DISCUSSION PAPER SERIES

DP21676

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INDUSTRIAL ORGANIZATION AND COMPETITION POLICY

ISSN 0265-8003

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Discussion Paper DP21676
Published 29 June 2026
Submitted 29 June 2026

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This Discussion Paper is issued under the auspices of the Centre's research programmes:

- Industrial Organization
- Competition Policy

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Abstract

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JEL Classification: L13, L41, L51

Keywords: N/A

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Acknowledgements
*Le: Aalto University School of Business and Helsinki Graduate School of Economics (hung.h.le@aalto.fi). Toivanen: Aalto University School of Business, Helsinki Graduate School of Economics and CEPR otto.toivanen@aalto.fi). We would like to thank Heski Bar-Isaac, Robert Clark, Nic de Roos, Pierre Dubois, Laura Grigolon, Alessandro Iaria, Aljoscha Janssen, Kei Kawai, Joao Montez, Anders Munk-Nielsen, Robin Ng, Volker Nocke, Martin Peitz, Fransisco Poggi, Rob Porter, Kevin Remmy, Patrick Rey, Nicolas Schutz, Markku Siikanen, Michelle Sovinsky, Amanda Starc, Tom Wollman and Nahim Zahur for discussions and the seminar audiences at Helsinki GSE, MaCCI Summer Institute, Queen’s, Mannheim, Toulouse IO Winter Workshop and the Toulouse - CEPR Health Economics conference for comments at various stages of the research. We also thank the Swedish Dental and Pharmaceutical Benefits Agency’s (TLV’s) staff for answering our many queries. Le thanks the Foundation for Economic Education (Liikesivistysrahasto), the Jenny and Antti Wihuri Foundation, and both Le and Toivanen thank the Yrjö Jahnsson Foundation and the OP Research Foundation financial support. Toivanen is grateful for the hospitality of Mannheim University, Queen’s University and University of Chicago, and both Le and Toivanen for the hospitality of Toulouse School of Economics. The statements, findings, conclusions, views and opinions contained and expressed in this report are based in part on data obtained under license from the following IQVIA AG information services: IQVIA Pricing Insights and IQVIA MIDAS Quarterly Sales, 2009–2017. All Rights Reserved. The statements, findings, conclusions, views, and opinions contained and expressed herein are not necessarily those of IQVIA Inc. or any of its affiliated or subsidiary entities. We use the term "collusion" strictly in its economic, not its legal sense. All errors are ours.

Competition or Collusion? Entry Decisions in the Swedish Pharmaceutical Market *

Hung Le Otto Toivanen

June 29, 2026

Abstract

Price regulation may have unintended consequences, such as facilitating collusion or softening actual price competition by causing a reduction in the number of active firms. Observing different firms having a monopoly position in parts of a market may be the result of either intense post-entry competition and non-cooperative entry decisions, or collusive entry. This phenomenon and large price differences per pill within a market are widespread in the Swedish generic pharmaceutical market where price regulation through monthly auctions for each active ingredient–dosage form–strength–package size combination channels a large part of demand to the winner within each such substitution group. 22% of the markets are potentially collusive in having at least two firms as monopolies for different substitution groups at least some of the time and prices per pill in such markets are on average significantly higher. We take a structural model tailored to the Swedish circumstances to data on two markets. In one market, the entry patterns (monopoly package sizes) are suggestive of actual, in the other of attempted, collusion. Our counterfactual analysis where we induce substitution across package sizes yield savings of >50% in the first market, but lead to a modest expenditure increase in the other because intensified post-entry competition induces exit.

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1 Introduction

While price regulations are instituted to decrease prices, they may have unintended consequences. In pharmaceutical markets which are subject to price regulations in many countries (e.g. OECD 2008), generic competition initially managed to decrease prices substantially (e.g. Morton and Kyle, 2012) with entry, competition and increasingly sophisticated price regulations the primary drivers (Morton and Kyle 2012; Kortelainen et al. 2023; TLV 2025). As a response, pharmaceutical firms have an incentive to find ways to lessen the competitive pressure they encounter. Their solution need not be as dramatic as in the US where generic producers established a cartel (Clark et al., 2022; Starc and Wollmann, 2025), as it may be difficult for the regulator to get all details right and the regulator may therefore inadvertently end up facilitating tacit collusion.[1] The objective of this paper is to analyze whether entry decisions in the Swedish pharmaceutical market are competitive or collusive, with pharmaceutical firms avoiding competition by resorting to market sharing (Stigler, 1964) or spheres of influence (Bernheim and Whinston, 1990) via judiciously made entry decisions, and the role regulation played in the process.

Since 2009, Sweden employs monthly *product of the month* auctions at the substitution group, i.e., active ingredient–strength–dosage form–*package size* level, e.g., among 30 pill packages of drugs based on the same active ingredient (and having same strength). These auctions take place for products with generic competition; Kortelainen et al. (2023) find that the reform reduced pharmaceutical expenditures substantially in the first years after the introduction of these auctions. The firm with the lowest price gains a substantial market share within the substitution group by virtue of being essentially the only product for which customers get the maximum reimbursement from the government. In such an environment, colluding on prices may be difficult, but two quirks of the regulations may open the door for collusion via spheres of influence through not entering neighboring substitution groups, i.e., otherwise identical products but with different package sizes: First, neither regular customers nor pharmacists are allowed to substitute products across package sizes. Second, so-called dose pharmacies do not necessarily have an incentive to choose the cheapest product of the month as they effectively pass on the cost to their customers who constitute some 3% of the population, are mainly in elderly care and receive their multiple medicines in ready-made doses.

As an example of what may take place, Table 1 shows the prices per pill (Column (3)) for a particular active ingredient, strength and dosage form (henceforth a *market*) with 4 different packages sizes (=substitution groups or *nests*). Column (1) shows the number of pills in a given package size. As shown in Column (2), the two smallest package sizes are produced by 3-4 firms, the two larger ones are

[1] We use the term *collusion* strictly in its economic, not its legal sense and henceforth drop the word *tacit* when discussing collusion.

monopolies, each of the latter being produced by a different firm. As is imminent from Column (3), the monopoly package sizes are nearly four times more expensive per pill than the competitive package sizes. These higher prices do not mean that the sales in these nests would be of marginal importance: Column (4) reveals that the joint market share of the two monopoly package sizes is over 30% in terms of pills sold. Given their much higher prices, these package sizes generate 70% of the revenue in this market (Column (5)).

Table 1: Descriptive Statistics by Nest, Market 1

Package Size	No. of Firms	Price per Pill	Pill Share	Revenue Share
30	3.53	0.60	5%	2%
100	3.75	0.55	60%	28%
250	1	2.53	12%	25%
500	1	2.69	22%	45%

Notes: Time period: 9/2011-12/2017. Target market: A particular active ingredient (ATC5), strength, dosage form. No. of Firms: The average number of firms in each package size group. Price per Pill: The sales-weighted average price of each package size group. Pill Share: The market share of each package size group in the number of pills sold over the observation period. Revenue Share: The market share of each package size group in Swedish krona over the observation period. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

As we demonstrate below, markets with monopoly auctions or substitution groups are not a rarity: Auctions with only one participant are the second most common (Figure 1) with a median market share across all nests in a market, measured in pills sold, of 10% (Appendix Figure A-1). Furthermore, 22% of markets seem susceptible to collusion as there are at least two firms who are monopolists in at least two different auctions at least some of the time. As an example, over 40% of markets with four auctions have at least two monopoly nests of different firms (Figure 1). Our descriptive regressions reveal that prices are economically and statistically significantly higher in markets that exhibit two or more monopoly nests with different firms than in markets with only competitive nests (Table 3).

As alluded to above, there are two explanations for observing monopoly nests in equilibrium: The first is intense post-entry competition – after all, these products are close substitutes. Thus, the observation of e.g. Dasgupta and Stiglitz (1988) that (pp. 572) *"the more competitive ex post competition (competition is after entry) the less effective is the market discipline provided by potential competition."* may well apply. The second explanation is that by colluding, the monopoly firms have managed to create spheres of influence (Bernheim and Whinston, 1990) whereby each stays out of the substitution group of the other. The threat of entering the rival's substitution group leads to the incentive compatibility constraints of the firms being satisfied. With over 300 active ingredients and many more substitution groups, firms obviously have many ways to collude through spheres of influence, for example by staying out of given strengths of an active ingredient. Interesting as such possibilities are, we limit our attention in this paper to entry decisions within markets (active ingredient–strength–dosage form).

Building on our descriptive analysis, we proceed in a number of steps to answer our research question: First, we tailor an otherwise standard nested logit discrete choice demand model to accommodate the large market share shifts that occur when, within a substitution group, the product of the month changes. Second, by assuming that pricing is Bertrand-Nash, we recover marginal costs for firms for which all products are priced below the regulatory maximum. We recover the marginal costs for firms with at least one product at the price ceiling by projecting the estimated marginal costs on product characteristics and combining these estimates with first order conditions. Third, armed with demand and supply parameters, we estimate the upper and lower bounds of monthly fixed firm-specific entry costs for the substitution groups. Fourth, we analyze whether entry into the monopoly substitution groups would be profitable in a static setting if the fixed entry costs were similar to those in the competitive substitution groups. If that turns out not to be the case we conclude that the entry decisions cannot be supported by a model of competitive entry. As a fifth step, we then check whether the observed entry decisions satisfy the collusive incentive compatibility constraints.

We take our model to data on two markets which exhibit monopoly substitution groups occupied by two firms: One of the markets is the one for which we display price ratios and other statistics in Table 1 (*"market 1"*): It has a potentially collusive market structure throughout our observation period. The other market (*"market 2"*) is from another ATC4 (therapeutic subgroup) where the two monopoly firms are the same as in market 1, but the potentially collusive market structure is maintained for only (the early) part of our observation period. Our demand estimates suggest essentially no substitution across nests in market 1, but a reasonable level of cross-nest substitution in market 2. The observed entry patterns cannot be supported by a competitive model of entry in market 1, while the collusive incentive compatibility constraints of the firms are satisfied with very low discount factors. We find a more complicated picture for market 2: While the observed potentially collusive entry configuration is not a non-cooperative Nash equilibrium, it is also the case that one of the monopoly firms exits its monopoly nest after only 8 months without any other firm entering that nest anymore during our observation period. Our calculations suggest that the observed potentially collusive entry configuration generates lower profits for both monopoly firms than the unique static Nash equilibrium which coincides with the entry configuration we observe in the data after 8 months. We hypothesize that the firms experimented with spheres of influence but found out that it does not yield them higher profits, and then pivoted to the unique static Nash equilibrium. We find that price-cost margins are 10% or less in the competitive substitution groups and over 80% in the monopoly substitution groups in market 1 where the entry configuration is suggestive of collusion. In market 2 the two monopoly nests exhibit both the highest (over 70%) and lowest (about 20%) price-cost margins.

In light of these results, we proceed to a counterfactual analysis where we change the regulations which (inadvertedly) seem to facilitate collusion by determining the product of the month (partly) across nests. This means first, that in order to get the full reimbursement, regular patients need to potentially buy a different package size than the one they have been prescribed. Second, following a suggestion the Swedish Dental and Pharmaceutical Benefits Agency (TLV, Tandvårds- och läkemedelsförmånsverket in Swedish; see TLV (2020)) that was not implemented, this change means that dose pharmacies also need to buy the cheapest product of the month (measured by price per pill) across different compatible package sizes. Thus, e.g., five 100 pill packages may be substituted for a 500 pill package, or 8 packages of 30 pills for a 250-pill package. Our results suggest that the counterfactual regulatory regime does not lead to changes in entry decisions in market 1, but induces the exit of both monopoly firms from their monopoly nests in market 2, highlighting the complications that a regulator faces in balancing different forces, in this case the intensity of post-entry competition on the one hand and the number of actual competitors on the other hand. We find that prices decrease substantially, by 50%, in the collusive market 1, but rise slightly (by ca. 7%) in the competitive market 2. These result suggest that allowing for and inducing cross-nest (package size) substitution may be a powerful regulatory tool, but it does not uniformly deliver lower prices per pill because the prospect of intensified price competition may lead to exit and thereby less intense price competition in equilibrium.

There is a large literature on collusion in general (see Asker and Nocke, 2021, for a recent survey) and a theory literature on multimarket contact in particular (Bernheim and Whinston, 1990; Spagnolo, 1999; Bond and Syropoulos, 2008; see Laferrière et al., 2024 and references therein for experimental work on the topic). While the empirical literature on multimarket collusion finds price effects in airline markets (Evans and Kessides, 1994; Ciliberto and Williams, 2014; Miller, 2010), telecommunications markets (Parker and Röller, 1997; Busse, 2000), the cement industry (Jans and Rosenbaum, 1997), hospital markets (Schmitt, 2018) and in pharmaceuticals (Granlund and Rudholm, 2023; see below), the research looking at implementing collusion through entry decisions or spheres of influence is still in its infancy: The only study we are aware of is Sullivan (2020a,b) who studies the US ice cream market and finds evidence that in 2013 Ben & Jerry's and Häagen-Daz's behavior was in line with product choice and price coordination but not with competitive choices.[2] Hyytinen et al. (2019) report that in their data on Finnish legal cartels (1955 - 1993), 18% of manufacturing and 26% of non-manufacturing cartels used

[2]Bourreau et al. (2021) study a related but opposite phenomenon, namely the introduction of fighting brands in response to rival entry, using data from the French telecommunications market.

either area-based on non-area-based criteria to allocate the market among the cartel members (often in conjunction with other cartel clauses; see their Table 1). Using data on Austrian legal cartels, Fink et al. (2017) find that 32.5% use specialization which entails dividing the market in one way or another among the cartel members. The literature on semi-collusion (see Fershtman and Gandal, 1994 for a theoretical and Steen and Sørgard, 1999 for an empirical analysis) is concerned with collusion in one dimension but not others. The defining feature of these models is that firms are assumed to collude on a short-term variable such as price, but to compete in a longer-term variable such as investment; arguably, we study a situation where the opposite potentially holds. The markets we study feature price ceilings, but in contrast to Knittel and Stango (2003) and Martin and Verboven (2026) where the price-ceiling acts as a coordination device, in our setting the ceiling acts as a constraint on exercising market power; the rules on monthly auctions together with rules on substitution across package sizes are the regulatory tools inducing competition concerns in our setting. In addition to the aforementioned papers, Albæk et al. (1997) and Byrne et al. (2025) provide evidence of how a regulatory intervention (in the case of the two latter papers, of none other than the competition authority) inadvertently facilitates collusion. Feng et al. (2025) show that acquisitions enabled by high thresholds for merger control are associated with large price increases in the US pharmaceutical market. Byrne and de Roos (2019) is an important study illustrating difficulties in establishing collusion; in our setting the firms seem to have experimented with collusion in market 2 only to find out it does not pay off. As will become clear shortly, contributions of particular importance for us in the literature on collusion are Clark and Houde (2013), Igami and Sugaya (2021) and Starc and Wollmann (2025), even though they do not consider multimarket contact explicitly.

Similar to collusion, the empirical literature using structural entry models is by now large. From the very beginning (Bresnahan and Reiss, 1991), collusion has featured as part of the research agenda. Early contributions developed methods to accommodate entry in (geographic or product) space (Mazzeo, 2002), models of complete (Tamer, 2003) and incomplete information (Seim, 2006) and the role of rival entry (Toivanen and Waterson, 2005) using data on entry decisions alone. The more recent literature combines data on prices and quantities with data on entry decisions (Eizenberg, 2014; Wollmann, 2018, and often embeds entry decisions in a dynamic framework (e.g. Ryan, 2012).

We are by no means the first to study the Swedish pharmaceutical market: Janssen (2022, 2023) studies brand premia (which we allow for) and switching costs (which we abstract from) while Granlund and Rudholm (2023) assess the probability of collusion within auctions and find evidence supporting collusive behavior. According to their results, the probability of collusion is decreasing in the number participating firms and is increasing in multimarket contact. Kortelainen et al. (2023) study a number of price regulation reforms in the Nordic pharmaceutical markets, including the effects of introducing the product-of-the-month regime in Sweden in 2009. The authors find that the reform lead to substantial expenditure decreases in the first 3.5 years following the reform without affecting either quantity or the number of products in the market.

We build on a number of earlier methodological contributions. Our demand side specification follows the well-established discrete choice literature (Berry, 1994). We adopt a nested logit demand system as it neatly fits our institutional setting: The nests are the different auctions (package sizes) within a market. To accommodate the large (changes in) market share of the winning product within each nest we build on the literature on aggregative games for multiproduct firms (Nocke and Schutz, 2018; Garrido, 2024) to establish equilibrium existence. We use the approach developed by Dubois and Lasio (2018) and Fan and Zhang (2022) to estimate marginal costs for firms with (some) products that are priced at the regulated maximum and follow Eizenberg (2014) and Wollmann (2018) in estimating monthly fixed costs. We depart from most of the existing literature on entry in that we do not assume that entry into the monopoly markets is necessarily competitive - indeed, our results for market 1 demonstrate the infeasibility of doing so. We impose the assumption of competitive entry assumption only on nests with several firms. We then make use of the methods of Clark and Houde (2013), Igami and Sugaya (2021) and Starc and Wollmann (2025) in assessing whether the incentive compatibility constraint holds whenever the data does not support a competitive model of entry decisions. In implementing our counterfactual where we allow for partial substitution across package sizes (i.e., nests), we build on the nested logit demand model of Iaria and Wang (2021) which allows for overlapping nests. Given the well-known difficulties in estimating welfare in pharmaceutical markets due to the complicated decision-making process involving the physician, the patient and potentially the pharmacist (see e.g. Dubois and Lasio (2018)), we abstain from attempts to evaluate welfare and concentrate on price and quantity effects.

Following this introduction, we explain the main institutional features in Section 2 and provide details of the data in Section 3. That Section contains also our descriptive analysis, where we first analyze the prevalence of potential collusion, and the association between the price level and a market having monopoly package sizes of one or more firms, and then provide an analysis of the effect of the product of the month - regulation on variation in market shares as well as an analysis of the relationship between the number of bidders and bid levels. The stylized facts of our descriptive analysis suggest that a non-negligible fraction of markets exhibit monopoly packages sizes by different firms; that monopoly package sizes are associated with higher prices; that a change in the identity of the product of the month results in large market share changes; and that the absolute (though not necessarily relative) differences between the winning (lowest) price and other prices (bids) is declining in the number of bidders. We also motivate in Section 3 our choice of the two markets we study in more detail using a structural model. We devote Section 4 to our model which we build to capture stylized facts of the product of the month regime. We present estimates of the structural parameters in Section 5 and investigate the competitive nature of entry decisions in Section 6. Section 7 contains our counterfactual analysis. We present our conclusions in Section 8.

2 Institutions

Reimbursement. A key characteristics of the Swedish pharmaceutical market is a needs-based reimbursement system, where the reimbursement rate increases for a given consumer within a 12 month period with the amount spent on pharmaceuticals, starting at 50% when expenditure reaches circa 90€/$ and reaching 100% at roughly 450€/$.[3]

Prescriptions. In outpatient care, the prescribed product is decided by the physician who in principle can take prices of different products in a given substitution group, and in neighboring substitution groups (i.e., different package sizes) into account. Neither the patient nor the pharmacist can substitute to a product outside the substitution group. Therefore it is not for example possible to substitute 5 packages of 100 pills each for a 500 pill package, or the other way round. The vast majority of outpatients purchase their drugs by visiting a community pharmacy.[4]

Price regulation. Since 2002,[5] Sweden has had an internal reference price system for products with generic competition, with patients getting full compensation only if they bought the cheapest product within a *substitution group*, with substitution groups defined at the active ingredient–dosage form–strength–package size (group) level.[6] If they bought the prescribed product, they would pay the price difference to the cheapest product out of pocket. Finally, though exceedingly rare, if a patient bought a product that was neither the cheapest nor the prescribed one, they would pay the whole price fully out of pocket. Besides the product of the month regulation, each substitution group is assigned a regulated price ceiling.[7] If a firm prices above the price ceiling, the government does not offer any reimbursement

[3] In Sweden, the reimbursement rate is calculated within 12-month windows for each individual (i.e., not e.g. on a calendar year basis). According to Lamin (2022), 33% of Swedes reached the maximum threshold 2012–2017 and therefore paid nothing at the margin for their medicines for the remaining duration of the 12-month period. See Kortelainen et al. (2023) for further details.

[4] There are some 1 400 community pharmacies in Sweden. The majority belong to one of four community pharmacy chains in Sweden, and slightly less than 50 are independent (see Konkurrensverket 2024; Sveriges Apoteksförening 2024).

[5] See Lag (2002:160) om läkemedelsförmåner m.m. §21.

[6] Sometimes the package size can very slightly within a substitution group, e.g., packages of 28 and 30 pills would be in the same substitution group.

[7] According to TLV (2021), a (fixed) price ceiling is introduced at the earliest 4 months after generic entry, and only once the

to those buying the product. According to TLV (2025) (see Figure 4 in TLV 2025), Swedish prices for pharmaceuticals with generic competition are the lowest in a comparison between 20 European countries.

In 2009, the national pharmacy monopoly was dismantled, and product of the month auctions within substitution groups were introduced. Auctions for prices in month t are run in month $t-2$ and prices are published in month $t-1$. The cheapest product within a substitution group is the designated *Product of the Month* (POTM), conditional on the firm guaranteeing availability.[8] In the first two weeks of a month, patients get full reimbursement also for buying the previous month's product of the month. These auctions determine the national retail price of each product, as pharmacy markups are regulated and are a function of the wholesale price (see Appendix Table A-2). The manufacturers therefore in effect set retail prices.

Dose pharmacies. Dose pharmacies serve roughly 300 000 mostly elderly individuals who take many medicines at the same time and are not capable of handling the medicines themselves (Sveriges Apotekförening 2024; Konkurrensverket 2024).[9] Dose pharmacies provide their customers *doses* of several medicines.[10] Most of these patients live in care homes, with a small minority still living at home. Dose pharmacies can purchase the medicines in which ever package size they want, as long as the package has been approved for usage by the dose pharmacies (TLV 2020, pp. 12). They then use special machinery to unpack the different pills or else do this manually, and then package them into the doses that are shipped to customers. Swedish regions use public procurement for these services, where the three dose pharmacies bid on the extra cost of producing and delivering the doses, but not on the price of the pharmaceuticals. Dose pharmacies are paid the same margin as all other (community) pharmacies. While dose pharmacies are obliged to buy a POTM, they do not necessarily have an incentive to by the cheapest POTM in a market with several substitution groups as their customers get reimbursed on the POTM the dose pharmacies buy. Swedish regulators have identified this issue, and in 2020, the Swedish Dental and Pharmaceutical Benefits Agency (see TLV 2020) suggested changes to the regulatory system that would have incentivized dose pharmacies to buy POTMs with lower (lowest) price per pill. These recommendations were however not implemented.[11]

price of the cheapest product has decreased by at least 30% compared to the price before generic entry.

[8] We find that the POTM is the cheapest product 92.3% of the time when we use data on competitive substitution groups across all markets (in monopoly nests, the POTM is the cheapest by definition). In markets 1 and 2 which we investigate in more detail this probability is 98.5% and 88.3%; see Appendix Table A-1. We describe in Section 3.2 how we choose markets 1 and 2.

[9] The Swedish population was slightly shy of 10 million for most of our observation period and slightly exceeded 10 million in 2017: see e.g. OECD.

[10] These patients get a special prescription ("dose prescription"); see Konkurrensverket (2024).

[11] We had this confirmed via email by TLV in April 2026.

3 Data and Descriptive Statistics

3.1 Data

Data sources. Our main data sources are TLV for prices and IQVIA for sales. The data covers more than 300 active ingredients (i.e., ATC5 level). We observe prices[12] and quantities sold at the monthly level for all products. Besides prices, we observe a number of other product characteristics: Brand status, package size and form, dosage form, producer name, product–of–the–month status, strength, Nordic product number, product name, active ingredient and whether or not only dose pharmacies are allowed to purchase the product. With this information, we can place each product into a substitution group within which the product of the month–auctions take place. The longest observation period available to us is 2009/12-2017/12. As we explain in more detail in Section 5.1, we use different samples for different parts of our estimation process both in terms of coverage of pharmaceuticals and the time period.

Hierarchy of pharmaceutical markets. A common way to categorize pharmaceutical markets is the Anatomical Therapeutic Chemical (ATC) classification and we follow that tradition. The system has 5 levels of which ATC4 and ATC5 are relevant for us. At the ATC4 level products are divided into pharmacological or therapeutic groups, i.e., the products in a given ATC4 class treat (mainly) the same diseases. Within a given ATC5 group, products share the same active ingredient, i.e., the chemical compound affecting the illness.

Given that we are interested in competition between firms, we restrict our attention to ATC5 groups where the patent of the original drug has lapsed. We define a *market* to consist of all products within the same ATC5 group with the same strength and dosage form. Substitution groups (i.e., different package sizes) within a market, in which the POTM auctions take place, define *nests*. We observe 1 328 markets with the number of nests varying from one to 18 (2.2 on average; see Figure 1 for the distribution). These markets reside in 316 ATC5 classes within 184 ATC4 classes.

3.2 Descriptive Statistics for All Markets

Prevalence of potential collusion through spheres of influence. To understand the extent to which a possibility of collusion through spheres of influence exists in a given market, we start by investigating the propensity of observing at least two monopoly auctions with a different firm in each of

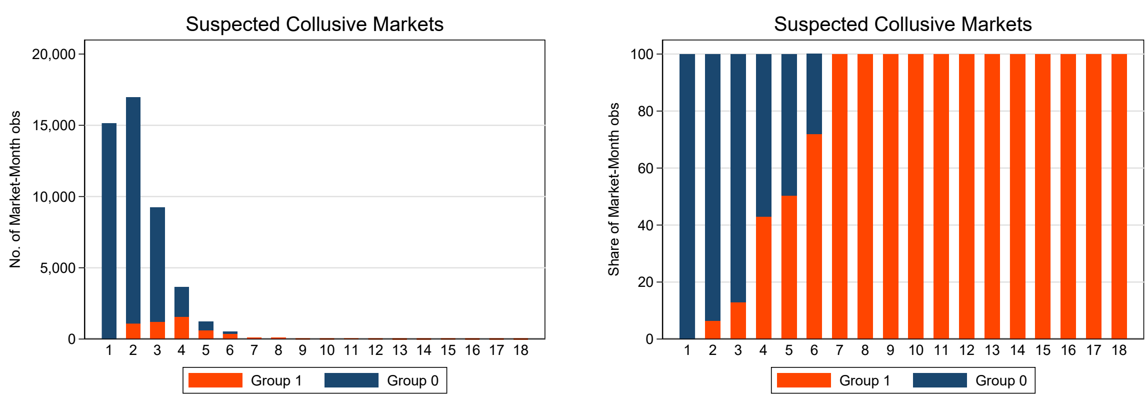
[12] IQVIA national audits and IQVIA MIDAS® reflect local industry standard source of pack prices, which might be list price or average invoice price, depending upon the country and the available information; they do not take into account rebates or clawbacks, details of which are normally confidential, and therefore these estimated prices do not reflect net prices realised by the manufacturers.

the monopoly nests in a given market (and month). Such markets have a *potentially collusive* entry configuration.

The left panel of Figure 1 shows that the vast majority of market–month observations come from markets with at most three nests. By definition, markets with one nest cannot exhibit collusion through spheres of influence within the market.[13] We learn from the right panel that in markets with 4 nests (as in our example market in the Introduction, market 1), more than 40% of market-month observations have an entry configuration suggestive of collusion through spheres of influence, and this share reaches 100% of markets with 7 or more nests, though one should keep in mind that such markets are a small fraction of all market-month observations (left panel).[14] All in all, of the 1 328 markets, 292 or 22% are potentially collusive at least some of the time and in terms of market-month observations, 12% are potentially collusive. The potentially collusive markets generate 34% and the potentially collusive market-month observations 11% of the sales, measured in Swedish krona (SEK).[15]

Figure 1: Markets with ≥2 Monopoly Nests with Different Firms

Count | Share



Notes: Group 1 = In a given market and month, there are at least two nests with different monopolists; Group 0 = The rest of the market-month observations. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

We present in Table 2 statistics on how often the 9 firms with the largest number of monopoly nests are engaged in a potentially collusive entry configuration. There is substantial variation across firm pairs both in how many markets they meet in and how often they form a potentially collusive entry configuration (i.e., each being a monopolist in at least one nest), conditional on being in the same market. For example, the firm pair 93-276 is potentially collusive in all the 22 markets in which

[13] As we alluded to above, the firms may collude also across markets.

[14] Appendix Figure A-2 shows that in absolute terms, most monopoly nests occur in package sizes in the middle of the package size distribution. Appendix Figure A-3 then reveals that there are monopoly nests in all but one package size and their share, conditional on being strictly positive, varies between 10 and 80%.

[15] 1 SEK ≈ 0.1$ or €.

both firms are participating for at least a month during our observation period whereas the firm pair 596-371 only collude in one of the 172 markets in which they meet. The firms that are monopolies in our example market (market 1; firms 22 and 371) form a potentially collusive pair in 7 out of the 164 markets in which both of them are present for at least one month.

Firms that have monopoly nests are also active in the competitive nests (see Appendix Table A-3): They participate 29% of the time in competitive nests as well and their products in those nests have an average market share of 18% (compared to 13% average market share for non-monopolist firms) which translates into a 35% (24% for non-monopoly firms) within-(competitive) nest market share. Monopoly firms offer the POTM in competitive nests 32% of the time (25% for non-monopoly firms).

Table 2: Collusion between firms

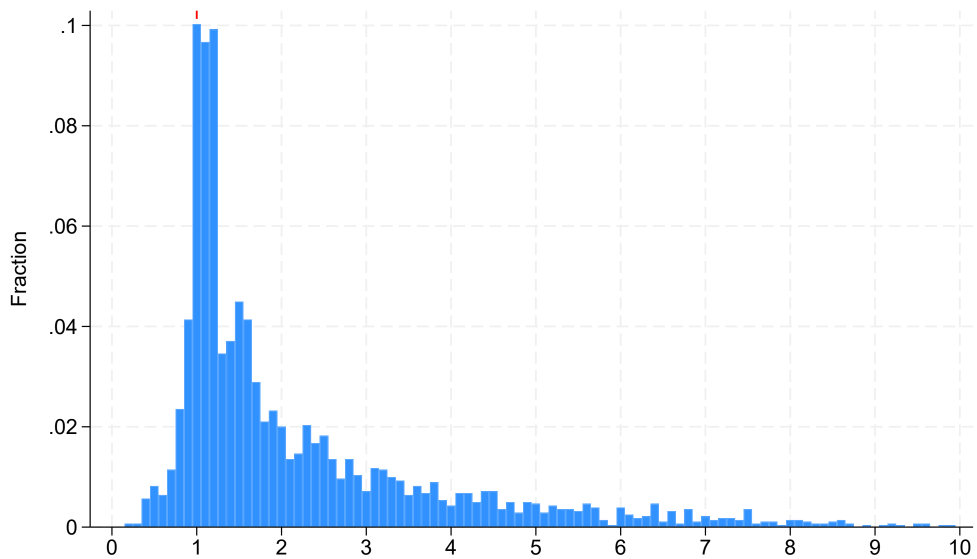
Firm ids	93	22	276	663	596	453	421	321	371
93			22/22						
22					11/240	2/146	17/25		7/164
276						4/5		1/1	
663								8/16	
596						2/153			1/172
453							2/16		1/1
421									
321									
371									

Notes: number of markets that are potentially collusive (both firms have monopoly nests) at one point / number of markets both firms participate at one point. Top 9 firms with the most monopoly nests. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

Summarizing, we find that a non-negligible share of sales and markets are potentially collusive through spheres of influence; that there are several pairs of firms that are possibly engaged in such activity; but that the fraction of markets in which both firms of a given firm-pair meet that is potentially collusive varies.

Potential collusion and the price-level. As a first cut, we present the price (per pill) ratio of monopoly nests to competitive nests using data from those market-month observations where we observe a potentially collusive entry configuration. As can be seen from Figure 2, the mass of the distribution lies to the right of one, indicating that prices per pill are higher in monopoly nests than in competitive nests. We find substantial variation, with a price-ratio of 1.12 at the 1st quartile, 1.55 at the median, 2.83 at the 3rd quartile, and a mean of 2.44.

Figure 2: Price ratio of monopoly nests over competitive nests of markets with suspected collusion



Notes: Graph truncated at price-ratio of 10. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

To further analyze whether monopoly nests are associated with the price level, we estimate descriptive regressions of the following form:

$$\bar{P}_{mt} = \alpha_0 + \alpha_1 SingleMS_{mt} + \alpha_2 SingleMM_{mt} + \alpha_3 PotColl_{mt} + \delta X_{mt} + \epsilon_{mt} \tag{1}$$

where the dependent price $\bar{P}_{mt}$ is the sales-weighted price per pill in market m in month t. The key explanatory variables are $SingleMS_{mt}$ and $SingleMM_{mt}$, indicator variables taking value 1 respectively if there is a single firm that acts as a monopolist in one ($SingleMS_{mt}$, *MS* for *monopoly* in a *single* nest) or more ($SingleMM_{mt}$, *MM* for *monopoly* in *multiple* nests) nests in market m in month t (and zero otherwise) and $PotColl_{mt}$, an indicator variable taking value 1 if there are at least two firms that act as monopolists in two or more nests in market m in month t. The coefficient of $PotColl_{mt}$ thus captures the price difference between markets that we characterize as potentially collusive and competitive markets. These variables are mutually exclusive; notice that the default market has only competitive nests. As an alternative to $SingleMS_{mt}$ and $SingleMM_{mt}$ we also use their sum $SingleM_{mt}$ in Columns (5) and (6). X_{mt} is a vector of control variables and ϵ_{mt} the error term while α_i, $i \in \{1, 2, 3\}$ are the parameters of interest, α_0 the constant and δ the vector of coefficients associated with the control variables. Our vector of control variables varies across columns and includes: A dummy for the product being in a jar, a dummy for the product being available for dose pharmacies only (Columns (1) and (2)) and alternatively (Columns (3)-(6)), the share of products in a market that are in jars or available to dose pharmacies only; month fixed effects (all Columns) and ATC4 fixed effects (Columns (5) and (6)); the number of firms in market m in month t as well as the number of nests in market m in month t (Columns (2), (4), and (6)). The estimation sample consists of all market-month observations for our observation period.

Table 3: Descriptive Price Regression

	(1)	(2)	(3)	(4)	(5)	(6)
Single monopolist					6.543***	4.692***
					(.943)	(1.059)
SM - Single nest	26.630***	28.496***	18.011***	23.235***		
	(3.058)	(3.143)	(2.711)	(3.068)		
SM - Multiple nests	34.761***	39.150***	33.676***	34.936***		
	(7.757)	(8.162)	(7.771)	(8.136)		
Suspected collusion	117.437***	132.171***	108.493***	130.930***	35.799***	32.158***
	(8.825)	(9.746)	(8.462)	(9.712)	(5.533)	(4.265)
Having jar products	-23.923***	-20.447***				
	(2.638)	(2.513)				
Having dose-pharmacies-only	-42.537***	-31.955***				
	(2.060)	(2.221)				
Share of jar products			-15.803***	-21.896***	-8.291***	-9.255***
			(3.493)	(3.8093)	(1.093)	(1.318)
Share of dose-pharmacies-only			-177.875***	-149.631***	-57.772***	-59.778***
			(10.191)	(8.653)	(7.397)	(9.488)
Number of nests		-8.960***		-11.246***		2.011
		(1.517)		(1.498)		(1.813)
Number of firms		-2.069***		-4.630***		-1.431***
		(.305)		(.356)		(.256)
Fixed Effects						
Month/Year	Yes	Yes	Yes	Yes	Yes	Yes
ATC4	No	No	No	No	Yes	Yes
Observations	47 017	47 017	47 017	47 017	47 017	47 017

Notes: Time period: 12/2009-12/2017. Robust standard errors in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

We find (Table 3) that average price per pill is higher in markets with any type of monopoly than in the default markets with only competitive nests: The coefficients of $SingleMS_{mt}$, $SingleMM_{mt}$, $SingleM_{mt}$ and $PotColl_{mt}$ are always positive and statistically significant at conventional levels. The highest prices are associated with potentially collusive entry configurations through spheres of influence, i.e., having two firms as monopolists in different nests (i.e., the coefficient of $PotColl_{mt}$ is larger than those of $SingleMS_{mt}$ and $SingleMM_{mt}$ or of $SingleM_{mt}$). The presence of products in jars, as well as having products available to only dose pharmacies are associated with lower prices, as are the number of nests and the number of firms.

Product of the month. Table 4 provides descriptive statistics on Product of the Month (POTM) auctions which show that the POTM changes with high probability, and the change in POTM status affects the market share of the product significantly. In the first row we show the probability of month $t-1$'s POTM winning (again) in month t. For nests with more than one firm in $t-1$ (first column), this probability is slightly less than 40% while it is very high in nests where in $t-1$ there was a monopoly (95%; Column 2). While the probability of the winner staying the same is 69% in nests with 2 firms, it drops to 33% in nests with 3 firms, and continues to drop as the number of firms grows.

On row 2 we find that the market share of the POTM is on average 57% in markets with more than one firm in $t-1$ (Column 1) and stays over 50% in irrespective of how many firms there were in $t-1$. On row 3 we learn that becoming the POTM while not having been the POTM in $t-1$ increases the average market share by 33 percentage points in nests with at least two firms (Column 1), and that this increase is positively correlated with the number of firms in the nest. Row 4 reveals that the losers' market share in nests with more than one firm in $t-1$ is slightly below 15% (Column 1), and varies between 37% (2 firms) and 5% (8 or more firms). The loss of POTM status (row 5) leads to a significant loss of market share, 24 percentage points on average in nests with at least two firms in $t-1$ (Column 1).

Price variation and within–nest competition. The Swedish regime puts a high emphasis on within-nest competition as that is the level at which customers get maximum reimbursement only for the POTM. We provide descriptive statistics on within-nest competition in Table 5. We learn that competition, as measured by the number of firms in a nest, decreases prices. This is reflected in the decreasing difference, measured in SEK, between the lowest and second lowest price when the number of firms (bidders) increases.

As reported in row 1 of Table 5, the average price–per–pill ratio between monopoly and competitive nests is 2.25 (Column 1), with the ratio monotonically increasing in the number of products in the competitive nest, the exception to the rule being nests with seven products. The average price difference between the POTM price and the second lowest price is on average 27% (row 2) and varies between 7.24% (8 or more firms in the nest) and 36.85% (4 firms in the nest). Notice that the relative price difference is very stable across nests with 3–5 products and thereafter declines monotonically. The absolute price difference (row 3) between the winning and second lowest bid, i.e., the POTM month and the second lowest price, is monotonically decreasing in the number of bidders. This pattern suggests

Table 4: Descriptive Statistics of POTM

No. of bids (period $t-1$)	>1	1	2	3	4	5	6	7	8	>8
Prob of re-winning	39.79%	94.88%	68.72%	33.75%	24.27%	21.15%	20.50%	22.27%	20.68%	18.03%
Market share of winning	57.37%	99.85%	62.23%	55.78%	54.74%	55.33%	55.21%	53.62%	53.93%	52.71%
Change in share L to W	33.53	-0.89	22.20	30.12	35.47	38.50	39.57	38.90	40.11	40.53
Market share of losing	14.77%	97.84%	37.15%	22.72%	15.68%	11.53%	9.23%	7.83%	6.49%	5.31%
Change in share W to L	-24.06	-6.55	-21.00	-23.26	-24.59	-25.76	-25.15	-25.17	-26.59	-25.36
Share of winning at least once	76.86%	97.04%	80.79%	78.90%	75.51%	75.58%	72.87%	67.95%	65.07%	59.76%
Share of nest-month	65.75%	34.25%	20.89%	14.09%	10.53%	7.09%	5.15%	3.13%	2.17%	2.68%

Notes: Change in share L to W: change in the market share (in percentage point) of a product that loses in period t-1 and wins in period t. Change in share W to L: change in the market share (in percentage point) of a product that wins in period t-1 and loses in period t. Share of winning at least once. Share of nest-month. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

that the increase in the monopoly price to competitive price ratio in row 1 is caused by competition increasing as the number of firms in a nest increases.

Summary. Our descriptive analysis suggests that a non-negligible fraction of markets and market-month observations are potentially collusive, and a potentially collusive market structure is associated with significantly higher prices per pill. Furthermore, the product of the month regime results in significant churn in the POTM, by which we mean that the likelihood of the product of the month changing within a nest from one month to next is sizable and results in large market share changes. The price difference between the lowest and second lowest bids (prices) is, by and large, decreasing in the number of firms in the nest (i.e., in the number of bidders (firms)). A structural model of the market should capture these features of the data.

Choosing the markets to be analyzed. Given the large number of markets in general, and of potentially collusive markets in particular, we do not attempt to model all such markets. To choose markets to study, we looked into the two ATC4 classes with the highest potentially collusive sales. Table 6 provides key descriptive statistics for these ATC4 classes. They turned out to be the 3rd and 5th largest ATC4 classes by sales (in SEK). ATC4_1 has 5 ATC5 categories and 41 markets, ATC4_2 4 ATC5 categories and 20 markets. The fraction of market-month observations that are potentially collusive is 22% and 40% respectively in ATC4_1 and ATC4_2 and the fraction of sales, measured in SEK, from

TABLE 5: DESCRIPTIVE STATISTICS OF PRICE VARIANCE

No. of bids (period T)	>1	2	3	4	5	6	7	8	>8
Price ratio monopoly /competitive	2.25	1.25	1.61	2.27	2.92	3.12	2.29	4.33	4.63
Price diff percentage	27.71%	17.38%	36.36%	36.85%	36.42%	29.86%	21.68%	14.25%	7.24%
Price diff (SEK) per dose	.83	1.11	1.15	.89	.57	.34	.17	.10	-.07

Notes: Price ratio: nest-sales-weighted price of all monopoly nests in a market / product-sales-weighted price of a competitive nest. Price diff percentage: (2nd lowest price per dose - winning price per dose) / winning price per dose. Price diff: 2nd lowest price per dose - winning price per dose. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

potentially collusive market-month observations 36 and 40%. Compared to the average ATC4 (Column 3), ATC4_1 and ATC4_2 have a larger number of ATC5 categories and markets; the share of potentially collusive markets is at the average for ATC4_1 but above it for ATC4_2, and the size of the potentially collusive markets is significantly higher in our chosen ATC4 categories than the average.

We chose one potentially collusive market for a closer analysis from each of these two ATC4s. Our first choice, *market 1*, comes from ATC4_1 and has 4 nests: 30, 100, 250 and 500 pills. We chose market 1 as this market is potentially collusive with two monopoly nests each with a different firm (which we label firm A, occupying the 500-pill nest and firm B, occupying the 250-pill nest), throughout our observation period. Firm A is present in the 100-pill competitive nest for the last 14 months but never during our observation period in the competitive 30-pill nest whereas firm B is present throughout our observation period in both competitive nests. The two monopolists' products in the competitive nests have an average market share of 8.9%, with the respective within-nest market shares being 23.3%. The two monopolists provide the POTM in the competitive nests 18.1% of the time. The price of POTM changes 97.5% of the time.

Given market 1 it was natural to choose *market 2* from ATC4_2 as the second market for closer analysis as the same two firms are monopolies in two nests in that market, but only for part of our observation period. Market 2 has 5 nests: 14, 28/30, 56, 98/100 and 250 pills. Market 2 exhibited potential collusion for only the first part of our observation period: Firm B was the monopoly supplier of the smallest 14-pill package 2011/10 - 2012/1 (4 months), 2012/3-2012/4 (2 months), 2012/11 and 2013/3, for a total of 8 months. The potentially collusive entry configuration was interrupted by periods where neither firm B nor any other firm offered the 14-pill package nest in 2013/4, no firm offered the 14-pill package during our observation period.[16]

Table 6: Markets to Be Analyzed

ATC4	ATC4_1	ATC4_2	All
# of ATC5	5	4	1.72
# of markets	41	20	7.22
% of collusive market (count)	21.95%	40.00%	22.02%
% of collusive market (SEK)	36.09%	40.44%	9.96%
Rank in collusive sales (out of 184 ATC4)	2	1	
Rank in total sales (out of 184 ATC4)	5	3	

Notes: % of collusive market (count) is in terms of collusive market-month observations over all market-month observations. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

We present the price and market share variation across nests for market 2 in Table 7. In contrast to market 1 (Table 1), it is not the case that the monopoly nests have systematically the highest prices. The 14-pill monopoly nest has the second highest average price, but the 250-pill monopoly nest has the second lowest. The two monopoly nests' combined market share (measured in pills) and revenue share are only slightly above 10% as market 2 is dominated by the 98/100 pill package size.

Table 7: Descriptive Statistics by Nest, Market 2

Package Size	No. of Firms	Price per Pill	Pill Share	Revenue Share
14	1	1.06	0.01%	0.02%
28/30	3.63	1.12	2%	5%
56	5.38	0.39	7%	6%
98/100	8.75	0.62	81%	78%
250	1	0.55	10%	11%

Notes: Time period: 10/2011-1/2012, 3/2012, 4/2012, 11/2012, 3/2013. Target market: A particular active ingredient (ATC5), strength, dosage form. No. of firms: The average number of firms in each package size group. Price per Pill: The sales-weighted average price of each package size group. Pill share: The market share of each package size group in the number of pills sold over the observation period. Revenue share: The market share of each package size group in Swedish krona over the observation period. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

In market 2, both monopoly firms are present in all three competitive nests throughout our observation period. The two monopolists' products in the competitive nests have an average market share of 4.4%, with the respective within-nest market shares being somewhat higher than in market 1, 25%. The monopolists provide the POTM in the competitive nests 29.2% of the time in market 2, i.e., more often

[16] For the period 2009/12-2010/10 there was always one other firm besides firm B in the 14-pill package nest. From 2010/11 onwards until 2011/8 firm B was the monopoly supplier. We do not include the market-month observations prior to 2011/10 in our marginal cost and fixed cost analyses because the price ceiling in was introduced to market 2 in 2011/10; see Section 5.1.

than in market 1. The price of POTM changes 80.8% of the time in market 2.

4 The Theoretical Model

This Section is devoted to presenting our theoretical model. As shown in Section 3.2, an important feature or demand is that in nests with multiple products, the probability of the winner, i.e., the product of the month, changing is high, and the ensuing changes in market share are also high. As will become apparent in Section 4.1, we do not attempt to exactly model the Swedish reimbursement system, but rather, our aim is to specify a demand model that accommodates these stylized facts. The reason for this choice of modeling is threefold: First, the reimbursement rates are individual-specific but we work with market-level data. Second, introducing a POTM-dummy into the indirect utility function would introduce a further endogenous variable for which it would be hard to find credible instruments. Third, a model that incorporated the key features of the reimbursement system would either (with complete information) lead to the existence of mixed-strategy equilibria only which, as discussed below, would generate insurmountable computational challenges, or would otherwise (with imperfect information) make proving equilibrium existence difficult. On the supply side we need to incorporate these same features as well as the possibility that the price of a product is constrained by the regulatory price ceiling. While the latter is straight forward, the former necessitates us deviating from the standard approach to modeling firms' pricing decisions.

4.1 Demand

The starting point of our demand model is a standard indirect utility function for all products, coupled with assumptions on the taste shocks such that we arrive at a nested logit demand specification. Our market definition includes all products with the same active ingredient–dosage form–strength in each month (we omit the time subscript in this Section) and an outside good. Each market is divided into nests, one for each package size. Each market consists of an outside good, nest-specific winning products, and other products. The indirect utility for consumer i from buying product j is given by:

$$v_{ij} = \alpha - \beta P_j + \gamma X_j + \xi_j + \epsilon_{ij} = \delta_j + \epsilon_{ij} \tag{2}$$

where P_j is the price per pill of product j, X_j include product characteristics delineated below, α, β and γ are parameters to be estimated and ξ_j is product quality which is observed by the consumer but unobserved by the econometrician. The customer and product–specific taste shock ϵ_{ij} follows a GEV distribution yielding a nested logit structure. We normalize the utility from the outside good to zero. While we model the decision–making process using an indirect utility function, it is worth keeping in mind (as emphasized by e.g. Dubois and Lasio, 2018) that decision–making in a pharmaceutical context involves several agents: The physician, the patient and the pharmacist. In the Swedish case the physician plays a particularly important role because of the regulation forbidding substitution across nests within a market. This means that the physician, through the prescription, essentially determines the substitution possibilities of the patient in the pharmacy. Similarly, for their customers, the role of the dose pharmacies is paramount.

In addition to the demand channeled its way via equation (2), the winning product appears as a "separate" product yielding indirect utility v_{iwg} to consumer i, with subscript w indicating that the product is the winning product and subscript g denoting the nest (group) that the product belongs to. We specify v_{iwg} as

$$v_{iwg} = \delta_{wg} + \epsilon_{iwg} \tag{3}$$

where δ_{wg} is the deterministic part of utility from buying the winning product in nest g and ϵ_{iwg} is the customer and nest–specific shock having the same distribution as ϵ_{ij} in equation 2. When product j wins the auction, some customers buy product j because the "regular" utility v_{ij} is the largest, others because the utility v_{iwg} is the largest.[17] The winning (POTM) product therefore gets, roughly speaking,[18] the market share it would get if the Swedish regulation wouldn't channel most of the demand towards it via the reimbursement policy, plus the extra market share via equation (3). If product j is the winning product in nest g, its market share is therefore given by

$$D_j = s_j + s_w = \underbrace{s_{j|g} \times s_g}_{s_j} + \underbrace{s_{w|g} \times s_g}_{s_w} = \frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g)} \times \frac{exp(\sigma V_g)}{1 + \sum_g exp(\sigma V_g)} + \frac{exp(\frac{\delta_{wg}}{\sigma})}{exp(V_g)} \times \frac{exp(\sigma V_g)}{1 + \sum_g exp(\sigma V_g)}. \tag{4}$$

Equation 4 shows that the observed market share of the winning product consists of the sum of the market share coming through what the product would have attracted had it not won (s_j) plus the additional market share gained through those consumers who choose the winning product via equation 3, s_w. Both of these can be decomposed into the within nest (group) market shares $s_{w|g}$ and

[17]One can think of v_{iwg} as a reduced form, or as the utility that consumers with full reimbursement get from buying the POTM. Such consumers pay nothing out of pocket when purchasing the POTM.

[18]There is some substitution between these two groups, i.e., if product j becomes the POTM, some individuals who would have chosen it even in the counterfactual of it not being the POTM will now choose it *because* if became the POTM. That is, for some individuals $v_{iwg} > v_{ij} > v_{ik}$, $j \neq k$, for the winning product j.

$s_{j|g}$, multiplied by the nest (group) market share s_g. The market share for a losing (=non-POTM) product j in nest g is given by:

$$s_j = s_{j|g} * s_g = \frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g)} \times \frac{exp(\sigma V_g)}{1 + \sum_g exp(\sigma V_g)} \tag{5}$$

where $V_g = ln\left(exp(\delta_{wg}/\sigma) + \sum_{k \in N_g} exp(\delta_k/\sigma)\right)$ is the inclusive value and N_g is the number of nests.

4.2 Supply

Solution Concept. A natural way of dealing with the fact that the winning product changes with a high probability in an environment where neither large taste shock nor marginal cost variations from one month to the other seem plausible would be to model a mixed strategy equilibrium. As it is known (Hausschultz and Munk-Nielsen, 2021) that solving for mixed strategy equilibria with asymmetric firms is difficult even with a much smaller number of firms and products that what we encounter, we need to resort to an alternative approach. We assume imperfect information, i.e., the winning product is unknown to firms by the time they submit bids in the auction and assume that firms play a pure strategy equilibrium with imperfect information and commitment. The timeline of the firms' pricing game is as follows:

1. **Imperfect Information.** With unknown product-specific unobserved quality shocks ξ_j, ξ_{-j} and a known distribution of ξ, each firm chooses a unique strategy $\boldsymbol{\delta_j}$ where $\boldsymbol{\delta_j}$ is a vector δ_j of all products it owns in all nests and is given by

$$\delta_j = \alpha - \beta P_j + \gamma X_j + \xi_j. \tag{6}$$

2. **Commitment.** Each firm commits to δ_j before ξ_j, ξ_{-j} are realized. Prices $\boldsymbol{P_j}$ are determined according to $\boldsymbol{\delta_j}$.
3. **Determination of winning product and demand.** The winning product in each nest is the product with the lowest price. Demand for each product is determined.

The Winning Probability Function. The condition for the price of product j in nest g to be the lowest among all products k is given by:

$$P_j \leq P_k \iff \frac{\delta_j - \alpha - \gamma X_j - \xi_j}{-\beta} \leq \frac{\delta_k - \alpha - \gamma X_k - \xi_k}{-\beta} \iff \frac{\delta_j - \gamma X_j - \xi_j}{\sigma} \geq \frac{\delta_k - \gamma X_k - \xi_k}{\sigma} \tag{7}$$

We assume that $(-\gamma X_j - \xi_j)/\sigma$ follows the EV type I distribution. The probability that product j is the winning product in nest g is then given by:

$$W_{j|g} = \frac{exp(\frac{\delta_j}{\sigma})}{\sum_{k \in N_g} exp(\frac{\delta_k}{\sigma})} \quad (8)$$

The Profit Maximization Problem. We can now write the profit maximization problem of firm f owning the set of products N^f in the market (i.e., all products of firm f in all nests g in a given market) as:

$$\max_{\delta_j} \Sigma_{j \in N^f} \int \left\{ \left(\frac{\delta_j - \alpha + \gamma X_j + \xi_j}{-\beta} - c_j \right) \times \left[s_{w|g} \times W_{j|g} + s_{j|g} \right] \times s_g \right\} f \left(\frac{-\gamma X_j - \xi_j}{\sigma} \right) d \left(\frac{-\gamma X_j - \xi_j}{\sigma} \right) \quad (9)$$

The term in the first brackets is price, expressed as a function of parameters and the choice variable ξ_j from which the constant marginal cost of product j, c_j, is deducted. The first term in the square brackets is the extra within-nest market share for product j it obtains conditional on winning, $s_{w|g}$, multiplied the probability of winning in nest g, $W_{j|g}$; and the second term the "regular" within-nest market share $s_{j|g}$. Together these constitute the expected within-nest market share which is multiplied by the market share of nest g, s_g. Our assumption that $(-\gamma X_j - \xi_j)/\sigma$ follows the EV type I distribution allows us to simplify equation (9) to

$$\max_{\delta_j} \Pi^f = \max_{\delta_j} \Sigma_{j \in N^f} \left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j \right) \times \left[\frac{exp(\frac{\delta_{wg}}{\sigma})}{exp(V_g)} \times \frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g) - exp(\frac{\delta_{wg}}{\sigma})} \times \frac{exp(\sigma V_g)}{1 + \sum_g exp(\sigma V_g)} + \frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g)} \times \frac{exp(\sigma V_g)}{1 + \sum_g exp(\sigma V_g)} \right] \quad (10)$$

where ω is the Euler–Mascheroni constant. The first-order condition (FOC) for every $j \in N^f$ can then be written as

$$\left(\frac{1}{-\beta} \right) \frac{D_j}{s_j} + \left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j \right) \frac{1}{\sigma} \frac{D_j}{s_j} - \left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j \right) \Sigma_{j' \in N^f_g} \left(\frac{1 - \sigma}{\sigma} \frac{D'_j}{s_g} + \frac{1}{\sigma} s_{w|g} \times W_{j'|g} \times \frac{W_{j'|g}}{s_{j'|g})} \right) - \Sigma_{j' \in N^f} \left(\frac{\delta_{j'} - \alpha + \omega}{-\beta} - c_{j'} \right) D_{j'} = 0. \quad (11)$$

Equilibrium Existence in the Pricing Game. As Garrido (2024) points out, an equilibrium is not guaranteed in pricing games among multi-product firms because firms' profit functions often fail to be quasi-concave. We follow the aggregative games approach of Nocke and Schutz (2018) and Garrido (2024) to establish equilibrium existence in our pricing game.

The outline of the existence proof is as follows. The term V_g, defined above, is the aggregative term for nest g, and $\boldsymbol{V}$ denotes the vector of all such terms. In Online Appendix OA-3, we show that for a given $\boldsymbol{V}$, there is a unique mapping from $\boldsymbol{V}$ to the vector $\delta^{*f}(\boldsymbol{V})$ (firms' pricing decisions in our model) that satisfies the first-order conditions. Denote $\boldsymbol{\Gamma}(\boldsymbol{V})$ the aggregate fitting-in function with each nest's element $\Gamma_g(\boldsymbol{V}) = ln\left(exp(\frac{\delta_{wg}}{\sigma}) + \Sigma_{k \in N_g} exp(\frac{\delta^*_k(\boldsymbol{V})}{\sigma})\right)$. The aggregate fitting-in function $\boldsymbol{\Gamma}(\boldsymbol{V})$ maps a convex and compact set into itself. Since $\boldsymbol{\Gamma}(\boldsymbol{V})$ is continuous, Brouwer's fixed-point theorem implies that $\boldsymbol{\Gamma}(\boldsymbol{V})$ has a fixed point. More details are provided in Online Appendix OA-5.

In Online Appendix OA-4, we show that there is a unique mapping from the aggregate terms excluding firm f, $\boldsymbol{V}^{-f}$, to the vector $\delta^{*f}(\boldsymbol{V}^{-f})$ that satisfies the first-order conditions when the market share s_w is low enough. With this condition, we prove in Online Appendix OA-5 that the fitting-in function is consistent with the best response. The consistency of the best response function and the fitting-in function tells us that whether we start with the aggregate terms $\boldsymbol{V}$ or the aggregate terms excluding firm f, $\boldsymbol{V}^{-f}$, the FOCs always give us the same $\delta^{*f}(.)$ for firm f. Because the fitting-in function is consistent with the best response, each fixed point constitutes a Nash-Bertrand equilibrium.

Although multiple equilibria, or equivalently, multiple fixed points, may exist, Garrido (2024) provides evidence that equilibrium uniqueness is prevalent in our setting. Theorem 3 of Garrido (2024) shows that $\boldsymbol{\Gamma}(\boldsymbol{V})$ is monotone in $\boldsymbol{V}$ when there is a single hyper-nest. Since our model has only one nesting level, this monotonicity condition is satisfied. Conditional on monotonicity, Garrido (2024) uses an algorithm and demonstrates that it always returns a unique equilibrium.

4.3 The Entry Game

Following Seim (2006), several papers assume incomplete information when modeling entry; in essentially all such applications, the firms observe own fixed cost shocks, but not those of their rivals (e.g. Eizenberg, 2014; Wollmann, 2018). We deviate from this literature, and indeed from that assuming complete information (e.g. Toivanen and Waterson, 2005) in that we assume that there are no shocks to the fixed entry cost into a nest. The benefit of this assumption is that we avoid having an incomplete empirical model of entry, of the type studied by Tamer (2003). We assume that when deciding whether to introduce a given product j in a given nest g, firm f compares the change in expected profits gross of entry costs to the cost of introducing product j into nest g, denoted K^f_g:

$$\Pi^f_{N^f} - \Pi^f_{N^f - j} - K^f_g \geq 0 \tag{12}$$

where the subscript $N^f - j$ denotes the set of products of firm f, N^f, excluding product j. We assume that the fixed monthly entry cost K^f_g, which we allow to be firm-specific in our empirical application, is known to all firms. It is well known that such a game exhibits multiple equilibria (e.g. Bajari et al., 2010). We assume that firms play the same equilibrium. In other words, we assume, the monopoly nests excluded, that observing a firm offering a product in a given nest implies that, fixing other firms entry decisions, equation 12 has been satisfied for the firm in question, and vice versa.

We only consider the entry decisions of the monopoly firms into each others' nests. We thus make a distinction with "the other" monopolist and the firms that are present only in the competitive nests. We entertain the possibility that the entry of the other monopolist could be profitable, but assume that the other firms do not find it profitable to enter either of the monopoly nests. Further, we keep the entry decisions of the monopoly firms regarding the competitive nests constant, and do not entertain the possibility of a monopoly firm simultaneously entering the monopoly nest of its rival and exiting its own monopoly nest. As we explain in more detail in Section 6, these assumptions are supported by the data.

5 Econometric Model and Estimation Results

5.1 Estimation Samples

We use different data for each of the three steps of our estimation process, namely demand, marginal cost and fixed cost estimation. We have collected key information on the estimation samples into Table 8.

Demand estimation sample. In order to increase precision, we follow e.g. Dubois et al. (2022) and use data from all markets within a given ATC4 though we depart from them and other precursors (e.g. Dubois and Lasio, 2018) in that we measure price and quantity at the package level (as in Björnerstedt and Verboven, 2016). While we thereby estimate demand for more precisely defined products than is the norm, we simplify the demand structure by assuming that there is no substitution across markets within an ATC4. The observation period we use for the demand estimation is 2009/12-2017/12.

Marginal cost estimation sample. The Swedish price regulations dictate that a price ceiling is introduced only some time after generic competition has taken place. Because of this, there was no price ceiling prior to 2011/9 in market 1 and 2011/10 for market 2. Given that we want to study firm behavior under the prevailing regulation which includes price ceilings, we restrict the estimation sample for marginal cost estimation accordingly and use the time period 2011/9-2017/21 for ATC4_1 and 2011/10-2017/12 for ATC4_2. To reduce heterogeneity across products we restrict the estimation sample to only include products with the same active ingredient as in markets 1 and 2 (i.e., products in the same ATC5 group having the same form (=pill) as the products in markets 1 and 2 respectively).

Fixed cost estimation sample. As our main interest is in obtaining fixed cost estimates for the potentially collusive firms in markets 1 and 2, we only use data from markets 1 and 2 for the two monopolists, and only use those months when the entry configuration in these markets was potentially collusive.

Table 8: Estimation Data Sample

	Whole Dataset	Demand		Marginal Costs		Fixed Costs	
		Market 1	Market 2	Market 1	Market 2	Market 1	Market 2
Level		ATC4		ATC5-Form		ATC5-Form-Strength	
Time Period	12/2009-12/2017	12/2009-12/2017	12/2009-12/2017	9/2011-12/2017	10/2011-12/2017	9/2011-12/2017	10/2011-1/2012, 3/2012, 4/2012, 11/2012, 3/2013
# ATC5s	316	5	4	1	1	1	1
# Markets	1328	23	13	3	2	1	1
# Firms/Market	4.54	7.30	9.92	6.33	13.50	7.00	13.00
# Nests/Market	2.97	4.00	4.38	3.33	4.50	4.00	5.00

Notes: Time period: 12/2009-12/2017. Sample data: Whole dataset. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

5.2 Demand and Marginal Cost Estimation

Main demand estimation. As a consequence of the existence and modeling of POTM, we cannot estimate demand for all products at the same time, but first estimate the common demand parameters using only data on losing products. The reason is that in our model, the market share D_{jt} of a winning product comes from two sources: The typical market share of product j, s_{jt}, and the additional winning market share s_{wt}. We only observe total market shares $D_{jt} = s_{jt} + s_{wt}$ for the winning product, but $D_{jt} = s_{jt}$ for losing products. We explain below how we recover the winning product parameter δ_{wt}.

To address the endogeneity of prices, we construct a Hausman-style instrument by matching the prices of products in Sweden to the prices of the same products in Denmark, Finland, and Norway. In the case of not finding a match, we calculate imputed prices based on a projection of observed prices in neighboring countries on product characteristics (see Appendix A-1 for more detail). The exclusion restriction on which our instrument is based on is that the same product should have the same cost shock across these geographical/national markets, but that the demand shocks, conditional on our observables (like month FE) across the Nordic countries are independent. It is worth bearing in mind that advertising of prescription drugs is not allowed in any of these countries. We display the first stage regression results in Appendix Table A-4. We find plausible coefficient estimates and F-test values exceeding 40, implying that our instrument vector is strong.

We estimate the following demand equation, assigning a market share of 5% to the outside good in each market.[19]

$$ln(D_{jt}) - ln(s_{0t}) = \alpha_t - \beta P_{jt} + \gamma X_{jt} + (1-\sigma)ln(s_{jt|g}) + \xi_{jt} = \delta_{jt} + (1-\sigma)ln(s_{jt|g}) \tag{13}$$

The vector X_{jt} contains a dummy for the product being branded and a dummy for the product being a parallel–imported product, thereby leaving the generic products as the base category, as well as a dummy for products in jars, another for products being available for dose pharmacies only and month and market fixed effects.

The results of the demand estimation are presented in Table 9. Both price coefficients are precisely measured and of the right sign. We report the coefficient of $ln(s_{jt|g})$, which is $1-\sigma$. The nesting parameter σ obtains a low value for ATC4_1, but is larger but relatively precisely measured for ATC4_2. These parameter values have consequences for the ability of firms to collude through spheres of influence: A high value of σ suggests that physicians (dose pharmacies) do substitute across nests, thereby weakening the market power of nest-specific monopolists. As to the additional coefficients, we find in line with previous studies that the branded product dummy obtains a large positive coefficient. More unusually, we find that the parallel import–dummy obtains a large positive coefficient in ATC4_1, suggesting that consumers prefer them to generic products (the baseline category). It is worth bearing in mind that the parallel imported products are produced by the original (branded) manufacturer, but initially sold in another EU country (see Dubois and Sæthre 2020). Products in jars are valued more highly than other products in market 1, but note that we excluded the jar-dummy from the specification for market 2 because of collinearity with the dose pharmacy - dummy. The latter variable obtains a noisy negative coefficient in market 1, but a large positive and statistically significant coefficient in market 2, where it is best interpreted as approximately capturing the joint effect of the product being in a jar and the product being available for dose pharmacies only.

[19] Given that we model the demand for prescription drugs, it is sensible to assume a low market share for the outside good. As a robustness test, we have re-estimated our model using a 10% market share for the outside good. The results are comparable to those we obtain with the 5% market share of the outside good.

Table 9: Demand Estimation

	ATC4_1	ATC4_2
Price	-1.041***	-0.758***
	(0.088)	(0.091)
Log(within *MS*)	0.985***	0.163**
	(0.092)	(0.079)
Branded	3.228***	3.321***
	(0.241)	(0.250)
Parallel Import	5.219***	0.349
	(0.694)	(0.267)
Jar	1.004***	
	(0.086)	
Dose pharmacies only	-0.201	2.583***
	(0.162)	(0.109)
Month/Year	Yes	Yes
Market	Yes	Yes
Observations	7352	10738
1st-stage F-test	50.962	57.833

Notes: Robust SEs in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

Estimation of winning product parameter δ_{wt}. As detailed in Appendix Section A-3, we can express the (log) difference between the extra market share the winning product gains, s_{wgt}, and the outside good market share by adjusting equation 13 for the winning product. We approximate s_{jt} for the winning product by the (market-month) mean s_{jt} for losing products in that nest. We find an average s_{wgt} of 53%.[20] We recover δ_{wgt} by formulating an equation where the left hand side is the log difference between $D_{jt} - \hat{s}_{jt}$ and the market share of the outside good, and the right hand side consists of δ_{wgt} and an expression we can calculate based on data and estimated parameters.

Calculation of marginal cost. Having obtained all the demand side parameters allows us to solve the FOCs (equation 11) for those firms for which no product is at the regulatory price ceiling. Notice that the FOCs determine directly the marginal costs. To estimate marginal costs for firms with at least one product at the price ceiling, we follow Dubois and Lasio (2018) and **?** and project the (log) estimated marginal costs for the subset of products whose producers have no products at the price ceiling in a given month in a given market on observables. The observables are: Strength (dummies), (log) package size and month fixed effects. The results of these marginal cost regressions are presented in Appendix Table A-5. As is intuitive, we find that marginal costs are decreasing in package size. We use the estimated parameters to estimate the marginal costs for those products at the price ceiling, and can thereby obtain the marginal costs for the other products of the firms with at least one product at the price ceiling by using the FOC (equation 11).

5.3 Implications of Demand and Marginal Cost Parameters

Table 10 summarizes key variables describing the pricing and intensity of competition across nests in markets 1 and 2. The estimated marginal costs per pill are decreasing in package size.[21] However, though not shown in the Table, marginal costs per package are monotonically increasing in package size. Observed prices per pill on the other hand are clearly higher in the larger monopoly package sizes in market 1 (250- and 500-pill packages), with prices in the two monopoly packages sizes very close or at the regulated price ceiling. This is not the case in market 2, where the monopoly markets (14- and 250-pill packages) have prices per pill that are in the middle of the distribution (14-pill package) or lowest of all (250-pill package, though this price is at the price ceiling).[22] Given this pricing and marginal cost pattern it comes as no surprise that the price-cost margins in the monopoly nests are

[20] Using any of the quartiles of the losing products' market share would give an s_{wgt} in the range of 50-51%.

[21] The one exception is that the mean marginal cost per pill for the 14-pill package is a little lower than that for the 28/30 pill package; these estimates are so noisy that one can regard them as being equal.

[22] It is one of the features of the Swedish price regulation that the price ceiling may vary across nests, i.e., package sizes. The price ceiling is capped at a percentage of the original branded medicine's historical price. Different historical baseline prices for different package sizes yield different price ceilings. See TLV (2021) for more details.

much higher in market 1 than in the competitive nests, but are quite similar to the price-cost margins of the competitive nests in market 2. It is worth noting that according to our estimates, the price-cost margin in the 30-pill nest in market 1 is very low (1%). Notice also that the highest price-cost margin in market 2 is for the 250-pill monopoly product, despite its price ceiling binding.

Table 10: Price and Marginal Cost Estimation

Package	Price Ceiling	Price per pill	Marginal Cost per pill	Price-Cost Margin %	No. of Firms	No. of Obs.
Market 1						
30-pill	1.02	0.714	0.707	1	3.61	268
100-pill	1.08	0.66	0.59	10	3.93	285
250-pill	2.60	2.53	0.44	83	1	76
500-pill	2.69	2.69	0.37	86	1	76
Market 2						
Package	Price Ceiling	Price per pill	Marginal Cost per pill	Price-Cost Margin %	No. of Firms	No. of Obs.
14-pill	1.25	1.06	0.83	22	1	8
28/30-pill	1.70	1.47	0.85	42	3.90	29
56-pill	1.72	0.51	0.36	29	5.47	43
98/100-pill	1.63	0.69	0.25	63	9.09	70
250-pill	0.55	0.55	0.15	72	1	8

Notes: **Monopoly nests** are in bold. Market 1: 2011m9-2017m12. Market 2: 2011m10-2017m12. No. of Obs.: the number of product-month observations. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

5.4 Fixed Cost Estimation

We calculate the fixed costs for only firms A and B that are monopolies in a given nest using data only from those market-month observations in markets 1 and 2 where the entry configuration was potentially collusive (see Table 8). In market 1, firm A is a monopolist for the 500-pill package, but also present in the competitive 100-pill package nest. Firm B is a monopolist in the 250-pill package nest, and participates in both competitive nests (30 and 100 pill packages). In market 2 there are 5 nests: 14, 28/30, 56, 98/100 and 250 pills, with the largest and smallest package sizes being monopolies (for part of our observation period). Firm A is a monopolist in the 250-pill, firm B in the 14-pill package size nest. Both firms are also present in all three competitive nests. While only the bounds for competitive nests are informative of true fixed costs, we calculate the bounds also for the monopoly nests in order to provide a comparison. As an example, given the observed entry patterns, we can use firm A to calculate the lower bound of the fixed monthly entry cost into the 250 pill monopoly nest (occupied by firm B) in market 1, and the upper bound for the 100 and 500 pill nests, also in market 1. Similarly, firm B's entry decisions allow us to calculate the lower bound for the 500 pill nest (occupied by firm A) in market 1, and the lower bound for the 30, 100 and 250 pill package nests in market 1. We calculate each bound for each market-month observation for those months where we observe a potentially collusive entry configuration and present the median of each (lower and upper) bound thus obtained. For a given nest, the upper bound reflects the fixed costs of the monopoly firm that provides the product in that nest, and the lower bound the fixed cost of the monopoly firm not providing that product (but being a monopolist for another product).

We present the estimates of the (median of the) fixed cost bounds in Table 11, with market 1 on the left and market 2 on the right hand side. The upper panel contains the absolute fixed costs in SEK per month and the lower the fixed costs relative to our lowest estimated (median) upper bound of the competitive nests. Looking first at market 1, it is immediately clear that even the estimated lower bound fixed monthly entry costs into the monopoly nests are significantly higher than the estimated upper bound fixed costs for the competitive nests. The lower left panel of Table 11 shows that the estimated lower bound fixed costs for the monopoly nests are 14 and 37 times higher than the upper bound estimated for the competitive 100–pill package nest; the upper bounds for the monopoly nests are further orders of magnitude higher. These large differences in estimated fixed costs are suggestive evidence that entry decisions into the monopoly nests might not be competitive. The estimated upper bound fixed cost for the 30-pill package is slightly negative, and we therefore take as our estimate of fixed cost of entry the 127SEK estimated for the 100-pill package.

Looking then at market 2 (the right hand side of the table), a very different picture emerges. Taking the upper bound of the competitive 56-pill nest as our benchmark, we find that the ratio of the upper bounds of the estimated fixed costs in monopoly nests (14- and 250-pills) to this benchmark are 1.27 (14-pill market) and 7.47 (250-pill market). While both ratios are above 1, they are much closer to the competitive nests' fixed costs and do not strongly suggest that the monopoly nests would be the result of collusion through spheres of influence. We take the lowest of the upper bounds of the competitive nests, 3 612SEK, as our preferred fixed cost estimate in market 2.

6 Competition or Collusion?

In this Section, we analyze a static game where firms A and B first decide which current monopoly nests (250-pill and 500-pill in market 1, 14-pill and 250-pill in market 2) to enter and then play the pricing

Table 11: Fixed Cost Bounds

Profit (SEK)					
Market 1			Market 2		
Package	Lower Bound	Upper Bound	Package	Lower Bound	Upper Bound
500-pill	4703	612168	**250-pill**	1533	26979
250-pill	1868	231754	98/100-pill		16144
100-pill		127	56-pill		3612
30-pill		-5	28/30-pill		4362
			14-pill	3406	4585
Profit Ratio					
Market 1			Market 2		
Package	Lower Bound	Upper Bound	Package	Lower Bound	Upper Bound
500-pill	37.09	4828.03	**250-pill**	0.42	7.47
250-pill	14.73	1827.79	98/100-pill		4.47
100-pill		1.00	56-pill		1.00
30-pill		-0.04	28/30-pill		1.21
			14-pill	0.94	1.27

Notes: **Monopoly nests** are in bold. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

game described in our model. In this static game, an entry deviation from the observed entry pattern (into monopoly nests) results in re–optimization of price of not only the deviating firm but also the other firms. By analyzing this static game, we want to find a long-term equilibrium of entry and exit where both firms can adjust prices to react to potential deviations in entry. Throughout this exercise, we keep the entry decisions of all other firms, as well as the entry decisions of firms A and B into the competitive nests constant. These assumptions are based on us only rarely observing either entry into monopoly nests by competitive firms or exit by monopoly firms from the competitive nests: The probability that a non-monopolist enters a monopoly nest is 0.5% across all markets in our data; there is no such entry in market 1 and in market 2 only in the brief period before TLV instituted the price ceiling. The probability of a monopoly firm entering a competitive nest is 1% and the probability of a monopoly firm exiting a competitive nest is 4%. The simultaneous entry of a monopolist into another firm's monopoly nest and exit from its own monopoly nest is an occurrence that we do not find in the data and we hence do not consider it either.

Tables 12 and 13 show the payoff matrix of the static game for different levels of fixed entry cost for market 1 and 2 respectively. The payoffs are in bold when the entry configuration is a static pure-strategy non-cooperative Nash equilibrium and in red when the entry configuration is the potentially collusive one observed in the data.

If this analysis suggests that the observed entry pattern of firms A and B into the monopoly nests is a pure strategy Nash equilibrium, we conclude that the entry decisions are competitive. On the other hand, if that turns not to be the case, we proceed to analyzing the discount factors that would support the observed entry decisions being the outcome of collusion. We analyze markets 1 and 2 separately, starting with market 1.

6.1 Entry Decisions in Market 1

The Static Game. We present the payoffs of the monopoly firms A and B for market 1 in Table 12. The top panel contains gross profits, i.e., ignoring the fixed costs of entry. The middle panel contains the payoffs obtained using our preferred estimate of fixed costs for market 1 with the bottom panel containing the profits net of an alternative fixed cost estimate taken from market 2.[23] We learn from the middle panel of Table 12 that in market 1, for the observed outcome, i.e., firm A in the 500-pill package nest and firm B in the 250-pill package nest, the (monthly net) payoffs (in red) are 603 659 SEK for firm A and 272 802 SEK for firm B. This is however not a static pure-strategy Nash equilibrium. There are two such equilibria, in both of which one or the other monopoly firm enters both the 250- and the 500-pill package nest and the other continues to produce the product that formerly was its monopoly. Notice that the observed outcome is not maximizing the joint profits of firms A and B, nor is either of the Nash equilibria: Joint profits would be maximized if firm A provided both the 250- and 500-pill packages and firm B provided neither. The division of profits would however naturally be very asymmetric with that entry configuration. Assuming that firms cannot engage in transfers, we argue that the observed entry configuration is the result of collusion where the two firms divide the monopoly nests between themselves. Using the alternative, much higher, fixed cost estimate doesn't make the observed entry configuration a Nash equilibrium, but would wipe out one of the two Nash equilibria.

The Dynamic Game. Given the above, we study a dynamic game where the starting point is collusion of firms A and B. Each firm has the option to deviate and enter the other monopoly nest *by surprise*. In the current period, an entry deviation results in price re-optimization of only the deviating firm but not the other firm(s). From the following period onwards, we assume that the non-deviating firm punishes the deviation by always participating in both monopoly nests. The payoffs in Table 12 suggest that during the punishment phase the best response of the deviating firm is to exit the nest it entered. If firm A deviates and enters the 250-pill nest, its one-period deviation profit is 677 061 SEK. During the punishment phase firm A exits the 250-pill nest while firm B provides both the 250- and 500-pill packages. Firm A's continuation profit is then 41 071 SEK (bottom row, middle column in

[23] The purpose of the top panel is to allow the reader to entertain alternative fixed entry cost estimates. We use the estimated fixed cost for the 28/30-pill package in market 2 (4 362SEK) as our alternative fixed cost estimate for both markets.

TABLE 12: STATIC GAME PAYOFF MATRIX . MARKET 1

Fixed Cost: 0 SEK						
B \ A	**Competitive**		**Competitive+500**		**Competitive+250+500**	
Competitive	48928	0	38783	660339	35543	854880
Competitive+250	340731	0	273183	603809	**121108**	**605569**
Competitive+250+500	827941	0	**278121**	**41221**	38834	9028

Fixed Cost: 127 SEK						
B \ A	**Competitive**		**Competitive+500**		**Competitive+250+500**	
Competitive	48674	-23	38529	660188	35289	854604
Competitive+250	340350	-23	272802	603659	**120728**	**605292**
Competitive+250+500	827434	-23	**277614**	**41071**	38326	8751

Fixed Cost: 4362 SEK						
B \ A	**Competitive**		**Competitive+500**		**Competitive+250+500**	
Competitive	40204	-803	30059	655173	26819	845353
Competitive+250	327645	-803	260097	598643	108022	596041
Competitive+250+500	810493	-803	**260673**	**36056**	21386	-500

Notes: Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

middle panel of Table 12). Similarly, firm B earns a deviation profit of 832 654 SEK if it unexpectedly enters the 500-pill nest. Once firm A punishes by entering the 250-pill nest, firm B's best response is to exit the 500-pill nest, after with firm B's continuation profit is 120 728 SEK (middle row, right column in middle panel of Table 12).

The IC constraint is:

$$(\Pi_{1nest,1nest} - K) \times \Sigma_{t=0}^{t} \rho^t \geq (\Pi_{2nests(surprise),1nest} - 2 \times K) + (\Pi_{1nest,2nests} - K) \times \Sigma_{t=1}^{t} \rho^t \tag{14}$$

where $\Pi_{1nest,1nest}$ is the per period profit when both monopolists stay in their respective monopoly nests, $\Pi_{2nests(surprise),1nest}$ is the per period profit from deviating from collusion by entering the monopoly nest of the rival by surprise, meaning that the rival monopoly adjusts neither its entry nor its pricing decisions and the other rival firms in the competitive nests do not adjust their pricing decisions. $\Pi_{1nest,2nests}$ are the continuation profits of the deviating monopoly firm, earned after the rival monopolist enters the monopoly nest of the deviating firm and the deviating firm, as an optimal response, exits the monopoly nest of the rival.[24] Using the IC constraint with a horizon of 12 months, the minimum annual discount factor to sustain collusion is approximately 0 for both firms.[25] We conclude that in

[24]In addition, the firms providing only the products in the competitive nests also adjust their prices.
[25]Lengthening the time horizon would only strengthen the result.

market 1, the observed entry configuration of firms A and B is suggestive of collusion through spheres of influence.

6.2 Entry Decisions in Market 2

The Static Game. We display the payoffs from market 2 in Table 13. We again report the gross profits for firms A and B in the top panel, the profits net of our preferred fixed cost estimate in the middle panel and the profits net of our alternative fixed cost estimate of 4 362 SEK in the bottom panel. The preferred estimate is the lowest (median) upper bound fixed cost estimate for the monopoly firms in market 2 (obtained for the 56-pill package); the alternative is the second lowest, obtained for the 28/30-pill package. Firm A is the monopolist in the 250-pill nest, firm B in the 14-pill nest. The observed entry pattern is not a static Nash equilibrium with either fixed cost estimate because firm B would want to exit the 14-pill nest. The per period profits in the middle and bottom panel suggest that both firms' profits would increase shifting from the observed entry configuration to the static Nash equilibrium; this is what actually happened relatively early in our observation period (i.e., firm B exited the 14-pill nest permanently in 2013/4). We conclude that the observed entry configuration is not collusive even though the firms may have initially thought it would yield higher profits than the noncooperative static Nash equilibrium entry configuration.

TABLE 13: STATIC GAME PAYOFF MATRIX - MARKET 2

Fixed Cost: 0 SEK						
B \ A	**Competitive**		**Competitive+250**		**Competitive+14+250**	
Competitive	30147	29642	24094	55380	23659	57249
Competitive+14	33129	28989	26567	54402	25358	58071
Competitive+14+250	57839	23279	28007	39027	**41150**	**40627**
Fixed Cost: 3612 SEK						
B \ A	**Competitive**		**Competitive+250**		**Competitive+14+250**	
Competitive	19310	18805	**13257**	**40931**	12822	39187
Competitive+14	18679	18152	12117	39952	10909	40009
Competitive+14+250	39777	12442	9946	24578	23088	22565
Fixed Cost: 4 362 SEK						
B \ A	**Competitive**		**Competitive+250**		**Competitive+14+250**	
Competitive	17061	16557	**11009**	**37934**	10574	35441
Competitive+14	15682	15904	9120	36955	7912	36262
Competitive+14+250	36031	10194	6199	21581	19341	18818

Notes: Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

7 Counterfactual Analysis

In the counterfactual we study what would happen if the regulations were changed so that the product of the month would be partly determined across nests. To achieve this, we implement the following regulatory changes: First, for some (monopoly) packages sizes we allow substitution to the closest compatible (competitive) package size. Second, the POTM for a given package size is the cheapest per pill across the compatible package sizes. This means that in order to get reimbursed, a patient may need to buy a different package size than what they have been prescribed. To illustrate, think of the following two cases in market 1: In the first, the cheapest 100-pill package has a lower price per pill than the (monopoly) 500-pill package. Then the POTM for patients with a 500-pill prescription would be the same as for patients with a 100-pill prescription, i.e., the cheapest 100-pill package. In the second, the 500-pill package is cheaper per pill than the cheapest 100-pill package. In this case, the POTM for patients with a 500-pill prescription would be the 500-pill package, the POTM for patients with a 100-pill package would be the cheapest 100-pill package. Patients continue to only get full reimbursement if they buy the POTM for the package size they have been prescribed. We continue to require that dose pharmacies buy a POTM. Given that the set of POTM changes in our counterfactual, the dose pharmacies may end up buying different products (and package sizes) than has been the case. In this sense, our counterfactual is in the spirit of a suggested reform of dose pharmacy purchasing practices made by the Swedish Dental and Pharmaceutical Benefits Agency (TLV, see TLV (2020)) that was not implemented.[26]

In executing the counterfactual we rely on the methodology of Iaria and Wang (2021) which allows substitution across nests. We first check whether the observed entry configuration is a (collusive) equilibrium in the counterfactual. If that turns out not to be the case, we compute the counterfactual for the (new) equilibrium entry configuration. As in the previous Section, we proceed market by market, and start with market 1.

7.1 Market 1

We change the regulations in market 1 as follows: First, the compatible package sizes for a 250-pill prescription are the 30-pill and 250-pill packages. The only compatible package size for a 30-pill prescription is the 30-pill package. Second, the compatible package sizes for a 500-pill prescription are the 100-pill and 500-pill packages. The only compatible package size for a 100-pill prescription is the 100-pill package. POTM for a given prescription is the cheapest product among all products with the

[26]TLV suggested that dose pharmacies would be required to buy the cheapest POTM across all package sizes, in terms of price per pill. We require substitution across compatible packages only.

compatible package sizes.

TABLE 14: STATIC GAME PAYOFF MATRIX - MARKET 1 - COUNTERFACTUAL

Fixed Cost: 127 SEK				
B \ A	**Competitive**		**Competitive+500**	
Competitive	43820	775	31262	46192
Competitive+250	144178	713	**106158**	**44612**

Notes: Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

Table 14 shows the static payoffs of firms A and B when they either continue providing their monopoly products, or revert to providing only the competitive products. The observed entry configuration is the equilibrium and hence the counterfactual, the results of which are displayed in Table 15, is calculated assuming that each monopoly firm continues to provide its monopoly product in addition to the competitive products it is providing. The upper panel of Table 15 reports the data and the lower panel the counterfactual. With the exception of the 30-pill nest, we find minor changes in the market shares of the differently sized packages. While the average price in the 30-pill nest increases by some 8%, prices in all other nests decrease, and dramatically so in the two monopoly nests, by over 60 and almost 80%. These price decreases are due to the competitive pressure now exerted by the 30- and 100-pill packages. The result is that the average price per pill decreases by over 50% and the market share of the outside good decreases somewhat from (the assumed) 5% to 4.5%.

TABLE 15: COUNTERFACTUAL - MARKET 1

Original					
Package Size	Sales (SEK)	Sales (pills)	Shares in pills (%)	Average Price per Pill	
30	36344	63024	5.20	0.60	
100	434328	789796	56.91	0.55	
250	322730	126247	11.64	2.53	
500	720938	268007	21.25	2.69	
Total	**1514339**	**1247072**	**95.00**	**1.27**	
Counterfactual					
Package Size	Sales (SEK)	Sales (pills)	Shares in pills (%)	Average Price per Pill	% Change in price
30	71457	110650	8.38	0.65	8.47
100	371405	715646	54.59	0.53	-4.26
250	140405	141137	10.72	0.97	-61.64
500	154444	285690	21.77	0.54	-79.79
Total	**737712**	**1253124**	**95.46**	**0.59**	**-53.58**

Notes: Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

7.2 Market 2

In market 2, we define the compatible package sizes for a 28-pill prescription to be the 28-pill and 14-pill packages. The only compatible package size for a 14-pill prescription is the 14-pill package. The compatible package sizes for a 250-pill prescription are the 98/100-pill and 250-pill packages. The only compatible package size for a 98/100-pill prescription is the 98/100-pill package. The only compatible package size for a 56-pill prescription continues to be the 56-pill package. POTM for a given prescription is the cheapest product among all products with compatible package sizes. Our investigation of the monopoly firms' entry decisions, reported in Table 16, suggests that in the counterfactual regulatory regime both of them would exit their monopoly products. We therefore execute our counterfactual calculations assuming that this would happen.

Table 16: Static Game Payoff Matrix - Market 2 - Counterfactual

Fixed Cost: 3 612 SEK				
B \ A	**Competitive**		**Competitive+250**	
Competitive	**16437**	**12625**	14693	8411
Competitive+14	15486	9851	13166	5444

Notes: Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

We report the results of the counterfactual in Table 17 where we again display the data in the upper panel and the counterfactual in the lower panel. We now find that the average prices of two of the three competitive nests increase, and substantially so, by almost 40 and by over 140%. The modest price reduction in the 98/100-pill nest of 2% is not sufficient to counterbalance these increases even if the market share of this nest is over 80% in terms of pills sold. We therefore overall record an increase in the price per pill of 7% and an increase in the outside good market share from 5 to 10.2%. Our counterfactual in market 2 exemplifies how intensified price competition post entry may lead to exit and thereby less intense price competition in equilibrium.

Table 17: Counterfactual - Market 2

Package Size	Sales (SEK)	Sales (pills)	Shares in pills (%)	Average Price per Pill	% Change in price
Original					
14	42	47	0.01	1.06	
28/30	8810	8120	2.09	1.12	
56	9861	25207	6.46	0.39	
98/100	192354	303833	77.17	0.62	
250	20195	36719	9.26	0.55	
Total	**231263**	**373926**	**95.00**	**0.61**	
Counterfactual					
Package Size	Sales (SEK)	Sales (pills)	Shares in pills (%)	Average Price per Pill	% Change in price
14					
28/30	17468	11563	2.94	1.52	36.18
56	14914	15376	3.89	0.95	141.99
98/100	202747	326382	82.94	0.61	-1.97
250					
Total	**235129**	**353320**	**89.77**	**0.65**	**7.22**

Notes: Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

8 Conclusion

Price regulations are introduced and managed in order to decrease prices and expenditure, but they can be complex to design and may have unintended consequences. In line with many other developed countries, Sweden has introduced various price regulation regimes in order to decrease the prices of prescription pharmaceuticals for products where generic alternatives are available. The current regime, in place since 2009, is based on monthly auctions at the active ingredient–strength–dosage form–*package size* level where the winner (the product with the lowest price) gains a substantial market share in the substitution group, and has proven effective in reducing pharmaceutical expenditure. However, pharmaceutical companies still find ways to circumvent both competitive pressures and regulatory innovations. In the Swedish case, two peculiar details of the regulatory regime may have opened such a possibility by judicious choice of what package sizes to provide: First, neither the patient nor the pharmacist can substitute across package sizes, but must contain their choice to those products that have the same package size as the product prescribed by the physician. Second, the so-called dose pharmacies serving some 3% of the population (mostly individuals in elderly care homes) pass on the cost of pharmaceuticals to their customers who get reimbursed as long as the pharmacy is buying some product of the month irrespective of how expensive per pill the package is.

The entry and price patterns that we document suggest that pharmaceutical firms may have realized that mutually not entering a package size offered by a rival may offer them an escape from the price pressures created by the product of the month regulation as firms become monopolies in given package sizes. Our data suggests that this is neither an isolated nor an insignificant phenomenon. We find that 22% of markets that generate 34% of sales exhibit a potentially collusive entry configuration with 2 firms as monopolists in different package sizes at some point and that market-month observations with such suspicious entry configurations generate 11% of sales. Furthermore, markets with a potentially collusive entry configuration are associated with economically and statistically significantly higher prices per pill. To study the phenomenon in more detail, we zoom in on two markets from those ATC4 categories where the potentially collusive sales are the highest. The first market we study has a potentially collusive market structure throughout our observation period, the second only for 8 months. What makes this pair of markets particularly interesting is that the same pair of firms provides the monopoly package sizes in both markets.

We tailor our nested logit demand model to capture the large market share changes induced by the product of the month often changing in the data, and find in market 1 that the price-cost margins in the monopoly nests are clearly higher than in the competitive nests. This is however not the case in market 2 which is characterized by a much smaller nesting parameter, indicating substitution across nests.

The observed entry configuration in market 1 is not a static pure strategy Nash equilibrium but suggestive of collusion through spheres of influence, and collusion can be sustained with very low discount factors. In contrast, while the observed potentially collusive entry configuration in market 2 is not a static pure strategy Nash equilibrium either, we observe the potentially collusive firms switching to the unique static Nash equilibrium entry configuration after a relatively short experimentation period. Our results are suggestive of the two monopoly firms colluding in market 1 and having experimented with collusion in market 2 only to find out it was not worthwhile.

In our counterfactual analysis, we find that allowing for and inducing substitution across nests by changing the product of the month regulations, in line with what the Swedish regulator suggested for dose pharmacies a few years ago, leads to a sizable decrease in prices per pill in the collusive market 1, but to a modest increase in prices per pill in the (more) competitive market 2 because the prospect of intensified price competition lead to exit and thereby to less intense price competition in equilibrium. The results of our analysis of the current regime as well as the results of our counterfactual highlight the challenges regulators face in designing well functioning regulatory regimes.

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Appendix

A-1 Additional tables

We present additional descriptive statistics and estimation results in this Appendix. Table A-1 contains statistics on the absolute and relative share of observations where the lowest price was not assigned POTM status in a given substitution group in a given month. Less than 8% of all substitution group–month observations have such an outcome overall. The respective shares for markets 1 and 2 are 1.5 and 11.7%.

TABLE A-1: WINNING POTM NOT HAVING THE MINIMUM PRICE

Sample	Total POTMs	Not-min-price POTMs	Share
All Markets	95 383	7 372	7.73%
Market 1	265	4	1.51%
Market 2	410	48	11.71%

Notes: Time period: 12/2009-12/2017. Sample data: whole dataset. Data source: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

We present the Swedish formulae for pharmacy margins in Table A-2. PPP stands for the Pharmacy Purchasing Price, i.e., the wholesale price firms announce in the product of the month auctions. The margin consists of a fixed part (in SEK) and a multiplier for the PPP which is decreasing in PPP. The formula changed slightly in 2016/4 when the fixed parts were adjusted slightly downwards.

TABLE A-2: PHARMACY MARGINS

Before 4/2016	
Pharmacy Purchasing Price	Retail Price
0-75	PPP $\times 1.20 + 31.25 + 10.00$
75-300	PPP $\times 1.03 + 44.00 + 10.00$
300-6000	PPP $\times 1.02 + 47.00 + 10.00$
6000-	PPP + 167.00 + 10.00
After 4/2016	
Pharmacy Purchasing Price	Retail Price
0-75	PPP $\times 1.20 + 30.50 + 10.00$
75-300	PPP $\times 1.03 + 43.25 + 10.00$
300-50000	PPP $\times 1.02 + 46.25 + 10.00$
50000-	PPP + 1046.25 + 10.00

Table A-3 displays statistics on the performance of monopoly firms (i.e., those that are the monopoly supplier in at least one nest (substitution group) in a given market) and non-monopoly firms in the competitive nests in our data. We find that monopoly firms participate in the competitive nests 29% of the time and, conditional on participating, have higher overall and within-nest market shares than the non-monopoly firms. Monopoly firms also provide the POTM in the competitive nests more often than individual non-monopoly firms. Note that the statistics for both types of firms are calculated on a per firm, not a per firm-category, basis.

We present the first-stage regression estimates in Table A-4. The dependent variables are price and (log) within-nest market share. The samples for the first-stage estimates are the same as those used for the demand estimation, described in Subsection 5.1. We include the same controls as in the demand

Table A-3: Monopoly Firms in the Competitive Nests, all markets

Firm	Participation in Competitive Nests	Market Share in Competitive Nests	Within-nest MS in Competitive Nests	POTM in Competitive Nests
Monopoly	29%	18%	35%	32%
Non-monopoly	98%	13%	24%	25%

Notes: Time period: 12/2009-12/2017. Sample data: whole dataset. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

estimation.

As instruments, we include the prices in Finland, Denmark and Norway. In case the price of product j in country c in month t is imputed, we interact the imputed price with a dummy for imputation. Our vector of instruments consists thus of the prices in the three neighboring countries and the interactions between each of these prices and an imputation dummy.

To impute the missing prices, we use a random forest estimator where the dependent variable is the log package price in local currency and as explanatory variables. We include the following product characteristics: A dummy for the product being a branded product, a dummy for the product being a parallel imported product, package size (=number of pills), strength (in mg), firm, month and dosage form fixed effects. We estimate the model separately for each of the three countries. We exponentiate the predicted prices and divide both the observed and imputed package prices by the number of pills to arrive at a price per pill for product j in country c in month t which we then use as our instruments.

20 out of the 24 coefficients for our instruments are statistically significant. The exceptions are: The imputed Norwegian price in both the price and log within market share regressions for ATC4_1; the Danish price in the log within market share regression for ATC4_1 and the Finnish price in the price regression for ATC4_2. The F-test in Table A-4 is an F-test of the joint significance of these 6 variables. The observation period spans 2009/12–2017/12.

Table A-5 presents the marginal cost regression estimates. The sample used for the marginal cost regressions is a subset of the products observed within the sample described in Subsection 5.1. Specifically, the estimation sample includes only products offered by firms with no products priced at the price ceiling. The reason for this is that the FOCs of other firms do not hold even for products that are not priced at the price ceiling. The estimation period spans 2011/09–2017/12 for ATC4_1 and 2011/10–2017/12 for ATC4_2. The outcome variable is the log of estimated marginal cost of product j in month t. The explanatory variables are dummies for strengths 30 and 45mg for ATC4_1 and dummies for strengths 40 and 45mg for ATC4_2, the log of the package size of product j (equal to the log of package size of all products of nest g in which product j resides), and month fixed effects. The base strength in ATC4_1 is 15mg and in ATC4_2 20mg.

TABLE A-4: FIRST STAGE REGRESSION

	ATC4_1 Prices	ATC4_1 Log(Within Share)	ATC4_2 Prices	ATC4_2 Log(Within Share)
Brand Status				
Branded	1.331***	-0.082	1.891***	0.074
	(0.236)	(0.199)	(0.111)	(0.106)
Parallel Import	3.865***	-1.849***	0.053	-1.990***
	(0.547)	(0.209)	(0.176)	(0.173)
Finland Matching × Finland Imputed Prices				
0 × Finland Prices	1.834***	0.631**	0.119	1.482***
	(0.326)	(0.240)	(0.123)	(0.130)
1 × Finland Prices	3.294***	2.269***	0.935***	1.988***
	(0.321)	(0.240)	(0.141)	(0.160)
Denmark Matching × Denmark Imputed Prices				
0 × Denmark Prices	0.155***	0.007	0.254***	0.082***
	(0.028)	(0.022)	(0.021)	(0.020)
1 × Denmark Prices	0.124***	0.156***	0.282***	0.195***
	(0.024)	(0.019)	(0.020)	(0.016)
Norway Matching × Norway Imputed Prices				
0 × Norway Prices	0.104***	-0.134***	-0.066**	-0.109***
	(0.035)	(0.027)	(0.020)	(0.031)
1 × Norway Prices	0.043	0.030	-0.132***	0.238***
	(0.046)	(0.036)	(0.029)	(0.041)
Jar	0.579***	0.262**		
	(0.065)	(0.108)		
Dose pharmacies only	-0.423***	1.365***	0.553***	1.164***
	(0.088)	(0.135)	(0.061)	(0.099)
F-test	50.96	65.35	57.83	76.74
Obs	7352	7352	10738	10738

Notes: Robust standard errors in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

TABLE A-5: REGRESSION RESULTS FOR LOG(COST)

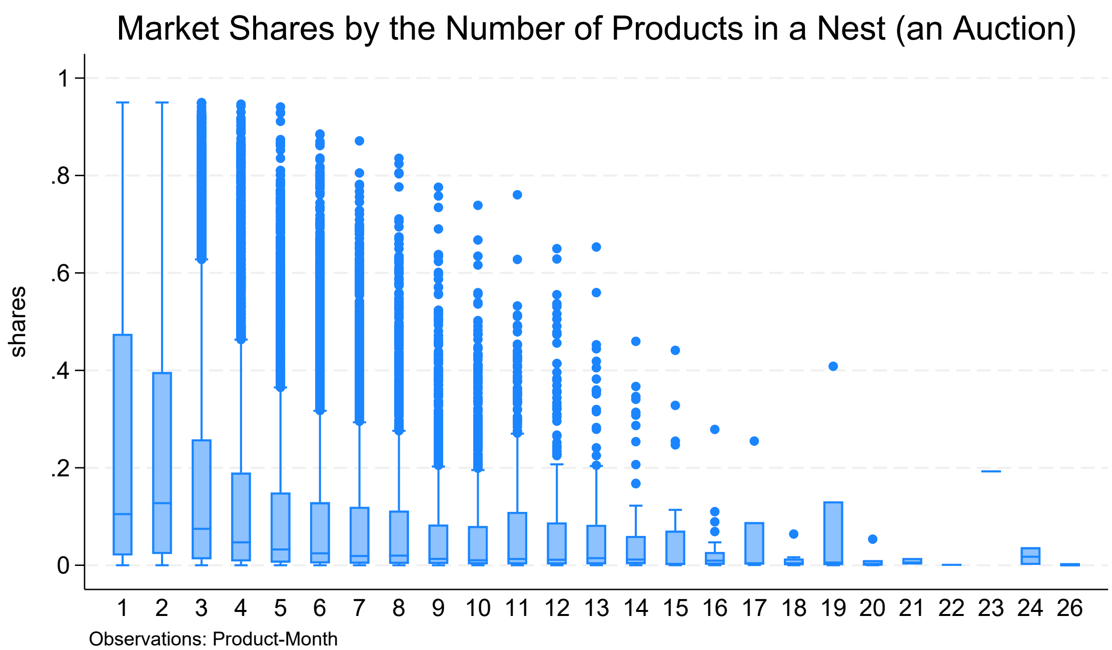
	ATC4_1 Log(Cost)	ATC4_2 Log(Cost)
30mg/40mg	-0.438***	0.454***
	(0.051)	(0.114)
45mg	0.545***	-
	(0.078)	
log(Package Size)	-0.226***	-0.582***
	(0.055)	(0.129)
Month FEs	Yes	Yes
Observations	717	456

Notes: The base strength in ATC4_1 is 15mg and in ATC4_2 20mg. Robust standard errors in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

A-2 Additional graphs

We present additional graphs in this Appendix. In Figure A-1 we present, with whisker-plots, the average market share of products, conditioning on the number of products in the same nest. The market shares are calculated in terms of number of pills. Thus, for example, the products that are monopoly products in their nest (x-axis value 1) have a mean market share of roughly 10%, calculated across all products (irrespective of their nest) in a given market. Similarly, the mean market share of products that reside in nests with 2 products is somewhat higher. The relatively high mean market share of monopoly nests in term of number of pills suggests that they are not a marginally important phenomenon.

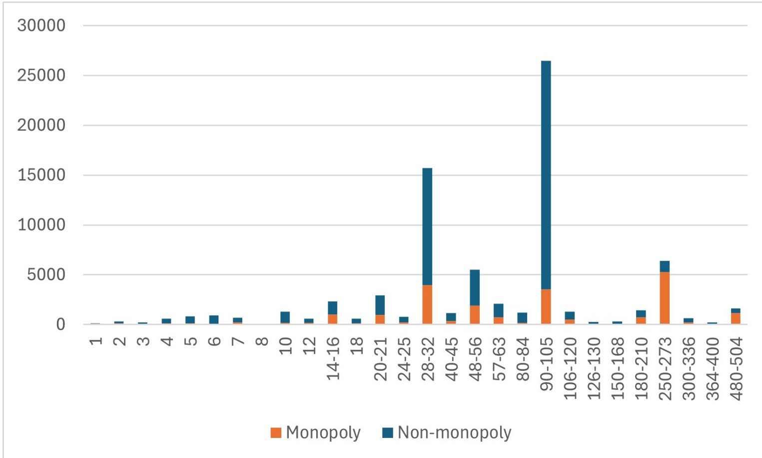
FIGURE A-1



Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

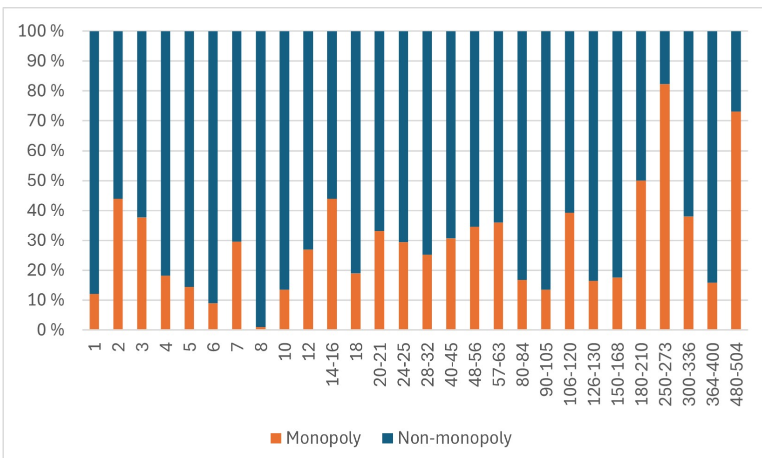
We display the distribution of monopoly nests by package size in Figures A-2 and A-3, with the first one showing the count of nests (substitution groups) of a given package size, with blue indicating non-monopoly nests (with 2 or more firms) and orange monopoly nests. One learns from Figure A-2 that the majority of package sizes are in the middle of the distribution, as is the majority of monopoly nests. Figure A-3 on the other hand reveals that with the exception of 8-pill packages, each package size exhibits at least 10% of monopoly nests and that the largest monopoly nest shares are in the large package sizes.

Figure A-2



Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

Figure A-3



Data sources: TLV, IQVIA MIDAS Quarterly Sales and IQVIA Pricing Insights.

A-3 Estimation of δ_{wgt}

Our estimate of the "losing" market share $\widehat{s_{jt}}$ is the average market share of all losing products in each market in each month. Then, using the estimated value of the nesting parameter σ from the demand estimation, we estimate equation A-1 by regressing the calculated LHS on time FEs, market FEs, and nest (group) FEs. We obtain $\hat{\delta}_{wgt}$ from the estimation as the sum of the time, market and nest fixed effects.

$$ln\left(D_{jt} - \widehat{s_{jt}}\right) - ln(s_{0t}) = \delta_{wgt} + (1-\sigma)ln\left(\frac{D_{jt} - \widehat{s_{jt}}}{s_{gt}}\right) + \epsilon_{gt}$$

$$ln\left(D_{jt} - \widehat{s_{jt}}\right) - ln(s_{0t}) - (1-\sigma)ln\left(\frac{D_{jt} - \widehat{s_{jt}}}{s_{gt}}\right) = \delta_{wgt} + \epsilon_{gt} \tag{A-1}$$

OA-1 Online Appendix Outline

We follow Garrido (2024) closely in proving equilibrium existence. First, in Online Appendix OA-2, we solve the profit maximization problem to get the first-order conditions.

In Online Appendix OA-3 (similar to Garrido (2024)'s Appendix B), we show that for a given $\boldsymbol{V}$ (the vector of the aggregative terms), there is a unique mapping from $\boldsymbol{V}$ to the vector $\delta^{*f}(\boldsymbol{V})$ (firms' pricing decisions in our model) that satisfies the first-order conditions (similar to Lemma B.1, Lemma B.2, Lemma B.3 in Garrido (2024)). Denote $\boldsymbol{\Gamma}(\boldsymbol{V})$ the aggregate fitting-in function with each nest's element $\Gamma_g(\boldsymbol{V}) = ln\left(exp(\frac{\delta_{wg}}{\sigma}) + \Sigma_{k\in N_g} exp(\frac{\delta_k^*(\boldsymbol{V})}{\sigma})\right)$. The aggregate fitting-in function $\boldsymbol{\Gamma}(\boldsymbol{V})$ maps a convex and compact set into itself (similar to Lemma B.5 in Garrido (2024)). Since $\boldsymbol{\Gamma}(\boldsymbol{V})$ is continuous, Brouwer's fixed-point theorem implies that $\boldsymbol{\Gamma}(\boldsymbol{V})$ has a fixed point . More details are provided in Online Appendix OA-5 (Similar to the proof of Theorem 3.2. in the Appendix (Theorem 2 in the paper) of Garrido (2024)).

In Online Appendix OA-4 (similar to Garrido (2024)'s Appendix A), we show that there is a unique mapping from the aggregate terms excluding firm f, $\boldsymbol{V}^{-f}$, to the vector $\delta^{*f}(\boldsymbol{V}^{-f})$ that satisfies the first-order conditions when the market share s_w is low enough (similar to Lemma A.3, Lemma A.4, Lemma A.5 in Garrido (2024)'s Appendix A). With this condition, we prove in Online Appendix OA-5 (similar to Lemma B.4 - Consistency in Garrido (2024)'s Appendix B) that the fitting-in function is consistent with the best response. The consistency of the best response function and the fitting-in function tells us that whether we start with the aggregate terms $\boldsymbol{V}$ or the aggregate terms excluding firm f, $\boldsymbol{V}^{-f}$, the FOCs always give us the same $\delta^{*f}(.)$ for firm f. Because the fitting-in function is consistent with the best response, each fixed point constitutes a Nash-Bertrand equilibrium.

OA-2 Profit Maximization Problem

The profit maximization problem of the firms is given by equation OA-2.

$$\max_{\delta^f} \Sigma_{j\in N^f}\left(\frac{\delta_j-\alpha+\omega}{-\beta}-c_j\right)\left[s_{w|g}*W_{j|g}*s_g+s_{j|g}*s_g\right]$$

$$\max_{\delta^f} \Sigma_{j\in N^f}\left(\frac{\delta_j-\alpha+\omega}{-\beta}-c_j\right)\left[\frac{exp(\frac{\delta_{wg}}{\sigma})}{exp(V_g)}*\frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g)-exp(\frac{\delta_{wg}}{\sigma})}*\frac{exp(\sigma V_g)}{1+\sum_g exp(\sigma V_g)}+\frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g)}*\frac{exp(\sigma V_g)}{1+\sum_g exp(\sigma V_g)}\right] \tag{OA-1}$$

where $V_g = ln\left(exp(\frac{\delta_{wg}}{\sigma})+\sum_{k\in N_g} exp(\frac{\delta_k}{\sigma})\right)$, ω is the Euler–Mascheroni constant. Before taking the first order condition we note a few simplifications that will be useful. First, notice that we can write the partial derivative of V_g with respect to δ_j as follows:

$$\frac{\partial V_g}{\partial \delta_j} = \frac{1}{\sigma}\frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g)} = \frac{1}{\sigma}s_{j|g}.$$

Second, we find the indirect effect of δ_j on $D_{j'}$ through V_g in the case $j' \in N_g^f$ (product j' in nest g).

$$\begin{aligned}\frac{\partial D_{j'}}{\partial V_g}\frac{\partial V_g}{\partial \delta_j} &= \left(-s_{w|g}W_{j'|g}s_g - s_{w|g}W_{j'|g}\frac{W_{j'|g}}{s_{j'|g}}s_g + s_{w|g}W_{j'|g}\sigma s_g - s_{w|g}W_{j'|g}\sigma s_g^2 - s_{j'|g}s_g + s_{j'|g}\sigma s_g - s_{j'|g}\sigma s_g^2\right)*\frac{1}{\sigma}s_{j|g} \\ &= \left(-D_{j'}+\sigma D_{j'}-\sigma D_{j'}s_g - s_{w|g}W_{j'|g}\frac{W_{j'|g}}{s_{j'|g}}s_g\right)*\frac{1}{\sigma}\frac{s_j}{s_g} \\ &= -\frac{1-\sigma}{\sigma}\frac{D_{j'}}{s_g}s_j - D_{j'}s_j - \frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{W_{j'|g}}{s_{j'|g}}s_j\end{aligned}$$

Third, we find the indirect effect of δ_j on $D_{j'}$ through V_g in the case $j' \in N^f_{g'}$ (product j' in a different nest g')

$$\frac{\partial D_{j'}}{\partial V_g}\frac{\partial V_g}{\partial \delta_j} = (-s_{w|g'}W_{j'|g'}s_{g'}\sigma s_g - s_{j'|g'}s_{g'}\sigma s_g) * \frac{1}{\sigma}s_{j|g} = -\sigma D_{j'}s_g\frac{1}{\sigma}s_{j|g} = -D_{j'}s_j$$

Armed with these, we can write the first-order condition for every $j \in N^f$ as follows:

$$\frac{\partial \Pi^f}{\partial \delta_j} = \left(\frac{1}{-\beta}\right)D_j + \left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j\right)\frac{1}{\sigma}D_j + \Sigma_{j'\in N^f_g}\left(\frac{\delta_{j'} - \alpha + \omega}{-\beta} - c_{j'}\right)\left(-\frac{1-\sigma}{\sigma}\frac{D_{j'}}{s_g}s_j - \frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{W_{j'|g}}{s_{j'|g}}s_j\right)$$
$$- \Sigma_{j'\in N^f}\left(\frac{\delta_{j'} - \alpha + \omega}{-\beta} - c_{j'}\right)D_{j'}s_j = 0$$

We then divide both sides by s_j.

$$\left(\frac{1}{-\beta}\right)\frac{D_j}{s_j} + \left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j\right)\frac{1}{\sigma}\frac{D_j}{s_j} - \Sigma_{j'\in N^f_g}\left(\frac{\delta_{j'} - \alpha + \omega}{-\beta} - c_{j'}\right)\left(\frac{1-\sigma}{\sigma}\frac{D_{j'}}{s_g} + \frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{W_{j'|g}}{s_{j'|g}}\right)$$
$$- \Sigma_{j'\in N^f}\left(\frac{\delta_{j'} - \alpha + \omega}{-\beta} - c_{j'}\right)D_{j'} = 0 \quad \text{(OA-2)}$$

To simplify the FOCs further, we show that all products j of the same firm in the same nest have the same expected markups $\left(\frac{\delta_j - \alpha+\omega}{-\beta} - c_j\right)$ (similar to Garrido (2024)'s Lemma 3.1. in Appendix A).

$$\frac{D_j}{s_j} = \frac{s_{w|g}W_{j|g}s_g + s_{j|g}s_g}{s_{j|g}s_g} = \frac{exp(\frac{\delta_{wg}}{\sigma})}{exp(V_g) - exp(\frac{\delta_{wg}}{\sigma})} + 1$$

All products j of the same firm in the same nest have the same V_g and the same δ_{wg} and therefore the same $\frac{D_j}{s_j}$. From Equation OA-2, because all products j of the same firm in the same nest have the same $\frac{D_j}{s_j}$, they have the same expected markups $\left(\frac{\delta_j-\alpha+\omega}{-\beta} - c_j\right)$.

Given the above, we can now rewrite the FOCs as:

$$\left(\frac{1}{-\beta}\right)\frac{D_j}{s_j} + \left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j\right)\frac{1}{\sigma}\frac{D_j}{s_j} - \left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j\right)\Sigma_{j'\in N^f_g}\left(\frac{1-\sigma}{\sigma}\frac{D_{j'}}{s_g} + \frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{W_{j'|g}}{s_{j'|g}}\right)$$
$$- \Sigma_{j'\in N^f}\left(\frac{\delta_{j'} - \alpha + \omega}{-\beta} - c_{j'}\right)D_{j'} = 0 \quad \text{(OA-3)}$$

OA-3 Fitting-In Function

Denote by $\boldsymbol{V}$ the aggregate terms including firm f with each nest's element

$$V_g = ln\left(exp(\frac{\delta_{wg}}{\sigma}) + \Sigma_{k\in N_g} exp(\frac{\delta_k}{\sigma})\right).$$

Similar to Lemma 3.2 in Appendix Section B of Garrido (2024), we prove in two steps that there exists a unique mapping from $\boldsymbol{V}$ to $\delta^*(\boldsymbol{V})$ that satisfies the profit maximization problem's FOCs. The steps are very similar to those in Appendix Section B of Garrido (2024). The first step is to show that there is a unique mapping from $\boldsymbol{V}$ and the total payoff Π^f to $\delta^*(\boldsymbol{V}, \Pi^f)$ that satisfies the FOCs (similar to Garrido (2024)'s Lemma B.1. and Lemma B.2. in Appendix Section B, we only have 1 level of nexts instead of 2 levels). The second step is to show that there is a unique mapping from $\boldsymbol{V}$ to the total payoff Π^f that satisfies the FOCs (similar to Lemma B.3. in Appendix Section B of Garrido (2024)).

OA-3.1 Mapping $\boldsymbol{V}$ and Π^f to $\delta_j^*(\boldsymbol{V}, \Pi^f)$

$$\frac{D_j}{s_j} = \frac{s_{w|g}W_{j|g}s_g + s_{j|g}s_g}{s_{j|g}s_g} = \frac{exp(\frac{\delta_{wg}}{\sigma})}{exp(V_g) - exp(\frac{\delta_{wg}}{\sigma})} + 1 = \frac{exp(V_g)}{exp(V_g) - exp(\frac{\delta_{wg}}{\sigma})} = \frac{W_{j|g}}{s_{j|g}}$$

Denoting $\Pi^f = \Sigma_{j'\in N^f}\left(\frac{\delta_{j'}-\alpha+\omega}{-\beta} - c_{j'}\right)D_{j'}$, we can rewrite the FOC OA-3 as:

$$\left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j\right) = \frac{\Pi^f + \frac{1}{\beta}\frac{D_j}{s_j}}{\frac{1}{\sigma}\frac{D_j}{s_j} - \Sigma_{j'\in N_g^f}\left(\frac{1-\sigma}{\sigma}\frac{D_{j'}}{s_g} + \frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{W_{j'|g}}{s_{j'|g}}\right)}$$

$$\left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j\right)\left[\frac{1}{\sigma}\frac{D_j}{s_j} - \Sigma_{j'\in N_g^f}\left(\frac{1-\sigma}{\sigma}(s_{w|g}W_{j'|g} + s_{j'|g}) + \frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{D_{j'}}{s_{j'}}\right)\right] = \Pi^f + \frac{1}{\beta}\frac{D_j}{s_j} \quad \text{(OA-4)}$$

For a given V_g and a given Π^f, there exists a unique δ_j^* that satisfies the above equation because the LHS is decreasing in δ_j (because $s_{j|g}$ and $W_{j|g}$ are increasing in δ_j) and the RHS is fixed. Also, with a given V_g, the higher Π^f is, the higher RHS is. Therefore, for a given V_g, δ_j^* is decreasing in Π^f.

OA-3.2 Mapping $\boldsymbol{V}$ to Π^f

Given $\boldsymbol{V}$, denote $L(\boldsymbol{V}, \Pi^f) = \Sigma_{j'\in N^f}\left(\frac{\delta_{j'}^*(\boldsymbol{V},\Pi^f)-\alpha+\omega}{-\beta} - c_{j'}\right)D_{j'}$ where $\boldsymbol{V}$ is a vector of all V_g.

$$\frac{\partial L(\boldsymbol{V}, \Pi^f)}{\partial \delta_j^*} = \frac{d\Sigma_{j'\in N^f}\left(\frac{\delta_{j'}^*(\boldsymbol{V},\Pi^f)-\alpha+\omega}{-\beta} - c_{j'}\right)(s_{wg}W_{j'|g}s_g + s_{j'|g}s_g)}{\partial \delta_j}$$

$$= \frac{1}{-\beta}(s_{wg}W_{j|g}s_g + s_{j|g}s_g) + \left(\frac{\delta_j^*(\boldsymbol{V}, \Pi^f) - \alpha + \omega}{-\beta} - c_j\right)\frac{1}{\sigma}(s_{w|g}W_{j|g}s_g + s_{j|g}s_g)$$

Also, the expected markup is larger than $\frac{\sigma}{\beta}$ (similar to Corollary A.1 in Garrido (2024)) because

$$\left(\frac{\delta_j^* - \alpha + \omega}{-\beta} - c_j\right) = \frac{\Pi^f + \frac{1}{\beta}\frac{D_j}{s_j}}{\frac{1}{\sigma}\frac{D_j}{s_j} - \Sigma_{j' \in N_g^f}\left(\frac{1-\sigma}{\sigma}(s_{w|g}W_{j'|g} + s_{j'|g}) + \frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{D_{j'}}{s_{j'}}\right)} > \frac{\frac{1}{\beta}\frac{D_j}{s_j}}{\frac{1}{\sigma}\frac{D_j}{s_j}} = \frac{\sigma}{\beta}$$

Because the expected markup is larger than $\frac{\sigma}{\beta}$, the derivative $\frac{dL(\boldsymbol{V})}{\delta_j^*}$ is positive. Therefore, $L(\boldsymbol{V}, \Pi^f)$ is increasing in δ_j^*.

We can show that for a given $\boldsymbol{V}$, there exists a unique fixed point Π^f that satisfies first-order conditions OA-4 and that $L(\boldsymbol{V}, \Pi^f) = \Pi^f$. First, for a given V_g, δ_j^* is decreasing in Π^f (previous part). Because $L(\boldsymbol{V}, \Pi^f)$ is increasing in δ_j^*, $L(\boldsymbol{V}, \Pi^f)$ is decreasing in Π^f. Second, when Π^f goes to 0, δ_j^* goes to finite negative and market shares D_j goes to finite positive because of OA-4. Therefore, when Π^f goes to 0, $L(\boldsymbol{V}, \Pi^f)$ goes to finite positive. Third, when Π^f goes to infinity, all δ_j^* go to minus infinity and all market shares D_j go to 0 because of OA-4. We use L'Hôpital's rule to show that $L(\boldsymbol{V}, \Pi^f)$ goes to 0 when Π^f goes to infinity (or when all δ_j^* go to minus infinity):

$$\lim_{\Pi^f \to \infty} \Sigma_{j \in N^f}\left(\frac{\delta_j^*(\boldsymbol{V}, \Pi^f) - \alpha + \omega}{-\beta} - c_j\right) D_j = \Sigma_{j \in N^f} \lim_{\delta_j^* \to -\infty}\left(\frac{\delta_j^*(\boldsymbol{V}, \Pi^f) - \alpha + \omega}{-\beta} - c_j\right) D_j$$

$$= \Sigma_{j \in N^f} \lim_{\delta_j^* \to -\infty} \frac{\left(\frac{\delta_j^*(\boldsymbol{V}, \Pi^f) - \alpha + \omega}{-\beta} - c_j\right)}{\frac{1}{D_j}} = \Sigma_{j \in N^f} \lim_{\delta_j^* \to -\infty} \frac{\frac{1}{-\beta}}{\frac{-D_j \frac{1}{\sigma}}{D_j^2}} = \Sigma_{j \in N^f} \lim_{\delta_j^* \to -\infty} \frac{\sigma}{\beta} D_j = 0$$

$L(\boldsymbol{V}, \Pi^f)$ is decreasing in Π^f. When Π^f goes to 0, $L(\boldsymbol{V}, \Pi^f)$ goes to finite positive, and when Π^f goes to infinity, $L(\boldsymbol{V}, \Pi^f)$ goes to 0. Therefore, for a given $\boldsymbol{V}$, there exists a unique fixed point Π^f that satisfies $L(\boldsymbol{V}, \Pi^f) = \Pi^f$. From the previous part, there is a unique mapping from $\boldsymbol{V}$ and the total payoff Π^f to $\delta_j^*(\boldsymbol{V}, \Pi^f)$ that solves the FOCs OA-4. Hence, there exists a unique mapping from $\boldsymbol{V}$ to $\delta^*(\boldsymbol{V})$ that satisfies the profit maximization problem's FOCs OA-4.

OA-4 Best Response Function

Denote by $\boldsymbol{V}^{-f}$ the aggregate terms excluding firm f with each nest's element

$$V_g^{-f} = ln\left(exp(\frac{\delta_{wg}}{\sigma}) + \Sigma_{k \in N_g, k \notin N_g^f} exp(\frac{\delta_k}{\sigma})\right)$$

.

Similar to Garrido (2024)'s Lemma A.6, we prove in two steps that there exists a unique mapping from $\boldsymbol{V}^{-f}$ to $\hat{\delta^*}(\boldsymbol{V}^{-f})$ that satisfies the profit maximization problem's FOCs. The steps are very similar to those in Appendix Section A of Garrido (2024). The first step is to show that there is a unique mapping from $\boldsymbol{V}^{-f}$ and the total payoff Π^f to $\hat{\delta^*}(\boldsymbol{V}^{-f}, \Pi^f)$ that satisfies the FOCs (similar to Lemma A.3 and Lemma A.4 in Garrido (2024), though we only have 1 level of nests instead of 2 levels). We can show that there is a unique mapping when the set up is similar to Garrido (2024) (the winning market share is $s_w = 0$), so by continuity, there should also be a unique mapping when the winning market share s_w is low enough. The second step is to show that there is a unique mapping from $\boldsymbol{V}^{-f}$ to the total payoff Π^f that satisfies the FOCs (similar to Lemma A.5 in Garrido (2024)).

OA-4.1 Mapping $\boldsymbol{V}^{-f}$ and Π^f to $\hat{\delta^*}(\boldsymbol{V}^{-f}, \Pi^f)$

First, we calculate the derivative of $\frac{D_j}{s_j}$ with respect to δ_j.

$$\frac{D_j}{s_j} = \frac{s_{w|g} W_{j|g} s_g + s_{j|g} s_g}{s_{j|g} s_g} = \frac{exp(\frac{\delta_{wg}}{\sigma})}{exp(V_g) - exp(\frac{\delta_{wg}}{\sigma})} + 1 = \frac{exp(V_g)}{exp(V_g) - exp(\frac{\delta_{wg}}{\sigma})} = \frac{W_{j|g}}{s_{j|g}}$$
$$= \frac{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma})}{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma}) - exp(\frac{\delta_{wg}}{\sigma})}$$

$$\frac{\partial \frac{D_j}{s_j}}{\partial \delta_j} = \frac{1}{\sigma} \frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma}) - exp(\frac{\delta_{wg}}{\sigma})} - \frac{D_j}{s_j} \frac{1}{\sigma} \frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma}) - exp(\frac{\delta_{wg}}{\sigma})}$$
$$= \frac{1}{\sigma} W_{j|g}\left(1 - \frac{D_j}{s_j}\right) = -\frac{1}{\sigma} W_{j|g} \frac{exp(\frac{\delta_{wg}}{\sigma})}{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma}) - exp(\frac{\delta_{wg}}{\sigma})} = \left(-\frac{1}{\sigma}\right) W_{j|g} s_{w|g} \frac{D_j}{s_j}$$

Second, we calculate the derivatives of $s_{w|g}, W_{j|g}, s_{j|g}$ with respect to δ_j.

$$s_{w|g} = \frac{exp(\frac{\delta_{wg}}{\sigma})}{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma})}, \frac{\partial s_{w|g}}{\partial \delta_j} = \left(-\frac{1}{\sigma}\right) s_{w|g} s_{j|g}$$

$$W_{j|g} = \frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma}) - exp(\frac{\delta_{wg}}{\sigma})}, \frac{\partial W_{j|g}}{\partial \delta_j} = \frac{1}{\sigma} W_{j|g}(1 - W_{j|g})$$

$$s_{j|g} = \frac{exp(\frac{\delta_j}{\sigma})}{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma})}, \frac{\partial s_{j|g}}{\partial \delta_j} = \frac{1}{\sigma} s_{j|g}(1 - s_{j|g})$$

Third, we calculate the derivative of $W_{j'|g}, s_{j'|g}$ with respect to δ_j (Product $j' \in N_g^f, j' \neq j$).

$$W_{j'|g} = \frac{exp(\frac{\delta_{j'}}{\sigma})}{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma}) - exp(\frac{\delta_{wg}}{\sigma})}, \frac{\partial W_{j'|g}}{\partial \delta_j} = \left(-\frac{1}{\sigma}\right) W_{j'|g} W_{j|g}$$

$$s_{j'|g} = \frac{exp(\frac{\delta_{j'}}{\sigma})}{exp(V_g^{-f}) + \Sigma_{j' \in N_g^f} exp(\frac{\delta_{j'}}{\sigma})}, \frac{\partial s_{j'|g}}{\partial \delta_j} = \left(-\frac{1}{\sigma}\right) s_{j'|g} s_{j|g}$$

Denoting $\Pi^f = \Sigma_{j' \in N^f} \left(\frac{\delta_{j'} - \alpha + \omega}{-\beta} - c_{j'}\right) D_{j'}$, we can rewrite the FOCs OA-3 as:

$$\left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j\right) = \frac{\Pi^f + \frac{1}{\beta}\frac{D_j}{s_j}}{\frac{1}{\sigma}\frac{D_j}{s_j} - \Sigma_{j' \in N_g^f}\left(\frac{1-\sigma}{\sigma}\frac{D_{j'}}{s_g} + \frac{1}{\sigma} s_{w|g} W_{j'|g} \frac{W_{j'|g}}{s_{j'|g}}\right)}$$

By rearranging the terms and because $\frac{D_j}{s_j} = \frac{W_{j|g}}{s_{j|g}}$, we have:

$$\left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j\right)\left[\frac{1}{\sigma}\frac{D_j}{s_j} - \Sigma_{j' \in N_g^f}\left(\frac{1-\sigma}{\sigma}(s_{w|g} W_{j'|g} + s_{j'|g}) + \frac{1}{\sigma} s_{w|g} W_{j'|g} \frac{D_{j'}}{s_{j'}}\right)\right] - \frac{1}{\beta}\frac{D_j}{s_j} = \Pi^f \quad \text{(OA-5)}$$

Now we calculate the derivative of the LHS with respect to δ_j:

$$\frac{1}{-\beta}\left[\frac{1}{\sigma}\frac{D_j}{s_j} - \Sigma_{j' \in N_g^f}\left(\frac{1-\sigma}{\sigma}(s_{w|g} W_{j'|g} + s_{j'|g}) + \frac{1}{\sigma} s_{w|g} W_{j'|g} \frac{D_{j'}}{s_{j'}}\right)\right] + \left(\frac{\delta_j - \alpha + \omega}{-\beta} - c_j\right) *$$
$$\Bigg\{\frac{1}{\sigma}\frac{\partial \frac{D_j}{s_j}}{\partial \delta_j} - \frac{1-\sigma}{\sigma}\left(s_{w|g}\frac{\partial W_{j|g}}{\partial \delta_j} + W_{j|g}\frac{\partial s_{w|g}}{\partial \delta_j} + \frac{\partial s_{j|g}}{\partial \delta_j}\right) - \frac{1}{\sigma}\frac{\partial s_{w|g}}{\partial \delta_j} W_{j|g}\frac{D_j}{s_j} - \frac{1}{\sigma}\frac{\partial W_{j|g}}{\partial \delta_j} s_{w|g}\frac{D_j}{s_j} - \frac{1}{\sigma} s_{w|g} W_{j|g}\frac{\partial \frac{D_j}{s_j}}{\partial \delta_j}$$
$$+\Sigma_{j' \in N_g^f, j' \neq j}\left[-\frac{1-\sigma}{\sigma}\left(s_{w|g}\frac{\partial W_{j'|g}}{\partial \delta_j} + W_{j'|g}\frac{\partial s_{w|g}}{\partial \delta_j} + \frac{\partial s_{j'|g}}{\partial \delta_j}\right) - \frac{1}{\sigma}\frac{\partial s_{w|g}}{\partial \delta_j} W_{j'|g}\frac{D_{j'}}{s_{j'}} - \frac{1}{\sigma}\frac{\partial W_{j'|g}}{\partial \delta_j} s_{w|g}\frac{D_{j'}}{s_{j'}} - \frac{1}{\sigma} s_{w|g} W_{j'|g}\frac{\partial \frac{D_{j'}}{s_{j'}}}{\partial \delta_j}\right]\Bigg\}$$
$$+ \frac{1}{-\beta}\frac{\partial \frac{D_j}{s_j}}{\partial \delta_j}$$

$$\frac{1}{-\beta}\left[\frac{1}{\sigma}\frac{D_j}{s_j}-\Sigma_{j'\in N_g^f}\left(\frac{1-\sigma}{\sigma}(s_{w|g}W_{j'|g}+s_{j'|g})+\frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{D_{j'}}{s_{j'}}\right)\right]+\left(\frac{\delta_j-\alpha+\omega}{-\beta}-c_j\right)*$$
$$\left\{\frac{1}{\sigma}\left(-\frac{1}{\sigma}\right)W_{j|g}s_{w|g}\frac{D_j}{s_j}-\frac{1-\sigma}{\sigma}\left(s_{w|g}\frac{1}{\sigma}W_{j|g}(1-W_{j|g})+W_{j|g}\left(-\frac{1}{\sigma}\right)s_{w|g}s_{j|g}+\frac{1}{\sigma}s_{j|g}(1-s_{j|g})\right)\right.$$
$$-\frac{1}{\sigma}\left(-\frac{1}{\sigma}\right)s_{w|g}s_{j|g}W_{j|g}\frac{D_j}{s_j}-\frac{1}{\sigma}\frac{1}{\sigma}W_{j|g}(1-W_{j|g})s_{w|g}\frac{D_j}{s_j}-\frac{1}{\sigma}s_{w|g}W_{j|g}\left(-\frac{1}{\sigma}\right)W_{j|g}s_{w|g}\frac{D_j}{s_j}$$
$$+\Sigma_{j'\in N_g^f,j'\neq j}\left[-\frac{1-\sigma}{\sigma}\left(s_{w|g}\left(-\frac{1}{\sigma}\right)W_{j'|g}W_{j|g}+W_{j'|g}\left(-\frac{1}{\sigma}\right)s_{w|g}s_{j|g}+\left(-\frac{1}{\sigma}\right)s_{j'|g}s_{j|g}\right)\right]$$
$$\left.+\Sigma_{j'\in N_g^f,j'\neq j}\left[-\frac{1}{\sigma}\left(-\frac{1}{\sigma}\right)s_{w|g}s_{j|g}W_{j'|g}\frac{D_{j'}}{s_{j'}}-\frac{1}{\sigma}\left(-\frac{1}{\sigma}\right)W_{j'|g}W_{j|g}s_{w|g}\frac{D_{j'}}{s_{j'}}-\frac{1}{\sigma}s_{w|g}W_{j'|g}\left(-\frac{1}{\sigma}\right)W_{j|g}s_{w|g}\frac{D_j}{s_j}\right]\right\}$$
$$+\frac{1}{-\beta}\frac{\partial\frac{D_j}{s_j}}{\partial\delta_j}$$

$$=\frac{1}{-\beta}\left[\frac{1}{\sigma}\frac{D_j}{s_j}-\Sigma_{j'\in N_g^f}\left(\frac{1-\sigma}{\sigma}(s_{w|g}W_{j'|g}+s_{j'|g})+\frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{D_{j'}}{s_{j'}}\right)\right]+\left(\frac{\delta_j-\alpha+\omega}{-\beta}-c_j\right)*$$
$$\left\{\frac{1}{\sigma}\left(-\frac{1}{\sigma}\right)W_{j|g}s_{w|g}\frac{D_j}{s_j}(1-s_{w|g}W_{j|g}-s_{j|g})-\frac{1-\sigma}{\sigma}\frac{1}{\sigma}s_{j|g}(1-s_{j|g}-W_{j|g}s_{w|g})\right.$$
$$-\frac{1-\sigma}{\sigma}s_{w|g}\frac{1}{\sigma}W_{j|g}(1-W_{j|g})-\frac{1}{\sigma}\frac{1}{\sigma}W_{j|g}(1-W_{j|g})s_{w|g}\frac{D_j}{s_j}$$
$$+\Sigma_{j'\in N_g^f,j'\neq j}\left[\frac{1-\sigma}{\sigma}\frac{1}{\sigma}s_{j'|g}s_{j|g}+\frac{1-\sigma}{\sigma}\frac{1}{\sigma}W_{j'|g}s_{w|g}s_{j|g}\right]$$
$$+\Sigma_{j'\in N_g^f,j'\neq j}\left[-\frac{1-\sigma}{\sigma}s_{w|g}\left(-\frac{1}{\sigma}\right)W_{j'|g}W_{j|g}s_{j'|g}s_{j|g}\right]$$
$$\left.+\Sigma_{j'\in N_g^f,j'\neq j}\left[-\frac{1}{\sigma}\left(-\frac{1}{\sigma}\right)s_{w|g}s_{j|g}W_{j'|g}\frac{D_{j'}}{s_{j'}}-\frac{1}{\sigma}\left(-\frac{1}{\sigma}\right)W_{j'|g}W_{j|g}s_{w|g}\frac{D_{j'}}{s_{j'}}-\frac{1}{\sigma}s_{w|g}W_{j'|g}\left(-\frac{1}{\sigma}\right)W_{j|g}s_{w|g}\frac{D_j}{s_j}\right]\right\}$$
$$+\frac{1}{-\beta}(-\frac{1}{\sigma})W_{j|g}s_{w|g}\frac{D_j}{s_j}$$

With $s_{w_g}=0$, we have

$$=\frac{1}{-\beta}\left[\frac{1}{\sigma}\frac{D_j}{s_j}-\Sigma_{j'\in N_g^f}\frac{1-\sigma}{\sigma}s_{j'|g}\right]+\left(\frac{\delta_j-\alpha+\omega}{-\beta}-c_j\right)*\left[-\frac{1-\sigma}{\sigma}\frac{1}{\sigma}s_{j|g}(1-s_{j|g})+\Sigma_{j'\in N_g^f,j'\neq j}\left(\frac{1-\sigma}{\sigma}\frac{1}{\sigma}s_{j'|g}s_{j|g}\right)\right]$$

$$=\frac{1}{-\beta}\left[\frac{1}{\sigma}\left(1-\Sigma_{j'\in N_g^f}s_{j'|g}\right)+\Sigma_{j'\in N_g^f}s_{j|g}\right]+\left(\frac{\delta_j-\alpha+\omega}{-\beta}-c_j\right)*\left[-\frac{1-\sigma}{\sigma}\frac{1}{\sigma}s_{j|g}(1-\Sigma_{j'\in N_g^f}s_{j'|g})\right]$$

The LHS is decreasing in δ_j if $s_{w_g}=0$ or if s_{w_g} is low enough.

With that condition, for a given V_g^{-f} and a given Π^f, there exists a unique $\hat{\delta^*}$ that satisfies the above equation because the LHS is decreasing in δ_j and the RHS is fixed. Also, with a given V_g^{-f}, the higher is Π^f, the higher is the RHS. Therefore, for a given V_g^{-f}, $\hat{\delta^*}$ is decreasing in Π^f.

OA-4.2 Mapping $\boldsymbol{V}^{-f}$ to Π^f

Given $\boldsymbol{V}^{-f}$, denote $L(\boldsymbol{V}^{-f},\Pi^f) = \Sigma_{j'\in N^f}\left(\frac{\hat{\delta^*}_{j'}(\boldsymbol{V}^{-f},\Pi^f)-\alpha+\omega}{-\beta} - c_{j'}\right)D_{j'}$ where $\boldsymbol{V}^{-f}$ is the vector of all V_g^{-f}.

$$
\begin{aligned}
\frac{\partial L(\boldsymbol{V}^{-f},\Pi^f)}{\partial\hat{\delta^*}_j} &= \frac{d\Sigma_{j'\in N^f}\left(\frac{\hat{\delta^*}_{j'}(\boldsymbol{V}^{-f},\Pi^f)-\alpha+\omega}{-\beta} - c_{j'}\right)(s_{wg}W_{j'|g}s_g + s_{j'|g}s_g)}{\partial\hat{\delta^*}_j}\\
&= \frac{1}{-\beta}D_j + \left(\frac{\hat{\delta^*}_j(\boldsymbol{V}^{-f},\Pi^f)-\alpha+\omega}{-\beta} - c_j\right)\left(\frac{1}{\sigma}D_j - \Sigma_{j'\in N_g^f}\left(\frac{1-\sigma}{\sigma}\frac{D_{j'}}{s_g}s_j - \frac{1}{\sigma}s_{w|g}W_{j'|g}\frac{W_{j'|g}}{s_{j'|g}}s_j\right)\right)\\
&\quad - \Sigma_{j'\in N^f}\left(\frac{\hat{\delta^*}_{j'}(\boldsymbol{V}^{-f},\Pi^f)-\alpha+\omega}{-\beta} - c_{j'}\right)D_{j'}s_j = \frac{1}{-\beta}D_j + s_j(\Pi^f + \frac{1}{\beta}\frac{D_j}{s_j}) - s_jL(\boldsymbol{V}^{-f},\Pi^f)\\
&= s_j[\Pi^f - L(\boldsymbol{V}^{-f},\Pi^f)]
\end{aligned}
$$

$$
\frac{\partial L(\boldsymbol{V}^{-f},\Pi^f)}{\partial\Pi^f} = \frac{\partial L(\boldsymbol{V}^{-f},\Pi^f)}{\partial\hat{\delta^*}_j} * \frac{\partial\hat{\delta^*}_j}{\partial\Pi^f} = s_j[\Pi^f - L(\boldsymbol{V}^{-f},\Pi^f)]\frac{\partial\hat{\delta^*}_j}{\partial\Pi^f}
$$

We can show that for a given $\boldsymbol{V}^{-f}$, there exists a unique fixed point Π^f that satisfies first-order conditions OA-5 and that $L(\boldsymbol{V}^{-f},\Pi^f) = \Pi^f$. First, if $L = \Pi^f$, then $\frac{\partial L}{\partial\Pi^f} = 0$, so L can have at most one fixed point. Second, when Π^f goes to 0, $\hat{\delta^*}_j$ goes to finite negative and market shares D_j go to finite positive because of OA-5. Therefore, when Π^f goes to 0, $L(\boldsymbol{V}^{-f},\Pi^f)$ goes to finite positive. Third, when Π^f goes to infinity, all $\hat{\delta^*}_j$ go to minus infinity and all market shares D_j go to 0 because of OA-5. We use L'Hôpital's rule to show that $L(\boldsymbol{V}^{-f},\Pi^f)$ goes to 0 when Π^f goes to infinity (or when all $\hat{\delta^*}_j$ go to minus infinity):

$$
\begin{aligned}
\lim_{\Pi^f\to\infty}\Sigma_{j\in N^f}\left(\frac{\hat{\delta^*}_j(\boldsymbol{V}^{-f},\Pi^f)-\alpha+\omega}{-\beta} - c_j\right)D_j &= \Sigma_{j\in N^f}\lim_{\hat{\delta^*}_j\to-\infty}\left(\frac{\hat{\delta^*}_j(\boldsymbol{V}^{-f},\Pi^f)-\alpha+\omega}{-\beta} - c_j\right)D_j\\
&= \Sigma_{j\in N^f}\lim_{\hat{\delta^*}_j\to-\infty}\frac{\left(\frac{\hat{\delta^*}_j(\boldsymbol{V}^{-f},\Pi^f)-\alpha+\omega}{-\beta} - c_j\right)}{\frac{1}{D_j}} = \Sigma_{j\in N^f}\lim_{\hat{\delta^*}_j\to-\infty}\frac{\frac{1}{-\beta}}{\frac{-D_j\frac{1}{\sigma}}{D_j^2}} = \Sigma_{j\in N^f}\lim_{\hat{\delta^*}_j\to-\infty}\frac{\sigma}{\beta}D_j = 0
\end{aligned}
$$

L can have at most one fixed point. When Π^f goes to 0, $L(\boldsymbol{V}^{-f},\Pi^f)$ goes to finite positive, and when Π^f goes to infinity, $L(\boldsymbol{V}^{-f},\Pi^f)$ goes to 0. Therefore, for a given $\boldsymbol{V}^{-f}$, there exists a unique fixed point Π^f that satisfies $L(\boldsymbol{V}^{-f},\Pi^f) = \Pi^f$. From the previous part, there is a unique mapping from $\boldsymbol{V}^{-f}$ and the total payoff Π^f to $\hat{\delta^*}_j(\boldsymbol{V}^{-f},\Pi^f)$ that solves the FOCs OA-4. Hence, there exists a unique mapping from $\boldsymbol{V}^{-f}$ to $\hat{\delta^*}(\boldsymbol{V}^{-f})$ that satisfies the profit maximization problem's FOCs OA-4.

OA-5 Equilibrium Existence

Denote by $\mathbf{\Gamma}(\mathbf{V})$ the aggregate fitting-in function with each nest's element

$$\Gamma_g(\mathbf{V}) = ln\left(exp(\frac{\delta_{wg}}{\sigma}) + \Sigma_{k\in N_g} exp(\frac{\delta^*_k(\mathbf{V})}{\sigma})\right)$$

.

$\mathbf{V}$ is the vector of the aggregate terms with each nest's element $V_g = ln\left(exp(\frac{\delta_{wg}}{\sigma}) + \Sigma_{k\in N_g} exp(\frac{\delta_k}{\sigma})\right)$.

Similar to Theorem 3.2 in Garrido (2024)'s Appendix B, we have the following theorem:

Theorem 1 *Vector $\mathbf{V}$ is a fixed point for $\mathbf{\Gamma}(\mathbf{V})$ if and only if the vector of deltas $(\delta^{*f}(\mathbf{V}))_{f\in F}$ is a Nash-Bertrand equilibrium. There exists at least one fixed point (one Nash-Bertrand equilibrium) when the winning market share s_w is low enough.*

Proof.

The definition of $\mathbf{V}$ and $\mathbf{\Gamma}(\mathbf{V})$ guarantees the necessary statement. To prove the sufficiency, we first need to show the consistency of the best response function and the fitting-in function (in Subsection OA-5.1) when the winning market share s_w is low enough.

The consistency of the best response function and the fitting-in function tells us that whether we start with the aggregate terms $\mathbf{V}$ or the aggregate terms excluding firm f $\mathbf{V}^{-f}$, the FOCs always give us the same deltas for firm f. Let $\mathbf{V}$ be a fixed point of $\mathbf{\Gamma}$, we have $\mathbf{V}^{-f}$ as the aggregate terms excluding firm f $(\delta^{*-f}(\mathbf{V}))_{f\in F}$. Therefore, we have $\delta^{*f}(\mathbf{V}) = \hat{\delta}^{*f}(\mathbf{V}^{-f})$. It means that for all f, $\delta^{*f}(\mathbf{V})$ maximizes firm f's profit given $\delta^{*-f}(\mathbf{V})$, $(\delta^{*f}(\mathbf{V}))_{f\in F}$ is a Nash-Bertrand equilibrium.

Each fixed point of $\mathbf{V}$ constitutes a Nash-Bertrand equilibrium. We show that there exists at least one fixed point by using the Brouwer's fixed point theorem (in Subsection OA-5.2). ■

OA-5.1 Consistency of the best response function and the fitting-in function (Similar to Lemma B.4 in Garrido (2024)'s Appendix B)

Given the aggregate of other firms' choices $\mathbf{V}^{-f}$, there exists a unique firm's best response $\hat{\delta}^{*f}(\mathbf{V}^{-f})$ that solves the FOCs when the winning market share s_w is low enough. Fixing the vector of aggregate terms $\mathbf{V} = \mathbf{V}(\hat{\delta}^{*f}(\mathbf{V}^{-f}), \mathbf{V}^{-f})$, because our fitting-in function $\delta^{*f}(\mathbf{V}^*)$ is the unique solution of the FOCs, we have $\delta^{*f}(\mathbf{V}) = \hat{\delta}^{*f}(\mathbf{V}^{-f})$. Hence, we have the consistency of the fitting-in function and the best response when the winning market share s_w is low enough.

OA-5.2 Bounds of V and the Brouwer's fixed-point theorem (Similar to Lemma B.5 in Garrido (2024)'s Appendix B)

To use the Brouwer's fixed point theorem, we first need to prove that $\mathbf{V}$ belongs to a compact and convex set by showing that $\mathbf{V}$ has an upper bound and a lower bound. δ_j has an upper bound $\bar{\delta}_j$ because the expected markup is non-negative. Let $\bar{\mathbf{H}}$ be the vector of inclusive values that results from all firms setting $\delta_j = \bar{\delta}_j$. We have $\mathbf{V} \leq \mathbf{V}(\bar{\delta}) = \bar{\mathbf{H}}$.

Denote $\mathbf{V}^{-f}$ the aggregate term of all rival firms. It is bounded above by $\bar{\mathbf{H}}$ and bounded below by 0. Because the best response of firm f $\delta^*_j(\mathbf{V}^{-f})$ is a continuous function and $\mathbf{V}^{-f}$ belongs to a compact set, the best response achieves a finite minimum $\underline{\delta_j}$. Hence, the best response satisfies $\delta^*_j(\mathbf{V}^{-f}) \geq \underline{\delta_j}$. Let $\bar{\mathbf{H}}$ be the vector of inclusive values that results from all firms setting $\delta_j = \underline{\delta_j}$. We have $\mathbf{V} \geq \mathbf{V}(\underline{\delta}) = \underline{\mathbf{H}}$

All equilibrium $\mathbf{V}$ are contained in the compact and convex set $[\underline{\mathbf{H}}, \bar{\mathbf{H}}]$. Fix $V \in [\bar{\mathbf{H}}, \underline{\mathbf{H}}]$, we have $\underline{\delta_j} \leq \delta^*_j(\mathbf{V}) \leq \bar{\delta}_j$. Therefore, $\underline{\mathbf{H}} \leq \mathbf{\Gamma}(\mathbf{V}) \leq \bar{\mathbf{H}}$

$\mathbf{\Gamma}(\mathbf{V})$ maps the convex and compact set $[\underline{\mathbf{H}}, \bar{\mathbf{H}}]$ to itself. Also because the fitting-in function is a continuous function, then so is $\mathbf{\Gamma}(\mathbf{V})$. So, by the Brouwer's fixed-point theorem, $\mathbf{\Gamma}(\mathbf{V})$ has a fixed point.