# 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. For example, manufacturers who are the only supplier of a substance do not vary their prices. In oligopolies with two or three suppliers, firms occasionally rotate their prices in a symmetrical fashion. In markets with more than three suppliers, the cheapest firm often increases its price in the next month. The price patterns follow predictions from a model of dynamic price competition, where the demand for pharmaceuticals incorporates the known biases of consumers: habit persistence and brand preferences.

Keywords: Dynamic Oligopoly, State Dependence, Pharmaceutical Pricing, Price Cycles

JEL Codes: D43, L13, L40, L65

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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 pricing 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 to examine the pricing of off-patent pharmaceuticals. In particular, I aim to understand the reasons for marked cyclical patterns in the prices of some pharmaceuticals. The market for off-patent pharmaceuticals in Sweden is highly regulated. On the demand side, patients are reimbursed for the cheapest available generic on the market. On the supply side, centralized monthly auctions determine pharmaceutical prices. Pricing patterns for different segments (groups of medically equivalent pharmaceutical products) are heterogeneous. On one hand, the intertemporal variability of prices in segments where only one product is present is nearly nonexistent. On the other hand, prices in segments with more than one firm change frequently over time. In segments with more than two competitors, the price of many of the cheapest products increases drastically in the future month, such that potential patients are reimbursed only if they substitute on a monthly basis. Most interestingly, symmetric price cycles (SPCs) arise in segments with two or three competitors. In these price cycles, two competing pharmaceutical firms alternate their monthly prices such that patients observe a higher priced and a lower priced product each month. Furthermore, one recognizes subgroups when there are two competitors, where both firms charge the identical price over time. Figure 1 shows an example of a segment for Valsartan 320 mg as a treatment against high blood pressure and congestive heart

[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 homogenous product(Los Angeles Times, 2016). 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 of antitrust authority in November 2016 (Bloomberg, 2016).

failure. The segment shows two common characteristics: (1) SPCs with two generics between mid-2012 and mid-2013 and (2) reverting prices from mid-2013 to mid-2015. There are three competitors, where the cheapest product in a month increases its price in the subsequent month such that a competitor offers a lower price.

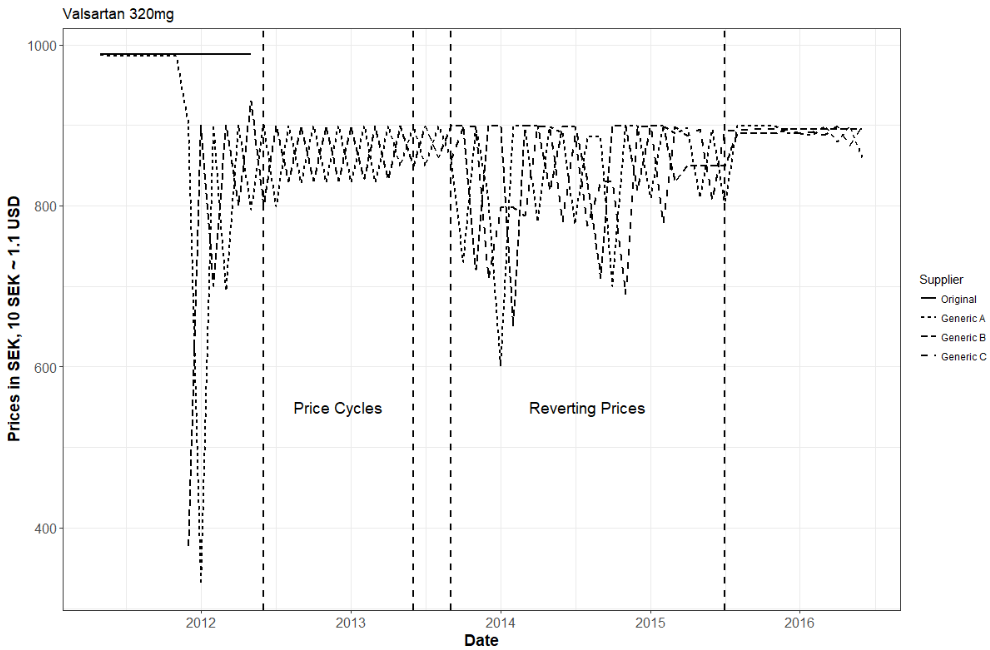



Figure 1: Example of price cycles and reverting prices

To frame the empirical analysis, I build a dynamic oligopoly model where firms repeatedly compete in prices. I explore the role of patients' behavior on pricing mechanisms by firms. The perceived quality difference of medically equivalent products (Bronnenberg et al., 2015), as well as persistent purchasing habits (Feng, 2017; Crawford and Shum, 2005; Hollis, 2002), are well documented in the literature. I characterize Markov perfect equilibria and subgame perfect equilibria in repeated games where patients are habit persistent and have different perceived qualities of products. I describe observable pricing patterns that are conditional on the number of competitors. Additionally, I present conditions under which collusion schemes between two competitors that are based on alternating prices are most efficient if patients are habit persistent and/or have brand preferences. Finally, I describe conditions under which two competitors form collusion schemes in which both firms charge identical prices over time.

The intent within the empirical part of my paper is to examine price patterns in the Swedish pharmaceutical market and relate the predictions of the model to observable outcomes. In a first step, I explore the the supply side. Using segment and time fixed effects, I exploit within-segment variation in market structure to identify links between pricing patterns and number of competitors. Important features of my model are consistent with the data. For example, (1) monopolists do not vary their prices, whereas price variation is high in subgroups with more than one competitor; (2) alternating prices between two firms are present in subgroups with two and three competitors; and (3) the majority of firms that offer the cheapest product one month increase the price of their product in the future month.

In a second step, I incorporate the demand side. I demonstrate that the development of market shares can be explained by patient's habit persistence and brand preferences. Using variation of habit persistence across therapeutic subgroups I show that the model is well suited for prediction of competitive as well as tacit collusive pricing equilibria.

The model, as well as the empirical investigation of the Swedish pharmaceutical market, exemplify the importance of inter-temporal demand for pricing incentives of firms. Thereby, the consumer's dynamic demand offers the possibility to detect tacit collusion. In markets where brand preferences and habit persistence of patients is low, dynamic prices in competitive equilibria are indistinguishable from tacit collusion. 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, habit persistence can facilitate detection of tacit collusion schemes as dynamic price relations are different from those in competitive equilibria.

## 2 Related Literature

My model describes a dynamic oligopoly where firms compete in 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) provide 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 leads 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.[4]

The existence of switching costs has been documented in various empirical studies, i.e., Calem and Mester (1995), Dubé et al. (2010), Keane (1997), Shcherbakov (2016), Shum (2004), Shy (2002), or Viard (2007). In a study relevant to the pharmaceutical market, Hollis (2002) shows that the first generic pharmaceutical in the Canadian market has a competitive advantage to followers. Further, Feng (2017) presents evidence that the demand for pharmaceuticals in the anti-cholesterol market shows habit persistence. Also Crawford and Shum (2005) suggests switching costs for anti-ulcer drugs. Janssen (2019) estimates switching costs of Painkillers, Antibiotics and Anti-epileptics in the Swedish market. I show that switching costs are one explanation for observable price patterns in theory as well as in the observable data.

The model of this article is closely related to the approaches by Padilla (1995), Anderson et al. (2004), and Anderson and Kumar (2007).[5] I extend the model to three competitors and

[2]General evidence of different perceptions of patients toward substitution can be found in Bronnenberg et al. (2015), Hassali et al. (2005), or Pereira et al. (2005).

[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, i.e., Dutta et al. (2007).

[4]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 about previous literature and questions about when switching costs make markets more or less competitive can be found in Ruiz-Aliseda (2016).

[5]Unlike previous approaches, I restrict the analysis to switching costs that are high enough such that habit persistence is independent of price differences, and patients stick to their product in the short term with certainty.

characterize Markov perfect equilibria with three firms. Padilla (1995) and Anderson et al. (2004) briefly discuss tacit collusion within dynamic oligopolies. They restrict their attention to cases in which both firms charge a monopoly price. Thus, collusion is less sustainable than in the absence of switching costs. I further extend the literature by characterizing a tacit collusion mechanism where firms alternate 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. Einav (2007) presents evidence that in the US motion picture industry, alternating film release dates are strategic objects and not exogenously determined. 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 habit persistence of patients.

This article is related to the pricing of pharmaceuticals under generic entry. Generic entry and the price-setting behavior of generic and brand product manufacturers has received considerable attention in the literature. 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)[6]). This article differs, as I investigate dynamic competition between branded and generic pharmaceuticals 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.

Price cycles in the form of Edgeworth cycles are well documented in the economic literature. Maskin and Tirole (1988) show that oligopolistic competition may result in dynamic prices where competitors marginally undercut each other before one competitor considerably increases the price. Afterwards, the cycles repeat. Edgeworth cycles are observable in retail gasoline prices (see, e.g.,

[6] One explanation is a segmentation of the market into cross-price-elastic patients and loyal, entirely-price-inelastic patients. Producers from branded pharmaceuticals may focus solely on price-inelastic patients after a generic product has entered the market (Frank and Salkever, 1997). Strategic entry deterrence may also play a crucial role (for a discussion, see, i.e., (Ellison and Ellison, 2011).

Noel, 2007a, Noel, 2007b or Doyle et al., 2010). However, 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. My study is further related to factors that facilitate collusion and collusion detection. Porter (2005) gives an overview of these topics.[7]

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 of a predefined group of identical substances. The introduction of the reform decreased the prices of generics by approximately 10%. Granlund et al. (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.

[7]Throughout the paper, I focus on tacit collusion in which firms infer all their information from market outcomes. In the Swedish pharmaceutical market, firms can immediately observe a deviation from a possible collusion scheme, which decreases the profit of deviation (see, e.g., Albaek et al. (1997) for an empirical case study). Entry barriers are relatively high regarding financial and time costs, as a firm with a new generic has to apply for marketing authorization from a medical product agency, which is the authority responsible for providing marketing authorization for medical products. Further, the medical product agency decides about the possibility of substitution before entering a market. Nevertheless, entry possibilities may facilitate collusion detection. An example can be found in Bajari and Ye (2003), who show an empirical method in which collusive firms can be detected, as their strategies are different from non-collusive firms conditional on observable characteristics. Pharmaceutical firms in Sweden compete in various markets, and the literature has shown (i.e., (Ciliberto and Williams, 2014) as a theoretical example) that multimarket contacts may facilitate collusion.

# 3 Institutional Background

The Swedish health care system is mainly government-funded, and health care coverage is universal. The system covers reimbursement for prescription drugs.[8] Patients' co-payments for all health care expenditures are decreasing with yearly expenses. A cost ceiling is reached over 5300 Swedish Krona (approx. $ 550).[9] Patients' out-of-pocket expenses are dependent on the yearly costs. The higher the yearly expenditures are, the lower the share of out-of-pocket costs. After reaching a ceiling, all costs are covered.[10]

One important characteristic of the Swedish pharmaceutical system is that patients are incentivized to acquire the cheapest available generic substitute. 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, 2016c), 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 as shown in Table 1. Second, the product of the month may be out of stock. The pharmacy is then allowed to substitute the second cheapest product (reserve 1) or, if neither is available, the pharmacy dispenses the second reserve product. 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. Only the price of the product of the

[8]The exact products that are reimbursed are subject to the decision of the Dental and Pharmaceutical Benefits Agency (TLV). Note that some products are just partly reimbursed. See TLV (2016e) for detailed information.

[9]The exact copayment function before and after a reform in 2012 are described in Empirical Online Appendix N. Expenses for visits to a primary health care provider, visits to specialists, hospital treatments, and prescription drugs are accumulatively covered in the benefit scheme, which is subject to yearly co-payments. Additional user charges for health care visits, as well as per-bed-day stays in hospitals, also exist. Costs for pharmaceuticals that are not in the benefit scheme are not covered, and their prices are therefore less regulated. Prescription-free medicines (over-the-counter) that are not solely sold in pharmacies and 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 patients do not have any expenses.

[10]Bergman et al. (2012) note that approximately half of the revenue in the pharmaceutical sector in 2000 was due to individuals who had reached the high-cost ceiling with no co-payment.

month is subject to the co-payment structure.[11] Previous research has indicated that a substantial number of patients do not receive the product of the month.[12]

Off-patent drugs are subject to a tendering system.[13] The Dental and Pharmaceutical Benefits Agency (TLV) organizes a monthly auction such that the cheapest product of a predefined substitution group (determined by the medical product agency) receives product-of-the-month status.[14] The details of the first-price sealed-bid auction 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 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.[15] In the middle of the next month (*Month B*), the TLV publishes a preliminary result of the auctions. 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.[16] One essential feature of the timing is that pharmaceutical suppliers see the preliminary list for the next month before bidding for the month after next (TLV, 2016c).

[11] In case the original prescription drug is chosen, the price difference between the cheapest and the prescribed product is equal to the out of pocket expenses. If the patients would like to purchase a third pharmaceutical that is neither prescribed nor the product of the month the entire price is equal to the out of pocket expenses. Note that empirically only out of pocket expenses equal to the price differences are observable.

[12] See estimation of Janssen (2019) and Bergman et al. (2012). For example 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.

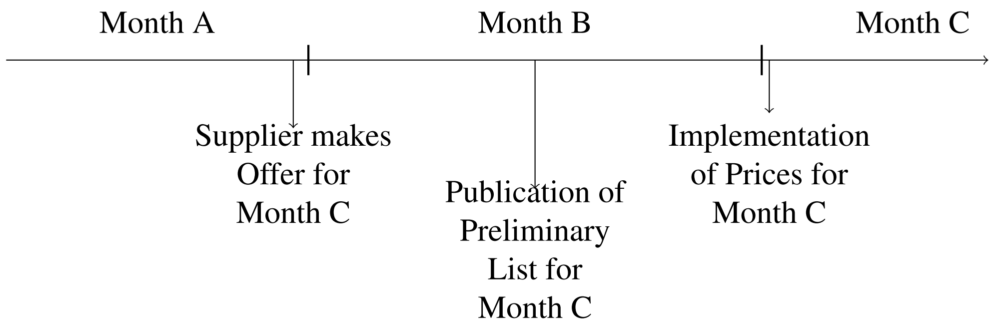
[13] The pharmaceutical market for prescription drugs in Sweden was approximately $4.51 billion in 2015. Prescription drugs accounted for 61% of the market ($3.08 billion). Patients' co-payments in this segment were $0.64 billion in 2015 (TLV, 2016a).

[14] Note that usually patients get prescription for a specific group. It could be possible to substitute between substitution group, like for example in size or strength. However, empirically the substitution between substitution groups is rather uncommon and happens mostly if a product is not in stock, which happens in approximately 3% of the cases, see Section 5. Therefore it is appropriate to treat a substitution group as an independent market. Before 2014, the system determined the product of the month that pharmacies were supposed to dispense. Since 2014, the system determines the product of the month as well as two reserves, which are the second and third cheapest products in a substitution group. The reason for choosing the two reserves is that pharmacies often experience difficulties dispensing only the single product of the month

[15] 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, 2016b).

[16] If a company confirms its ability to deliver but fails to do so, it is subject to a penalty fee.

Figure 2: *Timeline of auction*




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[17] (TLV, 2016d).[18] Pharmacies are obliged to dispense the product of the month if not opposed by physicians or patients. Profits for prescription drugs are increasing in price of products, such that pharmacies could enhance their profits by dispensing a more expensive product.[19] If the product of the month is not in stock, the pharmacy dispenses the cheapest available reserve product. [20]

# 4 Model

I follow the model setup of Padilla (1995) and Anderson et al. (2004) and extend it to three competitors and by integrating the institutional background of the Swedish system. I describe the setup in subsection 4.1. The remaining subsections show results for different competitive environments.

[17] The exact function from purchasing to retail prices is described in Empirical Online Appendix O. The function has been subject to slight change in 2016(TLV, 2016d).

[18] Pharmacies were privatized in 2009. Two thirds of the pharmacies were privatized, and the remaining one third remains under public control.

[19] Anecdotal as well as empirical evidence (Janssen, 2019) shows that pharmacies follow the rule.

[20] 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.

## 4.1 Setup

There are $N = \{1,...,n\}$ firms that produce a homogenous product and compete in prices. Marginal costs are equal to zero. In each time $t \in \{1,2,...\}$, firm $j \in N$ sets a price $p^t_j$. Prices are set simultaneously and they are bounded by $P = [0,R]$. Firm $j$ faces a demand $D^t_j$. The firm-specific demand depends on a state $x^t \in \mathscr{L} = \{1,...,n\}$. 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 (the firm $j$ for which $x^t = j$). Third, each firm has firm-specific loyal patients $l_j$. Loyal patients have specific brand preferences and are price inelastic. I define the patients with a brand preference as a share of a unit mass such that $\sum_j l_j = 1$. 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. 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 $\frac{1-l^H}{N-1} = l^L$. The value of the habit-persistent patients $\theta$ and patients with a brand preference $l^L$ and $l^H$ is time-independent. 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[21]

$$D^t_j = \begin{cases} l_j & \text{if} \quad p^t_j \geq p^t_{-j} \\ 1 + l_j & \text{if} \quad p^t_j < p^t_{-j} \end{cases}$$

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

$$D^t_j = \begin{cases} \theta + l_j & \text{if} \quad p^t_j > p^t_{-j} \\ 1 + \theta + l_j & \text{if} \quad p^t_j \leq p^t_{-j}. \end{cases}$$

The initial state $x^1$ is given. For each period $t > 1$ a transition function $T$ determines the state

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

$x^t$. 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 has been $x^{t-1} = j$, 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 who 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.

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

**Definition 1.** The game $\mathscr{G}(x^1)$ is a tuple $\langle N, P, (V_j)_{j\in N}, T, \delta \rangle$. $N = \{1, 2, ..., n\}$ is a set of players.

$P = [0,R]$ is an action space that is the same for all players. The initial state $x^1 \in \mathscr{L}$ is given. $V_j(P^n, x)$ is a payoff function for each player. $T : \cup_{x \in \mathscr{L}}(\{x\} \times P^n) \to \Delta\mathscr{L}$ is a transition function. Further, $\delta \in (0,1)$ is a discount factor.

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 pay-off relevant strategies of a subgame. Naturally, an MPE forms an SPE. Formally, players condition their strategies in an MPE on pay-off relevant states, $\mathscr{S}_j : \mathscr{L} \to \Delta(P)$. $(s_j^*)_{j \in N} \in \mathscr{S}_j$ then 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 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 a SPE if and only if for all $j \in N$ and all $t \in \{1, 2, ...\}$, $V_j^t(s_j^{t*}, s_{-j}^{t*}, x^t) \geq V_j^t(s_j^t, s_{-j}^{t*}, x^t)$.

## 4.2 Results

### 4.2.1 Monopoly

Given perfect inelastic demand, a monopolist maximizes his profits by choosing the highest possible price. A monopolist sets the price at the upper bound and does not vary his 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.* Theoretical Online Appendix A. □

### 4.2.2 Duopoly

I begin with 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 the 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.[22] 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 $j = 1$ reaches a price where it would have an incentive to increase its price up to $R$, as the habit-persistent patients is sufficiently high. The next proposition characterizes the mixed equilibrium of the game. Note that I use the subscripts to indicate if $x = j$ (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 $j \in N$:*

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

2. *Valuation functions:*

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

*Proof.* Theoretical Online Appendix C. □

[22] Proof in Lemma 2; see Theoretical Online Appendix B.

*Numerical Example*. Theoretical Online Appendix C.

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.[23]

In *Theoretical Online Appendix D*, 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 homogenous share 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:** I analyze the collusion scheme 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 when there are habit-persistent patients (i.e., $\theta \neq 0$). 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 $x = j$) 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 higher profit

[23]Note that the lower support of the distribution between a firm with and a firm without habit-persistent patients is identical. The reason is that the firm without habit-persistent patients has no incentive to decrease its price further, and the firm with habit-persistent patients is exactly indifferent. 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., $f(p|x \neq j) < f(p|x = j)$. 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).

than the non-deviating profit.[24] Correspondingly, market sharing by setting $p = R$ for both firms cannot be the first best collusion, as one firm (the firm that starts in the unfavorable state $x^1 \neq j$) 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.[25]

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 a 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*

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

*Proof.* Theoretical Online Appendix F. □

Firms coordinate on alternating prices in subsequent periods. The firm with habit-persistent patients charges the high price, whereas the firm without habit-persistent patients sets a low price. The deviation is prevented by a sufficiently high price such that neither the firm with nor the firm without habit-persistent patients has an incentive to deviate.[26]

[24] See Theoretical Online Appendix E for a proof of this result.

[25] 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 $l$.

[26] 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 only 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 $\underline{p}$.

### 4.2.3 Triopoly

For $N = \{1,2,3\}$, I derive a general MPE for the two most common situations of the pharmaceutical market, namely (1) when three generics with an equal share of patients with a brand preference are competing such that $l_1 = l_2 = l_3 = l^L$ and (2) when two generic products compete with a branded product such that $l_1 = l^H > l^L = l_2 = l_3$.

**Proposition 3.** *The game $\mathscr{G}(x^1)$ with $N = \{1,2,3\}$, $l_1 = l_2 = l_3 = l^L = l$, $\delta \in (0,1)$ given any initial state $x^1 \in \mathscr{L}$ has an MPE defined by the following conditions:*

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

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

2. *Valuation functions:*

$$V(\underline{p}|x \neq j) = \frac{\underline{p}(1+l)+\delta R(\theta+l)}{1-\delta^2} \qquad \text{where } \underline{p} = \frac{R(l-\delta\theta)}{1+l}$$
$$V(\underline{p}|x = j) = \frac{R(\theta+l)+\delta\underline{p}(1+l)}{1-\delta^2}$$

*Proof.* Theoretical Online Appendix G. □

*Numerical Example*. Theoretical Online Appendix G.

The basic intuition of the MPE is the following. The firm with habit-persistent patients is charging the maximum price $R$ with certainty. The two remaining firms compete for the new patients. As in the duopoly MPE, the two firms without habit-persistent patients randomize their prices. At the same time, the firm with habit-persistent patients has no incentive to deviate given the minimum support $\underline{p}$. As both randomizing firms have no habit-persistent patients, the minimum support is lower than in the MPE of a duopoly. The essential difference to the MPE of duopolists is that the firm with the lowest price always increases its price in the following period.

In the second case, one branded firm (firm 1) has a higher mass of patients with a brand preference than two generic firms (firm 2 and 3).

**Proposition 4.** *The game $\mathscr{G}(x^1)$ with $N=\{1,2,3\}$, $l_1=l^H>l^L=l_2=l_3$, $\delta\in(0,1)$ given any initial state $x^1\in\mathscr{L}$ has an MPE defined by the following conditions:*

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

$$S_1: p_1 = R$$

$$S_j: \begin{cases} p_j \sim F(p) = \frac{p(1+l^L+\theta)-V(\cdot|x=j)(1-\delta)}{p+\delta(V(\cdot|x=j)-V(\cdot|x\neq j))} & \text{for } p\in[\underline{p},R] \quad \text{if } x\neq j \quad \text{for all } j\in\{2,3\} \\ p_j \sim F_1^j(p) = \frac{p(1+l^L)+\delta V(\cdot|x=j)-V(\cdot|x\neq j)}{p+\delta(V(\cdot|x=j)-V(\cdot|x\neq j))} & \text{for } p\in[\underline{p},R] \quad \text{if } x=j \quad \text{for all } j\in\{2,3\} \end{cases}$$

2. *Valuation functions:*

$$V_j = \frac{Rl^H}{1-\delta} \qquad \text{for } j=1$$

$$V_j(\underline{p}|x\neq j) = \frac{\underline{p}(1+l^L+\theta\delta)}{1-\delta} \qquad \text{for all } j\in\{2,3\} \quad \text{where } \underline{p} = \frac{R(\theta+l^L)}{1+l^L+\theta+\delta\theta}$$ [27]

$$V_j(\underline{p}|x=j) = \frac{\underline{p}(1+l^L+\theta)}{1-\delta} \qquad \text{for all } j\in\{2,3\}$$

*Proof.* Theoretical Online Appendix H. □

In this MPE, the supplier of a branded product charges the highest possible price $R$. The two remaining firms with a generic product set their price as in a duopoly. Both randomize their prices, and the firm with habit-persistent patients has a higher possibility of charging a higher price. To guarantee the existence of this equilibrium, the firm of the branded product should have no incentive to deviate from charging $R$. Given a sufficiently low minimum support $\underline{p}$, the branded product firm has no incentive to deviate. In general, the difference between the mass of patients with a brand preference for the original and the non-branded product has to be sufficiently high.

**Collusion between generics:** In a triopoly, one may observe a different kind of collusion scheme.[28] A collusion scheme with two firms is achievable if one focuses on the case of heterogeneous bases of patients with a brand preference. In the following, I present an SPE in which

[27] Note that we require that $\underline{p} = \frac{R(\theta+l^L)}{1+l^L+\theta+\delta\theta} \leq \frac{R(l^H-\delta\theta)}{1+l^H}$ such that the firm with $l^H$ has no incentive to deviate.

[28] It may be possible that three firms take part in a collusion scheme. In the analysis, I focus on the analysis of collusion schemes with two firms. In line with previous research, the coordination of three firms requires more patience by firms, all else being equal.

the two firms with $l^L$ implement a tacit collusion scheme in which they rotate prices. At the same time, the firm with a higher base of patients with a brand preference $l^H > l^L$ has no incentive to deviate from charging a price equal to the price ceiling. The punishment of deviation is reversion to the previous MPE, defined in Proposition 4.

**Proposition 5.** *The game $\mathscr{G}^{SP}(x^1)$ with $N = \{1,2,3\}$, $l_1 = l^H > l^L = l_2 = l_3$, $\delta \in (0,1)$ given any initial state $x^1 \in \mathscr{L}$ has SPE of the following strategies:*

$$\mathscr{S}_j^t : p_j^t = R \quad \text{for } j = 1$$

$$\mathscr{S}_j^t : \begin{cases} p_j^t = R & \text{if } x^t = j \text{ and } t = 1 \quad \text{for all } j \in \{2,3\} \\ p_j^t = \underline{p} & \text{if } x^t \neq j \text{ and } t = 1 \quad \text{for all } j \in \{2,3\} \\ p_j^t = R & \text{if } p_j^{t-1} = \underline{p} \text{ and } p_{-j}^{t-1} = R \quad \text{for all } t > 1 \quad \text{and } j \in \{2,3\} \\ p_j^t = \underline{p} & \text{if } p_j^{t-1} = R \text{ and } p_{-j}^{t-1} = \underline{p} \quad \text{for all } t > 1 \quad \text{and } j \in \{2,3\} \\ \text{Reversion to MPE} & \text{otherwise} \quad \text{for all } j \in \{2,3\} \end{cases}$$

*Where in each equilibria $\underline{p}$ satisfies:*

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

*Proof.* Appendix I. □

One restriction of such an SPE is that $\underline{p}$ is bounded from below as well as from above. On the one side, the firm with $l^L$ patients with a brand preference and no habit-persistent patients should have no incentive to increase its price from $\underline{p}$, which results in a lower bound. On the other side, the firm with $l^H$ should have no incentive to decrease its price from $R$, which leads to the upper bound. Note that one needs sufficiently patient patients and a sufficiently high difference between $l^H$ and $l^L$ for such an equilibrium to exist.

### 4.2.4 Oligopoly with more than three firms

In the case of $|N| \geq 4$, I do not completely characterize the MPE and possible collusion schemes in SPE. However, I will highlight some main features that will hold even with $|N| \geq 4$. First, consider Markov strategies. A firm with locked-in patients has an incentive to increase its price up to the maximum price. The intuition is the same as for three competitors, where all suppliers are offering generic products: at least two firms without locked-in patients offer a generic product. These firms compete for new patients. Correspondingly, the firm with locked-in patients has no incentive to lower its price given the higher base of price-inelastic patients. I expect that the price of the cheapest product (product of the month) will increase in the forthcoming month.

I already have noted that rotation schemes that form a SPE have more requirements for three firms than for two firms. However, the reasoning that one original brand product competes with two generics and that an original brand product has a higher mass of loyal consumers leads to the possibility of a rotational SPE where the generic products share the market but the original brand solely set the highest possible price. If there are at least three firms who offer generic products, a collusion scheme will require a higher degree of coordination. A possible collusion scheme would be based on three generics that share the market. Such a collusion mechanism increases the incentive to deviate. Within this paper, I focus on the collusion schemes of two firms. In markets with more than three firms, I predict that these collusion schemes are less likely.

# 5 Data

I use two data sources to validate the model empirically. 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 substiution group it belongs to. I exclude subgroups that were in place 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. Data of quantities are restricted to a level such that I can differentiate between neither substitution groups nor products. Therefore, I can only use quantities for basic summary purposes.

For the analysis of the demand side, I use 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 (ATC code:[29] N02), anti-antiepileptics/anticonvulsants (ATC code: N03), antibiotics (ATC code: J01), and beta-blockers (ATC code: C07). The data of the demand side is on the same level (product specific, monthly) as the supply data. It includes product specific monthly sales which allows to explore market shares of products within substitution groups (substance $\times$ strength $\times$ package combination) of the four pharmaceutical subgroups.

I begin the analysis with a general description of the price data. Table 1 shows summary statistics on the individual product level, where the price of a product at time $t$ corresponds to one observation. The first column summarizes the entire sample. The second column represents those observations of products in an asymmetric price cycle (APC), and the third column describes the observations in an SPC. For the duration of 6.5 years, I observe 350,057 prices, where 2389 and 1365 prices are of products in APCs and SPCs, respectively. Products in a price cycle are more often the product of the month (cheapest product in a substitution group in a period) and almost always one of the three cheapest products. In the complete sample, the majority of prices, around 75.4%, are set by generics, 15.2% are from original producers, and the remaining are from parallel importers or parallel distributors. Products participating in a price cycle are more often generics (around 90%) and less likely to be originals (approximately 7% for APCs and 9% for SPCs). Products in a price cycle are cheaper than products of the entire sample.

Table 2 shows summary statistics on the substitution group level. The complete sample has 2251 substitution groups. In 258 and 162 substitution groups, one observes APCs and SPCs in at least some periods. The average number of competitors in a substitution group is lower in substitution groups *during* price cycles (2.53 in APCs and 2.39 in SPCs) than in a representative

[29] The ATC code is ordered according to five levels. The first level describes the anatomical main group, the second level the therapeutic main group, the third level the pharmacological subgroup, the fourth level the chemical subgroup, and the fifth level the exact chemical substance.

Table 1: Summary Statistics, Products

| | Entire | APC | SPC |
|---|---|---|---|
| N | 350057 | 2389 | 1365 |
| Share Prod. Month | 0.334 | 0.523 | 0.672 |
| Share Prod. Month or Res. | 0.501 | 0.948 | 0.967 |
| Share Original | 0.152 | 0.069 | 0.089 |
| Share Generics | 0.754 | 0.916 | 0.897 |
| Share Parallelimp. | 0.051 | 0.015 | 0.014 |
| Price | 378.57 | 216.43 | 181.34 |
| | (1356.91) | (331.93) | (221.09) |
| Mean log(P) | 5.19 | 5.03 | 4.95 |
| | (0.981) | (0.705) | (0.625) |

*Notes: Summary statistics on individual product level. One Observation corresponds to a product in a time period t. N are the number of observations. The Prod. Month is usually the cheapest available product in a substitution group at time t. Res. is the reserve status which is awarded to the second as well as third cheapest product in a substitution group. Price is the retail price of a product, averaged across products and months between January 2010 and June 2016. Standard deviations in parentheses.*

substitution group of the entire sample (2.79). However, the distributions of the number of competitors among substitution groups differ substantially when comparing the complete sample and the price cycle subsamples. Approximately 43.9% of the substitution groups over time only have one price-setting firm. The majority of substitution groups where I observe price cycles is composed of two ($N = 2$, 63% of APCs and 69% of SPCs) or three ($N = 3$, 28% of APCs and 25% of SPCs) firms. The average price difference between the highest and the lowest observed price in a substitution group is lower for substitution groups with price cycles. The number of prescriptions is on average slightly higher in substitution groups with price cycles. One observes the same correlation for the average number of dispensed daily doses of a substance per person. However, both differences are not statistically significant. On average, 0.75 products enter and exit a substitution group. In substitution groups during a price cycle, the entry and exit observations are considerably lower.

Finally, I describe the demand data for the four different therapeutic subgroups.[30] As shown in

[30] I compare the supply and demand side directly in Empirical Online Appendix A.

Table 2: Summary Statistics, Substitution Groups

| | Entire | APC | SPC |
|---|---|---|---|
| Subst. Groups | 2251 | 258 | 162 |
| Mean No. Comp | 2.79 | 2.53 | 2.39 |
| | (2.58) | (0.94) | (0.68) |
| N=1 | 0.439 | 0 | 0 |
| N=2 | 0.206 | 0.634 | 0.688 |
| N=3 | 0.108 | 0.279 | 0.248 |
| N>3 | 0.247 | 0.087 | 0.063 |
| Average Maximal Price Diff. | 112.2 | 21.2 | 14.7 |
| Avg. No. Presc. | 40719.3 | 41278.3 | 43218.4 |
| | (62683.4) | (45974.5) | (50764.4) |
| Avg. DDD p.P. | 197.5 | 205.1 | 189 |
| | (214) | (242.3) | (247.5) |
| Mean Entries | 0.77 | 0.058 | 0.037 |
| | (1.386) | (0.234) | (0.189) |
| Mean Exits | 0.758 | 0.097 | 0.123 |
| | (1.391) | (0.309) | (0.348) |

*Notes: Summary statistics on the substitution group level. One observation corresponds to a substitution group at time t. The Mean of Number of Competitors is the the mean over all substitution groups and time periods. For the calculation of the mean of the number of competitors in price cycles one restricts the observations to those substitution groups where two competitors are in a price cycle at time t. $N = 1$, $N = 2$, $N = 3$ and $N > 3$ corresponds to the substitution groups which have one, two, three or more than three competing products at time t. The Mean of Maximal Price Diff. evaluates the difference between the maximum price between the cheapest and most expensive product in a substitution group at time t. The Mean Number of Prescriptions incorporates information about the number of prescriptions whereas the Mean DDD p.P evaluates the dispensed daily doses per Person in t. Note that the number of prescriptions as well as the dispensed daily doses data is on a yearly level and not available for every substitution group. Averages across products and months between January 2010 and June 2016. Standard deviations in parentheses.*

Table 3, the number of substitution groups as well as the products of the four therapeutic subgroups is a subset of the entire pharmaceutical market. The number of purchase occasions within the time horizon simply describes 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 one. 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. In rare cases, physicians prohibited substitution or pharmacies did not substitute because the product of the month was unavailable.

# 6 Supply Side

Given the modeling assumptions, I expect to observe pricing patterns conditional on the number of competitors. Besides general differences in MPE pricing, I further expect tacit collusion in some markets. In the following, I present some key implications of the model.

I start with fundamental implications for possible tacit collusion schemes. I define a possible collusion scheme as a rotation between two firms. To identify rotation schemes in the data, I define two different rotation types. The first rotation is based on a price cycle where firms rotate between a common upper and lower price floor. Each period, one of the two firms offers the cheapest product.

**Definition 2.** A firm $j \in N$ in period $t$ is rotating its price if and only if the following conditions hold:

Table 3: Summary Statistics, Demand Side

| | Painkillers | Antiepileptic | Antibiotics | Beta-Blocker |
|---|---|---|---|---|
| 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 p.P. | 12.06 | 9.42 | 2.92 | 20.25 |
| | (26.27) | (14.12) | (3.56) | (27.77) |
| Frac. Consumption of Period of the Month | 0.73 | 0.93 | 0.87 | 0.86 |
| | (0.44) | (0.26) | (0.34) | (0.35) |
| Frac. Opposed Substitution by Patient | 0.209 | 0.028 | 0.094 | 0.08 |
| | (0.406) | (0.165) | (0.292) | (0.272) |
| Frac. Substitution Prohibited by Physician | 0.024 | 0.018 | 0.005 | 0.038 |
| | (0.152) | (0.132) | (0.071) | (0.192) |
| Frac. 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 of the four therapeutic groups. Prescriptions between January 2010 and June 2016 are considered. One purchase occasion corresponds to a filled in prescription.*

1. $0 < |p_{jt+1} - p_{jt}|$

2. $0 = |p_{jt+2} - p_{jt}|$

The firms that are rotating at time $t$ are $C_t^{PC} \in N$. The firms are in an SPC if and only if the following conditions hold:

3. $|C_t^{PC}| \geq 2$

4. $p_{it} = p_{jt+1}$, where $i, j \in C_t^{PC} \wedge i \neq j$

Second, I define an APC where firms rotate between an individual upper and lower price floor. Again, a different firm is the cheaper available option in each period.

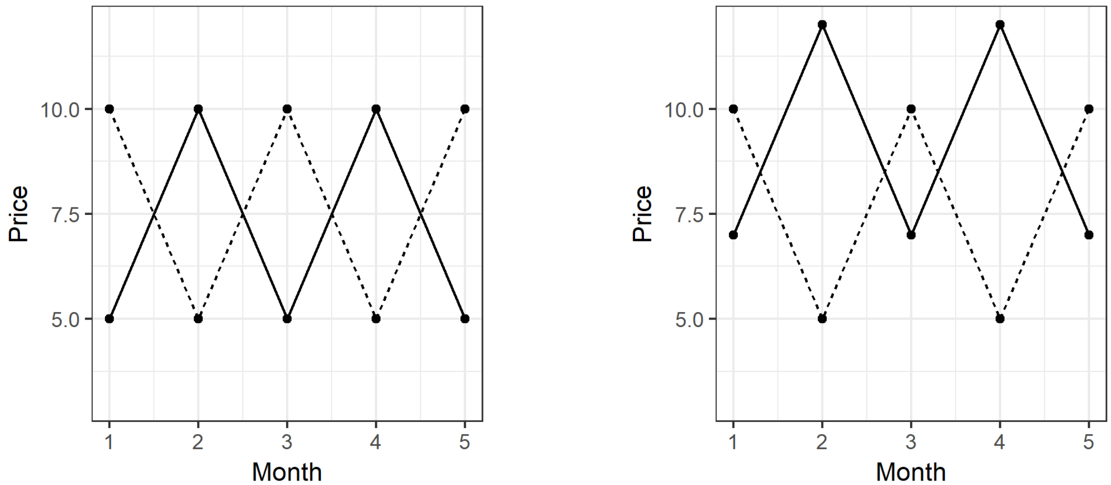
**Definition 3.** The firms are in an APC if and only if the following conditions hold:

3. $|C_t^{PC}| \geq 2$

4. $p_{it} > \min\{p_{jt}\}_{\forall j}$ 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 $i, j \in C_t^{PC}$.

I show an example of an SPC and an APC in Figure 3. Note that the firms in an APC are a

Figure 3: Example Price Cycles




(a) SPC

(b) APC

*Notes: Example of a symmetric price cycle (SPC) and asymmetric price cycle (APC).*

subset of those in an SPC.[31] In the following hypotheses, I refer to APC and SPC as price cycles.

I start by defining the model implication for monopolists.

**Hypothesis S1.** *Monopolists do not form a price cycle. They change prices infrequently. Compared to substitution groups with higher competition, fluctuation in prices is less common.*

Although I do not expect price cycles for monopolists, I expect price cycles in substitution groups with two competitors. Further, I the models predicts that in market situations with three competitors, two competitors may form price cycles when one firm has a higher base of patients with a brand preference.

When turning to substitution groups with $|N| \geq 4$, at least three competitors have no habit-persistent patients. To observe price cycles as defined in Definition 2 and 3, at least two firms outside the price cycle should have no incentive to undercut the prices by the two firms in the collusion scheme. I expect that it is unlikely that two firms have a high enough base of patients

[31] Price cycles are implicitly restricted to two colluding firms, as I am focusing on tacit collusion schemes between two competitors. Further, reoccurring price cycles over subsequent periods of time are identified as new independent cycles. Price cycles are identified each month separately. Empirical Online Appendix G addresses the concerns.

with a brand preference that prevents undercutting.

**Hypothesis S2.** *Tacit collusion schemes exist in the form of price cycles for markets with two competitors. Price cycles also exist in a triopoly. In detail, two generics form a price cycle when one original is present. However, in substitution groups with more than three competitors, price cycles between two competitors are less common.*

The model offers the possibility of evaluating further supply side hypotheses. In the Appendix I derive additional hypotheses based on the number of competitors and observable prices.

## 6.1 Examination of Pricing Patterns

I now turn to relating observable price patterns to the presented hypotheses of the model. I assume that demand patterns regarding habit persistence and brand preference vary across substitution groups but are stable within a substitution group. I therefore relate pricing patterns to the number of firms. Analyzing the demand side with limited data availability in Section 7, I show that the assumptions of habit persistence and brand preferences are reasonable.

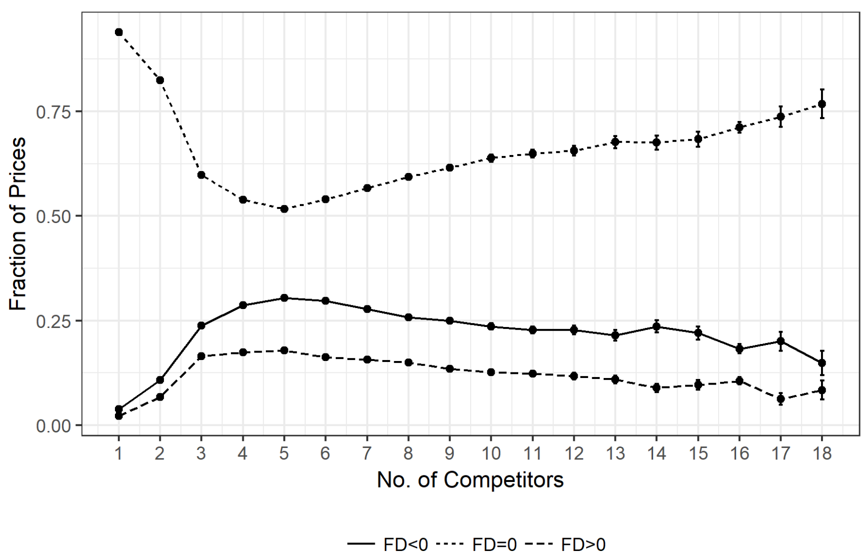
One primary concern of analyzing the effects of increasing competition on collusive behavior among firms is that the number of firms in a substitution group is endogenous and may be dependent on distinct unobservable demand patterns. I control for this by using time as well as substitution group specific 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.[32]

[32] In Empirical Online Appendix C, I relax the assumption of stable consumer characteristics and address possible endogeneity concerns using robustness checks. Empirical Online Appendix B shows that the linear models used in this section are robust to nonlinear specifications. I explore the role of multi-market contacts and multi-product firms in Empirical Online Appendix E. Neither do specific multi-product firms drive presented results not do multi-market contacts explain prices. In Empirical Online Appendix F I extend the robustness check and show that results are stable when using producer fixed effects. Empirical Online Appendix G addresses concerns of auto correlation and different forms of price cycle definitions, while I show in Empirical Online Appendix I that habit persistence itself is not a function of the number of competitors.

**The monopolist**

Now, I turn to substitution groups with one supplier present. The theoretical model predicts that a single firm charges monopoly prices and that price changes are due to changes in the regulatory price ceiling (*Hypothesis S1*). To give descriptive evidence that changes in the product prices of a monopolist are less common, I plot in Figure 4 the share of observations with positive, negative, and zero first price differences conditional on the number of competitors. The proportion of monopolists who do not change the price in the future month is 97.42%. Compared to other competitive market conditions, monopolists change their prices less frequently. Furthermore, one sees a share of 0.55% increases and 2.02% decreases.[33]

Figure 4: Dirst Differences in Prices



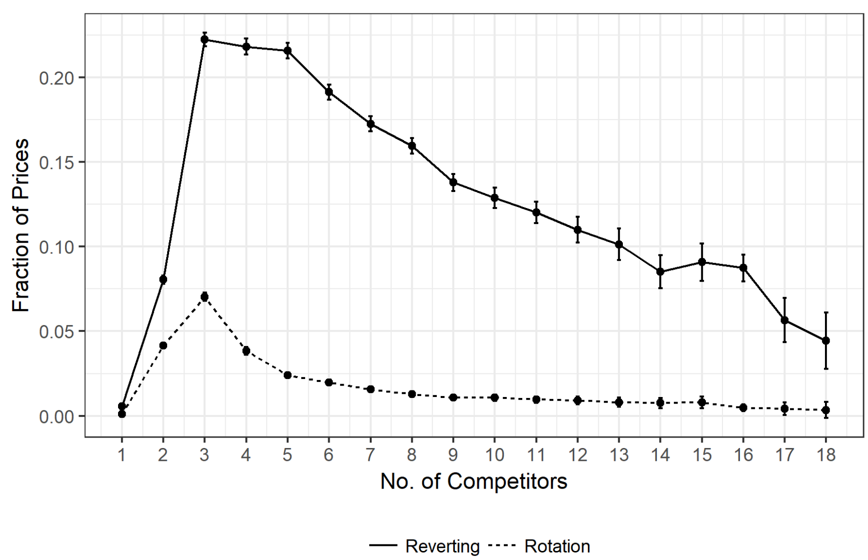

*Notes: First price differences of prices conditional on the number of competitors in a substitution group. Conditional on the competitors in a substitution group at a time t, the three series show the share of products that have a negative, zero, or positive first price difference. Error bars correspond to the 95% confidence interval.*

*Hypothesis S1* also states that a monopolist does not set prices in a rotational scheme. Figure 4 already showed that there are no frequent price changes. Nevertheless, I also show some descriptive statistics of rotational price setting. The price cycles I have defined in Definitions 2 and 3 are

[33] Given the assumption of a general tendency to decrease regulatory price ceilings, this is an indication that monopolists change prices solely for regulatory reasons.

only relevant for two competitors, and the price patterns of monopolists are not included. In the following, I investigate whether any monopolist changes prices in a cyclical pattern. In Figure 5, I plot two different shares of prices conditional on the number of competitors. First, I plot the share of prices for which the first price difference is (smaller) greater than zero, and in the forthcoming period, the prices reverts such that the first difference in prices (greater) smaller than zero ($p_{t+1} - p_t > 0$ and $p_{t+2} - p_{t+1} < 0$ or $p_{t+1} - p_t < 0$ and $p_{t+2} - p_{t+1} > 0$). I call this pricing behavior *reverting*. Second, I plot the share of prices that rotate in a cyclical pattern, i.e., the first price difference is unequal to zero and the second price difference is equal to zero ($|p_{t+1} - p_t| \neq 0$ and $p_{t+2} - p_t = 0$).[34] Both individual pricing patterns are nearly nonexistent for monopolists. They neither revert nor rotate their prices.

Figure 5: Cyclical Pricing of Individual Firms




*Notes: Share of products that rotate as well as revert their prices conditional on the number of competitors in a substitution group. Conditional on the competitors in a substitution group at time t, the three series show the share of products that are reverting or rotating their prices. Error bars correspond to the 95% confidence interval.*

Although substitution groups with only one price-setting firm are the most common, price

[34] Note that rotation patterns are a subset of reverting patterns. In comparison to the definition of SPCs and APCs (*Definition 2* and *Definition 3*) rotating and reverting patterns are measured on the individual level. Therefore they also incorporate monopolies.

patterns in this subgroup differ substantially. The vast majority of monopolists do not change prices. Cyclical patterns are not observable. *Hypothesis S1* is supported by price patterns.

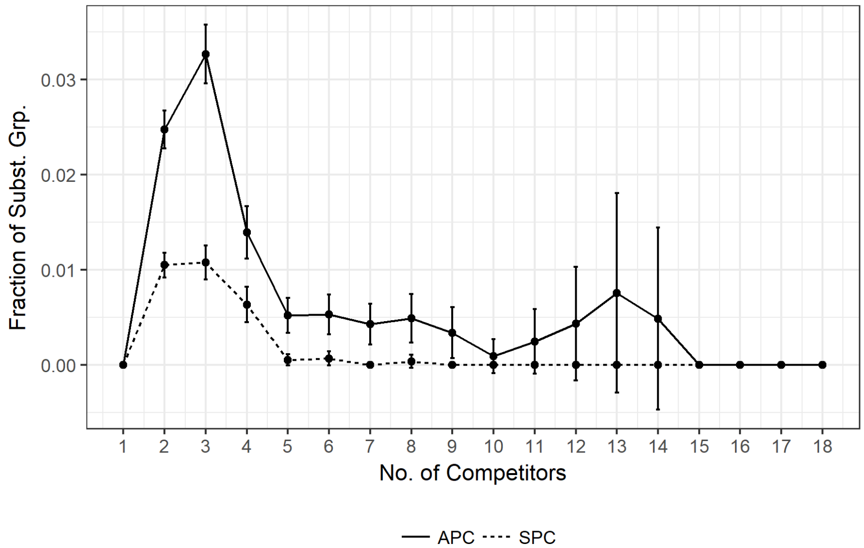
**Price cycles**

The model predicts tacit collusion schemes in the form of price cycles. As argued in Section 4, I expect that SPCs and APCs are observable in duopolies (*Hypothesis S2*). However, I also expect price cycles between two firms in substitution groups with three competitors where one firm has a higher base of patients with a brand preference (*Hypothesis S2*). If more firms compete, I expect less evidence of price cycles (*Hypothesis S2*). In the analysis of the monopolists, individual cyclical pricing in forms or rotations (see Figure 5) is most common for substitution groups with two, three, or four competitors. I extend the analysis by describing the share of substitution groups in price cycles (according to Definitions 2 and 3) conditional on the number of competitors. Afterward, I analyze the probability of price cycles by applying necessary panel data linear probability frameworks.

Figure 6 presents the fraction of substitution groups in SPCs (Definition 2) and APCs (Definition 3) conditional on the number of competitors over all monthly time periods. The basic graphic analysis shows that prices cycles are most common in markets with two and three competitors. Increasing the number of competitors reduces the probability of price cycles. Note that the both fractions are not high, even for two competitors. The reason may be that competitors do not collude or that collusion of same price setting is chosen as the habit persistence is not important.

One may argue that the characteristics of subgroups with two competitors differ systematically from those groups with higher competition. In particular, substitution groups with higher competition could be characterized by different demand patterns. Cyclical pricing could be driven by demand patterns (i.e., brand preferences and habit persistence), and the competitive environment is correlated with those unobservables. The descriptive analysis of this article is not intended to provide complete identification for reasons of collusion. However, in the following, I try to investigate variation within substitution groups. The primary intuition for this approach is that patients within

Figure 6: Price Cycles




*Share of substitution groups in an SPC (Definition 3) and an APC (Definition 4) conditional on the number of competitors over all time periods. Error bars correspond to the 95% confidence interval.*

a substitution group behave similarly regarding their habit persistence and brand preferences, independent from the number of competing firms. Furthermore, the following approach controls for time fixed effects.[35] I collapse the data set on the substitution group level where I denote a substitution group with $i$. 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 five different linear probability models for SPCs and APCs.[36] The last of the five linear probability models takes the following form:

$$P(S_{it} = 1 | C_{it}) = \alpha_i + \gamma_t + \beta C_{it} + \varepsilon_{it},$$

[35]Empirical Online Appendix C addresses possible endogeneity concerns.

[36]Note that I use a linear probability model for several reasons. First, I do not know the exact functional form of the conditional expectation function. The linear probability model approximates the conditional expectation function, which is a good first approximation, as I would like to avoid assuming a nonlinear form. Second, using the linear probability model avoids identification due to functional form (as specific other models would do). Third, the fixed effects would lead to an incidental parameter problem in the case of using probit or logit models. When using the linear probability model, I do not have problems of incidental parameters. Finally, an easy interpretation of the linear probability model for the basic empirical exercise is preferred. However, I include logit models for a robustness check in Empirical Online Appendix B. I cluster standard errors and adjust them for autocorrelation and heteroskedasticity.

where $\alpha_i$ is a vector of substitution group fixed effects, $\gamma_t$ is a vector of time fixed effects, and $\beta$ is a vector of parameters. $C_{it}$ 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. $\varepsilon_{it}$ is an error. Table 4 presents the following regression evidence, where the dependent variable is the SPC and APC dummy variable, respectively. In Model 1 and 4, I use a pooled regression (naive estimator), where I omit time as well as substitution group fixed effects but control for the first level of the ATC code, which allows me to control for possible demand patterns that are similar to the anatomical main group (for example, the difference between a narcotic and an anti- infective). In Models 2 and 5, I uses only substitution group fixed effects.[37] Finally, in Models 2 and 6, the previously explained specification is used.

We see similar results for SPCs and APCs. Note that the competition coefficient for $C_{it} = 1$ is excluded, so the reference value is defined by substitution group with one price-setting firm. In the pooled regression models without subgroup fixed effects, subgroups with an initially higher number of competitors are associated with a higher probability of being in a price cycle. The coefficients are, however, the highest for two and three competitors. In the preferred specification, which is the model with subgroup and time fixed effects, only subgroups with two competitors are increasing the possibility of being in a price cycle significantly. Thus, subgroups with two competitors, in comparison to a monopolistic substitution group, increase the probability of being in an SPC by 0.7% and of being in an APC by 2.1%. Substitution groups with three competitors show a positive but insignificant coefficient, whereas subgroups with more competitors are negatively associated with the existence of price cycles.

When controlling for fixed effects among subgroups, and solely looking at variation within subgroups, the results back up that price cycles in duopolies and less common price cycles for more than three competitors (*Hypothesis S2*). I have also shown that price cycles are observable for three competitors, although controlling for substitution and time fixed effects reduces the significance. For a complete evaluation of *Hypothesis S2*, it remains necessary to show that, in subgroups with

[37] Note that the controls are dropped as they are captured by the individual fixed effect.

Table 4: Regression, SPCs and APCs

| | Price Cycle | | | | | |
|---|---|---|---|---|---|---|
| | SPC | SPC | SPC | APC | APC | APC |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| C=2 | $0.011^{***}$ | $0.007^{*}$ | $0.007^{***}$ | $0.027^{***}$ | $0.020^{***}$ | $0.021^{***}$ |
| | (0.002) | (0.003) | (0.005) | (0.004) | (0.005) | (0.005) |
| C=3 | $0.010^{***}$ | −0.003 | −0.003 | $0.031^{***}$ | 0.006 | 0.006 |
| | (0.002) | (0.004) | (0.005) | (0.004) | (0.006) | (0.006) |
| C=4 | $0.007^{**}$ | −0.009 | $-0.009^{*}$ | $0.015^{***}$ | −0.012 | −0.011 |
| | (0.002) | (0.005) | (0.006) | (0.003) | (0.007) | (0.007) |
| C≥ 5 | 0.001 | $-0.012^{**}$ | $-0.013^{**}$ | $0.005^{***}$ | $-0.019^{*}$ | $-0.019^{*}$ |
| | (0.0004) | (0.005) | (0.008) | (0.001) | (0.008) | (0.008) |
| Constant | 0.001 | | | −0.003 | | |
| | (0.002) | | | (0.002) | | |
| Fixed effects | No | Subgroup | Subgroup and Time | No | Subgroup | Subgroup and Time |
| Controls | Yes | No | No | Yes | No | No |
| R-Squared | 0.009 | 0.161 | 0.165 | 0.017 | 0.167 | 0.175 |
| *N* | 115,549 | 115,869 | 115,869 | 115,549 | 115,869 | 115,869 |

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.02$, $^{***}$ $p < 0.001$

*Notes: One observation corresponds to a substitution group at time t. In the first three models the dependent variable is a Dummy which takes the value one in case that a substitution group at time t is in a symmetric price cycle (SPC) while the fourth to sixth model correspond to an asymmetric price cycle (APC). C are the number of competitors in a substitution group at t. More than five competitors are merged. In the Online Appendix I present a Table with all competitors used individually. Model (1) and (4) a pooled regression controlling for the ATC code, Model (2) and (5) use substitution group fixed effects and ATC controls are dropped as they are perfectly correlated with the substitution group, Model (3) and (6) include substitution- as well as time fixed effects. Standard errors are clustered on the substitution group level and adjusted for auto-correlation as well as heteroskedasticity. The $R^2$ corresponds to the the full model, including the fixed effects.*

three competitors, the existence of an original brand product with (by assumption) a higher base of patients with a brand preference facilitates tacit collusion. For subgroups with three competitors, I expect collusion, which is only possible if one brand has a higher base of patients with a specific brand preference. The two remaining firms form a collusion scheme by rotating their prices. I also expect that collusion is less likely, as possible equilibria have stricter requirements for the parameters of brand preferences, habit persistence, and patience of consumers. First, note that generic products are more likely to form price cycles in substitution groups with three competitors. To investigate the impact of an existent original brand on price cycles, I adjust the linear probability model by using an interaction between the number of competitors and a variable that distinguishes whether an original brand is one of the price-setting firms as a regressor. Table 5 shows regression evidence of three linear probability models. As before, the dependent variable is the dummy $S_{it}$ (Model 1-3: SPC, Model 4-6: APC). I show three regression specifications for each price cycle form: (1) a pooled regression with controls, (2) subgroup fixed effects, and (3) time and subgroup fixed effects.

The reference level of the regression is a monopolist that supplies an original branded product. Consider first the substitution groups with two competitors. For all specifications, the substitution groups without an original branded product are associated with a higher probability of forming an SPC (with subgroup and time fixed effects a substitution group without originals is associated to 3.9 percentage points higher possibility of a SPC) as well as an APC (4.1 percentage points). However, substitution groups with an original product are only associated with a higher probability of price cycles without subgroup and time fixed effects. In substitution groups with three competitors where two firms form a price cycle, regression evidence differs. In a pooled regression specification, both substitution groups with and without an original product are associated with a higher probability of a SPC (1.7 percentage points without and 2.2 percentage point with an original) and an APC (2.4 percentage points without and 3.6 percentage point with an original). Including time and subgroup fixed effects, the coefficients are insignificantly different from zero for both price cycles. However, the sign of the coefficients for the case with and without originals do not align but support the

Table 5: Regression, Originals and Generics

| | SPC | | | APC | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| C=1,No O | −0.001 | 0.008 | 0.006 | −0.0003 | $0.014^{*}$ | 0.009 |
| | (0.0003) | (0.004) | (0.004) | (0.001) | (0.007) | (0.007) |
| C=2,NO O | $0.015^{***}$ | $0.021^{***}$ | $0.019^{***}$ | $0.040^{***}$ | $0.053^{***}$ | $0.047^{***}$ |
| | (0.003) | (0.006) | (0.006) | (0.007) | (0.010) | (0.010) |
| C=2,O | $0.007^{*}$ | −0.0005 | 0.0002 | $0.013^{***}$ | −0.002 | 0.0002 |
| | (0.003) | (0.001) | (0.001) | (0.004) | (0.002) | (0.002) |
| C=3,No O | $0.011^{*}$ | 0.002 | −0.0004 | $0.028^{***}$ | 0.015 | 0.007 |
| | (0.005) | (0.006) | (0.006) | (0.007) | (0.009) | (0.009) |
| C=3,O | $0.010^{***}$ | 0.001 | 0.001 | $0.036^{***}$ | 0.011 | 0.011 |
| | (0.003) | (0.004) | (0.004) | (0.006) | (0.006) | (0.006) |
| C=4,No O | $0.008^{*}$ | −0.004 | −0.007 | $0.013^{**}$ | −0.002 | −0.008 |
| | (0.004) | (0.008) | (0.008) | (0.005) | (0.010) | (0.010) |
| C=4,O | 0.005 | −0.004 | −0.004 | $0.015^{***}$ | −0.007 | −0.007 |
| | (0.003) | (0.004) | (0.004) | (0.004) | (0.006) | (0.006) |
| C≥5,No O | 0.0001 | −0.007 | −0.010 | $0.004^{***}$ | −0.010 | $-0.018^{*}$ |
| | (0.001) | (0.005) | (0.006) | (0.001) | (0.008) | (0.009) |
| C≥5,O | 0.001 | −0.008 | −0.009 | $0.005^{***}$ | −0.012 | −0.013 |
| | (0.0005) | (0.005) | (0.005) | (0.001) | (0.008) | (0.008) |
| Constant | 0.001 | | | −0.003 | | |
| | (0.002) | | | (0.002) | | |
| Fixed effects | No | Subgroup | Subgroup and Time | No | Subgroup | Subgroup and Time |
| Controls | Yes | No | No | Yes | No | No |
| R-Squared | 0.01 | 0.162 | 0.166 | 0.021 | 0.169 | 0.177 |
| *N* | 114,467 | 114,787 | 114,787 | 114,467 | 114,787 | 114,787 |

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.02$, $^{***}$ $p < 0.001$

*Notes: One observation corresponds to a substitution group at time t. The dependent variable for Models (1) to (3) is a Dummy which takes the value one in case that a substitution group at time t is in a Symmetric Price Cycle (SPC). For Model (3) to (6) the dependent Variable is a Dummy which takes the value one in case that a substitution group at time t is in an Asymmetric Price Cycle (APC). C are the number of competitors in a substitution group at t. O stands for the existence of an original product of the substitution group in t whereas NoO means that an original is not existing. More than five competitors are merged. In the Online Appendix I present a Table with all competitors used individually. Models (1) and (4) are pooled regressions controlling for the ATC code, Models (2) and (5) use substitution group fixed effects and ATC controls are dropped as they are perfectly correlated with the substitution group, Models (3) and (6) include substitution- as well as time fixed effects. he coefficients for more than 9 competitors are omitted. Standard errors are clustered on the substitution group level and adjusted for auto-correlation as well as heteroskedasticity. The $R^2$ corresponds to the the full model, including the fixed effects.*

theory. In detail, the existence of an original product is related to a higher probability of both price cycle types (0.4 percentage point for an SPC and 1.0 percentage point for an APC), whereas substitution groups without an original are associated with a lower probability of price cycles (-0.6 percentage point for an SPC and -0.3 percentage point for an APC). Given the insignificance, I cannot confirm the role of originals entirely. Thus, one may conclude that (1) price cycles in triopolies are observable and (2) the insignificant result does not contradict that an original product in substitution groups with three competitors facilitates tacit collusion in the form of price cycles.

# 7 Demand Side

The dynamic model simplifies the environment (i.e., no entry decision, perfect information on the demand structure, equal marginal costs). Nevertheless, the model incorporates important features of the pharmaceutical market. In the substitution groups of the four therapeutic subgroups (painkillers, antiepileptics, antibiotics, and beta-blockers), the summary statistics have shown that, in approximately 73 to 93% of purchases, the cheapest product (product of the month) is dispensed.[38] The price-elastic unit mass of consumers entering each period can be directly related to this observation. Two groups are relevant. First, particular products have price-inelastic demand due to a branding effect (i.e., original brand products). The patients with a brand preference $l_j$ are representing this effect. In markets with solely generics, I assume that branding effects are measurable but not dissimilar between products, such that $l$ is equal for all products. In other markets, a branded product has a higher base of patients with a brand preference ($l^H$). Second, $\theta$ describes habit-persistent patients who do not substitute a product after a previous purchase. The interpretation of this lag in demand is twofold. First, patients take a distinct substance over two periods and do not substitute to another product within a treatment. Second, it is an approximation of lags in demand caused by (1) patients who had a previous positive experience with a particular drug (that was a product of the month in the initial treatment) and (2) physicians who prescribe a previous

[38] Also Bergman et al. (2012) show that the product of the month accounts for approximately 70% of the products sold.

product of the month lead patients to oppose substitution.

Janssen (2019) uses individual choice data of the Swedish prescription drugs under generic competition and shows that patients experience switching costs when purchasing painkillers and antibiotics, but not when consuming antiepileptics. Switching costs are directly related to habit-persistence. Using patent expires as quasi-natural experiments he also shows that the effects are primary strong in the first month and decreasing afterward. Both observations are in line with the demand assumptions of the theoretical model.

Within this section, I use the available monthly market share data on the product level to show evidence for habit persistence, to explore heterogeneity and relate it to model predictions of price cycles and competitive Markov perfect equilibria. The demand function in the model is based on habit persistence and brand preferences:

**Hypothesis D1.** *Patients are habit-persistent and have brand preferences when choosing prescription drugs under generic competition.*

The frequency of price cycles[39] is *not* a function of habit persistence alone. Indeed, theory shows that price cycles emerge when patients are habit persistence or when there are patients with heterogeneous brand preferences across firms. Further, the size of habit persistence does not increase the probability of collusion. While I am not able to explain why collusion arises, theory shows that under the existence of any habit persistence or heterogeneous brand preferences on the patient's side the profit maximizing market sharing rule is price cycles. In the case without habit persistence or heterogenous brand preferences firms maximize profits by setting the same price. However, same price setting is not necessary a collusive agreement as also competitive equilibira without habit persistence and brand preferences have the same price dynamics.

**Hypothesis D2.** *Brand preferences of originals, as well as habit persistence, is associated with price cycles. The non-existence of both behavioral frictions may lead to identical prices.*

[39] Defined in *Definition 2* (SPC) and *Definition 3* (APC).

Price cycles as a first best collusion mechanism are based on the assumption of pharmacies procurement behavior. In detail, new consumers buy from the larger firms (the firm with habit-persistent patients or more patients with brand preferences) when multiple firms set an equal price as pharmacies maximize their profits by purchasing high amounts of one product. I assume that pharmacies have a lower profit when procuring high quantities of two products compared to sticking to one product. In case two pharmaceutical companies set the same price, pharmacies purchase mainly one product, and the indifferent new patients are dispensed the unique available pharmaceutical. If one product has a higher default mass of purchases due to habit persistence or brand preferences, pharmacies choose this pharmaceutical. In case neither firm has a higher mass of patients, I assume that the pharmacy randomly dispenses one product.

**Hypothesis D3.** *In case that two firms set identical prices and share the product of the month status I expect that the firm with the higher mass of habit-persistent patients or the firm producing an original product has a higher market share.*

### Evidence for Habit-persistence

In the following, I investigate if market share patterns of products in the four therapeutic groups show evidence of a 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.[40] Consider the following model, where one observation corresponds to product $i$ in month $t$:

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

[40]Note that pharmacies are allowed to sell the remaining stock of previously purchased product 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 their substitution group.[41] $Original_{it}$ and $PI_{it}$ (where PI = parallel import) are dummy variables that take the value one if $i$ is an original branded or parallel imported product and zero 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 zero 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 has been 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 PoM status with the four therapeutic subgroups $ThSub = \{Painkillers, Antibiotics, Antiepileptics, Beta\text{-}Blocker\}$ to explore heterogeneity in habit persistence. Finally, $\alpha_i$ is a product fixed effect (a product is a specific brand within a substitution group)[42] and $\gamma_t$ 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 a positive coefficient of $\beta_0$, an original branded product, is associated with a higher market share. In the model, the positive coefficient would translate to the existence of the 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 $\rho_0$. Further, the model assumes that a mass of $\theta$ patients are habit persistent and consume the product of the previous month. Therefore, I expect a positive coefficient of $\rho_1$, which should be smaller than $\rho_0$. Finally, habit persistence in the model exists over just one period, such that $\rho_2$ and $\rho_3$ should not be significantly different from zero or at least much smaller than $\rho_1$. Finally, following Janssen (2019) results for different therapeutic groups

[41] Note that prescriptions are on the substitution group level. Substitution between substitution groups happens seldom.

[42] Note that including product fixed effects excludes the regressor *Original*.

are heterogeneous.

Table 6 shows evidence from three different models.[43] Model 1 does not include fixed effects. In Model 2, I include product fixed effects, and Model 3 incorporates product and time fixed effects.[44] The coefficient for an original product is significant and positive. An original product is related to a 9 percentage points higher market share. 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 40 and 41 percentage points higher market share ($\rho_0$) on the baseline level which is a beta-blocker. 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 *POM* has a lower market share (11 percentage points less in the pooled regression and 3.7 percent less with the product ad time fixed effects. The variable that captures potential habit persistence over one period is captured in the lagged $PoMn_{t-1}$ status. $\rho_1$ on the baseline level (Beta Blocker) is significant in Model 1 and 3 and much lower than $\rho_0$ ( between 4.5 and 6.2 percentage points). The result is similar for antibiotics and painkillers when introducing product and time fixed effects. Only patients of antiepileptics seem to be not habit-persistent.[45] This result is in line with the individual choice analysis in Janssen (2019). 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 five percent level for all therapeutic subgroups.[46]

Patient's habit persistence translates to a higher market share of 4 to 6 percentage points in the

[43] I start by providing evidence for the basic model. In Empirical Online Appendix H I extend the analysis to separate investigations for each therapeutic subgroup. Further, I explore the role of originals and generics and their relation to habit-persistence. The results of both robustness checks are in line with the following summarized version. As in the supply side analysis, I cluster standard errors on the product level. Standard errors are adjusted for autocorrelation and heteroskedasticity.

[44] Note that product fixed effects should capture the variation of the regressor *Original* such that I drop the indicator in Models 2 and 3.

[45] In detail, it seems that patients of antibiotics have a negative coefficient. A product that has been the product of the month in the previous month may even have a lower market share. An explanation for this specific observation in the pharmaceutical market is provided in Janssen (2019). Patients of very antibiotics are very used to change products as they are consuming the products often for long. As they are used to substitution, they change mostly to the cheapest product. In case of high variation in prices that are correlated with being the product of the month, the negative coefficient is rationalized with frequent changes of consumers.

[46] For Beta Blocker the coefficient of $PoMn_{t-3}$ suggest that being the product in $t-1$ increases the market share by 1.4 percentage points. However, the coefficients are solely significant on the 10 percent level, and the coefficients of all other therapeutic subgroups are negative.

## Table 6: 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) | | |
| Painkiller | $0.075^{***}$ | | |
| | (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) |
| Painkiller 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) |
| Painkiller 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) |
| Painkiller 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) |
| Painkiller 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 |

$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

*Notes: One observation corresponds to a product i in a substitution groups of painkiller, antibiotics, antiepilepics of beta blocker within a month t. The outcome variable is the monthly market share. $Add.Expense$ are the out of pocket expenses for product i, the difference between the price of product i and the product of the month. $POM$is a dummy that takes the value one if product i is the cheapest available product of the month in t. $POMn(t-1)$, $POMn(t-2)$, $POMn(t-2)$ is a dummy that takes the value one if product i is the cheapest available product of the month in $t-1$, $t-2$ or $t-3$ but not subsequent month up to t. $Painkiller$, $Antibiotics$, and $Antiepileptics$ are dummys that take the value one if the products belongs to the therapeutic subgroup. The default is a Beta-Blocker. Each model includes the $Number\ of\ Competitors$ as controls, where each competitor is taken as a own variable to allow for nonlinear effects. Standard errors are reported in parentheses, they are clustered on the product group level, adjusted for serial correlation or heteroskedasticity.*

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 in Model 2 (both) and Model 1 (only $PoMn_{it-3}$). The reduced-form evidence for the four therapeutic groups confirms the demand assumptions of *Hypothesis D1*.[47]

### Habit Persistence and Price Cycles

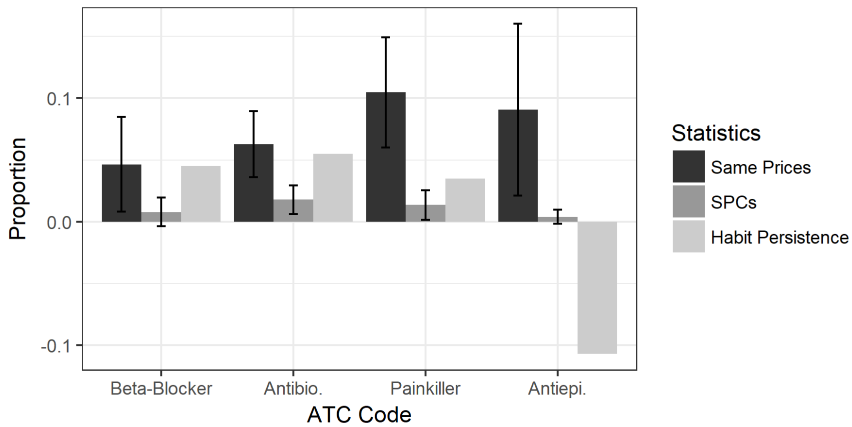
In the following, I evaluate *Hypothesis D2*. The model predicts that the first best collusion systems under habit persistence or with heterogeneous brand preferences of patients across firms are price cycles (described in *Definitions 2 and 3*. In the absence of the behavioral characteristics of patients, setting an equivalent price is profit-maximizing. Following theory and assumptions on behavioral characteristics, the price dynamics allow identifying tacit collusion due to price cycles while equivalent prices could be due to competitive (marginal cost) or collusive price setting.

Figure 7 shows the share of identical prices, SPCs and the estimate of habit persistence for each therapeutic subgroup.[48] Estimates of habit persistence are from Regression model 1. The share of *available* originals of all products across substitution groups for the four therapeutic groups is the following: 66% for painkillers, 66% for beta-blocker, 47% for antibiotics and no originals for antiepileptics. The Figure shows that equivalent prices are observable in all substitution groups, to a more considerable extent for painkiller and antiepileptics. SPCs are foremost visible for Antibiotics and Painkiller. The results are aligned with model predictions: In groups with habit persistence (higher for antibiotics and painkiller) and brand preferences (originals present in substitution groups for beta-blocker, antibiotics, and painkillers which may lead to heterogeneous brand preferences) one observes price cycles. For antiepileptics where neither originals are present nor do consumers experience habit persistence one sees relatively more same prices of competitors compared to price cycles. The results do not contradict *Hypothesis D2*.

[47] In Empirical Online Appendix I, I show evidence that habit persistence is not a function of the number of competitors.

[48] Please see a table with the results in Empirical Online Appendix H.

Figure 7: Habit Persistence, Identical Prices and Price Cycles




*I show three different statistics for each therapeutic subgroup (Beta-Blockers, Antibiotics, Painkillers, Antiepileptics). The coefficients of the habit persistence are from Regression Model 1. They are not comparable to the other statistics. Same Prices shows the share of substitution groups where at least two firms had identical prices (and were products of the month) over three consecutive periods over time. SPCs shows the share of substitution groups where firms form a SPC over time. The sample includes all observation more or equal than two competitors as all statistics of interest require at least two competitors. The error bars correspond to the 95% confidence interval using the standard errors across substitution group averages.*

### Identical Prices, Pharmacies and Demand

*Hypothesis D3* states that one firm receives a much higher market share when several firms set the lowest price simultaneously. The firm with a higher share of patients with habit-persistence and patients with brand preferences receives a higher market share. In the following, I demonstrate that the data supports this crucial assumption of the model. Consider the following regression model that estimates market shares in a similar to Regression Model 1.

$$
\begin{aligned}
Share_{it} =& \theta Add.Expenses_{it} + \rho_0 PoM_{it} + \rho_1 TPoM_{it} + \kappa_0 Share_{it-1} + \beta_0 Original_{it} + \\
& \kappa_1 TPoM_{it} \times Share_{it-1} + \beta_1 TPoM_{it} \times Original_{it} + \alpha_i + \gamma_t + \zeta NoComp_{it} + \varepsilon_{it},
\end{aligned}
$$

In comparison to the Regression Model in 1 I use the lagged market share $Share_{it-1}$ as a regressor to explore the size of habit persistence.[49] $TPoM_{it}$ takes the value one if firm $i$ in $t$ is the product of the month together with another firm. Note that also $PoM_{it}$ would take the value one for $i$. If the larger firm with more habit-persistent patients indeed receives a large share of the market I expect that for products where at least two products are product of the month the lagged market share is important. Therefore I expect that $\kappa_1$ is positive and significant. $\kappa_0$ captures the general habit-persistence, the effect that patients may stick with the product they have consumed before. In the case of identical prices, the size itself of a company becomes even more important as it determines the procurement behavior of pharmacy. I try to approximate this term by evaluating if the lagged market share plays an even larger role in the cases of the same prices. I also investigate the role of the originals.

Table 7 shows the results for three models: without fixed effects, with product fixed effects and with product and time fixed effects. Originals drop when using product fixed effects. In the pooled model Originals are still associated with a higher market share. However if an original is one of the firms that set the same price the brand premium diminishes which leads to the conclusion that brand premia are not leading to specific procurement of pharmacies. The product of the month is still the most important predictor of high market shares in all models. With two firms and identical prices (and product of the month status) the market share for the product of the month decreases (in the preferred model specification with product and time fixed effects it decreases by 28.8 percentage points from 42.3 percentage points due to the general product of the month status) However, past market shares are important. Habit-persistent is still observable, such that (with product and time fixed effects) a one percent higher market share in the last period increases market shares by 0.15 percentage points. However, in the case of two products with identical prices, habit persistence gets even more important. In such cases, a one percent higher market share means that the market share increases further by 0.32 percentage points. On average the correlation of past market shares

[49] In model 1 I included the regressor $PoMn_{t-1}$ (a dummy that take the value one if a product has been POM in $t-1$ but not in $t$) instead of the lagged market share. The major intuition is that I would like to have a direct relationship between patients attracted to a product that is not the product of the month and those that have consumed the product of the month already before. Instead, I am now interested in a specific absolut relation between past and new market shares. In Empirical Online Appendix J, I show results using $PoMn_{t-1}$ to show that the results are robust.

triples for products that have the product of the month status and have the same prices. This observation supports *Hypothesis D3* and therefore an important assumption of the model.

Table 7: Regression, Identical Prices and Market Shares

| | Share | Share | Share |
|---|---|---|---|
| | (1) | (2) | (3) |
| Add. Expenses (SEK) | $-0.0001^{***}$ | $-0.0001^{***}$ | $-0.0001^{***}$ |
| | (0.00002) | (0.00003) | (0.00003) |
| POM | $0.352^{***}$ | $0.378^{***}$ | $0.423^{***}$ |
| | (0.008) | (0.007) | (0.007) |
| POM and SP | $-0.307^{***}$ | $-0.292^{***}$ | $-0.288^{***}$ |
| | (0.014) | (0.012) | (0.011) |
| Share(t-1) | $0.359^{***}$ | $0.155^{***}$ | $0.158^{***}$ |
| | (0.014) | (0.010) | (0.009) |
| Original | $0.083^{***}$ | | |
| | (0.010) | | |
| POM SP x Share(t-1) | $0.392^{***}$ | $0.334^{***}$ | $0.323^{***}$ |
| | (0.025) | (0.022) | (0.019) |
| POM SP x Original | $-0.085^{***}$ | | |
| | (0.020) | | |
| Constant | $0.311^{***}$ | | |
| | (0.016) | | |
| Fixed effects | No | Product | Product and Time |
| Competition Controls | Yes | Yes | Yes |
| R-Squared | 0.763 | 0.832 | 0.853 |
| *N* | 46,135 | 46,135 | 46,135 |

$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

*Notes: One observation corresponds to a product i in a substitution groups of painkiller, antibiotics, antiepilepics of beta blocker within a month t. The outcome variable is the monthly market share. Add.Expense are the out of pocket expenses for product i, the difference between the price of product i and the product of the month. POMis a dummy that takes the value one if product i is the cheapest available product of the month in t. Share$(t-1)$ is the market share of product i in $t-1$. POM and SP is a dummy that takes the value one if i and at least one different product have been product of the month in t. Original is a dummy that takes the value one if product i is an original. All models include the Number of Competitors as controls, where each competitor is taken as a own variable to allow for nonlinear effects. Model (1) is a pooled regression, Model (2) includes product fixed effects and Model (3) includes product as well as time fixed effects. Standard errors are reported in parentheses, they are clustered on the product group level, adjusted for serial correlation or heteroskedasticity. The $R^2$ corresponds to the the full model, including the fixed effects.*

# 8 Discussion

I have built a dynamic oligopoly model where some of the patients are habit persistent. Pharmacists who are acting under highly regulated retailers are obliged to dispense the cheapest available generic. However, they increase their profits by increasing mainly the quantity of one pharmaceutical product if multiple products have the same price within a month.

I have shown that, depending on the patience of firms and the state-dependence of patients, two firms can form profit-increasing tacit collusion schemes where the firms are alternating 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. However, the research focuses on the collusion of two participants. The model predicted that collusion of two firms might be possible in markets with three firms competing. In detail, one firm may exploit patients with a brand preference whereas 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 characterized main predictions of pricing behavior in the market absence of collusion conditional on the number of competitors.

The apparent characteristic of alternating prices allows us to detect possible tacit collusion. 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, wherein subgroups of three competitors form a cycle more often the two generics, whereas an original does not participate. Second, the price difference between firms establishing an alternating collusion scheme is higher for three than for two competitors. Furthermore, markets where one does not observe collusive patterns are confirming the model's prediction: (1) monopolists do not vary their prices and (2) the product of the month is more likely to increase its price in substitution groups with more than two competitors compared to a market where two firms compete. The main results are robust when I include a panel data method and look at variation within a market.

Using demand data I verify the important assumptions of the model. I show that patients are habit persistent and have brand preferences. Further, I confirm important behavior by pharmacies who dispense the product of the firm with the larger secured base of purchases. Finally, I exploit variation in habit persistence to demonstrate that model prediction hold in competitive equilibira and equilibria of tacit collusion.

The results of the theory, as well as the empirical exercise, have important implications for policy. Not only in pharmaceutical but a lot of retail markets products have a low degree of differentiation. If consumers generally do not have strong preferences and margins for retailers are the same across products retailers do not have an incentive to increase the product portfolio. Furthermore, consumers in a lot of markets are habit persistent or have brand preferences. Habit persistence and brand preferences shape dynamic pricing and variable prices in competitive equilibria. Due to retailer's behavior price cycles are profit maximizing tacit collusion schemes. Dynamic prices between competitive equilibria and tacit collusion schemes are different. This possibility of identification using dynamic prices is different to markets with homogeneous products where consumers are not habit persistent. In such cases, competitive equilibria are indistinguishable from tacit collusion scheme when solely observing price dynamics.

From a policy standpoint, the competitive environment of the studied market facilitates collusion. Firms compete simultaneously once per month and a price ceiling is set by a regulator. Reducing the frequency of interactions and reducing the informational frictions of consumers (i.e., reducing habit persistence and brand preferences) would reduce profitability and therefore reduce the frequency of tacit collusion.

# 9 Appendix

## A Additional Hypotheses

The model allows the evaluation of additional hypotheses. In the following, I derive some additional hypotheses of the supply as well as demand side. I evaluate them in the Empirical Online Appendix U and V. I show that I cannot reject any of the following hypotheses.

### Supply Side

Under the assumption that demand characteristics are balanced over substitution group, I can formulate a hypothesis about the relative difference between the lower and upper floors of price cycles. In the case of a duopoly, the model predicts that price cycles are sustainable as long as the lower price of a price cycle is sufficiently high. For the case of three competitors where two firms form a price cycle, the model predicts that price cycles are only sustainable if the lower price is sufficiently high such that the two firms in the price cycle do not deviate and that the lower price is sufficiently low such that the firm that does not participate in a price cycle has no incentive to undercut. Comparing the two cases, I expect a smaller relative price difference in the case of two competitors compared to a market with three competitors.

**Hypothesis S3.** *If firms collude and demand characteristics are balanced across markets, the difference between the cheapest product and the price upper bound is lower in markets with* $|N| = 2$ *than in markets with* $|N| = 3$.

If firms face patients with habit persistence or heterogeneous brand preferences across firms in substitution groups they neither set identical prices in competitive nor in tacit collusive equilibria. Without any behavioral friction products are homogeneous and firms set identical prices in collusive and competitive equilibria. Finally, without habit persistence and with homogeneous brand preferences across firms, firms set identical prices only in an equilibrium of tacit collusion. In contrast to the case with habit persistence one cannot distinguish price dynamics between collusive and non-collusive outcomes.

The intuition for this outcome is the behavior of the pharmacists. In a dynamic perspective the pharmacists will dispense only one product if several products have the same price. Further he will choose those product that has a larger initial base of customers (patients with habit persistence or brand preference).[50] Setting identical prices is therefore only profitable without habit persistence and equal share of brand preferences. However, if brand preferences are non-existence also a competitive equilibrium is characterized by same prices.

I expect to see identical prices as habit persistence may be non-existence. While I cannot identify collusion using theory, I expect that the substitution groups are different ones than those with habit persistence as the latter are characterized by different dynamics with and without collusion. Further, if part of the identical equilibria are due to collusion (i.e. homogeneous brand preferences, no habit persistence) I expect to observe less identical prices in substitution groups with more competition.

**Hypothesis S4.** *Price dynamics where firms charge the same prices over time exist. Substitution groups are different to those with price cycles. Identical prices are less common in substitution groups with more competitors.*

I still expect differences in price patterns conditional on the number of competitors in competitive equilibria with habit persistent patients. I have shown that an MPE with three or more players indicates that a firm that has been the cheapest product in the market (product of the month) increases its price in the subsequent period. This observation does not hold in markets with $|N| = 1$ or $|N| = 2$.

**Hypothesis S5.** *If firms do not collude in a duopoly, the firm with the cheapest product of the month does not increase its price in the subsequent period with certainty. However, if firms do not collude in a market with $|N| \geq 3$, the firm with the cheapest product of the month increases its price in the subsequent period with certainty. Further, the firm raises its price to the price ceiling.*

[50] See Section for a discussion and empirical investigation of this assumption.

### Demand Side

I use heterogeneity of habit persistence and brand preferences across therapeutic groups and demonstrate how well the variation of habit persistence matches pricing predictions of the model. In case of competitive Markov Perfect Equilibria described in *Proposition 1, 2* and *3* a higher value of $\theta$ changes the mixing distributions of the equilibrium strategies. Considering the minimum support $\underline{p}$, a higher $\theta$ has heterogeneous effects. The actual change depends on the competitive situation. In the case of two competitors and independent of the availability originals or generics (for a differentiated mass of brand preferences) higher habit-persistence is associated with a higher minimum support. [51] The same comparative static holds for triopolies with originals and generics ($l^H > l^L$).[52] However, in case of triopolies without originals (homogeneous mass of patients with brand preferences) or substitution groups with more competitors an increase in habit-persistence leads to a lower minimum support $\underline{p}$.[53]

**Hypothesis D4.** *Increased Habit-persistence is associated with larger price differences between the cheapest product and the price ceiling in substitution groups with two firms or three firms when an original is present. However, habit persistence decreases price differences in substitution groups with three competitors without an original or in substitution groups with higher competition.*

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[51] $\frac{\partial \underline{p}}{\partial \theta} > 0$ in *Proposition 1*.

[52] See $\underline{p}$ of *Proposition 4*.

[53] $\frac{\partial \underline{p}}{\partial \theta} > 0$ in *Proposition 3*.

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