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Contents

1 Introduction

In many markets, manufacturers often do not provide products directly to consumers but rely heavily on intermediaries or retailers in order to do so. For instance, in grocery markets, food manufacturers distribute their goods through supermarket chains, which in turn sell to final consumers; In pharmaceutical industries, drug manufacturers distribute their products to buyers through drug-stores or pharmacies. Other examples of such vertical markets include gasoline markets, health care sectors and television industries. These economic environments are widespread and usually feature a small number of retailers and manufacturers operating in each level of the supply chain. The contractual agreements reached are typically different from one-another, include vertical restraints and are determined through bargaining.

The interaction between firms in such settings has been studied in the vertical contracting literature. This literature dates back to the seminal double-marginalization paper of Spengler (1950) and mostly focuses on contractual agreements between retailers and manufacturers while taking a rather simplistic view on the consumer side of the market. The standard assumption has been that consumers can obtain information on product characteristics at no cost. However, many markets are characterized by significant informational frictions. Consumers are usually not informed about the prices that firms charge and have to engage in costly search in order to learn them. Stigler (1961) was the first to bring attention to this and provided the basics of consumer search theory. This literature has explicitly modelled the costs consumers incur when obtaining information, however, it has abstracted away from vertical markets.

In recent years, a new literature that combines the fields of vertical contracting and consumer search has emerged. This literature draws attention especially to vertical markets where retailers' costs are determined by a common manufacturer. Although consumers are only directly impacted by retail prices, having a better understanding of retailers' costs helps them in deciding if they should stop to purchase or continue to search. Therefore, consumers need to also take into account and form expectations about the costs that retailers face. In this thesis, we focus on such types of markets. The aim of this thesis is to provide insights on the effects of commonly used vertical practices that until now have mostly been analysed in frictionless markets. More specifically, we analyse the impact of wholesale price discrimination (Chapter 2), obfuscation and bargaining (Chapter 3) and regulated recommended retail prices (Chapter 4).

1.1 Retail Discrimination in Search Markets

Chapter 2, co-authored with Maarten Janssen, focuses on wholesale price discrimination. This practice in which manufacturers charge different prices to different prices has been under scrutiny from competition authorities since the Robinson-Patman Act of 1936. The legislation was introduced with the aim of preventing price discrimination in order to protect small retailers from large chain stores that were buying at lower prices. This chapter investigates the effect of wholesale price discrimination on downstream competition and on the prices that final consumers pay. The theoretical model features a vertical market structure where (i) the manufacturer is able to discriminate, (ii) retailers and manufacturers are locked in long-term contracts, and (iii) consumers have heterogeneous search costs.

One of the chapter's main contributions is to show that it can be optimal for the manufacturer to discriminate even if all retailers are ex ante identical. On the other hand, if one retailer has a higher retailing cost, we show that it is optimal for the manufacturer to charge different wholesale prices to exacerbate the cost difference. Moreover, we find that discrimination creates price dispersion in the downstream market and induces consumers to search more. The low-cost retailers sell to a disproportionately larger share of low search cost consumers, while high-cost retailers face a smaller customer base. This additional search and segregation of consumers intensifies retail competition, since both types of retailers face more elastic demands, and leads to lower retail margins, which is beneficial for final consumers. Thus, we find that wholesale price discrimination can lead to improved consumer welfare.

1.2 Vertical Bargaining and Obfuscation

In Chapter 3, I investigate the relation between bargaining and obfuscation arising in vertical markets. More specifically, I look at practices that manufacturers use with the intention of increasing consumers' search costs. Such actions are pervasive, especially in online markets. Examples include product proliferation, different informational vertical restraints that manufacturers use such as Minimum Advertised Prices (MAPs), or practices that prohibit retailers from selling online or from participating in price comparison websites. In order to do, so I build a vertical bargaining framework between a monopolist manufacturer and downstream retailers over wholesale prices and obfuscation levels.

This chapter's primary contribution is showing that it is retailers' bargaining power that gives rise to obfuscation in vertical markets. I find that if the manufacturer has all the bargaining power then the equilibrium features no obfuscation. It is important to note that this, however, does not imply that the consumers are better off, since the manufacturer acts as a monopolist and charges monopoly prices to its retailers, which then charge monopoly prices to the final consumers. The findings suggest that regulators should take into account the market structure when designing consumer protection policies. For instance, we find that policies that put caps on obfuscation may backfire in vertical markets. In addition to the desired effect of limiting obfuscation they also have an undesired effect of inducing higher wholesale prices. The findings suggest that, instead, policies that put caps on wholesale prices can be effective.

1.3 The Unintended Effects of Regulating Recommended Retail Prices

Finally, in Chapter 4, which is also joint work with Maarten Janssen, we analyse the effects of regulated recommended retail prices (RRPs). RRPs are suggestions made by manufacturers at which prices retailers should sell their products. Such recommendations are non-binding in nature and thus retailers do not have to adhere to them. In this chapter, we look at a particular regulation used by the Federal Trade Commission (FTC) that requires at least some sales to take place at RRPs. This regulation was introduced with the aim of protecting consumers from fictitious RRPs, often used in practice, at which no retailer was selling at. In order for manufacturers not to be legally responsible for engaging in deceptive pricing they have to make sure that these price suggestions are followed by some retailers.

In this chapter, we incorporate a vertical market structure in which wholesale contracts are unobserved. In particular, we look at settings where retailers are only aware of the price they pay to the manufacturer and do not know what prices other retailers are faced with. Consumers, on the other hand, do not know the wholesale prices faced by any of the retailers nor the prices that they charge. The most important contribution of this work is to show that such regulation enables manufacturers to commit to their unobserved contracts. The possibility to commit to its wholesale prices enables the existence of a wholesale price discrimination equilibrium. We find that such an equilibrium increases manufacturer's profits, however, it harms retailers' and consumers' welfare.

2 Retail Discrimination in Search Markets

This chapter is joint work with Maarten Janssen.

2.1 Introduction

This paper shows that manufacturers with market power can increase their profits by setting different prices to different retailers, even if these retailers are otherwise identical. If retailers have different retail cost, a manufacturer may exacerbate these differences by setting a higher wholesale price to the more inefficient retailer. The key mechanism we exploit is consumer search in the retail market. By engaging in wholesale price discrimination, a manufacturer stimulates search and creates a more competitive retail market, boosting her profits. As consumers, on average, are also better off, manufacturers may be shielded from being accused of anti-competitive behaviour. In fact, as wholesale price discrimination strengthens retail competition, it is consistent with the Robinson-Patman Act, the main piece of legislation in the U.S. dealing with wholesale price discrimination, as this Act considers these practices to be illegal (only) if their effect "may be to substantially lessen competition". On the other hand, our analysis shows that the European Union's regulation may be too restrictive as it forbids dominant firms to apply "dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage" (Article 102 (c) of the Treaty). Even though (some) retailers may complain they are treated "unfairly", consumers may benefit from this unequal treatment.

To gain insight suppose that under wholesale price discrimination, a manufacturer charges a low wholesale price to some retailers and a high wholesale price to others, resulting in low and high retail prices in the downstream market. Expecting some price dispersion, without knowing which retailer charges lower prices, consumers with different search cost will follow different search paths after their initial search: observing a high retail price at their first search low search cost consumers continue to search, while others will buy immediately. As a consequence, retailers do not face the same composition of search costs among their costumers: the demand of low cost retailers consists of a relatively larger share of low search cost consumers and, as these consumers continue searching if they expect lower prices elsewhere, this will induce more competition between low cost retailers. In addition, a high cost retailer will also lower margins compared to uniform wholesale (and retail) pricing as they have a smaller base of consumers and marginally raising their price will lead to a proportionally large share of consumers leaving the firm. Thus, both low and high cost retailers have lower margins under wholesale price discrimination. As lower retail margins *ceteris paribus* increase manufacturer profit, the manufacturer is better off engaging in wholesale price discrimination. Because of the change in the search cost composition of their demand, both low and high cost retailers will face a more elastic demand compared to the situation of uniform wholesale prices. Wholesale price discrimination ensures that there is price dispersion at the retail level stimulating some low search cost consumers to actively search beyond the first firm.

There are several key ingredients to this mechanism: (i) consumers have heterogeneous search costs, (ii) consumers expect retailers to charge different prices in response to different wholesale contracts and (iii) consumers do not know the details of each individual wholesale contract the manufacturer signs with its retailers. These ingredients are present in many markets where supply chain considerations are important. In industries that have relatively stable cost and demand patterns, large manufacturers (in, for example, the beer market, the market for soft drinks or personal care products, but also in the coffee market or in gasoline markets) and retailers (supermarkets, gas stations or drug stores) typically sign detailed long-term contracts where the contract specifies that the retailer regularly gets a rebate. Rebates may be in the form of quantity discounts, in the form of sales growth, or more random in the form of brand promotion (e.g., four times per year you get a 25% discount to induce consumers to try our product). A result of these complicated wholesale contracts is that at any point in time, different retailers may have different wholesale prices even though stable long-term contracts may be in place.[1] Thus, consumers are likely not to know who is the cheapest retailer at any particular point in time, although they may well know that the identity of the cheapest retailer fluctuates as they do not or cannot keep track of the fluctuations.[2] What is also clear is that many of the above mentioned markets are characterized by significant informational frictions on the side of consumers and that search costs are important.

We show that wholesale price discrimination has distributional consequences for welfare. Consumers that happen to encounter higher retail prices at their first search are worse off than those that first shop at a retailer with low prices. Numerically, we can ascertain, however, that on average, consumers are better off under wholesale price discrimination than under uniform pricing. As retail prices tend to be lower, total surplus is also higher under wholesale price discrimination. In addition, there is an additional positive welfare effect in case retailers differ in

[1]Using the Dominick's dataset, Garcia, Honda, and Janssen (2017) show wholesale and retail prices may fluctuate over time. This dataset only contains the wholesale and retail prices of one chain store, namely Dominick's Finer Foods, over the period 1989-1997. This dataset is therefore not suitable for detailing price discrimination across different retailers.

[2]Tappata (2009) has developed a test score measuring the volatility of the ranking (in terms of who is the cheapest) of any pair of retailers in a market and applied this ranking to retail gasoline markets.

their intrinsic cost levels: more consumers buy from low cost retailers as wholesale price discrimination exacerbates intrinsic retail cost differences, resulting in more consumers continuing to look for lower prices. Thus, our analysis questions the strong stance of the European Union on forbidding wholesale price discrimination, while supporting the views underlying the Robinson-Patman Act that considers these practices more positively if they increase (retail) competition.

Wholesale price discrimination is customary in many important markets.[3] Empirical studies dealing with wholesale price discrimination are scarce, however, due to the fact that the wholesale arrangement between manufacturers and retailers is not publicly observed. The few studies that explicitly study wholesale price discrimination include research on the coffee market in Germany (Villas-Boas (2009)) and on gasoline markets in the U.S.A. (Hastings (2009)). There may be many reasons why large manufacturers may want to engage in wholesale price discrimination, treating (at any point in time) different retailers differently. Differences in size or efficiency of different retailers may be among them and this is what most of the literature on wholesale price discrimination has focussed on (an overview of this literature is provided in the next paragraph). In the markets mentioned above, one may expect, however, that supermarkets and or chains of drug-stores are more or less equally efficient and in some of these markets differences in size also do not seem to play much of a role as different retail chains all have an overall large

[3]For some of the antitrust cases, see, e.g., the claim of Games People Play, a retailer for golf equipment in the US, against Nike, ruled by the federal district court in Beaumont, Texas in February 2015 (Games People Play, Inc. v. Nike, Inc.; case number 1:14-CV-321), or, earlier cases such as the decision on the European sugar industry in 1973 where the Commission ruled that, "the granting of a rebate which does not depend on the amount bought [...] is an unjustifiable discrimination [. . .]" (Recital II-E-1 of Commission decision 73/109/EC), or the the Michelin I judgement where the European Commission in 1981 contested the alleged discriminatory nature of wholesale prices in the tyre market (Recital 42 of Commission decision 81/969/EEC).

market share, but differ in their local presence.[4] This paper argues that in vertical supply chains manufacturers may have an incentive to engage in wholesale price discrimination even if retailers are *ex ante* identical and attributes wholesale price discrimination to consumer search frictions in the retail market.[5]

There are several branches of the literature to which this paper contributes. First, the starting point of seminal papers in the literature on price discrimination in intermediate goods markets (Katz (1987), DeGraba (1990) and Yoshida (2000)) is that downstream firms differ in their efficiency levels. A monopolist manufacturer who is unconstrained by possible demand substitution may choose to charge higher wholesale prices to more efficient firms, diminishing the cost differences between them. They argue that this may decrease total surplus relative to uniform wholesale pricing as the “wrong” firms get subsidized, creating the traditional argument why wholesale price discrimination should be banned. On the contrary, Inderst and Valleti (2009) show that a ban on discrimination may have negative effects if the assumption of an unconstrained manufacturer is relaxed. Our paper leads to a completely different prediction, namely that in retail markets, where consumer search is important, a manufacturer may exacerbate ex ante cost differences between retailers to stimulate more search so that more consumers buy from the lowest cost retailers. In this case, wholesale price discrimination subsidizes the right firms, leading to a more efficient allocation. In addition, a manufacturer may purposefully

[4] For example, Villas-Boas (2009) reports that in the German coffee market, even though Metro seems to have overall the largest market share (46%), followed by Markant (29%), Edeka (14%), and Rewe (11%), these numbers differ by manufacturer, and some manufacturer have also larger market shares with Edeka and Rewe.

[5] Herweg and Müller (2014) analyse input price discrimination in a setting where the retailers are better informed about the retail market than the manufacturer. This is also attributing wholesale price discrimination to information imperfections, but it is the manufacturer that is at an informational disadvantage relative to retailers. In our case, it is consumers who do not know retail prices that is at the core of the story. The welfare implications of our analysis are also markedly different.

create asymmetries between retailers that are ex ante symmetric.[6]

Second, there is a recent literature on vertically related industries with consumer search. Janssen and Shelegia (2015) show that markets can be quite inefficient if consumers search sequentially while not observing the wholesale arrangement between the manufacturer and retailers. Importantly, and in contrast to our paper, the manufacturer always sets the same wholesale price to all retailers and retailers know this. Garcia, Honda, and Janssen (2017) show that the inefficiency of vertical markets with consumer search continues to hold if there are many manufacturers and retailers engage in sequential search among these manufacturers. Lubensky (2017) shows that a manufacturer can use RRPs to signal his production cost to searching consumers. Asker and Bar-Isaac (2019) study different potential roles of minimum advertised prices (MAPs) with price discrimination as one of them. The rationale for wholesale price discrimination in their paper is close to the traditional role for price discrimination in extracting surplus from consumers with different valuations. In contrast, in our model consumers have identical valuations and wholesale price discrimination is a way to screen consumers with different search cost. We therefore have a purely informational story of price discrimination.

The paper that is closest to ours is Garcia and Janssen (2018). They focus on the interaction between one manufacturer and two retailers, where the manufacturer can commit to a correlation structure between the wholesale prices and where the retailers only observe their own wholesale price. In their main set-up, all consumers have the same search cost. Under commitment to wholesale prices, they show that the manufacturer may negatively correlate his wholesale prices in order to lower the consumer reservation price, preventing the Diamond paradox from arising in

[6]Bergstrom and Varian (1985) and Salant and Shaffer (1999) show that for a given total cost level, unequal distribution of firms' cost in a Cournot setting may lead to an increase in total surplus even though prices and total output remains unchanged as production is shifted to more efficient firms. Our model shows that in a search context, prices may actually decrease because of unequal marginal cost.

the retail market. The low cost retailer in their model, always chooses the retail monopoly price and consumers always buy at the first retailer they visit. There are several important differences with our paper. First, there is real competition in the retail market as we have a population of consumers with heterogeneous search cost. Second, wholesale price discrimination stimulates real search instead of a threat of search. Finally, as we have more than two retailers, the manufacturer may actually choose to set a pure strategy wholesale price and retailers may know all the wholesale prices that the manufacturer sets. The only thing that is important is that consumers do not know which retailer has received which wholesale price. Importantly, in this setting, it is clear how in real markets commitment may work, whereas it is difficult to see how in real markets manufacturers can commit, as assumed in Garcia and Janssen (2018), to a correlation that is not observed by anyone.

Third, there is a small literature on consumer search and price discrimination. In a market where the demand of high search cost consumers is less price sensitive than the demand of low search cost consumers, Salop (1977) shows that a monopolist who directly sells to consumers may engage in price discrimination: as low search cost consumers continue to search if they first encounter a high price, higher prices attract a disproportionally large fraction of consumers with higher search cost, who (by assumption) are also less price-sensitive. Unlike our purely informational theory of price discrimination, Salop (1977) follows the classical view of price discrimination as distinguishing between consumers with different valuations. In addition, his argument is based on the assumption that the monopolist retailer is committed to charging prices according to a price distribution and that any deviation from this distribution is observed by consumers. It is difficult to see, however, how consumers may observe a price distribution, while maintaining the assumption underlying the search cost literature that the consumer does not know the prices firms set. By studying a vertical supply chain, our paper, in contrast, can make a distinction between a manufacturer committing to wholesale prices to retailers, while consumers search for retail prices. Fabra and Reguant (2018) focus on markets with small and large buyers where large buyers have more incentives to search making firms compete more strongly for them. Again, and in contrast to our paper, differences in demand push firms to price discriminate in their paper. Likewise, differences in consumers' valuations (related to differences in the cost of studying products), and not differences in search (browsing) costs, lead to low valuation consumers paying lower prices also in the model studied by Heidhues, Johannes, and Köszegi (2018).

Finally, while most papers in the search literature assume at most two different levels of search cost (see, e.g., Stahl (1989)), there do exist some papers that consider more general forms of heterogeneity in consumers' search costs, such as Stahl (1996), Chen and Zhang (2011) and Moraga-González, Sándor, and Wildenbeest (2017). In contrast to these papers, however, we focus on vertically related industry structures and this paper is the first to consider general forms of search cost heterogeneity in such settings.

The main body of the paper analyses markets with linear wholesale pricing given that two-part tariffs, despite their theoretical appeal, are not often used in actual business transactions. Blair and Lafontaine (2015) state that, even in situations when two-part tariffs are adopted, the fixed component seems to be a relatively small part of the overall payment between firms (see, also, Kaufmann and Lafontaine (1994)). Differences in demand expectations, in risk attitude, the possibility of ex-post opportunism by the supplier and wealth constraints by the retailers are mentioned among reasons why two-part tariffs are not often implemented in actual transactions. In Appendix II, we show that our analysis is robust to manufacturers setting a fixed fee extracting part, but not all, of the retail profits.

The remainder of this paper is organized as follows. In the next section, we present the details of the model we consider. The impact of wholesale price discrimination on the retail market is discussed in Section 2.3. Section 2.4 shows that given that wholesale price discrimination increases competition in the retail market, the manufacturer finds it optimal to discriminate between ex ante identical retailers. We also show there that a manufacturer may want to *exacerbate* the cost difference between retailers by charging higher wholesale prices to retailers that have higher intrinsic costs. Section 2.5 determines the optimal wholesale contracts for the case of three retailers and that retailers are worse off, while consumers are on average better off. Depending on which retailer they visit first, high search cost consumers may, however, be worse off. Section 2.6 shows that for more than three retailers, the optimal contract entails more sophisticated forms of price discrimination where more than one retailer gets the lowest wholesale price. Section 2.7 concludes, while proofs are in Appendix I.

2.2 The Model

We focus on a vertically related industry with a monopolist manufacturer (she) in the upstream market supplying a homogeneous product to $N \geq 3$ retailers (he/they).[7] The manufacturer's production costs are normalized to zero. In principle, the manufacturer can charge a different wholesale price w_i to every retailer, so that formally the manufacturer's strategy is a tuple $(w_1, w_2, ..., w_N)$. For given wholesale prices, an individual retailer i sets his retail price p_i, $i = 1, ..., N$. Retailers take their wholesale price as given and do not face other costs except for the wholesale price paid to the manufacturer for each unit they sell. Given the retail prices they expect to be charged, consumers search sequentially.

[7]To study the effects of wholesale price discrimination, it is important there are at least two retailers that get the lowest wholesale price so we need at least three retailers in the downstream market.

There is a unit mass of consumers, each demanding $D(p)$ units of the good if they buy at price p. We make standard assumptions on the demand function so that it is well-behaved. In particular, there exists a $\overline{p}$ such that $D(p) = 0$ for all $p \geq \overline{p}$ and the demand function is continuously differentiable and downward sloping whenever demand is strictly positive, *i.e.*, $D^{'}(p) < 0$ for all $0 \leq p < \overline{p}$. For every $w \geq 0$, the retail monopoly price, denoted by $p^M(w)$ is uniquely defined by $D^{'}(p^M(w))(p^M(w) - w) + D(p^M(w)) = 0$ and $D''(p)(p - w) + 2D'(p) < 0$. Note that for $w = 0$, this condition gives that the profit function of an integrated monopolist is concave. We denote by $p^M(w^M)$ the double marginalization retail price, which arises in case there would be a monopoly at both levels of the supply chain. In numerical examples, we consider demand to be linear, $D(p) = 1 - p$.

In order to observe prices consumers have to engage in costly sequential search with perfect recall. Consumers differ in their search cost s. Search costs are distributed on the interval $[0, \overline{s}]$, where $\overline{s}$ may be infinite, according to the distribution function $G(s)$, with $G(0) = 0$. We denote by $g(s)$ the density of the search cost distribution, with $g(s) > 0$ for all $s \in [0, \overline{s}]$. We consider that the search cost distribution has an increasing hazard rate, i.e., $g(s)/(1 - G(s))$ is non-decreasing in s, and that $g'(s)$ is bounded, i.e., there exists a finite M such that $-M \leq g'(s) \leq M$. In numerical examples, we take $G(s)$ to be uniformly distributed and in Appendix II we show that our main qualitative results continue to hold for an exponential search cost distribution and for the Kumaraswamy distribution. As consumers are not informed about retail prices before they search, an equal share of consumers visits each retailer at the first search.[8]

A market is fully described by the number of retailers N, the demand function $D(p)$ and the search cost distribution $G(s)$. We compare uniform pricing to wholesale

[8]For most part of the analysis, it does not matter whether or not the first search is costly. We proceed assuming the first search is for free and do not consider the participation constraint of consumers.

price discrimination in markets where the manufacturer is able to commit to wholesale prices. This implies that under uniform pricing, the manufacturer chooses $w_i = w$ both on and off the equilibrium path. Under wholesale price discrimination the manufacturer chooses different prices to different retailers, so that there are at least two prices, w_L and w_H, with $w_L < w_H$, where some retailers get the low and others the high wholesale price. We interpret commitment here as the case where all retailers and consumers observe the contractual arrangements set by the manufacturer.[9] This allows us to focus on the impact of wholesale price discrimination on the retail market without having to consider the different beliefs retailers and consumers may have about wholesale contracts. The only belief that is relevant is the belief of consumers about retail prices. Also, it allows us to analyse the retail market as a subgame.

One way to think of this commitment is that manufacturers have long-term contracts with retailers, that consumers know about this and that the latter repeatedly buy. Commitment to uniform pricing refers to the case that all retailers and consumers know that the manufacturer always sets the same wholesale price to all retailers. Commitment to wholesale price discrimination refers to the case where consumers and retailers know that some retailers have obtained different wholesale prices. As it is essential to our theory that consumers cannot direct their first search to a particular retailer (as they are considered to be symmetric), one can re-interpret the wholesale price discrimination case as one in which the manufacturer gives all retailers identical wholesale contracts in which the range of wholesale prices is fixed and that who gets which wholesale price is randomly determined. This is can be interpreted in terms of a regular price and sales prices and that the contract specifies how often a retailer gets a sales price and how high

[9]In a study of first-mover advantage, Bagwell (1995) has shown that a player's ability to commit is equivalent to the observability of his actions. In our world, with a manufacturer, multiple retailers and many consumers, the issue of commitment is more subtle as the manufacturer may commit to an individual retailer, or to retailers in general, without committing to consumers.

the discount is.

In general, if a manufacturer sets different wholesale prices to different retailers, we can write $\mathbf{w}$ for the vector of wholesale prices she chooses and $p_i^*(w_i, \mathbf{w}_{-i})$ for the equilibrium retail price reaction of retailer i who has received the wholesale price w_i. Even though a retailer may only be directly interested in his own wholesale price, the other retail price (and thus their wholesale price) is of relevance as it determines consumers' search behaviour. In some parts of the paper it is useful to consider the manufacturer choosing two wholesale prices, w_L and w_H, where $N-1$ retailers receive the lowest wholesale price. In this case, retailers will react to these wholesale prices by setting (possibly) different retail prices, where $p_L^*(w_L, w_H)$, respectively, $p_H^*(w_L, w_H)$ denotes the retail price a low, respectively high, cost retailer sets when wholesale prices are w_L and w_H.

An equilibrium with wholesale price discrimination is defined as follows.[10]

Definition 2.1. An equilibrium with wholesale price discrimination is defined in two parts. First, for every $\mathbf{w}$ we define a symmetric retail equilibrium as retail pricing strategies $p_i^*(w_i, \mathbf{w}_{-i})$ and an optimal sequential search strategy for all consumers such that (i) retailers maximize their retail profits given consumers' optimal search strategy and choose symmetric strategies in the sense that all retailers receiving the same wholesale price set the same retail price and (ii) consumers' sequential search strategy is optimal given their beliefs. Consumer beliefs are updated using Bayes' rule whenever possible. Second, given a symmetric retail equilibrium, the manufacturer chooses $\mathbf{w}$ to maximize her profits.

This equilibrium definition does not specify consumers' out-of-equilibrium beliefs. The most natural assumption regarding beliefs in our context, and the one that has

[10]As the equilibrium definition of the benchmark with uniform pricing is a special case, we skip that formal definition.

been followed in most of the consumer search literature,[11] is that consumers have passive beliefs: after observing an out-of-equilibrium retail price consumers believe that the retailers that they have not yet visited charge their equilibrium prices. In the following Sections, we will follow the literature in this respect. As we will explain in more detail in the next Section, in case of wholesale price discrimination, when consumers expect different retail prices to prevail, passive beliefs do not provide enough precision to determine consumers' optimal search behaviour as consumers have to also have expectations, about the cost of the retailer that has deviated.

2.3 The Retail Market

As explained in the Introduction, a manufacturer has an incentive to price discriminate between *ex ante identical* retailers as doing so creates a more competitive retail market. In this Section, we explain in detail the mechanism by means of which this works and characterize the behaviour of consumers and retailers. With a finite number of retailers, it is clear that the mechanism should be such that at least two retailers should get the lowest price. The reason is that if one retailer knows it is getting the lowest price, then it does not face any competition from other retailers up to the second lowest equilibrium retail price in the market. Therefore, this retailer would then set a retail price (almost) equal to the second lowest equilibrium retail price in the market, giving the manufacturer an incentive to increase the lowest wholesale price. Thus, to keep a competitive constraint on the retailers receiving the lowest wholesale price, there should be at least two retailers being offered w_L. In the case of $N = 3$, wholesale price discrimination implies that two retailers buy at w_L and one buys at w_H. In the next Section, we show that for

[11]See Janssen and Shelegia (2019), for an analysis of alternative beliefs in the context of the Wolinsky (1986) model with a vertical industry structure.

general N, the manufacturer increases her profits by choosing to set a low wholesale price w_L to $N-1$ retailers and another higher wholesale price w_H to 1 retailer. That is why we also focus on this set of wholesale prices in the current Section.

As a benchmark, consider first the case of uniform pricing where all retailers have the same wholesale price w^*. Let $p^*(w)$ denote the equilibrium price charged by all retailers (which is the retail price consumers expect). To determine, for a given w, the equilibrium retail price, we need to investigate how a retailer's demand depends on his own price, which in turn depends on how consumers' search behaviour reacts to a price deviation. If a consumer buys at a deviation price $\widetilde{p} > p^*(w)$, he gets a surplus of $\int_{\widetilde{p}}^{\overline{p}} D(p)dp$. Under passive beliefs, a consumer with search cost s continues to search for the equilibrium price $p^*(w)$, if $s < \int_{p^*(w)}^{\overline{p}} D(p)dp - \int_{\widetilde{p}}^{\overline{p}} D(p)dp = \int_{p^*(w)}^{\widetilde{p}} D(p)dp$.

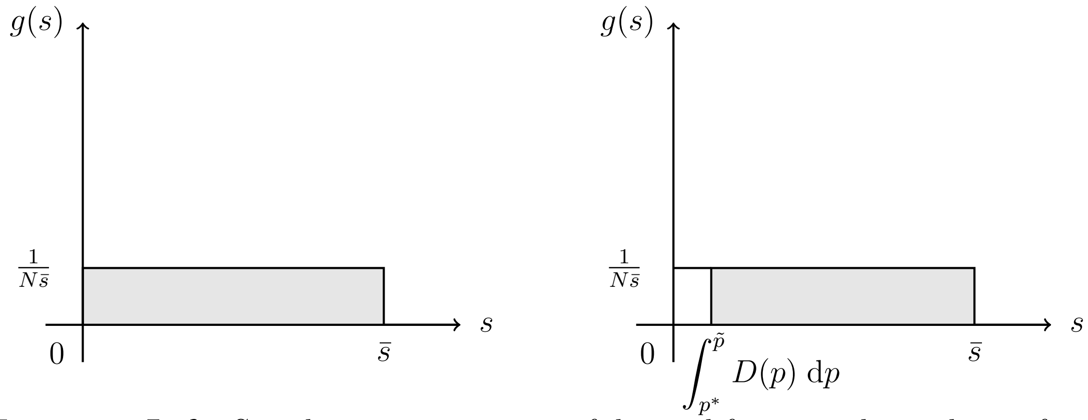

Figure 2.1: **Left:** Search cost composition of demand for a retailer under uniform pricing **Right:** Share of consumers that buy at the deviating retailer; where $s \sim U\left[0, \overline{s}\right]$.

Thus, of all consumers who visit a retailer deviating to a price $\widetilde{p} > p^*(w)$, a fraction $1 - G\left(\int_{p^*(w)}^{\widetilde{p}} D(p)dp\right)$ will continue buying from him. Therefore, the deviating retailer's profit in a uniform pricing equilibrium equals:

$$\pi_r(\widetilde{p}, p^*) = \frac{1}{N}\left(1 - G\left(\int_{p^*(w)}^{\widetilde{p}} D(p)dp\right)\right) D(\widetilde{p})(\widetilde{p} - w).$$

Maximizing retail profit and using the equilibrium condition $\widetilde{p}(w) = p^*(w)$, yields

$$-g(0)D^2(p^*)(p^* - w) + D^{'}(p^*)(p^* - w) + D(p^*) \leq 0. \tag{2.1}$$

Note that for a given w the equilibrium retail price is independent of the number of active retailers and that $p^*(w) \leq p^M(w)$. Note also that, in principle, *from the perspective of retailers* the first-order condition can be satisfied with a weak inequality as retailers will never have an incentive to lower their price as long as $p^*(w) \leq p^M(w^*)$: given that consumers search and do not observe these lower prices until at the retailer in question, retailers do not attract more consumers by lowering their prices. Thus, there exists a continuum of pure-strategy equilibria at the retail level including the retail monopoly price. In the next Section, we argue that in *the full vertical model*, taking the incentive of the manufacturer into account, it can never be the case that (2.1) holds with strict inequality, and this is what we focus on now.

Under wholesale price discrimination, the low and high cost retailers are expected to react to w_L and w_H by setting p_L^* and p_H^*, respectively. As consumers do not know which retailer faces the higher wholesale price, they do not know which retailer charges the higher retail price. The first effect of wholesale price discrimination on consumer search is that the low search cost consumers who happen to encounter the high cost retailer setting p_H^* will continue to search for lower retail prices. In particular, defining $\widehat{s} = \int_{p_L^*}^{p_H^*} D(p)dp$, all consumers who happen to observe p_H^* at their first search and have a search cost $s < \widehat{s}$ continue to search as updating beliefs using Bayes' rule implies that consumers believe all other retailers set p_L^*.[12]

[12] If there would be $m^* < N - 1$ retailers getting a low wholesale price, then the critical search cost value $\widehat{s}$ would be defined as:

$$\left(\frac{m^*}{N-1} + \frac{N-m^*-1}{N-1}\frac{m^*}{N-2} + .. + \frac{N-m^*-1}{N-1}\frac{N-m^*-2}{N-2} \cdot .... \cdot 1\right)\widehat{s} = \int_{p_L^*}^{p_H^*} D(p)dp$$

To understand how retailers will react to wholesale price discrimination, we have to be more specific here about consumer beliefs and go beyond passive beliefs: after the observation of an out-of-equilibrium price, consumers should also have beliefs about whether a high or a low cost retailer has deviated. Retail equilibrium requires that at prices p in the neighbourhood of p_H^* consumers believe it is a high-cost retailer that has deviated. The reason is as follows. If the high-cost retailer sets the equilibrium price p_H^* his profit equals

$$\pi_r^{H*} = \frac{1}{N}\left(1 - G\left(\widehat{s}\right)\right) D(p_H^*)(p_H^* - w_H).$$

If consumers attribute the deviation price to a low cost retailer, then after observing a price $p_H \neq p_H^*$ they become more pessimistic about finding lower prices on their next search than after observing p_H^*. In particular, they would believe there is a probability $\frac{1}{N-1}$ that they encounter a high-cost retailer on their next search, so that it takes them an expected search cost of $\frac{N-2}{N-1}s + \frac{1}{N-1}2s = \frac{N}{N-1}s$ to find a lower price. Thus, these first time consumers encountering a price $p_H > p_H^*$ would continue to search if their search cost is $s < \frac{N-1}{N}\int_{p_L^*}^{p_H} D(p)dp$. More consumers would then decide not to continue searching if they observe such a deviation price than after observing p_H^*, but this would make it profitable for a high cost retailer to deviate.

Thus, specifying that after observing a price p_H in the neighbourhood of p_H^* consumers blame a high cost retailer for the deviation, they will continue to search if their search cost is such that

$$s < \widehat{s} + \int_{p_H^*}^{\overline{p}} D(p)dp - \int_{p_H}^{\overline{p}} D(p)dp = \int_{p_L^*}^{p_H} D(p)dp.$$

The left panel of Figure 2.2 illustrates the search cost composition of demand for

as there is a chance that consumers will not immediately encounter p_L^* on their next search.

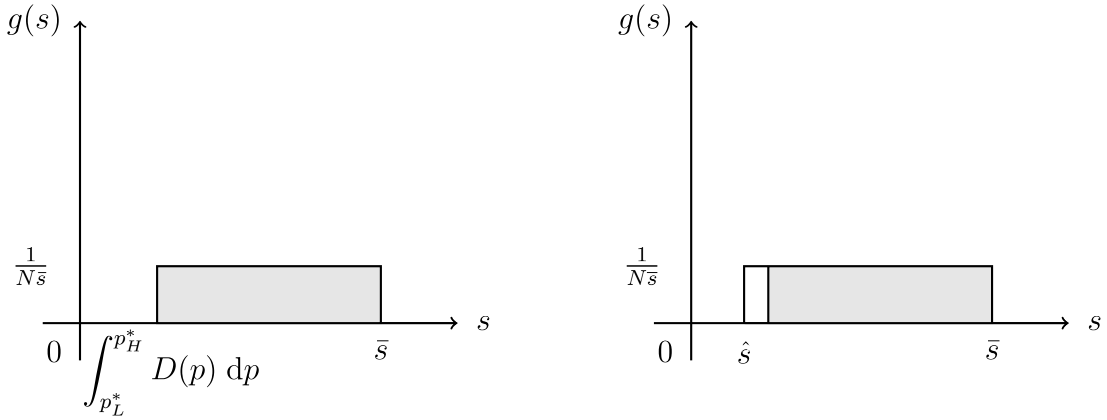

Figure 2.2: **Left:** Search cost compositions of demand for a high cost retailer. **Right:** Share of consumers that buy at the deviating high cost retailer; where $s \sim U[0, \overline{s}]$.

the high cost retailer, when search costs are uniformly distributed on the interval $[0, \overline{s}]$. The right panel shows which consumers are also continuing to search for lower prices if the high cost retailer deviates to a higher price.

Therefore, the profit of a retailer who has a wholesale price w_H and sets a price p_H in the neighbourhood of p_H^* will be:

$$\pi_r^H(p_H, p_L^*; w_H^*) = \frac{1}{N}\left(1 - G\left(\int_{p_L^*}^{p_H} D(p)dp\right)\right) D(p_H)(p_H - w_H). \tag{2.2}$$

Consider now a low cost retailer contemplating a deviation to a price p_L in the neighbourhood of p_L^*. As in any costly sequential search model, downward deviations are not optimal as they do not attract additional demand. Consider then an upward deviation. Here, we are free to specify which retailer consumers blame for such a deviation. The equilibrium price level p_L^* depends, of course, on how we specify these beliefs. The higher the fraction of consumers blaming upward deviations on the high cost retailer, the more competitive the retail market will become as more consumers will continue searching after observing an upward deviation from p_L^*. In the full model, considered in the next Sections, a more competitive retail market implies higher profits for the manufacturer. As we do not want our results to be driven by arbitrary out-of-equilibrium beliefs that favour retail competition, we assume that consumers attribute deviations to a low cost retailer if the deviation price p_L is in the neighbourhood of p_L^*. This also implies that beliefs are continuous in a neighbourhood of both equilibrium prices.[13] At the end of this Section we will determine the retail price p_L^* under alternative beliefs.

Given these beliefs, there are two important differences with the case of uniform pricing in evaluating the profitability of an upward deviation by the low cost retailer. First, consumers are less inclined to continue searching compared to the uniform pricing case as now there is a positive probability that they will encounter an even higher retail price on their next search. We call this the *anti-competitive effect* of wholesale price discrimination. As low search cost consumers will continue to search until they find the lowest expected price p_L^* in the market, the benefit of search equals $\int_{p_L^*}^{p_L} D(p)dp$, whereas the expected cost of search equals $\frac{N-2}{N-1}s + \frac{1}{N-1}2s = \frac{N}{N-1}s$. Thus, these first time consumers encountering a price p_L will continue to search if their search cost is $s < \frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp$.

For a low cost retailer contemplating a deviation to a price $p_L > p_L^*$ there is, however, an important other effect of wholesale price discrimination on consumer search. Due to the fact that low search cost consumers continue to search if they observe p_H^* on their first search, low cost retailers will serve a disproportionately larger share of low search cost consumers. Therefore, they are losing relatively more consumers if they deviate and increase their prices. The number of additional consumers a low cost retailer attracts if it deviates is computed as follows. The

[13]Consumers observing the equilibrium price p_L^* believe that if they continue to search, there is a probability of $\frac{1}{N-1}$ they will observe a price p_H^* on their next search. Consumers observing the equilibrium price p_H^* believe that there is zero probability that they will observe a price p_H^* on their next search. Thus, also on the-equilibrium path beliefs about retail prices on the next search depend on which retail price is observed.

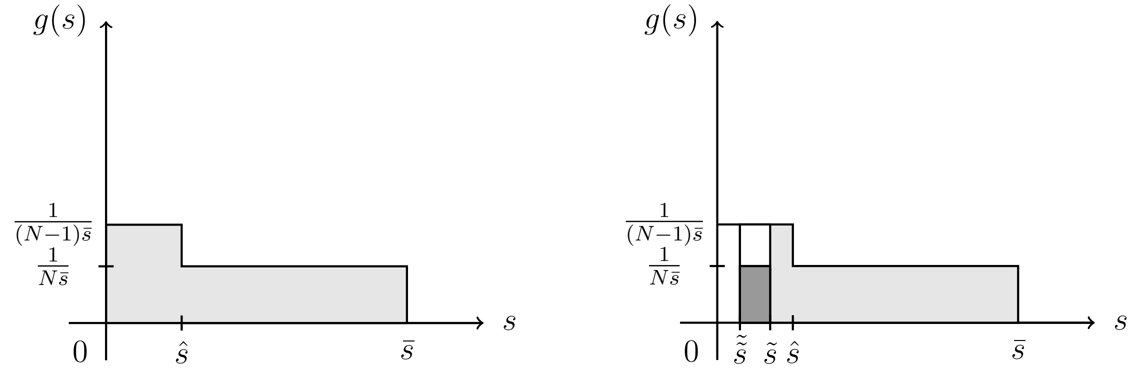

Figure 2.3: **Left:** Search cost compositions of demand for a low cost retailer. **Right:** Share of consumers that buy at the deviating low cost retailer; where $s \sim U[0, \overline{s}]$.

fraction of consumers that first visits a high cost retailer and continue to search is equal to $\frac{G\left(\int_{p_L^*}^{p_H^*} D(p)dp\right)}{N}$. Of these consumers a fraction $\frac{1}{(N-1)}$ visits the deviating firm on their second visit and then buy there if their search cost is larger than $G\left(\int_{p_L^*}^{p_L} D(p)dp\right)$. Consumers that visit another low cost retailer on their second visit will not continue searching and thus not buy from the firm under consideration. We call this the *screening effect* of wholesale price discrimination and illustrate it in the right panel of Figure 2.3.

Combining these two effects, when deviating to a price p_L, with $p_L^* < p_L < p_H^*$, a low cost retailer's profit function, denoted by $\pi_r^L(p_L; p_L^*, p_H, w_L^*)$, will be:

$$\frac{1}{N}\left[1 - G\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right) + \frac{G\left(\int_{p_L^*}^{p_H^*} D(p)dp\right) - G\left(\int_{p_L^*}^{p_L} D(p)dp\right)}{(N-1)}\right] D(p_L)(p_L - w_L). \tag{2.3}$$

Thus, there are two important differences in this profit function relative to the uniform pricing case. First, the term $\frac{N-1}{N}$ in the first $G(s)$ function reflects the *anti-competitive effect* described above. The last term in the square brackets reflects the *screening effect* of low cost retailers having a disproportionately large share of low search cost consumers.

The different effects of wholesale price discrimination on consumer search have important implications for competition in the retail market as can be seen from taking the first-order condition of the profit functions for the different retailers. Taking the first-order condition of (2.2) with respect to p_H and substituting $p_H = p_H^*$ yields

$$-\frac{g(\widehat{s})D^2(p_H^*)(p_H^*-w_H)}{1-G\left(\widehat{s}\right)}+\left[D^{'}(p_H^*)(p_H^*-w_H)+D(p_H^*)\right]=0. \tag{2.4}$$

First, note that the FOC condition has to hold with equality as a high-cost retailer may also have an incentive to lower price to prevent more consumers from continuing to search. Second, comparing this FOC condition with that in (2.1) reveals that *ceteris paribus* the only difference is that the first term is multiplied by the hazard rate $\frac{g(\widehat{s})}{1-G(\widehat{s})}$ instead of by $g(0)$. As this first term is negative, this implies that high cost retailers will have lower margins if, and only if, $\frac{g(\widehat{s})}{1-G(\widehat{s})} > g(0)$, which is the case as we assumed the search cost distribution has an increasing hazard rate.

In a symmetric retail equilibrium, we also have to take the first-order condition of (2.3) with respect to p_L and evaluate it at the equilibrium value. This yields:

$$-\frac{\left(\frac{(N-1)^2}{N}+1\right)g\left(0\right)D^2(p_L^*)(p_L^*-w_L)}{(N-1)+G(\widehat{s})}+\left[D^{'}(p_L^*)(p_L^*-w_L)+D(p_L^*)\right]\leq 0. \tag{2.5}$$

Comparing this FOC with that in (2.1) reveals that *ceteris paribus* the only difference is that the first term is multiplied by $\frac{\frac{(N-1)^2}{N}+1}{(N-1)+G(\widehat{s})}$ instead of 1. It is easy to see that the term in (2.5) is larger than 1 if, and only if, $G(\widehat{s}) \leq 1/N$. Especially, when N is small, this term creates an important difference and illustrates an important effect of wholesale price discrimination as discussed in the Introduction: even though low search cost consumers who first visit a low cost retailer are less inclined to continue to search (as they may not directly find another low cost retailer), the fact that low cost retailers are more frequently visited by low search cost consumers outweighs this effect.

Note that (2.4) holds with equality, while (2.5) holds with weak inequality. The reason is that the high cost retailer can both gain and loose consumers if it is changing its prices. A low cost retailer, however, cannot attract extra consumers by lowering its price as consumers only observe the price once they are visiting the firm. This is different for a high cost retailer who may prevent consumers from continuing to search if it sets a lower price than consumers expect a high cost retailer to set. In Section 2.4 we will argue that in the full model, the FOC of the low cost retailer also must hold with equality and in the rest of this Section we will already provide some features of the retail equilibrium assuming this to be the case.

From the first-order conditions it is clear that retail prices are "*strategic complements"*, where with a little abuse of terminology, we look at the symmetric retail reactions of low cost retailers to a change in the retail price of a high cost retailer. As $\widehat{s} = \int_{p_L^*}^{p_H^*} D(p)dp$, it follows that $G(\widehat{s})$ -and thus, the first term in (2.5) is increasing in p_H^*. To satisfy (2.5) it follows that p_L^* has to increase if p_H^* increases (for example, because of an increase in w_H).[14] Similarly, as $\frac{g(\widehat{s})}{1-G(\widehat{s})}$ is increasing in $\widehat{s}$ and $\widehat{s}$ is decreasing in p_L^* it follows that the first term in (4.7) is increasing in p_L^*. To satisfy (2.4) it follows that p_H^* has to increase if p_L^* increases (for example, because of an increase in w_L). Strategic complementarity is an important reason for the main substantive result of this section.

Proposition 2.1. *Consider markets for which the solutions to (2.1),(2.4) and (2.5) holding with equality are uniquely defined. The retail prices* $p_L^*(w_L, w_H)$ *and*

[14]Note that this is true even if the search cost distribution does not satisfy the increasing hazard rate property.

$p_H^*(w_L, w_H)$ are discontinuous at $(w_L, w_H) = (w, w)$.[15] *For any $G(s)$, there exists a small enough $\varepsilon > 0$ and a $k > 0$ such that for all (w_L, w_H) with $w_H = w_L + \varepsilon$ we have that $p_L^*(w_L, w_H) + k < p_H^*(w_L, w_H) + k < p^*(w)$. If $g(0) \to \infty$, $k \to 0$. Moreover, $\partial p_L^*(w_L, w_H)/\partial w_L, \partial p_H^*(w_L, w_H)/\partial w_H > 0$.*

The discontinuity of retail prices at $(w_L, w_H) = (w, w)$ can be understood as follows. Suppose, for any small enough $\varepsilon > 0$, that $w_H = w_L + \varepsilon$. From (2.4) and the continuity of $g(s)$ it follows that the direct effect is a small (continuous) increase in p_H. As this implies that $\widehat{s} > 0$, it follows from (2.5) and (2.1) that p_L drops discontinuously (as $\frac{\frac{(N-1)^2}{N}+1}{(N-1)+G(\widehat{s})} > 1$ for $\widehat{s} \approx 0$). This, in turn implies that there is a discontinuous, indirect, increase in $\widehat{s}$, which (because of strategic complementarity) in turn implies a discontinuous decrease in p_H. Thus, for any small deviation from uniform wholesale prices, retail prices decrease discontinuously. That $p_L^*(w_L, w_H) < p_H^*(w_L, w_H)$ follows from the fact that at $p_L^* = p_H^*$ $\widehat{s} = 0$ in which case (4.7) and (2.1) coincide, but the LHS of (2.5) is negative as $\frac{(N-1)^2}{N} + 1 > N - 1$ so that p_L has to adjust downwards to satisfy the FOC.

These effects are illustrated in Figure 2.4. The two dots on the 45 degree line represent the equilibrium retail price $p^*(w)$ and the equilibrium wholesale price w^* under uniform pricing. The two "reaction curves"[16] represent (2.4) and (4.8) for $w_L = w$ and $w_H = w + \varepsilon$, where $\varepsilon = 0.001$. It is clear that the prices are strategic complements. For $p_L = p^*(w)$ the reaction curve for the high cost retailer shows that the optimal reaction to $w_H = w + \varepsilon$ is a slight increase in p_H. As some low search cost consumers that first visit the high cost retailer will now continue to search for low prices, the low cost retailers with $w_L = w$ now charge a

[15]Note that (2.3) is continuous, also at $p_L = p_H^*$. At that point, the profit function is not continuously differentiable, however. As at that point, the high cost retailer reaches maximum profits, and the high cost retailer has higher cost, the right-hand side derivative of the low cost retailer's profit is negative. Thus, even if $w_L = w$ and $w_H = w + \varepsilon$ the optimal $p_L < p_H^*$.

[16]Note that these are not real reaction curves as we have imposed the equilibrium condition that in equilibrium the low cost retailers should set the same price.

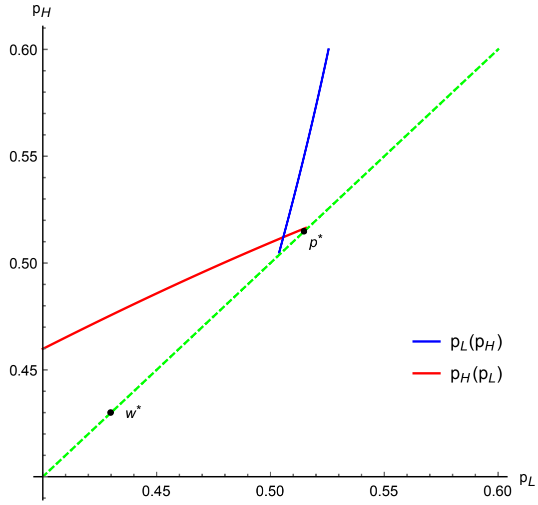

Figure 2.4: Retailers' behaviour for marginal deviations from uniform wholesale prices, when $\overline{s} = 0.05$, $w^* = 0.4299$ and $p^* = 0.5149$

p_L that is strictly (and discontinuously) smaller than $p^*(w)$. Because of strategic complementarity, the intersection point of the "two reaction curves" has both prices strictly smaller than $p^*(w)$.

These are the important effects of wholesale price discrimination discussed in the Introduction: as (some) retailers have lower retail prices, it is more attractive for consumers to continue searching if they have visited a high cost retailer. This has two effects. First, low cost retailers have relatively more low search cost consumers, which forces them to lower their margins. Second, high cost retailers have fewer buying customers (represented by $1 - G(\widehat{s})$) and an upward deviation from the equilibrium price will cause $g(\widehat{s})$ consumers to leave relative to $g(0)$ in the uniform pricing equilibrium. This imposes a more severe competitive constraint on these retailers as, in relative terms, the impact of consumers leaving is now larger.

So far, we have assumed the markets are such that a retail equilibrium as characterized by either (2.1) or (2.4) and (2.5) exists and is unique (to facilitate a comparative statics analysis). The following Proposition provides sufficient conditions for existence. Existence follows from the continuity of the best response functions as defined in (4.7) and (2.5). This is the case if the profit functions are quasi-concave. In our setting, a sufficient, but by no means necessary condition, is that the search cost distribution is sufficiently concentrated around 0. The two first-order conditions (2.4) and (2.5) holding with equality together define the retail pricing equilibrium $p_L^*(w_L^*, w_H^*)$ and $p_H^*(w_L^*, w_H^*)$ in any equilibrium of the whole game. Uniqueness is then a by-product as the "reaction functions" have a slope smaller than 1.

Proposition 2.2. *For any set of wholesale prices (w_L, w_H) with $w_H = w_L$ a retail price equilibrium exists, where $p^*(w)$ is given by the solution to (2.1). If $\overline{s}$ is close enough to 0 and $g(s)$ is large, a retail price equilibrium exists for any $w_H > w_L$, where the retail prices are given by $p_L^*(w_L, w_H)$ and $p_H^*(w_L, w_H)$ as the solutions to (2.4) and (2.5). In addition, the retail equilibrium prices of the whole game, $p_L^*(w_L^*, w_H^*)$ and $p_H^*(w_L^*, w_H^*)$, are uniquely defined for any (w_L, w_H) with $w_H \geq w_L$.*

If we would specify out-of-equilibrium beliefs differently, so that consumers would always blame a high cost retailer for having deviated, then a low cost retailer's deviation profit function, denoted by $\pi_r^L(p_L; p_L^*, p_H^*, w_L^*)$, would be:

$$\frac{1}{N}\left[1 - G\left(\int_{p_L^*}^{p_L} D(p)dp\right) + \frac{G\left(\int_{p_L^*}^{p_H^*} D(p)dp\right) - G\left(\int_{p_L^*}^{p_L} D(p)dp\right)}{(N-1)}\right] D(p_L)(p_L - w_L^*).$$

Comparing this to the deviation profit under uniform pricing, one easily sees that the only important difference is the third term in the square brackets. This is the *screening effect* of wholesale price discrimination which is pro-competitive. In this case

$$-\frac{Ng\,(0)\,D^2(p_L^*)(p_L^* - w_L^*)}{(N-1) + G(\widehat{s})} + \left[D^{'}(p_L^*)(p_L^* - w_L^*) + D(p_L^*)\right] \leq 0.$$

Thus, under this specification of out-of-equilibrium beliefs, low-cost retail margins would always be smaller under wholesale price discrimination compared to uniform pricing.

2.4 Wholesale Contracts

The above discussion shows that *ceteris paribus* retail margins are generally lower under wholesale price discrimination. *Ceteris paribus* here mainly is a clause relating to wholesale prices. The important question then is how these changes in the first-order retail price conditions impact the manufacturer's incentives to set wholesale prices. In this Section, we show our main result, namely that if the manufacturer is able to price discriminate between her retailers, she will want to do so, i.e., under price discrimination the manufacturer will always make more profit. To this end, we will compare uniform wholesale pricing with wholesale price discrimination.

2.4.1 Uniform pricing

Under uniform pricing, the manufacturer chooses one wholesale price w (both on and off the equilibrium path). Interestingly, even though in the retail market equilibrium for fixed w there is a continuum of equilibria, this continuum disappears in the equilibrium of the full vertical model as in the full model (2.1) has to hold with equality. The reason is that otherwise it would be profitable for the manufacturer to marginally increase her wholesale price as retailers would not adjust their retail prices and therefore the manufacturer's demand would not be affected, increasing the manufacturer's profits.

Thus, with uniform pricing the wholesale price w is set such that

$$\frac{\delta \Pi^M}{\delta w} = wD'(p(w))\frac{\partial p^*}{\partial w} + D(p(w)) = 0. \tag{2.6}$$

To determine the optimal wholesale price we still have to evaluate $\frac{\partial p^*}{\partial w}$. Taking the total differential of (4.1) it follows that

$$\frac{\partial p^*}{\partial w} = \frac{D'(p^*) - g(0)D^2(p^*)}{-2g(0)D(p^*)D'(p^*)(p^* - w) - g(0)D^2(p^*) + (D''(p^*)(p^* - w) + 2D'(p^*))}.$$

As, given that the profit function is continuous and the interval of wholesale prices that the manufacturer can sensibly choose is compact, we have the following result.

Proposition 2.3. *If the manufacturer commits to uniform pricing, an equilibrium exists. The equilibrium wholesale price w^* satisfies (2.6), while the retail price $p^*(w)$ satisfies (2.1).*

2.4.2 The profitability of wholesale price discrimination

To show that wholesale price discrimination increases the manufacturer's profits, consider the manufacturer deviating from the optimal wholesale contract under uniform pricing considered above and charges one retailer a slightly higher price. Note that in the previous subsection we only considered uniform pricing deviation so that this deviation was not considered. Thus, denote by $w_L = w^*$ the price set to $N-1$ retailers and $w_H = w^* + \varepsilon$ the wholesale price set to one retailer. Retailers react by setting $p_L(w_L, w_H)$ and $p_H(w_L, w_H)$. The equilibrium profit of the manufacturer can then be written as

$$\frac{N-1+G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N} w_L D(p_L(w_L, w_H)) + \frac{1-G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N} w_H D(p_H(w_L, w_H)).$$

We will argue that the first-order effect with respect to w_H is positive if evaluated at $w_L = w^*$ and $w_H = w^* + \varepsilon, \varepsilon > 0$.[17] The first-order effect is

[17] Note that we showed in Section 2.3 that retail prices are not continuous for a deviation in w_H at $w_L = w_H = w^*$. Thus, we cannot take the usual first-order conditions and we have to directly compare the manhufacturer profit under uniform pricing ($w_L = w_H = w^*$) with the profit under wholesale price discrimination for $w_L = w^*$ and $w_H = w^* + \varepsilon$.

$$
\begin{aligned}
& \frac{N-1+G\left(\int_{p_L(w^*,w^*+\varepsilon)}^{p_H(w^*,w^*+\varepsilon)} D(p)dp\right)}{N} w_L D(p_L(w^*,w^*+\varepsilon)) - \frac{N-1}{N} w^* D(p^*) \\
& + \frac{1-G\left(\int_{p_L(w^*,w^*+\varepsilon)}^{p_H(w^*,w^*+\varepsilon)} D(p)dp\right)}{N} w_H D(p_H(w^*,w^*+\varepsilon)) - \frac{1}{N} w^* D(p^*) \\
= \; & \frac{N-1}{N} w^* \left[D(p_L(w^*,w^*+\varepsilon)) - D(p^*)\right] \\
& + \frac{G\left(\int_{p_L(w^*,w^*+\varepsilon)}^{p_H(w^*,w^*+\varepsilon)} D(p)dp\right)}{N} \left[w^* D(p_L(w^*,w^*+\varepsilon)) - (w^*+\varepsilon) D(p_H(w^*,w^*+\varepsilon))\right] \\
& + \frac{1}{N} \left[(w^*+\varepsilon) D(p_H(w^*,w^*+\varepsilon)) - w^* D(p^*)\right].
\end{aligned}
$$

From Proposition 2.1, we know that for any search cost distribution $G(s)$ there exists a $k > 0$ such that $\lim_{\varepsilon\to 0} p_L(w^*, w^*+\varepsilon) - k < \lim_{\varepsilon\to 0} p_H(w^*, w^*+\varepsilon) - k < p^*$. As demand is downward sloping, this implies that for small enough ε all three terms are positive. Thus, our first main result follows.

Theorem 1. *If a retail equilibrium exists, the manufacturer makes strictly more profit by price discriminating compared to uniform pricing.*

This is a strong result as it is independent of the specific shape of the demand curve or the shape of the search cost distribution. As the main effect of wholesale price discrimination is its impact on the retail market, the intuition follows directly from Figure 2.4. A small increase in w_H leads to a discontinuous decrease in the retail price low cost retailers set as they get relatively more low search cost consumers. Because of strategic complementarity, this effect is reinforced and thus the high cost retailer charges lower prices as well. As the wholesale prices are weakly larger than under uniform pricing, the manufacturer must be better off.

The result does not define the optimal form of price discrimination.

As $\lim_{\varepsilon\to 0} p_L(w^*, w^*+\varepsilon) < \lim_{\varepsilon\to 0} p_H(w^*, w^*+\varepsilon)$, at $w_L = w^*$ and $w_H = w^* + \varepsilon$ the manufacturer makes more profit over the low cost retailers than over the high cost one. He will then want to sell to more consumers at the lower wholesale price increasing the difference between w_H and w_L beyond ε. Our second main result shows that a manufacturer has an incentive to further exacerbate initial cost differences between retailers if these initial cost differences are small enough and consumers do not know which retailer has a higher cost.

Theorem 2. *If one retailer is more inefficient than others, in that it has a slightly higher cost of retailing, then the manufacturer can increase its profits by exacerbating this cost difference and setting a higher wholesale price to this retailer compared to uniform pricing.*

This result is important in that it shows one positive welfare effect of wholesale price discrimination, namely that it shifts the allocation of demand towards more efficient firms. In the absence of wholesale price discrimination, a manufacturer makes more profit over the more efficient retailers as these have lower prices and thus generate more demand. The theorem shows that a manufacturer wants to exacerbate this difference so as to shift even more demand to these low cost retailers. Note that this is in sharp contrast to the received literature (Katz (1987), DeGraba (1990) and Yoshida (2000)) on wholesale price discrimination according to which a manufacturer price discriminates to *reduce* the natural cost differences between retailers, shifting more demand to the inefficient retailer.

2.5 Optimal Wholesale Contracts with Three Retailers

We now analyse optimal wholesale contracts and the implications for consumer welfare and retail profits. It should be clear that it is not optimal for the manufacturer to induce a retail equilibrium where $\widehat{s} \geq \overline{s}$. If that would be an equilibrium, retailers receiving a high wholesale offer, reacting with a retail price p_H^*, would be effectively foreclosed from the market, putting the remaining retailers in a similar position as under uniform pricing with the exception that the remaining effective retailers will charge higher margins as consumers (not knowing which retailer got a high wholesale price) are less inclined to continue searching if they observe an off-equilibrium retail price. As this can never be optimal for the manufacturer, it must be the case that $0 \leq \widehat{s} \leq \overline{s}$.

It is difficult to characterize the optimal wholesale contract for an arbitrary number of retailers as it is problematic to characterize how many retailers should get identical wholesale prices. With three retailers it is clear, however, that in the optimal contract, two retailers should get the low wholesale price, while one gets a higher wholesale price. It cannot be that only one retailer receives a lower wholesale price as in that case, he will have monopoly power up to the second lowest retail price. The manufacturer can then increase his profits by raising the lowest wholesale price and squeezing the retailer. In this Section we therefore restrict the analysis to three retailers. As a benchmark we first characterize the equilibrium in case the manufacturer cannot price discriminate, and subsequently characterize the optimal contract.

Proposition 2.4. *If $g(s)$ is large, then under uniform pricing the uniform retail and wholesale prices converge to $p^* = w^*$, where w^* solves $w^* D'(w^*) + D(w^*) = 0$. Moreover, $\frac{dp^*}{d\left(\frac{1}{g(0)}\right)} = 0$ and $\frac{dw^*}{d\left(\frac{1}{g(0)}\right)} = -\frac{1}{D(p^*)}$ so that $\frac{d\Pi^M}{d\left(\frac{1}{g(0)}\right)} = -1$.*

Not surprisingly, for search cost distributions concentrated around 0, the manufacturer sets the uniform wholesale price close to the price of an integrated monopolist as retailers' margin should be close to 0 for any w. Starting from this point, if the search cost distribution becomes less concentrated, the manufacturer profit decreases by reducing the wholesale price in such a way that the retail price remains approximately unchanged.

For search cost distributions that are *not* concentrated around 0, the general expressions provided above allow us to solve the model numerically, for different demand functions and search cost distributions. To compare numerical results across different environments, we focus on the case of linear demand $D(p) = 1 - p$ and a uniform search cost distribution, where $g(s) = 1/\overline{s}$. Figure 2.5 clearly shows that the retail price increases, while the wholesale price decreases in reaction to an increasing support of the search cost distribution: when retailers have more market power because of the increasing importance of search costs, the manufacturer prevents a larger decrease in demand by lowering the wholesale price. As a result, retail profits are increasing, the manufacturer profit is decreasing and consumers are worse off if search costs become larger.

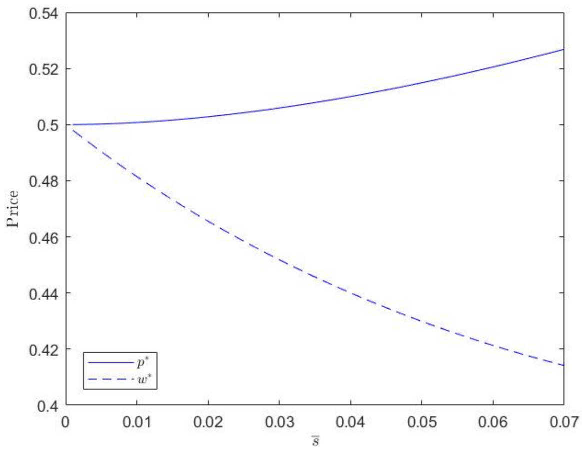

Figure 2.5: Uniform retail and wholesale prices for different values of $\overline{s}$

2.5.1 Wholesale Price Discrimination

We now characterize the optimal wholesale contract with three retailers. We will cast the argument somewhat more generally by considering that the manufacturer sets two different wholesale prices, w_L and w_H, and offers the lowest wholesale price to $N-1$ retailers and w_H to one retailer. For $N = 3$ retailers this represents the optimal wholesale arrangement where two retailers receive w_L. In the next section, we will use this more general result to show that for $N > 3$, this type of contract is not the optimal contract.

If the manufacturer sets two different wholesale prices as indicated above, he will choose those prices w_L and w_H to maximize the following profit function:

$$\Pi^M(w_L, w_H) = \frac{1}{N}\left[1 - G(\widehat{s})\right] w_H D(p_H^*(w_L, w_H)) + \frac{N-1+G(\widehat{s})}{N} w_L D(p_L^*(w_L, w_H)). \tag{2.7}$$

Above we have argued that the equilibrium retail reactions are given by $p_L^*(w_L, w_H)$ and $p_H^*(w_L, w_H)$, i.e., both retail prices depend directly on the corresponding wholesale price, but also indirectly on the other wholesale price, through its influence on the other retail price. By setting w_L and w_H optimally, the manufacturer takes into account how these retail prices change in reaction to changes in w_L and w_H. In general, it is not optimal to set w_H marginally higher than w_L, as we considered in the previous section. The reason is that if she would do so, the manufacturer gains more profit per transaction over the retailers receiving the lower wholesale price and then it is optimal to increase the fraction of consumers who buy at the lowest price by making more consumer search through increasing the difference between wholesale prices. Optimality requires that the first-order conditions with respect to w_L and w_H are satisfied:

$$\begin{aligned} 0 &= (w_L D(p_L^*) - w_H D(p_H^*)) \left(D(p_H^*) \frac{\partial p_H^*}{\partial w_H^*} - D(p_L^*) \frac{\partial p_L^*}{\partial w_H^*} \right) \qquad (2.8) \\ &\quad + \frac{[1 - G(\widehat{s})]}{g(\widehat{s})} \left[D(p_H^*) + w_H D'(p_H^*) \frac{\partial p_H^*}{\partial w_H^*} \right] + \frac{N-1+G(\widehat{s})}{g(\widehat{s})} w_L D'(p_L^*) \frac{\partial p_L^*}{\partial w_H^*}, \end{aligned}$$

and

$$\begin{aligned} 0 &= (w_L D(p_L^*) - w_H D(p_H^*)) \left(D(p_H^*) \frac{\partial p_H^*}{\partial w_L^*} - D(p_L^*) \frac{\partial p_L^*}{\partial w_L^*} \right) \qquad (2.9) \\ &\quad + \frac{N-1+G(\widehat{s})}{g(\widehat{s})} \left[D(p_L^*) + w_L D'(p_L^*) \frac{\partial p_L^*}{\partial w_L^*} \right] + \frac{[1 - G(\widehat{s})]}{g(\widehat{s})} w_H D'(p_H^*) \frac{\partial p_H^*}{\partial w_L^*}. \end{aligned}$$

Thus, under wholesale price discrimination there are three effects of a change in a wholesale price. First, there is the direct effect that a change in either w_L or w_H has on the profit a manufacturer makes over the retailer in question. Importantly, however, there are also two indirect effects. A second (indirect) effect is that an increase in w_L, respectively w_H leads to an increase in the retail prices of the other type of retailer, indirectly lowering the manufacturer profits. For example, an increase in w_L raises p_L^* and thereby decreases the incentives of consumers that first visit the high cost retailer to continue searching. This increases the market power of the high cost retailer and the price he charges. Similarly, an increase in w_H increases the incentives of consumers that first visit the high cost retailer to continue searching, but as these are not the marginal consumers that would continue searching if the low cost retailer deviates, it increases the market power of the low cost retailers and the retail prices they set. Third, (and the second indirect effect), the per consumer profit the manufacturer makes over the different retailers may not be equal, with the manufacturer generally making more profit over the low cost retailers than over the high cost retailers. Thus, by choosing optimal wholesale prices, the manufacturer must take into account how many consumers will continue to search and buy at the respective prices.

Figure 2.6, below, illustrates a typical example of the different manufacturer profit functions in case of optimal wholesale contracts. The lower green curve illustrates, as a benchmark, the profit function $wD(p(w))$ under uniform wholesale pricing, where w^* directly maximizes this expression. The other two curves represents the per consumer profit the manufacturer makes over the low and the high cost retailer, $w_L D(p_L^*(w_L, w_H^*))$, respectively $w_H D(p_H^*(w_L^*, w_H))$. A first notable aspect of Figure 2.6 is that (in line with Proposition 2.1) the manufacturer makes more per consumer profit over both types of retailers than under uniform pricing. A second important aspect is that the choices of w_L^* and w_H^* do not directly maximize the per consumer profits $w_L D(p_L^*(w_L, w_H^*))$, respectively $w_H D(p_H^*(w_L^*, w_H))$. In particular, the equilibrium levels of w_L^* and w_H^* are at the point of the curves where $w_L D(p_L^*(w_L, w_H^*))$ and $w_H D(p_H^*(w_L^*, w_H))$ are increasing. A final aspect is that $w_L^* D(p_L^*(w_L^*, w_H^*)) \neq w_H^* D(p_H^*(w_L^*, w_H^*))$.

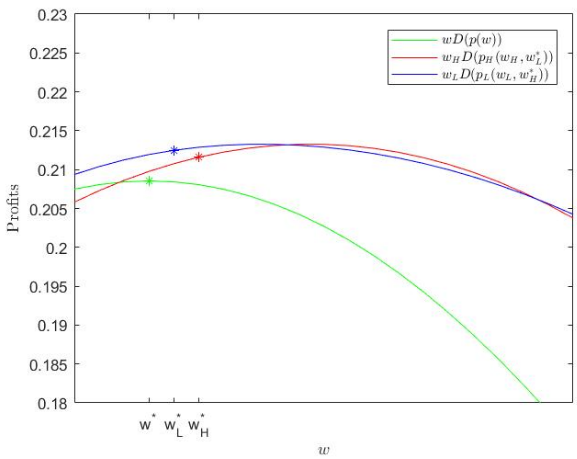

Figure 2.6: Manufacturer's Profit for $\overline{s} = 0.05$, when $w^* = 0.4299$ and $p^* = 0.5149$

The fact that there are these three effects also implies that, in general, it is difficult to characterize the equilibrium with wholesale price discrimination beyond stating the FOCs that need to be satisfied. For search cost distributions that are sufficiently concentrated around 0, we can go further and also characterize the retail margins and the fraction $G(\widehat{s})$ of consumers that continue searching if they first visit the high cost retailer:

Proposition 2.5. *If $N = 3$, the manufacturer offers w_L to two retailers and $w_H > w_L$ to one retailer in an optimal wholesale contract. For search cost distributions concentrated around 0, an equilibrium with wholesale price discrimination always exists, while wholesale prices w_L^* and w_H^* and retail prices p_L^* and p_H^* converge to w^* and p^*, with $p^* = w^*$ solving $w^* D'(w^*) + D(w^*) = 0$. The retail margins are* *given by:*

$$\begin{aligned}
\frac{d\left(p_L^* - w_L^*\right)}{d\overline{s}} &= \left(\frac{N}{2\left(N^2+1\right)\left(N^2-N+1\right)} + \frac{N\left(2N-1\right)}{\left(2N^2-N+2\right)}\right)\frac{1}{D(p_L^*)} < \\
\frac{d\left(p_H^* - w_H^*\right)}{d\overline{s}} &= \left(-\frac{1}{2\left(N^2+1\right)} + \frac{2N^2-N+1}{2N^2-N+2}\right)\frac{1}{D(p_L^*)} < \frac{1}{D(p_L^*)}.
\end{aligned}$$

while $G(\widehat{s}) = \frac{37}{340}$.

Indeed, as $\frac{d\left(p_i^* - w_i^*\right)}{d\left(\frac{1}{g(0)}\right)} < \frac{1}{D(p_L^*)} = \frac{d(p^* - w^*)}{d\left(\frac{1}{g(0)}\right)}, i = L, H$, it is clear that both retailers make lower margins under wholesale price discrimination than under uniform pricing. The result also shows that around 11% of consumers who first visit the high cost retailer continue to search.

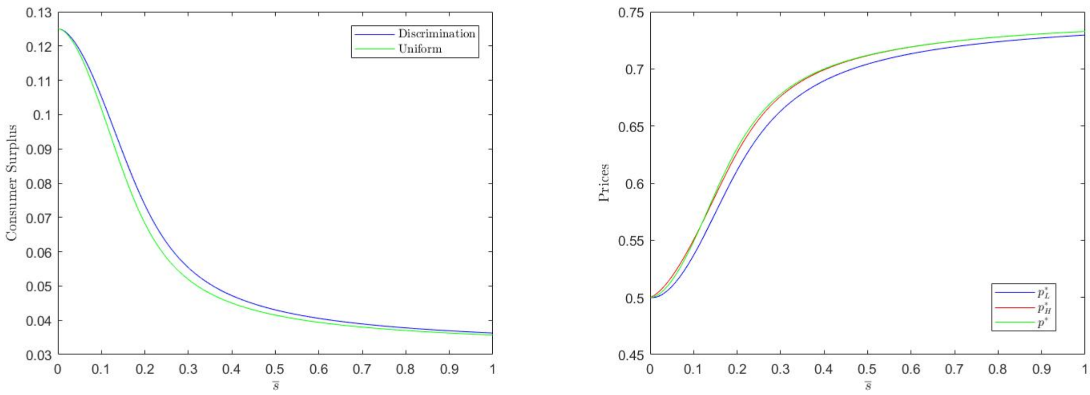

Figure 2.7: **Left:** Expected Consumer Surplus for different values of $\overline{s}$. **Right:** Retail Prices for different values of $\overline{s}$.

What is not clear, then, is whether or not consumers are better off. This depends on the retail prices (a result of wholesale prices and retail margins), and not on the retail margins only. In the proof we show that the first-order approximations leave the price levels undetermined. A numerical analysis clearly shows that, on average, consumers are better off. Figure 2.7(Left) shows for linear demand and a uniform search cost distribution that the average consumer surplus including search cost is higher under wholesale price discrimination than under uniform pricing.[18] The difference can be approximately 8% (for $\overline{s} \approx 0.2$). Figure 2.7(Right) shows that, depending on the support of the search cost distribution, all consumers are better off (as all retail prices are lower) under wholesale price discrimination, or that consumers that buy at the high retail price are worse off.

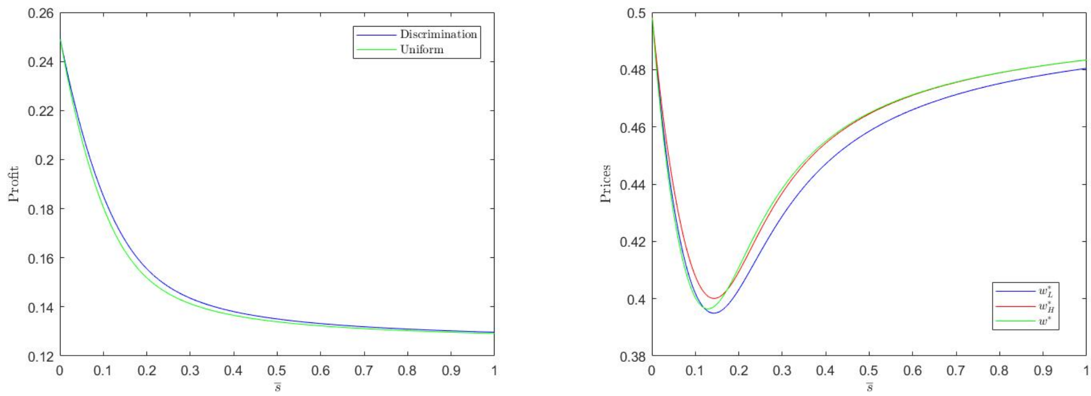

Figure 2.8: **Left:** Manufacturer's profit for different values of $\overline{s}$. **Right:** Wholesale prices for different values of $\overline{s}$.

Figure 2.8(Left) shows that depending on the search cost distribution the manufacturer can increase profits by up to 2.6% if it engages in wholesale price discrimination. To obtain maximal profits, the figure on the right shows that both wholesale prices under wholesale price discrimination can both be lower or higher than under uniform prices, depending on the how concentrated the search cost distribution is. Figure 2.8(Right) also shows that all wholesale prices are non-monotonic in the search cost parameter. This is quite intuitive: if the search cost distribution is concentrated around 0, the retail market is very competitive and the manufacturer wants to set the monopoly price of the integrated monopolists. On the other hand, when search costs can also be very large, retailers almost have monopoly power

[18] A numerical analysis for other search cost distributions (such as the exponential distribution and the Kumaraswamy distribution) is provided in Appendix II.

and under linear demand, the optimal reaction of the manufacturer is to set the same wholesale price.

2.6 More than Three Retailers

Finally, we show that for $N > 3$, the manufacturer can further increase profits, i.e., it is either optimal to set more than two different wholesale prices or it is optimal to have more than one retailer getting the higher wholesale price. In Section 2.4, we have argued that uniform pricing is not optimal for $N \geq 3$ as the manufacturer is better off deviating to $w_L = w^*$ and $w_H = w^* + \varepsilon$. We now show that for $N > 3$ the manufacturer is better off setting w_L to $N-2$ retailers, $w_L + \varepsilon$ to one retailer and w_H to another retailer compared to setting w_L to $N-1$ retailers and w_H to one retailer. It is then clear that for $N > 3$ the optimal wholesale arrangement depends on the demand function, the search cost distribution and the number of retailers in a non-trivial way. The characterization of such optimal wholesale arrangement is beyond the scope of this paper.

Proposition 2.6. *Consider $N > 3$. For search cost distributions concentrated around 0, an equilibrium with wholesale price discrimination always exists. It is either optimal to set more than two different wholesale prices or it is optimal to have more than one retailer getting the higher wholesale price. For $g(0)$ large enough to 0, wholesale and retail prices converge to w^* and p^*, with $p^* = w^*$ solving $w^* D^{'}(w^*) + D(w^*) = 0$.*

The argument that is used in the proposition is essentially the same as the argument used in the text to establish Proposition 2.3: by setting $w_L + \varepsilon$ to one retailer and keeping all the other retailers at w_L, respectively w_H, the manufacturer can increase the competition between low cost retailers as they get a larger fraction of very low cost consumers, who continue to search in case of a deviation. Doing so, will only marginally affect the manufacturer profits over the high and the medium cost retailer, while discontinuously increasing the profits over the low cost retailers.

The determination of the optimal wholesale contract for $N > 3$ is tedious and dependent on the specific number of retailers, the demand function and search cost distribution. Even for the theoretical case of a continuum of retailers, it is not easy to characterize the optimal contract as it may well be that it is optimal to set the same wholesale price to a fraction of retailers. Apart from the fact that the manufacturer can always do better by discriminating between different retailers (which is what we have established in Proposition 2.2), the analysis of these cases would not yield additional managerial insight.

2.7 Conclusion

In this paper, we have focused on the interaction between wholesale and retail markets where consumers in the retail market have heterogeneous search cost. We have shown that the manufacturer can increase profits by setting different wholesale prices to different retailers in order to stimulate consumers to search for lower prices. Wholesale price discrimination induces more competition between retailers resulting in lower retail margins. The manufacturer effectively indirectly screens consumers according to their search costs: it sets wholesale prices such that the resulting retail price dispersion is such that low search cost consumers continue to search if they encounter a high retail price at their first search, while consumers with higher search cost immediately buy, even if they observe a high retail price. By price discriminating, the manufacturer ensures that retailers have lower margins. Interestingly, on average consumers are also better off.

The vast bulk of the price discrimination literature focuses on firms differentiating between consumers with different valuations. In this paper, we have focussed on a very different function of price discrimination, namely to indirectly screen consumers with different search cost. In our story, it is essential that (i) consumers *believe* that some retailers have lower prices than others because they contract at a lower wholesale price, but do not know which retailer has which wholesale (or retail) price, and that (ii) consumers differ in their search cost. This is enough to induce more retail competition, lower retail margins and to increase manufacturer profits. For (i) to be true, it must be that either retailers cannot effectively advertise their prices to a majority of consumers (for example because consumers do not read these advertisements), or that a minimum advertised price (MAP) is in place forbidding retailers to advertise low retail prices (see Asker and Bar-Isaac (2019)).

We have focussed on a specific form of price discrimination where the manufacturer sets linear prices to all of her retailers. In Appendix II, we show that our main result continues to hold if the manufacturer extracts some, but not the full, retail profits in terms of a fixed fee. The mechanism that is at the core of this paper, namely that the manufacturer can create a more competitive retail market by treating retailers asymmetrically, may also affect other non-price aspects of the vertical relationship between manufacturers and retailers and we think that it is worthwhile in future research to see on which issues that are governed in contractual arrangements, manufacturers may induce asymmetries between retailers to induce more retail competition and when this may benefit or harm consumers.

2.8 Appendix I

Proof of Proposition 2.2: We can rewrite the FOC of the high cost retailer (2.4) as $F_H(p_H^*; p_L^*, w_H) = 0$. The total differential of this equation is therefore

$$\frac{\partial F_H}{\partial p_H^*}dp_H^* + \frac{\partial F_H}{\partial p_L^*}dp_L^* + \frac{\partial F_H}{\partial w_H^*}dw_H^* = 0.$$

As in a retail equilibrium, the second-order derivative of the retail profit function is negative, we know that $\frac{\partial F_H}{\partial p_H^*} < 0$. In addition, it is easy to see that $\frac{\partial F_H}{\partial w_H^*} = \frac{g(\widehat{s})D^2(p_H^*)}{1-G(\widehat{s})} - D'(p_H^*) > 0$. Thus, we have that $\frac{\partial p_H^*}{\partial w_H^*} = -\frac{\partial F_H}{\partial w_H^*} / \frac{\partial F_H}{\partial p_H^*} > 0$.

Also, $\frac{\partial F_H}{\partial p_L^*} = \left(\frac{g'(\widehat{s})(1-G(\widehat{s}))+g^2(\widehat{s})}{(1-G(\widehat{s}))^2}\right) D(p_L^*)D^2(p_H^*)(p_H^* - w_H) > 0$ if $g'(\widehat{s}) > -\frac{g^2(\widehat{s})}{(1-G(\widehat{s}))}$, which is the case if the search cost distribution has an increasing hazard rate. Thus, $\frac{\partial p_H^*}{\partial p_L^*} = -\frac{\partial F_H}{\partial p_L^*} / \frac{\partial F_H}{\partial p_H^*} > 0$.

Similarly, we can rewrite the FOC for the low cost retailers as $F_L(p_L^*; p_H^*, w_L) = 0$. As $\frac{\partial F_L}{\partial p_L^*} < 0$ and $\frac{\partial F_L}{\partial w_L^*} = \frac{\left(\frac{(N-1)^2}{N}+1\right)g(0)D^2(p_L^*)}{(N-1)+G(\widehat{s})} - D'(p_L^*) > 0$, it follows that $\frac{\partial p_L^*}{\partial w_L^*} = -\frac{\partial F_L}{\partial w_L^*} / \frac{\partial F_L}{\partial p_L^*} > 0$. Also, $\frac{\partial F_L}{\partial p_H^*} = \left(\frac{g(\widehat{s})}{((N-1)+G(\widehat{s}))^2}\right)\left(\frac{(N-1)^2}{N}+1\right) g(0)\, D(p_H^*)D^2(p_L^*)(p_L^* - w_L^*) > 0$. Thus, $\frac{\partial p_L^*}{\partial p_H^*} = -\frac{\partial F_L}{\partial p_H^*} / \frac{\partial F_L}{\partial p_L^*} > 0$ and the retail prices are "strategic complements".

We will now show that the retail equilibrium is discontinuous at $(w_L, w_H) = (w, w)$. To this end, consider $w_H = w + \varepsilon$ for ε arbitrarily small. From the above it follows that $\partial p_H^*(w, w+\varepsilon)/\partial\varepsilon > 0$. As $\frac{\left(\frac{(N-1)^2}{N}+1\right)g(0)}{(N-1)+G(\widehat{s})} > g(0)$ for $G(\widehat{s}) \approx 0$ it follows that that there exists a $k_1 > 0$ such that the $p_L^*(w_L, p_H)$ that solves (2.5) for $w_L = w$ and $p_H = p^* + o(\varepsilon)$ is such that $p_L^*(w_L, p_H) < p^* - k_1$. That is, the "best response" of the low cost retailers is discontinuous at $(w_L, w_H) = (w, w)$. Because of the strategic complementarity it follows that $p_L^*(w, w+\varepsilon)$ and $p_H^*(w, w+\varepsilon)$ are discontinuous at $\varepsilon = 0$ and that $p_L^*(w, w+\varepsilon)$ and $p_H^*(w, w+\varepsilon)$ are both strictly smaller than $p^*(w) - k$ for some k.

Finally, the claim that $p_L^*(w, w+\varepsilon) < p_H^*(w, w+\varepsilon) - k$ for some $k > 0$ follows from the fact that $\widehat{s} = 0$ if $p_L^*(w, w+\varepsilon) = p_H^*(w, w+\varepsilon)$ and that in that case (2.4) reduces to (4.1) implying that $p_H^*(w, w+\varepsilon) > p^*(w)$, whereas from (2.5) it would follow that $p_L^*(w, w+\varepsilon) < p_H^*(w, w+\varepsilon)$. The continuity of (2.4) and (2.5) at $(w_L, w_H) = (w, w+\varepsilon)$ implies that $p_L^*(w, w+\varepsilon) < p_H^*(w, w+\varepsilon)$.

Proof of Proposition 2.3: The existence of a retail equilibrium $p^*(w)$ simply follows from the fact that the LHS of (2.1) is continuous in p^* and that at $p^* = w$ the LHS is strictly positive, whereas the LHS is negative for $p = \overline{p}$. For the existence of a retail equilibrium under wholesale price discrimination more is needed, however. A necessary condition is that the "best response" curves (2.4) and (2.5) have an intersection point. To prove this, we show that If the search cost distribution is sufficiently concentrated around 0 (in the sense that $g(0)$ is large enough), the second-order derivative of retailers' profit function is negative if the first-order condition holds (and thus that the profit function is quasi-concave). This implies that these "best responses" are continuous functions.

To prove the existence of a retail equilibrium we need to additionally verify that (2.4) and (2.5) indeed define "best responses". The point is that (2.4) and (2.5) assume certain out-of-equilibrium beliefs in the neighbourhood of the respective equilibrium prices. We need to make sure that a high (low) cost retailer has an incentive to imitate the equilibrium price of the low (high) cost retailer and that we can find out-of-equilibrium beliefs that are such that no retailer wants to deviate from the reaction defined by (2.4) and (2.5).

Note that if the other low cost retailers set p_L^* (and the high cost retailer sets p_H^*) the FOC for a low cost retailer is such that $p_L \geq p_L^*$ should solve[19]

$$-\left(\tfrac{N-1}{N} g\left(\tfrac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right) + \tfrac{1}{(N-1)} g\left(\int_{p_L^*}^{p_L} D(p)dp\right)\right) D^2(p_L)(p_L - w_L)$$

$$+\left[1 - G\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right) + \frac{G\left(\int_{p_L^*}^{p_H^*} D(p)dp\right) - G\left(\int_{p_L^*}^{p_L} D(p)dp\right)}{(N-1)}\right]$$
$$\cdot\left[D'(p_L)(p_L - w_L) + D(p_L)\right] = 0.$$

[19] Only if $p_L = p_L^*$ can the FOC hold with inequality.

The second-order derivative of the profit function of a low cost retailer is then given by

$$\begin{aligned}
&-\left(\left(\frac{N-1}{N}\right)^2 g'\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right)+\frac{1}{(N-1)}g'\left(\int_{p_L^*}^{p_L} D(p)dp\right)\right)D^3(p_L)(p_L-w_L) \\
&\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (2.10)\\
&-\left(\frac{N-1}{N}g\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right)+\frac{1}{(N-1)}g\left(\int_{p_L^*}^{p_L} D(p)dp\right)\right)D(p_L)\left[2D^{'}(p_L)(p_L-w_L)+D(p_L)\right] \\
&-\left(\frac{N-1}{N}g\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right)+\frac{1}{(N-1)}g\left(\int_{p_L^*}^{p_L} D(p)dp\right)\right)\left[D^{'}(p_L)(p_L-w_L)+D(p_L)\right] \\
&+\left[1-G\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right)+\frac{G\left(\int_{p_L^*}^{p_H^*} D(p)dp\right)-G\left(\int_{p_L^*}^{p_L} D(p)dp\right)}{(N-1)}\right]\left[D''(p_L)(p_L-w_L)+2D'(p_L)\right].
\end{aligned}$$

The last line is clearly negative as $D^{''}(p_L)(p_L-w_L)+2D'(p_L)<0$ by assumption. The first and the third line together are also clearly negative as from the FOC it follows that $D^2(p_L)(p_L-w_L)$ is close to 0 and $D^{'}(p_L)(p_L-w_L)+D(p_L)>0$, while $g'(\cdot)/g(\cdot)$ and $D(p_L)$ are bounded. The terms in the second line are also negative if $2D^{'}(p_L)(p_L-w_L)+D(p_L)>0$. Using the FOC, $2D^{'}(p_L)(p_L-w_L)+D(p_L)$ has the sign of

$$D^{'}(p_L)+\frac{\left(\frac{N-1}{N}g\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right)+\frac{1}{(N-1)}g\left(\int_{p_L^*}^{p_L} D(p)dp\right)\right)D^2(p_L)}{1-G\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right)+\frac{G\left(\int_{p_L^*}^{p_H^*} D(p)dp\right)-G\left(\int_{p_L^*}^{p_L} D(p)dp\right)}{(N-1)}},$$

which is clearly positive as $g(\cdot)$ is unbounded for all relevant p_L. Thus, as all terms are negative, the whole expression is clearly negative.

To evaluate $\frac{\partial p_L^*}{\partial p_H^*}$ we need the second-order derivative at the equilibrium value

p_L^*. Substituting $p_L = p_L^*$ into (2.10) we obtain

$$-\frac{\left(\frac{(N-1)^2}{N}+1\right)g(0)D(p_L^*)(p_L^*-w_L)\left[D^{'}(p_L^*)+\frac{\left(\frac{(N-1)^2}{N}+1\right)g(0)D^2(p_L^*)}{(N-1)+G(\widehat{s})}\right]}{(N-1)+G(\widehat{s})} \tag{2.11}$$
$$-\left(\frac{g(\widehat{s})\left(\frac{(N-1)^2}{N}+1\right)}{\left((N-1)+G(\widehat{s})\right)^2}\right)g(0)D^3(p_L^*)(p_L^*-w_L)+D^{''}(p_L^*)(p_L^*-w_L)+2D^{'}(p_L^*).$$

Given that in the proof of Proposition 2.2 we showed that:

$\frac{\partial F_L}{\partial p_H^*} = \left(\frac{g(\widehat{s})}{((N-1)+G(\widehat{s}))^2}\right)\left(\frac{(N-1)^2}{N}+1\right)g\left(0\right)D(p_H^*)D^2(p_L^*)(p_L^*-w_L^*) > 0,$

it follows that $\frac{\partial p_L^*}{\partial p_H^*} = -\frac{\partial F_L}{\partial p_H^*}/\frac{\partial F_L}{\partial p_L^*} < 1$, as $\frac{\partial F_L}{\partial p_L^*}$ is given by (2.11).

The second-order derivative of the profit function of the high cost retailer is easier to obtain (as there is only one high cost retailer);

$$-\frac{g(\widehat{s})D(p_H^*)\left[2D^{'}(p_H^*)(p_H^*-w_H)+D(p_H^*)\right]}{1-G\left(\widehat{s}\right)}$$
$$-\left(\frac{g^{'}(\widehat{s})\left(1-G\left(\widehat{s}\right)\right)+g^2(\widehat{s})}{\left(1-G\left(\widehat{s}\right)\right)^2}\right)D^3(p_H^*)(p_H^*-w_H)+2D^{''}(p_H^*)+D^{'}(p_H^*)(p_H^*-w_H),$$

which, using the FOC, can be rewritten as

$$-\frac{g(\widehat{s})D(p_H^*)(p_H^*-w_H)\left[D^{'}(p_H^*)+\frac{g(\widehat{s})D^2(p_H^*)}{1-G(\widehat{s})}\right]}{1-G\left(\widehat{s}\right)}$$
$$-\left(\frac{g^{'}(\widehat{s})\left(1-G\left(\widehat{s}\right)\right)+g^2(\widehat{s})}{\left(1-G\left(\widehat{s}\right)\right)^2}\right)D^3(p_H^*)(p_H^*-w_H)+2D^{''}(p_H^*)+D^{'}(p_H^*)(p_H^*-w_H).$$

As the search cost distribution has an increasing hazard rate $\frac{g(\widehat{s})}{1-G(\widehat{s})} > g(0)$. It follows that if $g(0)$ is sufficiently large, the term in the square brackets is positive so that the whole expression is negative. Also, in this case $\frac{\partial p_L^*}{\partial p_H^*} < 1$.

We now show that neither type of retailer has an incentive to imitate the equilibrium price of the other type of retailer and that we can find out-of-equilibrium beliefs that are such that no retailer wants to deviate from the reaction defined by (2.4) and (4.8). For a low cost retailer this is obvious. The above shows that a low cost retailer does not want to deviate if consumers believe that non-equilibrium prices are set by low cost retailers, i.e., if consumers have pessimistic views about the chance of finding a lower price on their next search. As fewer consumers buy after a deviation if they believe that non-equilibrium prices are set by a high cost retailer (i.e., they have more optimistic beliefs about finding a lower price on their next search), the deviation profits will be even lower under alternative beliefs.

To show that a high cost retailer does not want to deviate for alternative beliefs, a slightly more involved argument is needed. Note that from (4.8) it follows that if $g(0)$ is large enough p_L^* arbitrarily is close to w_L. Thus, $p_L^* < w_H$ for every $w_L < w_H$ if $g(0)$ is large enough. The high-cost retailer does not want to imitate the retail equilibrium price of the low cost retailer or to set a price in the neighbourhood of p_H^*. We also need to show that for any $p \in (p_L^*, p_H^*)$ we can find out-of-equilibrium beliefs about who has deviated such that the high cost retailer does not have an incentive to deviate to prices outside the neighbourhood of p_H^*. For any $p \in (p_L^* + \varepsilon, p_H^* - \varepsilon)$ (that is outside the immediate neighbourhoods of the equilibrium prices) we can write $p = \alpha p_L^* + (1-\alpha)p_H^*$ for some $\alpha \in (0,1)$ and choose a function $f(\cdot)$ such that the consumer out-of-equilibrium belief Pr(low cost retailer has deviated to price $p) = f(\alpha)$. Given that the profit function of the high cost retailer (assuming any deviation is attributed to a high cost retailer) is quasi-concave and that the high cost retailer does not have an incentive to deviate to prices in the neighbourhood of p_L^* it follows that there exists a a continuous function $f(\alpha)$ such that the high cost retailer does not want to deviate to prices $p \in (p_L^* + \varepsilon, p_H^* - \varepsilon)$. If consumers blame high cost retailers for deviations to prices $p > p_H^*$, it is clear that these retailers also do not want to deviate upwards.

We conclude that the equations (2.5) and (4.7) define real "best response" for a set of out-of-equilibrium beliefs. As the profit functions are quasi-concave, the "best responses" are continuous. In addition, as the slopes of "best response" functions are smaller than 1, there exists a unique equilibrium.

In the case of uniform pricing, uniqueness also follows from the second-order derivative of (2.1) being negative if $g(0)$ is large enough. In this case, the second-order derivative yields

$$-g(0)D(p^*)\left[2D^{'}(p^*)(p^*-w)+D(p^*)\right]+D^{''}(p^*)(p^*-w)+2D^{'}(p^*),$$

which, using the first-order condition can be rewritten as

$$-g(0)D(p^*)(p^*-w)\left[D^{'}(p^*)+g(0)D^2(p^*)\right]+D^{''}(p^*)(p^*-w)+2D^{'}(p^*),$$

which is clearly negative if $g(0)$ is large enough.

Proof of Theorem 2: Suppose that one retailer has a higher marginal cost δ of retailing relative to the other retailers. Without loss of generality, we normalize the cost of the other retailers to 0. If the manufacturer sets this retailer a wholesale price w_H and other retailers a wholesale price w_L with $w_H > w_L - \delta$, the profit of the manufacturer can be written as

$$\frac{N-1+G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N} w_L D(p_L(w_L, w_H+\delta)) + \frac{1-G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N} w_H D(p_H(w_L, w_H+\delta)).$$

We will argue that the first-order effect with respect to w_H is positive if evaluated at $w_L = w_H = w^*$.[20] As retail prices are anyway different as long as $w_H > w_L - \delta$ the profit function is differentiable as long as this condition is satisfied. Note that this condition includes the case of uniform pricing where $w_L = w_H$.

Consider first that under uniform pricing, the manufacturer would charge all retailers a wholesale price w^* that satisfies

$$\begin{aligned}
&\frac{g\left(\int_{p_L}^{p_H} D(p)dp\right)\left(D(p_H(w^*,w^*+\delta))\frac{\partial p_H}{\partial w^*} - D(p_L(w^*,w^*+\delta))\frac{\partial p_L}{\partial w^*}\right)}{N} \\
&\cdot w^*\left[D(p_L(w^*,w^*+\delta))) - D(p_H(w^*,w^*+\delta))\right] \\
&+ \frac{N-1+G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N}\left(D(p_L(w^*,w^*+\delta)) + w^* D^{'}(p_L(w^*,w^*+\delta))\frac{\partial p_L}{\partial w^*}\right) \\
&+ \frac{1-G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N}\left(D(p_H(w^*,w^*+\delta)) + w^* D'(p_H(w^*,w^*+\delta))\frac{\partial p_H}{\partial w^*}\right) = 0.
\end{aligned}$$

If instead the manufacturer engages in wholesale price discrimination and sets $w_L = w^*$ and $w_H = w^* + \varepsilon$ for small enough ε the first-order effect evaluated at $w_L = w_H = w^*$ is

$$\begin{aligned}
&\frac{g\left(\int_{p_L(w^*,w^*+\delta)}^{p_H(w^*,w^*+\delta)} D(p)dp\right)\left(D(p_H(w^*,w^*+\delta))\frac{\partial p_H}{\partial w_H} - D(p_L(w^*,w^*+\delta))\frac{\partial p_L}{\partial w_H}\right)}{N} \\
&\cdot w^*\left[D(p_L(w^*,w^*+\delta))) - D(p_H(w^*,w^*+\delta))\right] \\
&+ \frac{N-1+G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N} w^* D^{'}(p_L(w^*,w^*+\delta))\frac{\partial p_L}{\partial w_H} \\
&+ \frac{1-G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N}\left(D(p_H(w^*,w^*+\delta)) + w^* D'(p_H(w^*,w^*+\delta))\frac{\partial p_H}{\partial w_H}\right) = 0.
\end{aligned}$$

Using, the optimality condition under uniform pricing, this first-order effect of wholesale price discrimination is positive if

[20] Note that we showed in Section 2.3 that retail prices are not continuous for a deviation in w_H at $w_L = w_H = w^*$. Thus, we cannot take the usual first-order conditions and we have to directly compare the manufacturer profit under uniform pricing ($w_L = w_H = w^*$) with the profit under wholesale price discrimination for $w_L = w^*$ and $w_H = w^* + \varepsilon$.

$$\frac{g\left(\int_{p_L(w^*,w^*+\delta)}^{p_H(w^*,w^*+\delta)} D(p)dp\right)\left(D(p_H(w^*,w^*+\delta))\left(\frac{\partial p_H}{\partial w_H}-\frac{\partial p_H}{\partial w^*}\right)-D(p_L(w^*,w^*+\delta))\left(\frac{\partial p_L}{\partial w_H}-\frac{\partial p_L}{\partial w^*}\right)\right)}{N}$$
$$\cdot\, w^*\left[D(p_L(w^*,w^*+\delta)))-D(p_H(w^*,w^*+\delta))\right]$$
$$+\frac{N-1+G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N}\left(D(p_L(w^*,w^*+\delta))+w^*D^{'}(p_L(w^*,w^*+\delta))\left(\frac{\partial p_L}{\partial w_H}-\frac{\partial p_L}{\partial w^*}\right)\right)$$
$$+\frac{1-G\left(\int_{p_L}^{p_H} D(p)dp\right)}{N}w^*D'(p_H(w^*,w^*+\delta))\left(\frac{\partial p_H}{\partial w_H}-\frac{\partial p_H}{\partial w^*}\right)>0.$$

Due to strategic complementarities of the retail prices, it is clear that $\frac{\partial p_i}{\partial w_H}-\frac{\partial p_i}{\partial w^*}<0$ so that the last two terms are indeed positive. Moreover, as (i) $\frac{\partial p_H}{\partial w_H}>\frac{\partial p_L}{\partial w_H}>0$,[21] $(ii)\frac{\partial p_H}{\partial w^*}\approx\frac{\partial p_L}{\partial w^*}$ for δ close enough to 0, while (iii) $D(p_L(w^*,w^*+\delta)))>D(p_H(w^*,w^*+\delta))$ the first effect is also positive. Therefore, the first-order-effect of wholesale price discrimination is positive and the manufacturer wants to exacerbate initial cost differences between retailers.

Proof of Proposition 2.4: It is clear that for $\overline{s}$ small enough ($g(0)$ large enough), p^* is close to w^* so that w^* solves $w^*D^{'}(w^*)+D(w^*)=0$.

We now discuss the comparative static result. Given the expression for $\frac{\partial p^*}{\partial w}$ the manufacturer's first-order condition can be written as

$$0=wD'(p^*)\left(\frac{D'(p^*)}{g(0)}-D^2(p^*)\right)-2D^2(p^*)D^{'}(p^*)(p^*-w)-D^3(p^*)+\frac{D(p^*)D^{''}(p^*)(p^*-w)}{g(0)}+\frac{2D(p^*)D'(p^*)}{g(0)}.$$

Taking the total differential evaluated in a neighbourhood of $\overline{s}=0$ gives

$$0=\left(2D(p^*)D'(p^*)+wD'^2(p^*)\right)d\frac{1}{g(0)}+D'(p^*)D^2(p^*)dw,$$

which, using $D(p^*)+wD'(p^*)=0$, gives $dw=-\frac{1}{D(p^*)}d\frac{1}{g(0)}$.

[21] This follows from the fact that $\frac{\partial p_L}{\partial w_H}=\frac{\partial p_L}{\partial p_H}\frac{\partial p_H}{\partial w_H}$ and from the proof of Proposition 2.2 we know that $\frac{\partial p_L}{\partial p_H}<1$.

Taking the total differential of the first-order condition (2.1) of the retailer and evaluating it in a neighbourhood of $\frac{1}{g(0)} = 0$ where $g(0) \to \infty$ gives $d\frac{1}{g(0)} + D(p^*)dw^* - D(p^*)dp^* = 0$. Substituting $dw = -\frac{1}{D(p^*)}d\frac{1}{g(0)}$ yields $dp^* = 0$.

Proof of Proposition 2.5. That an equilibrium exists and is characterized by wholesale price discrimination is easy to see. In a neighbourhood of $\frac{1}{g(0)} = 0$, Proposition 2.2 shows that a retail equilibrium exists. As the manufacturer profit is a continuous function on a compact set, its maximum is reached in the set. Combined with Proposition 2.3, it follows that the equilibrium involves wholesale price discrimination.

We now turn to the comparative statics results for $N = 3$. As the proof of the next Proposition uses these expressions for general N we prove the result for setting w_L to $N-1$ retailers and w_H to 1 retailer. The result for $N = 3$ simply follows by substitution. The total differential of the FOC with respect to w_H (2.8) in the neighbourhood of $\frac{1}{g(0)} = 0$ where $wD'(p) \approx -D(p)$ and $D(p_L^*) \approx D(p_H^*)$ can be written as

$$\begin{aligned} 0 = \; & (dp_H - dw_H - (dp_L - dw_L)) \left(\frac{\partial p_H^*}{\partial w_H} - \frac{\partial p_L^*}{\partial w_H} \right) - (dp_H - dp_L) \left(1 - \left(\frac{\partial p_H^*}{\partial w_H} - \frac{\partial p_L^*}{\partial w_H} \right) \right) \\ & + \left([1 - G(\widehat{s})] \left[1 - \frac{\partial p_H^*}{\partial w_H} \right] - [N - (1 - G(\widehat{s}))] \frac{\partial p_L^*}{\partial w_H} \right) d\frac{1}{D(p_H^*)g(\widehat{s})} \end{aligned} \tag{2.12}$$

and

$$\begin{aligned} 0 = \; & (dp_H - dw_H - (dp_L - dw_L)) \left(\frac{\partial p_H^*}{\partial w_L} - \frac{\partial p_L^*}{\partial w_L} \right) + (dp_H - dp_L) \left(1 + \left(\frac{\partial p_H^*}{\partial w_L} - \frac{\partial p_L^*}{\partial w_L} \right) \right) \\ & + \left([N - (1 - G(\widehat{s}))] \left[1 - \frac{\partial p_L^*}{\partial w_L} \right] - [1 - G(\widehat{s})] \frac{\partial p_H^*}{\partial w_L} \right) d\frac{1}{D(p_L^*)g(\widehat{s})}. \end{aligned} \tag{2.13}$$

To further evaluate these expressions, we need to know how retail prices react to changes in wholesale prices, i.e., we need to evaluate the respective different partial derivatives, in the neighbourhood of $\frac{1}{g(0)} = 0$. Rewriting the retail first-order conditions (2.4) and (2.5) as

$$-D^2(p_H^*)(p_H^*-w_H)+\frac{(1-G(\widehat{s}))}{g(\widehat{s})}\left[D'(p_H^*)(p_H^*-w_H)+D(p_H^*)\right]=0, \quad (2.14)$$

and

$$-\left(\tfrac{(N-1)^2}{N}+1\right)D^2(p_L^*)(p_L^*-w_L)+\tfrac{((N-1)+G(\widehat{s}))}{g(0)}\left[D'(p_L^*)(p_L^*-w_L)+D(p_L^*)\right]=0, \quad (2.15)$$

and using the fact that in the neighbourhood of $\overline{s}=\frac{1}{g(0)}=0$ we have that $p_H^*\approx w_H$ and $D(p_H^*)\approx D(p_L^*)$,[22] the total differential of (2.14) approximately yields $-D^2(p_H^*)\left(dp_H^*-dw_H\right)-D(p_H^*)\left(D(p_H^*)dp_H^*-D(p_L^*)dp_L^*\right)+D(p_H^*)d\frac{1-G(\widehat{s})}{g(\widehat{s})}=0$, or

$$-2dp_H^*+dw_H+dp_L^*+d\frac{1-G(\widehat{s})}{D(p_H^*)g(\widehat{s})}\approx 0.$$

Taking the total differential of (2.15) and leaving out "irrelevant" terms we obtain $-\left(\frac{(N-1)^2}{N}+1\right)D^2(p_L^*)\left(dp_L^*-dw_L\right)+\frac{g(\widehat{s})}{g(0)}D(p_L^*)\left(D(p_H^*)dp_H^*-D(p_L^*)dp_L^*\right)+D(p_L^*)d\frac{N-(1-G(\widehat{s}))}{g(0)}\approx 0$. As $g'(s)$ is bounded and $g(0)$ is very, very large, it must be that $\frac{g(\widehat{s})}{g(0)}\approx 1$ so that we can rewrite this condition as

$$-\frac{N^2-(1-x)N+1}{N}dp_L^*+\frac{N^2-N+1}{N}dw_L+dp_H^*+d\frac{N-(1-G(\widehat{s}))}{D(p_L^*)g(0)}\approx 0.$$

Thus, the total effects of $w_L$and w_H on retail prices can be calculated by substituting these two equations into each other:

$$-\frac{2N^2-N+2}{2N}dp_L^*+\frac{N^2-N+1}{N}dw_L+\frac{1}{2}dw_H^*+d\frac{2N-(1-G(\widehat{s}))}{2D(p_L^*)g(\widehat{s})}=0.$$

[22] Note that the discontinuity in the retail equilibrium at $(w,w+\varepsilon)$ described in Proposition 2.1, becomes arbitrarily small in the neighbourhood of $\overline{s}=\frac{1}{g(0)}=0$.

or

$$\left(2N^2 - N + 2\right) dp_L^* = 2\left(N^2 - N + 1\right) dw_L + N dw_H + N d \frac{2N - (1 - G(\widehat{s}))}{D(p_L^*) g(\widehat{s})}, \tag{2.16}$$

and

$$\tfrac{N^2+1}{N}\left(-2dp_H^* + dw_H + d\tfrac{1-G(\widehat{s})}{D(p_H^*)g(\widehat{s})}\right) + \tfrac{N^2-N+1}{N} dw_L + dp_H^* + d\tfrac{N-(1-G(\widehat{s}))}{D(p_L^*)g(0)} = 0$$

or

$$\left(2N^2 - N + 2\right) dp_H^* = \left(N^2 + 1\right) dw_H + \left(N^2 - N + 1\right) dw_L + d\tfrac{N^2 + \left(N^2 - N + 1\right)(1 - G(\widehat{s}))}{D(p_H^*)g(\widehat{s})}. \tag{2.17}$$

Thus, these equations give the unique equilibrium retail price reactions to w_L and w_H in a neighbourhood of $\overline{s} = 0$. It follows that

$$\begin{aligned} \frac{\partial p_H^*}{\partial w_L^*} - \frac{\partial p_L^*}{\partial w_L^*} &= \frac{\left(N^2 - N + 1\right) - 2\left(N^2 - N + 1\right)}{2N^2 - N + 2} = \frac{-N^2 + N - 1}{2N^2 - N + 2} < 0, \\ \frac{\partial p_H^*}{\partial w_H^*} - \frac{\partial p_L^*}{\partial w_H^*} &= \frac{\left(N^2 - N + 1\right) - N}{2N^2 - N + 2} = \frac{N^2 - N + 1}{2N^2 - N + 2} > 0. \end{aligned}$$

We are now able to further evaluate (2.12) and (2.13). First, note that in their first-order approximation, (2.12) and (2.13) are identical. To see that, note that adding (2.12) and (2.13) gives

$$\begin{aligned} &0 = \left(2dp_H - dw_H - (2dp_L - dw_L) - [1 - G(\widehat{s})]\, d\frac{1}{g(\widehat{s})}\right)\left(\left(\frac{\partial p_H^*}{\partial w_H} - \frac{\partial p_L^*}{\partial w_H}\right) + \left(\frac{\partial p_H^*}{\partial w_L} - \frac{\partial p_L^*}{\partial w_L}\right)\right) \\ &N\left[1 - \frac{\partial p_L^*}{\partial w_H} - \frac{\partial p_L^*}{\partial w_L}\right] d\frac{1}{D(p_L^*)g(\widehat{s})}, \end{aligned} \tag{2.18}$$

where $\left(\frac{\partial p_H^*}{\partial w_H} - \frac{\partial p_L^*}{\partial w_H}\right) = -\left(\frac{\partial p_H^*}{\partial w_L} - \frac{\partial p_L^*}{\partial w_L}\right)$ and $\frac{\partial p_L^*}{\partial w_H} + \frac{\partial p_L^*}{\partial w_L} = 1$.

The total differential of the first first-order condition in the neighbourhood of $\overline{s} = \frac{1}{g(0)} = 0$ where $wD'(p) \approx -D(p)$ and $D(p_L^*) \approx D(p_H^*)$ can be written as

$$\left(D(p_L^*) + w_L D'(p_L^*)\frac{\partial p_L^*}{\partial w_L^*} - w_H D'(p_H^*)\frac{\partial p_H^*}{\partial w_L^*}\right)\left(D(p_H^*)\frac{\partial p_H^*}{\partial w_H^*} - D(p_L^*)\frac{\partial p_L^*}{\partial w_H^*}\right) dw_L -$$
$$\left(D(p_H^*) - w_L D'(p_L^*)\frac{\partial p_L^*}{\partial w_H^*} + w_H D'(p_H^*)\frac{\partial p_H^*}{\partial w_H^*}\right)\left(D(p_H^*)\frac{\partial p_H^*}{\partial w_H^*} - D(p_L^*)\frac{\partial p_L^*}{\partial w_H^*}\right) dw_H -$$
$$\left(D(p_H^*) + w_H D'(p_H^*)\frac{\partial p_H^*}{\partial w_H^*} - w_H D'(p_H^*)\frac{\partial p_L^*}{\partial w_H^*}\right) D(p_L^*)\left(\left(\frac{\partial p_H^*}{\partial w_H^*} - \frac{\partial p_L^*}{\partial w_H^*}\right) dw_H + \left(\frac{\partial p_H^*}{\partial w_L^*} - \frac{\partial p_L^*}{\partial w_L^*}\right) dw_L\right)$$
$$+\left(\left[D(p_H^*) + w_H D'(p_H^*)\frac{\partial p_H^*}{\partial w_H^*}\right] + [N-1]\, w_L D'(p_L^*)\frac{\partial p_L^*}{\partial w_H^*}\right) d\frac{1}{g(\widehat{s})} = 0,$$

or

$$\left(\frac{\partial p_H^*}{\partial w_H^*} - \frac{\partial p_L^*}{\partial w_H^*}\right)\left(\left(1 + \frac{\partial p_H^*}{\partial w_L^*} - \frac{\partial p_L^*}{\partial w_L^*}\right) dw_L - \left(1 - \frac{\partial p_H^*}{\partial w_H^*} + \frac{\partial p_L^*}{\partial w_H^*}\right) dw_H\right) \quad (2.19)$$
$$-\left(1 - \left(\frac{\partial p_H^*}{\partial w_H^*} - \frac{\partial p_L^*}{\partial w_H^*}\right)\right)\left(\left(\frac{\partial p_H^*}{\partial w_H^*} - \frac{\partial p_L^*}{\partial w_H^*}\right) dw_H + \left(\frac{\partial p_H^*}{\partial w_L^*} - \frac{\partial p_L^*}{\partial w_L^*}\right) dw_L\right)$$
$$+\left(\left[1 - \frac{\partial p_H^*}{\partial w_H^*}\right] - [N-1]\frac{\partial p_L^*}{\partial w_H^*}\right) d\frac{1}{D(p_H^*)g(\widehat{s})} = 0.$$

Using the expressions for $\frac{\partial p_H^*}{\partial w_H^*} - \frac{\partial p_L^*}{\partial w_H^*}$ and $\frac{\partial p_H^*}{\partial w_L^*} - \frac{\partial p_L^*}{\partial w_L^*}$ (2.19) can be simplified as

$$\frac{N^2 - N + 1}{(2N^2 - N + 2)}\left(\left(1 + \frac{-N^2 + N - 1}{(2N^2 - N + 2)}\right) dw_L - \left(1 - \frac{(N^2 - N + 1)}{(2N^2 - N + 2)}\right) dw_H\right)$$
$$-\left(1 - \frac{(N^2 - N + 1)}{(2N^2 - N + 2)}\right)\left(\frac{(N^2 - N + 1)}{(2N^2 - N + 2)} dw_H + \frac{-N^2 + N - 1}{(2N^2 - N + 2)} dw_L\right)$$
$$+\left(\left[1 - \frac{N^2 + 1}{2N^2 - N + 2}\right] - [N-1]\frac{N}{2N^2 - N + 2}\right) d\frac{1}{D(p_H^*)g(\widehat{s})} = 0,$$

or

$$2\frac{N^2 - N + 1}{2N^2 - N + 2}\left(N^2 + 1\right)(dw_L - dw_H) + d\frac{1}{D(p_H^*)g(\widehat{s})} = 0,$$

Substituting this into (2.16) and (2.17) yields

$$dp_L^* - dw_L^* = \left(\frac{N}{2\left(N^2 + 1\right)\left(N^2 - N + 1\right)} + \frac{N\left(2N - 1\right)}{(2N^2 - N + 2)}\right) d\frac{1}{D(p_L^*)g(\widehat{s})}, \quad (2.20)$$

and

$$dp_H^* - dw_H^* = \left(-\frac{1}{2\left(N^2+1\right)} + \frac{2N^2-N+1}{2N^2-N+2} \right) d\frac{1}{D(p_L^*)g(\widehat{s})}. \tag{2.21}$$

Also, we can approximate the fraction of consumers that continue to search after visiting the high cost retailer, $G(\int_{p_L^*}^{p_H^*} D(p)dp)$, by

$$D(p_H^*)\frac{dp_H^* - dp_L^*}{d(\frac{1}{g(0)})} = -\frac{N^2-N+1}{2N^2-N+2}D(p_H^*)\frac{dw_L^* - dw_H^*}{d(\frac{1}{g(0)})} + d\frac{1}{g(\widehat{s})}\frac{1}{(2N^2-N+2)},$$

which can be rewritten as

$$D(p_H^*)\left(\frac{dp_H^*}{d(\frac{1}{g(0)})} - \frac{dp_L^*}{d(\frac{1}{g(0)})}\right) = \frac{4N^2-N+4}{2(N^2+1)(2N^2-N+2)} < \frac{1}{N}.$$

Finally, we need to show that for any $p \in (p_L^* + \varepsilon, p_H^* - \varepsilon)$ we can find out-of-equilibrium beliefs about who has deviated such that the high cost retailer does not have an incentive to deviate to prices outside the neighbourhood of p_H^*. If he would deviate and set p_L^* his profits will be equal to $(p_L^* - w_H^*)D(p_L^*)$ and we first show that in a neighbourhood of $\overline{s} = 0$ this is strictly smaller than his equilibrium profits $(1 - G(\widehat{s}))(p_H^* - w_H^*)D(p_H^*)$. This is the case if, and only if,

$$\frac{dp_L^* - dp_H^*}{d(\frac{1}{g(0)})} + \frac{dp_H^* - dw_H^*}{d(\frac{1}{g(0)})} < \frac{dp_H^* - dw_H^*}{d(\frac{1}{g(0)})}(1 - G(\widehat{s})),$$

or $G(\widehat{s})\frac{dp_H^* - dw_H^*}{d(\frac{1}{g(0)})} < \frac{dp_H^* - dp_L^*}{d(\frac{1}{g(0)})}$, or $-\frac{1}{2(N^2+1)} + \frac{2N^2-N+1}{2N^2-N+2} < 1$. This is certainly the case. By the same token, a deviation to a price p in the neighbourhood of p_L^* or any price smaller than p_L^* is not optimal. For any $p \in (p_L^* + \varepsilon, p_H^* - \varepsilon)$ (that is outside the immediate neighbourhoods of the equilibrium prices) we can write $p = \alpha p_L^* + (1-\alpha)p_H^*$ for some $\alpha \in (0,1)$ and define the following consumer out-of-equilibrium belief Pr(low cost retailer has deviated to price p) $= \alpha$. Given that the profit function of the high cost retailer (assuming any deviation is attributed to a high cost retailer) is concave and that the high cost retailer does not have an incentive to deviate to prices in the neighbourhood of p_L^* it follows that given these beliefs, the high cost retailer does not want to deviate to prices $p \in (p_L^* + \varepsilon, p_H^* - \varepsilon)$. If consumers blame high cost retailers for deviations to prices $p > p_H^*$, it is clear that these retailers also do not want to deviate upwards.

Proof of Proposition 2.6. If the manufacturer sets three different wholesale prices, its profit is equal to

$$\begin{aligned}&\frac{N-2+G(\widehat{s}_M)+\frac{N-2+x}{N-1}G(\widehat{s}_H)}{N}w_L D(p_L^3)+\\&\frac{1-G(\widehat{s}_M)+\frac{1-x}{N-1}G(\widehat{s}_H)}{N}w_M D(p_M^3)+\frac{1-G\left(\widehat{s}_H\right)}{N}w_H D(p_H^3),\end{aligned} \tag{2.22}$$

where $G(\widehat{s}_H)$ is the fraction of the consumers that first visited the high cost retailer and then continues to search, $G(\widehat{s}_M)$ is the fraction of the consumers that first visited the medium cost retailer and then continues to search and x is the fraction of of the consumers that first visited the high cost retailer and then the medium cost retailer who continue to search a low cost retailer, and for notational convenience we suppress the dependence of retail prices on the wholesale prices. To indicate that the retail prices may differ, we mark the retail prices in case the manufacturer sets three wholesale prices with a superscript "3".

We are interested in whether keeping w_L and w_H at the same level, the manufacturer can do better by setting $w_M^* = w_L^* + \varepsilon$ to one retailer, i.e., whether in this case (2.22) is larger than (2.7). This is the case if

$$\begin{aligned}
&\frac{N-1+G\left(\widehat{s}\right)}{N}w_L\left[D(p_L)-D(p_L^3)\right]+\frac{1-G\left(\widehat{s}\right)}{N}w_H\left[D(p_H)-D(p_H^3)\right]\\
&+\frac{1-G(\widehat{s}_M)+G(\widehat{s})-\frac{N-2+x}{N-1}G(\widehat{s}_H)}{N}w_LD(p_L^3)-\frac{G\left(\widehat{s}\right)-G\left(\widehat{s}_H\right)}{N}w_HD(p_H^3)\\
&-\frac{1-G(\widehat{s}_M)+\frac{1-x}{N-1}G(\widehat{s}_H)}{N}w_MD(p_M^3)\\
<\;& 0,
\end{aligned}$$

which can be rewritten as

$$\begin{aligned}
&\frac{1+\frac{1-x}{N-1}G(\widehat{s}_H)-G(\widehat{s}_M)}{N}\left[w_LD(p_L^3)-w_MD(p_M^3)\right]\\
&+\frac{G\left(\widehat{s}\right)-G\left(\widehat{s}_H\right)}{N}\left[w_LD(p_L^3)-w_HD(p_H^3)\right]\\
&+\frac{N-1+G\left(\widehat{s}\right)}{N}w_L\left[D(p_L)-D(p_L^3)\right]+\frac{1-G\left(\widehat{s}\right)}{N}w_H\left[D(p_H)-D(p_H^3)\right]<0,
\end{aligned}$$

It is clear that by setting $w_M=w_L+\varepsilon$ for very small $\varepsilon>0$ the medium cost retailer faces almost the same considerations as the low cost retailer with two wholesale prices, i.e., $p_M^3\approx p_L$.Thus, this expression is indeed negative if

$$\begin{aligned}
&\frac{N-\frac{1-x}{N-1}G(\widehat{s}_H)+G(\widehat{s}_M)+G\left(\widehat{s}\right)}{N}w_L\left[D(p_L)-D(p_L^3)\right]\\
&+\frac{1-G\left(\widehat{s}\right)}{N}w_H\left[D(p_H)-D(p_H^3)\right]+\frac{G\left(\widehat{s}\right)-G\left(\widehat{s}_H\right)}{N}\left[w_LD(p_L^3)-w_HD(p_H^3)\right]\\
<\;& 0,
\end{aligned}$$

This is indeed the case if we can show that $p_L^3<p_L$. If $p_L^3<p_L$, it follows that $D(p_L)-D(p_L^3)<0$ and it then also follows that $p_H^3<p_H$ and $D(p_H)-D(p_H^3)<0$ as consumers who first visit the high cost retailer will then have lower prices to expect if they continue to search, making search more attractive.

So, we should consider the incentives of a low cost retailer to deviate in case the manufacturer charges three wholesale prices with $w_M^* = w_L^* + \varepsilon$ and the deviating retailer sets a marginally higher price p_L with $p_M^3 > p_L > p_L^3$. To calculate these deviation pay-offs we have to consider three groups of consumers, depending on whom they searched first: (i) the group that first visit the deviating retailer, (ii) the group that first visits the medium cost retailer and then, finally (iii) the group that first visits the high cost retailer. The group that first visited a retailer that sets p_L^* is not explicitly considered as these consumers immediately buy from these retailers.

First, consider the consumers that first visited the deviating retailer. They will only decide to continue to search if they search for p_L^*. Thus, their expected search cost equals $\frac{N-3}{N-1}s + \frac{2}{N-1}\frac{N-3}{N-2}2s + \frac{2}{N-1}\frac{1}{N-2}3s$, where the three terms reflect the chance they encounter p_L^* on their first, second, or third next search. This expression can be rewritten as $\frac{N-3}{N-1}s + \frac{2N-3}{N-2}2s = \frac{N}{N-2}s$. As $1/N$ consumers first visit the deviating firm, this means that out of the total mass of consumers

$$\frac{1}{N}\left[1 - G\left(\frac{N-2}{N}\int_{p_L^{3*}}^{p_L^3} D(p)dp\right)\right] \tag{2.23}$$

belongs to this group that buys from the deviating firm.

Next, consider a consumer who first visits the retailer that sets p_M^* and considers searching further, does not know that a firm has deviated and therefore has an expected search cost of $\frac{N-2}{N-1}s + \frac{1}{N-1}2s = \frac{N}{N-1}s$ to search for a low cost retailer. These consumers that continue searching and may in the end potentially buy from the deviating firm form a fraction $G\left(\frac{N-1}{N}\int_{p_L^{3*}}^{p3_M^*} D(p)dp\right)/N$ of the total mass of consumers. Out of this group, a fraction $1/(N-1)$ visits the deviating firm on their second visit. These consumers face an expected search cost of $\frac{N-3}{N-2}s + \frac{1}{N-2}2s = \frac{N-1}{N-2}s$ of continuing searching for p_L^* and thus will buy if their search cost is larger than $\frac{N-2}{N-1}\int_{p_L^{3*}}^{p_L^3} D(p)dp$. Out of this same group that first visits the retailer that sets p_M^*

and continues to search, another fraction $1/(N-1)$ visits the firm that sets p_H^{3*} on their second visit. These consumers certainly will continue searching on and with probability $1/(N-2)$ visit the deviating firm on their third visit face and buy then if their search cost is larger than $\int_{p_L^{3*}}^{p_L^3} D(p)dp$ as they expect to certainly find a firm that sets p_L^{3*}. Thus, as the fraction of consumers that along their search path visits a retailer that sets p_L^{3*} will not buy from the deviating firm, the deviating firm also sells to a fraction

$$\frac{G\left(\frac{N-1}{N}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right)-G\left(\frac{N-2}{N-1}\int_{p_L^{3*}}^{p_L^3} D(p)dp\right)}{N(N-1)}+\frac{G\left(\frac{N-1}{N}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right)-G\left(\int_{p_L^{3*}}^{p_L^3} D(p)dp\right)}{N(N-1)(N-2)}. \tag{2.24}$$

Finally, we have to consider consumers who first visit the retailer that sets p_H^{3*} and consider searching further. Here, in principle, we have to distinguish two cases, namely whether or not the marginal consumer who considers to search further will also want to continue to search if he finds p_M^{3*} on his second visit. In case the marginal consumer does not search further if he finds p_M^{3*} on his second visit, his expected benefit of search equals $\frac{N-2}{N-1}\int_{p_L^{3*}}^{p_H^{3*}} D(p)dp + \frac{1}{N-1}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp$ so that he continues searching if $s < \frac{N-2}{N-1}\int_{p_L^{3*}}^{p_H^{3*}} D(p)dp + \frac{1}{N-1}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp$.[23] Whether the (non-marginal) consumers continue searching to the deviating firm and buy there involves identical considerations as in the previous case. Thus, the deviating firm also sells to a fraction

$$\begin{aligned}&\frac{G\left(\frac{N-2}{N-1}\int_{p_L^{3*}}^{p_H^{3*}} D(p)dp+\frac{1}{N-1}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right)-G\left(\frac{N-2}{N-1}\int_{p_L^{3*}}^{p_L^3} D(p)dp\right)}{N(N-1)}\\&+\frac{G\left(\frac{N-2}{N-1}\int_{p_L^{3*}}^{p_H^{3*}} D(p)dp+\frac{1}{N-1}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right)-G\left(\int_{p_L^{3*}}^{p_L^3} D(p)dp\right)}{N\left(N-1\right)\left(N-2\right)}.\end{aligned} \tag{2.25}$$

[23] As we consider $w_M^* = w_L^* + \varepsilon$ it is clear that p_M^* is somewhat close to p_L^* so that we focus on this case. If, however, the marginal consumer does search further , his expected benefit of search equals $\frac{N-1}{N}\int_{p_L^*}^{p_H^*} D(p)dp$. the substantive analysis of both cases is identical, however.

The pay-off of a deviating firm is thus, the sum of these the terms in (2.23), (2.24) and (2.25) multiplied by $D(p_L^3)(p_L^3 - w_L^{3*})$. Taking the first-order condition and setting p_L^3 equal to p_L^{3*} yields

$$0 = -\left(\frac{N-2}{N} + \frac{N-2}{(N-1)^2 N} + \frac{1}{N(N-1)^2(N-2)}\right) g(0) D^2(p_L^{3*})(p_L^{3*} - w_L^{3*}) + \left[1 + \left(\frac{G\left(\frac{N-1}{N}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right) + G\left(\frac{N-2}{N-1}\int_{p_L^{3*}}^{p_H^{3*}} D(p)dp + \frac{1}{N-1}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right)}{N-2}\right)\right]\left[D'(p_L^{3*})(p_L^{3*} - w_L^{3*}) + D(p_L^{3*})\right].$$

or

$$0 = -\frac{\left[\frac{(N-2)^2}{N} + \frac{2(N^2-3N+3)}{(N-1)^2}\right] g(0) D^2(p_L^{3*})(p_L^{3*} - w_L^{3*})}{N-2+G\left(\frac{N-1}{N}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right)+G\left(\frac{N-2}{N-1}\int_{p_L^{3*}}^{p_H^{3*}} D(p)dp+\frac{1}{N-1}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right)} + \left[D'(p_L^{3*})(p_L^{3*} - w_L^{3*}) + D(p_L^{3*})\right]. \tag{2.26}$$

If

$$\frac{\left(\frac{(N-1)^2}{N}+1\right)}{(N-1)+G(\widehat{s})} < \frac{\left[\frac{(N-2)^2}{N} + \frac{2(N^2-3N+3)}{(N-1)^2}\right]}{N-2+G\left(\frac{N-1}{N}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right)+G\left(\frac{N-2}{N-1}\int_{p_L^{3*}}^{p_H^{3*}} D(p)dp+\frac{1}{N-1}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right)}$$

then $p_L^3 < p_L$, *i.e.*, low cost retailers will indeed charge lower margins if the manufacturer sets three wholesale prices. As $p_M^* < p_H^*$ this is certainly the case if

$$\begin{aligned} &\left(\frac{(N-1)^2}{N} + 1\right)\left[N - 2 + G\left(\frac{N-1}{N}\int_{p_L^{3*}}^{p_M^{3*}} D(p)dp\right) + G\left(\widehat{s}\right)\right] \\ < &\left[\frac{(N-2)^2}{N} + \frac{2(N^2-3N+3)}{(N-1)^2}\right]\left[(N-1) + G(\widehat{s})\right]. \end{aligned}$$

As $p_M^{3*} \approx p_L$ and $p_M^{3*} > p_L^{3*}$ it is either the case that $p_L^{3*} < p_L$ (in which case we are done) or $p_M^{3*} \approx p_L^{3*}$ in which case the above inequality holds if

$$\frac{(N-1)(N-2)}{N} - \frac{(N-1)(N-4)+2N}{(N-1)} < \left[\frac{(N-2)^2}{N} + \frac{2(N^2-3N+3)}{(N-1)^2} - \left(\frac{(N-1)^2}{N} + 1\right)\right] G(\widehat{s}),$$

or

$$\frac{N+2}{N} - \frac{2N}{(N-1)} < \left[\frac{-2N+3}{N} + \frac{N^2-4N+5}{(N-1)^2}\right] G(\widehat{s}),$$

As the RHS is larger than $\left[\frac{(N-2)^2}{N} + \frac{2(N^2-3N+3)}{(N-1)^2} - \left(\frac{(N-1)^2}{N}+1\right)\right] G(\widehat{s})$, which in turn is larger than $\frac{-2N+3}{N} + \frac{N^2-4N+5}{(N-1)^2} = \frac{-N^2+4N-3}{N(N-1)} - \frac{2N-4}{(N-1)^2}$, the inequality certainly holds if

$$\frac{-3N+1}{N} < -\frac{2N-4}{N-1},$$

which is true for all $N \geq 4$. Thus, $p_L^{3*} < p_L$.

2.9 Appendix II

In this supplementary Appendix we consider several issues. First, we take up the issue of two-part-tariffs. Then, we provide additional numerical simulations for different search cost distributions, which reconfirm the paper's finding that the manufacturer earns higher profits under wholesale price discrimination. Finally, we provide a more formal justification for using $d\overline{s}$, $d(1/g(0))$ and $d(1/g(\widehat{s}))$ interchangeably in the paper.

2.9.1 Two-part-tariffs

We now investigate how allowing the monopolist manufacturer to have the possibility of choosing two-part tariffs affects our results. Clearly, if the manufacturer has all the bargaining power, then he will set a wholesale price that induces the retailers to choose the integrated monopolist price and set a fixed fee equal to the retail profit. Wholesale price discrimination does not add to the manufacturer's profit in this case. In most markets, however, the bargaining power is not exclusively with the manufacturer. In this section, we exogenously fix the relative bargaining power and denote by α the bargaining power of a given retailer, where α measures the share of the retail profit that the retailer can keep for himself. We show that our results continue to hold for any $\alpha > 0$. In an equilibrium under the uniform pricing scheme, an individual retailer's profit will be:

$$\pi_r^*(p^*) = \frac{\alpha}{N} D(p^*(w^*))(p^* - w^*).$$

Whereas, the monopolist manufacturer's profit in equilibrium is given by:

$$\pi(w^*) = w^* D(p^*(w^*)) + (1 - \alpha)(p^* - w^*)D(p^*(w^*))$$

Thus, if $\alpha = 0$, the manufacturer extracts all profits from its retailers and if $\alpha = 1$, then the profits will be the same as in the paper. It is clear that with this formulation, the retailer's problem is identical to the one analysed in Section 2.3 of the paper and thus the equilibrium condition for the retail prices remains the same. On the other hand, the equilibrium condition for the uniform wholesale price changes since the manufacturer now directly maximizes:

$$\pi(w) = wD(p(w)) + (1 - \alpha)(p - w)D(p(w))$$

Thus, with uniform pricing and two-part tariffs the wholesale price w is set such that:

$$wD'(p(w))\frac{\delta p^*}{\delta w} + D(p(w)) + (1-\alpha)\left[(p - w)D'(p(w))\frac{\delta p^*}{\delta w} + (\frac{\delta p^*}{\delta w} - 1)D(p(w))\right] = 0. \tag{2.27}$$

Figures 2.9 below, depicts retail and wholesale prices under uniform pricing for different values of $\overline{s}$, when $\alpha = 1$ and $\alpha = 0.1$ respectively.

Under wholesale price discrimination with two-part tariffs, the manufacturer will

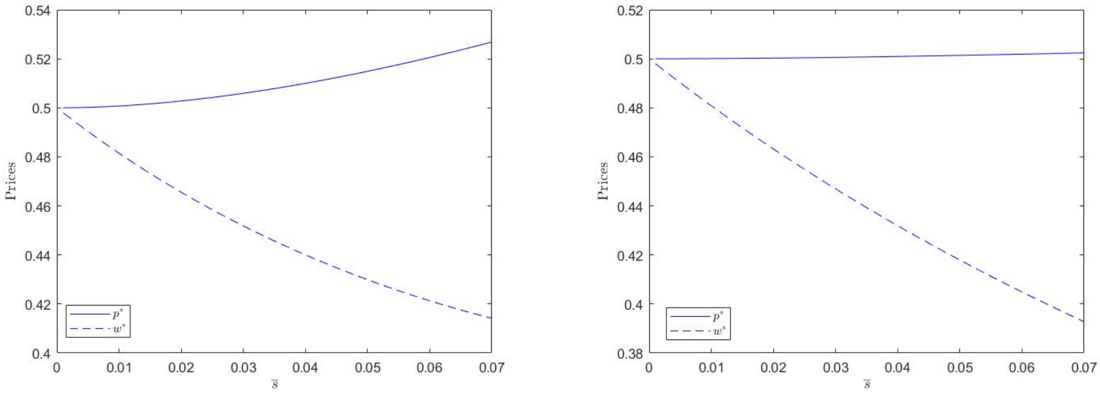

Figure 2.9: **Left:** Uniform retail and wholesale prices for different values of $\overline{s}$, when $\alpha = 1$. **Right:**Uniform retail and wholesale prices for different values of $\overline{s}$, when $\alpha = 0.1$.

chose two different wholesale prices, w_L and w_H, to directly maximize:

$$\begin{aligned}\pi(w_L, w_H) \;\; = \;\; & \frac{1}{N}\left[1 - G(\widehat{s})\right]\left[w_H D(p_H^*(w_H)) + (1-\alpha)(p_H^* - w_H) D(p_H^*(w_H))\right] \\ & + \frac{N - 1 + G(\widehat{s})}{N}\left[w_L D(p_L^*(w_L)) + (1-\alpha)(p_L^* - w_L) D(p_L^*(w_L))\right]\end{aligned}$$

which yields the two following first-order conditions below:

$$\begin{aligned}0 = & \left[w_H D(p_H^*) + (1-\alpha)(p_H^* - w_H) D(p_H^*) - w_L D(p_L^*) - (1-\alpha)(p_L^* - w_L) D(p_L^*)\right]\left(D(p_L^*)\frac{\partial p_L^*}{\partial w_H^*} - D(p_H^*)\frac{\partial p_H^*}{\partial w_H^*}\right) \\ & + \frac{N-1+G(\widehat{s})}{g(\widehat{s})}\left[w_L D'(p_L^*)\frac{\partial p_L^*}{\partial w_H^*} + (1-\alpha)\left(\frac{\partial p_L^*}{\partial w_H^*} D(p_L^*) + (p_L^* - w_L) D'^{*}_{L})\frac{\partial p_L^*}{\partial w_H^*}\right)\right] \\ & + \frac{[1-G(\widehat{s})]}{g(\widehat{s})}\left[D(p_H^*) + w_H D'(p_H^*)\frac{\partial p_H^*}{\partial w_H^*} + (1-\alpha)\left((\frac{\partial p_H^*}{\partial w_H^*} - 1) D(p_H^*) + (p_H^* - w_H) D'^{*}_{H})\frac{\partial p_H^*}{\partial w_H^*}\right)\right]\end{aligned}$$

and

$$\begin{aligned}0 = & \left[w_H D(p_H^*) + (1-\alpha)(p_H^* - w_H) D(p_H^*) - w_L D(p_L^*) - (1-\alpha)(p_L^* - w_L) D(p_L^*)\right]\left(D(p_L^*)\frac{\partial p_L^*}{\partial w_L^*} - D(p_H^*)\frac{\partial p_H^*}{\partial w_L^*}\right) \\ & + \frac{N-1+G(\widehat{s})}{g(\widehat{s})}\left[D(p_L^*) + w_L D'(p_L^*)\frac{\partial p_L^*}{\partial w_L^*} + (1-\alpha)\left((\frac{\partial p_L^*}{\partial w_L^*} - 1) D(p_L^*) + (p_L^* - w_L) D'^{*}_{L})\frac{\partial p_L^*}{\partial w_L^*}\right)\right] \\ & + \frac{[1-G(\widehat{s})]}{g(\widehat{s})}\left[w_H D'(p_H^*)\frac{\partial p_H^*}{\partial w_L^*} + (1-\alpha)\left(\frac{\partial p_H^*}{\partial w_L^*} D(p_H^*) + (p_H^* - w_H) D'^{*}_{H})\frac{\partial p_H^*}{\partial w_L^*}\right)\right]\end{aligned}$$

The following three figures show that the profit of the manufacturer is indeed higher under wholesale price discrimination compared to uniform pricing even under two-part tariffs. The figures show the manufacturer's profit functions under both setting for different values of α, first starting with the case of $\alpha = 1$ in Figure 2.10, which is what we have assumed in the paper, and then two other examples of smaller values of α that translate to cases where the retailer cannot keep all of his profit.

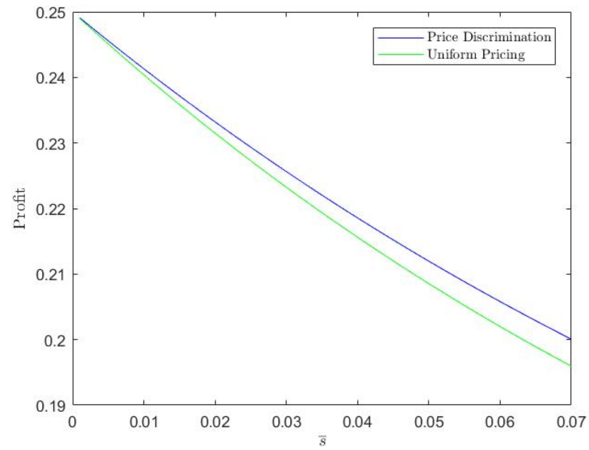

Figure 2.10: Manufacturer's Profit for different values of $\overline{s}$ and $\alpha = 1$

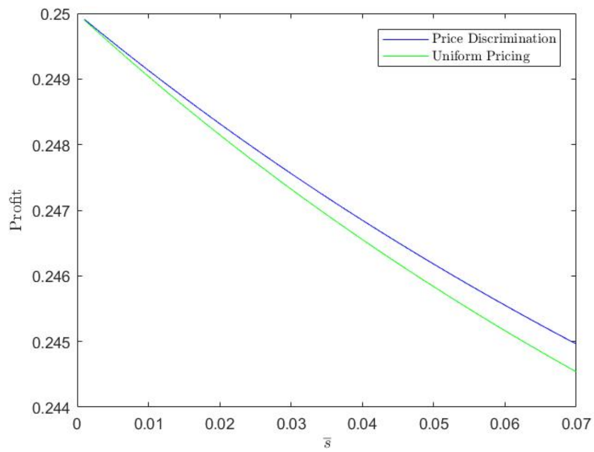

Figure 2.11: Manufacturer's Profit for different values of $\overline{s}$ and $\alpha = 0.1$

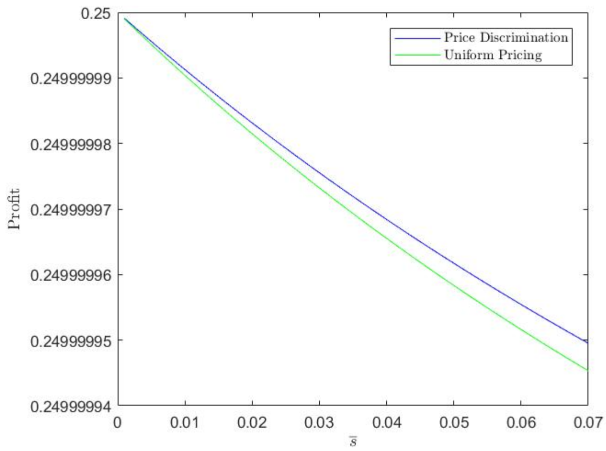

Figure 2.12: Manufacturer's Profit for different values of $\overline{s}$ and $\alpha = 0.000001$

2.9.2 Different search cost distributions

Here, we show that the numerical results regarding the retail and wholesale prices, consumer surplus and manufacturer's profit, obtained in the paper for the case where consumers' search costs were uniformly distributed on $[0, \overline{s}]$, are robust also under different search cost distributions. First, we present the case of the Exponential distribution and then also the results from a special case of the Kumaraswamy distribution.

Exponential Distribution

Here we have assumed that the consumers' search cost follow the Exponential distribution and thus we have that $G(s) = 1 - e^{-\lambda s}$. Figure 2.13(Left) shows that for the case of linear demand and an exponential search cost distribution that the average consumer surplus, including the first costly search, is higher under wholesale price discrimination. Similarly, as for the case of the uniform distribution, Figure 2.13(Right) shows that retail prices, depending on the support of the search cost distribution, can either all be lower than the uniform retail price, or that the high retail price can be higher than what retailers would charge under uniform pricing. Figure 2.14(Left) shows that the manufacturer makes higher profits under wholesale price discrimination compared to uniform pricing, even if search costs are exponentially distributed. Furthermore, in Figure 2.14(Right),we see that, just as we had in the paper under uniform search costs, wholesale prices are non-monotonic in the support of the search cost distribution even for the case of Exponential distribution. Therefore, the wholesale prices can be lower or higher under discrimination compared to uniform pricing, but this will still lead to higher manufacturer profits. The intuition behind the non-monotonicity of wholesale prices is described in Section 2.5 of the paper.

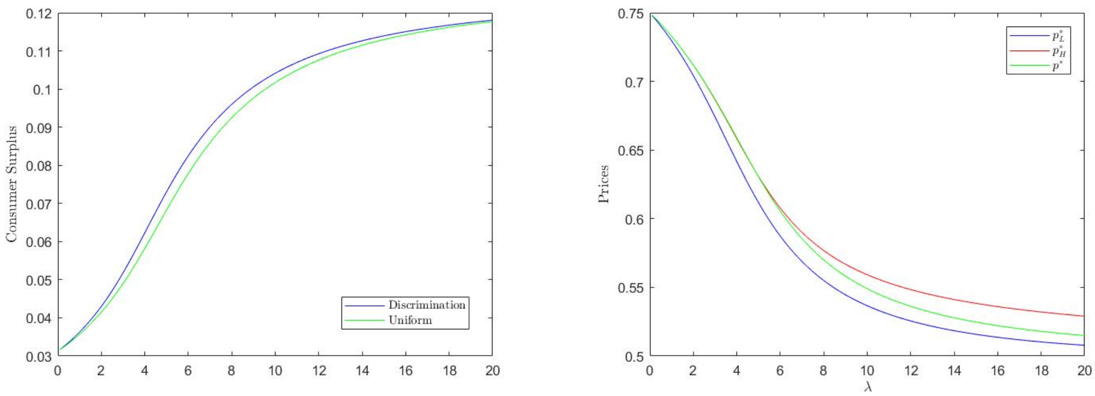

Figure 2.13: **Left:** Consumer surplus for different values of λ. **Right:** Retail prices for different λ.

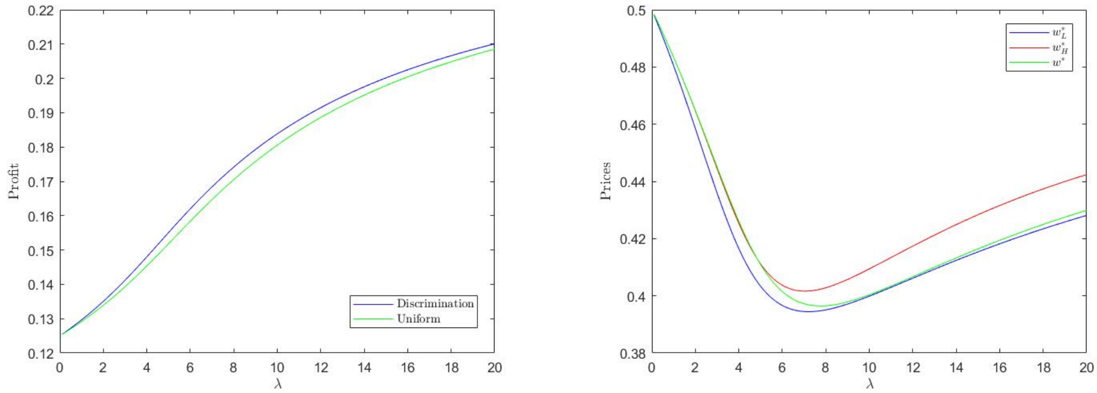

Figure 2.14: **Left:** Manufacturer's profit for different values of λ. **Right:** Wholesale prices for different values of λ.

Kumaraswamy Distribution

Below, we present the results of numerical analysis obtained for the case when consumers search costs follow a special case of the Kumaraswamy distribution, where the shape parameter a is restricted to 1 and the shape parameter b is unrestricted. Therefore, we have that $G(s) = 1 - (1 - s)^b$. Figure 2.15(Left), shows that even for the Kumaraswamy distribution, consumer surplus is higher under wholesale price discrimination. More specifically, for the case of $b = 8$, consumer surplus is almost 4% higher than under uniform pricing. In Figure 2.15(Right), we also see that the behaviour of retail prices depends on the shape parameter b. The high retail price can sometimes either be higher or lower than the uniform retail price. Finally, Figure 2.16(Left) confirms that the manufacturer is better off under discrimination even for this given search cost distribution. The profit increase can be as high as 2.5% under wholesale price discrimination.

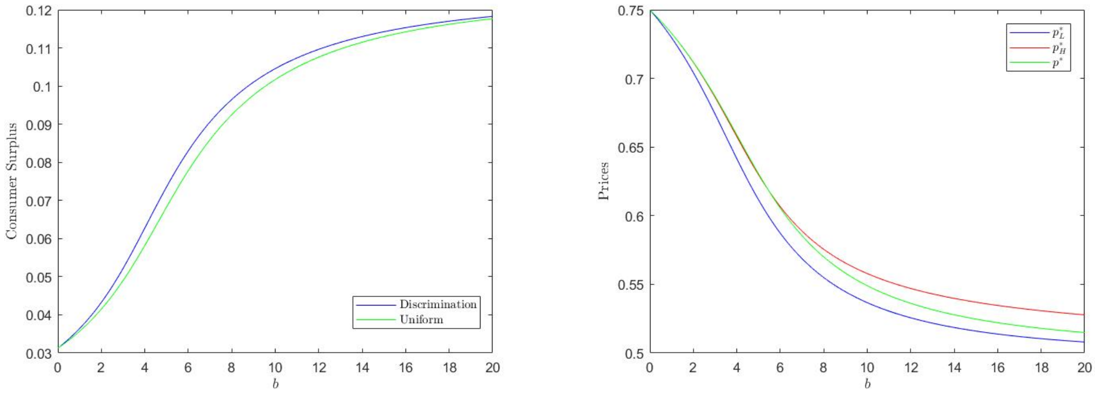

Figure 2.15: **Left:** Consumer surplus for different values of b. **Right:** Retail prices for different b.

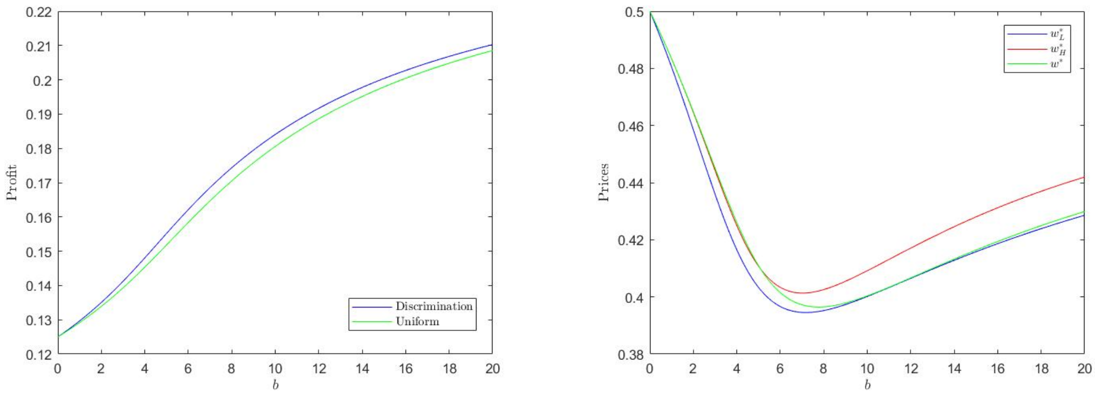

Figure 2.16: **Left:** Manufacturer's profit for different values of b. **Right:** Wholesale prices for different values of b.

2.9.3 $\overline{s}$ approximation

Here, we argue more formally that in a neighbourhood of $\overline{s} = 0$ we can approximate $\overline{s}$ with $1/g(0)$ or $1/g(\widehat{s})$ providing a formal justification for using $d\overline{s}$, $d(1/g(0))$ and $d(1/g(\widehat{s}))$ interchangeably.

Take a sequence of upper bounds of the search cost distribution $\{\overline{s}_n\}_{n=1}^{\infty} \to 0$ and define $g_n(0) = \lim_{\Delta s \downarrow 0} g_n(\Delta s)$.

From the fact that we have assumed that there exists an $M < \infty$ such that $-M < g_n^{'}(s) < M$ it follows that

$$1 = \int_0^{\overline{s}_n} g_n(s) \leq [g_n(0) + M\overline{s}_n]\, \overline{s}_n.$$

This implies that $1/\overline{s}_n - g_n(0) \leq M\overline{s}_n$ so that

$$\lim_{n\to\infty} (1/\overline{s}_n - g_n(0)) \leq 0 = M \lim_{n\to\infty} \overline{s}_n.$$

Similarly,

$$1 = \int_0^{\overline{s}_n} g_n(s) \geq [g_n(0) - M\overline{s}_n]\, \overline{s}_n,$$

which implies that $1/\overline{s}_n - g_n(0) \geq M\overline{s}_n$ so that

$$\lim_{n\to\infty} (1/\overline{s}_n - g_n(0)) \geq 0 = M \lim_{n\to\infty} \overline{s}_n.$$

So, $\lim_{n\to\infty} \overline{s}_n = \lim_{n\to\infty} 1/g_n(0)$.

Extending this argument we now show that $\lim_{n\to\infty} \overline{s}_n = \lim_{n\to\infty} 1/g_n(\widehat{s}_n)$ for every $\widehat{s}_n = f_n(\overline{s}_n)$ with $\lim_{n\to\infty} f_n(\overline{s}_n) = 0$. In particular, as for every $\widehat{s}_n < \overline{s}_n$ we can write $\widehat{s}_n = f_n(\overline{s}_n)$ and provide upper and lower bounds of $g_n(\widehat{s}_n)$ as $g_n(0) - f_n(\overline{s}_n)M \leq g_n(\widehat{s}_n) \leq g_n(0) + f_n(\overline{s}_n)M$, we have, for example, that

$$1 = \int_0^{\overline{s}_n} g_n(s) \leq [g_n(0) + M\overline{s}_n]\, \overline{s}_n \leq [g_n(\widehat{s}_n) + Mf_n(\overline{s}_n) + M\overline{s}_n]\, \overline{s}_n.$$

This implies that $1/\overline{s}_n - g_n(\widehat{s}_n) \leq M\overline{s}_n + +Mf_n(\overline{s}_n)$ so that

$$\lim_{n\to\infty} (1/\overline{s}_n - g_n(\widehat{s}_n)) \leq 0 = M \lim_{n\to\infty} (\overline{s}_n + f_n(\overline{s}_n))\, .$$

In the same way we can establish that 0 is the lower bound of $\lim_{n\to\infty}(1/\overline{s}_n - g_n(\widehat{s}_n))$.

3 Vertical Bargaining and Obfuscation

3.1 Introduction

Obfuscation practices, defined as actions taken by firms that increase consumers' costs of finding out product information, are prevalent in many markets. In this paper, we analyse settings where product manufacturers engage in such obfuscation techniques. According to Ellison and Ellison (2018), one way manufacturers obfuscate is by "proliferating product varieties, even along dimensions that customers do not care about, so that comparing prices becomes a complicated and tedious process". For instance, Richards, Bonnet, Zohra, and Gordon (2016) show that soft-drink manufacturers offer retail-specific variants of their products, which differ only slightly on their multi-pack or container sizes. Vertical restraints are another form of obfuscation manufacturers very often use. Asker and Bar-Isaac (2019) show that informational restraints, such as Minimum Advertised Prices (MAPs) policies, limit the information from retailers to consumers and make it more difficult for them to find and compare products. According to a recent report of the European Commission (2017), retailers are faced with different informational restraints, such as not being allowed to freely advertise prices, selling online or participating in price comparison websites.

Despite the widespread use of such practices by manufacturers, the literature on obfuscation has largely ignored vertical markets. This paper seeks to fill this gap by developing a model that incorporates a vertical market and enables the analysis of manufacturer obfuscation. We analyse a vertical bargaining framework where a monopolist manufacturer bargains with his retailers over wholesale prices and obfuscation levels. In vertical markets, the issue of who sets prices and who imposes vertical restraints is subtle. The vertical contracting literature has mainly worked under the assumption that the bargaining power rests upstream. However, given the dramatic developments in retail markets, such as scanner devices and the introduction of discounters, buyer power has increased. In many markets, lately, the general perception is that the bargaining power has shifted towards retailers.[1] Retailers with high bargaining power have also been known to impose restraints on their suppliers. Such type of practices are known as "buyer-driven" restraints.[2] Therefore, a framework of vertical bargaining over wholesale prices and obfuscation levels seems reasonable to use when analysing such settings.[3]

To analyse the drivers and welfare effects of obfuscation and bargaining, we consider a setting where a monopolist manufacturer produces a homogeneous product and sells it to two downstream retailers who then compete in prices. In the first stage, the manufacturer bargains with the retailers over a linear wholesale price and over the search cost, or obfuscation level. Afterwards, retailers set their prices. Lastly, consumers engage in sequential search. The consumers have unit demands and are modelled a lá Stahl (1989). Thus a fraction of them are shoppers and can search freely, while a fraction are non-shoppers and incur a search cost to learn a firm's price. The novelty here is that the search cost faced by the non-shoppers is an endogenous outcome of the vertical bargaining process between the manufacturer and retailers. We study a situation where the manufacturer cannot

[1] Inderst and Wey (2007), Competition Commission (2000), Competition Commission (2008) and OECD (2009) provide evidence on the growing bargaining power of retailers across Europe and in the US.

[2] Examples of buyer-driven restraints include most-favoured customer clauses, additional payment requirements, conditional purchase behaviour, deliberate risk shifting, etc. For a survey on such restraints see Dobson (2008).

[3] Draganska, Klapper, and Villas-Boas (2010) provide evidence of vertical bargaining in the coffee industry,Crawford and Yurukoglu (2012) show that distributors bargain over input prices in the cable TV industry and Ho and Lee (2017) analyse bargaining in health care markets.

discriminate between its retailers, which is in line with most of the legislation regulating wholesale price discrimination.[4]

We show that in equilibrium the downstream market exhibits price dispersion. Retailers face the trade-off of charging high prices to extract profit from the non-shoppers and charging low prices to attract shoppers (Stahl (1989)). Retailers have an incentive to engage in obfuscation, while the manufacturer does not. The reasoning goes as follows. First, an increase in obfuscation means that the non-shoppers face a higher search cost, which in turn implies that retailers have more market power and can thus charge higher prices. Second, given that the expected retail price is increasing in both wholesale price and search cost, a higher search cost restricts the manufacturer's ability to set a high wholesale price without losing any consumers. Therefore, obfuscation increases retailers' profits by increasing their market power and by also restricting the wholesale prices charged by the manufacturer. The monopolist manufacturer can achieve maximum profits if he sets the monopoly wholesale price equal to the consumers' valuation. This, is only possible if no consumer incurs a positive search cost. Under obfuscation, however, if the manufacturer charges the monopoly wholesale price, then the consumers that have to incur the search cost would have to drop out from the market. So, in order for him not to lose any consumers, he has to charge a lower price. Therefore, in contrast to the retailers, the manufacturer has no incentive to increase non-shoppers' search cost.

This paper makes three contributions. First, our analysis highlights the role of bargaining power by showing that it is the retailers' bargaining power that gives rise to obfuscation. Thus, it provides a new rationale for the widespread use of obfuscation practices by manufacturers. As mentioned, most of the literature on

[4]See, e.g., European Union's Article 102 (c) of the treaty, which forbids dominant firms from applying "dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage".

vertical markets assumes that the bargaining power lies with the suppliers. Yet, over the last years, the bargaining power in many markets has shifted to large retailers. Empirical evidence indicates that the strong position of the retailers is positively correlated with buyer-driven vertical restrains (see e.g., Dobson (2008)). Furthermore, there is anecdotal evidence that many retailers pressure their manufacturers in imposing informational vertical restraints such as MAPs. Our analysis confirms these observations. If the bargaining power is upstream, the manufacturer charges the monopoly price and the retailers set retail prices equal to their marginal costs. Therefore, the industry monopoly outcome is achieved without obfuscation. If retailers have some bargaining power, however, obfuscation arises in equilibrium.

Second, we show that once a vertical structure is considered in a search model with obfuscation, qualitatively different properties arise as compared to settings which disregard upstream arrangements. More specifically, we show that when the production costs of the retailers are not exogenously fixed but set strategically by an upstream manufacturer, an increase in the bargaining power of the retailers, while leading to an increased obfuscation level, results in lower prices for final consumers. Therefore, consumers are better off when faced with higher search costs. This happens because an increase in the bargaining power of the retailers does not only affect the obfuscation or search level that consumers incur but also the input price that the manufacturer sets to the retailers.

The mechanism works as follows. An increase in the bargaining power of retailers has two distinct effects. First, it enables the retailers to bargain a higher search cost, which gives them more market power and increases their profits. We call this the *obfuscation effect*. Second, it allows them to obtain better deals in terms of wholesale prices from the manufacturer, we name this the *input effect*. The *obfuscation effect* puts upward pressure on retail prices, while the *input effect* drives them down. We show that in our setting, as long as the market features a positive share of shoppers, the *input effect* dominates and thus consumers are better off when retailers have higher bargaining power. We find that if the manufacturer has all the bargaining power, no obfuscation occurs in equilibrium and thus the downstream market is perfectly competitive. Consumers, however, are worse off compared to settings where retailers have some bargaining power. This is because the manufacturer acts as a monopolist, charges all retailers the monopoly price and gains monopoly profits by driving both retailers' profits and consumer surplus down to zero.

Finally, as a third contribution, the paper shows that taking vertical markets into account makes a difference when considering the effectiveness of regulation. We discuss the effects that different policy interventions might have in settings where obfuscation and vertical markets coexist. We show that a policy that puts a cap on obfuscation, which has been known to work, may not be effective in protecting consumers. For instance, regulators can ask firms to disclose their fees, to display their prices in such a way that they include all possible add on prices or taxes or to limit the length of complicated contracts. Such a policy has the direct effect of limiting obfuscation, however it also has an indirect unindented effect of inducing higher wholesale prices. We show that, under a binding obfuscation cap, the manufacturer bargains a higher wholesale price. Therefore, any reduction in obfuscation would be outweighed by a higher wholesale price, which would in turn be passed down from retailers to the final consumers. We propose that in cases where the upstream market is either monopolistic or where not enough supplier rivalry exists, consumer protection policies that instead impose a cap on the wholesale price could be effective. Such a policy intervention is followed for instance by Ofgem, the government regulator for gas and electricity markets in the U.K. In 2018, the regulator imposed a cap on wholesale prices and plans to remove it in 2020 if there is enough evidence of supplier rivalry.

In Section 3.5, we show that the findings are robust to a number of extensions. If there is an oligopoly in the downstream market rather than a duopoly, we find that wholesale prices increase with the number of retailers. This implies that an additional countervailing buyer effect arises. We also show that the analysis is robust to the use of two-part tariffs, where the manufacturer and retailers bargain over a search cost, a wholesale price and a fixed fee. Additionally, the results do not change if we think of obfuscation as a decrease in the share of shoppers in the market instead of an increase in the search cost of non-shoppers nor if retailers differ in terms of their bargaining power.

Related Literature. This paper contributes to the expanding obfuscation literature which analyses firms' incentives to impede consumer search (see, e.g. Carlin (2009), Wilson (2010), Ellison and Wolinsky (2012), Piccione and Speigler (2012), Gamp (2016) and Petrikaitė (2018)). The focus of many of the papers in this literature is the so called "collective action" problem, which notes that while it may be collectively rational for firms to obfuscate, it might not be individually rational for them to do so. This is true especially if the obfuscation level is observed ex-ante by consumers. This issue disappears when analysing a setting with an upstream manufacturer, as in our paper, since the manufacturer partakes in obfuscation.

Unlike the present paper, the existing studies do not consider a vertical setting and thus take the firms' production costs as exogenously given. A notable exception is Asker and Bar-Isaac (2019), which focuses on the pro- and anti-competitive effects of Minimum Advertised Prices (MAPs). MAPs are seen as restrictions used by an upstream manufacturer in order to obfuscate actual rather than advertised prices. The authors assume that the manufacturer has all the bargaining power and makes take-it-or-leave-it offers to the retailers. The paper makes use of differences either in consumers' valuations, in retailers' marginal costs or considers upstream competition, in order to provide either a price discrimination, service provision or collusion rationale for MAPs. We differ from this paper in many aspects. First, by not restricting our analysis to a setting where the bargaining power is entirely with the manufacturer, second by not focusing only on a specific form of vertical restraint, such as MAPs. Lastly, we provide a different rationale for upstream obfuscation which is not driven by differences either in consumers' valuations, retailers marginal costs or on upstream competition, but simply by the bargaining power of retailers and the manufacturer.

This paper also adds to the literature on search in vertically related markets (see, e.g Janssen and Shelegia (2015), Lubensky (2017), Garcia, Honda, and Janssen (2017), Garcia and Janssen (2018), Rhodes, Watanabe, and Zhou (2018), Janssen and Shelegia (2018) and Janssen and Reshidi (2019)). All of these existing papers work under the assumption that the bargaining power lies entirely either with the upstream manufacturer or, in special instances, with a monopolist intermediary. Therefore, none of them considers the possibility of bargaining between firms in the supply chain. Furthermore, they take the cost of search as exogenously given and do not allow the possibility of obfuscation. This paper differs from the rest of the literature on vertical markets with search by incorporating vertical bargaining over wholesale prices and search costs, thus allowing for the possibility of endogenously affecting the search cost.

The remainder of the paper is organized as follows. First, in Section 3.2, we describe the model and the vertical bargaining protocol between the manufacturer and the retailers. Then, in Section 3.3, we characterize the equilibrium, first by analysing the retail market and then by looking at the outcome of the bargaining stage and show comparative static results. Section 3.4, discusses policy implications, while extensions are provided in Section 3.5. Finally, Section 3.6 concludes.

3.2 The Model

A monopolist manufacturer, M, produces a homogeneous good and sells it to two competing downstream retailers, R_1 and R_2.[5] For simplicity, the manufacturer's production costs are normalized to zero and this is assumed to be common knowledge to all market participants. Retailers compete in prices and the wholesale price is the only cost they face. There is a unit mass of rational final consumers. Each consumer has unit demand and a maximum willingness to pay of v. Consumers differ in their search costs and are indistinguishable to retailers. A share $\lambda \in (0, 1)$ are shoppers and have zero search costs, while a share $(1 - \lambda)$ of final consumers are non-shoppers and have to pay a search cost $s > 0$ for every search they make, including the first one. Therefore, the model considered in this paper is close to the one first used in Janssen and Shelegia (2015), given that it adds a wholesale level to the model analysed in Stahl (1989). There are, however, three main differences with the Janssen and Shelegia (2015) setting. First, to incorporate the fact that manufacturers can engage in obfuscation, we enable the manufacturer to endogenously affect consumers' search cost and not only the wholesale prices. Second, we allow for vertical bargaining between the manufacturer and the retailers over these two choice variables.[6] Thus, the wholesale price and the search cost that the non-shoppers face, are endogenous outcomes of the bargaining process between the manufacturer and retailers. Finally, to simplify the analysis and be able to study such settings, we focus on the case of unit demand, where we are able to explicitly solve for the reservation price.

The timing of the game is as follows. First, the manufacturer bargains with retailers over the wholesale price and the level of search cost. The bargaining process can be over different wholesale prices w_i and different levels of search costs

[5] The case of $N \geq 2$ is considered as an extension.

[6] In an extension, we also consider the case where the manufacturer bargains over wholesale prices and the share of shoppers λ.

s_i. We focus on an equilibrium which is uniform in wholesale prices and search costs. The retailers and the manufacturer can influence the search cost at no cost. We work under the assumption of observable wholesale prices and search costs.[7] Then, the retailers compete in the downstream market and set retail prices. The retail price distribution is denoted by $F(p)$ and its density by $f(p)$. Finally, after observing the wholesale price w and the level the search cost s, but not knowing retail prices, consumers engage in sequential search with perfect recall. We use SPE as the solution concept, given that the wholesale price and search cost are observed.

3.2.1 Bargaining Protocol

In the first stage, the manufacturer bargains with the retailers over the wholesale price and the obfuscation level. We denote the bargaining power of the manufacturer by β, while the bargaining power of each retailer is $(1-\beta)$, with $\beta \in (0,1)$. When discrimination is forbidden, the two retailers pay the same wholesale price to the upstream manufacturer and also negotiate the same obfuscation levels or search costs. In these scenarios, it is not clear what role each retailer plays in determining the wholesale price and search costs.

I follow O'Brien (2014) and allow the manufacturer to randomly select one of the two retailers to negotiate a wholesale price and search cost[8]. Given that retailers are symmetric in terms of their bargaining power, they are indifferent about which one of them is chosen to bargain with the upstream manufacturer.[9] Therefore, we

[7] In a setting without vertical markets, Ellison and Wolinsky (2012) assume that consumers will be aware of the value of the search cost s_i only once they visit firm i. They show that in that case consumers must view firms as ex-ante identical and that the search order will not matter.

[8] Another form of bargaining, would be for M to negotiate jointly with both retailers; we discuss this in Section 3.6.

[9] The setting would be more complicated to analyse if the retailers were asymmetric in terms of their bargaining power. We abstract from such asymmetries for now, but refer the reader to Section 3.5, for an extension of the model to asymmetric retailers.

assume that the bargaining stage goes as follows. The manufacturer randomly chooses one of the two retailers to bargain over the contract terms and after a successful bargaining he then makes a take-it-or-leave-it offer to the remaining retailer. Following Nash (1950), the generalized bargaining process between the manufacturer and the chosen retailer solves:

$$\max_{w,s} \left[\pi_M(w,s) - \pi_M^0(\hat{w},\hat{s})\right]^{\beta} \left[\pi_R(w,s) - \pi_R^0\right]^{1-\beta}$$

$$s.t \qquad \pi_M(w,s) \geq \pi_M^0(\hat{w},\hat{s}) \quad and \quad \pi_R(w,s) \geq \pi_R^0$$

where (w, s) is the bargaining outcome; $\pi_M(w, s)$ and $\pi_R(w, s)$ are the profits of the manufacturer and the chosen retailer, respectively, and $\hat{w}$ and $\hat{s}$ are the wholesale price and the search cost negotiated with the remaining retailer. Thus, π_M^0 and π_R^0 are the disagreement profits in case the negotiation with the chosen retailer breaks down. Given that the manufacturer is a monopolist, we normalize the retailers' disagreement profits π_R^0 to zero, while the manufacturer's disagreement profit $\pi_M^0(\hat{w},\hat{s})$ is determined endogenously.

3.3 Equilibrium analysis

In this section, we solve the model by initially considering the retail market and analysing consumers' and retailers' behaviour for a given wholesale price w and a given search cost s. Afterwards, we analyse the outcomes of bargaining and also provide comparative statics results with respect to the bargaining power parameter β.

3.3.1 The retail market

In a setting with shoppers, $\lambda \in (0, 1)$, and non-shoppers, retailers face a trade-off between charging high prices to extract profit from the non-shoppers and charging low prices to attract shoppers. In such cases there exists no pure strategy equilibrium and there are no mass points in the equilibrium price distribution. Stahl (1989) has shown that there is, however, a unique symmetric equilibrium in mixed strategies where consumers' behaviour satisfies a reservation price property. In this equilibrium, retailers have to be indifferent between charging any price in the support $[\underline{p}, \overline{p}]$ of the equilibrium price distribution $F(p)$. Given a mixed strategy chosen by the competitor, a retailer's profit form charging any price p in the support of $F(p)$ will be:

$$\pi_R(p, F(p), w) = (p - w)\left[\frac{(1-\lambda)}{2} + \lambda(1 - F(p))\right].$$

The first term represents the profit the retailer makes over the non-shoppers, while the second term corresponds to the profit made from the shoppers, whom the retailer serves with probability $(1 - F(p))$. This profit must equal the profit that the retailer makes if it charged the upper bound of the price distribution $\overline{p}$, which equals:

$$\pi_R(\overline{p}, w) = \frac{(1-\lambda)}{2}(\overline{p} - w) \tag{3.1}$$

Janssen, Moraga-González, and Wildenbeest (2005) have shown that in a setting where the first search is costly, the upper bound of the support $\overline{p}$ must be equal to the consumers' reservation price ρ. Therefore, in a symmetric equilibrium no retailer will have an incentive to charge a price higher than the consumers' reservation price. The equilibrium retail price distribution, shown in Stahl (1989), is characterized in Proposition 3.1.

Proposition 3.1. *For $\lambda \in (0, 1)$, the equilibrium price distribution for the subgame starting with a given w and s is given by:*

$$F(p, w) = 1 - \frac{1-\lambda}{2\lambda}\frac{\overline{p}-p}{p-w} \tag{3.2}$$

with density

$$f(p, w) = \frac{\overline{p}-w}{(p-w)^2}\frac{1-\lambda}{2\lambda} \tag{3.3}$$

and support $[\underline{p}, \overline{p}]$ *where* $\underline{p} = \frac{(1-\lambda)\overline{p}+2\lambda w}{1+\lambda}$ *and* $\overline{p} = \rho$*.*

Proof. See Stahl (1989). □

Proposition 3.1 gives the equilibrium retail price distribution for a given wholesale price w and search cost s, where both are assumed to be observed by the final consumers. Now, we analyse optimal consumer behaviour. The reservation price ρ, is the price that makes the non-shoppers indifferent between purchasing at ρ and paying an extra search cost to receive a new price quote from the equilibrium price distribution. Thus, given a distribution of prices $F(p)$ and an observed price p', the non-shoppers' reservation price, ρ, is determined by solving the following equality:

$$v - \rho = v - s - \int_{\underline{p}}^{\rho} p' f(p)dp$$

Given that in equilibrium $\overline{p} = \rho$, the above expression becomes:

$$\rho = s + E(p) \tag{3.4}$$

Janssen, Pichler, and Weidenholzer (2011) have shown that the expected price paid by the shoppers, who observe all prices in the market and buy at the lowest price, denoted by $E(p_l)$, with $p_l = min\{p_1, p_2\}$, can be expressed as:

$$E(p_l) = w + \frac{1-\lambda}{\lambda}s, \tag{3.5}$$

On the other hand, the expected price paid by the non-shoppers $E(p)$ can be written as:

$$E(p) = w + \frac{\alpha}{1-\alpha}s, \tag{3.6}$$

where $\alpha = \int_0^1 \frac{1}{1+\frac{2\lambda}{1-\lambda}z}dz \in [0,1)$. Note that α goes to one as the fraction of shoppers shrinks, $\lambda \to 0$.

We make use of these results to simplify the expressions needed when analysing the first-stage bargaining process. Equations (3.4) and (3.6), imply that we can rewrite ρ as:

$$\rho = \overline{p} = w + \frac{s}{1-\alpha} \tag{3.7}$$

Furthermore, the non-shoppers must find it worthwhile to search once rather then not at all, therefore in equilibrium the following full participation condition needs to be satisfied:

$$v - E(p) - s \geq 0$$

which by making use of equation (3.6), can be rewritten as:

$$v - w - \frac{s}{(1-\alpha)} \geq 0 \tag{3.8}$$

Finally, by using (3.7), we can rewrite the retail profit given in (3.1) as:

$$\pi_R(w,s) = \frac{s}{(1-\alpha)}\frac{(1-\lambda)}{2} \tag{3.9}$$

Note that because the upper bound of the price distribution $\overline{p}$ simply adds a mark-up over the wholesale price w, the retail profit does not depend on w, however it is decreasing in the fraction of shoppers λ and increasing in non-shoppers search cost s. This summarizes the behaviour of retailers and consumers for a given w

and s. Next, we focus on characterizing the bargaining process outcome between the monopolist manufacturer and the downstream retailers.

3.3.2 Bargaining over the wholesale price and obfuscation

Suppose the manufacturer bargains with R_1 and makes a take-it-or-leave-it offer to R_2. In order to determine the outcome of the bargaining process between M and R_1, we first need to determine the disagreement profit $\pi^0_{M_1}$, which is the profit the manufacturer would obtain if the negotiations with R_1 break down. In case the negotiation with R_1 breaks down, the manufacturer will have to bargain with the last remaining retailer, R_2. If the negotiations with R_2 fail, then given that there is no other retailer to bargain with, the manufacturer's disagreement profit when bargaining with R_2 are $\pi^0_{M_2} = 0$. In this instance, R_2 is a monopolist in the market and his profit will be $\pi_{R_2}(w, s) = v - s - w$. The manufacturer's profit will be $\pi_M = w$, since there is a unit mass of final consumers and his production costs are normalized to zero. Therefore, the generalized bargaining process between M and R_2 solves the following problem:

$$\begin{gathered} \max_{w,s} \left[(w)^{\beta}(v - s - w)^{(1-\beta)}\right] \\ s.t \quad w \geq 0 \quad and \quad v - s - w \geq 0 \end{gathered} \tag{3.10}$$

Solving, we obtain $w^* = \beta v$ and $s^* = 0$. Therefore, the manufacturer's profit in case of a successful negotiation with R_2 is $\pi_{M_2} = \beta v$. This profit, which is endogenously determined by negotiations between M and R_2, serves as the manufacturer's disagreement profit when bargaining with the chosen retailer R_1. Thus, we can write $\pi^0_{M_1} = \beta v$. We have calculated and simplified the profit of a given retailer in the retail market analysis above. This profit is given in (3.9) and will now serve as the profit of the chosen retailer R_1. Furthermore, note that the wholesale price and obfuscation level outcomes are subject to the full participation constraint explained and simplified in (3.8).

Therefore, the generalized Nash bargaining problem between M and R_1 is:

$$\max_{w,s} \left[(w-\beta v)^{\beta} \left(\frac{s}{(1-\alpha)} \frac{(1-\lambda)}{2} \right)^{(1-\beta)} \right] \qquad s.t \quad v - w - \frac{s}{1-\alpha} \geq 0 \tag{3.11}$$

Proposition 3.2, below, is one of the main results and characterizes the equilibrium outcome of the bargaining stage.

Proposition 3.2. *Under uniform wholesale prices and search costs, the equilibrium wholesale price and search cost are given by:*

$$w^* = v - (1-\beta)^2 v \tag{3.12}$$

$$s^* = v(1-\alpha)(1-\beta)^2 \tag{3.13}$$

where $\alpha = \int_0^1 \frac{1}{1+\frac{2\lambda}{(1-\lambda)}z} dz \in [0,1)$. *The wholesale price is increasing in* β, *while the search cost is decreasing in* β. *The profit of the manufacturer increases in* β, *while the retail profits decrease in* β.

The above result shows that if the bargaining power rests downstream, i.e when $\beta = 0$, the manufacturer sets the wholesale price equal to his marginal cost, which we have normalized to zero, and chooses the highest value of obfuscation that can be set without losing any consumers. By contrast, if the bargaining power lies entirely with the manufacturer, i.e, when $\beta = 1$, the manufacturer does not engage in obfuscation and sets the wholesale price at the monopoly level. The obfuscation level decreases in the manufacturer's bargaining power and is positive for any β smaller than 1. Therefore, this result supports the view that higher obfuscation levels are associated with higher bargaining power of retailers. The manufacturer's profit increases in w and decreases in the obfuscation level faced by the final consumers in the downstream market, while the opposite holds true for the retailers. Therefore, unsurprisingly, the profit of the manufacturer increases in β, while the retailers' profits decrease in β. Figure 3.1 below depicts the equilibrium wholesale price and search cost for different values of the bargaining power parameter.

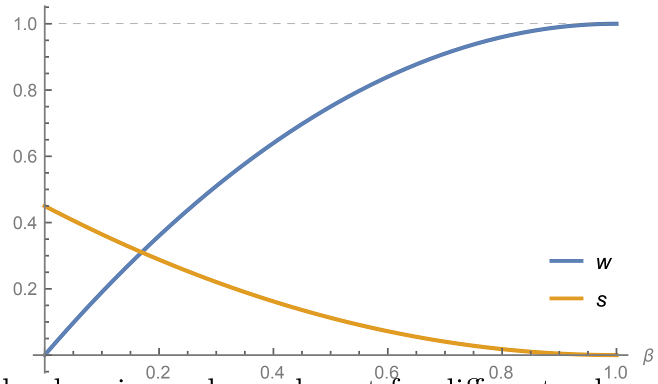

Figure 3.1: Wholesale price and search cost for different values of β, when $v = 1$ and $\lambda = 0.5$

3.3.3 Comparative statics

In our model, a decrease in the manufacturer's bargaining power, denoted by β, has two different effects on the expected retail prices, that paid by the shoppers and that paid by the non-shoppers. First, it decreases the wholesale price charged by the manufacturer to the retailers, thus putting downward pressure on expected retail prices which makes consumers better off. We call this the *"input effect"*. Secondly, a decrease in β increases the search cost that the final consumers face. We call this the *"obfuscation effect"*. The following proposition shows that in our setting the *"input effect"* dominates the *"obfuscation effect"*. Thus, expected prices increase and consumer surplus decreases with an increase on the bargaining power of the manufacturer.

Proposition 3.3. *The expected price paid by the non-shoppers $E(p)$ and the expected price paid by the shoppers $E(p_l)$ are both increasing in β. Consumer* *surplus decreases in β. In the limit, as $\beta \to 1$, $E(p), E(p_l)$ and w^* converge to the monopoly price v.*

In order to understand the mechanism that is driving this result, let us first substitute the optimal bargained values of the wholesale price w^* and search cost s^* into the expected price that the non-shoppers pay given in 3.6. Doing so, we obtain:

$$E(p) = v - (1-\beta)^2 v + \alpha v(1-\beta)^2 \tag{3.14}$$

Taking the derivative of 3.14 with respect to β gives:

$$\frac{\partial E(p)}{\partial \beta} = \underbrace{2v(1-\beta)}_{\text{input effect}} - \underbrace{2v(1-\beta)\alpha}_{\text{obfuscation effect}} \tag{3.15}$$

From 3.15 one can see that, because $\alpha \in [0, 1)$, the input effect dominates the obfuscation effect. As the fraction of shoppers shrinks, $\lambda \to 0$, α goes to one. In this case, the effects cancel out and thus the expected price paid by the non-shoppers does not change with β. However, as long as there are some shoppers in the market, α is smaller than one and thus an increase in the bargaining power of the manufacturer leads to a higher expected retail price. Intuitively, obfuscation affects competition less because it changes the way the non-shoppers search while it does not affect the search process of shoppers. On the other hand, a change in the wholesale price, given that it changes the marginal cost of all units sold, affects both types of consumers.

Figure 3.2, depicts both expected prices and the consumer surplus for different values of β. The expected consumer surplus $E(CS)$ is calculated using the following expression:

$$E(CS) = \lambda(v - E(p_l)) + (1-\lambda)(v - E(p) - s)$$

The first term on the right denotes the surplus of the shoppers, of which there is an

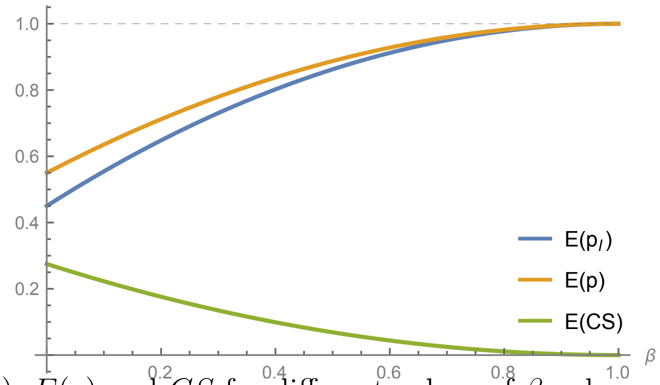

Figure 3.2: $E(p_l)$, $E(p)$ and CS for different values of β, when $v = 1$ and $\lambda = 0.5$

λ share, while the second term denotes the surplus from the non-shoppers, of which there is a $(1 - \lambda)$ share in the market. When the bargaining power rests completely with the manufacturer, there is no obfuscation and thus the downstream market is perfectly competitive. However, while consumers face no search cost, they get no surplus. This is because the manufacturer acts as a monopolist and sets the wholesale price equal to the consumers' valuation. Retailers in turn set retail prices equal to their marginal cost of v. The comparative static results in Proposition 3.2 and in Proposition 3.3 generate new testable predictions. Specifically, the model predicts that we should observe higher obfuscation levels when retailers have more bargaining power and that expected retail prices will be higher under lower search costs.

Proposition 3.4. *The expected price paid by the non-shoppers $E(p)$ and the expected price paid by the shoppers $E(p_l)$ are both decreasing in λ. Consumer surplus increases in λ. In the limit, as $\lambda \to 1$, $E(p)$ and $E(p_l)$ converge to the wholesale price w^*. The wholesale price w is independent of λ, while the search cost s is increasing in λ.*

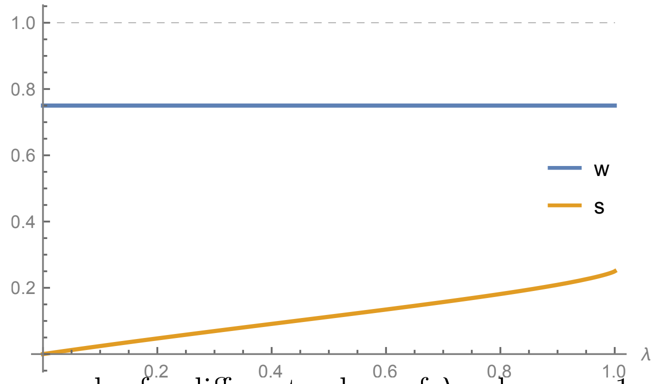

Figure 3.3: w and s for different values of λ, when $v = 1$ and $\beta = 0.5$

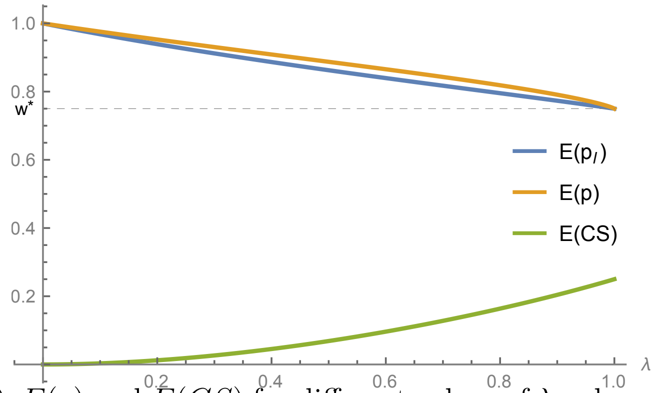

Figure 3.4: $E(p_l)$, $E(p)$ and $E(CS)$ for different values of λ, when $v = 1$ and $\beta = 0.5$

In our model, an increase in the share of shoppers increases the search cost s through its effect on α, which unambiguously puts downward pressure on w. Furthermore, an increase in λ decreases the expected retail price that the non-shoppers pay, again through its effect on α, which puts upward pressure on w. Proposition 3.4 showed that the net result of these two effects on w is zero. In Figure 3.3, we depict the wholesale price and the search cost for different values of the share of shoppers, while in Figure 3.4 we show how the expected retail prices and the expected consumer surplus change with λ.

3.4 Policy Implications

In this Section, we discuss potential effects of different regulations and show that some of them may have undesired effects in vertical markets.

First, suppose that a regulator imposes a cap of $\overline{s} \geq 0$ on the search cost. Then, the bargained search cost should be below the cap. If the cap is not binding then the bargained outcomes s^* and w^* would not be affected and still be as in (12) and (13). However, if the imposed cap $\overline{s}$ is binding, then $s = \overline{s}$ is the optimal search cost and $\overline{w} = v - \frac{\overline{s}}{1-\alpha}$. Given that $\overline{s} < s^*$, this implies that $\overline{w} > w^*$. As we have shown before, such an increase in the wholesale price outweighs the decrease in the search cost and results in a higher expected retail price. So a regulation that would impose a (binding) cap on s, would first have the desired effect of limiting obfuscation. However, such a regulation would also have an indirect undesired effect of inducing higher input (wholesale) prices. Such an intervention would lead to higher expected retail prices and thus make final consumers worse off. So we find that while policies that limit obfuscation may be effective in retail markets they can backfire when imposed in vertical markets.

One can also lower obfuscation in vertical markets by reducing retailers' bargaining power. Recently, with an increase in the buyer power of retailers, regulators have also been interested in implementing such type of policies. For instance, Hayashida (2019) shows that policy makers in Japan are trying to equalize the bargaining power between suppliers and retailers in the Japanese grocery supply chains. He finds that such a policy translates to higher wholesale prices, which in turn result in higher retail prices and thus lower consumer welfare. In our model, such a policy can be interpreted as an exogenous decrease in β. According to our comparative statics result with respect to β, a decrease in retailers' bargaining power leads to higher expected retail prices and thus lower consumer welfare. Therefore, policies that try to reduce retailers' bargaining power may yield undesired effects.

Alternatively, suppose that a regulator implements a policy that increases the share of shoppers in the market. This could be done, for instance, by offering educational programmes or by promoting price comparison websites. In order to analyse if such an intervention would have the desired effects, it suffices to consider what happens to the expected consumer surplus with an increase in λ. In the previous Section, we have shown that an increase in the share of shoppers, λ, leads to lower expected retail prices and thus higher expected consumer surplus. Thus, in these markets, instead of limiting obfuscation, an effective policy on the consumers side could be an intervention that increases the share of shoppers.

Finally, suppose that a regulator imposes a cap $\overline{w} > 0$ on the wholesale price that the manufacturer charges. This would imply that the wholesale price bargained would be $\in [0, \overline{w}]$. If the cap is binding then, in equilibrium, $w^* = \overline{w}$, while the search cost would be $\overline{s} = (v - \overline{w})(1 - \alpha) > (v - w)(1 - \alpha) = s^*$. Depending on the increase in the search cost, such a policy could be effective in protecting consumers. An example of such a policy intervention is Ofgem, the government regulator for gas and electricity markets in the U.K. In 2018, the regulator imposed a cap on wholesale prices and plans to remove it in 2020 if there is enough evidence of supplier rivalry. We propose that a combination of both caps, one on s and another on w would be ideal in protecting final consumers. This because a combination of caps removes the undesired indirect effects of imposing only one type of cap. For instance, we showed that a cap on obfuscation leads to higher wholesale prices, however, if there is a binding cap on the wholesale price as well then this undesired effect is eliminated. Thus, consumers are directly protected from both higher wholesale prices and higher search costs.

3.5 Extensions

In this section, I discuss some extensions of the model.

3.5.1 Many Retailers

Until now, we have looked at a duopoly setting in the downstream market. This was done with the aim of making the bargaining protocol process between the manufacturer and retailers easy to understand and follow. Here, we analyse the robustness of our results in an oligopoly setting. We find that an additional countervailing buyer power arises in these markets. A larger number of retailers downstream leads to higher wholesale and retail prices. We will show how this mechanism works.

First, assume that there are $N \geq 2$ retailers in the downstream market. As we have shown in Section 3.3, there exist a unique symmetric equilibrium in mixed strategies. A retailers profit from charging a price any price p in the support $[\underline{p}, \overline{p}]$ of the equilibrium price distribution $F(p)$ will be:

$$\pi_R(p, F(p), w) = \left[\frac{1-\lambda}{N} + \lambda(1 - F(p))^{N-1}\right](p - w)$$

The first term gives the profit that the retailer makes from the non-shoppers, while the second term shows the profit a retailer makes over the shoppers (which he serves with probability $(1 - F(p))^{N-1}$. In a mixed strategy equilibrium, this profit has to be equal to the profit that a retailer makes if it charges the upper bound of the price distribution, which is $\frac{1-\lambda}{N}(\overline{p} - w)$. The equilibrium price distribution is characterized below.

Proposition 3.5. *For $\lambda \in (0, 1)$, the equilibrium price distribution for the subgame starting with a given w and s is given by:*

$$F(p, w) = 1 - \left(\frac{1-\lambda}{N\lambda}\frac{\overline{p} - p}{p - w}\right)^{\frac{1}{N-1}} \tag{3.16}$$

with density

$$f(p,w) = \frac{1}{N-1}\frac{\overline{p}-w}{(p-w)^2}\left(\frac{1-\lambda}{N\lambda}\right)^{\frac{1}{N-1}}\left(\frac{\overline{p}-p}{p-w}\right)^{\frac{2-N}{N-1}} \tag{3.17}$$

and support $[\underline{p},\overline{p}]$ *where* $\underline{p} = \frac{\lambda N}{\lambda N+1-\lambda}w + \frac{1-\lambda}{\lambda N+1-\lambda}\overline{p}$ *and* $\overline{p} = \rho$.

The optimal consumer behaviour does not change and thus the reservation price ρ and the expected prices, $E(p_l)$ and $E(p)$, are as given in $(4), (5)$ and (6). Thus, the generalizes Nash bargaining problem between M and R_1 is:

$$\max_{w,s}\left[(w-(v-(1-\beta)^{(N-1)}v))^{\beta}\left(\frac{s}{(1-\alpha)}\frac{(1-\lambda)}{N}\right)^{(1-\beta)}\right] \qquad s.t \quad v-w-\frac{s}{1-\alpha}\geq 0 \tag{3.18}$$

The following proposition characterizes the equilibrium outcome of the bargaining stage for the case of oligopoly instead of the duopoly case that we characterized before.

Proposition 3.6. *When there are* $N \geq 2$ *retailers in the downstream market, the wholesale price and search cost are given by:*

$$w^* = v - (1-\beta)^N v \tag{3.19}$$

$$s^* = v(1-\alpha)(1-\beta)^N \tag{3.20}$$

where $\alpha = \int_0^1 \frac{1}{1+\frac{N\lambda}{(1-\lambda)}z^{N-1}}dz \in [0,1)$. *The wholesale price is increasing in* β, *while the search cost is decreasing in* β. *The profit of the manufacturer increases in* β, *while the retail profits decreases in* β.

The comparative static result with respect to the number of retailers is given in the following proposition. This result shows that the optimal wholesale price is increasing in the number of retailers, while the opposite holds true for the search cost bargained.

Proposition 3.7. *The wholesale price increases in N, while the search cost decreases in N. As $N \to \infty$, w^* converges to the monopoly price v, while s^* converges to* 0.

This relates to the concept of countervailing buyer power, which says that greater retail concentration not only increases retailers' market power, but also increases their bargaining power and in this way it can lead to lower input prices. We see that, in our setting, a countervailing effect arises since wholesale prices are indeed lower for smaller N. The Stahl (1989) type models have the interesting feature that the equilibrium expected price $E(p)$ increases with the number of firms. As N increases, competition increases which pushes firms to charge lower prices; but with an increase in N, the probability of being the cheapest firm also decreases, which puts upward pressure on prices. It has been shown that, overall, the second effect dominates. Here, however, we are showing that under bargaining another force will also drive equilibrium expected retail prices upwards, and this is the change in the input price that the retailers will face. So, a higher N will also mean higher input or wholesale prices.

In this paper, we are showing another way in which countervailing buyer power may arise, by increasing consumers' search costs and not retail concentration. We have seen that an increase in search costs, while leading to higher market power of retailers, also led to an increase in their bargaining power and lower input prices. It is important, however, to note the difference in the countervailing effects coming from these two distinct situations. An increase in retail concentration increases retailers' bargaining power through decreasing the manufacturer's disagreement profit that the manufacturer obtains in case of a negotiation breakdown. However, an increase in search costs, increases the bargaining power of retailers' by limiting the scope of the wholesale price that the manufacturer can set without losing final consumers.

3.5.2 Two-part tariffs

Until now our model has worked under the assumption that the vertical contracts between the manufacturer and the retailers are linear in wholesale prices. Once we have positive search costs in the downstream market, such contracts lead to double marginalization problems. Such types of contracts are used extensively in practice.[10] However, there are also markets where firms engage in either optimal or sub-optimal non-linear contracts, which enable firms to maximize their joint profits. In this section, we extend the model to two-part tariffs. More specifically, we analyse cases in which the manufacturer and retailers do not bargain only over a liner wholesale price w and a search cost s, but also over a fixed fee F. We show that the manufacturer is not better off under two-part tariffs.

Let us assume that the manufacturer chooses to bargain with R_1. As we have done before, we first have to determine what the disagreement profit is in case of a negotiation breakdown. This is be determined endogenously, by a separate bargaining between M and R_2. Thus, the generalized bargaining process between M and R_2 solves:

$$\begin{gathered}\max_{w,F,s}\left[(w+F)^{\beta}(v-w-F)^{(1-\beta)}\right]\\ s.t \quad w+F\geq 0 \quad and \quad v-w-F\geq 0\end{gathered}\tag{3.21}$$

Solving we obtain $w^{*}=\beta v$, $F^{*}=0$ and $s^{*}=0$. So, we have determined that the profit in case of negotiation failure equals $\pi_M^0=\beta v$. Thus, the generalized Nash bargaining problem between M and R_1 is:

[10] For evidence on linear contracts see e.g., Crawford and Yurukoglu (2012) on arrangements between TV channels and cable-TV distributors, Grennan (2013) on medical device manufacturers and hospitals, Gilbert (2015) on book publishers and resellers.

$$\max_{w,F,s}\left[(w+F-\beta v)^{\beta}\left(\frac{s}{(1-\alpha)}\frac{(1-\lambda)}{2}-F\right)^{(1-\beta)}\right] \qquad s.t \quad v-w-\frac{s}{1-\alpha}\geq 0 \tag{3.22}$$

The proposition below characterizes the equilibrium outcome of this bargaining stage.

Proposition 3.8. *Under two-part tariffs, the wholesale price, the fixed fee and the search cost are given by:*

$$w^{*}=\frac{(-1+\lambda+2\beta)v}{(1+\lambda)} \tag{3.23}$$

$$F^{*}=\frac{(1-\lambda)(1-\beta)v}{(1+\lambda)} \tag{3.24}$$

$$s^{*}=\frac{2(1-\alpha)(1-\beta)v}{(1+\lambda)} \tag{3.25}$$

where $\alpha=\int_0^1 \frac{1}{1+\frac{2\lambda}{1-\lambda}z}dz\in[0,1)$. *The wholesale price* w *increases in* β*, while the fixed fee* F *and the search cost* s *decrease in* β*.*

Proposition 3.8 shows that the results we have obtained in the case of linear tariffs are robust even if the manufacturer and retailers bargain over two-part tariffs. More specifically, we find that the wholesale price increases in the manufacturer's bargaining power, while the fixed fee and the search cost decrease in β. It is interesting to point out, that the manufacturer is not better off under two-part tariffs. This because he has to first bargain over the fixed fee and thus cannot simply extract the retail profit completely and second because the search cost under two-part tariffs are higher compared to the case of linear contracts.

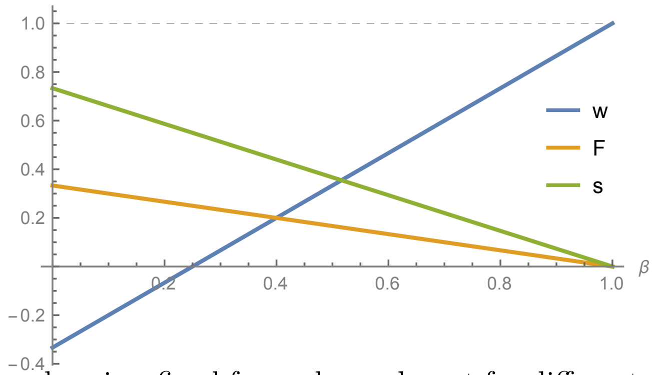

Figure 3.5: Wholesale price, fixed fee and search cost for different values of β, $v = 1$, $\lambda = 0.5$

3.5.3 Asymmetric Retailers

Until now we have worked under the assumption that retailers are symmetric in terms of their bargaining power. However, it is natural to think that some retailers may have stronger bargaining power compared to others. In such settings, the retailers might prefer that the one with the stronger bargaining power is chosen to bargain with the manufacturer, since better terms could be negotiated for both of them. On the other hand, the manufacturer might prefer to negotiate with the weaker retailer. Therefore, the choice of the negotiating retailer may be more tedious compared to settings with symmetric retailers.

In order to provide answers to such questions, we now analyse a setting where the retailers in the downstream market differ in their bargaining power and have to negotiate with the upstream manufacturer. Let us denote the bargaining power of R_1 by $(1 - \beta_1)$ and the bargaining power of R_2 by $(1 - \beta_2)$, and suppose that $\beta_1 < \beta_2$. Therefore, we are assuming that retailer R_1 is stronger in bargaining than retailer R_2. Suppose that the manufacturer chooses to negotiate with the weaker retailer R_2. We know from our analysis before, that if this bargain fails, then the manufacturer would have to negotiate with R_1. So, the disagreement profit when M negotiates with R_2, is $\pi_M^0 = \beta_1 v$. So, the Nash bargaining problem between M

and R_2 would be:

$$\max_{w,s}\left[(w-\beta_1 v)^{\beta_2}\left(\frac{s}{(1-\alpha)}\frac{(1-\lambda)}{2}\right)^{(1-\beta_2)}\right] \qquad s.t \quad v-w-\frac{s}{1-\alpha}\geq 0 \tag{3.26}$$

Alternatively, suppose that M decides to first bargain with the stronger retailer R_1. In this case, the disagreement profit in case of negotiation failure equals $\pi_M^0=\beta_2 v$ and thus the Nash bargaining problem between M and R_1 solves:

$$\max_{w,s}\left[(w-\beta_2 v)^{\beta_1}\left(\frac{s}{(1-\alpha)}\frac{(1-\lambda)}{2}\right)^{(1-\beta_1)}\right] \qquad s.t \quad v-w-\frac{s}{1-\alpha}\geq 0 \tag{3.27}$$

In the following proposition we characterize the equilibrium outcomes of both of these Nash bargaining problems. We show that, under endogenous disagreement profit calculations, it does not matter which retailer is chosen as the "representative" retailer to bargain with the manufacturer since the equilibrium outcomes of both of these problems coincide.[11] In addition, we show that, as long as at least one of the retailers has some bargaining power, the equilibrium will exhibit obfuscation.

Proposition 3.9. *Let $N=2$, and let the bargaining power of R_1, respectively R_2, be denoted by $(1-\beta_1)$, respectively $(1-\beta_2)$, where $\beta_1<\beta_2$. No matter which retailer is chosen by the manufacturer to bargain with, the wholesale price and*

[11] The issue would be different if the legal regulation on wholesale price discrimination imposed on the manufacturer would also have to hold for the disagreement profits. This would imply that in case of negotiation failure, with either one of the retailers, the manufacturer' disagreement profit would be set to zero. In this case, if M chose to bargain with R_1 then we would have $w^*=\beta_1 v$ and $s^*=(1-\alpha)(1-\beta_1)v$, while if M were to bargain with R_2 we would have $w^*=\beta_2 v$ and $s^*=(1-\alpha)(1-\beta_2)v$. In such scenarios, coordination issues may arise in case retailers are able to coordinate their actions and thus the weaker retailer could simply refuse to negotiate with the manufacturer. If we abstract away such coordination possibilities from our analysis, we could think that M would choose to bargain with R_2, which would lead to an equilibrium with higher wholesale prices and lower search costs under asymmetric retailers.

search cost are given by:

$$w^* = v - (1-\beta_1)(1-\beta_2)v$$

$$s^* = (1-\alpha)(1-\beta_1)(1-\beta_2)v$$

where $\alpha = \int_0^1 \frac{1}{1+\frac{2\lambda}{1-\lambda}z}dz \in [0,1)$. *The wholesale price* w^* *increases in* β_1 *and* β_2, *while the search cost* s^* *decreases in* β_1 *and* β_2.

Thus, as long as the bargaining protocol remains the same, where one retailer is chosen at random and the other receives a take-it-or-leave-it offer from the manufacturer, the results of this paper are robust to retailers having different bargaining powers. This since no matter which retailer is chosen as a representative, the tension between the manufacturer wanting higher wholesale prices and lower obfuscation levels and the retailers preferring the opposite does not disappear, and nor does it depend on differences in the retailers' bargaining powers.

3.5.4 Bargaining over λ instead of s

Up to this point, we have thought of obfuscation as an action that increases consumers' search cost. However, we can also think of obfuscation as an action that leads to a smaller share of shoppers in the market. Thus, we would then have a setting in which the manufacturer and retailers bargain over the wholesale price w and the share of shoppers λ, while the search cost s would be exogenously given. In that case, if the bargaining with R_1 fail, the manufacturer bargains with the remaining retailer R_2. Thus, the generalized bargaining process between M and R_2 solves the following problem:

$$\begin{aligned} &\max_{w,\lambda} \left[(\lambda w)^{\beta}(\lambda(v-w))^{(1-\beta)}\right] \\ &s.t \quad w \geq 0 \quad and \quad v-w \geq 0 \end{aligned} \tag{3.28}$$

Solving we obtain $w^* = \beta v$ and $\lambda^* = 1$. Therefore, the manufacturer's profit in case of a successful negotiation with R_2 is $\pi_{M_2} = \beta v$. This profit, which is endogenously determined by negotiations between M and R_2, serves as the manufacturer's disagreement profit when bargaining with the chosen retailer R_1. Thus, we can write $\pi^0_{M_1} = \beta v$. We have calculated and simplified the profit of a given retailer in the retail market analysis above. This profit is given in (3.9) and will now serve as the profit of the chosen retailer R_1. Furthermore, note that the wholesale price and obfuscation level outcomes are subject to the full participation constraint explained and simplified in (3.8). Therefore, the generalized Nash bargaining problem between M and R_1 in this case is:

$$\max_{w,\lambda} \left[(w - \beta v)^{\beta} \left(\frac{s}{(1-\alpha)} \frac{(1-\lambda)}{2} \right)^{(1-\beta)} \right] \qquad s.t \qquad v - w - \frac{s}{1-\alpha} \geq 0 \tag{3.29}$$

where $\alpha = \int_0^1 \frac{1}{1+\frac{2\lambda}{1-\lambda}z} dz \in [0,1)$.

The proposition below characterizes the equilibrium outcome of this bargaining stage.

Proposition 3.10. *When bargaining over λ and w, the wholesale price is given by:*

$$w^* = v - 2sf(\lambda^*)$$

where $f(\lambda^*) = \frac{\lambda}{2\lambda - (1-\lambda)\log[\frac{1+\lambda}{1-\lambda}]}$ and λ^* is the solution to:

$$(1-\lambda^*)(v(1-\beta)^2 - 2sf(\lambda^*))f'(\lambda^*) - (1-\beta)f(\lambda^*)(v(1-\beta) - 2sf(\lambda^*)) = 0$$

The wholesale price w and the share of shoppers λ are increasing in β. In the *limit, as* $\beta \to 1$*,* λ^* *goes to* 1*, while* $f(\lambda^*) \to \frac{1}{2}$ *and thus* w^* *converges to* $v - s$*.*

3.6 Conclusion

In this paper, we analyse obfuscation practices that come from upstream manufacturers rather than downstream firms. Such practices, that increase consumers' costs of searching for prices, are widespread in many different markets. Manufacturers can obfuscate by imposing different vertical restraints that limit the information consumers have on prices or products. We show that obfuscation will arise once retailers have some bargaining power. On the other hand, when the bargaining power lies entirely with the monopolist manufacturer no obfuscation occurs in equilibrium and thus the downstream market is perfectly competitive. The fact that there is no obfuscation does not imply, however, that the consumers are better off, since the manufacturer acts as a monopolist and charges monopoly prices to its retailers, which then charge monopoly prices to the final consumers.

The findings suggest that regulators should take into account the market structure when designing consumer protection policies. For instance, we find that policies that put caps on obfuscation may backfire in vertical markets. In addition to the desired effect of limiting obfuscation they also have an undesired effect of inducing higher wholesale prices. The findings suggest that, instead, policies that put caps on wholesale prices or that induce an increase in the share of shoppers may be effective. Recently, such a policy that limits wholesale prices is being used in by the regulator of gas and electricity markets in the U.K.

The bargaining protocol used relates to the "delegation approach" method used in the theoretical bargaining literature. In many applied fields of economics, such as labour, international, and financial economics, a group of individuals is considered as a single bargainer. This approach is suitable especially in settings where the group members are symmetric. Thus, in our case, given that we consider symmetric retailers in terms of marginal costs and in terms of their bargaining power, this seems to be a simplified and reasonable protocol to follow. We have also shown that the findings are robust even if retailers were to differ in their bargaining powers, even though the issue of choosing the retailer with whom to negotiate becomes more subtle. Another form of bargaining would be for manufacturers to negotiate jointly with retailers. Our findings are robust even under such a bargaining protocol, however we do not focus on this here since such forms of bargaining seem improbable and might be dubious from an antitrust perspective given that retailers have to compete in the downstream market.

3.7 Appendix

Proof of Proposition 3.2: The first order conditions for 3.11 are:

$$2^{(-1+\beta)}\beta\left(\frac{s(1-\lambda)}{(1-\alpha)}\right)^{(1-\beta)}(w-\beta v)^{(-1+\beta)}-\mu=0 \tag{3.30}$$

$$\frac{2\mu-2^{\beta}(-1+\beta)(-1+\lambda)\left(\frac{s(-1+\lambda)}{(-1+\alpha)}\right)^{-\beta}(w-\beta v)^{\beta}}{2(-1+\alpha)}=0 \tag{3.31}$$

$$\mu\geq 0, \qquad \mu\left(v-w-\frac{s}{1-\alpha}\right)=0 \tag{3.32}$$

where μ is the Lagrangian multiplier. We obtain 3.12 and 3.13 by solving 3.30, 3.31 and 3.32. The second order conditions for 3.11 are:

$$-2^{(-1+\beta)}\beta(1-\beta)\left(\frac{s(1-\lambda)}{(1-\alpha)}\right)^{(1-\beta)}(w-\beta v)^{(-2+\beta)}<0$$

$$\frac{-2^{(-1+\beta)}\beta(1-\beta)\left(\frac{s(1-\lambda)}{(1-\alpha)}\right)^{(1-\beta)}(w-\beta v)^{\beta}}{s^2}<0$$

We now derive the comparative static result. Taking the derivative of 3.12 with respect to β, we obtain:

$$\frac{\partial w^*}{\partial \beta} = 2v(1-\beta) > 0$$

On the other hand, taking the derivative of 3.13 with respect to β gives:

$$\frac{\partial s^*}{\partial \beta} = -2v(1-\alpha)(1-\beta) < 0$$

Substituting 3.12 and 3.13 into the manufacturer's profit function and into the retailer's profit functions gives: $\pi_M^* = \beta v(2-\beta)$ and $\pi_{R_i}^* = v(1-\beta)^2 \frac{(1-\lambda)}{2}$, where $i = 1, 2$. Taking the derivative with respect to β gives: $\frac{\partial \pi_M^*}{\partial \beta} = 2v(1-\beta) > 0$ and $\frac{\partial \pi_{R_i}^*}{\partial \beta} = -v(1-\alpha)(1-\beta) < 0$.

Proof of Proposition 3.3: Substituting the equilibrium wholesale price w^* given in 3.12 and the equilibrium search cost s^* given in 3.13 into 3.5 and 3.6 gives:

$$E(p_l) = \beta v(2-\beta) + \frac{(1-\lambda)v(1-\alpha)(1-\beta)^2}{\lambda} \tag{3.33}$$

$$E(p) = \beta v(2-\beta) + \alpha v(1-\beta)^2 \tag{3.34}$$

Taking the derivative of 3.33 and 3.34 with respect to β, we obtain:

$$\frac{\partial E(p_l)}{\partial \beta} = \frac{2v(1-\beta)\left[\lambda(1-\alpha)+\alpha\right]}{\lambda} > 0$$

$$\frac{\partial E(p)}{\partial \beta} = 2v(1-\alpha)(1-\beta) > 0$$

On the other hand, the expected consumer surplus becomes:

$$E(CS) = v\lambda(1-\beta)^2 - s(1-\lambda) \tag{3.35}$$

Taking the derivative of 3.35 with respect to β, we obtain:

$$\frac{\partial E(CS)}{\partial \beta} = -2\lambda v(1-\beta) < 0$$

Proof of Proposition 3.4: Taking the derivative of 3.33 and 3.34 with respect to λ, we obtain:

$$\frac{\partial E(p_l)}{\partial \lambda} = \frac{2v(1-\beta)\left[\lambda(1-\alpha)+\alpha\right]}{\lambda} < 0$$

$$\frac{\partial E(p)}{\partial \lambda} = 2v(1-\alpha)(1-\beta) < 0$$

Finally, taking the derivative of 3.35 with respect to λ, we obtain:

$$\frac{\partial E(CS)}{\partial \lambda} = v(1-\beta)^2 + s > 0$$

On the other hand, the derivatives of 3.12 and 3.13 with respect to the share of shoppers are as follows: $\frac{\partial w}{\partial \lambda} = 0$, and $\frac{\partial s}{\partial \lambda} = -v(1-\beta)^2 \frac{\partial \alpha}{\partial \lambda} > 0$ because $\frac{\partial \alpha}{\partial \lambda} < 0$.

Proof of Proposition 3.6: It is easy to observe that the manufacturer's disagreement profit $\pi^0_{M,N}$ satisfies the following recursive relation:

$$\pi^0_{M,N} = \begin{cases} \beta(v - \pi^0_{M,N-1}) + \pi^0_{M,N-1} & N \geq 1 \\ 0 & N = 0 \end{cases} \tag{3.36}$$

We claim that: $\pi^0_{M,N} = v - (1-\beta)^N v$. We proceed by induction. The base case holds trivially. Now, assume that this holds for $(N-1)$, i.e., $\pi^0_{M,N-1} =$

$v - (1-\beta)^{N-1}v$. We now show that $\pi^0_{M,N} = v - (1-\beta)^N v$. Indeed,

$$\begin{aligned}
\pi^0_{M,N} &= \beta(v - w_{N-1}) + w_{N-1} \\
&= \beta(v - (v - (1-\beta)^{N-1}v)) + v - (1-\beta)^{N-1}v \\
&= v - (1-\beta)^N v,
\end{aligned}$$

which proves our claim.

We can thus write the disagreement profit when M bargains with one out of N retailers as $\pi^0_M = v - (1-\beta)^{N-1}v$, and so in this case the Nash bargaining product between M and R_1 becomes the one given in 3.18. Substituting the binding full participation condition $w = v - \frac{s}{1-\alpha}$ into 3.18 we have:

$$\max_{w,s} \left[(v - \frac{s}{1-\alpha} - (v - (1-\beta)^{(N-1)}v))^{\beta} \left(\frac{s}{(1-\alpha)} \frac{(1-\lambda)}{N} \right)^{(1-\beta)} \right] \tag{3.37}$$

Maximizing 3.37 with respect to s gives:

$$s = v(1-\alpha)(1-\beta)^N$$

Substituting this into $w = v - \frac{s}{1-\alpha}$, we obtain: $w = v - (1-\beta)^N v$.

Now, we can derive the comparative statics results. Taking the derivative of 3.19 with respect to β we get $\frac{\partial w}{\partial \beta} = N(1-\beta)^{N-1}v > 0$, while taking the derivative of 3.20 with respect to β we have $\frac{\partial s}{\partial \beta} = -Nv(1-\alpha)(1-\beta)^{N-1} < 0$.

Proof of Proposition 3.7: Taking the derivative of 3.19 with respect to N, we obtain:

$$\frac{\partial w^*}{\partial N} = -v(1-\beta)^N \ln(1-\beta) > 0$$

Since $\ln(1-\beta) < 1$ given $\beta \in [0,1]$.

On the other hand, taking the derivative of 3.20 with respect to N gives:

$$\frac{\partial s^*}{\partial N} = v(1-\beta)^N \left[(1-\alpha)\ln(1-\beta) - \frac{\partial \alpha}{\partial N} \right] < 0$$

This since $\left[(1-\alpha)\ln(1-\beta) - \frac{\partial \alpha}{\partial N}\right] < 0$ given $\ln(1-\beta) < 0$, and since $\frac{\partial \alpha}{\partial N} > 0$.

Proof of Proposition 3.8: Rewriting the binding full-participation constraint $w = v - \frac{s}{1-\alpha}$ and substituting it into 3.22 gives:

$$\max_{w,F,s} \left[(v - \frac{s}{1-\alpha} + F - \beta v)^{\beta} \left(\frac{s}{(1-\alpha)} \frac{(1-\lambda)}{2} - F \right)^{(1-\beta)} \right] \tag{3.38}$$

Maximizing 3.38 with respect to s yields:

$$s = \frac{(1-\alpha)\left[F((1+\beta) - (1-\beta)\lambda) + (1-\beta)^2(1-\lambda)v\right]}{(1-\lambda)} \tag{3.39}$$

Substituting 3.39 into 3.38 and then maximizing 3.38 with respect to F gives:

$$F^* = \frac{(1-\beta)(1-\lambda)v}{(1+\lambda)} \tag{3.40}$$

Substituting 3.40 into 3.39 gives:

$$s^* = \frac{2(1-\alpha)(1-\beta)v}{(1+\lambda)} \tag{3.41}$$

Finally, substituting 3.41 into $w = v - \frac{s}{1-\alpha}$ gives:

$$w^* = \frac{(-1+\lambda+2\beta)v}{(1+\lambda)} \tag{3.42}$$

Taking the derivative of 3.42 with respect to β gives: $\frac{2v}{(1+\lambda)} > 0$, while the derivative of 3.41 with respect to β gives $\frac{-2(1-\alpha)v}{(1+\lambda)} < 0$. Finally, taking the taking the derivative of 3.40 with respect to β equal $\frac{-(1-\lambda)v}{(1+\lambda)} < 0$.

Proof of Proposition 3.9: We can rewrite the full participation constraint as: $w = v - \frac{s}{1-\alpha}$ and since it is binding, we can substitute it into 3.26 to obtain:

$$\max_{w,s} \left[(v - \frac{s}{1-\alpha} - \beta_1 v)^{\beta_2} \left(\frac{s}{(1-\alpha)} \frac{(1-\lambda)}{2} \right)^{(1-\beta_2)} \right] \tag{3.43}$$

Taking the first order condition of 3.43 with respect to s and solving for s, we obtain:

$$s^* = (1-\alpha)(1-\beta_1)(1-\beta_2)v \tag{3.44}$$

Substituting 3.44 into w, we obtain:

$$w^* = v - (1-\beta_1)(1-\beta_2)v \tag{3.45}$$

The optimal values of w^* and s^* when the manufacturer bargains with R_1 are obtained in the same manner. Now, we derive the comparative static results. Taking the derivative of 3.44 with respect to β_1, respectively β_2, we obtain: $\frac{\partial s}{\partial \beta_1} = -(1-\alpha)(1-\beta_2)v < 0$, respectively $\frac{\partial s}{\partial \beta_2} = -(1-\alpha)(1-\beta_1)v < 0$. On the other hand, taking the derivative of 3.45 with respect to β_1, respectively β, we obtain: $\frac{\partial w}{\partial \beta_1} = (1-\beta_2)v > 0$, respectively $\frac{\partial w}{\partial \beta_2} = (1-\beta_1)v > 0$.

Proof of Proposition 3.10: By making use of the fact that $\alpha = \int_0^1 \frac{1}{1+\frac{2\lambda}{1-\lambda}z} dz$ and the binding constraint $w = v - \frac{s}{1-\alpha}$, we can rewrite 3.29 as:

$$\max_{w,\lambda} \left[\left((1-\beta)v - \frac{2s\lambda}{2\lambda - (1-\lambda)\log[\frac{1+\lambda}{1-\lambda}]} \right)^{\beta} \left(\frac{s(1-\lambda)\lambda}{2\lambda - (1-\lambda)\log[\frac{1+\lambda}{1-\lambda}]} \right)^{(1-\beta)} \right] \tag{3.46}$$

Define the following function:

$$f(\lambda) = \frac{\lambda}{2\lambda - (1-\lambda)\log[\frac{1+\lambda}{1-\lambda}]}$$

It is easy to see that this function is always positive and its derivative is:

$$f'(\lambda) = \frac{2\lambda - (1+\lambda)\log[\frac{1+\lambda}{1-\lambda}]}{(1+\lambda)\left(2\lambda - (1-\lambda)\log[\frac{1+\lambda}{1-\lambda}]\right)^2} \tag{3.47}$$

which is always negative. Thus, this function is always positive, but as λ increases, its value decreases. We can write the initial problem in 3.46 as follows:

$$(s(1-\lambda)f(\lambda))^{1-\beta}\,(v(1-\beta) - 2sf(\lambda))^{\beta} \tag{3.48}$$

To ensure that this value is positive, we assume that the following holds:

$$v(1-\beta) - 2sf(\lambda) > 0$$

This implicitly defines a lower value for λ, call it $\tilde{\lambda}$. Thus, we are considering $\lambda \in (\tilde{\lambda}, 1]$. Now, notice that if $\lambda = \tilde{\lambda}$, the right side of 3.48 would equal 0, so the whole value equals to 0. On the other hand, if $\lambda = 1$, the left side of 3.48 will equal to 0 and thus once again the whole value would be 0. Below, I argue that the function is maximized for some interior value of $\lambda \in (\tilde{\lambda}, 1]$. Taking the derivative of 3.48 with respect to λ, we obtain:

$$\frac{\left(s(s(1-\lambda)f(\lambda))^{-\beta}(v(1-\beta)-2sf(\lambda))^{\beta}((-1+\beta)f(\lambda)(v(-1+\beta)+2sf(\lambda))+(-1+\lambda)(v(-1+\beta)^2-2sf(\lambda))f'(\lambda)\right)}{-(v(1-\beta)-2sf(\lambda))}$$

Since we have assumed that $(v(1-\beta) - 2sf(\lambda)) > 0$, it must be the case that the sign of the denominator is negative. Furthermore, $(s(s(1-\lambda)f(\lambda))$ is clearly positive, as is $(v(1-\beta) - 2sf(\lambda))$. Thus, the sign of the derivative, taking into account the sign of the denominator, is determined by:

$$(1-\beta)f(\lambda)(v(-1+\beta)+2sf(\lambda))+(1-\lambda)(v(-1+\beta)^2-2sf(\lambda))f'(\lambda)$$

which we can write as:

$$(1-\lambda)(v(1-\beta)^2-2sf(\lambda))f'(\lambda)-(1-\beta)f(\lambda)(v(1-\beta)-2sf(\lambda))$$

Now, when $\lambda = \tilde{\lambda}$, the above reduces to $(1-\lambda)(v(1-\beta)^2-2sf(\lambda))f'(\lambda)$. If $v(1-\beta)-2sf(\lambda) = 0$, then clearly $(1-\beta)^2-2sf(\lambda) < 0$ and since $f'(\lambda)$ is negative, the derivative is initially positive. Now, as we increase λ further $-(1-\beta)f(\lambda)(v(1-\beta)-2sf(\lambda))$, is continuously becoming more negative. As λ goes to 1, $f(\lambda)$ converges to $\frac{1}{2}$, and $-(1-\beta)f(\lambda)(v(1-\beta)-2sf(\lambda))$ converges to $\frac{1}{2}(v(1-\beta)-s)(1-\beta)$. While the left part, $(1-\lambda)(v(1-\beta)^2-2sf(\lambda))f'(\lambda)$, converges to 0 as λ goes to 1. Thus, to ensure that the derivative eventually becomes negative, it must be that $v(1-\beta) > s$. To recap, if $\lambda = \tilde{\lambda}$, the initial derivative is positive, it is monotonically decreasing as λ increases, and if $v(1-\beta) > s$, then it eventually becomes negative. Thus, there must exist some λ^* that sets the derivative equal to 0. We define λ^* implicitly by setting the derivative equal to 0:

$$(1-\lambda^*)(v(1-\beta)^2-2sf(\lambda^*))f'(\lambda^*)-(1-\beta)f(\lambda^*)(v(1-\beta)-2sf(\lambda^*)) = 0 \quad (3.49)$$

Now, we derive the comparative static results. Our implicit function is:

$$F(v,s,\beta,\lambda) = (1-\lambda^*)(v(1-\beta)^2-2sf(\lambda^*))f'(\lambda^*)-(1-\beta)f(\lambda^*)(v(1-\beta)-2sf(\lambda^*)) = 0 \quad (3.50)$$

From the implicit function theorem: $\frac{\partial\lambda}{\partial\beta} = -\frac{\frac{\partial F(v,s,\beta,\lambda)}{\partial\beta}}{\frac{\partial F(v,s,\beta,\lambda)}{\partial\lambda}}$. We know from above that the denominator is negative, the first order derivative is monotonically decreasing in λ. So, the sign of $\frac{\partial\lambda}{\partial\beta}$ is determined by $\frac{\partial F(v,s,\beta,\lambda)}{\partial\beta}$. Taking the derivative of 3.49 with respect to β, we obtain:

$$2f(\lambda^*)(v(1-\beta)-sf(\lambda^*))-2v(1-\beta)(1-\lambda^*)f'(\lambda^*)$$

$2f(\lambda^*)(v(1-\beta)-sf(\lambda^*))$ is positive, $2v(1-\beta)(1-\lambda^*)$ is positive, $f'(\lambda^*)$ is negative, thus the expression is positive. As a consequence: $\frac{\partial\lambda^*}{\partial\beta}>0$. On the other hand, we have $w^*=v-2sf(\lambda^*)$. Taking the first derivative with respect to β we obtain: $-2sf'(\lambda)\frac{\partial\lambda}{\partial\beta}$. We showed that $\frac{\partial\lambda}{\partial\beta}>0$ and we know that $f'(\lambda)<0$, thus $\frac{\partial w}{\partial\beta}>0$.

4 Unintended Effects of Regulating Recommended Retail Prices

This chapter is joint work with Maarten Janssen.

4.1 Introduction

Recommended retail prices (RRPs) are non-binding suggestions of manufacturers at which prices retailers should sell their product. As retailers are free to deviate from the recommendation, an important question is whether these price proposals affect market behaviour and if so how. Competition authorities have been concerned that RRPs affect competition negatively through their impact on consumers. By seeing prices at or below the RRP, a consumer may be tempted to buy and not continue to search, enabling retailers to increase their margins. In practice, it has also been documented that retailers often come up with false recommendations of this nature in order to influence the purchasing decision of consumers.[1] These practices are labelled as "fictitious pricing" by the Federal Trade Commission (FTC) and have attracted quite a lot of attention in policy discussions.

In recent years, RRPs have started to be regulated. In the U.S., for example, the Code of Federal Regulations used by the FTC states that "to the extent that list or suggested retail prices do not in fact correspond to prices at which a substantial number of sales of the article in question are made, the advertisement of a reduction

[1] see, e.g., https://www.nytimes.com/2016/03/06/technology/its-discounted-but-is-it-a-deal-how-list-prices-lost-their-meaning.html

may mislead the consumer". The Code of Federal Regulation rightfully observes that a recommended retail price may also be addressed to consumers (and not only to retailers) and may affect their purchasing behaviour. We interpret this as an implicit recognition of the importance of consumer search. If consumers do not engage in search, the markets become less competitive and retailers are able to increase their margins. Therefore, the regulation states that in order for manufacturers and retailers not to be found liable of having engaged in deceptive practices they should make sure that a substantial number of sales is made at the recommended retail price.

In this paper, we analyse the effect of such regulation on RRPs. We argue that despite its intention to protect consumers, the Code of Federal Regulations may actually aversely affect them. We point out that while the regulation makes deceptive pricing more difficult, it has an additional unintended effect of serving as a commitment device for manufacturers. Once manufacturers are able to commit to their wholesale prices, we show that they will engage in wholesale price discrimination. We will explain how this mechanism works and why it makes consumers (and retailers) worse off. In order to do so, we develop a simple model where a manufacturer sells a homogeneous product via retailers to consumers. We focus on the case of homogeneous products given that the intention of RRPs was to help standardize prices of same products.

In vertical market analysis, it is important to treat the observability of wholesale contracts with care. In Janssen and Reshidi (2019), we have analysed markets where wholesale arrangements are observed, both by the retailers and the final consumers. Such an assumption is reasonable when analysing markets where long-term supply contracts are in place and where consumers are aware of this and they repeatedly buy. However, unless there are good reasons to believe that long-term wholesale contracts are being used, a natural way to think about this is that wholesale arrangements between manufacturers and retailers are unobserved. This is the approach we follow here. More specifically, a retailer only observes her own wholesale price and does not observe the wholesale arrangements of other retailers while consumers do not know the wholesale arrangements of any retailer. In such settings, the manufacturer can deviate from the prices the retailers and consumers expect him to charge without being noticed.

The results of the paper are as follows. First, we find that in the absence of the restrictions imposed by the Code of Federal Regulations the manufacturer cannot engage in wholesale price discrimination. We show that a uniform wholesale price equilibrium where the manufacturer charges all retailers the same wholesale prices always exists. To understand the mechanism behind this result let us first describe what happens under discrimination. Consider the manufacturer charges low prices to some retailers and high prices to others. The retailers then respond to these costs optimally and thus some of them sell at higher retail prices than others. The price dispersion that emerges in the retail market stimulates consumers to search. This increased search implies that both low and high cost retailers face more price sensitive demands compared to uniform pricing. It is important to note that, while high search cost consumers stop their search early on, consumers with low search costs will stop searching only once they find a low cost retailer. In this way, the retailers that are charged the lower wholesale price face a more elastic demand compared to high cost retailers and thus react less to increases in the wholesale price. Despite the fact that the manufacturer charges a lower wholesale price, the increased demand resulting from lower retail margins implies that the manufacturer makes more profits over the low cost retailers compared to the high cost retailers. The manufacturer thus has an incentive to secretly deviate and charge all retailers the same low wholesale price. As retailers only observe their own wholesale price, and are thus not able to observe such a deviation, their prices would be unaffected.

Therefore, without the regulation on RRPs, only uniform wholesale pricing can be sustained in equilibrium.

Next, we show that the restrictions imposed by the Code of Federal Regulations effectively provide the manufacturer with a commitment device that enables him to engage in wholesale price discrimination. The manufacturer may announce the price at which the high cost retailer sells her product as the recommended retail price. Given the announcement, she should make sure that at least some products are sold at this price and thus she is not free to deviate and sell to all retailers at the lower wholesale price that generates more profits. Some retailers follow the recommended retail price, as this is simply their optimal price given their individual wholesale price. Other retailers sell at a price below the recommended retail price as they receive lower wholesale prices. We show that once this possible profitable deviation is eliminated, wholesale price discrimination can be sustained as an equilibrium outcome.

Lastly, we show that under wholesale price discrimination the average wholesale and retail prices increase, increasing manufacturer profits, but decreasing retailers' profits and consumer welfare compared to uniform pricing. As consumers search more, retailers face more elastic demands under discrimination. In this way, retail prices react less to wholesale price changes creating a more inelastic demand for the manufacturer. This, together with the fact that wholesale contracts are unobserved, provides the manufacturer with an incentive to set higher wholesale prices, which results in higher retail prices. In this way, regardless of lower retail margins, consumers face higher prices under discrimination. On top of that, a fraction of consumers with low search costs has to search to find the low retail price, while they do not need to do so under uniform pricing. We thus show that although the regulation on RRPs is introduced with the aim of protecting consumers, it indirectly provides mechanisms that enable wholesale price discrimination and makes consumers worse off.

There are several branches of the literature to which this paper contributes. First, the paper adds to the literature on non-binding recommended retail prices. Two empirical papers (Faber and Janssen (2019) and De los Santos, Kim, and (2018)) show that recommended retail prices do affect market behavior. Buehler and Gärtner (2013) see recommended retail prices as communication devices between a manufacturer and its retailers and where recommended retail prices are part of a relational contract enabling the manufacturer and retailer to maximize joint surplus in a indefinitely repeated setting. Lubensky (2017) is closer in spirit to our model, he shows that a manufacturer can use recommended retail prices to signal his production cost to searching consumers. As both, consumers and the manufacturer, prefer more search when the manufacturer production cost is low and less search when it is high, the manufacturer's recommendation informs consumers via cheap talk of its cost. In contrast to these papers, we are the first to analyse the effect of regulation on RRPs in vertical markets with search. The easiest way to study the effect of such regulation is to start with markets where RRPs would otherwise be ineffective. We show that such regulation helps manufacturers enforce their recommendations and increase their profits, even in markets where the manufacturers' cost are stable over time and where uncertainty does not play a role.

Second, the paper relates to the literature on unobservable contracts. The seminal papers in this literature have shown that a manufacturer may be subject to opportunism when contracting secretly with downstream retailers and that equilibrium behaviour depends on the type of beliefs retailers hold (see, Hart and Tirole (1990), O'Brien and Shaffer (1992) and McAfee and Schwartz (1994)). We differ from these papers by analysing wholesale price discrimination in search markets where regulations on RRPs are imposed. We find that when contracts are unobserved, an equilibrium with wholesale price discrimination does not exist. We show that, unlike the argument on opportunism, the reason for this non-existence result in our context is not because of specific assumptions on out-of-equilibrium beliefs. The profitable deviation is the unilateral deviation where the manufacturer gives the retailer that is supposed to get a higher wholesale price the same (lower) wholesale equilibrium price as all the other retailers.

Third, the paper adds to the growing literature on vertically related industries with consumer search (Janssen and Shelegia (2015), Garcia, Honda, and Janssen (2017), Garcia and Janssen (2018), Janssen and Reshidi (2019), Asker and Bar-Isaac (2019), Janssen and Shelegia (2019) and Janssen (2019)). Janssen and Shelegia (2015) show that markets can be quite inefficient if consumers search sequentially while not observing the wholesale arrangement between the manufacturer and retailers. Garcia, Honda, and Janssen (2017) extend that argument to wholesale markets where retailers search sequentially among different manufacturers. Both these papers assume that manufacturers treat retailers symmetrically and do not engage in wholesale price discrimination (although the latter paper allows for manufacturers to randomize their decision to choose wholesale prices). Garcia and Janssen (2018) allows for wholesale price discrimination, but mainly focuses on how a manufacturer can correlate his wholesale prices to increase profits. By contrast, we focus on the competitive impact of wholesale price discrimination by changing the search cost composition of different retailers. Asker and Bar-Isaac (2019) study the impact of minimum advertised prices (MAPs). Janssen and Shelegia (2019) study consumer beliefs in vertical markets with differentiated goods while Janssen (2019) focuses on cases where the manufacturer can offer unobserved two-part tariff contracts. The paper closes to ours is Janssen and Reshidi (2019). In that paper, wholesale price discrimination in vertical markets is analysed under the assumption that wholesale contracts are observed. In contrast, we study a setting where the contract between manufactures and retailers are not observed, neither by the competing retailers nor from the consumers. We find that wholesale and retail prices will be higher when contracts are unobserved compared to settings when they are observed. Furthermore, we show that without the existence of an equilibrium with wholesale price discrimination hinges on the observability of wholesale contracts.

Finally, the paper also adds to the literature on price discrimination with search. The idea that a monopolist may want to sell at different prices to discriminate between consumers with different search cost is not new. In fact, Salop (1977) argues that a monopolist may want to sell at higher prices to less price-sensitive consumers with higher search cost, while selling at lower prices to consumers with lower search cost. His argument, however, critically depends on the assumption that the monopolist is committed to charging prices according to a price distribution and that any deviation from this distribution is observed by consumers and consumers will react by changing their search strategy. From a formal game theoretic point of view, however, it is difficult to see how consumers may observe a price distribution, while maintaining the assumption underlying the search cost literature that the consumer does not know the prices the firm sets. Without this commitment, Salop's argument breaks down, however, as the monopolist will have an incentive to secretly increase the prices in the lower part of the price distribution. Our paper shows that with unobserved wholesale contracts, screening consumers with different search costs can be effective in a vertical relations model where the manufacturer imposes the screening contract to retailers, while consumers search for low retail prices. Finally, Fabra and Reguant (2018) have introduced heterogeneity in buyers' size in a simultaneous search model. In contrast to our paper, they find that differences in demand, and not in search costs, give rise to discrimination.

The remainder of this paper is organized as follows. In the next section, we present the model and the equilibrium concept we use. The analysis under uniform wholesale pricing is presented and discussed in Section 4.3. Section 4.4 analyses the implications of imposing the regulation on RRPs, as the Code of Federal Regulations does. Finally, Section 4.5 concludes.

4.2 The Model

We analyse a setting where in the upstream market a single manufacturer sells a homogeneous product to $N \geq 3$ downstream retailers. The manufacturer chooses linear wholesale contracts and can charge different wholesale prices w_i to retailers, and so the manufacturer's strategy is a tuple $(w_1, w_2, ..., w_N)$. [2] For simplicity, the production costs of the manufacturer are set to zero. Retailers compete in prices and the wholesale price is the only cost they are faced with. For given expected wholesale prices and given their own wholesale price, an individual retailer i sets his retail price p_i, $i = 1, ..., N$.

In the downstream market, there is a unit mass of final consumers. At price p, every consumer demands $D(p)$ units of the good. We make standard assumptions on the demand function so that it is well-behaved. In particular, there exists a $\overline{p}$ such that $D(p) = 0$ for all $p \geq \overline{p}$ and the demand function is continuously differentiable and downward sloping whenever demand is strictly positive, *i.e.*, $D^{'}(p) < 0$ for all $0 \leq p < \overline{p}$. For every $w \geq 0$, the retail monopoly price, denoted by $p^M(w)$ is uniquely defined by $D^{'}(p^M(w))(p^M(w) - w) + D(p^M(w)) = 0$ and $D''(p)(p - w) + 2D'(p) < 0$. Note that for $w = 0$, this condition gives that the profit function of an integrated monopolist is concave. We denote by $p^M(w^M)$ the double marginalization retail price, which arises in case there would be a monopoly at both levels of the supply chain.

In order to observe prices consumers have to engage in costly sequential search

[2]For two-part tariff analysis we refer the reader to check Janssen (2019).

with perfect recall. Consumers differ in their search cost s. Search costs are distributed on the interval $[0, \overline{s}]$ according to the distribution function $G(s)$, with $G(0) = 0$. We denote by $g(s)$ the density of the search cost distribution, with $g(s) > 0$ for all $s \in [0, \overline{s}]$ and a finite M such that $-M < g'(s) < M$. In numerical examples, we consider $G(s)$ to be uniformly distributed. As consumers are not informed about retail prices before they search, an equal share of consumers visits each retailer at the first search.

For given expected wholesale prices, consumers sequentially search for retail prices. We will focus on two types of equilibria: (i) in a uniform pricing equilibrium the manufacturer chooses $w_i = w^*$, whereas in an equilibrium with price discrimination the manufacturer chooses two prices w_L^* and w_H^*, with $w_L^* < w_H^*$, and charges some retailers the low and others the high wholesale price. With unobserved contracts the manufacturer may secretly deviate from the prices retailers and consumers expect her to charge. A retailer only observes her own wholesale price and does not observe the wholesale arrangements of the other retailers. Consumers only observe the retail price they encounter when searching and do not know the wholesale arrangements. Thus, in this section, we should not only consider consumers', but also retailers' out-of-equilibrium beliefs. Moreover, we can have pure strategy equilibria that are consistent with consumers not knowing which retailer has the high wholesale price.

We define an equilibrium with wholesale price discrimination as follows.

Definition 4.1. An equilibrium with wholesale price discrimination is defined by a tuple $((w_L^*, w_H^*), p^*(w))$, with $w_L^* < w_H^*$, and an optimal sequential search strategy for all consumers such that

(i) the manufacturer maximizes profits given $p^*(w)$ and consumers' optimal search strategy,

(ii) retailers maximize their retail profits given the wholesale price they observe, their beliefs about the wholesale prices received by other retailers and consumers' optimal search strategy and

(iii) consumers' sequential search strategy is optimal given $((w_L^*, w_H^*), p^*(w))$ and their beliefs about retail prices not yet observed.

Beliefs are updated using Bayes' rule whenever possible.

The above definition does not specify off-the-equilibrium path beliefs. The most natural assumption in our setting, and one that has been used in papers analysing unobserved contracts with consumer search, is that retailers and consumers hold passive beliefs. Under wholesale price discrimination, however, passive beliefs do not provide enough precision to determine consumers' optimal search behaviour. As we will explain later, there consumers have to also form expectations about the cost of the retailer that has deviated.

4.3 Uniform Pricing

First, let us consider the case of uniform pricing where all retailers are expected to be charged the same wholesale price w^*. We denote the equilibrium retail price by $p^*(w^*)$. To determine $p^*(w^*)$, we follow the same steps as in Janssen and Reshidi (2019) and we investigate how a retailer's demand depends on his own price, which in turn depends on how consumers' search behaviour reacts to a price deviation. If a retailer deviates to a price $\widetilde{p}$ then a consumer who buys at this price would get a surplus of $\int_{\widetilde{p}}^{\overline{p}} D(p)dp$. Given our assumption on passive beliefs, only a fraction $1 - G\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right)$ will buy from the deviating retailer while all other consumers will continue searching for the equilibrium retail price $p^*(w^*)$. Therefore, a retailer that charges $\widetilde{p}$ will make a profit of:

$$\pi_r(\widetilde{p}, p^*) = \frac{1}{N}\left(1 - G\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right)\right) D(\widetilde{p})(\widetilde{p} - w^*).$$

Maximizing this profit and using the equilibrium condition $\widetilde{p}(w^*) = p^*(w^*)$, gives:

$$-g(0)D^2(p^*)(p^* - w^*) + D^{'}(p^*)(p^* - w^*) + D(p^*) \leq 0. \tag{4.1}$$

This condition shows that the equilibrium retail price does not depend on the number of retailers and that $p^* \leq p^M(w^*)$. Given that consumers cannot observe price deviations without searching, retailers will not have an incentive to deviate to lower prices as long as $p^* \leq p^M(w^*)$. Thus, this condition can be satisfied with a weak inequality, which implies the existence of a continuum of pure-strategy equilibria in the downstream market.

To determine the wholesale equilibrium price under uniform pricing under unobserved contracts, we should consider that it is not optimal for the manufacturer to deviate to one retailer and offer him a wholesale price w, while keeping the other retailers at w^*. If the manufacturer would deviate in this way and the retailer would react to w by choosing $\widetilde{p}$ (to be determined later), her profits would be:

$$\pi(w^*, w) = w^* D(p^*(w^*)) + \tfrac{1}{N}\left(1 - G\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right)\right)\left(wD(\widetilde{p}(w)) - w^* D(p^*(w^*))\right).$$

This expression is easily understood. Of the consumers who come across a price of $\widetilde{p}(w)$ at their first search (which is a fraction $1/N$ of them) a fraction $G\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right)$ continues to search for the equilibrium retail price as their search cost is low enough, while the consumers with a search cost larger than $\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp$ will buy at the deviation price $\widetilde{p}(w)$. All other consumers buy at the equilibrium price $p^*(w^*)$. A uniform pricing equilibrium requires that the first-order condition evaluated at $w = w^*$ is non-positive, i.e.,

$$g(0)D(\widetilde{p})\tfrac{\partial \widetilde{p}}{\partial w}\left(w^* D(p^*(w^*)) - wD(\widetilde{p}(w))\right) + \left(1 - G\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right)\right)\left(wD^{'}(\widetilde{p})\tfrac{\partial \widetilde{p}}{\partial w} + D(\widetilde{p})\right)$$

$$= \left(1 - G\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right)\right)\left(w^* D^{'}(p^*)\frac{\partial \widetilde{p}(w^*)}{\partial w} + D(p^*)\right) \leq 0,$$

which reduces to

$$w^* D^{'}(p^*(w^*))\frac{\partial \widetilde{p}(w^*)}{\partial w} + D(p^*(w^*)) \leq 0. \tag{4.2}$$

In a different context, Rey and Vergé (2004) have shown that an equilibrium where retailers hold passive beliefs may not exist. It is clear that condition 4.2 guarantees that the manufacturer does not have an incentive to deviate to multiple or even all retailers (provided that retailers hold passive beliefs). Therefore, in contrast to Rey and Vergé (2004), assuming that retailers hold passive beliefs does not lead to non-existence results in our setting.

Similar to the retailer's behaviour, the manufacturer does not have an incentive to lower his wholesale price as long as $p^* < \min(p^M(w^*), p^M(w^M))$ as retailers will not follow suit and keep their price at the equilibrium level if this condition is satisfied. In this case, the only requirement we have to impose is that the manufacturer does not want to increase his wholesale price and this is what (4.2) requires. On the other hand, nothing we have said so far precludes the possibility that the solutions to (4.1) and (4.2) result in such a high wholesale (and retail) price that $w^*D(p^*(w^*)) < w^M D(p^M(w^M))$. In this case, it would be optimal, however, for the manufacturer to deviate to all retailers by setting w^M and they will respond by setting $p^M(w^M)$. Thus, another condition that an equilibrium needs to fulfil is that the manufacturer's equilibrium profit satisfies $w^*D(p^*(w^*)) \geq w^M D(p^M(w^M))$.

To finalize the description of an equilibrium, we still have to evaluate how $\widetilde{p}$ depends on the deviation wholesale price w. For this we need to determine the best response function of retailers to non-equilibrium wholesale prices, taking into account that now consumers do not observe the manufacturer deviation and blame the individual retailer for any deviation from the equilibrium price. Given the retailers' profit function $\pi_r(\widetilde{p}, p^*) = \frac{1}{N}\left(1 - G\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right)\right) D(\widetilde{p})(\widetilde{p} - w)$, an individual retailer will react to upward deviations from w^* by setting $\widetilde{p}$ such that

$$-g\left(\int_{p^*}^{\widetilde{p}} D(p)dp\right) D^2(\widetilde{p})(\widetilde{p} - w) + \left(1 - G\left(\int_{p^*}^{\widetilde{p}} D(p)dp\right)\right)\left(D'(\widetilde{p})(\widetilde{p} - w) + D(\widetilde{p})\right) = 0. \tag{4.3}$$

Thus, the retailer's best response to any w depends on w itself as well as on the equilibrium price p^* that is expected by consumers. The retailer should not only consider the wholesale price itself, but also how consumers who do not observe the wholesale price react (and this depends on the retail prices they expect). In the proof of the next Proposition we show that evaluated at the equilibrium values we obtain:

$$\frac{\partial \widetilde{p}(w^*)}{\partial w} = \frac{D'(p^*) - g(0)D^2(p^*)}{-g'(0)D^3(p^*)(p^*-w) - 3g(0)D(p^*)D'(p^*)(p^*-w) - 2g(0)D^2(p^*) + 2D'(p^*) + 2D''(p^*)(p^*-w)}. \tag{4.4}$$

We then have the following result.

Proposition 4.1. *Under unobserved wholesale contracts, a uniform pricing equilibrium has to satisfy (4.1), (4.2), where* $\frac{\partial \widetilde{p}(w^*)}{\partial w}$ *is given by (4.4) and* $w^* D(p^*(w^*)) \geq w^M D(p^M(w^M))$.

Note that there can be multiple equilibria due to the fact that the first-order condition of the manufacturer only needs to hold with inequality. We focus on the equilibrium where the manufacturer makes most profits. This is the equilibrium where (4.2) holds with equality. Equilibria can be indexed by the wholesale price that retailers and consumers expect the manufacturer to choose. As the manufacturer is a monopolist, we believe it is natural to think that retailers and consumers expect that the manufacturer chooses the equilibrium wholesale price that maximizes her profits, which is the lowest of all equilibrium wholesale prices and is thus also in the interest of consumers.

If $g(0) \to \infty$ we have that $p^*(w^*) \to w^*$. What is perhaps more surprising is that when $g(0) \to \infty$ and $p^* \to w^*$ we can solve (4.2) for w^*. From (4.4) it is easy to see that if $g(0) \to \infty$ the expression for $\frac{\partial \widetilde{p}(w^*)}{\partial w}$ reduces to $\frac{1}{2}$ so that the wholesale price is significantly larger than that of an integrated monopolist. It is quite intuitive that retailers will not react as strongly to wholesale prices as when wholesale contracts are observed. Under uniform pricing with observed contracts, the manufacturer sets the same wholesale price to all retailers so if she sets a non-equilibrium price she does so to all retailers and consumers know this. Consumers believe that all other retailers set the equilibrium price and more consumers will continue to search if a retailer does not choose the price consumers expected. The next Proposition states the result.

Proposition 4.2. *Assume $\overline{s}$ close enough to 0, then $\partial p^M(w^M)/\partial w < 1$ and a uniform pricing equilibrium exists. As $\overline{s} \to 0$, the equilibrium retail price converges to $p^* = w^*$, where w^* solves $\frac{1}{2}w^* D^{'}(w^*) + D(w^*) \leq 0$ and $w^* D(p^*(w^*)) \geq w^M D(p^M(w^M))$. Moreover, $\frac{dp^*}{d\overline{s}} = -\frac{x}{D(p^*)} < 0$ and $\frac{dw^*}{d\overline{s}} = -\frac{1+x}{D(p^*)} < 0$,where $x = \frac{2D'(p^*)}{w^* D''(p^*) + 3D'(p^*)}$.*

The condition that the cost pass-through evaluated at the double marginalization price is smaller than 1 guarantees that $w^* D(p^*(w^*)) \geq w^M D(p^M(w^M))$. Weyl and Fabinger (2013) derive the cost pass-through in terms of primitives of the demand curve. We have not been able to find demand curves that satisfy that $D(p) = 0$ for $p > \overline{p}$ for which $w^* D(p^*(w^*)) < w^M D(p^M(w^M))$ in a neighbourhood of $\overline{s} = 0$.

In the context of a Stahl (1989) type model, where a fraction λ of consumers (the shoppers) has zero search cost and the remaining consumers have a search cost $s > 0$, Janssen and Shelegia (2015) show that if the search cost s is small an equilibrium exists if, and only if, λ is large enough. For linear demand, the critical value λ^* is approximately 0.47. The first part of the above Proposition says that if the search cost is small equilibrium existence is generally not an issue in our model where consumers have truly heterogeneous search cost and $g(s) > 0$ for all $s \geq 0$. Thus, our result shows that the equilibrium in-existence result in Janssen and Shelegia (2015) is due to the discreteness of the search cost distribution. From Janssen and Shelegia (2015), we know that we cannot guarantee existence for any search cost distribution that is non-concentrated ($\overline{s}$ is small), even if demand is linear.

The second part of the Proposition establishes that the manufacturer sets a much higher price than an integrated monopolist. This result is akin to Theorem 2 of Janssen and Shelegia (2015) where they show that as $s \to 0$, wholesale and retail prices converge to a price w^* that solves $\lambda w^* D^{'}(w^*) + D(w^*) = 0$. The reason why equilibrium prices are much higher than the price an integrated monopolist would set (despite the retail margins being close to 0) is that the manufacturer may deviate from the equilibrium price without consumers noticing it. This makes the manufacturer's demand much less elastic to her own price changes than the demand of an integrated monopolist. Theorem 2 of Janssen and Shelegia (2015) is obtained for duopoly retail markets and the Stahl (1989) specification of search costs. The above result shows that the intuition is much more general and holds for any search cost distribution and for any number of retailers. Also, as in Janssen and Shelegia (2015), an equilibrium only exists if λ is large enough, their limit prices tend to be (much) smaller than in our model.

In terms of comparative statics, Proposition 4.2 shows that in a neighbourhood of $\overline{s} = 0$ both the wholesale and retail price are decreasing in $\overline{s}$. This implies that consumers are better off if search costs are not vanishing. Janssen and Shelegia (2015) have a similar result, but only for the case of linear demand. This result indicates that price comparison websites that effectively reduce search costs and are believed to help consumers in getting better deals may in the end lead to higher prices.

For linear demand $D(p) = 1 - p$, the Proposition implies that in the limit when $\overline{s} \to 0$, $w^* \to 2/3$ and expected consumer surplus converges to $\frac{1}{18}$.[3] Using Proposition 4.2, we have that $\frac{dp^*}{d\overline{s}} = -2$, $\frac{dw^*}{d\overline{s}} = -5$ and $\frac{dESC}{d\overline{s}} = -(1-p^*)\frac{dp^*}{d\overline{s}} = \frac{2}{3}$. Figure 4.1 shows how the equilibrium retail and wholesale prices change for different values of $\overline{s}$. For small values of $\overline{s}$ the figure also confirms that both p^* and w^* are decreasing in $\overline{s}$. The figure also depicts the retail and wholesale prices and confirms that prices are much higher when wholesale contracts are not observed compared to when they are observed and that retail prices behave differently in these two cases: when contracts are observed, uniform retail prices are increasing in the upper bound of the search cost distribution, while they are decreasing when contracts are unobserved.

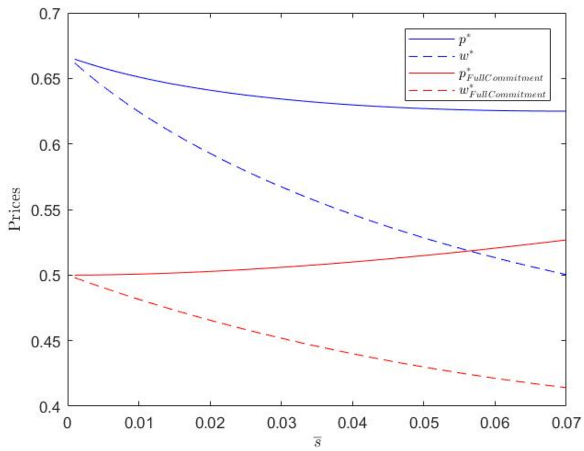

Figure 4.1: Uniform retail and wholesale prices for different values of $\overline{s}$

4.4 The effects of regulation on RRPs

In this section, we will analyse the effect of the regulation imposed by the FTC. This regulation requires that manufacturers make honest estimations of recommended retail prices. Therefore, in order for manufacturers not to be liable for having

[3]Other equilibria are such that $w^* \geq 2/3$, while the condition that deviation to the double marginalization solution is not optimal results in the condition $w^*(1-w^*) \geq 1/8$, or $w^* \leq \frac{2+\sqrt{2}}{4}$.

engaged in deceptive pricing practices, they have to make sure that at least some sales take place at these list prices. We will show, that this regulation gives rise to another equilibrium in which the manufacturer can price discriminate its retailers. We show that in this setting, wholesale and retail prices are higher compared to the uniform equilibrium presented in the previous section. At the end, we will show that if this regulation does not hold, an equilibrium with wholesale price discrimination will fail to exist.

4.4.1 Equilibrium under regulation

The U.S. Code of Federal Regulations requires that at least some sales have to take place at RRPs. This regulation acknowledges that many consumers believe that RRPs are prices at which products are generally sold. The regulation also addresses manufacturers' actions by claiming that in order for a manufacturer not to be chargeable with having participated in fictitious pricing it should suggest list prices by making an honest estimation of the actual retail price and make sure that at least some sales take place at the RRP. We will show that by requiring that at least some sales take place at the RRP, the Code of Federal Regulations allows the manufacturer to use RRPs to commit to wholesale price discrimination.

To illustrate the impact of wholesale price discrimination, consider the situation where a manufacturer is expected to set a wholesale price of w_L^* to $N-1$ retailers and w_H^* to 1 retailer, but consumers do not know which retailer faces the higher wholesale price. The low and high cost retailers, on their part, are expected to react by setting p_L^* and p_H^*, respectively. Under discrimination, consumers with low search costs that at their first search come across a high retail price will simply continue to search for the low retail price. If we let $\widehat{s} = \int_{p_L^*}^{p_H^*} D(p)dp$, then all consumers with search cost $s < \widehat{s}$ will continue to search for p_L^*. To understand how retailers will react to wholesale price discrimination, we have to be more specific here about consumer beliefs and go beyond passive beliefs: after the observation of an out-of-equilibrium price, consumers should also have beliefs about whether a high or a low cost retailer has deviated.

As in Janssen and Reshidi (2019), in order for a retail equilibrium to exist, consumers should blame high-cost retailers for deviations to prices in the neighbourhood of p_H^*. Under such beliefs, consumers will continue searching if:

$$s < \widehat{s} + \int_{p_H^*}^{\overline{p}} D(p)dp - \int_{p_H}^{\overline{p}} D(p)dp = \int_{p_L^*}^{p_H} D(p)dp.$$

Thus, the profit of a high cost retailer that deviates to a price p_H in the neighbourhood of p_H^* will be:

$$\pi_r^H(p_H, p_L^*; w_H^*) = \frac{1}{N}\left(1 - G\left(\int_{p_L^*}^{p_H} D(p)dp\right)\right) D(p_H)(p_H - w_H^*). \tag{4.5}$$

If the low cost retailers were to blame for such deviations, then more consumers would decide to buy and not search after seeing a price of p_H compared to seeing a retailer that sells at p_H^*. Such a deviation would then be profitable for a high cost retailer.

Let us now analyse a low cost retailer's deviation to a price p_L in the neighbourhood of p_L^*. Given that prices are not observed until a consumer visits a specific retailer, deviations to lower prices do not attract more demand and thus are not optimal. We should therefore only focus on analysing deviations to higher prices. When it comes to deviations to prices p_L higher than p_L^*, we are less restricted in specifying consumer's beliefs. We will continue with assuming that if consumers see a price p_L in a neighbourhood of p_L^* that they will blame the low cost retailer. [4]

[4]Consumers observing the equilibrium price p_L^* believe that if they continue to search, there is a probability of $\frac{1}{N-1}$ they will observe a price p_H^* on their next search. Consumers observing the equilibrium price p_H^* believe that there is zero probability that they will observe a price p_H^* on their next search.

Thus, under these beliefs, deviating to a price p_L, with $p_L^* < p_L < p_H^*$, a low cost retailer's profit function will be:

$$\pi_r^L(p_L; p_L^*, p_H^*, w_L^*) = \frac{1}{N}\left[1 - G\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right) + \frac{G\left(\int_{p_L}^{p_H^*} D(p)dp\right)}{(N-1)}\right] D(p_L)(p_L - w_L^*). \tag{4.6}$$

Taking the first-order condition of (4.5) with respect to p_H and substituting $p_H = p_H^*$ yields

$$-\frac{g(\widehat{s})D^2(p_H^*)(p_H^* - w_H^*)}{1 - G\left(\widehat{s}\right)} + \left[D^{'}(p_H^*)(p_H^* - w_H^*) + D(p_H^*)\right] = 0. \tag{4.7}$$

This FOC condition has to hold with equality as a high-cost retailer may also have an incentive to lower price to prevent more consumers from continuing to search. On the other hand, taking the first-order condition of (4.6) with respect to p_L and evaluating it at p_L^* yields:

$$-\frac{\left(\frac{(N-1)^2}{N}g\left(0\right) + g(\widehat{s})\right)D^2(p_L^*)(p_L^* - w_L^*)}{(N-1) + G(\widehat{s})} + \left[D^{'}(p_L^*)(p_L^* - w_L^*) + D(p_L^*)\right] \leq 0. \tag{4.8}$$

Now, we can analyse the upstream market. The manufacturer's profit function if she deviates in terms of w_H and w_L (to one low cost retailer) and retailers react to these deviations by setting p_H and p_L (to be determined later) is:

$$\begin{aligned}
\pi(w_L, w_H) &= \frac{1}{N}\left(1 + \frac{1}{(N-1)}G\left(\int_{p_L}^{p_H} D(p)dp\right) - G\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right)\right) w_L D(p_L(w_L)) \\
&+ \frac{N-2}{N}\left(1 + \frac{G\left(\int_{p_L^*}^{p_H} D(p)dp\right)}{(N-1)} + \frac{G\left(\int_{p_L^*}^{p_L} D(p)dp\right)}{(N-1)(N-2)} + \frac{G\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right)}{N-2}\right) w_L^* D(p_L^*(w_L^*)) \\
&+ \frac{1}{N}\left(1 - G\left(\int_{p_L^*}^{p_H} D(p)dp\right)\right) w_H D(p_H(w_H)).
\end{aligned}$$

This expression can be understood as follows. First, the term $\frac{1}{N}G\left(\int_{p_L^*}^{p_H} D(p)dp\right)$

in the last line is the share of consumers that first saw p_H and continue to search as they believe that all other firms choose p_L^*. The remaining of these consumers buy at the price p_H. Each of the other retailers gets $1/(N-1)$ of the consumers that continue to search. Retailers charging p_L^* will sell to these consumers, while a retailer that charges p_L will only get a fraction of these consumers, namely those with relatively higher search cost. Since they still believe that the other retailers charge p_L^*, all consumers with a search cost smaller than $G\left(\int_{p_L^*}^{p_L} D(p)dp\right)$ continue searching for the remaining retailers and buy there. Finally, there is a share of consumers that on their first search observes p_L and they continue to search if their search cost is smaller than $\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp$.

The first-order condition for the manufacturer with respect to w_H should be satisfied with equality. The reason is that in an equilibrium with wholesale price discrimination, a fraction $G(\widehat{s})$ of consumers continues to search if observing p_H^* so that both upward and downward deviations in w_H (and subsequently in p_H) affect demand. At w_L^*, however, only upward deviations can be profitable: as consumers will only find out about the deviations once they have visited the retailer in question, downward deviations in retail price (and thus in wholesale prices) do not attract additional demand making such deviations always unprofitable.

In the proof of the Proposition below we show that the first-order conditions with respect to w_L and w_H evaluated at the equilibrium wholesale prices yield

$$w_L^* D^{'}(p_L^*(w_L))\frac{\partial p_L}{\partial w_L} + D(p_L^*) \leq 0, \tag{4.9}$$

and

$$(1-G(\widehat{s}))\left[w_H^* D^{'}(p_H^*)\frac{\partial p_H}{\partial w_H} + D(p_H^*)\right] + g(0)D(p_H^*)\frac{\partial p_H}{\partial w_H}\left[w_L^* D(p_L^*) - w_H^* D(p_H^*)\right] = 0, \tag{4.10}$$

where the expressions for $\frac{\partial p_L}{\partial w_L}$ and $\frac{\partial p_H}{\partial w_H}$ are given in the Appendix. Note that (4.9) implies that the manufacturer does not have an incentive to deviate to multiple or even all low-cost retailers.

Proposition 4.3. *Assume regulation on RRPs (as the one described above) exists and the manufacturer announces* p_H^* *as the RRP, then an equilibrium with wholesale price discrimination exists and satisfies equations (4.7), (4.8), (4.10) and inequality (4.9).*

The next Proposition argues that the efficient equilibrium prices under wholesale price discrimination converge to the efficient equilibrium prices in the uniform pricing case if $\overline{s} \to 0$. Moreover, the comparative statics with respect to $\overline{s}$ is such that in a neighbourhood of $\overline{s} = 0$, the lowest wholesale and retail prices behave as in the uniform pricing equilibrium, whereas the highest wholesale and retail price charged are higher. Thus, consumers are worse off because of wholesale price discrimination. Furthermore, a fraction of consumers with low search costs has to search to find the low retail price p_L^*, while under uniform pricing consumers pay lower retail prices without further search.

Proposition 4.4. *As* $\overline{s} \to 0$*, in a wholesale price discrimination equilibrium, the retail and wholesale prices converge to* $p_L^* = w_L^* = p_H^* = w_H^*$*, where* $w_L^* = w_H^* = w^*$ *solves* $\frac{1}{2}w^* D'(w^*) + D(w^*) = 0$*. Moreover, in a neighbourhood of* $\overline{s} = 0$ *the comparative statics with respect to* $\overline{s}$ *is such that*

$$\begin{aligned}
\frac{dp_L^*}{d\overline{s}} &= -\frac{x}{D(p_H^*)}, \frac{dp_H^*}{d\overline{s}} = -\frac{1}{D(p_H^*)}\frac{xN-1}{N}, \\
\frac{dw_L^*}{d\overline{s}} &= -\frac{1+x}{D(p_H^*)} \text{ and } \frac{dw_H^*}{d\overline{s}} = -\frac{1}{D(p_H^*)}\frac{(1+x)N-2}{N}.
\end{aligned}$$

For larger values of $\overline{s}$ we numerically solve for linear demand and see how the equilibrium behaves under wholesale price discrimination. From the Proposition it follows that in a neighbourhood of $\overline{s} = 0$ and $N = 3$, $x = 2/3$, so that $\frac{dp_L^*}{d\overline{s}} \approx -2$,

$\frac{dw_L^*}{d\overline{s}} \approx -5$, $\frac{dp_H^*}{d\overline{s}} \approx -1, \frac{dw_H^*}{d\overline{s}} \approx -3$. Figure 4.2(Left) shows how wholesale and retail prices change for different values of $\overline{s}$. It is clear that wholesale and retail prices are decreasing in $\overline{s}$.

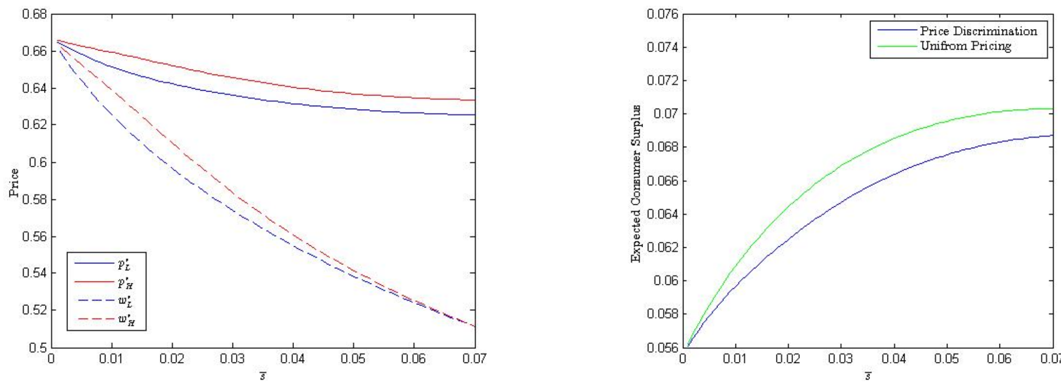

Figure 4.2: **Left:** Wholesale and Retail prices for different values of $\overline{s}$ and $N = 3$. **Right:** Expected Consumer Surplus for different values of $\overline{s}$ and $N = 3$.

Figure 4.2(Right) shows the difference in consumer surplus under wholesale price discrimination and uniform pricing. From the figure we can see that the impact of wholesale price discrimination on consumer surplus can be quite large. For instance, for an upper bound of the search cost distribution of 0.04, consumer surplus under wholesale price discrimination decreases by approximately 5%.

The comparison of retail prices under wholesale price discrimination and uniform pricing is depicted in Figure 4.3(Left) for general values of $\overline{s}$. It is clear that under wholesale price discrimination, both the low and the high retail prices are larger than the retail price under uniform pricing. The comparison between wholesale prices is depicted in Figure 4.3(Right) reinforcing Figure 4.3(Left) in that wholesale prices under wholesale price discrimination are larger than under uniform pricing.

Figure 4.4(Left) shows that both, low and high cost retailers, have lower margins under wholesale price discrimination. As argued before, wholesale price discrimination acts as a mechanism that indirectly screens searching consumers: consumers

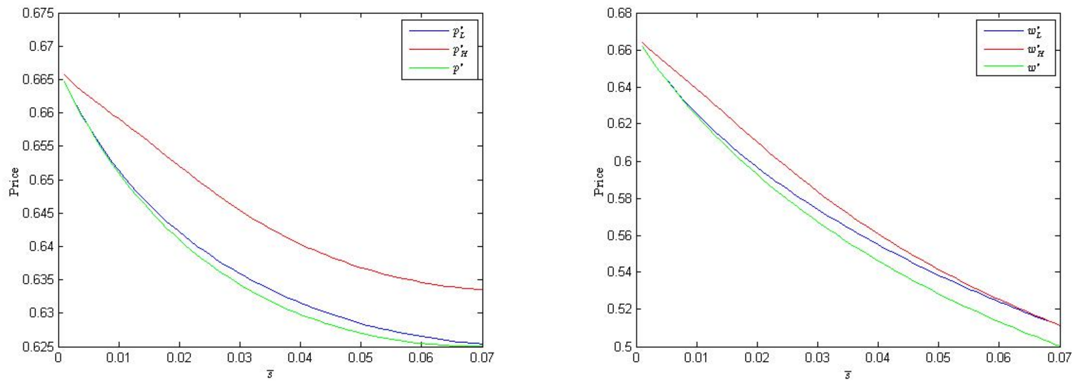

Figure 4.3: **Left:** Retail prices under uniform pricing and price discrimination and $N = 3$. **Right:** Wholesale prices under uniform pricing and price discrimination and $N = 3$.

with different search costs react differently to retail prices inducing more competition between retailers. Figure 4.4(Right) shows the difference in retail profits between uniform pricing and wholesale price discrimination. Despite the lower margins, low cost retailers earn higher profits compared to a retailer under uniform pricing for smaller values of $\overline{s}$. The reason is that the difference in margins is small, while low cost retailers gain more sales due to low cost searchers that first visited the high cost retailer and then continued to search for the low cost retailers. From Propositions 4.2 and 4.4 it follows that this is actually a general result for small values of $\overline{s}$: the first-order approximation for retail margins of the low cost retailers under wholesale price discrimination are equal to the ones under uniform pricing, but under price discrimination each of these retailers gets a share of $\frac{1}{N}\left(1 + \frac{1}{N(N-1)}\right)$ of the consumers, while under uniform pricing each retailer gets a share of $\frac{1}{N}$ of the consumers. For larger values of $\overline{s}$, the numerical analysis shows that it is the lower margins that dominate the impact on the low cost retailers' profits. The profit of retailers under uniform pricing are always higher than the profit the high cost retailer makes under wholesale price discrimination. Finally, we confirm in

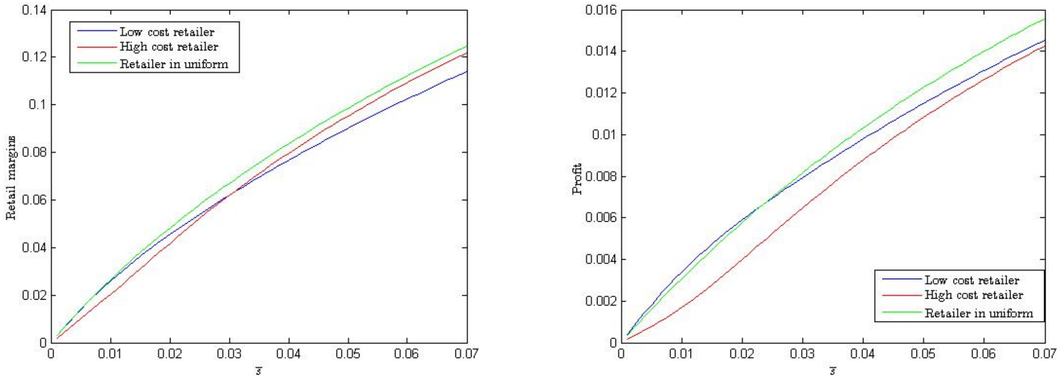

Figure 4.4: **Left:** Retail margins for different values of $\overline{s}$ and $N = 3$. **Right:** Retailers' Profit for different values of $\overline{s}$ and $N = 3$.

Figure 4.5 for $N = 3$ that the manufacturer earns higher profit under wholesale price discrimination and that the difference is increasing in $\overline{s}$.

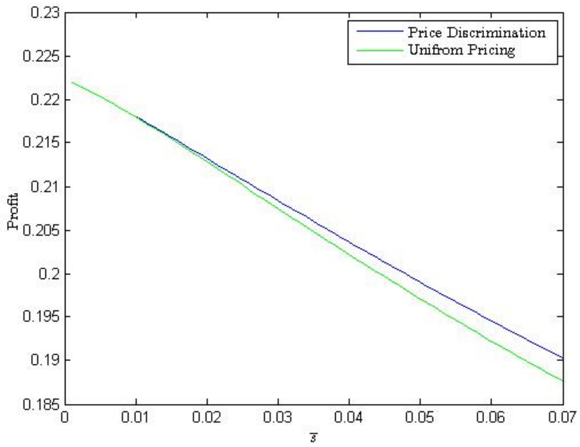

Figure 4.5: Manufacturer's Profit for different values of $\overline{s}$ and $N = 3$

4.4.2 Equilibrium under no regulation

In markets where wholesale arrangements are unobserved and there is no regulation on RRPs manufacturers cannot commit to their wholesale prices. For an equilibrium to exist, apart from the first-order conditions of the manufacturer, we also need to guarantee that the manufacturer does not have an incentive to give all retailers the same wholesale price, whether it is w_L^* or w_H^*. In principle, the manufacturer could set w_L^* or w_H^* to all retailers without any retailer noticing it at their price setting stage. To make such deviations unprofitable, we have to have that the manufacturer makes equal profits over the low and high cost retailers, thus we need:

$$w_H^* D(p_H^*) = w_L^* D(p_L^*) \tag{4.11}$$

in any equilibrium with wholesale price discrimination. Given (4.11) the first-order condition with respect to w_H can be simplified to

$$w_H^* D^{'}(p_H^*) \frac{\partial p_H}{\partial w_H} + D(p_H^*) = 0. \tag{4.12}$$

The next Proposition shows that when wholesale contracts are unobserved there does not exist an equilibrium with wholesale price discrimination.

Proposition 4.5. *Assume there is no regulation on RRPs, then an equilibrium with wholesale price discrimination does not exist.*

The proof of the proposition basically shows that the only way to satisfy the equal profit condition (4.11) and not to have an incentive to set a different high wholesale price ((4.12) is satisfied) is for the manufacturer to set a low wholesale price w_L^* for which it has an incentive to deviate. Alternatively, the only way to guarantee that (4.9) is satisfied is if $w_H^* D(p_H^*) < w_L^* D(p_L^*)$. However, given that retailers do not observe the wholesale prices set to their competitors, the manufacturer would then be able to profitably and secretly deviate and set w_L^* to all retailers. Figure 4.6 shows that for linear demand if, together with (4.7), (4.8) and (4.12), (4.9) is satisfied with equality, then $w_H^* D(p_H^*) < w_L^* D(p_L^*)$ for any value of $\overline{s}$. Non-existence of an equilibrium with wholesale price discrimination is thus not only an issue for small enough values of $\overline{s}$.

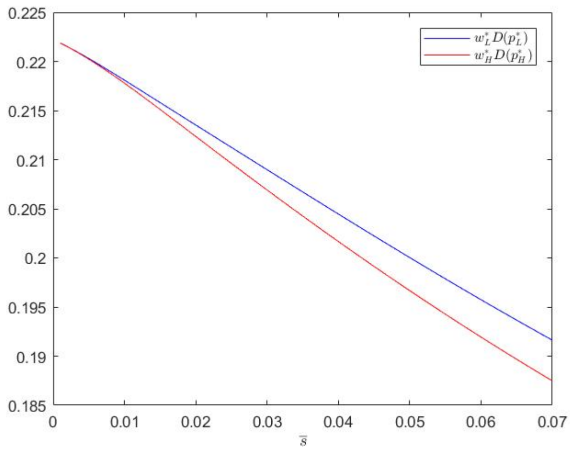

Figure 4.6: Manufacturer profit over the low and high cost retailers for different values of $\overline{s}$

Note that, unlike the argument on opportunism (see, e.g., McAfee and Schwartz (1994) and Rey and Vergé (2004)), the reason for the non-existence result in our context is *not* because we have assumed passive beliefs. As we have shown previously, an equilibrium with uniform pricing exists and the difference between unilateral and multilateral deviations that underlies the opportunism argument is not present here. The profitable deviation that is preventing equilibrium existence, not directly related to out-of-equilibrium beliefs at all, is the unilateral deviation where the manufacturer gives the retailer that is supposed to get a higher wholesale price the same (lower) wholesale equilibrium price as all the other retailers.

The regulation on RRPs, imposed by the Code of Federal Regulations, effectively resolves the issue of the non-existence of an equilibrium with wholesale price discrimination and allows the manufacturer to use RRPs to commit to wholesale price discrimination. The manufacturer announces the high retail price p_H^* as an RRP. She is then effectively committed to at least one retailer selling at this price and therefore has to choose w_H^* such that the retailer optimally reacts by setting p_H^*. Other retailers get a lower wholesale price w_L^* and sell at a price below the RRP. The deviation that destroyed the equilibrium with wholesale price discrimination (namely the manufacturer secretively setting the wholesale price w_L^* to all retailers) is penalized by the regulation and therefore not optimal any more. As the remaining equilibrium conditions (4.7), (4.8), (4.9) and (4.12) imply that $w_H^* D(p_H^*) < w_L^* D(p_L^*)$, the manufacturer is not tempted to set w_H^* to more than one retailer. Note that the observation that recommendations often do not bind in practice as most products sell at a price below the RRP naturally follows from our framework.

4.5 Conclusion

This paper contributes to the policy discussion on whether recommended retail prices should be regulated or not. More specifically, we have analysed the role of legislation requiring that a substantial number of sales are made at Recommended Retail Prices. This regulation was introduced by the Federal Trade Commission with the intention of protecting consumers from fictitious retail practices. We have found that without such legislation equilibria with wholesale price discrimination cannot exist. The reason is that in the absence of such restrictions, wholesale price discrimination can only be an equilibrium when the manufacturer makes identical profits over all retailers (those that received a low and a high wholesale price). If not, the manufacturer may secretly deviate and charge the same wholesale price to all retailers. However, this equal profit condition cannot be satisfied together with the first-order conditions that the low and high wholesale price have to satisfy. Thus, in the absence of the restrictions imposed on RRPs, a manufacturer will sell at a uniform price to all retailers, creating uniform pricing at the retail level.

We have demonstrated that such regulation grants manufacturers with the possibility to partially commit to their unobserved wholesale prices and allows them to engage in wholesale price discrimination. The discrimination prices are accompanied by an announcement that the retail price of the high cost retailer(s) is the RRP.

Once such an announcement is made, the manufacturer is not free to deviate and charge all retailers the same low wholesale price without violating the legislation. When discrimination is enabled, the price dispersion that emerges in the retail market induces consumers to search more. In this way, retail competition intensifies and retailer react less to increases in the wholesale prices. The manufacturer thus faces a less elastic demand and charges higher wholesale prices which result in higher retail prices. Therefore, despite the fact that competition authorities impose such restrictions with the aim of protecting consumers, we have shown that such rulings may actually have the opposite effect on consumer welfare. Crucial to our analysis is that consumers in the retail market have heterogeneous search cost and that neither they nor retailers observe the wholesale arrangements. In particular, it is important that consumers only observe the retail price they encounter when searching and that they do not know the wholesale arrangements. Retailers, on the other hand, only observe their own wholesale price and are not aware of the prices that other retailers face.

4.6 Appendix

Proof of Proposition 4.1: Apart from the expression for $\frac{\partial \widetilde{p}(w^*)}{\partial w}$ all the equilibrium conditions are explained in the main text. From (4.3) it follows that:

$$
\begin{aligned}
&- g^{'}\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right) D^3(\widetilde{p})(\widetilde{p}-w)\frac{d\widetilde{p}}{dw} - 2g\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right) D(\widetilde{p})D^{'}(\widetilde{p})(\widetilde{p}-w)\frac{d\widetilde{p}}{dw}\\
&- g\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right) D(\widetilde{p})\left(D^{'}(\widetilde{p})(\widetilde{p}-w)+D(\widetilde{p})\right)\frac{d\widetilde{p}}{dw} - g\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right) D^2(\widetilde{p})(\frac{d\widetilde{p}}{dw}-1)\\
&+\left(1-G\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right)\right)\left(\left(D^{''}(\widetilde{p})(\widetilde{p}-w)+D^{\prime}(\widetilde{p})\right)\frac{d\widetilde{p}}{dw}+D^{\prime}(\widetilde{p})(\frac{d\widetilde{p}}{dw}-1)\right)=0,
\end{aligned}
$$

or,

$$
\begin{aligned}
&- g^{'}\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right) D^3(\widetilde{p})(\widetilde{p}-w)\frac{d\widetilde{p}}{dw} - 3g\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right) D(\widetilde{p})D^{'}(\widetilde{p})(\widetilde{p}-w)\frac{\partial\widetilde{p}}{\partial w}\\
&- g\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right) D^2(\widetilde{p})(2\frac{\partial\widetilde{p}}{\partial w}-1) + \left(1-G\left(\int_{p^*(w^*)}^{\widetilde{p}} D(p)dp\right)\right)\left(D^{''}(\widetilde{p})(\widetilde{p}-w)\frac{\partial\widetilde{p}}{\partial w}+D^{\prime}(\widetilde{p})(2\frac{\partial\widetilde{p}}{\partial w}-1)\right)=0.
\end{aligned}
$$

Using the fact that we want to evaluate $\frac{d\widetilde{p}}{dw}$ at $w = w^*$ we can use (4.1) to get

$$-g^{'}(0)\, D^3(\widetilde{p})(\widetilde{p}-w)\frac{d\widetilde{p}}{dw} - 3g(0)D(\widetilde{p})D^{'}(\widetilde{p})(\widetilde{p}-w)\frac{d\widetilde{p}}{dw} - g(0)D^2(\widetilde{p})(2\frac{d\widetilde{p}}{dw}-1)$$
$$+D^{''}(\widetilde{p})(\widetilde{p}-w)\frac{d\widetilde{p}}{dw} + D'(\widetilde{p})(2\frac{d\widetilde{p}}{dw}-1) = 0,$$

which gives the expression in (4.4).

Proof of Proposition 4.2: The first part of the Proposition easily follows as the expression for $\frac{\partial\widetilde{p}(w^*)}{\partial w}$ reduces to $\frac{1}{2}$ if $g(0) \to \infty$. To show existence we first show that the manufacturer does not want to *increase* her wholesale price. In particular, we show that

$$D(\widetilde{p}) + wD'(\widetilde{p})\frac{\partial\widetilde{p}}{\partial w} \leq 0 \quad \text{ for all } w > w^*.$$

First, note that if the manufacturer deviates and sets a w to one or multiple retailers such that all consumers who visit these retailers continue to search, she cannot make more profit than in equilibrium. In the best case, if the manufacturer sticks to the wholesale equilibrium price for one retailer, she will make the same profit as in equilibrium, while if she deviates to all retailers, she will make less profit as the retailers will react by setting $\widetilde{p} = w$ and $wD(w)$ is decreasing in w for all $w > w^*$ (because $2D'(w) + wD''(w) < 0$ and the equilibrium wholesale price is such that $\frac{1}{2}w^*D^{'}(w^*) + D(w^*) \leq 0$ and thus larger than the optimal price of an integrated monopolist).

Thus, consider deviations such that some consumers still buy from the retailer where the manufacturer has deviated. In this case, the above inequality holds certainly true if the derivative of the LHS with respect to w

$$2D'(\widetilde{p})\frac{\partial\widetilde{p}}{\partial w} + wD''(\widetilde{p})\left(\frac{\partial\widetilde{p}}{\partial w}\right)^2 + wD'(\widetilde{p})\frac{\partial^2\widetilde{p}}{\partial w^2} < 0 \quad \text{ for all } w > w^*. \tag{4.13}$$

From (9) it follows that in a neighbourhood of $\overline{s} = 0$ where $g(s) \to \infty$ $\frac{\partial \widetilde{p}}{\partial w}$ can be approximated by

$$\frac{d\widetilde{p}}{dw} = \frac{1}{2} + \frac{3D^{'}(\tilde{p})(\widetilde{p} - w)}{-4D(\widetilde{p})} > \frac{1}{2}.$$

As $\lim_{\overline{s} \to \infty} \frac{\partial \widetilde{p}}{\partial w} = \frac{1}{2}$, it must be the case that $\frac{\partial^2 \widetilde{p}}{\partial w^2} > 0$ for small enough values of $\overline{s}$. Thus, (4.13) holds true if $(2D'(\widetilde{p}) + wD''(\widetilde{p})) \frac{\partial \widetilde{p}}{\partial w} < 0$. This is certainly the case as $2D'(\widetilde{p}) + wD''(\widetilde{p}) \approx 2D'(pw) + wD''(w) < 0$ for small enough values of $\overline{s}$ and $\frac{\partial \widetilde{p}}{\partial w} > 0$.

We next show that the manufacturer does not want to *decrease* her wholesale price either. The only candidate deviation is to deviate to w^M. So, we have to compare the equilibrium profit $w^* D(p^*)$ to $w^M D(p^M(w^M))$. If $w^* \leq p^M(w^M)$, deviating downwards to w^M cannot be profitable as retailers would not react to such a deviation. So, consider $w^* > p^M(w^M)$. In that case $\frac{1}{2} p^M(w^M) D^{'}(p^M(w^M)) + D(p^M(w^M)) \geq 0$.[5] Combining this inequality with the FOC of the retail monopoly price $D(p^M(w^M)) + (p^M(w) - w^M) D'(p^M(w)) = 0$ it follows that $p^M(w) - w^M > \frac{1}{2} p^M(w^M)$ or $p^M(w^M) > 2w^M$. But this contradicts the manufacturer's optimality condition of the double marginalization price $D(p^M(w^M)) + w^M D'(p^M(w)) \frac{\partial p^M(w^M)}{\partial w} = 0$ if $\frac{\partial p^M(w^M)}{\partial w} > 1$ as $w^* > 2w^M$.

To establish that an equilibrium exists for small enough values of $\overline{s}$, we also have to consider the retailer's decision problem. It is clear that downward deviations are not optimal for the retailer as they do not attract new customers by doing so. From the retailer's profit function, it follows that for all $\widetilde{p} \geq p^*$ the first-order derivative equals

$$-g\left(\int_{p^*}^{\widetilde{p}} D(p)dp\right) D^2(\widetilde{p})(\widetilde{p} - w) + D^{'}(\widetilde{p})(\widetilde{p} - w) + D(\widetilde{p}),$$

[5] As $pD''(p) + 2D'(p) < 0$ it follows that the derivative of $\frac{1}{2} pD^{'}(p) + D(p) < 0$.

while the second-order derivative equals:

$$-g'\left(\int_{p^*}^{\widetilde{p}} D(p)dp\right) D^3(\widetilde{p})(\widetilde{p}-w) - g\left(\int_{p^*}^{\widetilde{p}} D(p)dp\right) D(\widetilde{p})\left(2D^{'}(\widetilde{p})(\widetilde{p}-w)+D(\widetilde{p})\right) + D^{''}(\widetilde{p})(\widetilde{p}-w) + 2D^{'}(\widetilde{p}).$$

As $(\widetilde{p}-w)$ is close to 0 if $\overline{s}$ is small and as $g'(s) > -M$ this expression is smaller than 0 if $\overline{s}$ is small. Thus, for small enough values of $\overline{s}$ the profit function is concave and the retailers' FOC yields the global maximum.

To prove the comparative statics results, we first rewrite the equilibrium condition for the manufacturer in a neighbourhood of $\overline{s}=0$ as

$$\begin{aligned} 0 &= wD'(p^*)\left(\frac{D'(p^*)}{g(0)} - D^2(p^*)\right) - 3D^2(p^*)D^{'}(p^*)(p^*-w) - 2D^3(p^*) \\ &\quad + \frac{2D'(p^*)D(p^*) + 2D^{''}(p^*)D(p^*)(p^*-w) - g^{'}(0)\, D^4(p^*)(p^*-w)}{g(0)}. \end{aligned}$$

Taking the total differential and taking into account that in a neighbourhood of $\overline{s}=0, g(0) \to \infty$ this approximately yields

$$\begin{aligned} 0 &\approx D'(p^*)\left(w^*D'(p^*) + 2D(p^*)\right) d\frac{1}{g(0)} + 2D'(p^*)D^2(p^*)dw \\ &\quad + \left(-w^*D''(p^*)D^2(p^*) - 2w^*D'^2(p^*)D(p^*) - 9D^2(p^*)D^{'}(p^*)\right) dp^*. \end{aligned}$$

As $\frac{1}{2}w^*D'(p^*) + D(p^*) = 0$ the first term is approximately equal to 0 so that we have

$$dw^* = \frac{w^*D''(p^*) + 5D^{'}(p^*)}{2D'(p^*)} dp^*.$$

Taking the total differential of the first-order condition (4.1) of the retailer evaluated in a neighbourhood of $\overline{s}=0$ is

$$d\frac{1}{g(0)} + D(p^*)dw^* - D(p^*)dp^* = 0.$$

Combining these two equations gives

$$\frac{dw^*}{d\frac{1}{g(0)}} = -\frac{w^* D''(p^*) + 5D^{'}(p^*)}{D(p^*)\left(w^* D''(p^*) + 3D^{'}(p^*)\right)}.$$

As the demand function satisfies $w^* D''(p^*) + 2D^{'}(p^*) < 0$ it follows that both $\frac{dw^*}{d\frac{1}{g(0)}}$ and $\frac{dp^*}{d\frac{1}{g(0)}}$tare negative.

Proof of Proposition 4.3 Here we prove an equilibrium with wholesale price discrimination exists if $\overline{s}$ is small enough and $\frac{\partial p^M(w^M)}{\partial w} < 1$. The first part to notice is that the comparative statics results will indeed show that $p_H^* > p_L^*$ and $w_H^* > w_L^*$ in a neighbourhood of $\overline{s} = 0$. Next, we will show, separately for both both w_H^* and w_L^*, that the manufacturer does not want to increase these respective wholesale prices beyond their equilibrium values. It is clear that the manufacturer does not want to increase its prices such that all consumers visiting that retailer will continue to search. In addition, in the range of prices where some consumers continue to buy from a retailer it suffices that the second-order derivative of the manufacturer's profit function with respect to $w_i, i = L, H$, is negative

$$2D'(\widetilde{p}_i)\frac{\partial \widetilde{p}_i}{\partial w_i} + w_i D''(\widetilde{p}_i)\left(\frac{\partial \widetilde{p}_i}{\partial w_i}\right)^2 + w_i D'(\widetilde{p}_i)\frac{\partial^2 \widetilde{p}_i}{\partial w_i^2} < 0 \quad \text{for } i = L, H \text{ and all } w > w^*.$$

From (4.20) it follows that in a neighbourhood of $\overline{s} = 0$ where $g(s) \to \infty$ $\frac{\partial \widetilde{p}_H}{\partial w_H}$ can be approximated by

$$\frac{\partial \widetilde{p}_H}{\partial w_H} \approx \frac{1}{2} + \frac{3D'(p_H^*)(p_H - w_H)}{-4D(p_H)} > \frac{1}{2}.$$

Similarly, in a neighbourhood of $\overline{s} = 0$ (4.22) can be approximated by

$$\frac{\partial \widetilde{p}_L}{\partial w_L} \approx \frac{1}{2} + \frac{3D'(p_L^*)(p_L - w_L)}{-2D(p_L)} > \frac{1}{2}.$$

Thus, we can argue that $\frac{\partial^2 \widetilde{p}_i}{\partial w_i^2} > 0, i = L, H$ in a neighbourhood of $\overline{s} = 0$. Therefore, the second-order condition is satisfied and the manufacturer does not want to increase her wholesale prices beyond their equilibrium values.

To show that the manufacturer does not want to deviate with multiple wholesale prices, we proceed in a few steps. First, it is clear that the manufacturer does not want to decrease w_L, as these retailers will not follow suit in lowering retail prices in response. Second, consider an increase in w_H and an increase in one or more w_L's. From the above it is clear that, keeping all w_L's at their equilibrium values, an increase in w_H cannot increase profits, despite the fact that $w_H^* D(p_H^*) < w_L^* D(p_L^*)$. As it follows from (4.9) that $w_L D(p_L(w_L))$ is decreasing in w_L it cannot be the case that increasing w_H and one or more w_L's is profitable. Finally, and similar to the second step, one can argue that a decrease in w_H combined with an increase in one or more w_L's is not profitable.

Finally, we need to show that in the equilibrium $w_L^* D(p_L^*) > w_H^* D(p_H^*)$ so that the manufacturer does not want to set w_H^* to more firms (while the regulation requiring some sales to occur at p_H^* after announcing p_H^* as the RRP prevents the manufacturer to charge all firms w_L^*. This part of the proof relies heavily on the proof of Proposition 4.5. First, from that proof we know that $w_L^* D(p_L^*)$ cannot be equal to $w_H^* D(p_H^*)$. Suppose then that $w_L^* D(p_L^*) < w_H^* D(p_H^*)$. From (4.10) it then follows that $w_H^* D'(p_H^*) \frac{\partial p_H}{\partial w_H} + D(p_H^*) > 0$. We need to show that this implies that $w_L^* D'(p_L^*) \frac{\partial p_L}{\partial w_L} + D(p_L^*) > 0$. We can follow the same steps as in the second part of the proof of Proposition 4.5. In particular, we can use (4.23) and use that from the hypothesis that $w_L^* D(p_L^*) < w_H^* D(p_H^*)$ in a neighbourhood of $\overline{s} = 0$ (while $w_L^* D(p_L^*) = w_H^* D(p_H^*)$ at $\overline{s} = 0$) it follows that $D(p^*) dw_L + w^* D'(p^*) dp_L < D(p^*) dw_H + w^* D'(p^*) dp_H$ so that $dw_H - dw_L > 2\left(dp_H - dp_L\right)$ and continue using the proof of Proposition 4.5.

Proof of Proposition 4.4. We will show that if an equilibrium exists, it must be that $\frac{1}{2}w^*D^{'}(w^*)+D(w^*)=0$ in the limit where $\overline{s}\to 0$. From (4.7) it is clear that in any equilibrium with wholesale price discrimination $p_H^*\to w_H^*$. As $0<\widehat{s}<\overline{s}$, where $\widehat{s}=\int_{p_L^*}^{p_H^*}D(p)dp$, it must be the case that $p_H^*\to p_L^*$ if $\overline{s}\to 0$. Next, consider (4.8) if $\overline{s}\to 0$. Since also $\hat{s}\to 0$, and $D^{'}(p_L^*)<0$ while $D(p_L^*)>0$ it must be that in any equilibrium with wholesale price discrimination $p_L^*\to w_L^*$. Thus, if $\overline{s}\to 0$ it follows that $p_H^*\approx p_L^*\approx w_H^*\approx w_L^*$. It remains to be seen to which values the wholesale and retail prices converge. Consider (10) and that (4.21) implies that $\frac{\partial p_L}{\partial w_L}\approx\frac{1}{2}$ in a neighbourhood of $\overline{s}=0$ where $p_L^*-w_L^*\approx 0$ the first-order condition determining w_L^* can be simplified to $\frac{1}{2}w_L^*D^{'}(w_L^*)+D(w_L^*)\approx 0$.

We now prove the comparative statics results assuming an equilibrium exists and come back to the existence issue at the end of the proof. Substituting (4.22), (4.9) can be written as

$$\begin{aligned}0 \;=\; & -w_L^*D^{'}(p_L^*)D(p_L^*)+D''(p_L^*)2D(p_L^*)(p_L^*-w_L^*)^2-2D^2(p_L^*)\\ & -\left[D'(p_L^*)(p_L^*-w_L^*)^2+D(p_L^*)(p_L^*-w_L^*)\right]\left(3D'(p_L^*)+\frac{\left(\frac{N-1}{N}\right)^2g'(0)-\frac{g'(\widehat{s})}{N-1}}{\left(\frac{N-1}{N}g(0)+\frac{g(\widehat{s})}{N-1}\right)}\right).\end{aligned}$$

Taking the total differential in a neighbourhood of $\overline{s}=0$, where $p_L^*\approx w_L^*$ and $g(0)$ and $g(\widehat{s})$ are large, gives

$$-D(p_L^*)D'(p_L^*)dw_L^*-w_L^*\left(D(p_L^*)D''(p_L^*)+D'^2(p_L^*)\right)dp_L^*-4D(p_L^*)D'(p_L^*)dp_L^*-3D^{'}(p_L^*)D(p_L^*)\left(dp_L^*-dw_L^*\right)\approx 0,$$

which can be rewritten as

$$2D'(p_L^*)dw_L^*-\left(w_L^*D''(p_L^*)+w_L^*\frac{D'^2(p_L^*)}{D(p_L^*)}+7D'(p_L^*)\right)dp_L^*\approx 0.$$

Thus, we have

$$dw_L^* \approx \left(\frac{w_L^* D''(p_L^*) + 5D'(p_L^*)}{2D'(p_L^*)} \right) dp_L^*. \tag{4.14}$$

As $g'(s)$ is bounded we can approximate $G(\widehat{s})$ in a neighbourhood of $\overline{s} = 0$ by $g(0) \int_{p_L^*}^{p_H^*} D(p)dp$ and approximate the first-order condition of the low-cost retailer as

$$0 \approx \; -\left(\frac{(N-1)^2}{N} + 1 \right) D^2(p_L^*)(p_L^* - w_L^*) + \int_{p_L^*}^{p_H^*} D(p)dp \left[D^{'}(p_L^*)(p_L^* - w_L^*) + D(p_L^*) \right] + \frac{(N-1)\left[D^{'}(p_L^*)(p_L^* - w_L^*) + D(p_L^*) \right]}{g\,(0)}.$$

Taking the total differential in a neighbourhood of $\overline{s} = 0$ gives

$$0 \approx -\left(\frac{(N-1)^2}{N} + 1 \right) D(p_L^*)(dp_L^* - dw_L^*) + (N-1) d\frac{1}{g\,(0)} + D(p_L^*)dp_H^* - D(p_L^*)dp_L^*. \tag{4.15}$$

Similarly, we can rewrite the first-order condition of the high-cost retailer as

$$-D^2(p_H^*)(p_H^* - w_H) - \left[D^{'}(p_H^*)(p_H^* - w_H) + D(p_H^*) \right] \int_{p_L^*}^{p_H^*} D(p)dp + \frac{\left[D^{'}(p_H^*)(p_H^* - w_H) + D(p_H^*) \right]}{g(0)} \approx 0.$$

Taking the total differential in a neighbourhood of $\overline{s} = 0$ gives

$$-D^2(p_H^*)(dp_H^* - dw_H) + D(p_H^*) d\frac{1}{g\,(0)} - D^2(p_H^*)dp_H^* + D(p_H^*)D(p_L^*)dp_L^* \approx 0,$$

or

$$-\, D(p_H^*)(2dp_H^* - dw_H) + d\frac{1}{g\,(0)} + D(p_H^*)dp_L^* \approx 0, \tag{4.16}$$

Finally, we consider the first-order condition of the manufacturer for the high-cost wholesale price

$$(1 - G(\widehat{s}))\left[w_H^* D'(p_H^*)\tfrac{\partial p_H}{\partial w_H} + D(p_H^*)\right] + g(0)D(p_H^*)\tfrac{\partial p_H}{\partial w_H}\left[w_L^* D(p_L^*) - w_H^* D(p_H^*)\right] = 0.$$

This can be approximated as

$$\left(\tfrac{1}{g(0)} - \int_{p_L^*}^{p_H^*} D(p)dp\right)\left[w_H^* D'(p_H^*)\tfrac{\partial p_H}{\partial w_H} + D(p_H^*)\right] + D(p_H^*)\tfrac{\partial p_H}{\partial w_H}\left[w_L^* D(p_L^*) - w_H^* D(p_H^*)\right] \approx 0,$$

so that the total differential in a neighbourhood of $\overline{s} = 0$ yields

$$w_L^* D'(p_L^*)dp_L^* + D(p_L^*)dw_L^* \approx w_H^* D'(p_H^*)dp_H^* + D(p_H^*)dw_H^*,$$

or, using $w_L^* D'(p_L^*)\frac{1}{2} + D(p_L^*) = 0$,

$$-2dp_L^* + dw_L^* \approx -2dp_H^* + dw_H^*, \tag{4.17}$$

Thus, we should solve the four equations (4.14), (4.15), (4.16) and (4.17) to solve for the respective derivatives. Combining (4.16) and (4.17) gives

$$D(p_H^*)(dp_L^* - dw_L^*) \approx d\frac{1}{g(0)}. \tag{4.18}$$

Combined with (4.14) gives

$$dp_L^* \approx -\frac{1}{D(p_H^*)}\frac{2D'(p_L^*)}{w_L^* D''(p_L^*) + 3D'(p_L^*)}d\frac{1}{g(0)},$$

and

$$dw_L^* \approx -\frac{1}{D(p_H^*)}\frac{w_L^* D''(p_L^*) + 5D'(p_L^*)}{w_L^* D''(p_L^*) + 3D'(p_L^*)}d\frac{1}{g(0)}$$

Substitute (4.18) into (4.15) gives

$$-\frac{1}{N}(dp_L^* - dw_L^*) + dp_H^* - dp_L^* \approx 0.$$

Combined with the expressions for dp_L^* and dw_L^* gives

$$dp_H^* \approx -\frac{1}{D(p_H^*)}\left(-\frac{1}{N} + \frac{2D'(p_L^*)}{w_L^* D''(p_L^*) + 3D'(p_L^*)}\right) d\frac{1}{g\left(0\right)}.$$

Substituting all expressions into (4.17) yields

$$\begin{aligned} dw_H^* &\approx 2\left(dp_H^* - dp_L^*\right) + dw_L^* \approx \frac{2}{N}\left(dp_L^* - dw_L^*\right) + dw_L^* \\ &\approx -\frac{1}{D(p_H^*)}\left(-\frac{2}{N} + \frac{w_L^* D''(p_L^*) + 5D'(p_L^*)}{w_L^* D''(p_L^*) + 3D'(p_L^*)}\right) d\frac{1}{g\left(0\right)}. \end{aligned}$$

This proves the comparative statics results.

Proof of Proposition 4.5. In an equilibrium the FOCs for profit maximization for both retailers should be satisfied. For the high-cost retailer the FOC can be written as

$$-g\left(\widehat{s} + \int_{p_H^*}^{p_H} D(p)dp\right) D^2(p_H)(p_H - w_H) + \left(1 - G\left(\widehat{s} + \int_{p_H^*}^{p_H} D(p)dp\right)\right)\left[D'(p_H)(p_H - w_H) + D(p_H)\right]. \tag{4.19}$$

Taking the total differential gives

$$\begin{aligned} &-3g\left(\widehat{s} + \int_{p_H^*}^{p_H} D(p)dp\right) D(p_H)D'(p_H)(p_H - w_H)\frac{dp_H}{dw_H} \\ &- g\left(\widehat{s} + \int_{p_H^*}^{p_H} D(p)dp\right) D^2(p_H)(2\frac{dp_H}{dw_H} - 1) - g'\left(\widehat{s} + \int_{p_H^*}^{p_H} D(p)dp\right) D^3(p_H)(p_H - w_H)\frac{dp_H}{dw_H} + \\ &\left(1 - G\left(\widehat{s} + \int_{p_H^*}^{p_H} D(p)dp\right)\right)\left[D''(p_H)(p_H - w_H)\frac{dp_H}{dw_H} + D'(p_H)(2\frac{dp_H}{dw_H} - 1)\right] = 0, \end{aligned}$$

which evaluated at the equilibrium values yields

$$
\begin{aligned}
&- g'\left(\widehat{s}\right) D^3(p_H^*)(p_H^* - w_H^*)\frac{dp_H}{dw_H} - 3g\left(\widehat{s}\right) D(p_H^*)D'(p_H^*)(p_H^* - w_H^*)\frac{dp_H}{dw_H} \\
&+ (1 - G\left(\widehat{s}\right)) \left[D''(p_H^*)(p_H^* - w_H^*)\frac{dp_H}{dw_H} + D'(p_H^*)(2\frac{dp_H}{dw_H} - 1)\right] \\
&- g\left(\widehat{s}\right) D^2(p_H^*)(2\frac{dp_H}{dw_H} - 1) = 0.
\end{aligned}
$$

Thus, $\frac{dp_H}{dw_H}$ is:

$$
\frac{(1-G(\widehat{s}))D'(p_H^*)-g(\widehat{s})D^2(p_H^*)}{-g'(\widehat{s})D^3(p_H^*)(p_H^*-w_H^*)-3g(\widehat{s})D(p_H^*)D'(p_H^*)(p_H^*-w_H^*)+(1-G(\widehat{s}))\left[D''(p_H^*)(p_H^*-w_H^*)+2D'(p_H^*)\right]-2g(\widehat{s})D^2(p_H^*)}.
$$

Using the first-order condition (4.7), we can rewrite

$$
\frac{dp_H}{dw_H} = \frac{-\frac{D(p_H^*)}{(p_H^*-w_H^*)}}{-\left(3D'(p_H^*) + \frac{g'(\widehat{s})}{g(\widehat{s})}\right)\left[\frac{D'(p_H^*)(p_H^*-w_H^*)}{D(p_H^*)} + 1\right] + D''(p_H^*)(p_H^* - w_H^*) - \frac{2D(p_H^*)}{(p_H^*-w_H^*)}}. \tag{4.20}
$$

For the low-cost retailer we can perform a similar analysis to evaluate $\frac{\partial p_L}{\partial w_L}$. Taking the first-order condition of (4.6) with respect to p_L yields

$$
\begin{aligned}
0 = \; &\left[1 - G\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right) + \frac{G\left(\int_{p_L}^{p_H^*} D(p)dp\right)}{(N-1)}\right] [D'(p_L)(p_L - w_L) + D(p_L)] \\
&- \left(\frac{N-1}{N} g\left(\frac{N-1}{N}\int_{p_L^*}^{p_L} D(p)dp\right) + \frac{g\left(\int_{p_L}^{p_H^*} D(p)dp\right)}{N-1}\right) D^2(p_L)(p_L - w_L).
\end{aligned}
$$

Taking the total differential and inserting equilibrium values gives

$$
\begin{aligned}
0 \;=\; & -\left[\frac{N-1}{N}g\left(0\right)+\frac{g\left(\widehat{s}\right)}{N-1}\right]D(p_L)\left[D'(p_L)(p_L-w_L)+D(p_L)\right]\frac{dp_L}{dw_L}+ \\
& \left[1+\frac{G\left(\widehat{s}\right)}{(N-1)}\right]\left[D''(p_L)(p_L-w_L)\frac{dp_L}{dw_L}+D'(p_L)(2\frac{dp_L}{dw_L}-1)\right] \\
& -\left(\left(\frac{N-1}{N}\right)^2g'\left(0\right)-\frac{g'\left(\widehat{s}\right)}{N-1}\right)D^3(p_L)(p_L-w_L)\frac{dp_L}{dw_L} \\
& -\left(\frac{N-1}{N}g\left(0\right)+\frac{g\left(\widehat{s}\right)}{N-1}\right)D(p_L)\left(2D'(p_L)(p_L-w_L)\frac{dp_L}{dw_L}+D(p_L)(\frac{dp_L}{dw_L}-1)\right),
\end{aligned}
$$

which can be rewritten as

$$
\begin{aligned}
0 \;=\; & -3\left[\frac{N-1}{N}g\left(0\right)+\frac{g\left(\widehat{s}\right)}{N-1}\right]D(p_L)D'(p_L)(p_L-w_L)\frac{dp_L}{dw_L}+ \\
& \left[1+\frac{G\left(\widehat{s}\right)}{(N-1)}\right]\left[D''(p_L)(p_L-w_L)\frac{dp_L}{dw_L}+D'(p_L)(2\frac{dp_L}{dw_L}-1)\right] \\
& -\left(\left(\frac{N-1}{N}\right)^2g'\left(0\right)-\frac{g'\left(\widehat{s}\right)}{N-1}\right)D^3(p_L)(p_L-w_L)\frac{dp_L}{dw_L} \\
& -\left(\frac{N-1}{N}g\left(0\right)+\frac{g\left(\widehat{s}\right)}{N-1}\right)D^2(p_L)(2\frac{dp_L}{dw_L}-1),
\end{aligned}
$$

or

$$
\frac{dp_L}{dw_L}=\frac{\left[1+\frac{G(\widehat{s})}{(N-1)}\right]D'(p_L^*)-\left(\frac{N-1}{N}g(0)+\frac{g(\widehat{s})}{N-1}\right)D^2(p_L^*)}{-\left(\left(\frac{N-1}{N}\right)^2g'(0)-\frac{g'(\widehat{s})}{N-1}\right)D^3(p_L^*)(p_L^*-w_L^*)-\left[\frac{N-1}{N}g(0)+\frac{g(\widehat{s})}{N-1}\right]\left(3D(p_L^*)D'(p_L^*)(p_L^*-w_L^*)+2D^2(p_L^*)\right)+\left[1+\frac{G(\widehat{s})}{(N-1)}\right]\left[D''(p_L^*)(p_L^*-w_L^*)+2D'(p_L^*)\right]} \tag{4.21}
$$

Using the first-order condition (4.8) evaluated at equilibrium values, we can rewrite

$$
\frac{dp_L}{dw_L}=\frac{-\frac{D(p_L^*)}{(p_L^*-w_L^*)}}{-\left[\frac{D'(p_L^*)}{D(p_L^*)}(p_L^*-w_L^*)+1\right]\left(3D'(p_L^*)+\frac{\left(\frac{N-1}{N}\right)^2g'(0)-\frac{g'(\widehat{s})}{N-1}}{\left(\frac{N-1}{N}g(0)+\frac{g(\widehat{s})}{N-1}\right)}\right)+D''(p_L^*)(p_L^*-w_L^*)-\frac{2D(p_L^*)}{p_L^*-w_L^*}}. \tag{4.22}
$$

From the expressions for $\frac{dp_H}{dw_H}$ and $\frac{dp_L}{dw_L}$ it follows that in a neighbourhood of $\overline{s}=0$ where $p_i^* \approx w_i^*, i=L,H$

$$\frac{dp_L}{dw_L}-\frac{dp_H}{dw_H}=-\frac{\left(3D'(p_L^*)+\frac{\left(\frac{N-1}{N}\right)^2 g'(0)-\frac{g'(\widehat{s})}{N-1}}{\left(\frac{N-1}{N}g(0)+\frac{g(\widehat{s})}{N-1}\right)}\right)(p_H^*-w_H^*)}{4D(p_L^*)}+\frac{\left(3D'(p_H^*)+\frac{g'(\widehat{s})}{g(\widehat{s})}\right)(p_L^*-w_L^*)}{4D(p_H^*)}.$$

We now prove that in a neighbourhood of $\overline{s}=0$ we have that if (4.12), then: $w_L^* D'(p_L^*)\frac{\partial p_L}{\partial w_L}+D(p_L^*)$

$$\approx w_L^* D'(p_L^*)\left(\frac{\partial p_H}{\partial w_H}-\frac{\left(3D'(p_L^*)+\frac{\left(\frac{N-1}{N}\right)^2 g'(0)-\frac{g'(\widehat{s})}{N-1}}{\left(\frac{N-1}{N}g(0)+\frac{g(\widehat{s})}{N-1}\right)}\right)(p_H^*-w_H^*)}{4D(p_L^*)}+\frac{\left(3D'(p_H^*)+\frac{g'(\widehat{s})}{g(\widehat{s})}\right)(p_L^*-w_L^*)}{4D(p_H^*)}\right)+D(p_L^*)>0.$$

Our claim is true if

$$\begin{aligned}0> \quad & (w_H^* D'(p_H^*)-w_L^* D'(p_L^*))\frac{\partial p_H}{\partial w_H}+D(p_H^*)-D(p_L^*)+\\ & w_L^* D'(p_L^*)\left(\frac{\left(3D'(p_L^*)+\frac{\left(\frac{N-1}{N}\right)^2 g'(0)-\frac{g'(\widehat{s})}{N-1}}{\left(\frac{N-1}{N}g(0)+\frac{g(\widehat{s})}{N-1}\right)}\right)(p_H^*-w_H^*)}{4D(p_L^*)}-\frac{\left(3D'(p_H^*)+\frac{g'(\widehat{s})}{g(\widehat{s})}\right)(p_L^*-w_L^*)}{4D(p_H^*)}\right).\end{aligned}$$

In a neighborhood of $\overline{s}=0$ we can write $w_i^*=w^*+dw_i$, $D(p_i^*)=D(p^*)+D'(p_i^*)dp_i^*$ and $D'(p_i^*)=D'(p^*)+D''(p_i^*)dp_i^*$, $i=L,H$. Thus, the first-order approximation of the right-hand side is

$$\begin{aligned}0>&(D'(p^*)(dw_H-dw_L)+w^*D''(p^*)(dp_H-dp_L))\frac{\partial p_H}{\partial w_H}+D'(p^*)(dp_H-dp_L)\\ &-w^*\frac{D'(p^*)}{4D(p^*)}\left(3D'(p^*)\left(dw_H-dw_L-(dp_H-dp_L)\right)-\frac{\left(\frac{N-1}{N}\right)^2 g'(0)-\frac{g'(\widehat{s})}{N-1}}{\left(\frac{N-1}{N}g(0)+\frac{g(\widehat{s})}{N-1}\right)}(dp_H-dw_H)+\frac{g'(\widehat{s})}{g(\widehat{s})}(dp_L-dw_L)\right).\end{aligned} \tag{4.23}$$

From the equal profit condition $w_L^* D(p_L^*)=w_H^* D(p_H^*)$ it follows that $D(p^*)dw_L+w^*D'(p^*)dp_L=D(p^*)dw_H+w^*D'(p^*)dp_H$ so that using $\frac{1}{2}w^*D'(p^*)+D(p^*)=0$ we have $dw_H-dw_L\approx 2\left(dp_H-dp_L\right)$. As $g(0)\to\infty$ when $\overline{s}\to 0$ and as $g'(s)$ is bounded so that $\frac{g'(\widehat{s})}{g(\widehat{s})}$ also approaches 0 if $\overline{s} \to 0$, we can rewrite (4.23) as

$$\left(w^* D''(p^*) \frac{\partial p_H}{\partial w_H} + 2D'(p^*) - \frac{3}{4} \frac{w^* D'^2(p^*)}{D(p^*)} \right) (dp_H - dp_L) < 0.$$

This clearly needs to be the case as in an equilibrium with wholesale price discrimination $dp_H - dp_L > 0$, whereas $w^* D''(p^*) \frac{\partial p_H}{\partial w_H} + 2D'(p^*) < 0$ because of the second-order condition for profit maximization.

Bibliography

Asker, John and Heski Bar-Isaac. 2019. "Vertical Information Restraints: Pro- and Anti-Competitive Impacts of Minimum Advertised Price Restrictions." *Journal of Law and Economics, Forthcoming* .

Bagwell, Kyle. 1995. "Commitment and observability in games." *Games and Economic Behavior* 8 (2):271–280.

Bergstrom, Theodore C. and Hal R. Varian. 1985. "When Are Nash Equilibria Independent of the Distribution of Agents' Characteristics?" *The Review of Economic Studies* 52 (4):715–718.

Blair, Roger D and Francine Lafontaine. 2015. "Formula Pricing and Profit Sharing in Inter-Firm Contracts." *Managerial and Decision Economics* 36(1):33–43.

Buehler, Stefan and Dennis L. Gärtner. 2013. "Making Sense of Nonbinding Retail-Price Recommendations." *The American Economic Review, 103(1):335-59* .

Carlin, B.I. 2009. "Strategic Price Complexity in Retail Financial Markets." *Journal of Financial Economics, Vol.91* :278–287.

Chen, Yongmin and Tianle Zhang. 2011. "Equilibrium price dispersion with heterogeneous searchers." *International Journal of Industrial Organization* 29 (6):645–654.

Competition Commission. 2000. "Supermarkets: A Report on the Supply of Groceries from Multiple Stores in the United Kingdom." *London* .

———. 2008. "The Supply of Groceries in the UK Market Investigation." *London* .

Crawford, G.S. and A. Yurukoglu. 2012. "The welfare effects of bundling in multichannel television markets." *American Economic Review, vol. 102(2)* :643–85.

De los Santos, Babur, In Kyung Kim, and Dmitry . 2018. "Do MSRPs decrease prices?" *International Journal of Industrial Organization* 59:429–457.

DeGraba, Patrick. 1990. "Input market price discrimination and the choice of technology." *The American Economic Review, 80 (5), 1246 – 1253* .

Dobson, Paul W. 2008. "Buyer-Driven Vertical Restraints." *Pros and Cons of Vertical Restraints, Stockholm, Konkurrensverket* .

Draganska, M., D. Klapper, and S.B. Villas-Boas. 2010. "A larger slice or a larger pie? An empirical investigation of bargaining power in the distribution channel." *Marketing Science, vol. 29(1)* :57–74.

Ellison, Gllen and Sara Fisher Ellison. 2018. "Search and Obfuscation in a technologically changing retail enviornment: some thoughts on Innovation and Policy." *Innov. Policy Econ* :1–25.

Ellison, Gllen and Alexander Wolinsky. 2012. "A search cost model of obfuscation." *The RAND Journal of Economics, (43)3 No.1* :417–441.

European Commission. 2017. "Final Report on the E-commerce Sector Inquiry." *http://ec.europa.eu/competition/antitrust/sector inquiry swd en.pdf* .

Faber, Riemer P. and Maarten Janssen. 2019. "On the effects of suggested prices in gasoline markets." *Th Scandinavian Journal of Economics* 121 (2):676–705.

Fabra, Natalia and Mar Reguant. 2018. "A Model of Search Costs with Price Discrimination." *CEPR Discussion Paper 12823* .

Gamp, Tobias. 2016. "Search, Differentiated Products and Obfuscation." *Working Paper, University of Bon* .

Garcia, Daniel, Jun Honda, and Maarten Janssen. 2017. "The Double Diamond Paradox." *American Economic Journal: Microeconomics* 9,No.3:63–99.

Garcia, Daniel and Maarten Janssen. 2018. "Retail Channel Management in Consumer Search Markets." *International Journal of Industrial Organization, Forthcoming* .

Gilbert, R.J. 2015. "E-books: a tale of digital disruption." *Journal of Economic Perspectives, vol. 29(3)* :165–84.

Grennan, M. 2013. "Price discrimination and bargaining: empirical evidence from medical devices." *American Economic Review, vol. (103)1* :145–77.

Hart, Oliver and Jean Tirole. 1990. "Vertical Integration and Market Foreclourse." *Brookings Papers on Economic Activity* :205–276.

Hastings, Justine. 2009. "Wholesale price discrimination and regulation: Implications for retail gasoline prices." *Unpublished first draft* .

Hayashida, Kohei. 2019. "Welfare Effect of Competition and Bargaining Power: The Case of Japanese Milk Transactions." *Working Paper* .

Heidhues, Paul, Johnen Johannes, and Botond Köszegi. 2018. "Browsing versus Studying: A Pro-Market Case for Regulation." *Working Paper* .

Herweg, Fabian and Daniel Müller. 2014. “Price discrimination in input markets: Quantity discounts and private information.” *The Economic Journal* 124 (577):776–804.

Ho, K. and R.S. Lee. 2017. “Insurer competition in health care markets.” *Econometrica, vol 85(2)* :379–417.

Inderst, R and T. Valleti. 2009. “Price discrimination in input markets.” *RAND Journal of Economics* 40 (1):1–19.

Inderst, R. and C. Wey. 2007. “Buyer Power and Supplier Incentives.” *European Economic Review, 51* :647–667.

Janssen, Maarten. 2019. “Vertical Contracts in Search Markets.” *International Journal of Industrial Organization* .

Janssen, Maarten, José Luis Moraga-González, and Matthijs R. Wildenbeest. 2005. “Truly costly sequential search and oligopolistic pricing.” *International Journal of Industrial Organization* :451–466.

Janssen, Maarten, Paul Pichler, and Simon Weidenholzer. 2011. “Oligopolistic markets with sequential search and production cost uncertainty.” *RAND Journal of Economics, Vol. 42, No.3* :444–470.

Janssen, Maarten and Edona Reshidi. 2019. “Retail Discrimination in Search Markets.” *University of Vienna, mimeo* .

Janssen, Maarten and Sandro Shelegia. 2015. “Consumer Search and Double Marginalization.” *The American Economic Review* 105 (6):1683–1710.

———. 2018. “Beliefs and Consumer Search in a Vertical Industry.” *Journal of the European Economic Association, Forthcoming* .

———. 2019. "Beliefs and Consumer Search in a Vertical Industry." *Journal of the European Economic Association, Forthcoming* .

Katz, Michael L. 1987. "The welfare effects of third-degree price discrimination in intermediate good markets." *The American Economic Review* :154–167.

Kaufmann, Patrick J and Francine Lafontaine. 1994. "Costs of Control: The Source of Economics Rents for McDonald's Franchisees." *The Journal of Law and Economics* 37, No.2:417–453.

Lubensky, Dmitry. 2017. "A model of recommended retail prices." *The RAND Journal of Economics* 48(2):358–386.

McAfee, Preston and Marius Schwartz. 1994. "Opportunism in Multilateral Vertical Contracting: Nondiscrimination, Exclusivity, and Uniformity." *The American Economic Review* 84, No.1:210–230.

Moraga-González, José L, Zsolt Sándor, and Matthijs R Wildenbeest. 2017. "Prices and Heterogeneous Search Costs." *The RAND Journal of Economics* 48:125–146.

Nash, JF Jr. 1950. "The bargaining problem." *Econometrica 18(2)* :155–162.

O'Brien, Daniel. 2014. "The welfare effects of third-degree price discrimination in intermediate good markets: the case of bargaining." *The RAND Journal of Economics, Vol. 45, No.1* :92–115.

O'Brien, Daniel P and Greg Shaffer. 1992. "Vertical Control with Bilateral Contracts." *The RAND Journal of Economics* 23, No.3:299–308.

OECD. 2009. "Policy Roundtables: Monopsony and Buyer Power, DAF/COMP." *Paris* .

Petrikaité, Vaiva. 2018. "Consumer Obfuscation by a Multiproduct Firm." *RAND Journal of Economics, Vol 49* :206–223.

Piccione, Michele and Ran Speigler. 2012. "Price Competition Under Limited Comparability." *Quarterly Jorunal of Economics, 127* :97–135.

Rey, Patrick and Thibaud Vergé. 2004. "Bilateral Control with Vertical Contracts." *The RAND Journal of Economics* 35, No.4:728–746.

Rhodes, A., M. Watanabe, and J. Zhou. 2018. "Multiproduct Intermediaries." *Discussion Paper, Yale University* .

Richards, Timothy J., Céline Bonnet, Bouamra-Mechemache Zohra, and Klein Gordon. 2016. "Strategic Obfuscation and Retail Pricing." *TSE Working Papers 16-733, Toulouse School of Economics (TSE)* :Available at: https://ideas.repec.org/p/tse/wpaper/31198.html.

Salant, Stephen W. and Greg Shaffer. 1999. "Unequal Treatment of Identical Agents in Cournot Equilibrium." *American Economic Review* 89 (3):585–604.

Salop, Steven. 1977. "The Noisy Monopolist: Imperfect Information, Price Dispersion and Price Discrimination." *Review of Economic Studies* 44, No.3:393–406.

Spengler, Joseph J. 1950. "Vertical integration and antitrust policy." *The Journal of Political Economy* :347–352.

Stahl, Dale O. 1989. "Oligopolistic pricing with sequential consumer search." *The American Economic Review* :700–712.

———. 1996. "Oligopolistic pricing with heterogeneous consumer search." *International Journal of Industrial Organization* 14 (2):243–268.

Stigler, George J. 1961. “The economics of information.” *The Journal of Political Economy* :213–225.

Tappata, Mariano. 2009. “Rockets and feathers: Understanding asymmetric pricing.” *The RAND Journal of Economics* 40,Issue 4:673–687.

Villas-Boas, Sofia Berto. 2009. “An empirical investigation of the welfare effects of banning wholesale price discrimination.” *The RAND Journal of Economics* :40(1), 20–46.

Weyl, E. Glen and Michal Fabinger. 2013. “Pass-Through as an Economic Tool: Principles of Incidence under Imperfect Competition.” *Journal of Political Economy* 121 (3):528–583.

Wilson, Chris. 2010. “Ordered Search and Equilibrium Obfuscation.” *International Journal of Industrial Organization, 28* :496–506.

Wolinsky, Asher. 1986. “True Monopolistic Competition as a Result of Imperfect Information.” *The Quarterly Journal of Economics* 101 (3):493–511.

Yoshida, Yoshihiro. 2000. “Third-degree price discrimination in input markets: Output and welfare.” *American Economic Review* 90:240–246.

Abstract

This thesis consists of three essays that study issues arising in vertical markets with consumer search. The first essay analyses wholesale price discrimination, the second essay examines vertical bargaining and obfuscation and the third essay evaluates the effect of regulated recommended retail prices.

In the first essay we show that manufacturers have an incentive to offer different retailers different contracts. The mechanism relies on consumers having heterogeneous search costs. Expecting price dispersion in the retail market, consumers are induced to search. Low-cost retailers sell to a disproportionately larger share of low search cost consumers, while high-cost retailers also lower margins given their smaller customer base. In this way, by discriminating, manufacturers can create a more competitive retail market and increase their profits. We find that consumers can be better off under wholesale price discrimination.

The second essay models manufacturer practices that impede consumer search. Examples include vertical informational restraints such as Minimum Advertised Prices (MAPs) and bans on online sales. We find that once the bargaining power rests with the manufacturer, the equilibrium involves no obfuscation. The final consumers, however, are worse off compared to settings when the retailers have all the bargaining power. We show that policies that impose caps on obfuscation may backfire since they induce higher wholesale and retail prices.

Finally, the third essay studies the effect of regulation that requires some sales to take place at Recommended Retail Prices (RRPs). We argue that this regulation enables manufacturers to commit to their unobserved contracts and discriminate

their retailers. Given the regulation, manufacturers are not free to deviate and sell to all retailers at lower wholesale prices that generate more profits. We show that without this regulation on RRPs only uniform pricing can be sustained as an equilibrium outcome and that consumers would be better off.

Zusammenfassung

In dieser Dissertation beleuchte ich drei Aspekte des Suchverhaltens von Konsumenten in vertikal integrierten Märkten. Der erste Artikel beschäftigt sich mit Preisdiskriminierung im Großhandel, der zweite mit Verhandlungen in vertikalen Beziehungen und Verschleierung und der dritte Artikel evaluiert den Effekt von Regulierung von Preisempfehlungen.

Im ersten Artikel zeigen wir, dass Produzenten einen Anreiz haben, verschiedenen Einzelhändlern verschiedene Verträge anzubieten. Eine Voraussetzung dafür ist, dass Konsumenten heterogene Suchkosten haben. Die Erwartung von Preisstreuung schafft Anreize zu suchen. Einzelhändler mit geringen Kosten verkaufen an einen verhältnismäßig hohen Anteil von Konsumenten mit geringen Suchkosten. Einzelhändler mit hohen Kosten reduzieren ihre Profitmargen aufgrund ihres geringen Marktanteils. Daher kann ein Produzent durch Preisdiskriminierung einen kompetitiveren Einzelhandel schaffen und seinen Profit erhöhen. Auch Konsumenten können von Preisdiskriminierung im Großhandel profitieren.

Im zweiten Artikel modellieren wir Methoden von Produzenten, die die Suche durch Konsumenten erschweren, beispielsweise vertikale Beschränkungen wie Mindestpreisbindungen oder die Untersagung von Online-Verkäufen. Unsere Analyse ergibt, dass, wenn der Produzent über volle Verhandlungsmacht verfügt, es im Gleichgewicht keine Verschleierung gibt. Nichtsdestotrotz erleiden Konsumenten Wohlfahrtsverluste, verglichen mit einem Szenario in dem Einzelhändler die volle Verhandlungsmacht haben. Wir zeigen, dass Maßnahmen, die Verschleierungspraktiken eindämmen sollen, genau das Gegenteil des erwünschten Effekts verursachen

können, nämlich höhere Großhandels- und Einzelhandelspreise.

Im dritten Artikel analysieren wir den Effekt einer Regulierung, die erfordert, dass zumindest manche Konsumenten zum "Empfohlenen Verkaufspreis" kaufen können. Wir stellen fest, dass diese Regulierung Produzenten ermöglicht, sich auf ihre unbeobachteten Verträge festzulegen und zwischen Einzelhändlern zu diskriminieren. Unter der Regulierung können Produzenten nicht abweichen und an alle Einzelhändler zu niedrigeren Großhandelspreisen verkaufen (und damit höhere Profite realisieren). Ohne diese Regulierung kann es im Gleichgewicht keine Preisdiskriminierung geben, wodurch Konsumenten besser gestellt werden.