Price Dynamics of Swedish Pharmaceuticals*

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February 20, 2020

Abstract

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

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

*I thank Richard Friberg and Albin Erlansson for detailed feedback. I also thank Liran Einav, Raffaele Fiocco, Magnus Johannesson, Brad Larsen, Erik Lindqvist, Dennis Rickert, Michelle Sovinsky, Giancarlo Spagnolo, Mark Voorneveld, and Jörgen Weibull as well as seminar participants at Stanford University, the Stockholm School of Economics, the annual conference of the EARIE 2018 in Athens, the annual conference of the EEA 2018 in Cologne, the annual conference of the IIOC 2018 in Indianapolis, the Spring Meeting of Young Economists at the University of the Balearic Islands, the annual conference of the Verein fuer Socialpolitik 2018 in Freiburg, the ENTER Jamboree 2018 at the Toulouse School of Economics, the SUDSWEC conference, the IO student workshop at the Toulouse School of Economics, the Swedish Workshop on Competition Economics and Public Procurement, and the Ruhr Graduate School of Economics doctoral conference for helpful comments. Financial support from the Jan Wallander and Tom Hedelius Foundation is gratefully acknowledged.
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1 Introduction

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

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

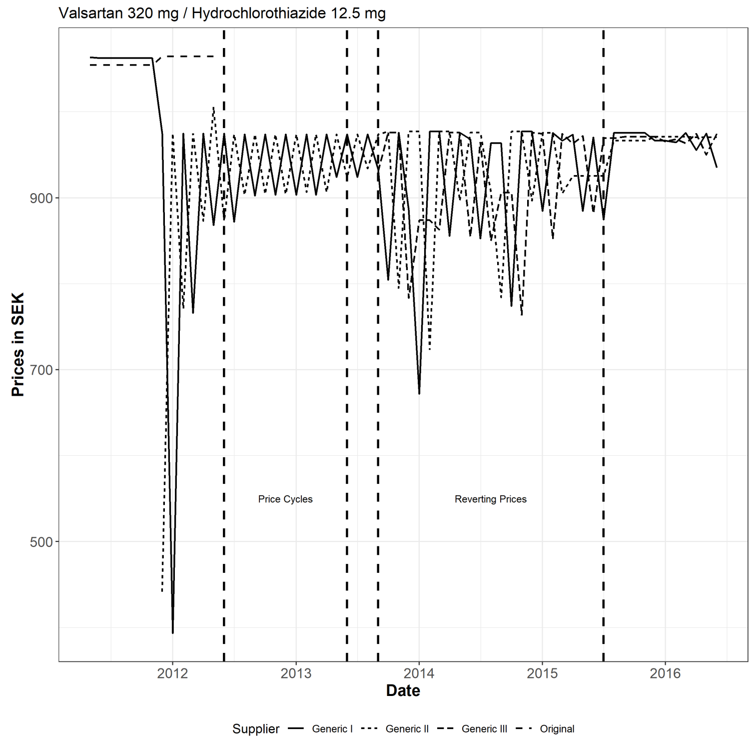
Pricing patterns for different segments (groups of medically equivalent pharmaceutical products) are heterogeneous. In segments where only one firm's product is available, the intertemporal variability of prices is nearly nonexistent. In segments with more than one firm, prices change frequently over time. In segments with more than two competitors, many of the cheapest products increase drastically in price in future months, requiring patients to switch products monthly in order to purchase the least expensive product. Interestingly, sometimes symmetric price cycles (SPCs) arise in segments with two or (very seldom) three competitors. In these price cycles, two competing firms alternate their monthly prices such that the market has a higher-priced and a lower-priced product each month. Furthermore, in some cases with two competitors, both firms charge identical prices over time. Figure 1 shows the example of Valsartan/ Hydrochlorothiazide 320 mg/ 12.5 mg, used for treatment of high blood pressure and congestive heart failure. The segment shows two common characteristics: (1) SPCs with two generics between mid-2012 and mid-2013 and (2) prices reverting after sporadic price decreases to a near-constant level from mid-2013 to mid-2015, when three competitors are present. In that period, the cheapest product in a month increases in price in the subsequent month such that a competitor offers a lower price.

To frame the empirical analysis, I build a dynamic oligopoly model where firms repeatedly compete on prices. I explore the role of patients' behavior on pricing mechanisms by firms. The perceived quality differences of medically equivalent products, as well as persistent purchasing habits, are well documented in the literature. I characterize Markov perfect equilibria and subgame perfect equilibria in repeated games where patients are habit persistent and perceive differences in product quality. I describe observable pricing patterns that are conditional on the number of competitors. Additionally, I present conditions under which tacit 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 tacit collusion schemes in which both firms charge identical prices over time.

The intent of 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 supply side. Using segment and time fixed effects, I exploit within-segment variation in market structure to identify links between pricing patterns and

[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), attracting the attention of antitrust regulators. The puzzle of many producers and increasing prices has been featured on Reinhardt's health care blog (Reinhardt, 2016). The suspected price increases by all competitors led to an investigation by antitrust authorities in November 2016 (Bloomberg, 2016).

Figure 1: Examples of Price Cycles and Reverting Prices



Note: 10 SEK = 1.1 USD.

the 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 rarely occur but may be 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 following month.

In a second step, I incorporate the demand side. I demonstrate that the development of market shares can be explained by patients' habit persistence and brand preferences. Looking at variation of habit persistence across therapeutic subgroups, I show that the model is well suited to predict competitive as well as (tacit-) collusive pricing equilibria.

The model, and the empirical investigation of the Swedish pharmaceutical market, exemplify the importance of intertemporal demand for pricing incentives of firms. Thus, consumers' dynamic demand offers the possibility to detect tacit collusion. In markets where patients' brand preferences and habit persistence are low, dynamic prices in competitive equilibria are indistinguishable from tacit collusion. 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, observed variation in habit persistence can facilitate detection of tacit collusion schemes, as dynamic price relations in scenarios with habit persistence are different from those in competitive equilibria.

2 Related Literature

Generic entry and the price-setting behavior of generic and brand-name 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).[2] This article adds to the literature by investigating 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.

My model describes a dynamic oligopoly in which 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.[3] Klemperer (1987a) and Klemperer (1987b) provided the first insights on the impact of switching costs on the competitive outcome in a duopoly. Within a two-period framework, he shows that switching costs lead to aggressive competition in the first period and higher prices in the second period as firms profit from locked-in customers with switching costs.[4] The literature has extended the work to a multi-period environment (Beggs and Klemperer, 1992; Padilla, 1995; Anderson et al., 2004; Anderson and Kumar, 2007; see also the survey in Farrell and Klemperer, 2007). Each of the models considers duopolies and finds that firms have an incentive to decrease prices sporadically and set higher prices in subsequent periods to harvest consumers. In these models, consumer switching costs soften dynamic competition.[5]

The existence of switching costs has been documented in various empirical studies, including Calem and Mester (1995), Dubé et al. (2010), Keane (1997), Shcherbakov (2016), Shum (2004), Shy (2002), and Viard (2007). In a study relevant to the pharmaceutical market, Hollis (2002) shows that the first generic pharmaceutical in the Canadian market has a competitive advantage over followers. Further, Feng (2017) presents evidence that the demand for pharmaceuticals in the anti-cholesterol market shows habit persistence. Crawford and Shum (2005) also suggest switching costs for anti-ulcer drugs.

Collusion in the form of alternating actions has received attention in economic theory as well as in empirical work. Daughety and Forsythe (1988) show that alternating monopoly prices in an oligopoly generate a first best collusion outcome without a common knowledge assumption. Further, Amelio and Biancini (2010) note that alternating monopoly price strategies may serve as a coordination device. Clark and Houde (2013) show that collusion among asymmetric retailers may result in delays of price changes to favor stronger firms. In my model framework, alternating collusion schemes arise due to the habit persistence of patients.

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. Edgeworth cycles are observable in retail gasoline prices (see, e.g., Noel, 2007a; Noel, 2007b; or Doyle et al., 2010). However, a recent study by Plum Hauschultz

[2] One explanation is a segmentation of the market into cross-price-elastic patients and loyal, entirely price-inelastic patients. Producers of branded pharmaceuticals may focus solely on price-inelastic patients after a generic product has entered the market (Frank and Salkever, 1997).

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

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

[5] Recent theoretical literature includes discussions on the possibility of lower degrees of switching costs in which competitive pressure may increase (Arie and Grieco, 2014; Cabral, 2016; Dubé et al., 2009; Fabra and García, 2015; Rhodes, 2014). A detailed discussion of the previous literature and questions about when switching costs make markets more or less competitive can be found in Ruiz-Aliseda (2016).

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.[6] My study exemplifies a market where behavioral frictions of consumers as well as specific market regulations may help in detecting tacit collusion. I show that in a model of dynamic competition with consumers that have brand preferences and experience habit persistence, price dynamics are different in competitive equilibria and equilibria of tacit collusion.

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

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.[7] Patients' co-payments for all health care expenditures decrease as yearly expenses increase, and a cost ceiling is reached at 5300 Swedish krona (approx. $550).[8]

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. Second, the product of the month may be out of stock. The pharmacy is then allowed to substitute the next cheapest product, and so on. As in the first case, patients still pay the same co-payments. Third, patients may oppose substitution. In this case, they pay

[6] Porter (2005) gives an overview of these topics.

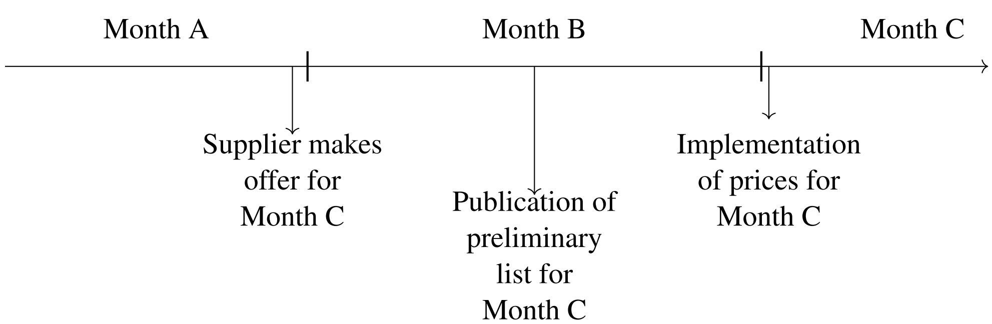
[7] The exact products that are reimbursed are subject to the decision of the Dental and Pharmaceutical Benefits Agency (TLV). Note that some products are just partly reimbursed. See TLV (2016e) for detailed information.

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

the difference between the chosen product (the prescribed product) and the product of the month.[9] Previous research has indicated that a substantial number of patients do not receive the product of the month, even though the cheapest product is presented. See for example the estimation of Janssen (2019) and Bergman et al. (2012). Bergman et al. (2012) estimate that, in 2012, 70% of consumers purchased the product of the month, and 11% of pharmaceutical purchases were the result of patients or physicians opposing substitution. Although search costs are an important determinant of demand in many pharmaceutical markets and can result in price dispersion across drugs (Sorensen, 2000), search costs are not relevant behavioral frictions in the Swedish market. Within the Swedish market, patients get dispensed the cheapest available generic by default. Finally, prices for all drugs are uniform across all pharmacies.

Off-patent drugs are subject to a tendering system.[10] The Dental and Pharmaceutical Benefits Agency (TLV) organizes a monthly price competition such that the cheapest product of a predefined substitution group (determined by the medical product agency) receives product-of-the-month status.[11] The details of the pricing system are described in Figure 2. The timing is as follows: at the end of a month (Month A), a pharmaceutical company submits the pharmacy purchase price for the month after the next (Month C). In the case of a missing bid, the price of the previous month is taken as a bid. Prices are regulated such that they cannot exceed a price ceiling that corresponds to 35% of the original brand product price before the expiration of the patent.[12] In the middle of the next month (Month B), the TLV publishes a preliminary list of the resulting prices. Before 2014, the prices were implemented in the next month (Month C), but since 2014, pharmaceutical companies have had to confirm that they can serve the entire Swedish market before the prices are implemented.[13] One essential feature of the timing is that pharmaceutical suppliers see the preliminary list for the next month before bidding for the following month (TLV, 2016c).

Figure 2: Timeline of Pricing



Final retail prices are regulated and directly dependent on pharmacy purchasing prices. Retail prices are an al-

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

[10]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' copayments in this segment were $0.64 billion in 2015 (TLV, 2016a).

[11]Note that usually patients get a prescription for a specific group. Substitution between groups is possible, such as when a different size or strength is requested; however, empirically substitution between groups is rather uncommon and happens mostly if a product is not in stock, which occurs in approximately 3% of cases (see Section 6). 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.

[12]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).

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

most linear function of pharmacy purchasing prices, and the difference determines the trade margin(TLV, 2016d).[14] Pharmacies are obliged to dispense the product of the month if it is not opposed by physicians or patients. Profits for prescription drugs increase with the price of products, such that pharmacies could enhance their profits by dispensing a more expensive product.[15] If the product of the month is not in stock, the pharmacy dispenses the cheapest available reserve product.[16]

4 Model

The model is related to the approaches by Padilla (1995), Anderson et al. (2004), and Anderson and Kumar (2007). I extend the model to three competitors and characterize Markov perfect equilibria with three firms. Further, I integrate the institutional background of the Swedish system. Padilla (1995) and Anderson et al. (2004) briefly discuss tacit collusion within dynamic oligopolies, but they restrict their attention to cases in which both firms charge a monopoly price. Thus, collusion is less sustainable than in the absence of switching costs. I extend the literature by characterizing a tacit collusion mechanism where firms alternate prices.

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 are bounded by $P = [0, R]$. Firm j faces a demand D^t_j.[17] 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 1. 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 θ 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[18]

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

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

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

[16] 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.

[17] Note that pharmacies are a passive actor in the market. They receive a fixed retail margin. Therefore I do not model pharmacies as an own agent but manufacturers that face consumers directly.

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

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

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

The demand implies an important *tie-breaker rule*. If two firms set the same lowest price, only one firm is in the state $x^t = j$ and receives the demand of price-elastic patients.[19] Therefore, the state x^t results in additional price-inelastic patients (θ) and the advantage of the tie-breaker rule.

On aggregate, the demand is not totally price-inelastic; however, some of the patients (i.e., the patients that are habit persistent and those that have a brand preference) are price inelastic. The unit mass of new patients is perfectly price elastic. As a result, demand for each product depends on the ranking of prices but not on the price differences.[20]

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

The transition can be described as follows:

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

If firm j was the strictly cheapest supplier in the previous period $t-1$, the new state is $x^t = j$. If j has offered a weakly lower price in $t-1$ and the previous state 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

[19] The assumption is based on the behavior of the pharmacy. Price-elastic patients do not have a brand preference and are indifferent between products. However, they reduce their costs by purchasing largely one product. In the empirical part of this article I investigate the assumption. If two firms set the same lowest price, market shares are asymmetric with one firm receiving a much higher market share.

[20] The assumption is in line with empirical observations within the data. Note first that the difference between the cheapest and most expensive product is often not high due to the tight setting of the upper bound R. The average maximal price difference between the cheapest and most expensive product across all substitution groups is 112.2 SEK (approx. 11.2 USD). After controlling for whether a product is the cheapest product within a substitution group, a price decrease of 100 SEK (approx. 10 USD) is associated with a market share increase of only 1 percentage points; see the empirical part of this paper in Section 8.

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 payoff-relevant strategies of a subgame. Naturally, an MPE forms an SPE. Formally, players condition their strategies in an MPE on payoff-relevant states, $\mathscr{S}_j : \mathscr{L} \to \Delta(P)$. $(s_j^*)_{j\in N} \in \mathscr{S}_j$ 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 of the Model

4.2.1 Monopoly

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

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

Proof. See Online Appendix A. □

4.2.2 Duopoly

I begin by characterizing MPE. Afterward, I show possible collusion schemes that rely on an SPE. Consider two competing firms, denoted as $j \in N = \{1,2\}$. First, I investigate the case of $l_1 = l_2 = l^L = l$. Each firm is in a state either with or without habit-persistent patients, and states are denoted as $x^t \in \mathscr{L} = \{1,2\}$, where $x^t = 1$ when firm $j = 1$ has 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.[21] 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

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

$p = R$. 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 number of habit-persistent patients is sufficiently high. The next proposition characterizes the mixed equilibrium of the game. Note that I use subscripts to indicate whether $x = j$ (habit-persistent patients) or $x \neq j$ (no habit-persistent patients).

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

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

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

2. *Valuation functions:*

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

Proof. See Online Appendix C. □

Numerical Example. See 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.[22]

In 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 scenario: 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.

[22]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).

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 than the non-deviating profit.[23] 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.[24]

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

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

Proof. See 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. 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 equal shares 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 $l_1 = l^H > l^L = l_2 = l_3$ (i.e., one firm has a greater share of patients with brand preference than the other firms have).

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

[24] 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.

In the first case, the three firms selling generics complete equally.

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. See Online Appendix G. □

Numerical Example. See Online Appendix G.

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 from 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 $j \in N$:*

$$S_1 : p_1 = R$$
$$S_j : \begin{cases} p_j \sim F(p) = \frac{p(1+l^L+\theta)-V(\cdot|x=j)(1-\delta)}{p+\delta(V(\cdot|x=j)-V(\cdot|x\neq j))} \quad \text{for } p \in [\underline{p}, R] & \text{if } x \neq j \quad \text{for all } j \in \{2,3\} \\ p_j \sim F_1^j(p) = \frac{p(1+l^L)+\delta V(\cdot|x=j)-V(\cdot|x\neq j)}{p+\delta(V(\cdot|x=j)-V(\cdot|x\neq j))} \quad \text{for } p \in [\underline{p}, R] & \text{if } x = j \quad \text{for all } j \in \{2,3\} \end{cases}$$

2. *Valuation functions:*

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

3. *Where $\underline{p}$ satisfies:*

$$\underline{p} = \frac{(\theta + l^L)}{1 + l^L + \theta + \delta\theta} \leq \frac{R(l^H - \delta\theta)}{1 + l^H}{}_{25} \tag{1}$$

Proof. See 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. Thus, relative to the value of the habit-persistent patients, the differential between the share of patients with a brand preference for the branded product and the share of patients with a brand preference for the non-branded product has to be sufficiently large.

Collusion between generics: In a triopoly, one may observe a different kind of collusion scheme.[26] 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 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:

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

Proof. See Online 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. Due to the tight bounds, existence of the equilibrium is not guaranteed.

[25] If all parameters are positive, this expression reduces to $l^H - l^L \geq (1+\delta)\theta$.

[26] 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.

A comparison of the upper and lower bound shows that the set of equilibria is non-empty if $l^H > \frac{3-2\delta^2+2\theta(1+\delta)}{1+2\delta^2}$.[27] Thus, the original manufacturer would need a relatively large amount of patients with a brand preference.[28]

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 sets the highest possible price. If there are at least three firms that offer generic products, a collusion scheme will require a higher degree of coordination. A possible collusion scheme would be based on the 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. I predict that in markets with more than three firms, these collusion schemes would be less likely.

5 Hypotheses

5.1 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.

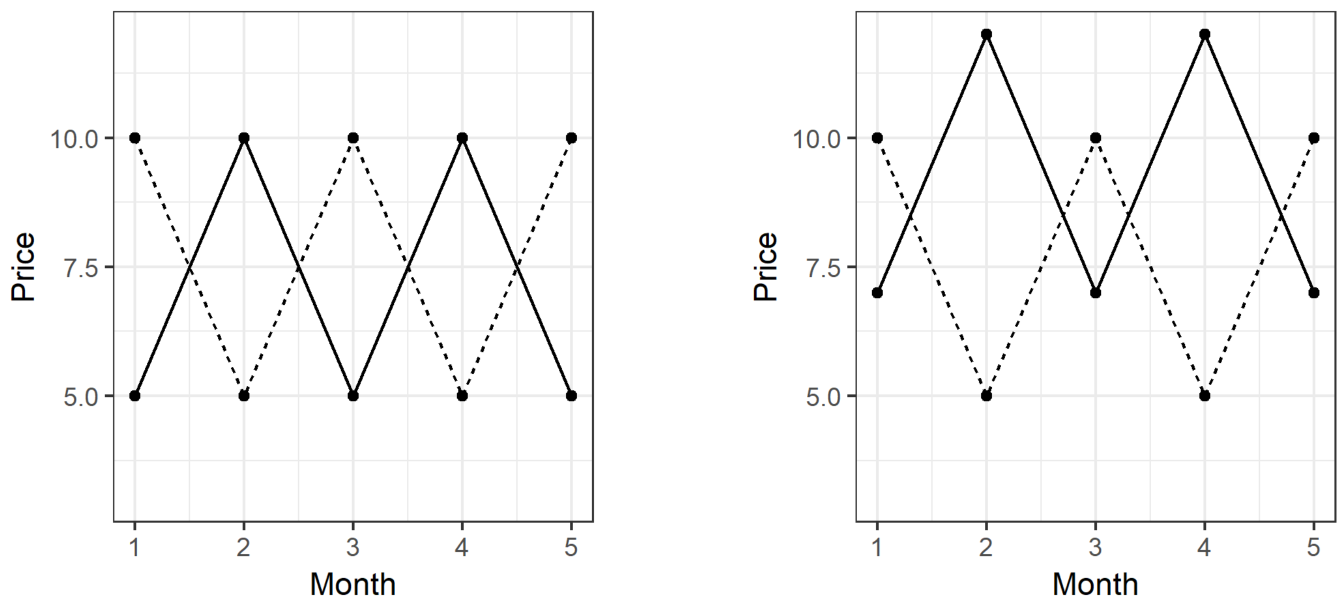
I start with fundamental implications for possible tacit collusion schemes. I define a possible collusion scheme as a rotation between two firms. To identify rotation schemes in the data, I define two different rotation types. The first rotation is based on a price cycle where firms rotate between a common upper price ceiling and lower price floor. In 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:
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 asymmetric price cycle (APC) where firms rotate between individual upper and lower price boundaries. Again, a different firm provides the cheaper option in each period.

[27] I am grateful to an anonymous referee for suggesting this transformation.
[28] To get to the expression, subtract the upper from the lower bound and substitute demand of the generic firm by $l^L = (1 - l^H)/2$.

Figure 3: Examples of Price Cycles



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

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 subset of those in an SPC.[29] In the following hypotheses, I refer to APCs and SPCs 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, the model 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. However, existence of the collusive equilibrium requires much higher brand preference for the original firms. Thus, the frequency is much lower.

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 Definitions 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 with a brand preference to prevent undercutting.

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

[29] 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. Online Appendix O addresses the concerns.

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. For example, the absence of behavioral frictions may lead to collusive schemes in which firms charge identical prices. Those should happen in different substitution groups than in those with habit-persistent patients and brand preferences.

5.2 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. Approximately 73% to 93% of patients purchase the cheapest product (product of the month). However, the share of patients consuming the cheapest available product varies substantially across specific pharmaceutical subgroups.[30] 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 represent 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, θ 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 consume a specific product over two periods and do not substitute to another product within a treatment period. 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 at the time of the initial treatment) and (2) physicians who prescribe a previous product of the month and thereby lead patients to oppose substitution.

To evaluate the fit of the model I test distinct assumptions. First, I show evidence for habit persistence. In detail, 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[31] is *not* a function of habit persistence alone. Indeed, theory shows that price cycles emerge when patients are habit persistent 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, my model shows that under the existence of any habit persistence or heterogeneous brand preferences on the patients' side, the profit-maximizing market-sharing rule is price cycles. In the case without habit persistence or heterogeneous brand preferences, firms maximize profits by setting the same price. However, same price setting is not necessary a collusive agreement, as competitive equilibria without habit persistence and brand preferences also have the same price dynamics.

Hypothesis D2. *Brand preference for originals, as well as habit persistence, is associated with price cycles. The nonexistence of both behavioral frictions may lead to identical prices.*

Price cycles as a first best collusion mechanism are based on the assumption of pharmacies' procurement behavior. The tie-breaker rule said that new consumers buy from the firm that offered the cheapest product in the previous period if that firm offers the cheaper price together with a competitor. The reasoning is that pharmacies maximize their profits by purchasing high amounts of one product. Pharmacies have a lower profit when procuring high quantities of two

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

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

products compared to sticking with 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. Furthermore, the pharmacy may have an oversupply of products from previous periods that it can dispense. In case neither firm has a higher mass of patients, I assume that the pharmacy randomly dispenses one product.

While I do not observe the true state as in the theoretical model, I can test whether the firm with habit-persistent patients (i.e., the firm with the lowest price in the previous period) indeed has a higher market share, all other factors being equal.

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

6 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 × strength × package combination, and the medical product agency decides about suitable substitutions. I observe bids from each exact product and the substitution group it belongs to. I exclude subgroups that were in place less than 6 months. I connected the data with pharmaceutical statistics from Socialstyrelsen, which is the Swedish governmental agency for health and welfare. The pharmaceutical statistics provide the annual number of prescriptions and dispensed units on the substance level from 2010 to 2015.

For the 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, antiepileptics/anticonvulsants, antibiotics, and beta-blockers. The data of the demand side is on the same level (product specific, monthly) as the supply data. It includes product-specific monthly sales information, which allows me to explore market shares of products within substitution groups (substance × strength × package combination) of the four pharmaceutical subgroups.

Table 1 shows summary statistics on the individual product level, where the price of a product at time t corresponds to one observation. For the duration of 6.5 years, I observe 350,057 prices, 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 prices 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 substitution group of the entire sample (2.79). However, the distributions of the number of competitors among substitution groups differ substantially when the complete sample and the price cycle

Table 1: Summary Statistics, Products

	Entire	APC	SPC
N	350057	2389	1365
Share Prod. of Month	0.334	0.523	0.672
Share Prod. of Month or Reserve	0.501	0.948	0.967
Fract. of Original	0.152	0.069	0.089
Fract. of Generics	0.754	0.916	0.897
Fract. of Parallel Imports	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 product of the month is usually the cheapest available product in a substitution group at time t. Reserve status is awarded to the second and third cheapest products in a substitution group. Price is the retail price of a product in SEK, averaged across products and months between January 2010 and June 2016. Standard deviations are reported in parentheses.

subsamples are compared. 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.[32] As shown in 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 1. In detail, approximately 28% of the purchases of painkillers, 7% of antiepileptics, 13% of antibiotics, and 14% of beta-blockers are not the product of the month. In the majority of the cases where the product of the month is not dispensed, the patient has opposed substitution.[33]

[32] I compare the supply and demand side directly in Online Appendix J.

[33] Note that the table describes individual choice data. However, I can use only aggregate market share data for the main analysis in Section 8.

Table 2: Summary Statistics, Substitution Groups

	Entire	APC	SPC
No. of Subst. Groups	2251	258	162
Mean No. of Competitors	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
Mean Maximal Price Diff.	112.2	21.2	14.7
Mean No. of Prescriptions	40,719.3	41,278.3	43,218.4
	(62,683.4)	(45,974.5)	(50,764.4)
Mean DDD per Person	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 number of competitors is 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* $N > 3$ *correspond to the substitution groups that have one, two, three, or more than three competing products at time t. The mean maximal price difference evaluates the difference between the maximum prices of the cheapest and most expensive products in a substitution group at time t. The mean number of prescriptions incorporates information about the number of prescriptions, whereas the mean DDD per person refers to the dispensed daily doses per person in t. Note that the number of prescriptions as well as the dispensed daily doses data are on a yearly level and not available for every substitution group. Averages across products and months between January 2010 and June 2016. Standard deviations are reported in parentheses.*

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 per Person	12.06	9.42	2.92	20.25
	(26.27)	(14.12)	(3.56)	(27.77)
Fract. Consumption of Period of the Month	0.73	0.93	0.87	0.86
	(0.44)	(0.26)	(0.34)	(0.35)
Fract. Opposed Substitution by Patient	0.209	0.028	0.094	0.08
	(0.406)	(0.165)	(0.292)	(0.272)
Fract. Substitution Prohibited by Physician	0.024	0.018	0.005	0.038
	(0.152)	(0.132)	(0.071)	(0.192)
Fract. No Substitution due to Pharmacy	0.034	0.026	0.034	0.021
	(0.180)	(0.158)	(0.182)	(0.144)
Repeated Consumption of Product	0.754	0.849	0.562	0.679
	(0.43)	(0.36)	(0.5)	(0.467)
Opposed Substitution Cond. on Repeated Consumption of Product	0.239	0.024	0.135	0.088
	(0.43)	(0.15)	(0.34)	(0.28)

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

7 Supply Side

7.1 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 8, 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. In Section 7.2 I show robustness checks.

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 with firms in other competitive market conditions, monopolists change their prices less frequently. Furthermore, one sees 0.55% with price increases and 2.02% with price decreases.[34]

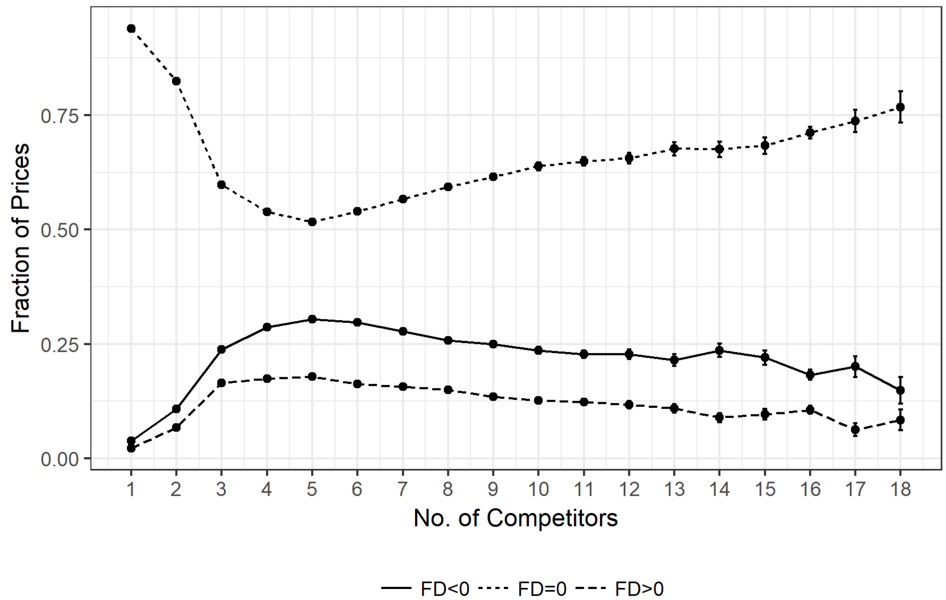
Hypothesis S1 also states that a monopolist does not set prices in a rotational scheme. Figure 4 already showed that there are no frequent price changes. Nevertheless, I also show some descriptive statistics of rotational price setting. The price cycles I have defined in Definitions 2 and 3 are only 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 greater (smaller) than zero, and in the forthcoming period, the prices reverts such that the first difference in prices smaller (greater) 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 $p_{t+2} - p_t = 0$).[35] Both individual pricing patterns are nearly nonexistent for monopolists. They neither revert nor rotate their prices.

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

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

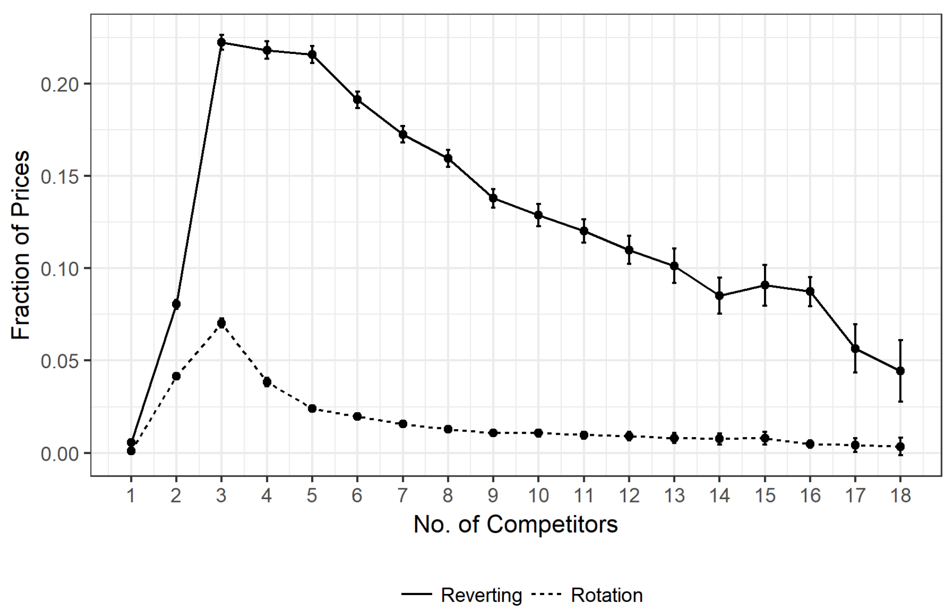
[35] Note that rotation patterns are a subset of reverting patterns. In comparison to the definition of SPCs and APCs (Definition 2 and Definition 3), rotating and reverting patterns are measured on the individual level. Therefore they also incorporate monopolies.

Figure 4: First Differences in Prices



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

Figure 5: Cyclical Pricing of Individual Firms



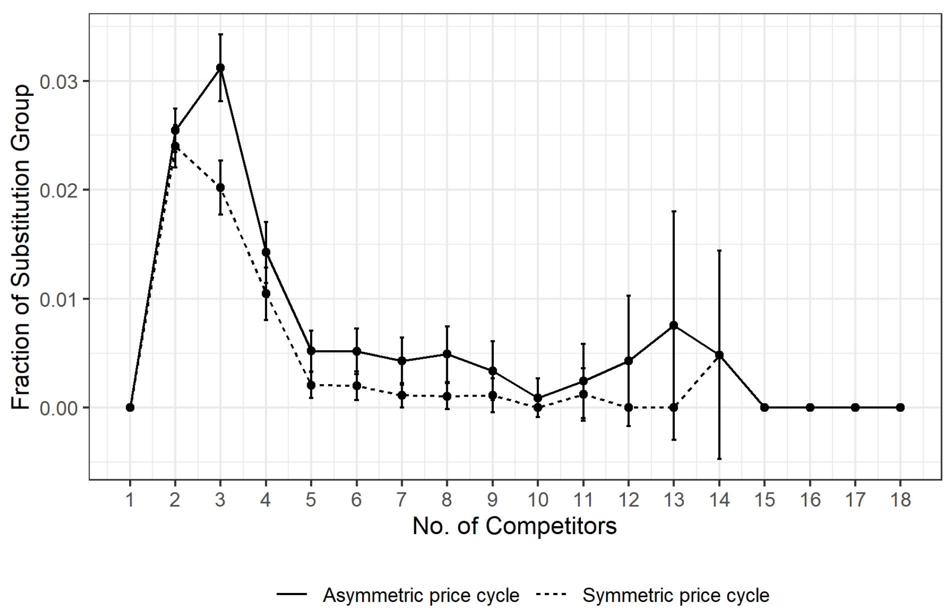
Notes: Share of products with rotating or reverting prices conditional on the number of competitors in a substitution group. Conditional on the number of competitors in a substitution group at time t, the three series show the share of products with reverting or rotating prices. Error bars correspond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

Two or more competitors

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). As shown in Figure 5, individual cyclical pricing in the forms of rotation 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 both fractions are not high, even for two competitors. Price cycles are not observed frequently. The reason may be that competitors do not collude or that they engage in collusion by setting the same price, as the habit persistence is not important.

Figure 6: Price Cycles



Notes: Share of substitution groups in a symmetric price cycle (Definition 3) and an asymmetric price cycle (Definition 4) conditional on the number of competitors over all time periods. Error bars correspond to the 95% confidence interval.

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 could be correlated with those unobservables. The descriptive analysis of this article is not intended to provide complete identification of reasons for collusion. However, in the following, I try to investigate variation within substitution groups. The primary intuition for this approach is that patients within a substitution group behave similarly regarding their habit persistence and brand preferences, independent of the number of competing firms. Furthermore, the following approach controls for time fixed effects.

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:

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

where α_i is a vector of substitution group fixed effects, γ_t is a vector of time fixed effects, and β 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. ε_{it} is an error term. Table 4 presents the following regression evidence, where the dependent variables are the SPC and APC dummy variable, respectively. In Models 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 use 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 a 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 increase 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 support that price cycles occur most often in duopolies and are less common in markets with more than three competitors (Hypothesis S2). For a complete evaluation of Hypothesis S2, it remains necessary to show that, in subgroups with 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

[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 Online Appendix K. I cluster standard errors and adjust them for autocorrelation and heteroskedasticity.

[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

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

Notes: One observation corresponds to a substitution group at time t. In the first three models, the dependent variable is a dummy that takes the value 1 if a substitution group at time t is in a symmetric price cycle (SPC), while the fourth to sixth models correspond to an asymmetric price cycle (APC). C is the number of competitors in a substitution group at t. Five or more competitors are merged. In the Online Appendix X, 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 (ATC controls are dropped as they are perfectly correlated with the substitution group), and Models 3 and 6 include substitution fixed effects as well as time fixed effects. Standard errors in parentheses 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.

firms as a regressor. Table 5 shows regression evidence of three linear probability models. As before, the dependent variable is the dummy S_{it} (Models 1-3, SPC; Models 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.

Table 5: Regression, Originals and Generics

	SPC			APC		
	(1)	(2)	(3)	(4)	(5)	(6)
C=1,NoO	−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,NoO	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,NoO	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,NoO	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,NoO	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

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

Notes: One observation corresponds to a substitution group at time t. The dependent variable for Models 1 to 3 is a dummy that takes the value 1 if a substitution group at time t is in a symmetric price cycle (SPC). For Models 3 to 6, the dependent variable is a dummy that takes the value 1 if a substitution group at time t is in an asymmetric price cycle (APC). C is 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 no original exists. Five or more competitors are merged. In the Online Appendix X, 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; ATC controls are dropped as they are perfectly correlated with the substitution group. Models 3 and 6 include substitution fixed effects as well as time fixed effects. The coefficients for more than nine 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.*

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 with a 1.9 percentage point increase in the possibility of an SPC) as well as an APC (4.7 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 an SPC (1.1 percentage points without and 1.0 percentage point with an original) and an APC (2.8 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. Given the insignificance, I cannot confirm the role of originals entirely. Thus, one may conclude that price cycles are less common in triopolies than in duopolies. One possibility to rationalize the non-result is that the equilibrium conditions of Proposition 5 required too high of a market share for the original product.

7.2 Robustness Checks

I perform a series of robustness checks. In Appendix A, I relax the assumption of stable consumer characteristics and address possible endogeneity concerns using robustness checks. It may be possible that entries or exits are correlated with demand characteristics. For example, in addition to patients' habit persistence, the lifetime of an ingredient could be related to competition. Also, policy or demand shocks could be different across ingredients and further change competition of firms. In the robustness check in Appendix A, I use models that incorporate ingredient × time fixed effects. Therefore, I solely explore variation between substitution groups of specific ingredients (i.e., different size or strength) in a given month.

Online Appendix K 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 Online Appendix M and find that specific multi-product firms do not drive the presented results; nor do multi-market contacts explain prices. In Online Appendix N, I extend the robustness check and show that results are stable when using producer fixed effects. Online Appendix O addresses concerns of autocorrelation and different forms of price cycle definitions, while I show in Online Appendix Q that habit persistence itself is not a function of the number of competitors.

8 Demand Side

Evidence for Habit Persistence

In the following, I investigate whether market share patterns of products in the four therapeutic groups show evidence of habit-persistent behavior as well as evidence for preferences for branded drugs. In detail, I use monthly market shares for each product within the four therapeutic subgroups.[38] Consider the following model, where one observation corresponds to product i in month t:

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

where $Share_{it}$ is the market share (between 0 and 1) of a product in its substitution group.[39] $Original_{it}$ and PI_{it} (where PI = parallel import) are dummy variables that take the value 1 if i is an original branded or parallel imported product and 0 otherwise. $Add.Expenses_{it}$ is the out-of-pocket expenses for products that are not the product of the month.

[38] 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.

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

Therefore, $Add.Expenses_{it}$ takes the value 0 if product i at time t is the product of the month. If i is not the product of the month, $Add.Expenses_{it}$ is the expenses a consumer bears by opposing substitution (i.e., the difference between the retail price of product i and the retail price of the product of the month). $PoMn_{it}$, $PoMn_{it-1}$, $PoMn_{it-2}$, and $PoMn_{it-3}$ are dummy variables. $PoMn_{it}$ is 1 if product i is the product of the month in i. $PoMn_{it-1}$, $PoMn_{it-2}$, and $PoMn_{it-3}$ are 1 if a product was the product of the month in $t-1$, $t-2$, or $t-3$, respectively, but not in subsequent periods. I interact the present and lagged indicators of the PoM status with the four therapeutic subgroups $ThSub = \{Painkillers, Antibiotics, Antiepileptics, Beta\text{-}Blocker\}$ to explore heterogeneity in habit persistence. Finally, α_i is a product fixed effect (a product is a specific brand within a substitution group),[40] and γ_t is a time fixed effect. Note that I also control for the number of competitors in a substitution group in month t.

I provide reduced-form evidence that the assumptions of the demand side are suitable. To back up the assumptions of the theoretical model, I expect that a positive coefficient of β_0, an original branded product, is associated with a higher market share. In the model, the positive coefficient would translate to the existence of patients with brand preferences. Further, the model assumes a unit mass of patients consuming the product of the month. In the basic regression, one would see a robust positive coefficient of ρ_0. Further, the model assumes that a mass of θ patients are habit persistent and consume the product of the previous month. Therefore, I expect a positive coefficient of ρ_1, which should be smaller than ρ_0. Finally, habit persistence in the model exists over just one period, such that ρ_2 and ρ_3 should not be significantly different from zero or at least much smaller than ρ_1. Finally, as I show in Janssen (2019), results for different therapeutic groups are heterogeneous.

Table 6 shows evidence from three different models.[41] Model 1 does not include fixed effects. In Model 2, I include product fixed effects, and Model 3 incorporates product and time fixed effects.[42] The coefficient for an original product is significant and positive. An original product is related to a market share that is 9 percentage points higher. Second, the product of the month has a significantly higher market share in all three specifications. Being a product of the month (*POM*) is associated with a market share (ρ_0) that is 41 percentage points higher market than the reference level, which is a beta-blocker in the preferred specification of Model 3. The levels are approximately the same for antibiotics and antiepileptics as the interaction terms of their indicators with *POM* are insignificant. However, for painkillers, the product of the month has a lower market share (3.7 percent less with the product and time fixed effects). The variable that captures potential habit persistence over one period is captured in the lagged $PoMn_{t-1}$ status. ρ_1 on the baseline level (beta-blocker) is significant in Models 1 and 3 and much lower than ρ_0 (between 6.2 and 4.5 percentage points). The result is similar for antibiotics and painkillers when introducing product and time fixed effects. Only patients who use antiepileptics seem to be not habit persistent.[43] 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 5% level for all therapeutic subgroups.

Patients' habit persistence translates to a higher market share in the following month. The coefficients of the following months show that habit persistence decreases. Indeed, the size of the coefficient for PoM_{it-2} and $PoMn_{it-3}$

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

[41]I start by providing evidence for the basic model. In Online Appendix P 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 those summarized here. As in the supply-side analysis, I cluster standard errors on the product level. Standard errors are adjusted for autocorrelation and heteroskedasticity.

[42]Note that product fixed effects capture the variation of the regressor *Original*.

[43]In detail, it seems that patients who use antiepileptics 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 who use antiepileptics do not usually change to entirely different products, as they often require antiepileptic medication for long periods. Because 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.

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

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

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

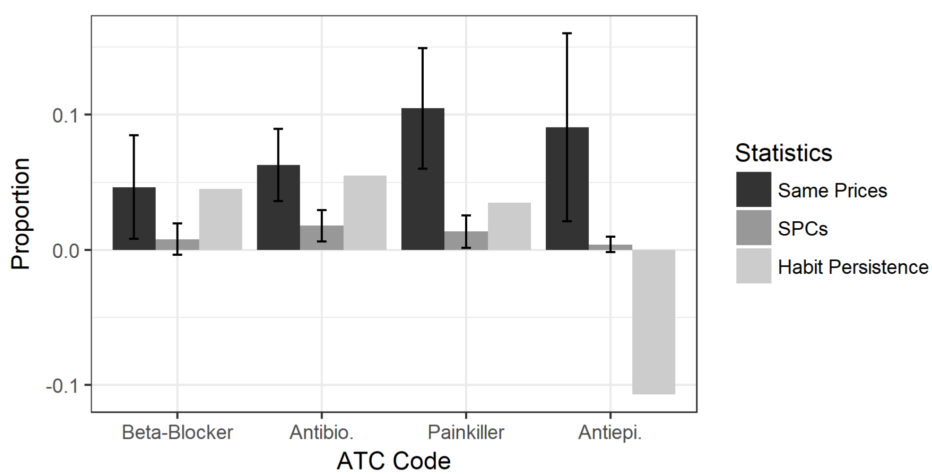
is much smaller and insignificant. The reduced-form evidence for the four therapeutic groups confirms the demand assumptions of Hypothesis D1.[44]

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 identification of 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.[45] Estimates of habit persistence are from Regression Model 2. The share of *available* originals of all products across substitution groups for each of the four therapeutic groups is the following: 66% for painkillers, 66% for beta-blockers, 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 painkillers and antiepileptics. SPCs are foremost visible for antibiotics and painkillers. The results are aligned with model predictions: In groups with habit persistence (higher for antibiotics and painkillers) and brand preferences (originals present in substitution groups for beta-blockers, antibiotics, and painkillers, which may lead to heterogeneous brand preferences), one observes price cycles. For antiepileptics, where originals are not present and consumers do not experience habit persistence, one sees relatively more same prices offered by competitors rather than price cycles. The results show evidence in support of Hypothesis D2.

Figure 7: Habit Persistence, Identical Prices, and Price Cycles



Notes: The graph shows three different statistics for each therapeutic subgroup (beta-blockers, antibiotics, painkillers, antiepileptics). The coefficients of the habit persistence are from Regression Model 2. 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 symmetric price cycle over time. The sample includes all observations with two or more competitors, as all statistics of interest require at least two competitors. The error bars for same prices and SPCs correspond to the 95% confidence interval using the standard errors across substitution group averages.

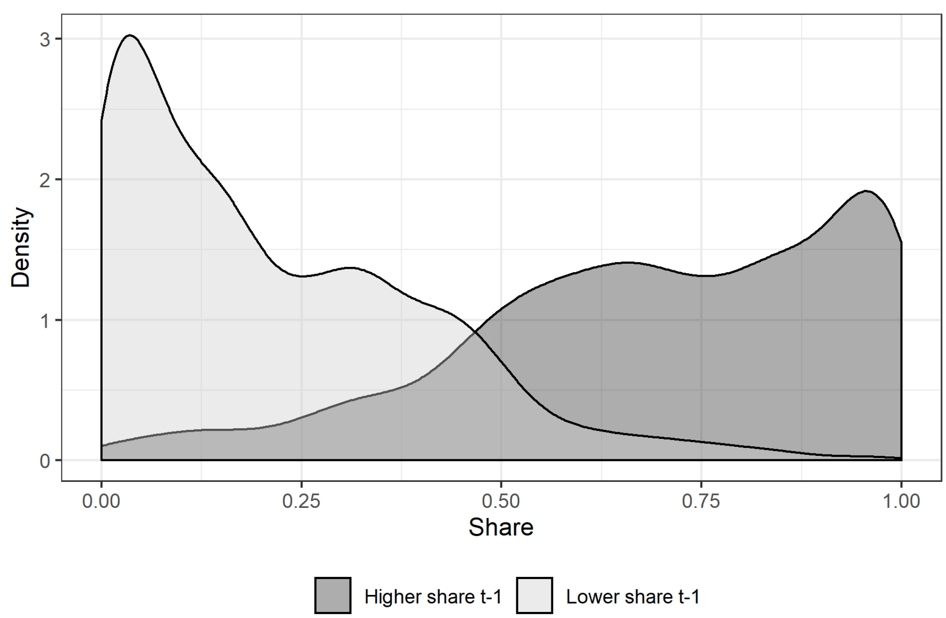
[44]In Online Appendix Q, I show evidence that habit persistence is not a function of the number of competitors.

[45]Please see a table with the results in Online Appendix P.

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. According to the theory, the firm with a higher mass of habit-persistent patients should receive a higher market share. I show in Figure 8 the the density of observable market shares in those markets where two firms charge the same lowest price. I then split the sample into two groups: first, those with the largest fraction of the market shares in the previous month and, second, a group with lower share in the previous period. The results show that the distributions of market shares are diverging. If firms have the same price, the market shares are not normally distributed around 0.5 but instead bimodal, with some having low market shares and some having high market shares. As Figure 8 shows, the firm with high market share is the one that also had a higher market share in previous periods.

Figure 8: Same Prices: Density of Market Shares



Notes: The graph shows the density of market shares of products where at least two firms set an identical lowest price within a substitution group. The density is divided into two groups: (1) the group with the lowest market share in the previous period and (2) the groups with higher market shares in the previous period.

In the following, I extend the argumentation that the data support this crucial assumption of the model. Consider the following regression model that estimates market shares in a similar to Regression Model 2.

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

In comparison to Regression Model 2, I use the lagged market share $Share_{it-1}$ as a regressor to explore the size of habit persistence.[46] $TPoM_{it}$ takes the value 1 if firm i in t is the product of the month together with another firm. Note

[46] In Model 2 I included the regressor $PoMn_{t-1}$ (a dummy that takes the value 1 if a product was the product of the month in $t-1$ but not in t) instead of the lagged market share. The major intuition is that I intend to explore whether there is a direct relationship between patients attracted to a product that is not the product of the month and those that have previously consumed the product of the month. Here, I am interested in a specific absolute relation between past and new market shares. In Online Appendix R, I show results using $PoMn_{t-1}$ to show that the results

that also PoM_{it} would take the value 1 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 κ_1 is positive and significant. κ_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 of a company itself becomes even more important as it determines the procurement behavior of the pharmacy. I try to approximate this term by evaluating whether the lagged market share plays an even larger role in cases of the same prices. I also investigate the role of original products.

Table 7 shows the results for three models: without fixed effects, with product fixed effects, and with product and time 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 do not lead to specific procurement behavior 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 persistence is still observable, such that (with product and time fixed effects) a 1 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 1 percent higher market share means that the market share increases further by 0.32 percentage points. On average the correlation of past market shares 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.

9 Discussion

Whereas standard economic theory predicts lower costs where competition is greater, the opposite has been seen in some pharmaceutical markets. 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, if multiple products have the same price within a month, they increase their profits mainly by increasing the quantity of one of the products.

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 in which the firms alternate their prices. Under the assumption of state-dependent patients, tacit collusion schemes of alternating prices are sustainable, whereas tacit collusion schemes of same prices are not. The model predicts that collusion between two firms is most likely in markets with two competitors. In markets with higher competition and sufficiently patient firms, collusion with three competitors may be possible. However, this research focuses on the collusion of two participants. The model predicts 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 while the other two firms form a collusion scheme. A sufficiently high base of patients with a brand preference leads to increasing profits for all three firms. Finally, I have also described the main predictions of pricing behavior in the absence of collusion conditional on the number of competitors in the market.

The apparent characteristic of alternating prices allows us to detect possible tacit collusion. I show that the sub-group 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. When

are robust.

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^{***}	-0.103^{***}	-0.082^{***}
	(0.020)	(0.010)	(0.008)
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

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

Notes: One observation corresponds to a product i in the substitution groups of painkillers, antibiotics, antiepileptics, or beta-blockers within a month t. The outcome variable is the monthly market share. Add.Expenses are the out-of-pocket expenses for product i, the difference between the price of product i and the price of the product of the month. POM is a dummy that takes the value 1 if product i is the cheapest available product of the month in t. Share$(t-1)$ is the market share of product i in $t-1$. POM and SP is a dummy that takes the value 1 if i and at least one different product have been product of the month in t. Original is a dummy that takes the value 1 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 and are clustered on the product group level, adjusted for serial correlation or heteroskedasticity. The R^2 corresponds to the full model, including the fixed effects.

a cycle forms in a market with three competitors, more often the cycle involves 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 confirm the model's prediction: (1) monopolists do not vary their prices and (2) the product of the month is more likely to increase in price in substitution groups with more than two competitors than in a market where only two firms compete. The main results are robust when I include a panel data method and look at variation within a market.

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 that dispense the product of the firm with the larger secured base of purchases. Finally, I exploit variation in habit persistence to demonstrate that the model predictions hold in competitive equilibria 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 markets, but in many retail markets, products have a low degree of differentiation. If consumers generally do not have strong preferences and the 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 retailers' 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 from the situation in markets with homogeneous products, where consumers are not habit persistent. In such cases, competitive equilibria are indistinguishable from tacit collusion schemes when price dynamics are observed in isolation.

From a policy standpoint, the competitive environment of the studied market may facilitates collusion. Firms compete simultaneously once per month, and a price ceiling is set by a regulator. Future research would be needed to evaluate the effects of policy reforms. For example, reducing the frequency of interactions and reducing the informational frictions of consumers (i.e., reducing habit persistence and brand preferences) could reduce profitability and therefore reduce the frequency of tacit collusion. While the analysis in this article is based on the Swedish case, another future research path concerns the impact of consumer behavior on price fluctuations and tacit collusion in less regulated markets. While consumer frictions shape firms' dynamic pricing strategies, tacit collusion also is dependent on consumer frictions. Future research may examine methods of tacit collusion detection that incorporate such consumer frictions in less regulated markets.

Appendix

A Robustness Check: Endogeneity

In the main analysis I verified Hypotheses S2 by a linear probability model across all substitution groups, including time and subgroup fixed effects. In this robustness check I address endogeneity concerns.

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

In detail, the regression of the main analysis had the following form:

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

Given time as well as substitution group fixed effects, possible unobservables that solely vary between substitution groups or time periods are absorbed. However, I have imposed the assumption of $E(\varepsilon_{it}|C_{it}, \alpha_i, \gamma_t) = 0$. One may argue that several unobservables vary with substitution group i as well as time period t. Possible factors are the time since a patent has run out or the substitutability with another (new) pharmaceutical that changes the demand composition for a specific substitution group. Both examples may effect entry and exit decisions of firms and would violate the assumption of $E(\varepsilon_{it}|C_{it}, \alpha_i, \gamma_t) = 0$.

Within this robustness check I first try to investigate possible endogeneity concerns. In detail, I start by considering substance groups according to the ATC code. An ATC code is an identifier for the active ingredient of a drug. If two drugs have the identical ATC code,[47] their chemical substance is identical. However, a unique chemical substance is not necessarily only present in one substitution group, as a substitution group is defined by substance, strength, and size.

Let k be a unique ATC code such that each product in substitution group i belongs to one ATC code $k \in K$. I estimate the probability of being in a price cycle by interacting the substance group with the time effect such that

$$P(S_{ikt} = 1|C_{kit}) = \beta C_{ikt} + \rho ATC_k \times date_t + \varepsilon_{ikt},$$

where C_{itk} is the number of competitors (treated as a discrete variable) in a substitution group, ATC_k is the ATC code, and $date_t$ is the monthly time period. Intuitively I allow for fixed effects in a substance group (ATC code) that is interacted with the time. The new requirements for an unbiased estimate of β is $E(\varepsilon_{ikt}|C_{it}, ATC_k \times date_t) = 0$. Assuming that products with the same substance group but different size and strength do not differ in unobservables within a given time period, I get an unbiased estimate. The mentioned examples such as the time since a patent has run out as well as substitutability with another product consisting of a different substance that enters the market would be captured by the interacted fixed effects.

Table A.1 shows results for a linear probability model where the outcome variable is the dummy for a symmetric price cycle (SPC). In detail, Model 1 shows the results with solely with ATC code fixed effect, and Model 2 shows the

[47] 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. For this analysis I use up the ATC code up to the fifth level.

results for only time fixed effects. In Model 3 I interact both effects. In Table A.2 I show the same regression analysis for asymmetric price cycles (APC). The coefficients for two and three competitors are significant for the interaction of the ATC code and time fixed effects. The same holds for APCs. The results are therefore robust to the main analysis and in line with Hypothesis S2.

Table A.1: Regression, SPC, Robustness

	(1) SPC	(2) SPC	(3) SPC
$C = 2$	0.0236***	0.0255***	0.0253***
	(0.00684)	(0.00704)	(0.00749)
$C = 3$	0.0191***	0.0213***	0.0224***
	(0.00388)	(0.00493)	(0.00591)
$C = 4$	0.00962*	0.0125*	0.0117*
	(0.00442)	(0.00524)	(0.00530)
$C = 5$	0.000765	0.00213	0.00155
	(0.00117)	(0.00275)	(0.00290)
$C = 6$	0.000358	0.00166	0.000234
	(0.00115)	(0.00235)	(0.00266)
$C = 7$	-0.000652	-0.000710	-0.000257
	(0.000869)	(0.00339)	(0.00313)
$C = 8$	-0.000224	-0.000676	-0.00131
	(0.000852)	(0.00414)	(0.00569)
$C = 9$	0.000209	0.00148	0.00298
	(0.000878)	(0.00304)	(0.00362)
$C = 10$	-0.000531	0.00103	0.0000692
	(0.000883)	(0.00308)	(0.00449)
$C = 11$	0.000224	0.00206	0.00565
	(0.00142)	(0.00404)	(0.00396)
$C = 12$	-0.000296	-0.00261	-0.0107
	(0.000905)	(0.00594)	(0.0147)
$C = 13$	-0.000801	0.00135	0.00461
	(0.00103)	(0.00482)	(0.00371)
$C = 14$	0.00153	0.00668	0.00338
	(0.00609)	(0.00707)	(0.00971)
$C = 15$	-0.00266*	0.00394	0.00262
	(0.00116)	(0.00427)	(0.00562)
$C = 16$	-0.00133	0.00623	0.00878**
	(0.00111)	(0.00335)	(0.00301)
$C = 17$	0.00158	0.00717*	0.00930**
	(0.000841)	(0.00301)	(0.00295)
$C = 18$	0.00106	0.00700*	0.00904**
	(0.000722)	(0.00302)	(0.00287)
Constant	-0.00749***	-0.000486	-0.000434
	(0.00168)	(0.00211)	(0.00224)
Fixed Effects	Time	ATC	ATC * Time
N	115,869	115,869	115,869

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

Notes: One observation corresponds to a substitution group at time t. The dependent variable is a dummy that takes the value 1 if a substitution group at time t is in a symmetric price cycle (SPC). C are dummies for the number of competitors in a substitution group at t. Due to multicollinearity the dummy for monopolies ($C = 1$) is omitted and presented in the constant. Model 1 is a least squares regression with time fixed effects. Model 2 includes fixed effects for the ATC code. Model 3 interacts the ATC code with the time period. The R^2 corresponds to the the full model, including the fixed effects. Standard errors are reported in parentheses.

To examine the last part of Hypothesis S2 I use the same regression evidence by differentiating between substitution groups with and without originals. The first three models of Table A.3 use the symmetric price cycle as an outcome, whereas Models 4 to 6 evaluate the probability of an asymmetric price cycle. Differentiating between substitution groups with and without an original gives the same conclusions as the main specification. For substitution groups with two competitors, symmetric price cycles are more common in substitution groups with an original. However, symmetric price cycles with three competitors are more probable when an original is present. For asymmetric

Table A.2: Regression, APC, Robustness

	(1) APC	(2) APC	(3) APC
$C = 2$	0.0249***	0.0270***	0.0267***
	(0.00715)	(0.00731)	(0.00773)
$C = 3$	0.0299***	0.0317***	0.0337***
	(0.00447)	(0.00550)	(0.00661)
$C = 4$	0.0133**	0.0166**	0.0162**
	(0.00451)	(0.00540)	(0.00545)
$C = 5$	0.00364*	0.00515	0.00402
	(0.00151)	(0.00311)	(0.00341)
$C = 6$	0.00317*	0.00487	0.00303
	(0.00153)	(0.00265)	(0.00311)
$C = 7$	0.00211	0.00292	0.00344
	(0.00145)	(0.00353)	(0.00337)
$C = 8$	0.00336*	0.00390	0.00341
	(0.00135)	(0.00409)	(0.00553)
$C = 9$	0.00228	0.00522	0.00711*
	(0.00121)	(0.00312)	(0.00350)
$C = 10$	0.000400	0.00371	0.00368
	(0.00108)	(0.00350)	(0.00476)
$C = 11$	0.00129	0.00546	0.00927
	(0.00206)	(0.00458)	(0.00524)
$C = 12$	0.00401	0.00351	-0.00412
	(0.00422)	(0.00429)	(0.0105)
$C = 13$	0.00662	0.0103	0.0145*
	(0.00491)	(0.00757)	(0.00718)
$C = 14$	0.000975	0.00716	0.00593
	(0.00624)	(0.00709)	(0.00976)
$C = 15$	-0.00327*	0.00409	0.00421
	(0.00137)	(0.00478)	(0.00605)
$C = 16$	-0.00174	0.00722*	0.0105***
	(0.00125)	(0.00360)	(0.00310)
$C = 17$	0.00149	0.00805*	0.0103***
	(0.000894)	(0.00317)	(0.00311)
$C = 18$	0.000950	0.00778*	0.00997***
	(0.000775)	(0.00315)	(0.00296)
Constant	-0.00946***	-0.000544	0.000586
	(0.00181)	(0.00219)	(0.00233)
Fixed Effects	Time	ATC	ATC * Time
N	115,869	115,869	115,869

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

Notes: One observation corresponds to a substitution group at time t. The dependent variable is a dummy that takes the value 1 if a substitution group at time t is in an asymmetric price cycle (APC). C are dummies for the number of competitors in a substitution group at t. Due to multicollinearity the dummy for monopolies ($C = 1$) is omitted and is presented in the constant. Model 1 is a least squares regression with time fixed effects. Model 2 includes fixed effects for the ATC code. Model 3 interacts the ATC code with the time period. The R^2 corresponds to the the full model, including the fixed effects. Standard errors are reported in parentheses.

price cycles also, substitution groups consisting of two competitors plus an original are associated with more price cycles. However, the coefficient is much smaller than for the substitution groups with two competitors and without originals. The results are robust when using interacted ATC codes and time fixed effects and confirm Hypothesis S2.

Table A.3: Regression, Role of Generics, Robustness

	(1) SPC	(2) SPC	(3) SPC	(4) APC	(5) APC	(6) APC
C=2,NO	0.0358**	0.0381***	0.0372**	0.0382**	0.0411***	0.0400***
	(0.0128)	(0.0111)	(0.0115)	(0.0135)	(0.0117)	(0.0120)
C=3,NO	0.0162**	0.0187**	0.0179*	0.0229***	0.0244***	0.0233*
	(0.00563)	(0.00645)	(0.00851)	(0.00571)	(0.00689)	(0.00903)
C=4,NO	0.00859	0.0116	0.00734	0.0115	0.0143	0.01000
	(0.00827)	(0.00882)	(0.00692)	(0.00835)	(0.00914)	(0.00706)
C=5,NO	-0.00197*	0.00240	0.00296	0.00149	0.00694	0.00723
	(0.000834)	(0.00345)	(0.00365)	(0.00149)	(0.00379)	(0.00401)
C=1,O	-0.000962*	0.00239	0.00243	-0.00113*	0.00216	0.00246
	(0.000459)	(0.00210)	(0.00195)	(0.000528)	(0.00220)	(0.00213)
C=2,O	0.0114*	0.0139*	0.0144*	0.0117*	0.0139*	0.0146*
	(0.00501)	(0.00685)	(0.00687)	(0.00504)	(0.00699)	(0.00702)
C=3,O	0.0208***	0.0234**	0.0267**	0.0345***	0.0374***	0.0427***
	(0.00506)	(0.00721)	(0.00818)	(0.00650)	(0.00863)	(0.0101)
C=4,O	0.00999*	0.0139*	0.0158*	0.0141**	0.0188**	0.0216**
	(0.00465)	(0.00610)	(0.00713)	(0.00485)	(0.00630)	(0.00739)
C=5,O	0.00198	0.00277	0.00170	0.00446*	0.00480	0.00299
	(0.00174)	(0.00354)	(0.00381)	(0.00215)	(0.00415)	(0.00467)
Constant	-0.00679***	-0.000913	-0.000951	-0.00869***	-0.000937	-0.00112
	(0.00153)	(0.00250)	(0.00253)	(0.00166)	(0.00261)	(0.00265)
Fixed Effects	Time	ATC	ATC * Time	Time	ATC	ATC * Time
N	115,869	115,869	115,869	115,869	115,869	115,869

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

Notes: One observation corresponds to a substitution group at time t. The dependent variable for Models 1 to 3 is a dummy that takes the value 1 if a substitution group at time t is in a symmetric price cycle (SPC). For Models 3 to 6 the dependent variable is a dummy variable that takes the value 1 if a substitution group at time t is in an asymmetric price cycle (APC). Each displayed regressor is a dummy variable for the number of competitors in a substitution group at t. O stands for the existence of an original product in the substitution group in t, whereas NO means that no original exists. Note that the dummy for the presence of one generic competitor is omitted due to multicollinearity. Models 1 and 4 are least squares regressions with time fixed effects. Models 2 and 5 include fixed effects for the ATC code. Models 3 and 6 interact the ATC code with the time period. The coefficients for more than five competitors are omitted in this table (but are part of the regression). 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. Standard errors are reported in parentheses.

B Additional Hypotheses

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

Supply Side

Under the assumption that demand characteristics are balanced over substitution groups, 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 the other firms. Comparing the two cases, I expect a smaller relative price difference in a market with two competitors than in 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 two competitors than in markets with three competitors.*

If firms face patients with habit persistence or heterogeneous brand preferences across firms in substitution groups, they do not set identical prices in competitive or 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 noncollusive outcomes.

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

I expect to see identical prices as habit persistence may be nonexistent. 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 fewer 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 from 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 a Markov perfect equilibrium with three or more competitors indicates that a firm that has had 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 one or two competitors.

Hypothesis S5. *If firms in a duopoly do not collude, the firm with the cheapest product of the month does not increase its price in the subsequent period with certainty. However, if firms in a market with three or more competitors do not collude, 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.*

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 Propositions 1, 2, and 3, a higher value of θ changes the mixing distributions of the equilibrium strategies. Considering the minimum support $\underline{p}$, a higher θ has heterogeneous effects. The actual change depends on the competitive situation. In the case of two competitors and independent of the availability of originals or generics (for a differentiated mass of brand preferences), higher habit persistence is associated with a higher minimum support.[48] The same comparative static holds for triopolies with originals and generics ($l^H > l^L$).[49] However, in the case of triopolies without originals (homogeneous mass of patients with brand preferences) or in substitution groups with more competitors, an increase in habit persistence leads to a lower minimum support $\underline{p}$.[50]

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 with 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.*

I evaluate this hypothesis in Online Appendix T.

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

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

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

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