Price Dynamics of Swedish Pharmaceuticals*

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Abstract

This paper investigates price patterns of off-patent pharmaceuticals in Sweden. I show that price dynamics are dependent on the number of competitors in the market. The price patterns follow predictions from a model of dynamic price competition in which the demand for pharmaceuticals incorporates the known biases of consumers: habit persistence and brand preferences. Using the regulated market of Swedish pharmaceuticals, I show that price dynamics may help in identifying possible tacit collusion by manufacturers in markets where consumers experience behavioral frictions.

JEL: D43, I11, L13, L40
Keywords: pharmaceutical pricing; dynamic oligopoly; state dependence; price cycles

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1 Introduction

Off-patent pharmaceuticals are subject to generic competition. Standard economic theory predicts that competitive forces decrease prices in the short term and provide steady low prices in the long term in the absence of cost and demand shocks. However, recent developments around the world have led to questions regarding this prediction as it pertains to the pricing of off-patent pharmaceuticals. Recently, the prices of many generic pharmaceuticals in the US have risen sharply.[1] Markets with more regulation than the US have also exhibited patterns in the pricing of off-patent drugs that are at odds with standard predictions of a market characterized by strong competition.

In the present article, I use rich data from Sweden, where the pharmaceutical market is highly regulated, to examine the pricing of off-patent pharmaceuticals. In particular, I aim to understand the reasons for heterogeneous patterns in the prices of some pharmaceuticals. On the demand side, patients are reimbursed for the cheapest available generic on the market. On the supply side, pharmaceutical prices are set by manufacturers once per month. Thus, the Swedish background offers a clean and structured environment to understand the reasons behind pricing patterns.

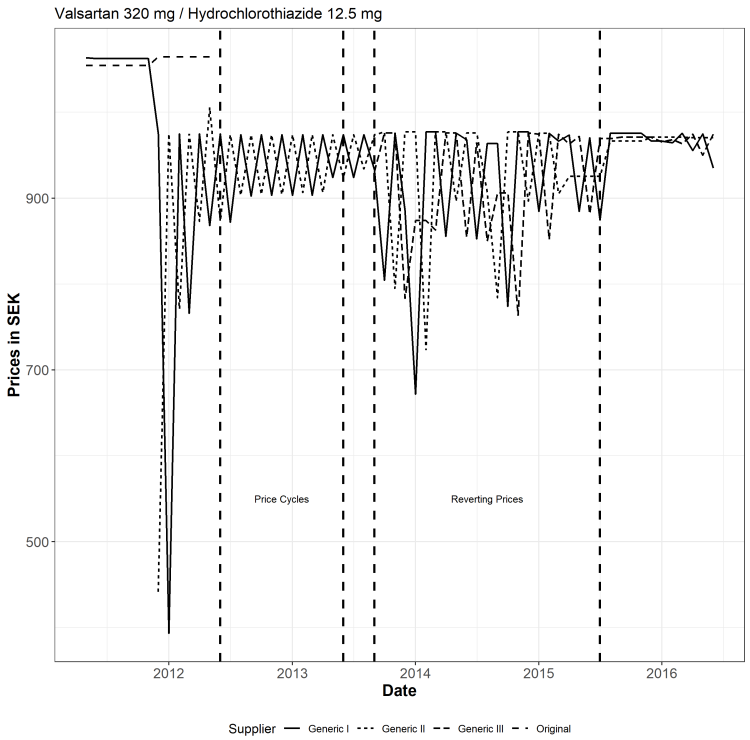
In the first part of the paper, I highlight the characteristics of price dynamics and price cycles in the Swedish pharmaceutical market. In markets where only one firm's product is available, the intertemporal variability of prices is nearly nonexistent. In segments with more than one firm, prices frequently change over time. In segments with more than two competitors, many of the cheapest products increase drastically in price in future months, requiring patients to switch products monthly in order to purchase the least expensive product. Seldom do price cycles arise in segments with two or three competitors. In these price cycles, two competing firms alternate their monthly prices such that the market has a higher-priced and a lower-priced product each month. Those price floors are fixed over time.

To exemplify this, Figure 1 shows the example of valsartan/hydrochlorothiazide 320 mg/12.5 mg, used for the treatment of high blood pressure and congestive heart failure. The segment shows two common characteristics: (1) symmetric price cycles (SPCs) with two generics between mid-2012 and mid-2013 and (2) prices reverting after sporadic price decreases to a near-constant level from mid-2013 to mid-2015, when three competitors are present. In that period, the cheapest product in a month increases in price in the subsequent month such that a competitor offers a lower price. The apparent characteristics of alternating prices are different from well-studied Edgeworth price cycles, where competitors marginally undercut each other before one competitor considerably increases the price (Maskin and Tirole, 2001). In the Swedish pharmaceutical market, we observe price cycles in approximately 8% of product segments but do not observe any Edgeworth price cycles.

After describing the price cycles, I present an oligopoly model that incorporates the Swedish market's regulatory framework. Firms repeatedly compete on prices while the regulator incentivizes consumers to purchase only the cheapest available product. Further, consumers experience behavioral frictions: Perceived quality differences of medically equivalent products, as well as persistent purchasing habits, are well documented in the literature (Bronnenberg et al., 2015; Feng, 2017). The model predicts that a monopolist does not engage in dynamic pricing. For two firms, the non-cooperative equilibrium involves both firms mixing over prices. In the case of more than two firms, the firm with a less elastic demand due to previous high market share increases its prices as much as possible while the remaining firms follow mixed pricing strategies. Compared to the non-cooperative equilibrium, the optimal collusive agreements involve rotation between prices.

[1] Regulation of substitution to generics is dependent on the federal state, and prices are based on a free-market mechanism. In 2014 and 2015, the prices of several generic products increased in the US, although there were many producers of a single homogeneous product (Los Angeles Times, 2016), attracting the attention of antitrust regulators. The puzzle of many producers and increasing prices has been featured on Reinhardt's health care blog (Reinhardt, 2016). The suspected price increases by all competitors led to an investigation by antitrust authorities in November 2016 (Bloomberg, 2016).

Figure 1: Examples of Price Cycles and Reverting Prices



Note: 10 SEK = 1.1 USD.

I then proceed to evaluate the predictions and assumptions of the model. Under generic competition in Sweden, the market for pharmaceuticals is organized in different segments (groups of medically equivalent pharmaceutical products). Variation across and within segments allows testing of predictions dependent on the number of competitors, demand characteristics, and identity (generic vs. originals) of products. Starting with the demand side, I demonstrate that the development of market shares can be explained by patients' habit persistence and brand preferences. Second, by evaluating the variation of habit persistence across therapeutic subgroups, I show that the model is well suited to predict competitive and (tacit) collusive pricing equilibria. In detail, higher habit persistence is related to alternating prices, while the same price-setting equilibria are not associated with habit persistence.

Observations in the data also match the prediction on the supply side of the model: Price cycles arise in segments with two and three competitors and are less likely in segments with higher competition. In the case of triopolies, price cycles are likely when an original product competes with two generics. While the original product relies on patients with brand preferences and charges a very high price, the two generics form price cycles.

The article offers two insights for policy-makers: (1) Governmental regulations on the supply side in connection with patients' behavioral frictions such as perceived quality differences of medically equivalent products and persistent purchasing habits create substantial intertemporal price variation. (2) Consumers' dynamic demand offers the possibility to detect tacit collusion. In markets where patients' brand preferences and habit persistence are low, dynamic prices in competitive equilibria are indistinguishable from tacit collusion without knowing marginal costs. With brand preferences and habit persistence, prices in competitive equilibria are variable and follow a stochastic function. Profit-maximizing tacit collusion schemes have different dynamics and are identifiable. Therefore, the observed variation in habit persistence can facilitate the detection of tacit collusion schemes, as dynamic price relations in scenarios with habit persistence are different from those in competitive equilibria.

This paper adds to multiple streams of literature in industrial organization. On the theory side, my model describes a dynamic oligopoly in which firms compete on price and consumers exhibit habit persistence. Such habit persistence can be seen as the explicit or implicit cost of switching products, which is a phenomenon that has been examined in the literature on switching costs.[2] Klemperer (1987a) and Klemperer (1987b) provided the first insights on the impact of switching costs on the competitive outcome in a duopoly. Within a two-period framework, he shows that switching costs lead to aggressive competition in the first period and higher prices in the second period as firms profit from locked-in customers with switching costs.[3] The literature has extended the work to a multi-period environment (Beggs and Klemperer, 1992; Padilla, 1995; Anderson et al., 2004; Anderson and Kumar, 2007; see also the survey in Farrell and Klemperer, 2007). Each of the models considers duopolies and finds that firms have an incentive to decrease prices sporadically and set higher prices in subsequent periods to harvest consumers. In these models, consumer switching costs soften dynamic competition. Recent theoretical literature includes discussions on the possibility of lower degrees of switching costs in which competitive pressure may increase (Arie and Grieco, 2014; Cabral, 2016; Dubé et al., 2009; Fabra and García, 2015; Rhodes, 2014). A detailed discussion of the previous literature and questions about when switching costs make markets more or less competitive can be found in Ruiz-Aliseda (2016).

Collusion in the pharmaceutical market receives recent attention (e.g., Clark et al., 2021; Cuddy, 2020; Starc and Wollmann, 2022) and adds to the long literature that evaluates competition of generics, prescribing behavior, pricing constraints, and parallel-trades on prices, profits and margins (e.g. Dubois and Lasio, 2018; Dubois and Sæthre, 2020). I add to the literature by showing a form of collusion in the market that involves alternating prices. Collusion in the form of alternating actions has received attention in economic theory as well as in empirical work. Daughety and Forsythe (1988) show that alternating monopoly prices in an oligopoly generate a first best collusion outcome without a common knowledge assumption. Further, Amelio and Biancini (2010) note that alternating monopoly price strategies may serve as a coordination device. In my model framework, alternating collusion schemes arise due to the behavioral frictions of patients.

On the empirical side, this study is related to a stream of literature investigating dynamic prices and price cycles. Price cycles in the form of Edgeworth cycles are well documented in the economic literature. Edgeworth cycles are observable in retail gasoline prices (see, e.g., Byrne et al., 2015; Castanias and Johnson, 1993; Lewis, 2012; Noel, 2007a; Noel, 2007b; Noel, 2008; Wang, 2009; Zimmerman et al., 2013). Within the gasoline market, Byrne and De Roos (2019) and Clark and Houde (2013) also show collusion in markets with Edgeworth price cycles. Besides gasoline markets, a recent study by Plum Hauschultz and Munk-Nielsen (2017) shows that Edgeworth price cycles of pharmaceuticals exist in Denmark. Although we do not observe Edgeworth price cycles in Sweden, another kind of price cycle exists in which competitors alternate their prices symmetrically.

In the literature on health economics, generic entry and the price-setting behavior of generic and brand-name product manufacturers has received considerable attention. The "generic competition paradox" (Frank and Salkever, 1997), which refers to the phenomenon of branded pharmaceutical firms increasing their price after a generic enters the market, has been documented by Regan (2008), Frank and Salkever (1991), Frank and Salkever (1997), and Grabowski (1996).

This article adds to the literature by investigating dynamic competition between branded and generic pharmaceuti-

[2]The existence of switching costs has been documented in various empirical studies, including Calem and Mester (1995), Dubé et al. (2010), Keane (1997), Shcherbakov (2016), Shum (2004), Shy (2002), and Viard (2007). Relevance in the pharmaceutical market is documented in Crawford and Shum (2005), Hollis (2002), and Feng (2017).

[3]Note also the existence of similar models in monopolistic competition, i.e., Conlisk et al. (1984), Sobel (1984), or Villas-Boas (2006). The literature shows that price cycles are even possible for monopolists under some conditions (i.e., durable goods). Another stream of literature considers similar models where consumers are forward looking, e.g., Dutta et al. (2007).

cals, not only initially after the entry of generics (i.e., the out-of-patent development), but also in generally competitive situations after generic products are established.

Researchers have examined aspects of patients' choices in the Swedish pharmaceutical market. Granlund (2010) examines the price effects of a reform in 2002 regarding the pricing of generics. After 2002, patients were reimbursed only for the cheapest available product within a predefined group of identical substances. The introduction of the reform decreased the prices of generics by approximately 10%. Also, competition matters: Granlund and Bergman (2018) show that additional competition decreases prices in the long and short term. Similar, Bergman et al. (2016) and Bergman et al. (2017) evaluate the Swedish substitution reform from a cost and welfare perspective. This article differs as I investigate price cycles and short-term price variations. Granlund and Rudholm (2008) investigate consumer loyalty for branded drugs. They show that patients have a tendency to pay the price difference and oppose substitution if the more expensive alternative is a branded drug. Opposing substitution with another generic is less likely. Andersson et al. (2005) show that patients decline substitution less often when the possible savings are large. The cyclical patterns have only been examined in a master's thesis (Cletus, 2016) that describes the cycles and shows that an overlapping permutation test rejects the hypothesis that the price patterns are random. I extend the work on price cycles as I characterize price cycles as well as other price dynamics in a systematic fashion. Further, I provide an explanation for different price dynamics that could help researchers distinguish price fluctuations in a competitive market from tacit collusion.

2 Institutional Background

The Swedish health care system is mainly government-funded, and health care coverage is universal. The system covers reimbursement for prescription drugs.

Patients' co-payments for all health care expenditures decrease as yearly expenses increase, and a cost ceiling is reached at 2350 SEK (approx. $240).[4]

One important characteristic of the Swedish pharmaceutical system is that patients are incentivized to acquire the cheapest available generic substitute, the product of the months. The intention is to decrease reimbursement costs and increase the competitive pressure among price-setting companies. Although pharmacies are obliged to dispense the cheapest available generic (TLV, 2016b), not all patients receive the cheapest available generic for different reasons. First, patients may have health conditions that require a more expensive product. A physician or health care provider can oppose substitution to a cheaper equivalent. In such cases, patients are subject to the same co-payment structure. Second, the product of the month may be out of stock. The pharmacy is then allowed to substitute the next cheapest product, and so on. As in the first case, patients still pay the same co-payments. Third, patients may oppose substitution. In this case, they pay the difference between the chosen product (the prescribed product) and the product of the month.[5] Thus, we can describe the cost for patients as being similar to the concept of margin-pricing or reference pricing, where patients pay the incremental price for more expensive treatment options (Einav et al., 2016). Previous research has indicated that a substantial number of patients do not receive the product of the month, even though the

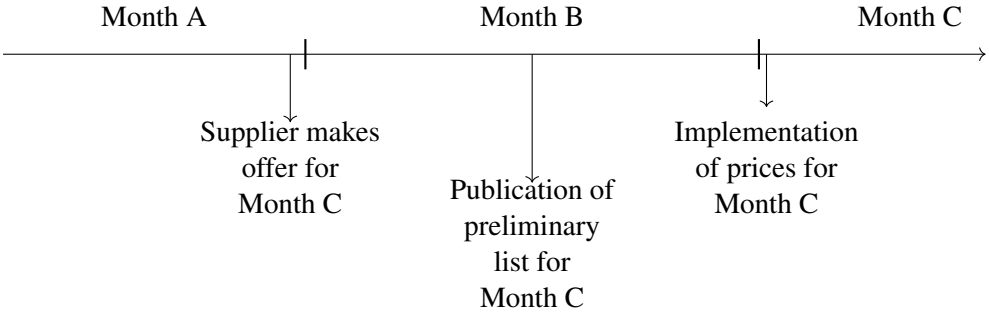
[4]The exact co-payment functions before and after a reform in 2012 are described in Online Appendix H. Costs for pharmaceuticals that are not in the benefit scheme are not covered, and their prices are therefore less regulated. Prescription-free (i.e., over-the-counter) medicines that are not solely sold in pharmacies and other traded pharmacy goods are generally not subsidized. Pharmaceuticals prescribed for children under 18 years old, insulin, pharmaceuticals that combat communicable diseases, and pharmaceuticals for persons who lack an understanding of their own illness are fully subsidized, and those patients do not have any expenses.

[5]In case the original prescription drug is chosen, the out-of-pocket expense equals the price difference between the cheapest product and the prescribed product. If a patient wants to purchase a third pharmaceutical that is neither prescribed nor the product of the month, the patient pays the entire price out of pocket. Note that empirically only out-of-pocket expenses equal to the price differences are observable.

cheapest product is presented. See for example the estimation of Janssen (2019) and Bergman et al. (2012). Bergman et al. (2012) estimate that, in 2012, 70% of consumers purchased the product of the month, and 11% of pharmaceutical purchases were the result of patients or physicians opposing substitution. Although search costs are an important determinant of demand in many pharmaceutical markets and can result in price dispersion across drugs (Sorensen, 2000), search costs are not relevant behavioral frictions in the Swedish market. Within the Swedish market, patients get dispensed the cheapest available generic by default. Finally, prices for all drugs are uniform across all pharmacies.

Off-patent drugs are subject to a tendering system. The Dental and Pharmaceutical Benefits Agency (TLV) organizes a monthly price competition such that the cheapest product of a predefined substitution group (determined by the medical product agency) receives product-of-the-month status. The details of the pricing system are described in Figure 2. The timing is as follows: At the end of a month (Month A), a pharmaceutical company submits the pharmacy purchase price for the month after the next (Month C). In the case of a missing bid, the price of the previous month is taken as a bid. Prices are regulated such that they cannot exceed a price ceiling that corresponds to 35% of the original brand product price before the expiration of the patent. [6] In the middle of the next month (Month B), the TLV publishes a preliminary list of the resulting prices. Before 2014, the prices were implemented in the next month (Month C), but since 2014, pharmaceutical companies have had to confirm that they can serve the entire Swedish market before the prices are implemented. One essential feature of the timing is that pharmaceutical suppliers see the preliminary list for the next month before bidding for the following month (TLV, 2016b).

Figure 2: Timeline of Pricing



Final retail prices are regulated and directly dependent on pharmacy purchasing prices. Retail prices are an almost linear function of pharmacy purchasing prices, and the difference determines the trade margin (TLV, 2016c).[7] Pharmacies are obliged to dispense the product of the month if it is not opposed by physicians or patients. Profits for prescription drugs increase with the price of products, such that pharmacies could enhance their profits by dispensing a more expensive product.

If the product of the month is not in stock, the pharmacy dispenses the cheapest available reserve product. [8] If substitution happens because the cheapest available product is not in stock, it does not increase the out-of-pocket expenditures of patients. However, substitution on the pharmacy level seldom happens, occurring in only 2% to 3%

[6] A price ceiling exists if a branded drug is under generic competition for at least four months and the price of a drug has decreased by 70% of the original branded product's price 12 months prior to patent expiration. If no price ceiling exists, the most expensive product of the month will serve as the price ceiling. If an original product has insufficient generic competition, prices may also be reduced by 7.5% if marketing approval was received at least 15 years before (TLV, 2016a).

[7] The exact function from purchasing to retail prices is described in Online Appendix I. The function had a slight change in 2016 (TLV, 2016c). Pharmacies were privatized in 2009. Two thirds of the pharmacies were privatized, and the remaining third remain under public control.

[8] Additionally, a pharmacy can sell the remainder of the previous product of the month during the first two weeks of a new month. After these two weeks, pharmacies can sell the products for the pharmacy-purchasing price without profit. Therefore, the pharmacy has no incentive to overstock a product of the month.

of all purchase occasions. Thus, pharmacies follow their obligation and stock the cheapest available product in a substitution group and try to get individuals to agree to the substitution. As up to 21% of patients (see Table 2) oppose substitution, pharmacies further have an incentive to also stock the original product or other frequently chosen products. In the event that two different products of a substitution group have the same price and both products are the product of the month, pharmacies can generally recommend one of the cheapest products. Overall, therefore, pharmacies steer purchase decisions only in the special case of identical prices.

3 Data

This article is based on two data sources. The backbone of the analysis is based on monthly prices and bids for outpatient pharmaceuticals under generic competition. The data are provided by the Swedish dental and medical authority (TLV) and cover monthly bids between January 2010 and June 2016. Each substitution group is defined by a substance $\times$ strength $\times$ package combination, and the medical product agency decides about suitable substitutions. I observe bids from each exact product and the substitution group it belongs to. I exclude subgroups that were in place for less than 6 months. I connected the data with pharmaceutical statistics from Socialstyrelsen, which is the Swedish governmental agency for health and welfare. The pharmaceutical statistics provide the annual number of prescriptions and dispensed units on the substance level from 2010 to 2015.

For the demand side analysis, I use aggregated choice data for the Swedish population between January 2010 and June 2016. The data are provided by Socialstyrelsen. I have access to the pharmaceutical product choices of four different therapeutic subgroups: painkillers/analgesics, antiepileptics/anticonvulsants, antibiotics, and beta-blockers. The data on the demand side are on the same level (product-specific, monthly) as the supply data. The data include product-specific monthly sales information, allowing me to explore product market shares within substitution groups (substance $\times$ strength $\times$ package combination) of the four pharmaceutical subgroups.

Table 1 shows summary statistics on the individual product level, where the price of a product at time t corresponds to one observation. For the duration of 6.5 years, I observe 350,057 prices. In the complete sample, the majority of prices, around 75.4%, are set by generics, 15.2% are from original producers, and the remaining prices are from parallel importers or parallel distributors. Panel B of Table 1 shows summary statistics on the substitution group level. The complete sample has 2251 substitution groups; 43.9% of substitution groups consist of only one product, while duopolies occur in 20.6% of cases. On average, 0.77 products enter and 0.76 products exit a substitution group in the sample period.

Finally, I describe the demand data for the four different therapeutic subgroups. As shown in Table 2, the substitution groups and the products of the four therapeutic subgroups are a subset of the entire pharmaceutical market. The number of purchase occasions within the time horizon represents the aggregate number of prescriptions filled. Between the four therapeutic groups, the aggregate number of purchase occasions, as well as the average number of purchase occasions per unique patient, differs. Painkillers have the highest number of purchase occasions (around 38.5 million) and the second-highest average number of patients (3.2 million) as well as purchase occasions per patient (12.06 purchase occasions). In comparison, antibiotics are used by a higher number of patients (4.7 million) but less frequently (2.9 purchases per patient on average). The fraction of purchases that are purchases of the product of the month is high but not close to 1. In detail, approximately 28% of the purchases of painkillers, 7% of antiepileptics, 13% of antibiotics, and 14% of beta-blockers are not the product of the month. In the majority of the cases where the product of the month is not dispensed, the patient has opposed substitution.

Table 1: Summary Statistics, Products

A: Products		B: Substitution Groups	
N	350,057	No. of Subst. Groups	2251
Share Prod. of Month	0.334	Mean No. of Competitors	2.79
Share Prod. of Month or Reserve	0.501		(2.58)
Fract. of Original	0.152	N=1	0.439
Fract. of Generics	0.754	N=2	0.206
Fract. of Parallel Imports	0.051	N=3	0.108
Price	378.57	Mean Entries	0.77
	(1356.91)		(1.386)
Mean log(P)	5.19	Mean Exits	0.758
	(0.981)		(1.391)

Notes: The table presents summary statistics on individual product level and on the substitution group level. In part A one observation corresponds to a product in a time period t. N are the number of observations. The product of the month is usually the cheapest available product in a substitution group at time t. Reserve status is awarded to the second and third cheapest products in a substitution group. Price is the retail price of a product in SEK, averaged across products and months between January 2010 and June 2016. In part B one observation corresponds to a substitution group at time t. The mean number of competitors is the mean over all substitution groups and time periods. Standard deviations are reported in parentheses.

Table 2: Summary Statistics, Demand Side

	Painkillers	Antiepileptics	Antibiotics	Beta-Blockers
Number of Substitution Groups	158	36	147	54
Number of Products	566	72	438	234
Number of Purchase Occasions	38,539,665	570,319	13,790,002	29,675,062
Number of Patients	3,196,577	60,558	4,731,408	1,465,210
Average Purchase Occasions per Person	12.06	9.42	2.92	20.25
	(26.27)	(14.12)	(3.56)	(27.77)
Fract. Consumption of Product of the Month	0.73	0.93	0.87	0.86
	(0.44)	(0.26)	(0.34)	(0.35)
Fract. Opposed Substitution by Patient	0.209	0.028	0.094	0.08
	(0.406)	(0.165)	(0.292)	(0.272)
Fract. Substitution Prohibited by Physician	0.024	0.018	0.005	0.038
	(0.152)	(0.132)	(0.071)	(0.192)
Fract. No Substitution due to Pharmacy	0.034	0.026	0.034	0.021
	(0.180)	(0.158)	(0.182)	(0.144)
Repeated Consumption of Product	0.754	0.849	0.562	0.679
	(0.43)	(0.36)	(0.5)	(0.467)
Opposed Substitution Cond. on Repeated Consumption of Product	0.239	0.024	0.135	0.088
	(0.43)	(0.15)	(0.34)	(0.28)

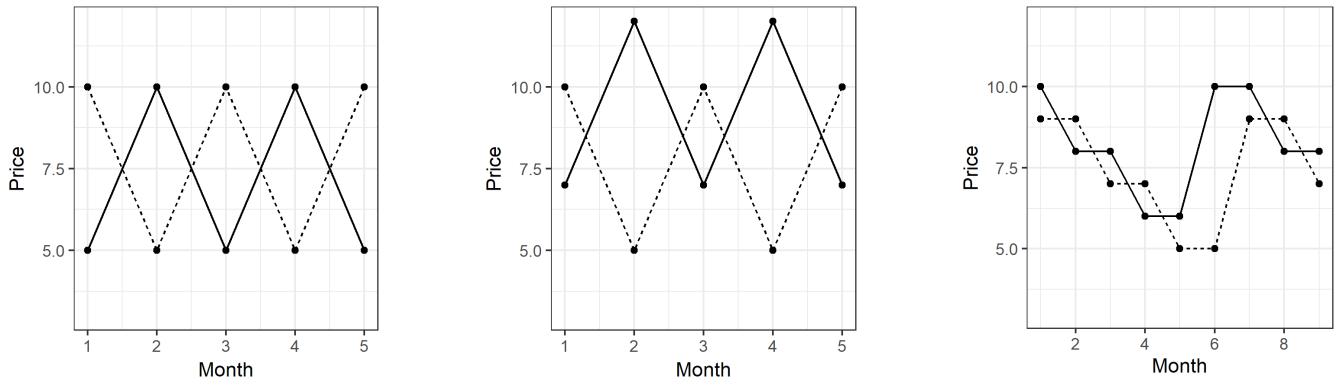
Notes: Summary statistics for choice data for the four therapeutic groups. Prescriptions between January 2010 and June 2016 are considered. Each purchase occasion corresponds to a filled prescription.

4 Price Cycles

In this section, I characterize price cycles in the Swedish pharmaceutical market. The price cycles of the Swedish market involve price rotation between two firms. I define two different rotation types. The first rotation is based on a price cycle in which firms rotate between a common upper price ceiling and a lower price floor. In each period, one of the two firms offers the cheapest product. I define those price cycles as symmetric price cycles (SPCs); see Figure 3a. Second, I define an asymmetric price cycle (APC) where firms rotate between individual upper and lower price boundaries. I show an example of an asymmetric price cycle in Figure 3b.

While SPCs and APCs are not common, economic literature has documented Edgeworth price cycles frequently in various markets.[9] Edgeworth price cycles differ from SPCs and APCs. Asymmetric Edgeworth price cycles are characterized by multiple firms sequentially undercutting one another before a price jump, which is again followed by repeated undercutting. I show an example of an Edgeworth price cycle in Figure 3c, which shows a cyclical pattern in prices characterized by an initial jump, followed by a slower decline back towards the initial level.

Figure 3: Examples of Price Cycles



(a) SPC (b) APC (c) Edgeworth Price Cycle

Notes: Examples of a symmetric price cycle (SPC), asymmetric price cycle (APC), and Edgeworth price cycle.

In the following, I formally define SPCs and APCs for one period. Note that a single-period APC cycle involves prices that follow the cycle in two future periods. Further, I define Edgeworth price cycles following identification strategies in the literature. Holt et al. (2021) give an overview of how the literature identifies Edgeworth price cycles. We follow the rather general approaches of Castanias and Johnson (1993) and Eckert (2002) to ensure that we recognize any possible occasion of Edgeworth cycles even though requirements are less strict compared to those for SPCs and APCs.

Definition 1. Symmetric Price Cycle:
Firms $C_t^{SPC} \in N$ in period t are part of a price cycle if it holds that:
1. $0 < |p_{kt+1} - p_{kt}| \; \forall k \in C_t^{SPC}$
2. $0 = |p_{kt+2} - p_{kt}| \; \forall k \in C_t^{SPC}$
3. $p_{it} = p_{jt+1}$, where $i, j \in C_t^{SPC} \wedge i \neq j$
4. $|C_t^{SPC}| \geq 2$

[9] Most prominent are examples in the gasoline market (see for example Byrne et al., 2015; Byrne and De Roos, 2019; Castanias and Johnson, 1993; Lewis, 2012; Noel, 2007a; Noel, 2007b; Noel, 2008; Wang, 2009; Zimmerman et al., 2013).

Definition 2. Asymmetric Price Cycle:
Firms $C_t^{APC} \in N$ in period t are part of a price cycle if it holds that:
1. $0 < |p_{kt+1} - p_{kt}| \; \forall k \in C_t^{APC}$
2. $0 = |p_{kt+2} - p_{kt}| \; \forall k \in C_t^{APC}$
3. $p_{it} > \min\{p_{jt}\}_{\forall j}$ and $p_{it+1} < \max\{p_{jt+1}\}_{\forall j}$ or $p_{it} < \max\{p_{jt}\}_{\forall j}$ and $p_{it+1} > \min\{p_{jt+1}\}_{\forall j}$, where $i, j \in C_t^{APC}$
4. $|C_t^{APC}| \geq 2$

Definition 3. Edgeworth Price Cycle:
Firms $C_t^{EPC} \in N$ in period t are part of a price cycle lasting u periods if it holds that:
1. $|\Delta P^+| < |\Delta P^-|$ where $\Delta p_i^+ \in^+$ and $\Delta p_i^- \in \Delta P^+$ are the sets of positive and negative first price difference.
2. $mean(\Delta p_i^+) > mean(\Delta p_i^-)$
3. $p_{it} = p_{jt+1}$ or $p_{jt} = p_{it+1}$, where $i, j \in C_t^{EPC} \wedge i \neq j$
4. $|C_t^{APC}| \geq 2$

The definitions, as well as Figure 3, show that I identify SPCs and APCs by monthly rotations of at least two competitors (Definition 1 and Definition 2: conditions 1, 2, and 4). Note that rotation requires a common upper ceiling and price floor for SPCs (Definition 1: condition 3), whereas it requires a competitor-specific upper ceiling and price floor for APCs (Definition 2: condition 3). Thus, a simple change in prices such that an increase follows a decrease is not sufficient. Finally, note that SPCs always qualify as APCs. In comparison, Edgeworth price cycles may differ in length as periods of mutual undercutting could vary in length. I require for an Edgeworth cycle over u periods that we observe more frequent price decreases and increases, that the average increases are larger than the decreases, and that firms set their product prices following a price leader.

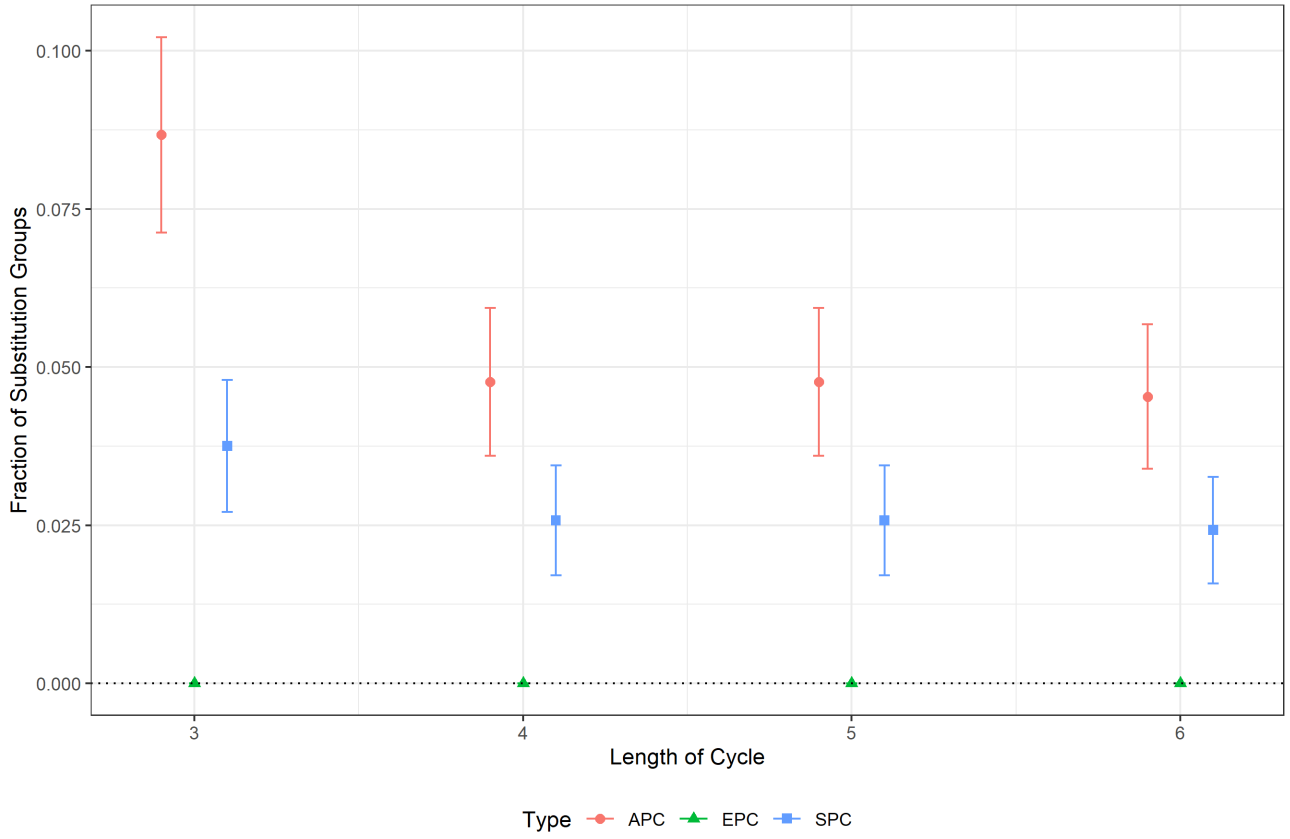
4.1 Price Cycles in the Swedish Pharmaceutical Market

In Figure 4 I show frequencies of different price cycles in the Swedish pharmaceutical market. Independent of the length of a potential cycle, one does not observe Edgeworth price cycles in the Swedish market. Instead, SPCs and APCs are occasionally observable. The longer one requires those price cycles to exist, the lower are the occurrences. Overall, the frequency of SPCs and APCs lead me to focus on investigating these price cycles.

Having established that SPCs and APCs are observed and Edgeworth price cycles are not, I now show examples of SPCs and APCs and describe how I identify the price cycles. Figure 5 shows that SPCs and APCs come in different shapes and are not necessarily stable over the years. Each of the subfigures shows the prices of a different substitution group. I indicate the identification of SPCs and APCs in the lower part of each subfigure. The substitution group in Figure 5a refers to mometasone, a steroid medication for the treatment of skin conditions and asthma. The majority of price cycles are similar to the example of this substitution group: Two firms are in an SPC for multiple subsequent months. Occasionally, the common upper price ceiling and lower price floors are adjusted slightly such that the price cycle may break down. Thus the identification of the price cycle can be interpreted as a conservative lower bound.

Figure 5b presents prices of cefadroxil, an antibiotic. The example shows another example of two firms competing by frequently undercutting each other and increasing prices after being the product of the month. However, note that an SPC or APC requires a constant and non-variable upper price ceiling and lower price floor between which rotation takes place. A majority of the price occasions do not satisfy the conditions of an APC or SPC. Figure 5c shows the prices of lansoprazole, a medication to decrease stomach acid. This example shows that price cycles may break down due to the arrival of new competitors. Here we see that a new competitor entered in January 2013, which decreased

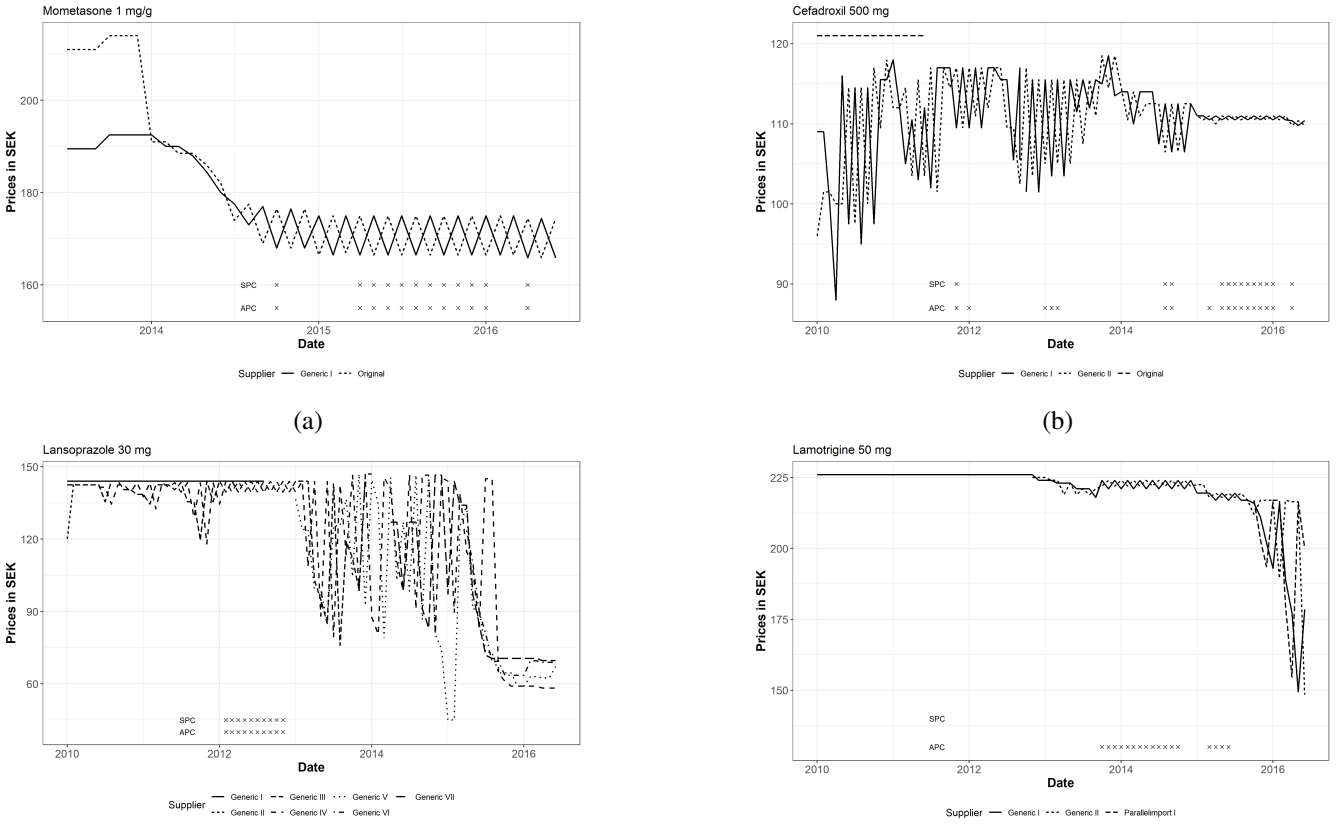
Figure 4: Frequencies of Price Cycles



Notes: The figure shows the fraction of substitution groups with at least 5% of prices in SPCs, APCs, or Edgeworth price cycles. The error bars refer to the 95% confidence intervals.

prices and caused the breakdown of a 10-month-long SPC. However, the volatility of prices remained high. Finally, the last example in Figure 5d shows prices for lamotrigine, a medication used to treat epilepsy and treat acute depression. This example highlights that a single product does not vary in price. Only the entry of a competitor changes behavior and leads to an APC. The APC breaks down when a third product enters the market.

Figure 5: Example of Substitution Groups with Price Cycles



Notes: Examples of monthly prices in four different substitution groups. SPC and APC indicate the identification of price cycles according to definitions 1 and 2.

5 A Stylized Model of the Swedish Pharmaceutical Market

The model is related to the approaches by Padilla (1995), Anderson et al. (2004), and Anderson and Kumar (2007). I integrate the institutional background of the Swedish system. Padilla (1995) and Anderson et al. (2004) briefly discuss tacit collusion within dynamic oligopolies, but they restrict their attention to cases in which both firms charge a monopoly price. I extend the literature by characterizing a tacit collusion mechanism where firms alternate prices.

Within the model, I formalize the hypotheses of crucial assumptions and predictions that are evaluated in the empirical section at the end of this article. I divide the testable assumptions or predictions into those referring to the demand side and those referring to the supply side.

5.1 Setup

There are $N = \{1,...,n\}$ firms that produce a homogeneous product and compete on prices. Marginal costs are equal to zero. In each time $t \in \{1,2,...\}$, firm $j \in N$ sets a price p_j^t. Prices are set simultaneously and are bounded by $P = [0,R]$. Note that the price ceiling is part of the Swedish institutional background. Generally, results without a price ceiling are similar if one assumes downward sloping demand components instead of price-inelastic patients. Firm j faces a demand D_j^t.[10] Demand is divided into three segments. The first segment is a unit mass of new patients who are perfectly price elastic. Second is a mass of $\theta \in [0,1]$ habit-persistent (or locked-in) patients who are perfectly price inelastic but solely buy the product from a unique firm. Habit-persistent patients only buy from the firm with the lowest price in the previous period, summarized in a state variable $x^t \in \mathscr{L} = \{1,...,n\}$ where only the firm j for which $x^t = j$ receives habit-persistent patients. Third, each firm has firm-specific loyal patients l_j. Loyal patients have specific brand preferences and are price inelastic.

Tie-breaker rule. While the unit mass of new patients is price elastic, the demand is subject to an important tie-breaker rule. If two firms set the same lowest price, only one firm is in the state $x^t = j$ and receives the demand of price-elastic patients.The assumption is based on the behavior of the pharmacy. Price-elastic patients do not have a brand preference and are indifferent between products. However, pharmacies reduce their costs by purchasing largely one product. In the empirical part of this article I investigate the assumption. If two firms set the same lowest price, market shares are asymmetric, with one firm receiving a much higher market share. Therefore, the state x^t results in additional price-inelastic patients (θ) and the advantage of the tie-breaker rule.

Demand Assumption 1. *Patients are habit persistent and have brand preferences when choosing prescription drugs under generic competition.*

I define the patients with a brand preference as a share of a unit mass such that $\sum_j l_j = 1$ such that brand preferences have the same size as those consumers that are perfectly price elastic. Firm j can have either a high share of patients with a brand preference, $l_j = l^H$, or a low share, $l_j = l^L$, where $l^H > l^L$. Within a market, the number of firms with a high share of patients with a brand preference is at most one. The difference between a high and a low share of brand preferences images the observation that usually one original brand with previous patent protection competes against multiple generics or only multiple generics are in a price competition. So either all firms have a low share of patients with a brand preference such that $l^L = \frac{1}{N}$ or one firm has a higher share of patients with a brand preference such that the relation is $\frac{1-l^H}{N-1} = l^L$. However, the exact share of l_j as well as the aggregate of all patients with a brand preference does not alter the overall results of the model. The value of the habit-persistent patients θ and patients with a brand preference l^L and l^H is constant over time. The demand of all firms within a period is $\sum_j D_j = 1 + \theta + \sum_j l_j$.

If $x^t \neq j$, firm j faces a demand of[11]

$$D_j^t = \begin{cases} l_j & \text{if} \quad p_j^t \geq p_{-j}^t \\ 1 + l_j & \text{if} \quad p_j^t < p_{-j}^t \end{cases}$$

whereas in the case of $x^t = j$, the demand is defined by

[10] Note that pharmacies are a passive actor in the market. They receive a fixed retail margin. Therefore I do not model pharmacies as agents but instead model manufacturers as facing consumers directly.

[11] Let $-j = N \setminus \{j\}$.

$$D_j^t = \begin{cases} \theta + l_j & \text{if} \quad p_j^t > p_{-j}^t \\ 1 + \theta + l_j & \text{if} \quad p_j^t \leq p_{-j}^t. \end{cases}$$

On aggregate, the demand is not totally price-inelastic; however, some of the patients (i.e., the patients that are habit persistent and those that have a brand preference) are price inelastic. The unit mass of new patients is perfectly price elastic. As a result, demand for each product depends on the ranking of prices but not on the price differences.[12]

The initial state x^1 is given. For each period $t > 1$ a transition function T determines the state x^t. In detail, the prices of the previous period $(p_j^{t-1})_{j \in N}$ for all firms and the state of the preceding time x^{t-1} resolve the state x^t.

The transition can be described as follows:

$$x^t = \begin{cases} j & \text{if } p_j^{t-1} < p_{-j}^{t-1} \text{ or } p_j^{t-1} \leq p_{-j}^{t-1} \text{ and } x^{t-1} = j \\ \sim \text{Uniform}\{\mathscr{N}\} \text{ where } \mathscr{N} \subset N & \text{if for each } j \in \mathscr{N} \quad p_j^{t-1} = p_{-j \in \mathscr{N}}^{t-1} \text{ and } p_j^{t-1} < p_{-j \notin \mathscr{N}}^{t-1} \text{ and } x^{t-1} \neq j. \end{cases}$$

If firm j was the strictly cheapest supplier in the previous period $t-1$, the new state is $x^t = j$. If j has offered a weakly lower price in $t-1$ and the previous state was $x^{t-1} = j$, the result for the new state is equivalent ($x^t = j$). If several firms have set the same strictly lowest price ($j \in \mathscr{N}$) and none of these firms has been in the state with the habit-persistent patients in $t-1$ ($x^{t-1} \neq j$ for all $j \in \mathscr{N}$), the state in x^t is randomized between the firms that offered the same lowest price ($x^t \sim \text{Uniform}\{\mathscr{N}\}$).

Firms maximize profits under complete information. Given a state $x^t \in \mathscr{L}$ the profits for one period are given by

$$\pi_j^t(p_j^t, p_{-j}^t | x^t \neq j) = \begin{cases} p_j^t l_j & \text{if} \quad p_j^t \geq p_{-j}^t \\ p_j^t(1 + l_j) & \text{if} \quad p_j^t < p_{-j}^t \end{cases}$$

$$\pi_j^t(p_j^t, p_{-j}^t | x^t = j) = \begin{cases} p_j^t(l_j + \theta) & \text{if} \quad p_j^t > p_{-j}^t \\ p_j^t(1 + l_j + \theta) & \text{if} \quad p_j^t \leq p_{-j}^t. \end{cases}$$

Similar to the one-period profits, one can describe the continuation valuation of a firm as dependent if firm j has habit-persistent patients ($x^t = j$). Firms discount future profits with $\delta \in (0,1)$. The time subscripts are dropped for simplicity, as the continuation payoff is time independent.

[12] The assumption is in line with empirical observations within the data. Note first that the difference between the cheapest and most expensive product is often not high due to the tight setting of the upper bound R. The average maximal price difference between the cheapest product and most expensive product across all substitution groups is 112.2 SEK (approx. 11.2 USD). After controlling for whether a product is the cheapest product within a substitution group, a price decrease of 100 SEK (approx. 10 USD) is associated with a market share increase of only 1 percentage point; see the empirical part of this paper in Section 6.

$$V_j(p_j, p_{-j}|x \neq j) = \begin{cases} p_j(l_j) + \delta V_j(\cdot|x \neq j) & \text{if} \quad p_j \geq p_{-j} \\ p_j(1+l_j) + \delta V_j(\cdot|x = j) & \text{if} \quad p_j < p_{-j} \end{cases}$$

$$V_j(p_j, p_{-j}|x = j) = \begin{cases} p_j(\theta + l_j) + \delta V_j(\cdot|x \neq j) & \text{if} \quad p_j > p_{-j} \\ p_j(1+\theta+l_j) + \delta V_j(\cdot|x = j) & \text{if} \quad p_j \leq p_{-j} \end{cases}$$

I begin by describing Markov perfect equilibria (MPEs). In line with Maskin and Tirole (2001), Markov perfect strategies are the simplest form of behavior that is consistent with rationality. Within an MPE, one restricts subgame perfect equilibria (SPEs) only to the payoff-relevant strategies of a subgame. Naturally, an MPE forms an SPE. Formally, players condition their strategies in an MPE on payoff-relevant states, $\mathscr{S}_j : \mathscr{L} \to \Delta(P)$. Then $(s_j^*)_{j \in N} \in \mathscr{S}_j$ forms a *stationary MPE* if and only if for all $j \in N$, $V_j(s_j^*, s_{-j}^*, x) \geq V_j(s_j, s_{-j}^*, x)$.

Besides MPEs, I also consider restricted SPEs of the game. In an SPE, firms condition their strategies not only on the state but also on the history of the game. In detail, a firm not only knows which firms have habit-persistent patients but also knows past prices. For tractability, I restrict the history to the actions of the last period. Firms condition their strategies on the past prices as well as the previously defined states, $\mathscr{S}_j : (p_j^{t-1})_{j \in N} \times \mathscr{L} \to \Delta(P^t)$. In an SPE, firms play a Nash equilibrium in every subgame (time period). $(s_j^{t*})_{j \in N} \in \mathscr{S}_j$ forms an SPE if and only if for all $j \in N$ and all $t \in \{1, 2, ...\}$, $V_j^t(s_j^{t*}, s_{-j}^{t*}, x^t) \geq V_j^t(s_j^t, s_{-j}^{t*}, x^t)$.

5.2 Results of the Model

Monopoly

Given perfect inelastic demand, a monopolist maximizes profits by choosing the highest possible price. A monopolist sets the price at the upper bound and does not vary this price over time.

Lemma 1. *A monopolist sets $p^t = R$ in each time t independent of the history $\mathscr{H}_t$. The valuation for the monopolist is $V = \frac{R(1+l+\theta)}{1-\delta}$. By definition, the equilibrium is Markov perfect as well as subgame perfect.*

Proof. See Online Appendix B. □

Supply Prediction 1. *Monopolists do not form a price cycle. They change prices infrequently. Compared to substitution groups with higher competition, fluctuation in prices is less common.*

Duopoly

I begin by characterizing MPE. Afterward, I show possible collusion schemes that rely on an SPE. Consider two competing firms, denoted as $j \in N = \{1, 2\}$. First, I investigate the case of $l_1 = l_2 = l^L = l$. Each firm is in a state either with or without habit-persistent patients, and states are denoted as $x^t \in \mathscr{L} = \{1, 2\}$, where $x^t = 1$ when firm $j = 1$ has habit-persistent patients in t and $x^t = 2$ when firm $j = 2$ has a higher price-inelastic demand.

Note first that the game has no MPE in pure strategies.[13] The intuition for this result is the following. Suppose firm $j = 1$ has habit-persistent patients or many patients with a brand preference and chooses to harvest them by setting $p = R$. The best reply for firm $j = 2$ is to set a price marginally lower than R. In this case, firm $j = 1$ has the incentive to undercut firm $j = 2$. The best replies for firm $j = 1$ and firm $j = 2$ would be to undercut each other until firm $j = 1$

[13] Proof in Lemma 2; see Online Appendix C.

reaches a price where it would have an incentive to increase its price up to R, as the number of habit-persistent patients is sufficiently high. The next proposition characterizes the mixed equilibrium of the game. Note that I use subscripts to indicate whether $x = j$ (habit-persistent patients) or $x \neq j$ (no habit-persistent patients).

Proposition 1. *The game $\mathscr{G}(x^1)$ with $N = \{1,2\}$, $l_1 = l_2 = l$, $\delta \in (0,1)$ and given any initial state $x^1 \in \mathscr{L}$ has a unique MPE in mixed strategies that is defined by the following conditions:*

1. *Strategies $\mathscr{S}_j$ for $j \in N$:*

$$S_j = \begin{cases} p_j \sim F(p) & = \frac{p(1+l+\theta)-V(\cdot|x=j)(1-\delta)}{p+\delta(V(\cdot|x=j)-V(\cdot|x\neq j))} \quad for \quad p \in [\underline{p},R] \quad if\, x \neq j \\ p_j \sim F(p) & = \frac{p(1+l)+\delta V(\cdot|x=j)-V(\cdot|x\neq j)}{p+\delta(V(\cdot|x=j)-V(\cdot|x\neq j))} \quad for \quad p \in [\underline{p},R] \quad if\, x = j \end{cases}$$

2. *Valuation functions:*

$$V(\underline{p},|x \neq j) = \frac{\underline{p}(1+l+\delta\theta)}{1-\delta} \qquad where\ \underline{p} = \frac{R(\theta+l)}{1+l+\theta+\delta\theta}$$
$$V(\underline{p},|x = j) = \frac{\underline{p}(1+l+\theta)}{1-\delta}$$

Proof. See Online Appendix D. □

Numerical Example. See Online Appendix D.

The core of the model is the strategies. Each firm mixes over a distinct distribution of prices. The firm without habit-persistent patients has a higher incentive to get new patients. However, the firm with habit-persistent patients prefers to undercut marginally given higher prices. The firm without habit-persistent patients mixes to make the firm with habit-persistent patients indifferent. At the same time, the firm with habit-persistent patients mixes such that the firm without habit-persistent patients is indifferent to increasing the price, so undercutting on its own is not the best reply. The firm with habit-persistent patients has a mass point at $p = R$, whereas the firm without habit-persistent patients has higher mass on prices $p < R$, i.e., $f(p|x \neq j) < f(p|x = j)$, the expected price is higher for the firm with habit-persistent patients.

So far, the presented results are identical to the model by Padilla (1995) and Anderson et al. (2004) in the case of sufficiently high switching costs. Some comparative static analysis can be found in Anderson (1995). The author shows that prices are increasing in habit-persistence for both firms. The intuition is that the firm with habit-persistent patients has a lower incentive to undercut which moves the distribution of prices for both firms upwards. A similar effect is observable with brand preferences l.

In Online Appendix E, I show the MPE for the case of $l_1 = l^H > l^L = l_2$. Results are comparable, as both firms play mixed strategies. The only difference to the case of homogeneous shares of patients with a brand preference is the minimum support of the distribution over which firms randomize. In the case of one firm with a higher share of patients with a brand preference, the distribution has a higher minimum support if the firm with l^H is in the state of $x = j$.

Collusion scenario: I analyze the collusion scenario by considering restricted SPEs. I assume that collusion schemes do not involve side payments or communication. Assume that firms' punishment strategies involve reversion to the MPE. In a standard dynamic oligopoly model where demand is perfectly price elastic, the first best tacit collusion

is where both firms set a price equal to R as long as both firms' prices in the last period were equal to R. As soon as one firm deviates, both firms play an MPE.

Such an SPE does not exist due to the tie-breaking assumption when two firms set the same price and there are habit-persistent patients (i.e., $\theta \neq 0$) or a heterogeneous mass of loyal patients ($l_1 \neq l_2$). The reason for this result is that if two competitors set the same price, the larger firm (i.e., the firm with habit-persistent patients, state $x = j$, or more loyal patients) sells to new patients. The smaller firm in this collusion scheme has an incentive to deviate by undercutting, and even the punishment, the MPE, brings it a profit that is higher than the non-deviating profit. Correspondingly, market sharing by setting $p = R$ for both firms cannot be the first best collusion, as one firm has a lower profit. If one shuts down the habit persistence of patients (and assumes the homogeneous base of loyal patients l), the first best collusion is a market-sharing rule.Nevertheless it is important to highlight that the actual competitive equilibrium is not equivalent to the Bertrand outcome of $p = c$ but rather also the mixed MPE described in Proposition 1 due to the inelastic patients with brand preferences l.

Instead, I consider a possible collusion scheme that involves a rotation, as described in the following proposition. Intertemporal price rotation gives higher profits than the MPE in Proposition 1 for both firms. Compared to the MPE, profits of both firms are higher.

Proposition 2. *The game $\mathscr{G}^{SP}(x^1)$ with $N = \{1,2\}$, $l_1 = l_2 = l$, and $\delta \in (0,1)$ has an SPE with the following strategies:*

$$\mathscr{S}_j^t : \begin{cases} p_j^t = \underline{p} & \text{if } x^1 \neq j \quad \text{if } t = 1 \\ p_j^t = R & \text{if } x^1 = j \quad \text{if } t = 1 \\ p_j^t = \underline{p} & \text{if } p_j^{t-1} = R \text{ and } p_{-j}^{t-1} = \underline{p} \quad \text{for all } t > 1 \\ p_j^t = R & \text{if } p_j^{t-1} = \underline{p} \text{ and } p_{-j}^{t-1} \quad \text{for all } t > 1 \\ \text{Reversion to MPE} & \text{otherwise} \end{cases}$$

where in each equilibrium, $\underline{p}$ satisfies

$$\underline{p} \in \left(R(1 - \frac{\delta^2(1+\delta\theta)}{1+l+\theta+\delta\theta}), R \right)$$

Proof. See Online Appendix G. □

Firms coordinate on alternating prices in subsequent periods. Considering positive habit persistence ($\theta > 0$), the firm with habit-persistent patients charges a high price, whereas the firm without habit-persistent patients set a low price. The deviation is prevented by a sufficiently high price such that neither the firm with habit-persistent patients nor the firm without habit-persistent patients has an incentive to deviate. The existence of habit persistence and/or brand preferences is necessary for price cycles. The price floor determines how large the price variations in price cycles could be. However, the condition describes the maximum price differences between upper and lower prices that are possible.

Key of the price coordination is the price floor. Higher habit persistence or brand preferences increases the price floor. The incentive to deviate from a low price within a cycle increases with the behavioral frictions as firms can rely on more patients that are price inelastic. Therefore, increasing both frictions does lead to the condition that the price difference between both price levels is smaller.

Also, the higher discount factor affects the price cycles through the lower price floor. If firms get less patient, the firm charging the lower price has a higher incentive to deviate and rely on those patients with a brand preference. A higher discount factor requires the lower price floor of the price cycle to be higher to reduce the incentive of deviation.

Note that profits for both firms are increasing functions of $\underline{p}$. It would be optimal for firms to set the lower price of the scheme marginally smaller than R. Three qualitative reasons may prevent this. First, firms would like to avoid market share loss that comes from pharmacy procurement behavior. Although not incorporated in the model, marginal differences could result in situations where both products get the product-of-the-month status such that pharmacies purchase from one producer, and the collusion scheme breaks down. Second, rotations avoid smoking-gun evidence of tacit collusion. Third, the collusion scheme can be stable when firms try to re-coordinate to a new $\underline{p}$.

Collusion where both firms have the same price floor $\underline{p}$ is identified by an SPC as defined in Definition 1. However, the collusion scheme does not require a common price floor; individual-specific price floors also are possible, such that we observe an APC as described in Definition 2. In particular, two firms could have a different mass of patients with a brand preference, or even the mass of habit-persistent patients could be product specific. Here price floors could be product specific and related to the advantage of a specific firm. Each product rotates prices such that the opponent has an incentive to deviate from the collusion. Accordingly, the rotation is a function of an opponent's mass of patients with a brand preference and/or mass of habit-persistent patients.

Supply Prediction 2. *Tacit collusion schemes exist in the form of price cycles for markets with two competitors.*

The frequency of price cycles is *not* a function of habit persistence alone. Indeed, the theory shows that price cycles emerge when patients are habit persistent and/or when there are patients with heterogeneous brand preferences across firms. Further, the extent of habit persistence does not increase the probability of collusion. While I am not able to explain why collusion arises, my model shows that under the existence of any habit persistence or heterogeneous brand preferences on the patients' side, the profit-maximizing market-sharing rule is a price cycle. In the case without habit persistence or heterogeneous brand preferences, firms maximize profits by setting the same price. However, the same price setting is not necessarily a collusive agreement, as competitive equilibria without habit persistence and brand preferences also have the same price dynamics.

Demand Prediction 2. *Brand preference for originals, as well as habit persistence, is associated with price cycles. The nonexistence of both behavioral frictions may lead to identical prices.*

Thus behavioral frictions are necessary conditions for the model predictions of price cycles. Nevertheless, the behavioral frictions are not sufficient for collusion as collusion involves an active decision of manufacturers to collude. Finally, note that habit-persistence and brand preferences also affect individual equilibria such as those in Proposition 1 or individually. We expect that an increase in habit-persistence also raises expected prices in a competitive equilibria of mixed strategies.

More Than Two Competitors

In the following, I briefly summarize the outcomes of the dynamic game with three competitors. I present formal descriptions of the model in the Online Appendix. Generally, we may differentiate in a market with three competitors between the case where all firms' products are generics, and thus we assume a homogeneous base of patients with a brand preference, and another case in which we see an original and two generic products compete. Here the original product has more patients with a brand preference.

In the first case, with three products and homogeneous brand preferences, only one firm is in a state with habit-persistent patients in each period. I show in Online Appendix A that the MPE in this case shows that the firm with the

lowest-priced product always increases its prices to the upper bound in the following period. The remaining two firms play a mixed strategy. A collusion scheme of price cycles between two firms does not exist in this situation.

In the second case, we observe a competitive MPE where the manufacturer of an original product can rely on patients with a brand preference compared to the remaining two firms. Given that the share of patients with brand preferences for the original product is large enough, the original product has an incentive to charge the maximum price while the two generic products play the MPE of a duopoly. As a result, it is also possible that we observe price cycles of two generic firms while the original firm charges the highest possible price without any price variation.[14]

Considering more than three competitors, I expect price cycles not to be observable, because at least three generics compete for habit-persistent patients. Three firms engaging in a price cycle would require that even a firm without habit-persistent patients is not competing for price-sensitive patients.

Supply Prediction 3. Tacit collusion schemes exist in the form of price cycles for markets with two competitors. Price cycles also exist (but are less frequent) in a triopoly. In detail, two generics form a price cycle when one original is present.

6 Demand Side

6.1 Demand Assumption 1

The first demand assumption states that patients are habit persistent and have brand preferences. Both patients' characteristics are essential assumptions of the model. In the following, I investigate whether market share patterns of products in the four therapeutic groups show evidence of habit-persistent behavior as well as evidence for preferences for branded drugs. In detail, I use monthly market shares for each product within the four therapeutic subgroups[15] and show simple correlations of market shares across months.

Note that the persistence in market shares may not necessarily be due to the state dependence of consumers. In particular, we do not observe heterogeneity across patients, which may confound past experiences and, therefore, state dependence (Dubé et al., 2010; Shin et al., 2012). Disentangling state dependence from unobserved heterogeneity is particularly difficult when market-level data rather than individual choices are observable. Literature in industrial organization and quantitative marketing disentangles state dependence from unobserved heterogeneity using structural models of consumer choice (MacKay and Remer, 2021; Nosal, 2012; Shcherbakov, 2016; Weiergraeber, 2021; Yeo and Miller, 2018). In the following, I focus on linear regression of market share and argue that part of the persistence in market shares is due to state dependence/habit persistence. The argument is based on past studies of the Swedish pharmaceutical markets that use patient choice data and differential estimation strategies to show that past choices of patients indeed affect future consumption through state dependence (Granlund, 2021; Janssen, 2019).

Consider the following model, where one observation corresponds to product i in month t:

$$\begin{aligned} Share_{it} =& \beta_0 Original_{it} + \beta_1 PI_{it} + \theta Add.Expenses_{it} + \rho_0 ThSub_i \times PoM_{it} + \\ & \rho_1 ThSub_i \times PoMn_{it-1} + \rho_2 ThSub_i \times PoMn_{it-2} + \rho_3 ThSub_i \times PoMn_{it-3} + \\ & \alpha_i + \gamma_t + \zeta NoComp_{it} + \varepsilon_{it}, \end{aligned} \tag{1}$$

[14] See Online Appendix A for details.

[15] Note that pharmacies are allowed to sell the remaining stock of previously purchased products in the first two weeks of the next month for the same price as the last month. I exclude those observations as they may lead to an overestimation of habit persistence. The presented estimate can be interpreted as a lower bound of habit persistence.

where $Share_{it}$ is the market share (between 0 and 1) of a product in its substitution group. $Original_{it}$ and PI_{it} (where PI = parallel import) are dummy variables that take the value 1 if i is an original branded or parallel imported product and 0 otherwise. $Add.Expenses_{it}$ is the out-of-pocket expenses for products that are not the product of the month. Therefore, $Add.Expenses_{it}$ takes the value 0 if product i at time t is the product of the month. If i is not the product of the month, $Add.Expenses_{it}$ is the expenses a consumer bears by opposing substitution (i.e., the difference between the retail price of product i and the retail price of the product of the month). $PoMn_{it}$, $PoMn_{it-1}$, $PoMn_{it-2}$, and $PoMn_{it-3}$ are dummy variables. $PoMn_{it}$ is 1 if product i is the product of the month in i. $PoMn_{it-1}$, $PoMn_{it-2}$, and $PoMn_{it-3}$ are 1 if a product was the product of the month in $t-1$, $t-2$, or $t-3$, respectively, but not in subsequent periods. I interact the present and lagged indicators of the product-of-the-month status with the four therapeutic subgroups $ThSub = \{Painkillers, Antibiotics, Antiepileptics, Beta\text{-}Blocker\}$ to explore heterogeneity in habit persistence. Finally, α_i is a product fixed effect (a product is a specific brand within a substitution group), and γ_t is a time fixed effect. Note that I also control for the number of competitors in a substitution group in month t.

I provide reduced-form evidence that the assumptions of the demand side are suitable. To back up the assumptions of the theoretical model, I expect that a positive coefficient of β_0, an original branded product, is associated with a higher market share. In the model, the positive coefficient would translate to the existence of patients with brand preferences. Further, the model assumes a unit mass of patients consuming the product of the month. In the basic regression, one would see a robust positive coefficient of ρ_0. Further, the model assumes that a mass of θ patients are habit persistent and consume the product of the previous month. Therefore, I expect a positive coefficient of ρ_1, which should be smaller than ρ_0. Finally, habit persistence in the model exists over just one period, such that ρ_2 and ρ_3 should not be significantly different from zero or at least much smaller than ρ_1.

Table 3 shows evidence from three different models. Model 1 does not include fixed effects. In Model 2, I include product fixed effects, and Model 3 incorporates product and time fixed effects. The coefficient for an original product is significant and positive. An original product is related to a market share that is 9 percentage points higher. Second, the product of the month has a significantly higher market share in all three specifications. Being a product of the month (POM) is associated with a market share (ρ_0) that is 41 percentage points higher than the reference level, which is a beta-blocker in the preferred specification of Model 3. The levels are approximately the same for antibiotics and antiepileptics as the interaction terms of their indicators with POM are insignificant. However, for painkillers, the product of the month has a lower market share (3.7 percent less with the product and time fixed effects). The variable that captures potential habit persistence over one period is captured in the lagged $PoMn_{t-1}$ status. ρ_1 on the baseline level (beta-blocker) is significant in Models 1 and 3 and much lower than ρ_0 (between 6.2 and 4.5 percentage points). The result is similar for antibiotics and painkillers when introducing product and time fixed effects. Only patients who use antiepileptics seem to be not habit persistent.[16] In the preferred specification of Model 3, the coefficients of $PoMn_{t-2}$ and $PoMn_{t-3}$ are not significantly different from zero on the 5% level for all therapeutic subgroups.

Patients' habit persistence translates to a higher market share in the following month. The coefficients of the following months show that habit persistence decreases. Indeed, the size of the coefficient for PoM_{it-2} and $PoMn_{it-3}$ is much smaller and insignificant. The reduced-form evidence for the four therapeutic groups confirms the demand assumption.

[16] One potential explanation is that users of antiepileptics are used to switch drugs within a substitution group frequently. Thus they are likely to switch a product if a new, cheaper product becomes available.

Table 3: Regression, Habit Persistence

	Share	Share	Share
	(1)	(2)	(3)
Original	0.090***		
	(0.016)		
Add. Expenses (SEK)	−0.0002***	−0.0002***	−0.0001***
	(0.00003)	(0.00003)	(0.00003)
Antibiotics	0.008		
	(0.013)		
Painkillers	0.075***		
	(0.015)		
Antiepileptics	0.057		
	(0.066)		
POM	0.403***	0.343***	0.410***
	(0.016)	(0.017)	(0.016)
POMn(t-1)	0.062***	0.015	0.045***
	(0.010)	(0.011)	(0.011)
POMn(t-2)	0.016	−0.015	0.012
	(0.009)	(0.010)	(0.010)
POMn(t-2)	0.017	−0.003	0.014
	(0.009)	(0.008)	(0.008)
Antibiotics x POM	−0.029	0.036	0.028
	(0.020)	(0.022)	(0.020)
Painkillers x POM	−0.115***	−0.021	−0.037*
	(0.022)	(0.020)	(0.019)
Antiepileptics x POM	0.047	0.039	0.003
	(0.068)	(0.072)	(0.069)
Antibiotics x POMn(t-1)	0.00004	0.021	0.010
	(0.014)	(0.016)	(0.015)
Painkillers x POMn(t-1)	−0.068***	0.003	−0.010
	(0.015)	(0.013)	(0.013)
Antiepileptics x POMn(t-1)	−0.090	−0.123	−0.152*
	(0.065)	(0.075)	(0.073)
Antibiotics x POMn(t-2)	0.020	0.030*	0.018
	(0.013)	(0.014)	(0.013)
Painkillers x POMn(t-2)	−0.035***	0.013	−0.0004
	(0.013)	(0.011)	(0.011)
Antiepileptics x POMn(t-2)	0.050	−0.016	−0.045
	(0.063)	(0.074)	(0.072)
Antibiotics x POMn(t-3)	−0.006	−0.001	−0.003
	(0.012)	(0.012)	(0.011)
Painkillers x POMn(t-3)	−0.038**	−0.002	−0.008
	(0.014)	(0.010)	(0.009)
Antiepileptics x POMn(t-3)	−0.012	−0.087	−0.103*
	(0.047)	(0.048)	(0.047)
Constant	0.617***		
	(0.018)		
Fixed effects	No	Product	Product and Time
Competition controls	Yes	Yes	Yes
R-Squared	0.673	0.809	0.832
N	46,045	46,045	46,045

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: One observation corresponds to a product i in the substitution groups of painkillers, antibiotics, antiepileptics, or beta-blockers within a month t. The outcome variable is the monthly market share. Add. Expenses are the out-of-pocket expenses for product i, the difference between the price of product i and the price of the product of the month. POM is a dummy that takes the value 1 if product i is the cheapest available product of the month in t. $POMn(t-1)$, $POMn(t-2)$, and $POMn(t-3)$ are dummies that take the value 1 if product i is the cheapest available product of the month in $t-1$, $t-2$, or $t-3$ but not in subsequent months up to t. Painkillers, Antibiotics, and Antiepileptics are dummies that take the value 1 if the product belongs to the therapeutic subgroup. The default is a beta-blocker. Each model includes the number of competitors as a control, where each competitor is taken as an individual variable to allow for nonlinear effects. Standard errors are clustered at the product group level, adjusted for within-cluster correlation, and reported in parentheses.

6.2 Demand Prediction 2

In the following, I evaluate Demand Prediction 2. The model predicts that the first best collusion systems under habit persistence or with heterogeneous brand preferences of patients across firms are price cycles (described in Definitions 1 and 2). In the absence of the behavioral characteristics of patients, setting an equivalent price is profit-maximizing. Following theory and assumptions on behavioral characteristics, the price dynamics would allow identification of tacit collusion due to price cycles, while equivalent prices could be due to competitive (marginal cost) or collusive price setting.

Janssen (2019) uses individual choice data of all patients in Sweden between 2012 and 2016 for antiepileptics, painkillers, and antibiotics to estimate habit persistence. In detail, the author uses the sample of each ATC code to estimate the following model:

$$P(OpposeSubst_{ist} = 1) = \alpha + \beta_1 D_{ist-1} + \beta_2 Med_{it} + \beta_3 D_{ist-1} \times Med_{it} + \rho X_{it} + D_{is0} + \gamma_{st} + \varepsilon_{ist}, \tag{2}$$

where $OpposeSubst_{ist}$ is a dummy variable indicating if individual i in period t opposes substitution to the cheapest available product of substitution group s. Next, D_{ist-1} is a dummy variable showing if individual i chose the same product in the last purchase occasion within the last months, and Med_{it} shows whether a patient has had medical education as a physician. The author adds controls X_{it}: the logarithm of income, the geographical location, and the general education level. Finally, Janssen (2019) integrates fixed effects of substitution groups in each time period (γ_{st}). Therefore, the variation of interest is between individuals who purchase a product within a given month. Also, fixed effects absorb the price differences between products in a month. The author faces the challenge of differentiating between unobserved heterogeneity and state dependence due to switching costs. Janssen (2019) shows state dependence by conditioning choices on the initial choice D_{is0}. The initial choice is a dummy that takes the value 1 if patient i consumed the same product as in t in the first observed period. The initial choice of a product can capture unobserved heterogeneity.

Note that $\hat{\beta}_{1c}$ for each different substance c indicates the degree of habit persistence as it shows the increase in probability to oppose substitution and increased monetary spending for individuals that already purchased a product in the last month compared to those that have not. The higher $\hat{\beta}_{1c}$ the stronger is the degree of habit-persistence.

Using the estimates of habit-persistence, I then continue to evaluate correlation between the estimates $\hat{\beta}_{1c}$, as well as the share of originals, which proxy higher brand preferences, and the share of price cycles as well as same price setting. Therefore I consider the following regression models:

$$\begin{aligned} y_c &= \alpha + \rho \hat{\beta}_{1c} + \gamma_1 \overline{NoComp}_c + \gamma_2 FirstATC + \varepsilon_c \\ y_c &= \alpha + \rho \overline{Originals}_c + \gamma_1 \overline{NoComp}_c + \gamma_2 FirstATC + \varepsilon_c \end{aligned} \tag{3}$$

where y_c is one of the following outcome variables: the fraction of observations across all monthly prices of substance c in an SPC or APC or the share of observations where we observe the same price setting.[17] The shares vary between 0 and 1. In the first regression equation, $\hat{\beta}_{1c}$ is the estimate of habit persistence described in equation 2. In the second regression equation, $\overline{Originals}_c$ describes the fraction of observations where originals are present. I partly control for the average number of competitors in the substitution group of substance c, $\overline{NoComp}_c$. Further, I include the first digit of the ATC code level ($FirstATC$), which introduces different intercepts for painkillers, antibiotics, and

[17] Note that the same price setting is defined as the situation in which at least two firms set the same price over three subsequent months.

antiepileptics. Finally, I also consider an additional model with a logarithmic specification, where I take the logarithm of the outcome variables as well as of $\hat{\beta}_{1c}$ and $\overline{Originals}_c$.[18] The specification gives the correlative effect a more convenient interpretation.

I show the regression results in Table 4. In Panel A, I observe some correlation between the estimates of habit persistence and price cycles. The results get stronger when controlling for competition and when including submarket fixed effects. Considering the logarithmic specification, we observe that a 1% change in the estimate of habit persistence increases the fraction of SPCs and APCs on average by around 1.4%. Note that the results solely show a correlation. With a sample size of 28, the significance is not high. However, the increasing effect size with higher controls and the evidence of correlation from two independent data sets with a lower chance of spurious correlation provide some reassuring correlative evidence for Demand Prediction 2.

In Panel B of Table 4, I show the relation between the share of the same price setting behavior and habit persistence as well as the share of originals. The basic intuition from the model is that we expect that the same prices cycles do not exist when patients are habit persistent or when patients have brand preferences. I consider the existence of originals as a proxy for a higher likelihood of brand preferences. The results show that we do not observe any correlation between the estimates of habit persistence or the competition from originals and the same price setting. However, we observe negative point estimates, which we would expect because only in the absence of habit persistence or brand preferences do we expect collusion in terms of the same price setting. Further, I do not observe an unexpected positive correlation between behavioral frictions and same price setting. Overall, the analysis reveals a correlation between the habit persistence of patients and price cycles. The same price setting behavior is not correlated with habit persistence.

7 Supply Side

7.1 Supply Prediction 1

I now turn to relate observable price patterns to the predictions on the supply side. The first supply prediction states that even under the assumption of habit persistence and brand preferences, monopolists neither participate in dynamic pricing nor form price cycles. First, Figure 6 shows two key measures of the prices: (1) the share of monthly price observations with positive, negative, and zero first price differences and (2) the fraction of substitution groups in SPCs (Definition 1) and APCs (Definition 2), both conditional on the number of competitors over all monthly time periods. We observe that monopolists do not change their prices and by definition do not engage in price cycles. This descriptive evidence is in line with the prediction from the theory.

7.2 Supply Prediction 2

The second supply prediction states that we expect price cycles when two firms compete. Considering Figure 6 and moving to two or three competitors, we observe first that price changes over two consecutive months are increasing and second that price cycles are observable. The observations are in line with the theory. Competitive equilibria involve a mixing equilibrium due to brand preferences as well as habit persistence. Thus we expect more price fluctuations compared to markets with a monopolist. On the other hand, a collusive equilibrium is based on price cycles. Because collusion becomes less likely the more competitors there are in a market, we expect a peak when there are two

[18] Note that $\hat{\beta}_{1c}$ is also negative. I therefore transform the variable by adding the absolute minimum of $\hat{\beta}_{1c}$ across substances and 0.001 to $\hat{\beta}_{1c}$ before taking the logarithm.

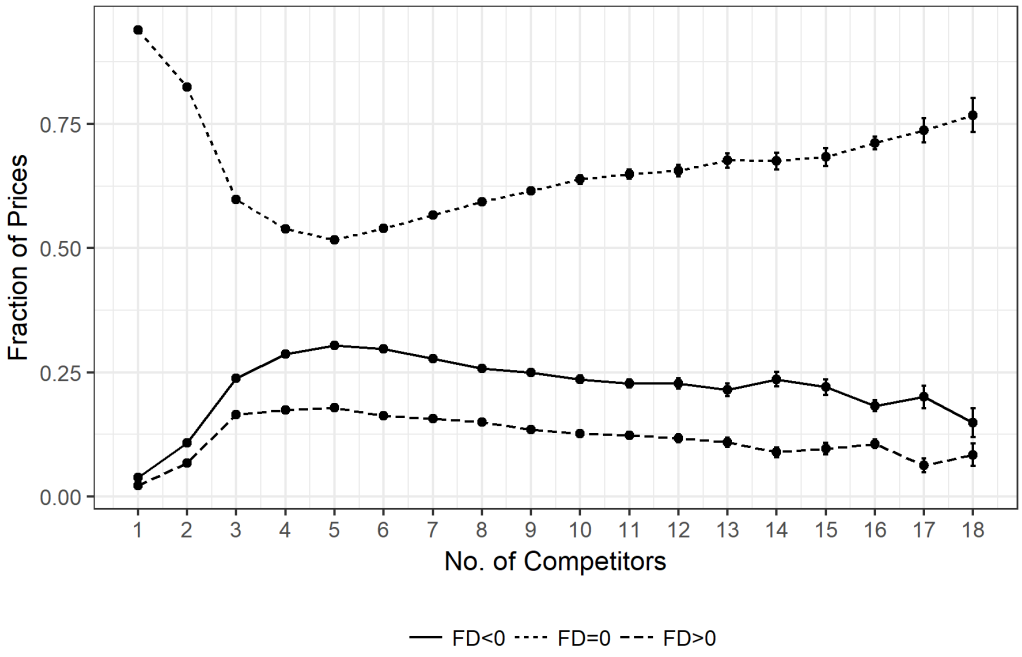
Table 4: Regressions, SPCs, APCs and Same Price Setting

Panel A: Price Cycles								
		$\overline{SPC}$		$log(\overline{SPC})$		$\overline{APC}$		$log(\overline{APC})$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\hat{\beta}_{1c}$	2.155**	2.445**	2.590*		2.380*	2.589*	3.151**	
	(0.872)	(1.070)	(1.267)		(1.192)	(1.341)	(1.466)	
$log(\beta_{1c})$				1.356**				1.388**
				(0.616)				(0.524)
Control for $\overline{NoComp}$	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Subsegment Control	No	No	Yes	Yes	No	No	Yes	Yes
N	28	28	28	28	28	28	28	28
R^2	0.151	0.195	0.207	0.165	0.098	0.110	0.160	0.130
Panel B: Same Price Setting								
		$\overline{Same}$		$log(\overline{Same})$		$\overline{Same}$		$log(\overline{Same})$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\hat{\beta}_{1c}$	−0.025	−0.038	−0.051					
	(0.033)	(0.050)	(0.062)					
$log(\beta_{1c})$				−0.042				
				(0.239)				
$\overline{Original}$					−0.001	−0.002	−0.004	
					(0.003)	(0.004)	(0.005)	
$log(\overline{Original})$								−0.082
								(0.138)
Control for $\overline{NoComp}$	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Subsegment Control	No	No	Yes	Yes	No	No	Yes	Yes
N	28	28	28	28	28	28	28	28
R^2	0.006	0.123	0.149	0.221	0.002	0.129	0.166	0.250

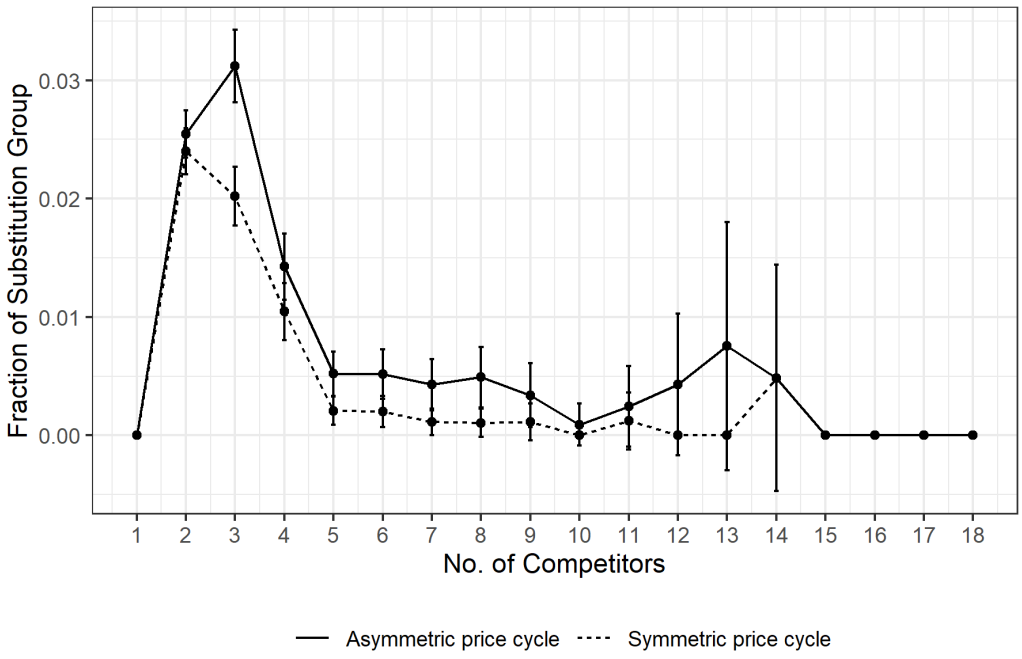
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table presents regression results of model 3. One observation is a substance (ATC code level). A substance includes multiple substitution groups. $\overline{SPC}$, $\overline{APC}$, and $\overline{Same}$ are the fraction of observations in c that are in an SPC, APC, or same price setting equilibrium over time. $\hat{\beta}_{1c}$ is the estimate of habit persistence based on Janssen (2019). $\overline{Original}$ is the average number of months when an original is one of the competing products. Control for $\overline{NoComp}$ and Subsegment Control indicate whether the model controls for the average number of competitors in a substance and the anatomical main group (painkillers, antibiotics, and antiepileptics). Standard errors are clustered on the substance level, adjusted for heterogeneity, and shown in parentheses.

Figure 6: Price Observations Conditional on the Number of Competitors



(a) First Differences in Prices



(b) Price Cycles

Notes: The figure presents two key measures of the pricing data. Figure 6a shows the first differences (FD) of prices conditional on the number of competitors in a substitution group. Conditional on the competitors in a substitution group at a time t, the three series show the share of products that have a negative, zero, or positive first price difference. Figure 6b presents the share of products in price cycles. Error bars correspond to the 95% confidence interval.

competitors (Supply Prediction 2). We observe price cycles in the situation of two competitors. However, the price data show even more price cycles with three competitors. Note also that price cycles are not observed frequently.

One primary concern of analyzing the effects of increasing competition on collusive behavior among firms is that the number of firms in a substitution group is endogenous and may be dependent on distinct unobservable demand patterns. I control for this by using time as well as substitution-group-specific fixed effects. Intuitively, I assume that demand patterns are stable in a substitution group, and I use the variation of competition within subgroups to identify effects. The analysis in this article is not intended to provide complete identification of the reasons for collusion. However, in the following, I try to investigate the variation within substitution groups, controlling for time-specific impacts within substances.

I collapse the data set on the substitution group level, where I denote a substitution group with i. Let k be a unique ATC code such that each product in substitution group i belongs to one ATC code $k \in K$.[19] An ATC code is an identifier for the active ingredient of a drug. If two drugs have identical ATC codes, their chemical substance is identical. However, a unique chemical substance is not necessarily only present in one substitution group, as a substitution group is defined by substance, strength, and size. The variable S_{it} takes the value 1 if one observes a price cycle in substitution group i at time t and 0 otherwise. I provide regression evidence for the following linear probability models for SPCs and APCs:

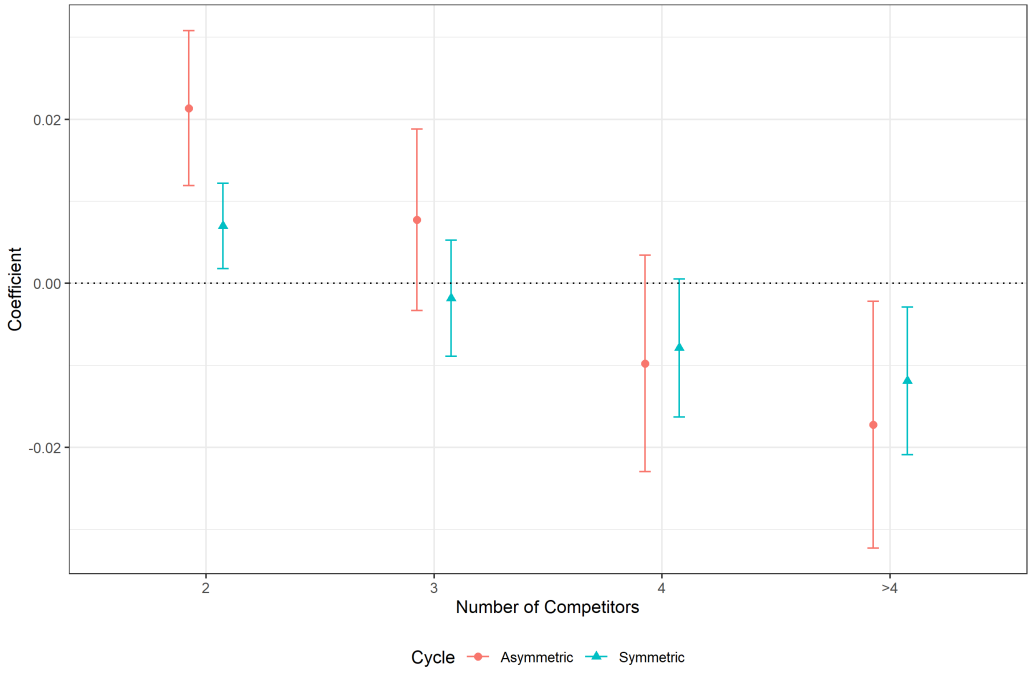
$$S_{ikt} = \beta C_{ikt} + \alpha_{ik} + \gamma_t + \rho ATC_k \cdot Month_t + \varepsilon_{ikt}, \tag{4}$$

where C_{ikt} is the number of competitors of substitution group i at time t, and I treat the variable as a factor to investigate possible discontinuous effects and combine the cases of more than four competitors. α_i is a vector of substitution group fixed effects, and γ_t is a vector of time fixed effects. In a final model, I include an interaction of the ATC code (ATC_k) and month-year as fixed effects. Without the interaction of the ATC code, I evaluate the effect of competition on price cycles using variation on the substitution group level with cross substitution-group-specific year-month fixed effects. With the interaction, I use variation between substitution groups at a given month on a substance level, controlling for substitution group fixed effects. For example, I would compare two substitution groups that offer the same antibiotic, once in 1-gram and the other in 2-gram pill size. It is likely that the ATC code allows controlling for multiple factors that may impact competition and could be related to price cycles, such as demand factors or the time since a product went off patent.

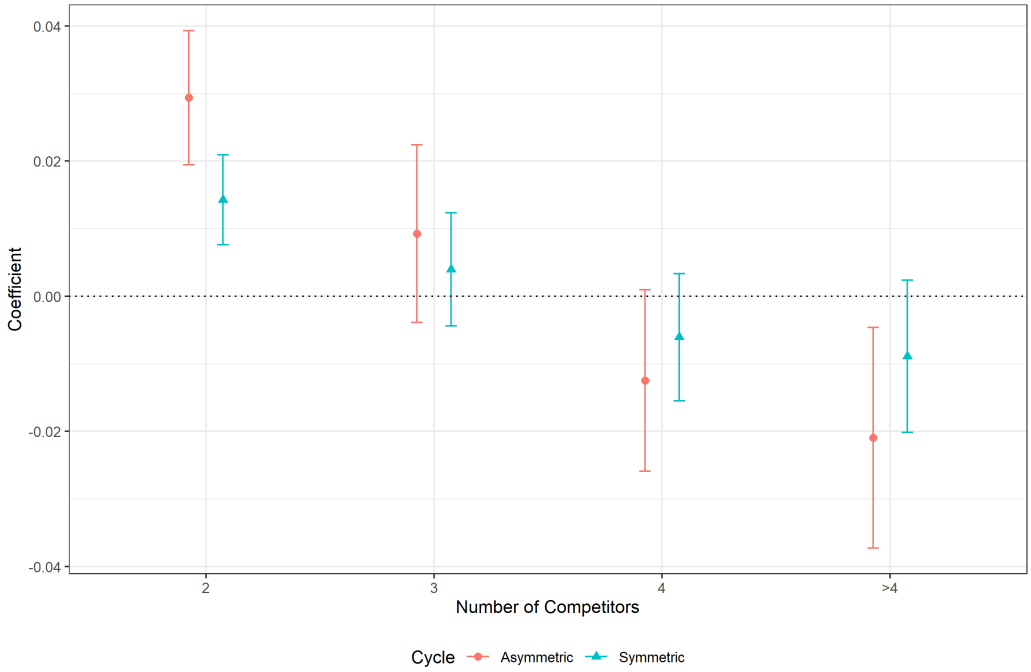
Figure 7 shows the estimated coefficients of β when using substitution and year-month (Figure 7a) fixed effects or when using substitution and ATC-code $\times$ year-month fixed effects (Figure 7a). Note that the competition coefficient for $C_{it} = 1$ is excluded, so the reference value is defined by a substitution group with one price-setting firm. Results for SPCs and APCs are similar: Subgroups with two competitors, compared to a monopolistic substitution group, increase the probability of being in an SPC by 0.7 to 1.5 and being in an APC by 2.1 to 3.1 percentage points. While price cycles are not common, the analysis confirms that the market structure of two competitors is especially related to the price cycle. This result aligns with the theory prediction that the most price cycles will occur when a tacit collusion scheme exists in a market environment with two competitors.

[19] The ATC code is ordered according to five levels. The first level describes the main anatomical group, the second level the main therapeutic group, the third level the pharmacological subgroup, the fourth level the chemical subgroup, and the fifth level the exact chemical substance. For this analysis, I use up the ATC code up to the fifth level.

Figure 7: Price Cycle Regressions



(a) Substitution and year-month fixed effects



(b) Substitution and ATC code $\times$ year-month fixed effects

Notes: The figure presents results of the regression framework of equation 4. One observation corresponds to a substitution group at time t. The dependent variable is a dummy that takes the value 1 if a substitution group at time t is in a symmetric price cycle (SPC) or asymmetric price cycle (APC). The subfigures show the estimates of β, the effect of the number of competitors. The reference value is a monopoly. I combine the competitors in cases of more than four firms in a market. Figure 7a includes substitution and year-month fixed effects while Figure 7b includes substitution and ATC code $\times$ year-month fixed effects. Standard errors are clustered at the substitution group level, adjusted for within-cluster correlation. The error bars represent 95% confidence intervals.

7.3 Supply Prediction 3

The third supply prediction states that price cycles due to tacit collusion exist for two and three competitors. Those are predicted when an original is available. From the descriptive data in Figure 6, we observe that the frequency of first positive and negative price differences over periods decreases slowly. Further, price cycles also are observable for three and even four competitors, but in comparison, when considering more than four competitors in a substitution group, the regression analysis presented in Figure 7 shows that price cycles decrease as the number of competitors increases. Substitution groups with three competitors show a positive but insignificant coefficient, whereas subgroups with more competitors are not associated with the existence of price cycles.

To investigate the impact of an existing original product on price cycles, I adjust the linear probability model of equation 4 by using an interaction between the number of competitors and a variable that indicates whether a firm with the original product is one of the price-setting firms as a regressor. In each model, I include substitution group and ATC code (ATC_k) $\times$ month-year fixed effects. I show results in Figure 8, where Figure 8a considers the effect on SPCs and Figure 8b the effect on APCs. Results in both are similar: we see a higher probability of price cycles for duopolies, independent of the existence of an original. However, for triopolies, only with an original do we observe a significant increase in the probability of SPCs or APCs. In comparison, we do not see an increase for triopolies of three generics. For more than three competitors, we see no effect on price cycles, independent of the availability of an original. Overall, the regression results are in line with Supply Prediction 3.

7.4 Alternative Explanations for Price Cycles

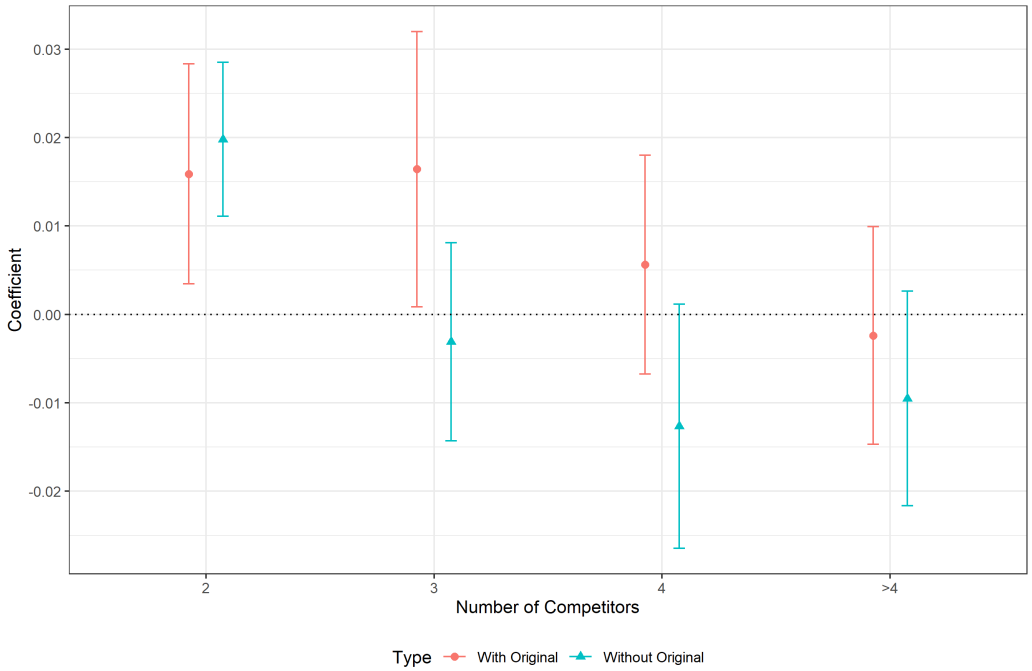
In the stylized model, I show that demand characteristics lead to the possibility of price cycles as the profit-maximizing collusion scheme. Within this section, I will discuss other potential channels that may affect firms' dynamic pricing incentives. Further, I will highlight which alternatives could explain SPCs and APCs in specific ways.

First, the model does not incorporate costs. Costs of firms likely differ, and, further, potential cost shocks could be idiosyncratic. Cost shocks over periods lead to the variability of prices. However, SPCs and APCs require regularly increasing and decreasing prices over at least three periods. Thus any relation to cost shocks would require regularity over cost shocks, which is less likely. Further, we observe SPCs and APCs for various substances, which likely have different cost factors, and therefore cost shocks could differ.

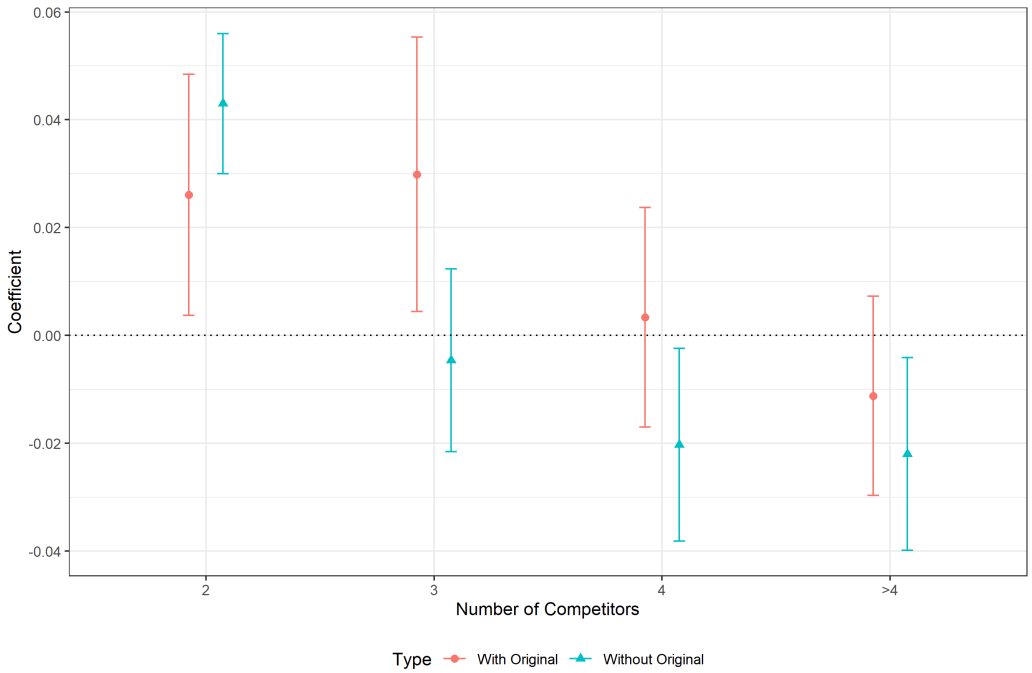
Note that competitive pricing in my and other models also leads to variation of prices that is non-random. Often firms may decrease prices to lock in consumers and follow with increased prices to harvest loyal buyers. Multiple models show that lock-ins of consumers lead to initially decreased and subsequently increased prices (see, e.g., Anderson and Kumar, 2007). Also, the competitive equilibria of my model show such behavior. In a duopoly, firms randomize, and the firm without locked-in (or habit-persistent) patients randomizes over a lower price distribution. In a triopoly, the firm with locked-in patients will increase its prices while the others randomize. Thus, the major difference between most competitive equilibria of the models in the literature, including the model in this paper, and price cycles is the regularity of prices within price cycles. Nevertheless, I fully acknowledge the possibility that other models could lead to competitive equilibria that also produce price cycles, as we see in the Swedish pharmaceutical market.

A third alternative explanation is capacity constraints. Manufacturers may face constraints as they cannot provide enough product for the entire Swedish market for several months. As the regulation requires that the cheapest available product should serve the full market capacity, constraints may cause firms that have had the cheapest product to increase their price in forthcoming periods to increase their storage. Therefore, even in the absence of habit-persistent

Figure 8: Price Cycle Regressions, Availability of Originals



(a) SPCs



(b) APCs

Notes: The two subfigures present results of the regression framework of equation 4 differentiating whether an original product is one of the price-setting firms. One observation corresponds to a substitution group at time t. The dependent variable is a dummy that takes the value 1 if a substitution group at time t is in an SPC (Figure 8a) or an APC (Figure 8b), Figures show the estimates of β, the effect of the number of competitors, either with one of them being an original or without an original. The reference value is a monopoly. I combine the competitors in the case of more than four firms in a market. Both regression include substitution and ATC code $\times$ year-month fixed effects. Standard errors are clustered at the substitution group level, adjusted for within-cluster correlation. The error bars represent 95% confidence intervals.

patients, we may observe individual firms that increase prices after having the cheapest product. Overall, I cannot exclude the possibility that capacity constraints could be the reason for price cycles. However, some arguments speak against the possibility of capacity constraints: First, we observe price cycles across substitution groups of different sizes. Second, we often observe that a price cycle arises and breaks down while the number of patients is stable. Third, price cycles often arise when a monopolist faces competition through an entry. However, the monopolists previously served the entire market without delivery problems. Finally, the Swedish market is rather small, and the majority of drug manufacturers also deliver their products to large markets in Germany or France.

8 Discussion

Whereas standard economic theory predicts lower costs where competition is greater, the opposite has been seen in some pharmaceutical markets. In this article, I have presented price cycles where firms rotate their prices between fixed upper and lower bounds. I have shown that the price cycles are the result of a profit-maximizing collusion scheme in a basic oligopoly framework where some of the patients are habit persistent. Further, pharmacists who are acting under highly regulated retailers are obliged to dispense the cheapest available generic. However, if multiple products have the same price within a month, they increase their profits mainly by increasing the quantity of one of the products.

Depending on the patience of firms and the state dependence of patients, two firms can form profit-increasing tacit collusion schemes in which the firms alternate their prices. Under the assumption of state-dependent patients, tacit collusion schemes of alternating prices are sustainable, whereas tacit collusion schemes of same prices are not. The model predicts that collusion between two firms is most likely in markets with two competitors. In markets with higher competition and sufficiently patient firms, collusion with three competitors may be possible, especially when an original with a high share of patients with a brand preference is present. In those markets, one firm may exploit patients with a brand preference while the other two firms form a collusion scheme. A sufficiently high base of patients with a brand preference leads to increasing profits for all three firms. Finally, I have also described the main predictions of pricing behavior in the absence of collusion conditional on the number of competitors in the market.

Besides documenting price cycles and rationalizing them within a model, the article has implications for collusion detection. Following the setup and assumption of the model, the apparent characteristic of alternating prices allows us to detect possible tacit collusion. While collusion schemes of constant pricing should be indistinguishable from marginal cost pricing as costs are unknown to a regulator, authorities could flag price cycles easily. Thus, in a market with habit persistence and brand preferences, it may be possible to detect collusion.[20]

However, collusion detection is based on the assumption that the oligopoly model and equilibria explain pricing in the markets entirely. I show that the subgroup of prices where I observe rotational patterns is in line with several predictions of the model. First, rotational price patterns between two firms are most frequently observed in markets with two and three competitors. Furthermore, markets where one does not observe collusive patterns confirm the model's prediction: (1) monopolists do not vary their prices and (2) the product of the month is more likely to increase in price in substitution groups with more than two competitors than in a market where only two firms compete. The main results are robust when I include a panel data method and look at variation within a market or within substances in a given month. Nevertheless, I emphasize that alternatives that explain price cycles, such as capacity constraints, are possible.

[20]Using prices to detect collusion is common in procurement auctions (Chassang et al., 2022; Ishii, 2014; Kawai and Nakabayashi, 2022; Kawai et al., 2022). Recent related research focuses on algorithmic pricing and collusion (Calvano et al., 2020).

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