well-known at least in the hotel industry, cf. e.g. Anderson (2011). Furthermore, the assumption on sequential consumer decisions seems plausible as consumers rarely compare all prices of several products across channels. For a related empirical analysis of consumer search behavior across online book stores, cf. e.g. De Los Santos, Hortaçsu, and Wildenbeest (2012).

[7]Note that this neutrality property does not necessarily hold for membership fees which consumers might pay up front as these can lead to an unravelling problem, cf. Gans (2012) and my literature review.

uct choice is based on prices on the platform). If these criteria are met, each seller's incentives to specialize on direct sales under a no-discrimination rule are relatively weak. Hence, the intermediary prefers imposing a no-discrimination rule, charging fees that are compatible with all sellers being active on his platform, to not imposing a no-discrimination rule. Each seller's outside option, specializing in direct sales and refusing to join the platform, implies less consumers being aware of her respective offer. However, specialization would also have a positive effect on seller profits: besides saving relatively high platform fees, it may relax seller competition.

Welfare implications depend on the difference between the intermediary's per-transaction costs and the costs sellers incur when selling directly to buyers, the distribution of consumers' heterogeneous valuations across channels, and the size of the initial fraction of platform consumers. Without a no-discrimination rule, both an over- and an underuse of the platform channel can arise. Imposing a no-discrimination rule always results in an underuse of the intermediary's marketplace; this is due to the basic inefficiency caused by the intermediary having market power. Consequently, prohibiting no-discrimination rules can have both positive and negative effects on welfare, even in a framework that excludes both service arguments and foreclosure effects.

Related literature

Considering the terminology used both by competition authorities and in my introduction (terms like "no-discrimination rules" and "most-favored customer clauses"), at first view my work may be seen as closely related to the literature on certain price relationship agreements in which a seller guarantees customers not to offer better conditions to any other customer (across-customers agreements or most-favored customer clauses) or not to offer conditions worse than those offered by competitors (across-sellers agreements like low-price guarantees).[8] However, the present studies focus on sellers who directly grant their customers some guarantee, excluding any form of intermediation between those two groups, while I analyze a specific form of a most-favored treatment clause *imposed by an intermediary* who offers a market-

[8] In particular, both across-customer and across-seller agreements can facilitate collusion (cf. e.g. Cooper, 1986; Neilson & Winter, 1993; Schnitzer, 1994; Hviid & Shaffer, 2010). Furthermore, price-matching guarantees may be used to signal a low price level (e.g. Moorthy & Winter, 2006) or to deter entry (e.g. Arbatskaya, 2001).

place but does not control prices of the traded goods. In particular, Aguzzoni et al. (2012), who summarize potential effects of price-relationship agreements (PRAs), point out that they "have not found any economic literature that specifically studies the possible competition effects of third-party PRAs".[9] Furthermore, they state that "to date th[e] literature [on two-sided markets] does not study the competitive effects of across-platforms parity agreements."[10]

In line with the first statement, I am not aware of any study that specifically analyzes an intermediary's decision on imposing a no-discrimination rule (or concluding an "across-platforms parity agreement") in a framework with (imperfectly) competing sellers who may set different prices across channels. However, across-platforms parity agreements exhibit at least some similarities with so-called "no-surcharge rules" which payment card networks (as a specific kind of platform operators) may impose. Before reviewing related work on card networks and no-surcharge/no-discrimination rules, I firstly address studies on two-sided markets and platform pricing.

Platform markets

The classical literature on two-sided markets[11] (e.g. Rochet & Tirole, 2006; Armstrong, 2006) basically discusses a platform's pricing behavior in reduced-form models that capture network effects through the *number* of members on the other side of the platform. Accordingly, each player's utility depends on everyone's joining decision. However, in the canonical models, utility does not depend on other decision variables of any member of the two sides of the market, in particular not on seller pricing in case of a trade platform.

However, there are a few recent exceptions which discuss proportional fees and, therefore, endogenize seller pricing (Shy & Wang, 2011; Miao, 2011; Z. Wang & Wright, 2012, and chapter 3 of this dissertation). Nevertheless, these studies do not allow for sellers bypassing the platform ("direct sales") or any other form of competition between platforms.

[9] Aguzzoni et al. (2012, p. 84). Third-party PRAs include "across-platform parity agreements" which are concluded between sellers and a platform operator and limit sellers' pricing decisions.

[10] Aguzzoni et al. (2012, p. 96).

[11] Jullien (2012) offers a comprehensive up-to-date survey on two-sided (B2B) platforms, including a general introduction to two-sided markets.

In contrast, Gans (2012) analyzes a framework where a single seller (content provider) can reach consumers (users of a mobile platform) both in an intermediated market and outside the marketplace. He finds that the platform provider cannot charge membership fees to consumers up front as he faces an unravelling problem. Imposing a most-favored customer clause may mitigate this problem, enabling the platform provider to charge positive membership fees to consumers.

Payment card networks, interchange fees, and no-surcharge rules (NSRs)

During the last decades, a considerable amount of studies focussed on the analysis of payment card networks. Although there are different network structures, all models share some basic features. When a consumer wants to purchase a product from a seller and it comes to paying, the consumer usually has (at least) two options: card or cash payment (assuming that the seller accepts and the consumer carries both means of payment). Both sellers and consumers may pay different kinds of fees to accept/carry and to use (debit or credit) cards. As the tariff systems of card networks typically comprise transaction-based components, sellers may have incentives to set prices based on the payment method used, discriminating between different means of payments by surcharging or granting discounts. However, card networks may impose no-surcharge or no-discrimination rules, prohibiting those practices.[12]

My work may be seen as a contribution to this strand of literature: sales channels correspond to different means of payment and the platform operator plays the role of a (unitary) card network, or, in case of a four party model, the role of an issuer who possesses market power and can set both buyer fees and the interchange fee which is passed through by competitive acquirers. In the following, I survey several models

[12]Legislation on the NSR considerably differs across countries. In the EU, imposing a NSR is prohibited: "The payment service provider shall not prevent the payee from requesting from the payer a charge or from offering him a reduction for the use of a given payment instrument." (European Commission, 2007a, article 52(3), meanwhile implemented by all Member States). However, surcharging may be generally prohibited (NSR imposed by law) – this is the case in 10 states of the US and several countries in Europe (e.g. Austria, Italy, Sweden – facilitated by the Payment Services Directive which also states that "Member States may forbid or limit the right to request charges taking into account the need to encourage competition and promote the use of efficient payment instruments"). In most states of the US, card networks are free to impose a NSR.

of payment card networks and some empirical insights on no-surcharge rules.[13]

As a precursor of the literature on two-sided markets, Rochet and Tirole (2002) discuss the interchange fee (i.e., the transaction-based payment between issuing and acquiring bank) in a four party credit card network. Acquiring banks are assumed to be perfectly competitive, setting the seller fee/discount equal to the sum of interchange fee and their per-transaction costs. Issuing banks have market power and set both the interchange fee and the consumer fee, playing the “balancing” platform role. Two sellers serve cardholders and non-cardholders, competing à la Hotelling and setting the same price to both customer groups. Under the no-surcharge rule, the interchange fee/seller discount is set equal to or above the efficient level, possibly leading to an overprovision of card payment services. Although the main analysis is conducted under the NSR, Rochet and Tirole argue that lifting the NSR would imply neutrality of the interchange fee (sellers simply pass costs through and price-discriminate) and would lead to an underprovision of card services. Consequently, the welfare implication of lifting the NSR is ambiguous. However, the network's decision on imposing a NSR remains unexplored.

Focussing on the potential neutrality of interchange fees, Gans and King (2003) explain that the interchange fee does not affect the market outcome under “payment separation”, i.e., if sellers can perfectly price-discriminate between cash-paying consumers and card users, or if each seller only serves one of the two groups.

Langlet and Uhlenbrock (2011) analyze the determination of the seller fee under the NSR when consumers pay no fees. They assume that there are two distinct groups of fixed (exogenous) sizes: card users and cash-paying consumers. In a framework of differentiated Bertrand competition between two sellers, they analyze how the proportion of card users and demand parameters affect the optimal seller fee.

Bourreau and Verdier (2010) demonstrate that a payment platform may set a low interchange fee to deter a seller, who competes with another seller à la Hotelling, from bypassing the platform by issuing private cards. As the issuing seller can charge a fee for using her private card, they implicitly allow for price discrimination between users of the private card and all other customers (cash-paying or non-private card users). However, the second seller cannot price-discriminate in their

[13] Verdier (2011) offers a good survey of the literature on interchange fees. The “Report on the retail banking sector inquiry” (European Commission, 2007b) offers (empirical) insights into the European banking system, in particular card payment arrangements and interchange fees.

framework, and the study does not offer a comparison between uniform pricing and surcharging/price discrimination.

Wright (2003) analyzes interchange fees and the adoption of a NSR based on the framework introduced by Rochet and Tirole (2002). However, Wright assumes that seller pricing is either monopolistic or perfectly competitive. He finds that with a monopoly seller, the NSR is both profitable to the card association and socially desirable as it diminishes otherwise excessive surcharging by the seller and also limits the interchange fee that the seller is willing to accept to the efficient level. With perfect competition between sellers, both a social planner and the card network are indifferent between allowing sellers to price discriminate and imposing the NSR. Furthermore, the level of the interchange fee becomes irrelevant; under the NSR, sellers specialize on either cash-paying consumers or card users, setting their respective price equal to their perceived per-transaction costs.

Schwartz and Vincent (2006) analyze the NSR when a payment network faces a single monopoly seller. Unlike Wright (2003), Schwartz and Vincent take each consumer's payment mode as exogenously given (two groups of consumers with fixed sizes), but transaction quantities are variable (elastic demand). They find that under the NSR the payment network prefers a price structure with low consumer fees. In general, the payment network prefers the NSR, to the detriment of cash-paying customers and the seller. The overall effect on welfare depends on the proportion of card users relative to cash users, the feasibility of granting consumers rebates (charging negative fees), and the seller's benefit from card vs. cash transactions.

Economides and Henriques (2011) analyze the no-surcharge rule in a classic two-sided market framework, offering a microeconomic foundation of network effects. They allow for various forms of seller competition/market power by assuming that, without a NSR, the price of a good equals a linear combination of consumers' willingness to pay and seller's perceived marginal costs (seller fee minus individual benefit from card payment). Although this assumption seems fairly general, it may also cause some problems within the given framework: firstly, as their assumption rules out any "strategic" effects of card acceptance, sellers only accept cards if their per-transaction benefit exceeds the seller fee. Therefore, perceived marginal costs are negative in equilibrium and seller's surcharge for card payments is always *negative*, i.e., cash prices are higher than card prices. Secondly, prices may become negative if sellers have little market power and the absolute value of perceived costs is high.

The empirical studies of Bolt, Jonker, and van Renselaar (2010) and Jonker (2011) examine the surcharging behavior of Dutch retailers (NSRs are prohibited in the Netherlands) and the corresponding consumer responses. They find that about 20% of all sellers indeed price discriminate by surcharging card transactions. Jonker points out that sellers become more likely to accept card payments with increasing competition, while surcharges increase in their market power. However, it turns out that the majority of consumers tries to avoid surcharges either by choosing different means of payment or by visiting another store.

Altogether, although some studies on payment card networks provide insights into the effects caused by NSRs, most work focusses on the interchange fee. Despite some general theoretical analogies between NSRs and other across-platforms parity agreements, the work surveyed above presumes a specific industry structure. Furthermore, it includes several limitations. The studies most closely related to my work are Rochet and Tirole (2002), Wright (2003), and Schwartz and Vincent (2006). Rochet and Tirole do not focus on NSRs, and, hence, do not analyze the intermediary's decision to impose a NSR. Wright only allows for extreme forms of seller competition. Schwartz and Vincent analyze a framework without seller competition and with an exogenous split-up between card users and cash users, but allow for elastic demand.

Outline

The remainder of this essay is structured as follows: in section 2, I introduce the framework. In section 3, I solve the model backwards, comparing sellers' decisions with and without a no-discrimination rule, and analyzing the intermediary's decision on imposing a no-discrimination rule. In section 4, I discuss welfare implications of no-discrimination rules. Finally, I give a discussion in section 5 and some concluding remarks in section 6.

4.2 Framework

I consider a framework with three sellers[14] who can become active in two sales channels: a platform (or marketplace)[15] provided by an intermediary, and a direct sales channel.

Each seller offers a single product (possibly using both channels). Products are horizontally differentiated: they are equidistantly located on the circumferences of two Salop circles.[16] Each Salop circle represents one sales channel.

Sellers face linear production costs. The costs (not including platform fees) that both channels have in common are normalized to zero. I assume that sellers incur additional per-transaction costs for processing sales outside the platform; this cost difference parameter is denoted by c.[17]

The intermediary provides a platform and can charge sellers and buyers per-transaction fees if trade takes place in his marketplace. The seller fee is denoted by f_s, and the buyer fee is called f_b. The intermediary bears costs of k for each transaction conducted over his platform.

Consumers apply a sequential decision rule. In a first step, they select their favorite product based on the prices observed in one of the two sales channel. In a second step, they buy one unit of the selected product, using the channel that yields the highest (individual) net utility.

I assume that consumers are heterogeneous in three independent dimensions. Firstly, they can be divided into two disjunct groups: a mass of M_d consumers searches for products outside the platform and selects their favorite product based on prices in the direct sales channel ("d"). The remaining mass, labeled M_m, chooses their respective favorite product based on the prices which the sellers charge within the intermediary's marketplace ("m"). Then, the assumption on sequential consumer decisions creates a spillover effect between channels: consumers search for products

[14] I choose *three* sellers to allow for a tractable analysis of asymmetric scenarios with one seller specializing on a single sales channel.

[15] In the following, I use the terms "platform" and "marketplace" interchangeably.

[16] I use *two* circles to allow for asymmetric scenarios with a different number of sellers in each channel. If all sellers are active in both channels, both circles are identical and, hence, one circle would suffice to describe horizontal product differentiation. For the basic model of a circular market, cf. Salop (1979).

[17] Note that this cost difference does not account for the seller fee introduced below.

and learn about existence in their respective channel $i \in \{d, m\}$, but may buy in the other channel $j \in \{m, d\}, j \neq i$. This implies that (i) not selling in channel i results in losing all potential buyers from group i (mass M_i is not aware of product/seller existence), and that (ii) it may be profitable to set a relatively low price in channel i and a higher price in channel $j \neq i$, attracting consumers in channel i who may finally buy in channel j (if they like channel j much better), or, cross-subsidizing between channels that differ in perceived costs.

Secondly, consumers differ in their attitude towards horizontal product characteristics: consumers choosing their favorite product in channel $i \in \{d, m\}$ are uniformly distributed on the circumference of the respective Salop circle for channel i. If a consumer who is located at x buys from a seller who is located at y on the circumference of the Salop circle that belongs to the consumer's channel, the consumer incurs quadratic transportation (or mismatch) costs of $t \cdot d(x, y)$, where

$$d(x, y) \equiv \min \left\{ (x - y)^2, (1 - |x - y|)^2 \right\}$$

equals the shortest quadratic distance between the consumer's and the seller's location.[18] The parameter t can be interpreted as a measure of sellers' market power.

Thirdly, consumers obtain heterogeneous benefits from using the platform instead of the direct sales channel.[19] All consumers are assumed to have the same initial reservation value r (before transportation costs) for buying a product in the direct sales channel. The additional benefits from platform usage may be positive or negative and are distributed according to a differentiable (cumulative) distribution function $F(v)$.[20]

Hence, the utility of a consumer who is located at x and buys from a seller who is located at y is given by

$$r - p_d - t \cdot d(x, y)$$

if he buys at a price of p_d, using the direct sales channel, or by

[18]While a linear distance function would also be feasible, the quadratic one ensures existence of pure-strategy equilibria in the pricing game also in asymmetric scenarios where one of the sellers serves a single sales channel.

[19]At least a certain degree of household heterogeneity seems reasonable. For empirical evidence on households' heterogeneous channel valuations, cf. e.g. Chintagunta, Chu, and Cebollada (2012).

[20]As parts of the analysis require a concrete specification of this distribution, I later will assume that the additional benefits follow a uniform distribution with $k - c \in (\underline{v}, \overline{v})$, where $[\underline{v}, \overline{v}]$ denotes the support.

$$r + v - p_m - t \cdot d(x, y)$$

if he buys at a price of p_m in the marketplace.

Timing

The timing is given as follows:

1. The intermediary decides on imposing a no-discrimination rule and sets corresponding per-transaction fees f_s and f_b.
2. Sellers' distribution and pricing decisions:
   i) Sellers simultaneously choose in which channels to offer their products.[21]
   ii) Sellers simultaneously set (channel-dependent) prices.
3. Consumers' sequential buying decisions:
   i) Consumers decide which product to buy (based on prices in the channel that corresponds to their respective group M_i, $i \in \{d, m\}$).
   ii) Consumers buy one unit of the chosen product, using the best sales channel.

The price that seller $k \in \{1, 2, 3\}$ charges in channel $i \in \{d, m\}$ will be denoted by $p_{k,i}$. If the intermediary imposes a no-discrimination rule, sellers are not allowed to discriminate between channels, i.e., each seller charges a uniform price p_k.[22]

I assume that sellers and the intermediary maximize their expected profits, i.e., they are risk neutral. Consumers maximize their individual surplus. All outside options are normalized to zero. In order to ensure existence of pure-strategy equilibria in (out-of-equilibrium) pricing subgames where one seller specializes on a single sales channel, I restrict the ratio between the ex-ante consumer masses: $\frac{M_m}{M_d} \in \left(\frac{1}{8}, 8\right)$.

[21] During the following analysis, I focus on cases with all sellers being active in both sales channels, i.e., I ensure that a *unilateral* specialization on a single sales channel is not profitable to any seller.

[22] I abstract from monitoring problems and sellers' attempts not to comply with an imposed NDR as platform operators can easily observe sellers' prices in other (online) channels and, moreover, can invite/incentivize consumers to report non-conform seller behavior (examples include Amazon's "Tell us about a lower price" function and their "Price Check" app, or HRS's money-back guarantee).

4.3 Analysis

In the following, I solve the model introduced in the previous section for the case of a symmetric Nash equilibrium within the pricing subgame (all sellers being active in both sales channels). Within the analysis of stage 2, I examine sellers' pricing decisions, firstly without a no-discrimination rule, then under a no-discrimination rule. I show that no seller has an incentive to be active in only one channel without a no-discrimination rule under a mild regularity condition. If the intermediary imposes a no-discrimination rule, his tariff reflects the sellers' participation constraints. Finally, I analyze the intermediary's decision on imposing a no-discrimination rule.

4.3.1 Consumers' sequential buying decisions

Decision on sales channel

Given his individual additional utility v from buying products on the platform, a consumer who selected seller k's product, $k \in \{1, 2, 3\}$, prefers buying outside the platform (i.e., in the direct channel) if

$$r - p_{k,d} \geq r + v - f_b - p_{k,m},$$

or, equivalently, if $v \leq f_b + p_{k,m} - p_{k,d}$. Hence, if a unit mass of consumers wants to buy product k and the respective seller is active in both channels, a (expected) mass of

$$Pr(v \leq f_b + p_{k,m} - p_{k,d}) = F(f_b + p_{k,m} - p_{k,d})$$

buys outside. I presume full market coverage, i.e., r being sufficiently high.

Selection of favorite product

Each consumer's selection of his respective favorite product within a given channel $i \in \{d, m\}$ follows the basic Salop model. Consumers' locations $x \in [0, 1)$ are denoted by the length of the circumference between them and the location of seller 1's product, measured clockwise. Hence, the location of seller 1's product is defined as $x_1 = 0$, the location of seller 2's product is $x_2 = \frac{1}{3}$, and seller 3's product is located at $x_3 = \frac{2}{3}$.

Firstly, I analyze a situation of all three firms being active in channel i. A consumer belonging to mass M_i, $i \in \{d, m\}$, who is located at $x \in \left[0, \frac{1}{2}\right]$ is indifferent between seller 1's and seller 2's product if his location x fulfills

$$p_{1,i} + t \cdot x^2 = p_{2,i} + t \cdot \left(\frac{1}{3} - x\right)^2 \Leftrightarrow x = \frac{1}{6} + 3 \cdot \frac{p_{2,i} - p_{1,i}}{2t}.$$

A consumer who is located at $x \in \left[\frac{1}{2}, 1\right)$ is indifferent between seller 1's and seller 3's product if his location x fulfills

$$p_{1,i} + t \cdot (1-x)^2 = p_{3,i} + t \cdot \left(x - \frac{2}{3}\right)^2 \Leftrightarrow x = \frac{5}{6} + 3 \cdot \frac{p_{1,i} - p_{3,i}}{2t}.$$

Accordingly, given the price of seller k and the prices of the two other sellers l_1 and l_2, a fraction of

$$q_{k,i}(p_{1,i}, p_{2,i}, p_{3,i}) = \frac{1}{3} + 3 \cdot \frac{p_{l_1,i} + p_{l_2,i} - 2 \cdot p_{k,i}}{2t}$$

chooses the product of seller k.

If only two sellers, without loss of generality labeled 2 and 3, are active in channel i and are equidistantly located on the respective circumference, it is straightforward to show that a fraction of

$$q_{k,i}(p_{2,i}, p_{3,i}) = \frac{1}{2} + 2 \cdot \frac{p_{l,i} - p_{k,i}}{t}$$

chooses the product of seller $k \neq l$.[23]

4.3.2 Sellers' distribution and pricing decisions

Pricing decisions under full participation without NDR

If all sellers are active in both channels, the overall mass of consumers who buy from seller k equals

$$Q_k(\mathbf{p_d}, \mathbf{p_m}) \equiv M_d \cdot q_{k,d}(\mathbf{p_d}) + M_m \cdot q_{k,m}(\mathbf{p_m}),$$

with $\mathbf{p_i} \equiv (p_{1,i}, p_{2,i}, p_{3,i})$, $i \in \{d, m\}$, defined as price vectors.

As the split-up between channels is determined by the sum of the buyer fee f_b and the price difference $\Delta p_k \equiv p_{k,m} - p_{k,d}$, seller k's expected profit can be written

[23] If k and l are asymmetrically located on the circumference, the slope of $q_{k,i}$ changes; in particular, if they are located as in the case with three sellers (e.g. at $x_k = \frac{1}{3}$ and $x_l = \frac{2}{3}$), it follows $q_{k,i}(p_{k,i}, p_{l,i}) = \frac{1}{2} + \frac{9}{4} \cdot \frac{p_{l,i} - p_{k,i}}{t}$.

as

$$\pi_k(\mathbf{p_d}, \mathbf{p_m}) \equiv Q_k(\mathbf{p_d}, \mathbf{p_m}) \cdot \{F(f_b + \Delta p_k) \cdot (p_{k,d} - c) + (1 - F(f_b + \Delta p_k)) \cdot (p_{k,m} - f_s)\}.^{24}$$

In a symmetric equilibrium with $p_{1,i} = p_{2,i} = p_{3,i}$, $i \in \{d, m\}$, the two first order conditions $\frac{\partial \pi_k}{\partial p_{k,i}} = 0$, $i \in \{d, m\}$, imply[25]

$$\Delta p_k = f_s - c + \frac{\frac{M_d}{M_d + M_m} - F(f_b + \Delta p_k)}{f(f_b + \Delta p_k)}. \tag{4.1}$$

This equation (implicitly) defines the equilibrium price difference Δp_k. Taking a closer look at the critical level of additional platform benefit $\widetilde{v} \equiv f_b + \Delta p_k$, I arrive at the following result:

Proposition 4.1 (No two-sidedness without NDR)**.**
As long as sellers are active in both channels and are free to set different prices across channels, the allocation of consumers between both channels only depends on the overall fee $f_b + f_s$, but not on the split-up of the fee between sellers and buyers.

As the overall number of transactions is fixed (I assume that the willingness to pay r is sufficiently high) and sellers fully internalize the impact of their decision on the division of sales between channels, the allocation of fees does not matter and the intermediary's fee structure features neutrality.[26] Hence, restricting the analysis by an assumption on the distribution $F(\cdot)$ is without loss of generality regarding the (ambiguous) split-up of fees between sellers and buyers. However, it restricts the pass-through rate, i.e., how sellers react to a change of the overall fee. Nevertheless, I make the following Assumption for the sake of tractability:

Assumption 4.1 (Additional platform benefits are uniformly distributed)**.**
Additional platform benefits follow a uniform distribution with support $[\underline{v}, \overline{v}]$. The difference between intermediary's and seller's costs, $k - c$, is contained in this support.[27]

[24] I assume that the distribution represented by F is such that all optimization problems are well-behaved. In particular, this is the case under Assumption 4.1.

[25] All derivations and proofs are relegated to the appendix.

[26] Note that this result is in line with previous literature, also cf. my literature review.

[27] The assumption $k - c \in (\underline{v}, \overline{v})$ ensures that neither of both sales channels is redundant from a social point of view. Note that the support may contain negative values. Hence, $k - c < 0$ is *not* ruled out.

In the subsequent analysis, I refer to the respective cumulative uniform distribution function by F_u, and to the respective density function by f_u, indicating use of Assumption 4.1.[28]

Given this Assumption, equation (4.1) can be solved for Δp_k:[29]

$$\Delta p_k = \frac{1}{2} \cdot \left(\frac{M_d}{M_d + M_m} \cdot (\overline{v} - \underline{v}) + \underline{v} + f_s - f_b - c \right). \tag{4.2}$$

This implies that the indifferent consumer between both channels is characterized by the critical level of additional platform benefit

$$\widetilde{v}(f_b + f_s) = \frac{1}{2} \cdot \left(\frac{M_d}{M_d + M_m} \cdot (\overline{v} - \underline{v}) + \underline{v} + (f_b + f_s) - c \right), \tag{4.3}$$

which reconfirms the neutrality of the fee structure. Furthermore, as the critical level of additional utility from platform use is increasing in both fees, and, in particular, in the seller's perceived difference of transaction costs, $(f_b + f_s) - c$, less consumers use the platform if fees are increased or sellers face lower costs c. Moreover, the ex-ante distribution of consumers between channels affects the equilibrium split-up: the more consumers search for their favorite products on the platform, the larger the mass of platform buyers (for a given fee level). The latter fact reflects that sellers' incentives to set lower prices to attract consumers in a channel become stronger if the relative mass of consumers in this channel (who can be allured) increases. I will come back to this "channel-importance" effect within the following discussion of sellers' pricing decisions.

Lemma 4.1 (Pricing in absence of a NDR)**.**
Without a no-discrimination rule, if all sellers are active in both channels, prices are given by

$$p^*_{k,m} = f_s + \frac{t}{9} + F_u(\widetilde{v}(f_b + f_s)) \cdot \left(\frac{M_d}{M_d + M_m} - \frac{f_b + f_s - c - \underline{v}}{\overline{v} - \underline{v}} \right) \cdot \left(\frac{\overline{v} - \underline{v}}{2} \right), \tag{4.4}$$

and

$$p^*_{k,d} = c + \frac{t}{9} - \{1 - F_u(\widetilde{v}(f_b + f_s))\} \cdot \left(\frac{M_d}{M_d + M_m} - \frac{f_b + f_s - c - \underline{v}}{\overline{v} - \underline{v}} \right) \cdot \left(\frac{\overline{v} - \underline{v}}{2} \right). \tag{4.5}$$

[28] Sellers' pricing decisions under a no-discrimination rule can be calculated without Assumption 4.1; prices in absence of a no-discrimination rule and the intermediary's tariff decisions explicitly rely on this Assumption.

[29] During the subsequent analysis, I assume that the difference $(f_b + f_s) - c$ is such that the indifferent consumer defined in (4.3) lies within $(\underline{v}, \overline{v})$. The optimal fees indeed fulfill this condition, cf. the analysis of stage 1.

Note that these prices reflect both competition between sellers within each channel and competition across channels. The first two summands of each price equal the respective price that would arise in an independent market with three sellers, offering differentiated products and competing à la Salop. The third summand of each price captures how sellers internalize that the distribution of consumers between channels is affected by the price difference. If the ex-ante fraction of consumers in the direct sales channel, $\frac{M_d}{M_d+M_m}$, does not coincide with the relative split-up that would result just from the difference between the overall platform fee $f_b + f_s$ and outside costs c, prices differ from the basic prices $c + \frac{t}{9}$ and $f_s + \frac{t}{9}$, respectively:

Corollary 4.1 (Benchmark: independent-markets pricing).
The prices defined by equations (4.4) and (4.5) coincide with the respective prices that would result in two independent markets with competition à la Salop if $\frac{M_d}{M_d+M_m} = \frac{f_b+f_s-c-\underline{v}}{\overline{v}-\underline{v}}$.

Corollary 4.2 (Benchmark: uniform pricing).
Sellers voluntarily set uniform prices if $f_s - c = \left(\frac{f_b+f_s-c-\underline{v}}{\overline{v}-\underline{v}} - \frac{M_d}{M_d+M_m}\right) \cdot \frac{\overline{v}-\underline{v}}{2}$.

However, note that the level of $p_{k,m}$ is somewhat arbitrary as for any given overall fee $f_b + f_s$, every distribution of this overall fee on sellers and buyers results in the same payoffs for all agents. Furthermore, taking a closer look at prices, I find that the deviation from independent-markets pricing in fact constitutes a cross-subsidization between channels with no effect on the seller's overall profits:

Proposition 4.2 (Cross-subsidization and seller's expected profits).
If all sellers are active in both channels, each seller's profit equals the sum of the basic Salop profits, $(M_d+M_m)\cdot\frac{t}{27}$*. Hence, the loss from deviating from independent-markets pricing in one channel is compensated by the gains from the higher price in the other channel.*

If the mass M_d of consumers who choose their preferred product in the direct sales channel is relatively large, this amplifies the effect of a change in $\mathbf{p_d}$ relative to the effect of a change in $\mathbf{p_m}$. Hence, if the direct sales channel is relatively important for product choice, competition becomes (relatively) fiercer in this channel, but more relaxed in the platform channel, and vice versa. The combination of horizontal product differentiation with unit demand and uniformly distributed consumers implies that the two effects (lower prices in one channel, but higher prices in the other one) cancel out and overall profit equals the basic Salop profit.

Before turning to sellers' pricing decisions under a no-discrimination rule, I make the following (mild) Assumption to ensure that specialization on a single sales channel is never profitable to a seller without a no-discrimination rule:

Assumption 4.2 (Differentiation parameters and ex-ante distribution of consumers on sales channels)**.**
The ratio between the range of additional platform utilities, $(\overline{v}-\underline{v})$ *(which measures heterogeneity of consumers' tastes regarding sales channels), and the transportation cost parameter* t *(which captures differences in consumers' tastes regarding products) is relatively small, given the ex-ante distribution of consumers on channels represented by* $\gamma \equiv \frac{M_m}{M_d}$*:*

$$\frac{\overline{v}-\underline{v}}{t} \leq (3+2\gamma)\cdot\frac{(15+8\gamma)\cdot\sqrt{1+\gamma}-(15+13\gamma)}{18\gamma^2}, \tag{4.6}$$

$$\frac{\overline{v}-\underline{v}}{t} \leq (2+3\gamma)\cdot\frac{(15\gamma+8)\cdot\sqrt{\frac{1+\gamma}{\gamma}}-(15\gamma+13)}{18}. \tag{4.7}$$

Proposition 4.3 (Specialization on a single sales channel is not profitable in absence of a NDR)**.**
Without a no-discrimination rule, a (unilateral) specialization on a single sales channel is not profitable to a seller, given Assumptions 4.1 and 4.2.

Note that Assumption 4.2 consists of two sufficient conditions which ensure that specialization is not profitable to a seller,[30] even under extreme fee levels that would maximize specialization incentives.

If a seller specialized on channel $i \in \{d,m\}$, this would relax competition in channel $j \in \{m,d\}$, $j \neq i$, and, hence, the remaining sellers would increase prices in this channel, indirectly increasing the overall price level and, in particular, prices in channel i. Specialization is most attractive if product differentiation is small, i.e., competition within channels is fierce, given differentiation between channels

[30]The upper bound for the ratio $\frac{\overline{v}-\underline{v}}{t}$ in condition (4.6) takes its minimum value 1.213 at $\gamma = 1.502$, and the upper bound in condition (4.7) takes the same minimum value at $\gamma = 1.502^{-1}$.

as measured by $(\overline{v} - \underline{v})$ and consumers' relative ex-ante distribution on channels, captured by γ.

The effects of seller specialization under a no-discrimination rule are discussed below.

Pricing decisions under full participation and NDR

In this paragraph, I consider sellers' pricing decisions under a no-discrimination rule with all sellers being active in both channels. Seller k's profit, given the vector $\mathbf{p} = (p_1, p_2, p_3)$ of uniform prices, equals

$$\pi_k(\mathbf{p}) \equiv Q_k(\mathbf{p}) \cdot \{p_k - F(f_b) \cdot c - (1 - F(f_b)) \cdot f_s\},$$

where the overall mass of consumers who buy from seller k under uniform pricing equals

$$Q_k(\mathbf{p}) \equiv (M_d + M_m) \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_{l_1} + p_{l_2} - 2 \cdot p_k}{2t} \right).$$

Accordingly, under uniform pricing, the split-up of consumers between channels only depends on the buyer fee f_b and is not affected by sellers' pricing decisions (as $\Delta p_k = 0$).

Proposition 4.4 (Pricing decisions and expected profits under NDR)**.**
Under a no-discrimination rule, sellers set a price of $\frac{t}{9} + F(f_b) \cdot c + (1 - F(f_b)) \cdot f_s$ *if all sellers are active in both sales channels. The corresponding profit is given by* $(M_d + M_m) \cdot \frac{t}{27}$*.*

Sellers' prices reflect their average costs. Due to the mode of competition, the assumption on inelastic demand, and the linear structure (additive additional benefits from platform use in combination with sequential consumer decision), sellers' profits under a no-discrimination rule with full participation equal the profits without no-discrimination rule, although sellers cannot price-discriminate.

Pricing under NDR when one seller does not serve platform consumers

In order to check when serving only the direct sales channel is profitable to a seller, I calculate the profit of a seller who specializes on this channel when the other sellers are active in both channels and a no-discrimination rule is imposed.[31] Afterwards, I compare this profit with the equilibrium profit reported in Proposition 4.4, deriving a seller participation constraint.

Suppose seller 1 does not offer her product in the marketplace. Then, her profit from serving only consumers in the direct sales channel is given by

$$\pi_1(\mathbf{p}) = M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_2 + p_3 - 2 \cdot p_1}{2t} \right) \cdot (p_1 - c).$$

The profit of seller 2 (who faces two competitors in the direct sales channel and only one competitor in the marketplace) reads[32]

$$\begin{aligned} \pi_2(\mathbf{p}) = M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_1 + p_3 - 2 \cdot p_2}{2t} \right) \cdot \{p_2 - F(f_b) \cdot c - (1 - F(f_b)) \cdot f_s\} \\ + M_m \cdot \left(\frac{1}{2} + 2 \cdot \frac{p_3 - p_2}{t} \right) \cdot \{p_2 - F(f_b) \cdot c - (1 - F(f_b)) \cdot f_s\}. \end{aligned}$$

Defining

$$\gamma \equiv \frac{M_m}{M_d} \tag{4.8}$$

as the ratio between the masses of consumers in the marketplace and the direct sales channel, calculating sellers' best responses, and inserting them into each other leads to

$$p_1^{dev} = \left(1 + \frac{5\gamma}{15 + 8\gamma} \right) \cdot \frac{t}{9} + c + \left(1 - \frac{9 + 4\gamma}{15 + 8\gamma} \right) \cdot (1 - F(f_b)) \cdot (f_s - c), \tag{4.9}$$

and

$$p_2^{dev} = p_3^{dev} = \left(1 + \frac{10\gamma}{15 + 8\gamma} \right) \cdot \frac{t}{9} + c + \left(1 - \frac{3}{15 + 8\gamma} \right) \cdot (1 - F(f_b)) \cdot (f_s - c). \tag{4.10}$$

These prices consist of a markup term and a weighted average of the respective seller's own (average) costs and the competitors' (average) costs. The markups can

[31] A specialization on *platform* sales would only be profitable if f_s was below a threshold smaller than c (cf. the condition derived in appendix, p. 148). Such a small fee would never be optimal for the intermediary as he would gain from higher fees (due to higher per-transaction revenues and a larger mass of potential customers in case the seller does not specialize on platform sales).

[32] This profit is calculated under the assumption that the distance between sellers 2 and 3 on the Salop circle that represents the platform equals $\frac{1}{2}$. The derivation for locations corresponding to the scenario with three sellers can be found in the appendix; my results are robust against changes in the locations of the remaining two sellers.

be understood as follows: when seller 1 specializes on one channel, this relaxes competition between sellers 2 and 3 in the other channel. Therefore, sellers 2 and 3 face incentives to set higher markups in the marketplace (compared to a situation where all three sellers are active in both channels). As they can only set uniform prices, this implies that sellers 2 and 3 set higher markups in both channels. In response, seller 1 also increases her markup, but to a lesser extent.

Comparing the profit of the specialized seller and the profit of a seller if all sellers are active in both channels, I arrive at the following result:[33]

Proposition 4.5 (Non-profitability of unilateral specialization on direct sales). *When a no-discrimination rule is imposed and all other sellers are active in both channels, specialization on the direct sales channel is not profitable to a seller if*

$$(1 - F(f_b)) \cdot (f_s - c) \leq \frac{t}{9} \cdot \left(\frac{(15 + 8\gamma) \cdot \sqrt{1 + \gamma} - (15 + 13\gamma)}{2 \cdot (3 + 2\gamma)} \right). \tag{4.11}$$

Note that the right-hand side of condition (4.11) is strictly positive for $\gamma > 0$ and strictly increasing in γ. There are three effects that arise if the seller specializes on outside sales:

(i) Reduced mass of potential customers: the seller loses all (potential) customers who select their favorite product on the platform.

(ii) Less competitive pressure: due to relaxed competition within the platform, all prices include higher markups under specialization.

(iii) Cost savings: all consumers who choose the specialized seller's product buy directly from the seller. This reduces the seller's costs: without specialization, a fraction of $1 - F(f_b)$ would buy using the platform, creating additional costs for the seller of $f_s - c$ per transaction.[34]

Accordingly, specialization is only attractive if relatively few consumers select their favorite product on the platform (γ is small), if the transportation cost parameter t

[33] Again, this result remains (qualitatively) unchanged when locations of sellers 2 and 3 in the platform channel correspond to their locations in the other channel, cf. p. 149.

[34] In this verbal discussion, I implicitly assume that $f_s > c$. The optimal platform fee indeed exceeds c if additional platform utilities are likely to be positive; otherwise $f_s - c$ can be negative, but relatively large compared to the level of (negative) additional platform utilities, cf. the subsequent analysis.

is relatively small (fierce seller competition/weak product differentiation), or if the seller fee f_s drastically exceeds the costs c of a direct transaction.

4.3.3 Intermediary's decision on fees and NDR

In the following, I firstly derive the intermediary's profit-maximizing fee and the corresponding profit if he does not impose a no-discrimination rule. Secondly, I calculate the maximum profit that he can achieve when imposing a no-discrimination rule, taking into account constraint (4.11) which ensures participation of all sellers in both channels. Finally, I analyze his decision on imposing a no-discrimination rule by comparing both profit levels (both calculated for the case of uniformly distributed additional platform benefits).

Profit-maximizing fee level without NDR

Given Assumptions 4.1 and 4.2, without imposing a no-discrimination rule, all sellers are active in both channels, regardless of the fees set by the intermediary. The number of transactions conducted over the intermediary's platform equals $(M_d + M_m) \cdot \{1 - F_u(\widetilde{v}(f_b + f_s))\}$, with $\widetilde{v}(f_b + f_s)$ as defined in (4.3) under the uniform distribution assumption. His profit comprises this transaction volume and his margin $f_b + f_s - k$, and it is given by

$$\Pi_0(f_b, f_s) = (M_d + M_m) \cdot \{1 - F_u(\widetilde{v}(f_b + f_s))\} \cdot (f_b + f_s - k).$$

Bearing in mind Proposition 4.1, i.e., the split-up of $f_b + f_s$ between buyers and sellers being arbitrary without a no-discrimination rule, I arrive at the following result:

Lemma 4.2 (Profit-maximizing fee level without NDR).
Without imposing a no-discrimination rule, the intermediary achieves a maximum profit of

$$\Pi_0^* = (1 + \gamma) \cdot M_d \cdot \left(\frac{\overline{v} - \underline{v}}{2}\right) \cdot \left\{1 - \frac{1}{2} \cdot \left(F_u(k - c) + \frac{1}{1 + \gamma}\right)\right\}^2 \tag{4.12}$$

by setting a fee level of $f_b + f_s = c + \underline{v} + \frac{(k-c)-\underline{v}}{2} + (\overline{v} - \underline{v}) \cdot \left(1 - \frac{1}{2(1+\gamma)}\right)$.

The optimal fee level is increasing in (average) transaction costs, in both the level and the spread of additional utility from platform usage, and in the ratio

γ (defined in (4.8)) which can be interpreted as "importance" of the platform for product choice.

Corollary 4.3 (Channel allocation without NDR).
When the intermediary does not impose a no-discrimination rule, the indifferent consumer between channels is given by

$$\widetilde{v}_0 = \underline{v} + \left\{ \frac{1}{2} + \frac{1}{4} \cdot \left(\frac{1}{1+\gamma} \right) \right\} \cdot (\overline{v} - \underline{v}) + \frac{(k-c) - \underline{v}}{4}. \tag{4.13}$$

A fraction of $F_u(\widetilde{v}_0) = \frac{1}{2} + \frac{1}{4} \cdot \frac{1}{1+\gamma} + \frac{1}{4} \cdot \frac{(k-c)-\underline{v}}{\overline{v}-\underline{v}}$ *of all consumers buys in the direct sales channel.*

The fraction $1 - F_u(\widetilde{v}_0)$ of consumers who buy in the marketplace is decreasing in the relative cost difference captured by $F_u(k-c) = \frac{(k-c)-\underline{v}}{\overline{v}-\underline{v}}$ and increasing in γ. The latter fact can be explained as follows: the larger γ, the lower sellers' platform prices (compared to prices in the direct sales channel), and, hence, the higher the fraction of consumers buying over the platform.

Profit-maximizing fees under NDR

If the intermediary imposes a no-discrimination rule, buyers' channel choices are not affected by the prices that sellers charge (assuming full market coverage). Consequently, the intermediary's profit with uniform prices and full seller participation reads

$$\Pi_1(f_s, f_b) = (M_d + M_m) \cdot (1 - F_u(f_b)) \cdot (f_b + f_s - k). \tag{4.14}$$

Lemma 4.3 (Profit-maximizing fees under NDR and full seller participation).
When imposing a no-discrimination rule, the intermediary can achieve a profit of

$$\begin{aligned} \Pi_1^* =& (1+\gamma) \cdot M_d \qquad (4.15) \\ & \times \left(\frac{\overline{v} - \underline{v}}{2} \right) \cdot \left\{ \frac{t}{\overline{v} - \underline{v}} \cdot \left(\frac{(15+8\gamma) \cdot \sqrt{1+\gamma} - (15+13\gamma)}{9 \cdot (3+2\gamma)} \right) + \frac{1}{2} \cdot (1 - F_u(k-c))^2 \right\} \end{aligned}$$

by setting a buyer fee of

$$f_b^* = \frac{k-c}{2} + \frac{\overline{v}}{2} \tag{4.16}$$

and a seller fee of

$$f_s^* = c + \frac{t}{9} \cdot \left(\frac{(15+8\gamma) \cdot \sqrt{1+\gamma} - (15+13\gamma)}{2 \cdot (3+2\gamma) \cdot (1 - F(f_b^*))} \right). \tag{4.17}$$

The intermediary sets his seller fee f_s such that constraint (4.11) binds,[35] while the buyer fee f_b is set to achieve the profit-maximizing split-up of buyers between channels.

Corollary 4.4 (Channel allocation under NDR).
When the intermediary imposes a no-discrimination rule, the indifferent consumer between channels is given by $\widetilde{v}_1 = f_b^*$ as defined in (4.16). Consequently, a fraction of $F_u(\widetilde{v}_1) = \frac{1}{2} + \frac{1}{2} \cdot \frac{(k-c)-\underline{v}}{\overline{v}-\underline{v}}$ of all consumers buys in the direct sales channel.

If the intermediary imposes a no-discrimination rule, the fraction $1 - F_u(\widetilde{v}_1)$ of consumers who buy in the marketplace only depends on the distribution of additional platform benefits and the cost difference $k - c$. Again, it is decreasing in the (relative) cost difference $F_u(k - c) = \frac{(k-c)-\underline{v}}{\overline{v}-\underline{v}}$ (i.e., in particular, decreasing in the intermediary's costs k and increasing in sellers' costs c). However, the split-up does not depend on γ as the effect of the ex-ante consumer distribution is absorbed by the seller fee f_s^* but does not enter f_b^*.

Intermediary's decision on imposing a NDR

Comparing profits (4.12) and (4.15), I can state the following result:

Proposition 4.6 (Profitability of imposing a NDR).
The intermediary decides to impose a no-discrimination rule if

$$\begin{aligned}&\frac{t}{\overline{v}-\underline{v}} \cdot \left(\frac{(15+8\gamma)\cdot\sqrt{1+\gamma}-(15+13\gamma)}{9\cdot(3+2\gamma)} \right) \\ &\quad > \left\{ 1 - \frac{1}{2} \cdot \left(F_u(k-c) + \frac{1}{1+\gamma} \right) \right\}^2 - \frac{1}{2} \cdot (1 - F_u(k-c))^2 .\end{aligned} \tag{4.18}$$

Condition (4.18) comprises three factors that influence the profitability of imposing a no-discrimination rule:

(i) the ratio between product differentiation parameter t (as an inverse measure of seller competition) and spread of additional platform benefits $\overline{v} - \underline{v}$ (as a measure of channel differentiation),

[35] Note that the intermediary's profit is increasing in f_s as long as all sellers remain active on the platform, cf. equation (4.14). I focus on symmetric outcomes with all sellers being active on the platform.

(ii) the relative cost difference $F_u(k-c)$ (difference in per-transaction costs relative to consumers' additional platform benefits),

(iii) the initial split-up of consumers on sales channels γ (as a measure of importance of the platform for product choice).

An increase in the first factor, $\frac{t}{\overline{v}-\underline{v}}$, makes imposing a no-discrimination rule relatively more profitable: if sellers face weaker competition (i.e., a higher level of t), the equilibrium split-up of consumers on sales channels, and, moreover, the intermediary's profit without a no-discrimination rule remain unchanged. However, an increase in t diminishes sellers' specialization incentives, relaxing their participation constraint, and, thereby, increasing the intermediary's profit under a no-discrimination rule.[36]

An increase in the second factor, $F_u(k-c)$, always results in lower platform profits. However, the profit under a no-discrimination rule and the profit without a no-discrimination rule are affected to different extents, changing the difference between them, and, hence, attractiveness of imposing a no-discrimination rule. More specifically, the intermediary's margin in equilibrium responds in the same way, regardless of his decision on a no-discrimination rule, but the channel split-up (characterized by the indifferent consumer) is less sensitive to a change in costs in absence of a no-discrimination rule as the price difference Δp_k implies a lower pass-through rate. Since sellers' prices are also driven by the "channel-importance" effect (without a no-discrimination rule), the overall effect of a change in $F_u(k-c)$ depends on γ: if γ and $F_u(k-c)$ are small, an increase in $F_u(k-c)$ makes imposing a no-discrimination rule less attractive, while for high levels of $F_u(k-c)$ and/or γ, an increase in the relative cost difference makes imposing a no-discrimination rule more attractive.[37]

The effect of the third factor, the ratio between the initial mass of platform consumers and consumers in the direct sales channel, is driven by two forces: under a no-discrimination rule, γ limits the seller fee, while without a no-discrimination rule, γ distorts the price difference since it determines (relative) competitive pressure within each channel. While the left-hand side of condition (4.18) is only "slightly"

[36]Note that I consider a change in this factor solely due to a change in t. A change in $\overline{v} - \underline{v}$ affects $F_u(k-c)$, too.

[37]Formally, the right-hand side of condition (4.18) is increasing in $F_u(k-c)$ if $F_u(k-c) < \frac{1}{1+\gamma}$, and decreasing in $F_u(k-c)$ otherwise.

concave (i.e., close to linear) in γ, the right-hand side has a more concave shape. Depending on the first two factors, two scenarios can be distinguished:

(a) Imposing a no-discrimination rule is profitable regardless of the level of γ – this is the case if t is relatively large (weak seller competition) and/or $F_u(k-c)$ takes an extreme level (in particular, if the intermediary faces relatively high costs).

(b) Imposing a no-discrimination rule is profitable only for extreme (i.e., low or high) levels of γ – this is the case if t is relatively small and $F_u(k-c)$ does not take extreme levels (in particular, $F_u(k-c)$ not close to 1).[38]

Taking a closer look at the intermediary's profits, the impact of the parameter γ can be understood as follows: on the one hand, without a no-discrimination rule, sellers' prices in the direct sales channel are relatively low (compared to prices in the marketplace) for small levels of γ as in these cases the direct sales channel is (relatively) more important for consumers' product choice. Therefore, only few consumers buy using the platform channel because of the large price difference $\Delta p_k = p_{k,m} - p_{k,d}$ that arises if γ is small. Accordingly, the intermediary's profit without a no-discrimination rule is increasing in γ, and an increase in γ makes imposing a no-discrimination rule less attractive. On the other hand, an increase in γ diminishes sellers' specialization incentives, relaxing the participation constraint that limits the intermediary's seller fee when he imposes a no-discrimination rule. Therefore, an increase in γ also leads to an increase in the intermediary's profit under a no-discrimination rule, and imposing a no-discrimination rule becomes more attractive.

For very small levels of γ (i.e., $M_d \gg M_m$), imposing a no-discrimination rule, balancing the equilibrium channel split-up despite a very skewed initial split-up of consumers on sales channels, is very attractive. When increasing γ (starting from a small level), the first effect (increase in profit without no-discrimination rule) dominates, and, hence, imposing a no-discrimination rule becomes less attractive for intermediate values of γ (i.e., $M_d \approx M_m$). However, for larger values of γ (i.e., $M_d \ll M_m$), the second effect (increase in profit under no-discrimination rule due

[38]For example, for the parameter constellation $\overline{v} - \underline{v} = 1$, $t = 1$, $F_u(k-c) = 0.5$, imposing a no-discrimination rule is profitable if $\gamma < 0.507$ or $\gamma > 2.361$, also cf. Figure 4.1.

to relaxed participation constraint) dominates, and imposing a no-discrimination rule becomes more attractive again. In particular, scenario (b) demonstrates that both forces can be decisive.

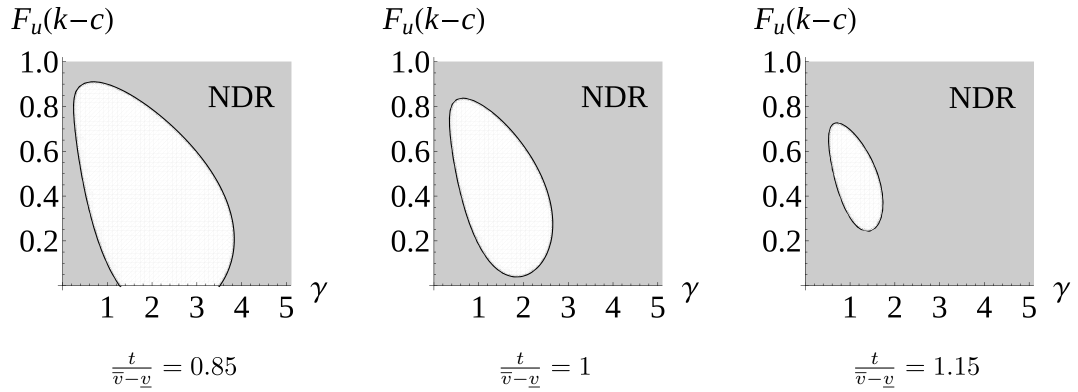

Figure 4.1: Profitability of imposing a no-discrimination rule

Focussing on scenario (b), Figure 4.1 illustrates under which combinations of the second factor $F_u(k-c)$ and the third factor γ the intermediary imposes a no-discrimination rule for different levels of the differentiation ratio $\frac{t}{\overline{v}-\underline{v}}$: for all parameter constellations within the shaded regions (i.e., outside the convex white regions), the intermediary prefers to impose a no-discrimination rule.

4.4 Welfare implications

I now turn to the welfare implications of imposing a no-discrimination rule. I illustrate that under certain parameter constellations, the intermediary imposes a no-discrimination rule, matching the socially desirable outcome (regarding the no-discrimination rule). However, under different parameter constellations, a ban on no-discrimination rules would increase welfare.

Social welfare comprises the intermediary's profit, sellers' profits, and consumer surplus. Firstly, the intermediary imposes a no-discrimination rule only if this is profitable to him. Secondly, with all sellers remaining active on the platform under a no-discrimination rule, sellers' profits are constant, irrespective of the intermediary's actual decision on imposing a no-discrimination rule. Therefore, within the given analysis, industry profits never decrease if the intermediary decides to impose a no-discrimination rule.

If the split-up of consumers between channels did not change when imposing a no-discrimination rule, the intermediary would gain solely to the detriment of consumers. As all consumers' gross utilities would remain unchanged, social welfare would remain constant. However, the indifferent consumer between the two channels is determined endogenously and usually differs between both scenarios (no-discrimination rule imposed/not imposed). Hence, given the assumption of markets being fully covered, the allocation of consumers on channels determines the overall effect on welfare.

Lemma 4.4 (First-best outcome).
The welfare-maximizing outcome is characterized by consumers being indifferent between channels at a platform benefit of $\widetilde{v}^* = k - c$.

From a social point of view, consumers should buy using the platform channel if and only if their additional benefit from platform use covers the cost difference $k - c$.

Comparing the channel allocation in the first-best outcome with the allocation under a no-discrimination rule (given by Corollary 4.4), I can state the following result:

Corollary 4.5 (Underuse of platform channel under NDR).
Under a no-discrimination rule, the platform channel is always underused, i.e., $1 - F_u(\widetilde{v}^*) > 1 - F_u(\widetilde{v}_1)$.

This result follows directly from the assumption that $k - c \in (\underline{v}, \overline{v})$ and is due to the monopoly inefficiency which is reflected in the profit-maximizing buyer fee f_b^* given in (4.16).

Without a no-discrimination rule, there may be an overuse or an underuse of the platform channel:

Corollary 4.6 (Platform use without NDR).
In absence of a no-discrimination rule, the platform channel is underused if and only if

$$F_u(\widetilde{v}^*) < \frac{2}{3} + \frac{1}{3} \cdot \left(\frac{M_d}{M_d + M_m}\right).$$

Conversely speaking, without a no-discrimination rule, the platform is overused in case of a very high cost difference $k - c$ (which equals $\widetilde{v}^*$) and a large initial fraction of platform consumers (captured by $\gamma = \frac{M_m}{M_d}$). In this (extreme) case, the channel-importance effect (i.e., sellers distorting platform prices downwards due to a high γ) overcompensates the effect caused by the platform's monopoly markup (which only partially internalizes the former effect). Under all other (less extreme) parameter constellations, the mass of consumers who buy in the direct sales channel given by Corollary 4.3 is excessive and the platform is underused also in absence of a no-discrimination rule.

Focussing on the latter cases, I find that this underuse problem may be more severe than under a no-discrimination rule, depending on the cost difference $k - c$ and the initial split-up of consumers on their "native" sales channels:

Proposition 4.7 (Imposing a NDR increases social welfare).
Imposing a no-discrimination rule results in more consumers buying in the platform channel, and, hence, in an increase in social welfare if $F_u(\widetilde{v}^*) < \frac{M_d}{M_d+M_m}$.

In absence of a no-discrimination rule, the intermediary's optimal fee level only partially offsets the channel-importance effect on final prices. Consequently, sellers' discriminating prices reflect this effect and the equilibrium split-up of consumers on channels depends on the initial channel distribution. In constrast, under a no-discrimination rule, the equilibrium split-up of consumers on channels is solely determined by the buyer fee set by the intermediary and reflects his monopoly power, but it does not depend on the initial channel split-up of consumers.

For large initial fractions of consumers in the direct sales channels, platform prices substantially exceed prices in the direct sales channel (in absence of a no-discrimination rule), leading to little platform usage. Imposing a no-discrimination rule eliminates this inefficient price distortion. If the ex-ante fraction of consumers in the direct sales channel exceeds the first-best fraction $F_u(\widetilde{v}^*)$, this positive effect dominates the additional monopoly inefficiency, resulting in a more efficient channel split-up and higher welfare.

Connecting this result and the discussion of Proposition 4.6, it is easy to construct both cases in which the intermediary profitably imposes a non-desirable no-discrimination rule, and cases in which the intermediary imposes a no-discrimination rule with a positive effect on social welfare. In particular, imposing a no-discrimination rule is both profitable to the intermediary and desirable from a social point of view if seller competition is very weak (i.e., $t \gg \overline{v} - \underline{v}$) while the intermediary's relative cost advantage is relatively large (i.e., $F_u(k-c)$ is small). Similarly, a no-discrimination rule can be profitable and lead to more platform use for intermediate levels of $F_u(k-c)$ if only few consumers select their favorite product on the platform (cf. scenario (b) from profitability discussion in previous section).

In contrast, a ban on no-discrimination rules would be desirable if the platform is very important for product choice (high level of γ) while the intermediary faces a (mild) relative cost disadvantage (e.g. $F_u(k-c) = \frac{2}{3}$). In this case, the intermediary imposes a no-discrimination rule and sets a relatively high buyer fee, resulting in poor platform usage. If the intermediary could not restrict pricing, he would set a relatively high fee level, but the strong channel-importance effect would drive sellers' platform prices down, reducing the price difference Δp_k and leading to more platform usage than under a no-discrimination rule.

4.5 Discussion

As pointed out in the introduction, several prominent intermediaries impose no-discrimination rules, restricting sellers' pricing decisions. However, before identifying conditions under which an intermediary profits from imposing a no-discrimination rule, and before discussing possible implications on welfare, it is necessary to understand why sellers may want to set different prices across sales channels first.

Given the framework introduced above, without a no-discrimination rule, sellers' prices firstly reflect the difference between platform fees and per-transaction costs in the direct sales channel. Secondly, the relative importance of channels for consumers' product choice, determined by the ex-ante distribution of consumers on sales channels, leads to pricing distortions whose extent depends on the degree of channel differentiation. For very skewed initial consumer distributions, prices in the channel in which most consumers decide which product to buy are lower than the respective "independent markets" price, while consumers in the other channel face a higher price level. Thirdly, prices would be affected if seller specialization on sales channels arose. However, under Assumption 4.2, specialization on a single sales channel is never profitable without a no-discrimination rule as product differentiation (measured by t) is relatively large compared to channel differentiation (measured by $\overline{v} - \underline{v}$).

Accordingly, if the intermediary does not restrict sellers' pricing decisions, the equilibrium split-up of consumers on sales channels is determined by the difference between the overall fee level and per-transaction costs, channel differentiation, and the initial distribution of consumers on channels. In particular, the intermediary has no direct control over the allocation of consumers on channels.

In contrast, if the intermediary imposes a no-discrimination rule, the channel split-up no longer depends on the price difference between channels (which would reflect the overall fee), but only on the buyer fee. Therefore, imposing a no-discrimination rule results in the intermediary having more control. However, as sellers now cannot set (relatively) higher prices in the platform channel in response to a high seller fee, consumers do not internalize the differences in sellers' (channel-dependent) per-transaction expenditures when deciding in which channel to buy their preferred product. Consequently, sellers face stronger specialization incentives, which limit the fee the intermediary can charge.

Taken together, the intermediary prefers to control the split-up of consumers on sales channels directly by imposing a no-discrimination rule if (i) the market is characterized by a parameter constellation that results in an unfavorable equilibrium split-up of consumers on sales channels (from the intermediary's point of view), and (ii) the "costs" due to the seller participation constraint do not exceed the benefit from the improvement of the split-up on channels.[39]

In particular, imposing a no-discrimination rule is most attractive if the initial distribution of consumers is strongly skewed: with a very small initial fraction of platform consumers, only few consumers buy in the platform channel due to the substantial price difference Δp_k, and imposing a no-discrimination rule results in more platform usage. In contrast, if most consumers select their preferred product on the platform, sellers' specialization incentives are weak and the intermediary can charge high seller fees under a no-discrimination rule (while reducing the number of platform transactions directly by charging a high buyer fee).

If the intermediary faces a relatively strong cost disadvantage (i.e., his per-transaction costs are high compared to the costs that a seller bears when selling in the direct sales channel), again, imposing a no-discrimination rule is more profitable:

[39]Note that the "costs" due to the limited seller fee can also become negative if product differentiation (measured by t) and/or platform importance, i.e., γ, is large, meaning that the intermediary can extract a larger part of the sellers' profits under a no-discrimination rule.

less transactions are conducted over the platform, but the intermediary gains due to a higher fee level.

In the latter case, a ban on no-discrimination rules is likely to be welfare-enhancing as it results in more platform usage, which improves the allocation of consumers on sales channels (except for very extreme cases in which non-restricted pricing results in a relatively strong overuse of the platform channel). However, although no-discrimination rules always lead to an underuse of the platform channel (compared to the first-best usage level), platform usage can still be lower without a no-discrimination rule, and imposing a no-discrimination rule is welfare-enhancing under certain conditions.

4.6 Conclusion and outlook

By analyzing a framework in which competing sellers can reach consumers through different channels, this study yields insights into sellers' pricing behavior and the division of sales between channels. Furthermore, it allows the examination of the tariff decision of a platform provider and its impact on market outcomes. In particular, both profitability and efficiency of no-discrimination rules are discussed.

Depending on several factors (importance of the platform for product choice, sellers' market power, channel differentiation, and cost differences), the platform operator decides in favor of or against imposing a no-discrimination rule. As the effect of a no-discrimination rule on efficiency (desirable split-up of consumers between channels) may be positive or negative, both parameter constellations under which the platform operator's decision to impose a no-discrimination rule matches the socially desirable outcome and constellations where it fails to match the welfare-maximizing outcome can be identified.

As Aguzzoni et al. (2012) indicate, so far there has not been any study explicitly analyzing no-discrimination rules (or, more generally, third-party price relationship agreements) in intermediated markets. Although parts of the substantial work on payment card networks exhibit certain theoretical analogies with the framework introduced in this study, that literature focusses on a different industry structure. Even when abstracting from the additional "bank level" intermediation, the studies on no-surcharge rules show certain limitations that restrict applicability on the cases mentioned in the introduction. In contrast to the studies of Wright (2003) and Schwartz and Vincent (2006), my framework allows for imperfect merchant competition and accounts for the spillover effect whose presence seems reasonable in a multi-channel sales framework[40] and impacts both specialization incentives and price levels.

Although this study may also be seen as an extension to the literature on no-surcharge rules imposed by payment card networks, the main contribution is the provision of a framework that fosters the ongoing debate about the effects of across-platforms parity agreements (also called most-favored treatment clauses or no-discrimination rules) on the use of different trade opportunities. In particular, it sheds light on the restrictions which several prominent platform operators (e.g. HRS, Booking.com, Amazon) use and which recently became subjects of litigation.

However, this study only constitutes a first step towards a better understanding of such practices and abstracts from several aspects which may also affect outcomes in intermediated markets. Firstly, in this study, existence of a direct sales channel introduces competition between channels, but excludes strategic interactions between multiple platform operators. Future research could introduce a second intermediary, analyzing the effects on potential competition (foreclosure effect of across-platforms parity agreements) or on actual competition between two established platform operators. Secondly, if platform operators face investment costs to establish their platforms or incur fixed costs to maintain or improve their platform services, imposing a no-discrimination rule may also be seen as a means to mitigate free-riding: without a restriction on sellers' pricing decisions, consumers utilize platform services to find their preferred product, but may buy in another (cheaper) channel which does not offer any service. This problem may lead to an underprovision of desirable services or, more generally, a lack of investment incentives. If the intermediary gains from a certain (desirable) investment under a no-discrimination rule, but cannot recover his investment costs without imposing a pricing restriction, prohibiting such restrictive practices may result in an inefficiently low investment level. Thirdly, future research could extent this framework by allowing for different types of platform fees. On the

[40]The spillover (or "billboard") effect, i.e., being active in one channel affects sales in the other channel due to consumers' endogenous decision where to buy their preferred product, has been documented at least for the hotel industry (cf. fn. 6). Furthermore, it has also been used as an argument within the opinion of the Higher Regional Court Duesseldorf (file no. 33 O 16/12) on HRS's practices.

one hand, charging membership fees to consumers seems to be a (theoretical) option, in particular, as these may mitigate potential free-riding problems. However, none of the platform operators mentioned in the discussion so far charges consumers non-zero membership fees, and charging membership fees may not be feasible due to several reasons (e.g. consumers being uncertain about the individual benefits of platform services or commitment issues). On the other hand, future work could include proportional fees (i.e., royalties based on revenues) as these may induce additional effects of no-discrimination rules on platform profits. In particular, with per-transaction fees, the platform operator usually gains from cross-subsidization between channels as this leads to more transactions on his platform. However, if sellers cross-subsidizing leads to lower prices on the platform, the effect on platform profits may be less clear under proportional fees.

4.7 Appendix

Background: HRS's most-favored treatment clause

HRS's best-price guarantee/most-favored treatment clause (HRS.com, 2012):

> "In principle, HRS expects its partner hotels to offer it the lowest room rates available. The Hotel guarantees that the HRS price is at parity with or lower than the lowest rate available for the Hotel on other reservation and travel platforms on the Internet or on offer on the Hotel's own Web pages."

As reactions on HRS's attempt to extend this most-favored treatment clause on prices at the reception desk and warning non-complying hotels, the German Cartel Office started an investigation (cf. Bundeskartellamt, 2012), and the Higher Regional Court Duesseldorf issued an injunction against warning letters that base on the extended version (file no. 33 O 16/12).

Background: Amazon's price parity rule

In the EU, Amazon introduced a price parity rule in May 2010 (Amazon.co.uk, 2011):

> "(...) since 1st May, we are asking sellers who choose to sell their products on Amazon.co.uk not to charge customers higher prices on Amazon than they charge customers elsewhere. Accordingly, sellers selling under the Amazon.co.uk marketplace Participation Agreement need to comply with price parity requirements as set forth below.
>
> Price parity for these sellers generally means that the item price and total price (total amount payable, including delivery charges but excluding taxes) of each product offered on Amazon.co.uk must not be higher than the corresponding prices at which the seller or its affiliates offers the product on other non-physical sales channels. This general requirement already applies to certain product categories in the Amazon.co.uk, Amazon.fr, and Amazon.de marketplaces, and has applied to the US marketplace for several years."

As a direct reaction, many sellers announced that they consider to stop selling on Amazon under a price parity rule. Furthermore, after an injuction against Amazon's price parity rule, issued by the District Court of Munich (file no. 37 O 7636/10), used books have been exempted from the price parity rule in Germany. Moreover, in February 2013, the German Cartel Office surveyed 2.400 marketplace sellers in order to assess Amazon's market position and potential effects of their tariff system on competition between different sales channels (Bundeskartellamt, 2013).

In response to a parliamentary question on concerns about Amazon's price parity rule, the European Commission stated earlier (Wills, 2010):

> "The Commission wishes to inform the Honourable Member that the Commission follows very closely the developments in the market for the online sales of books and is aware of Amazon's price policy.
>
> As regards compliance with competition rules, Article 101 TFEU prohibits anti-competitive agreements between two or more companies. In this case, it concerns a unilateral decision taken by Amazon. Therefore, it appears that Article 101 is not applicable. Article 102 TFEU prohibits companies with a dominant market position from abusing their position. However, the Commission has not assessed whether Amazon has a dominant position. The Commission is hence not in a position at this stage to take a view on whether or not Amazon's price policy is in line with EU competition rules."

Derivations & Proofs

Pricing decisions under full participation without NDR, proof of Proposition 4.1

The derivatives of seller k's profit

$$Q_k(\mathbf{p_d}, \mathbf{p_m}) \cdot \{F(f_b + \Delta p_k) \cdot (p_{k,d} - c) + (1 - F(f_b + \Delta p_k)) \cdot (p_{k,m} - f_s)\}$$

with respect to $p_{k,d}$ and $p_{k,m}$ read

$$\begin{aligned}\frac{\partial \pi_k}{\partial p_{k,d}} =& \{F(f_b + \Delta p_k) + f(f_b + \Delta p_k) \cdot (\Delta p_k - f_s + c))\} \\ &\times \left\{ M_m \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_{l_1,m} + p_{l_2,m} - 2p_{k,m}}{2t} \right) + M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_{l_1,d} + p_{l_2,d} - 2p_{k,d}}{2t} \right) \right\} \\ &- \frac{3M_d}{t} \cdot \{F(f_b + \Delta p_k) \cdot (p_{k,d} - c) + (1 - F(f_b + \Delta p_k)) \cdot (p_{k,m} - f_s)\}\end{aligned}$$

and

$$\begin{aligned}\frac{\partial \pi_k}{\partial p_{k,m}} =& \{1 - F(f_b + \Delta p_k) - f(f_b + \Delta p_k) \cdot (\Delta p_k - f_s + c))\} \\ &\times \left\{ M_m \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_{l_1,m} + p_{l_2,m} - 2p_{k,m}}{2t} \right) + M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_{l_1,d} + p_{l_2,d} - 2p_{k,d}}{2t} \right) \right\} \\ &- \frac{3M_m}{t} \cdot \{F(f_b + \Delta p_k) \cdot (p_{k,d} - c) + (1 - F(f_b + \Delta p_k)) \cdot (p_{k,m} - f_s)\}.\end{aligned}$$

In a symmetric equilibrium with $p_{k,i} = p_{l,i}$, the first order conditions become

$$\begin{aligned}&\{F(f_b + \Delta p_k) + f(f_b + \Delta p_k) \cdot (\Delta p_k - f_s + c)\} \times \{M_m + M_d\} \\ =& 9 \cdot \frac{M_d}{t} \cdot \{F(f_b + \Delta p_k) \cdot (p_{k,d} - c) + (1 - F(f_b + \Delta p_k)) \cdot (p_{k,m} - f_s)\} \qquad (4.19)\end{aligned}$$

and

$$\begin{aligned}&\{1 - F(f_b + \Delta p_k) - f(f_b + \Delta p_k) \cdot (\Delta p_k - f_s + c)\} \times \{M_m + M_d\} \\ =& 9 \cdot \frac{M_m}{t} \cdot \{F(f_b + \Delta p_k) \cdot (p_{k,d} - c) + (1 - F(f_b + \Delta p_k)) \cdot (p_{k,m} - f_s)\}. \qquad (4.20)\end{aligned}$$

Setting equal the equations which result after dividing equation (4.19) by $\frac{M_d}{t}$ and equation (4.20) by $\frac{M_m}{t}$ yields

$$\begin{aligned}&\{F(f_b + \Delta p_k) + f(f_b + \Delta p_k) \cdot (\Delta p_k - f_s + c)\} \times \frac{t \cdot (M_m + M_d)}{M_d} \\ =& \{1 - F(f_b + \Delta p_k) - f(f_b + \Delta p_k) \cdot (\Delta p_k - f_s + c)\} \times \frac{t \cdot (M_m + M_d)}{M_m},\end{aligned}$$

which is equivalent to

$$F(f_b + \Delta p_k) + f(f_b + \Delta p_k) \cdot \{\Delta p_k - f_s + c\} = \frac{M_d}{M_d + M_m}.$$

Application of the implicit function theorem proves Proposition 4.1:

$$\frac{\partial \cdot}{\partial \Delta p} = 2 \cdot f(f_b + \Delta p) + f'(f_b + \Delta p) \cdot \{\Delta p + c - f_s\}$$

$$\frac{\partial \cdot}{\partial f_s} = -f(f_b + \Delta p)$$

$$\frac{\partial \cdot}{\partial f_b} = f(f_b + \Delta p) + f'(f_b + \Delta p) \cdot \{\Delta p + c - f_s\}$$

$$\frac{\partial \Delta p}{\partial f_s} = -\frac{\frac{\partial \cdot}{\partial f_s}}{\frac{\partial \cdot}{\partial \Delta p}} = \frac{1}{2} - \frac{f'(f_b + \Delta p) \cdot \{\Delta p + c - f_s\}}{2 \cdot \{2 \cdot f(f_b + \Delta p) + f'(f_b + \Delta p) \cdot \{\Delta p + c - f_s\}\}}$$

$$\frac{\partial \Delta p}{\partial f_b} = -\frac{\frac{\partial \cdot}{\partial f_b}}{\frac{\partial \cdot}{\partial \Delta p}} = -\frac{1}{2} - \frac{f'(f_b + \Delta p) \cdot \{\Delta p + c - f_s\}}{2 \cdot \{2 \cdot f(f_b + \Delta p) + f'(f_b + \Delta p) \cdot \{\Delta p + c - f_s\}\}}$$

As the indifferent consumer between channels is given by $\widetilde{v} = f_b + \Delta p$, it follows that

$$\frac{\partial \widetilde{v}}{\partial f_b} = \frac{\partial \widetilde{v}}{\partial f_s}.$$

Hence, if $f_b + f_s = \text{const.}$, a marginal shift between f_b and f_s does not change $\widetilde{v}$, and the split-up of consumers between marketplace and direct sales channel remains unchanged.

Prices under uniformly distributed platform benefits (full participation, no NDR)

Bringing together equation (4.1) and Assumption 4.1, it follows that

$$\Delta p_k = f_s - c + \frac{\frac{M_d}{M_d+M_m} - \frac{(f_b+\Delta p_k)-\underline{v}}{\overline{v}-\underline{v}}}{\frac{1}{\overline{v}-\underline{v}}} \Leftrightarrow \Delta p_k = \frac{1}{2}\cdot\left(\frac{M_d}{M_d+M_m}\cdot(\overline{v}-\underline{v}) + \underline{v} + f_s - f_b - c\right),$$

which confirms equation (4.2).

Plugging Δp_k into the first order condition w.r.t. $p_{k,d}$, i.e., equation (4.19), leads to

$$\begin{aligned}
&\left\{f_b + \left(\frac{M_d}{M_d+M_m}\cdot(\overline{v}-\underline{v}) + \underline{v} + f_s - f_b - c\right) - \underline{v} + c - f_s\right\} \times \frac{t\cdot(M_m+M_d)}{9M_d} \\
&= (p_{k,m} - f_s)\cdot(\overline{v}-\underline{v}) \\
&\quad - \left\{f_b + \frac{1}{2}\cdot\left(\frac{M_d}{M_d+M_m}\cdot(\overline{v}-\underline{v}) + \underline{v} + f_s - f_b - c\right) - \underline{v}\right\} \\
&\quad \times \left(\frac{1}{2}\cdot\left(\frac{M_d}{M_d+M_m}\cdot(\overline{v}-\underline{v}) + \underline{v} + f_s - f_b - c\right) + c - f_s\right).
\end{aligned}$$

This is equivalent to

$$\frac{1}{4}\cdot\left(\frac{M_d}{M_d+M_m}\cdot(\overline{v}-\underline{v}) - x\right)\cdot\left(\frac{M_d}{M_d+M_m}\cdot(\overline{v}-\underline{v}) + x\right) = \left(p_{k,m} - f_s - \frac{t}{9}\right)\cdot(\overline{v}-\underline{v}),$$

with $x = \underline{v} - f_s - f_b + c$. Solving for $p_{k,m}$, taking into account that $F_u(\widetilde{v}(f_b + f_s)) = \frac{\widetilde{v}(f_b+f_s)-\underline{v}}{\overline{v}-\underline{v}}$, with $\widetilde{v}(f_b + f_s)$ as defined in equation (4.3), yields (4.4); (4.5) follows from $p_{k,d} = p_{k,m} - \Delta p_k$.

Proof of Proposition 4.2

In the symmetric equilibrium derived above, each seller's profit equals

$$\pi^* = \frac{1}{3}\cdot(M_d+M_m)\cdot\{F_u(\widetilde{v}(f_b+f_s))\cdot(p_{k,d}-c) + (1-F_u(\widetilde{v}(f_b+f_s)))\cdot(p_{k,m}-f_s)\}.$$

Inserting equilibrium prices (4.4) and (4.5) leads to

$$\begin{aligned}
&3\cdot\frac{\pi^*}{M_d+M_m} \\
&= F_u(\widetilde{v}(f_b+f_s))\cdot\left(\frac{t}{9} - \{1-F_u(\widetilde{v}(f_b+f_s))\}\cdot\left(\frac{M_d}{M_d+M_m} - \frac{f_b+f_s-c-\underline{v}}{\overline{v}-\underline{v}}\right)\cdot\left(\frac{\overline{v}-\underline{v}}{2}\right)\right) \\
&+ (1-F_u(\widetilde{v}(f_b+f_s))\cdot\left(\frac{t}{9} + F_u(\widetilde{v}(f_b+f_s))\cdot\left(\frac{M_d}{M_d+M_m} - \frac{f_b+f_s-c-\underline{v}}{\overline{v}-\underline{v}}\right)\cdot\left(\frac{\overline{v}-\underline{v}}{2}\right)\right).
\end{aligned}$$

This simplifies to $3 \cdot \frac{\pi^*}{M_d+M_m} = \frac{t}{9}$. Hence, equilibrium profit equals $\frac{t}{27} \cdot (M_d + M_m)$.

Proof of Proposition 4.3

Firstly, I show that specialization on the direct sales channel is not profitable without a NDR, given condition (4.6) in Assumption 4.2.

If seller 1 specializes on the direct sales channel while sellers 2 and 3 are active in both channels, without a NDR, profits read

$$\pi_1 = M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_{2,d} + p_{3,d} - 2p_1}{2t}\right) \cdot (p_1 - c),$$

and

$$\begin{aligned}\pi_2 = & \left\{M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_1 + p_{3,d} - 2p_{2,d}}{2t}\right) + M_m \cdot \left(\frac{1}{2} + 2 \cdot \frac{p_{3,m} - p_{2,m}}{t}\right)\right\} \\ & \times \{F(f_b + \Delta p) \cdot (p_{2,d} - c) + (1 - F(f_b + \Delta p)) \cdot (p_{2,m} - f_s)\}.\end{aligned}$$

As before, $\Delta p_k \equiv p_{k,m} - p_{k,d}$, and $\gamma \equiv \frac{M_m}{M_d}$. The best response of seller 1 can be calculated as

$$p_1(p_{2,d}, p_{3,d}) = \frac{t}{18} + \frac{c}{2} + \frac{p_{2,d} + p_{3,d}}{4}.$$

The partial derivatives of π_2 are

$$\begin{aligned}\frac{\partial \pi_2}{\partial p_{2,d}} = & -\frac{3M_d}{t} \cdot \{(p_{2,m} - f_s) - F(f_b + \Delta p) \cdot (\Delta p - f_s + c)\} \\ & + \left\{M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_1 + p_{3,d} - 2p_{2,d}}{2t}\right) + M_m \cdot \left(\frac{1}{2} + 2 \cdot \frac{p_{3,m} - p_{2,m}}{t}\right)\right\} \\ & \times \left(F(f_b + \Delta p) + f(f_b + \Delta p) \cdot (\Delta p - f_s + c)\right),\end{aligned}$$

and

$$\begin{aligned}\frac{\partial \pi_2}{\partial p_{2,m}} = & -\frac{2M_m}{t} \cdot \{(p_{2,m} - f_s) - F(f_b + \Delta p) \cdot (\Delta p - f_s + c)\} \\ & + \left\{M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_1 + p_{3,d} - 2p_{2,d}}{2t}\right) + M_m \cdot \left(\frac{1}{2} + 2 \cdot \frac{p_{3,m} - p_{2,m}}{t}\right)\right\} \\ & \times \left(1 - F(f_b + \Delta p) - f(f_b + \Delta p) \cdot (\Delta p - f_s + c)\right).\end{aligned}$$

Setting equal the last two derivatives (first order conditions) yields

$$\begin{aligned}& \frac{1}{3M_d} \cdot \left(F(f_b + \Delta p) + f(f_b + \Delta p) \cdot (\Delta p - f_s + c)\right) \\ = & \frac{1}{2M_m} \cdot \left(1 - F(f_b + \Delta p) - f(f_b + \Delta p) \cdot (\Delta p - f_s + c)\right),\end{aligned}$$

which is equivalent to

$$\frac{3}{3+2\gamma} = F(f_b + \Delta p) + f(f_b + \Delta p) \cdot (\Delta p - f_s + c).$$

With uniformly distributed platform benefits, this leads to

$$\Delta p = \frac{1}{2} \cdot \left(\frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v}) + \underline{v} + f_s - f_b - c \right).$$

From $\frac{\partial \pi_2}{\partial p_{2,d}} = 0$ and symmetry $p_{2,d} = p_{3,d}$, by inserting seller 1's best response, it follows

$$\begin{aligned} &\frac{3M_d}{t} \cdot \{(\Delta p + p_{2,d} - f_s) - F_u(f_b + \Delta p) \cdot (\Delta p - f_s + c)\} \\ &= \left\{ M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{\left(\frac{t}{18} + \frac{c}{2} + \frac{p_{2,d}}{2}\right) - p_{2,d}}{2t} \right) + \frac{M_m}{2} \right\} \\ &\quad \times \left(F_u(f_b + \Delta p) + f_u(f_b + \Delta p) \cdot (\Delta p - f_s + c)\right). \end{aligned}$$

This is equivalent to

$$\begin{aligned} &\frac{3M_d}{t} \cdot \{(\Delta p + p_{2,d} - f_s) - F_u(f_b + \Delta p) \cdot (\Delta p - f_s + c)\} \\ &= \left\{ M_d \cdot \left(\frac{5}{12} + \frac{3}{4} \cdot \left(\frac{c}{t} - \frac{p_{2,d}}{t} \right) \right) + \frac{M_m}{2} \right\} \cdot \left(F_u(f_b + \Delta p) + f_u(f_b + \Delta p) \cdot (\Delta p - f_s + c)\right), \end{aligned}$$

or

$$\begin{aligned} &p_{2,d} \cdot \left(1 + \frac{1}{4} \cdot \left(F_u(f_b + \Delta p) + f_u(f_b + \Delta p) \cdot (\Delta p - f_s + c)\right) \right) \\ &= \left\{ \frac{5}{36} \cdot t + \frac{c}{4} + \frac{\gamma}{6} \cdot t \right\} \cdot \left(F_u(f_b + \Delta p) + f_u(f_b + \Delta p) \cdot (\Delta p - f_s + c)\right) \\ &\quad + (1 - F_u(f_b + \Delta p)) \cdot (f_s - c - \Delta p) + c. \end{aligned}$$

This can be simplified as follows:

$$\begin{aligned} p_{2,d} &= \frac{c + (F_u(f_b + \Delta p) - f_u(f_b + \Delta p) \cdot (f_s - c - \Delta p)) \cdot \left\{ \left(\frac{5}{6} + \gamma\right) \cdot \frac{t}{6} + \frac{c}{4} \right\} + (1 - F_u(f_b + \Delta p)) \cdot (f_s - c - \Delta p)}{1 + \frac{1}{4} \cdot (F_u(f_b + \Delta p) - f_u(f_b + \Delta p) \cdot (f_s - c - \Delta p))} \\ &= \frac{c + \left(\frac{(f_b + \Delta p) - \underline{v}}{(\overline{v} - \underline{v})} - \frac{(f_s - c - \Delta p)}{(\overline{v} - \underline{v})} \right) \cdot \left\{ \left(\frac{5}{6} + \gamma\right) \cdot \frac{t}{6} + \frac{c}{4} \right\} + \left(1 - \frac{(f_b + \Delta p) - \underline{v}}{(\overline{v} - \underline{v})} \right) \cdot (f_s - c - \Delta p)}{1 + \frac{1}{4} \cdot \left(\frac{(f_b + \Delta p) - \underline{v}}{(\overline{v} - \underline{v})} - \frac{(f_s - c - \Delta p)}{(\overline{v} - \underline{v})} \right)} \\ &= \frac{4c \cdot (\overline{v} - \underline{v}) + (2\Delta p + f_b + c - f_s - \underline{v}) \cdot \left\{ \left(\frac{5}{6} + \gamma\right) \cdot \frac{2}{3} \cdot t + c \right\} + 4 \cdot ((\overline{v} - \underline{v}) - (f_b + \Delta p - \underline{v})) \cdot (f_s - c - \Delta p)}{4(\overline{v} - \underline{v}) + 2\Delta p + f_b + c - f_s - \underline{v}} \\ &= c + \frac{(2\Delta p + f_b + c - f_s - \underline{v}) \cdot \left(\frac{5}{6} + \gamma\right) \cdot \frac{2}{3} \cdot t + 4 \cdot ((\overline{v} - \underline{v}) - (f_b + \Delta p - \underline{v})) \cdot (f_s - c - \Delta p)}{4(\overline{v} - \underline{v}) + 2\Delta p + f_b + c - f_s - \underline{v}} \\ &= c + \frac{5 + 6\gamma}{15 + 8\gamma} \cdot \frac{t}{3} \\ &\quad - \frac{6 + 4\gamma}{15 + 8\gamma} \cdot \left(1 - \frac{1}{2} \cdot \left(\frac{\frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v}) - \underline{v} + f_b + f_s - c}{(\overline{v} - \underline{v})} \right) \right) \cdot \left(\frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v}) + \underline{v} - f_s - f_b + c \right). \end{aligned}$$

Inserting this price (which equals $p_{3,d}$ in equilibrium) into the best response function, the price of seller 1 turns out to be

$$\begin{aligned} p_1 =& c + \frac{t}{18} + \frac{5+6\gamma}{15+8\gamma} \cdot \frac{t}{6} \\ & - \frac{1}{2} \cdot \frac{6+4\gamma}{15+8\gamma} \cdot \left(1 - \frac{1}{2} \cdot \left(\frac{\frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v}) - \underline{v} + f_b + f_s - c}{(\overline{v} - \underline{v})}\right)\right) \\ & \times \left(\frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v}) + \underline{v} - f_s - f_b + c\right). \end{aligned}$$

Observing that

$$\begin{aligned} p_{2,d} - p_1 =& \underbrace{\frac{(5+6\gamma) - (5+\frac{8}{3}\gamma)}{15+8\gamma} \cdot \frac{t}{6}}_{=\frac{10\gamma}{15+8\gamma} \cdot \frac{t}{18}} \\ & - \frac{1}{2} \cdot \frac{6+4\gamma}{15+8\gamma} \cdot \left(1 - \frac{1}{2} \cdot \left(\frac{\frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v}) - \underline{v} + f_b + f_s - c}{(\overline{v} - \underline{v})}\right)\right) \\ & \times \left(\frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v}) + \underline{v} - f_s - f_b + c\right), \end{aligned}$$

the profit of seller 1 (specializing on direct sales) is given by

$$\begin{aligned} \pi_1^{dev} =& M_d \cdot \left(\frac{1}{3} + \frac{3}{2t} \cdot \frac{10\gamma}{15+8\gamma} \cdot \frac{t}{9}\right) \\ & + M_d \cdot \frac{3}{2t} \cdot \frac{6+4\gamma}{15+8\gamma} \cdot \left(1 - \frac{\frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v}) - \underline{v} + f_b + f_s - c}{2 \cdot (\overline{v} - \underline{v})}\right) \cdot \left(f_b + f_s - c - \underline{v} - \frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v})\right) \\ & \times \left(\frac{t}{18} + \frac{5+6\gamma}{15+8\gamma} \cdot \frac{t}{6} + \frac{1}{2} \cdot \frac{6+4\gamma}{15+8\gamma} \cdot \left(1 - \frac{\frac{3}{3+2\gamma} \cdot (\overline{v} - \underline{v}) - \underline{v} + f_b + f_s - c}{2 \cdot (\overline{v} - \underline{v})}\right) \cdot \left(f_b + f_s - c - \underline{v} - \frac{3 \cdot (\overline{v} - \underline{v})}{3+2\gamma}\right)\right) \\ =& \frac{3M_d}{t} \cdot \left(\frac{t}{9} + \frac{10\gamma}{15+8\gamma} \cdot \frac{t}{18} + \frac{1}{2} \cdot \frac{6+4\gamma}{15+8\gamma} \cdot \left(1 - \frac{\frac{3 \cdot (\overline{v} - \underline{v})}{3+2\gamma} - \underline{v} + f_b + f_s - c}{2 \cdot (\overline{v} - \underline{v})}\right) \cdot \left(f_b + f_s - c - \underline{v} - \frac{3 \cdot (\overline{v} - \underline{v})}{3+2\gamma}\right)\right)^2. \end{aligned}$$

Specialization on direct sales is not profitable if $\pi_1^{dev} \leq (1+\gamma) \cdot M_d \cdot \frac{t}{27}$, which is equivalent to

$$\begin{aligned} & \left| 15 + 13\gamma + 9 \cdot (3+2\gamma) \cdot \left(1 - \frac{\frac{3 \cdot (\overline{v} - \underline{v})}{3+2\gamma} + f_b + f_s - c - \underline{v}}{2 \cdot (\overline{v} - \underline{v})}\right) \cdot \left(\frac{f_b + f_s - c - \underline{v} - \frac{3 \cdot (\overline{v} - \underline{v})}{3+2\gamma}}{t}\right) \right| \\ & \leq (15+8\gamma) \cdot \sqrt{1+\gamma}. \end{aligned}$$

As $p_1 - c$ has to be positive for π_1^{dev} being positive (this is an implicit assumption made above), specialization is not profitable if

$$\begin{aligned} & 9 \cdot (3+2\gamma) \cdot \left(1 - \frac{\frac{3 \cdot (\overline{v} - \underline{v})}{3+2\gamma} + f_b + f_s - c - \underline{v}}{2 \cdot (\overline{v} - \underline{v})}\right) \cdot \left(\frac{f_b + f_s - c - \underline{v} - \frac{3 \cdot (\overline{v} - \underline{v})}{3+2\gamma}}{t}\right) \\ & \leq (15+8\gamma) \cdot \sqrt{1+\gamma} - (15+13\gamma). \end{aligned}$$

This can also be written as

$$9 \cdot \left(\frac{\overline{v}-\underline{v}}{t}\right) \cdot (3+2\gamma) \cdot \left[\frac{f_b+f_s-(c+\underline{v})}{\overline{v}-\underline{v}} - \frac{3}{3+2\gamma} - \frac{1}{2}\left\{\left(\frac{f_b+f_s-(c+\underline{v})}{\overline{v}-\underline{v}}\right)^2 - \frac{9}{(3+2\gamma)^2}\right\}\right]$$
$$\leq (15+8\gamma) \cdot \sqrt{1+\gamma} - (15+13\gamma).$$

The left-hand side of this inequality takes its maximum at $f_b + f_s = (c+\underline{v}) + (\overline{v}-\underline{v})$ (this fee level maximizes specialization incentives). Hence, the condition is fulfilled whenever

$$9 \cdot \left(\frac{\overline{v}-\underline{v}}{t}\right) \cdot \left[2\gamma - \frac{3+2\gamma}{2} + \frac{9}{2} \cdot \frac{1}{3+2\gamma}\right] \leq (15+8\gamma) \cdot \sqrt{1+\gamma} - (15+13\gamma),$$

which is equivalent to condition (4.6).

Along the same lines, it can be shown that specialization on platform sales is not profitable to a seller, given condition (4.7) in Assumption 4.2. If seller 1 specializes on platform sales, profits are as follows:

$$\pi_1 = M_m \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_{2,m}+p_{3,m}-2p_1}{2t}\right) \cdot (p_1 - f_s),$$

$$\pi_2 = \left\{M_m \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_1+p_{3,m}-2p_{2,m}}{2t}\right) + M_d \cdot \left(\frac{1}{2} + 2 \cdot \frac{p_{3,d}-p_{2,d}}{t}\right)\right\}$$
$$\times \{F(f_b+\Delta p) \cdot (p_{2,d}-c) + (1-F(f_b+\Delta p)) \cdot (p_{2,m}-f_s)\}.$$

With uniformly distributed additional platform benefits, the relevant prices under specialization can be calculated as

$$p_{2,m} = f_s + \frac{5\gamma+6}{15\gamma+8} \cdot \frac{t}{3} + \frac{1}{(\overline{v}-\underline{v})} \cdot \frac{2+3\gamma}{8+15\gamma} \cdot \left(\frac{2}{2+3\gamma} \cdot (\overline{v}-\underline{v}) + f_b + f_s - c - \underline{v}\right)$$
$$\times \left(\frac{2}{2+3\gamma} \cdot (\overline{v}-\underline{v}) - f_s - f_b + c + \underline{v}\right),$$

and

$$p_1 = f_s + \frac{t}{18} + \frac{5\gamma+6}{15\gamma+8} \cdot \frac{t}{6}$$
$$+ \frac{1}{(\overline{v}-\underline{v})} \cdot \frac{1}{2} \cdot \frac{2+3\gamma}{8+15\gamma} \cdot \left(\frac{2 \cdot (\overline{v}-\underline{v})}{2+3\gamma} + f_b + f_s - c - \underline{v}\right) \cdot \left(\frac{2 \cdot (\overline{v}-\underline{v})}{2+3\gamma} - f_s - f_b + c + \underline{v}\right).$$

Specialization is not profitable to seller 1 if

$$9 \cdot \frac{(\overline{v}-\underline{v})}{t} \cdot \left(\frac{2}{(2+3\gamma)} - \frac{(2+3\gamma)}{2} \cdot \left(\frac{f_b+f_s-(c+\underline{v})}{(\overline{v}-\underline{v})}\right)^2\right) \leq (15\gamma+8) \cdot \sqrt{\frac{1+\gamma}{\gamma}} - (15\gamma+13).$$

The left-hand side takes its maximum for $f_b + f_s = c + \underline{v}$. Hence, specialization is never profitable under condition (4.7).

Derivation of prices under NDR when one seller specializes on direct sales

Given the profit of seller 1,

$$\pi_1(\mathbf{p}) = M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_2 + p_3 - 2 \cdot p_1}{2t}\right) \cdot (p_1 - c),$$

her best response on prices p_2 and p_3 can be calculated as

$$p_1^{dev}(p_2, p_3) = \frac{t}{18} + \frac{p_2 + p_3}{4} + \frac{c}{2}.$$

After deriving the profit of seller 2,

$$\pi_2(\mathbf{p}) = M_d \cdot \left(\frac{1}{3} + 3 \cdot \frac{p_1 + p_3 - 2 \cdot p_2}{2t}\right) \cdot \{p_2 - F(f_b) \cdot c - (1 - F(f_b)) \cdot f_s\}$$
$$+ M_m \cdot \left(\frac{1}{2} + 2 \cdot \frac{p_3 - p_2}{t}\right) \cdot \{p_2 - F(f_b) \cdot c - (1 - F(f_b)) \cdot f_s\},$$

it follows that the respective first order condition in an equilibrium that features symmetry between sellers 2 and 3, i.e., $p_2 = p_3$, is equivalent to

$$p_2^{dev} = \frac{(18\, M_d + 12\, M_m) \cdot \{F(f_b) \cdot c + (1 - F(f_b)) \cdot f_s\} + (2\, M_d + 3\, M_m) \cdot t + 9\, M_d \cdot p_1^{dev}}{27\, M_d + 12\, M_m}.$$

Inserting the best response of seller 1 leads to

$$p_1^{dev} = \left(1 + \frac{5\gamma}{15 + 8\gamma}\right) \cdot \frac{t}{9} + c + \left(1 - \frac{9 + 4\gamma}{15 + 8\gamma}\right) \cdot (1 - F(f_b)) \cdot (f_s - c),$$

and

$$p_2^{dev} = p_3^{dev} = \left(1 + \frac{10\gamma}{15 + 8\gamma}\right) \cdot \frac{t}{9} + c + \left(1 - \frac{3}{15 + 8\gamma}\right) \cdot (1 - F(f_b)) \cdot (f_s - c),$$

where $\gamma = \frac{M_m}{M_d}$.

These prices indeed constitute an equilibrium if a unilateral (discrete) deviation, in particular undercutting the other sellers to serve all consumers, is not profitable. With quadratic transportation costs, a deviation is not profitable if the calculated prices imply positive market shares for all sellers, i.e.,

$$p_1^{dev} + \left(\frac{1}{2}\right)^2 \cdot t > p_2^{dev} + \left(\frac{1}{6}\right)^2 \cdot t \;\Leftrightarrow\; p_2^{dev} - p_1^{dev} < \left(\frac{1}{4} - \frac{1}{36}\right) \cdot t = \frac{2}{9} \cdot t.$$

As

$$p_2^{dev} - p_1^{dev} = \frac{5\gamma}{15 + 8\gamma} \cdot \frac{t}{9} + \left(\frac{6 + 4\gamma}{15 + 8\gamma}\right) \cdot (1 - F(f_b)) \cdot (f_s - c), \tag{4.21}$$

this condition is equivalent to

$$(1 - F(f_b)) \cdot (f_s - c) < \left(2 - \frac{5\gamma}{15 + 8\gamma}\right) \cdot \left(\frac{15 + 8\gamma}{6 + 4\gamma}\right) \cdot \frac{t}{9} = \left(\frac{30 + 11\gamma}{2 \cdot (3 + 2\gamma)}\right) \cdot \frac{t}{9}. \tag{4.22}$$

This condition is always fulfilled if both specialization on direct sales is not profitable (condition (4.11)) and $\gamma < 8$, cf. the subsequent analysis.

Proof of Proposition 4.5

Inserting the price difference given in equation (4.21) and p_1^{dev} defined in (4.9) into the profit function of seller 1, her profit can be rewritten as

$$3 \cdot M_d \cdot t \cdot \left(\frac{15+13\gamma}{15+8\gamma} \cdot \frac{1}{9} + \left(\frac{6+4\gamma}{15+8\gamma} \right) \cdot (1-F(f_b)) \cdot \frac{f_s - c}{t} \right)^2 .$$

If all sellers are active in both channels, each seller earns a profit of $(1+\gamma) \cdot M_d \cdot \frac{t}{27}$. Consequently, a unilateral specialization on direct sales is not profitable if

$$3 \cdot \left(\frac{15+13\gamma}{15+8\gamma} \cdot \frac{1}{9} + \left(\frac{6+4\gamma}{15+8\gamma} \right) \cdot (1-F(f_b)) \cdot \frac{f_s - c}{t} \right)^2 \leq \frac{1+\gamma}{27}.$$

This condition holds if condition (4.11) is fulfilled.

As $p_1^{dev} \geq 0$, the second alternative,

$$\frac{15+13\gamma}{15+8\gamma} \cdot \frac{1}{9} + \left(\frac{6+4\gamma}{15+8\gamma} \right) \cdot (1-F(f_b)) \cdot \frac{f_s - c}{t} \leq -\frac{\sqrt{1+\gamma}}{9},$$

is irrelevant.

Taking a closer look on the upper bound (right-hand side) of condition (4.11), it can be shown that it does not exceed the upper bound given just above in condition (4.22) if $\gamma \leq 8$. Hence, condition (4.11) ensures existence of the asymmetric specialization equilibrium (as a non-profitable outside option).

Condition: Non-profitability of unilateral specialization on platform sales under a NDR

Along the lines of the derivation of the prices under NDR when one seller specializes on direct sales, the best response of seller 1 can be calculated as

$$p_1^{dev}(p_2, p_3) = \frac{t}{18} + \frac{p_2 + p_3}{4} + \frac{f_s}{2}.$$

In an equilibrium that features symmetry between seller 2 and 3 (i.e., $p_2 = p_3$), the first order condition which follows from the maximization of the profit of a non-specializing seller is equivalent to

$$F(f_b) \cdot c + (1-F(f_b)) \cdot f_s + \frac{t}{2\,M_d + 3\,M_m} \cdot \left\{ \frac{M_d}{2} + \frac{M_m}{3} + \frac{3\,M_m}{2t} \cdot p_1 \right\} = \frac{2\,M_d + \frac{9}{2}\,M_m}{2\,M_d + 3\,M_m} \cdot p_2.$$

Inserting the best response of seller 1 leads to the prices

$$p_1^{dev} = \left(1 + \frac{5}{15\gamma + 8} \right) \cdot \frac{t}{9} + f_s + \left(1 - \frac{9\gamma + 4}{15\gamma + 8} \right) \cdot F(f_b) \cdot (c - f_s),$$

and

$$p_2^{dev} = p_3^{dev} = \left(1 + \frac{10}{15\gamma + 8}\right) \cdot \frac{t}{9} + f_s + \left(1 - \frac{3\gamma}{15\gamma + 8}\right) \cdot F(f_b) \cdot (c - f_s).$$

The profit of seller 1 under specialization equals

$$\pi_1^{dev} = M_m \cdot 3 \cdot t \cdot \left(\frac{1}{9} \cdot \left(1 + \frac{5}{15\gamma + 8}\right) + F(f_b) \cdot \frac{6\gamma + 4}{15\gamma + 8} \cdot \frac{c - f_s}{t}\right)^2.$$

Consequently, specialization on platform sales is not profitable under a NDR if

$$-F(f_b) \cdot (f_s - c) \leq \frac{t}{9} \cdot \left(\frac{(15\gamma + 8) \cdot \sqrt{1 + \frac{1}{\gamma}} - (15\gamma + 13)}{2 \cdot (3\gamma + 2)}\right),$$

where the right-hand side is strictly positive for $\gamma > 0$.

The calculated prices under specialization indeed constitute an equilibrium (in the pricing game) if

$$-F(f_b) \cdot (f_s - c) \leq \frac{t}{9} \cdot \frac{11 + 30\gamma}{4 + 6\gamma}.$$

This condition is implied by the non-profitability condition if $\gamma \geq \frac{1}{8}$.

Quantitative effect of a change in locations of non-specialized sellers

All profits in the main body are calculated under the assumption that sellers are always located such that the distance to their next competitor in clockwise order is the same as the distance to their next competitor in counter-clockwise order. In particular, if seller 1 specializes on channel j, the positions of the non-specialized sellers 2 and 3 fulfill $|x_3 - x_2| = \frac{1}{2}$ in channel $i \neq j$, while the distance between any two sellers in channel j equals $\frac{1}{3}$.

If the non-specialized sellers 2 and 3 are located as in the case with three sellers (i.e., at $x_2 = \frac{1}{3}$ and $x_3 = \frac{2}{3}$), demand for product $k \neq l$ in channel i equals

$$q_{k,i}(p_{2,i}, p_{3,i}) = \frac{1}{2} + \frac{9}{4} \cdot \frac{p_{l,i} - p_{k,i}}{t}.$$

Therefore, the "relaxed competition" effect is weaker than with perfectly symmetric positions (where the factor that is multiplied by the (relative) price difference equals $2 < \frac{9}{4}$), and the price increase due to specialization is less pronounced. Therefore, the condition for specialization on direct sales not being profitable is less demanding than before, making the no-discrimination rule (slightly) more attractive to the intermediary. More specifically, if the locations of the non-specialized sellers are the same in both channels, regardless of the third seller being present, the upper bound on $(1 - F(f_b)) \cdot (f_s - c)$ in condition (4.11) becomes

$$\frac{t}{9} \cdot \left(\frac{(10 + 6\gamma) \cdot \sqrt{1 + \gamma} - (10 + 9\gamma)}{4 + 3\gamma}\right).$$

However, all trade-offs remain qualitatively unchanged and, therefore, the results are robust against changes in the locations of the non-specialized sellers in the "outside option" scenario.

Proof of Lemma 4.2

Without a NDR, the intermediary's profit equals $(1+\gamma)\cdot M_d\cdot\{1-F(\widetilde{v}(f_b+f_s))\}\cdot(f_b+f_s-k)$.

Without loss of generality, I set $f_b = 0$ to calculate the optimal fee (without a NDR the fee structure features neutrality). Then, the first order condition w.r.t. f_s is given by

$$1 - F(\Delta p_k) = f(\Delta p_k) \cdot \frac{\partial \Delta p_k}{\partial f_s} \cdot (f_s - k).$$

Consequently, without a no-discrimination rule, given Assumption (4.1) and using definition (4.8), the platform operator's profit is maximized by setting

$$f_b + f_s = c + \underline{v} + \frac{(k-c) - \underline{v}}{2} + (\overline{v} - \underline{v}) \cdot \left(1 - \frac{1}{2(1+\gamma)}\right).$$

Given this fee level, the indifferent consumer between channels, defined in (4.3), turns out to be

$$\widetilde{v}(f_b + f_s) = \underline{v} + \frac{1}{2} \cdot (\overline{v} - \underline{v}) \cdot \left(\frac{1}{1+\gamma} + \frac{(k-c) - \underline{v}}{2 \cdot (\overline{v} - \underline{v})} + 1 - \frac{1}{2(1+\gamma)}\right).$$

Hence, the maximal profit equals

$$\begin{aligned}
\Pi_0^* &= (1+\gamma) \cdot M_d \cdot \{1 - F_u(\widetilde{v}(f_b + f_s))\} \cdot (f_b + f_s - k) \\
&= (1+\gamma) \cdot M_d \cdot \left\{1 - \frac{(k-c) - \underline{v}}{4 \cdot (\overline{v} - \underline{v})} - \frac{1}{2} - \frac{1}{4(1+\gamma)}\right\} \\
&\quad \times \left(c + \underline{v} + \frac{(k-c) - \underline{v}}{2} + (\overline{v} - \underline{v}) \cdot \left(1 - \frac{1}{2(1+\gamma)}\right) - k\right) \\
&= (1+\gamma) \cdot M_d \cdot \left(\frac{\overline{v} - \underline{v}}{2}\right) \cdot \left\{1 - \frac{1}{2} \cdot \left(F_u(k-c) + \frac{1}{1+\gamma}\right)\right\}^2.
\end{aligned}$$

Proof of Lemma 4.3

In order to maximize the profit given in (4.14), the intermediary sets the maximal seller fee that is compatible with participation constraint (4.11), i.e.,

$$f_s^* = c + \frac{t}{9} \cdot \left(\frac{(15+8\gamma) \cdot \sqrt{1+\gamma} - (15+13\gamma)}{2 \cdot (3+2\gamma) \cdot (1 - F(f_b))}\right).$$

Inserting this fee into the intermediary's profit (4.14) yields

$$\begin{aligned}
\Pi_1(f_b) &= (M_d + M_m) \cdot (1 - F(f_b)) \cdot \left(c + \frac{t}{9} \cdot \left(\frac{(15+8\gamma) \cdot \sqrt{1+\gamma} - (15+13\gamma)}{2 \cdot (3+2\gamma) \cdot (1 - F(f_b))}\right) + f_b - k\right) \\
&= (M_d + M_m) \cdot \left\{\frac{t}{9} \cdot \left(\frac{(15+8\gamma) \cdot \sqrt{1+\gamma} - (15+13\gamma)}{2 \cdot (3+2\gamma)}\right) + (1 - F(f_b)) \cdot (f_b - (k-c))\right\}.
\end{aligned}$$

Under Assumption (4.1), this expression takes its maximum at $f_b^* = \frac{k-c}{2} + \frac{\overline{v}}{2}$. The corresponding profit level equals

$$\Pi_1^* = (M_d + M_m) \cdot \left\{ \frac{t}{9} \cdot \left(\frac{(15+8\gamma)\cdot\sqrt{1+\gamma} - (15+13\gamma)}{2\cdot(3+2\gamma)} \right) + \left(\frac{\overline{v} - \underline{v}}{4} \right) \cdot (1 - F_u(k-c))^2 \right\}.$$

Proof of Proposition 4.7

Imposing a no-discrimination rule always results in an underuse of the platform channel, cf. Corollary 4.5. However, imposing a no-discrimination rule improves the allocation of consumers on channels if

$$1 - F_u(\widetilde{v}_1) > 1 - F_u(\widetilde{v}_0) \;\Leftrightarrow\; \widetilde{v}_1 < \widetilde{v}_0.$$

Comparing expressions (4.16) and (4.13), this is the case if

$$\frac{k-c}{2} + \frac{\overline{v}}{2} \;<\; \underline{v} + \left\{ \frac{1}{2} + \frac{1}{4} \cdot \left(\frac{1}{1+\gamma} \right) \right\} \cdot (\overline{v} - \underline{v}) + \frac{(k-c) - \underline{v}}{4},$$

or, equivalently, if

$$\frac{k-c}{4} \;<\; \frac{\underline{v}}{4} + \frac{1}{4} \cdot \left(\frac{1}{1+\gamma} \right) \cdot (\overline{v} - \underline{v}) \;\Leftrightarrow\; F_u(k-c) < \frac{1}{1+\gamma} = \frac{M_d}{M_d + M_m}.$$

Chapter 5

Concluding Remarks

Opening up manifold opportunities for both firms and consumers, the evolution of new information technologies poses many questions. Dealing with issues closely related to the topic of this dissertation, several recent contributions[1] as well as ongoing investigations by antitrust authorities[2] strongly indicate that the evaluation of certain business practices that have been facilitated by the spread of the Internet challenge both practitioners and researchers. However, several questions do not only arise within an e-commerce context, but refer to understanding basic decisions such as which intermediation mode to choose or which tariff structure to impose as an intermediary. Furthermore, availability of certain information technologies is also likely to affect traditional ("offline") markets: on the one hand, consumers have convenient access to a wider variety of information. On the other hand, "online markets" oftentimes exhibit externalities on "offline markets", and vice versa, in particular, as sellers and buyers are often active both online and offline. Therefore, one should consider interpreting both environments together as a potential single market,[3] or at least account for a change in the informational structure and firms using specific strategies within this changed environment.

[1]For examples, cf. Aguzzoni et al. (2012), Mayzlin et al. (2012), Z. Wang and Wright (2012), or Hagiu and Wright (2013).

[2]Cf. Bundeskartellamt (2012, 2013) or Office of Fair Trading (2012).

[3]In particular, abstracting from potential monitoring problems, the framework introduced in the third essay might be interpreted as a setup with competition between online and offline sales.

Motivated by several real-world observations and both theoretical and empirical insights, this dissertation builds on and extends previous research. It offers an in-depth analysis of specific issues, namely (i) a seller's pricing and marketing decisions when facing consumers who have access to potentially misleading product information, (ii) a platform's tariff choice when operating under a "dual mode" of intermediation, and (iii) a platform's decisions on its tariff and imposing a no-discrimination rule when facing sellers who can also reach consumers outside the platform. However, the scope of this analysis is restricted, aiming at a better understanding of a limited number of effects that arise within the given frameworks.

Altogether, this dissertation sheds light on selected business practices, identifying several trade-offs that firms face in different contexts, but it also illustrates that some results are highly sensitive to certain assumptions on the underlying circumstances. It provides answers to specific questions, but also poses new questions, fostering the discussion on intermediation, marketing, and strategic pricing.

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