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Investigation of Bid Collusion within the Swedish Generic Drugs Market

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Abstract

The aim of the thesis is to investigate whether there is bid collusion within the Swedish generic drugs market. Two types of collusion are considered: bid rotation and parallel bidding. Bid rotation means that companies take turns in winning the auction. Parallel bidding, on the other hand, means that two (or more) companies charge the same price every month and hence win together, sharing the market. The data used has been obtained from Tandvårds- och Läkemedelsförmånsverket (TLV) and contains monthly bids on over 1900 drugs for the years 2010-2015. The thesis presents a new method of identifying bid collusion, based on the investigation of the series of winners over time. The strategy is to test if a sequence of winners is random. The test identifies 231 products with suspicious bidding patterns (bid rotation or parallel bidding), which constitutes around 25% of all products for which there is data for at least 30 months. The average price of products marked as suspicious is on average 5 times higher than a comparable product with many bidders. The isolated impact of collusion according to the difference-in-difference methodology is 47% price increase and the estimated cost to the society is 148 million SEK at the minimum.

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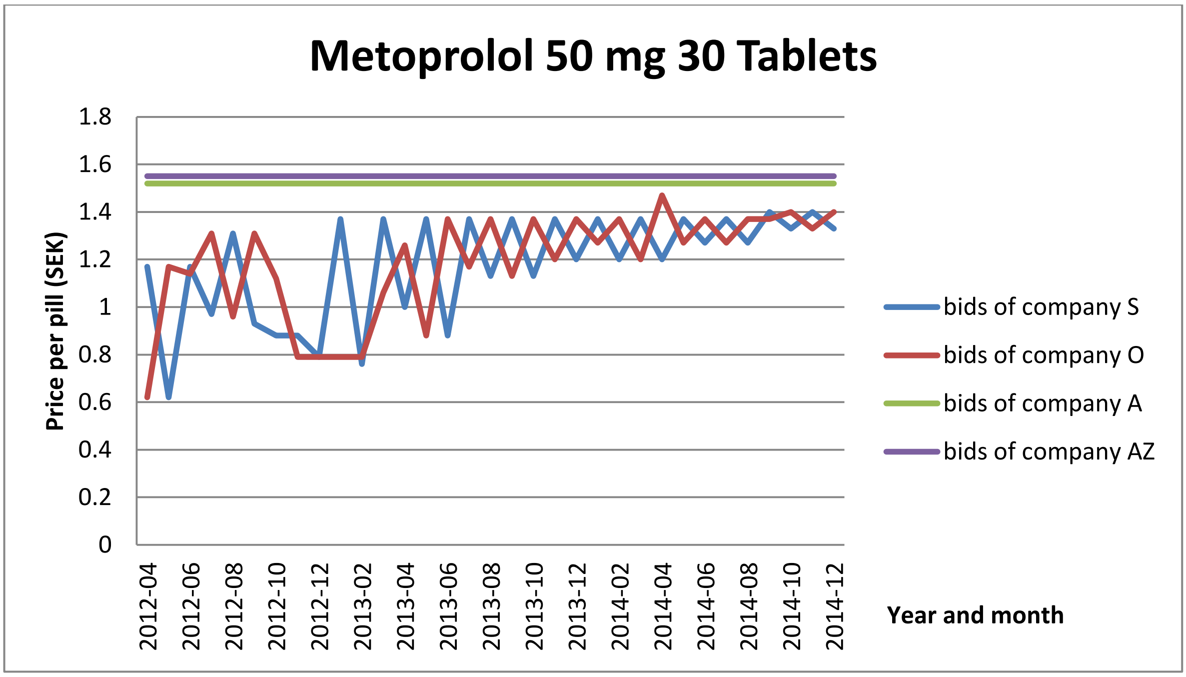
Contents

Introduction

Being a consumer of generic drugs I have observed strange patterns in the prices of my medicine after I moved to Sweden. Investigating the issue I found out that in Sweden generic drugs are procured through a monthly auction. The lowest bidder obtains status of the "product of the month" which should be recommended by the pharmacist, regardless of the producer of the drug on the prescription, within the replacement group. The replacement group is a group of pharmaceuticals containing the same active substance, of the same dosage, form and package size (for example Paracetamol 500 mg, 20 tablets). When I started to analyze monthly prices of a few generic drugs in Sweden in the recent years (2010-2015) I discovered that in some cases two companies seemed to interchange their bids. Company A would submit high price every odd month and low price every even month, with company S doing the opposite: submitting low price every odd month and high price every even month (as on the graph below).

Graph 1 Bid rotation example



This pattern is known in auction literature as bid rotation. Why do companies do that and is it sustainable in the long run? If a company obtains status of the "product of the month", its product will be recommended in around 70% of cases[1], whereas if its price is higher than the competitor's price, it can count only on part of the remaining 30%. The company's profit depends of course not only on price but also the quantity it sells, but we can already see that there is quite a strong incentive to obtain the "product of the month" status. And to do that one needs to offer the lowest price. If there are at least two producers of the same generic medicine, the only way to compete is price competition, since the product is homogenous (except perhaps for the original producer). Price

[1] Based on data gathered by Bergman, Granlund and Rudholm (2012). There are four reasons why the product will not be dispensed at the pharmacy, although it is a product of the month: the pharmacy might not have it in stock; the pharmacist might fail to recommend it; the customer might prefer another brand or the doctor might specify that a given brand should be disposed.

competition means that companies try to offer lower bid than others. But that drives the profit down. The other alternative is to reach an agreement with the competitors (could be also unspoken). In case of bid rotation the agreement is that they take turns: company A wins in even months and company B in odd months for example. It means that each company wins in only half of the periods, but, on the other hand, it is able to charge a higher price (since companies don't involve in price competition). Aoyagi (2003) shows that taking turns in the end leads to higher profits than in case of price competition and that it is sustainable. By sustainable he means that none of the colluding firms has an incentive to deviate from the bidding pattern. Hence, collusion can continue for many periods (possibly limitless). Skrzypacz and Hopenhayn (2004) show that bid collusion is sustainable even without explicit communication: via bids from the past (if they are publicly revealed by the auctioneer), which happens within the Swedish market. It is possible for companies to coordinate their prices without communication if they can observe the history of monthly prices of other companies. And tacit collusion is not illegal.

In order to identify markets where companies take turns or continuously charge the same price, I developed a test based on the history of winners. I use this to find whether the sequence in which firms win the status of the "product of the month" is random. The alternative is that competitors win one after another (bid rotation) or firms keep on winning together all the time because they submit the same bids (parallel bidding). I shall refer to both of these as suspicious bidding patterns. The test has identified 231 products with suspicious bidding patterns. In particular, there are 135 products with two or three firms submitting continuously same bids and 107 products where firms rotate on their bids[2].

Furthermore, in order to check the reliability of the test I compare average prices on these products compared to a medicine with the same active substance, dosage and form (just different package size). The average price of a product with suspicious bidding pattern is 5 times higher than that of a comparable product. Price difference is higher among products with parallel bidding (over 7 times), compared to bid rotation (3 times). In order to incorporate the impact of the number of bidders and avoid endogeneity from demand price elasticity, I use difference-in-difference specification. The estimated impact

[2] The numbers add up to more than 231 since in some cases the bid collusion pattern changes from parallel bidding to bid rotation or the other way.

of collusion within prices is then 47% and is statistically significant at 1% level.

The second check of reliability is to compare price variation on suspicious and similar, non-suspicious product. The idea comes from the fact that in the literature it is commonly stated that the variance of price is lower under collusion. Abrantes-Metz, Froeb and Taylor (2004) show that the variance of price in a cartel for frozen perch was a few times lower than after the cartel has been discovered and dismantled. Similarly, in case of cartels analysed by Bolotova, Connor and Miller (2008) there was a significant decrease in average price and increase in variance as the cartels have been dissolved. In the analysed generic drugs market, the price variation of products with suspicious bidding patterns is on average over three times less than price variation of comparable products (medicine with the same active substance, dosage and form, just different package size). The result is in line with the literature predictions for collusion.

The study is fundamentally different from previous literature on collusion, which is mainly post-factum, i.e. after the cartel has been discovered and dismantled. On the contrary, this paper aims at finding whether there is bid collusion within any of nearly 2000 products over 5 years' time. The proposed method is based on very few assumptions, which reduces the risk of misspecification. Moreover, it requires very little information: only about the sequence of winners. The data collection is therefore not costly and easy to perform. At the same time the method is robust as confirmed by price comparison.

The paper is organised in the following way: the first chapter contains introduction to the Swedish generic drug system, price regulations and subsidies. In the second chapter I discuss the relevant literature. In the third chapter the reader can find basic theoretical models of competition and collusion. The fourth chapter contains data description followed by the empirical strategy in the fifth chapter. The sixth chapter contains the results from the test as well as price comparisons, followed by conclusions.

I Swedish Generic Drugs Regulatory System

Since 2002 generic drugs in Sweden are subject to the tendering system: each month pharmaceutical companies submit their bids to the authorities (TLV), who, based on that, decide on the "product of the month". A pharmacist is legally obliged to suggest "product of the month", but patient has the right to decide to take the drug of the brand from the prescription. In that case he has to pay the difference in prices, regardless of whether he has reached the subsidy limit or not (more on the subsidy system below). There can be various reasons for consumers preferring a specific brand of a drug: one can consider original drug that went off-patent to be of better quality or the pill can have specific shape, colour or taste that makes difference for the patient. In some cases also coating can be made of different substance, which allows for easier swallowing or makes the pill remain active for a longer period. The studies done by Andersson et al. (2005), as well as Granlund and Rudholm (2008) suggest that indeed many Swedish customers view generic substitutes as inferior. As a consequence the original producer sometimes chooses not to involve in price competition and does not even try to obtain the status of the "product of the month".

Apart from the patient refusing generic substitution there are two more reasons for not dispensing the "product of the month". Firstly, the physician can write on prescription that a given drug has to be given and not be subject to generic replacement. Secondly, there can be lack of stock of the "product of the month". If the shortage of "product of the month" is due to generic producer's inability to cover the market, he can not become the "product of the month" the next month. Because it used to happen that the producer of the "product of the month" was not able to provide enough drugs for the whole market, from 2010 TLV specifies also "reserve 1" (R1) and "reserve 2" (R2) – second cheapest and third cheapest product that can be sold by the pharmacy if it was not able to purchase the "product of the month". Moreover, the pharmacies are allowed to sell the "product of the month" from the previous month up to day 16 of the month. After that if they continue selling the product of the previous month, their margin should go to the regional authorities (Bergman, Granlund and Rudholm (2012)).

The share of transactions where the "product of the month" was not dispensed and there was no real reason for that (no doctor's prescription, the patient did not object and the "product of the month" was available) was very high in 2006 and still remained relatively high in 2012. The adherence to the rules has increased from 51% in 2006 to 84% in 2012 (Bergman, Granlund and Rudholm (2012)). The increase in the adherence in attributed to changes in regulations[3]. The share of the product of the month has increased from 49% in 2006 to 70% in 2012 (Bergman, Granlund and Rudholm (2012)). In 2012 from

[33] However authors also note that higher adherence to rules was accompanies by an increase in prices. I suspect that this is due to development of collusion.

the remaining 30% only 14 percentage points were attributed to legal reasons. In some cases pharmacies do not hold stock of the "product of the month", even though they could. The reasons for that can be various. They can prefer to hold stock of drugs produced by bigger companies or those that are "product of the month" more often, so that they do not have to change orders every month. In case of parallel bidding there are two brands that could be recommended by the pharmacist. In that case it is most probably the pharmacy owner that makes the choice of stock provider. This can be one of the reasons why companies will prefer bid rotation rather than parallel bidding.

Another important aspect is the subsidy system. Without additional regulations, subsidy leads to price insensitivity which allows companies to charge high prices (the aim of collusion). The reimbursement system in Sweden is gradual, i.e. patients have to pay a whole sum of their medical expenses up to 1100 SEK. After that they pay 50% of the drug's price until they reach the next level, 2100 SEK when they pay only 25%. After reaching 3900 SEK they pay only 10% and finally when the cost of medicine is above 5400 in a 12-month period, one does not have to pay anything. The system can be summarized by a table below.

Table I.1. The subsidy system

Total cost of medicines in a year	**Discount on the excess payments**[4]
≤ 1100 SEK	0%
1100 – 2100 SEK	50%
2100 – 3900 SEK	75%
3900 – 5400 SEK	90%
>5400 SEK	100%

Source: TLV.se

Bergman, Granlund and Rudholm (2012) report that in year 2000 around half of the pharmaceuticals were purchased by individuals who had zero marginal cost. It is important for the thesis, since it means customers are completely price insensitive: they do not care what the price is. Perhaps they don't even know it, since in Sweden the subsidy is calculated right at the pharmacy counter and a patient does not need to apply for a reimbursement. That makes price rigging easier for the pharmaceutical companies.

[4] The discount is only on the amount that exceeds the threshold, ex. if the medicine costs 1200 SEK, patient obtains 50% discount on 100 SEK that exceeded the 1100 SEK threshold.

The way the tendering is organised and the characteristics of the market create good conditions for collaboration among companies, since:

- products are homogenous
- market is concentrated
- interactions are frequent
- firms compete on different markets

The Swedish authorities have narrow definition of a comparison group; hence the products are extremely homogenous: it is a medicine with the same active substance, dosage and package. Only the brand changes. Most of the people will see no difference. Furthermore, interactions between firms are frequent (monthly) and firms compete on different markets, since one drug producer usually provides hundreds of drugs. One way the authorities could try to make collusion more difficult would be by making the interaction less frequent (like the US vaccination tendering which happens once a year). In that case one would have to be very patient if he wanted to take part in taking turns and it would prevent such collaboration. However, that would not prevent parallel bidding. Another solution would be to increase the reference group, hence bringing up more competition.

II. Literature Review

If one looks at the recent literature on the generic drugs in the Nordic countries, there are no papers indicating that there might be some collusion within the market. It is commonly assumed that there is competition and the models used are based on the competitive assumptions. When it comes to the Swedish market for off-patent drugs, it has been analysed by Granlund (2010). He estimates the impact of introducing "generic substitution" in 2002 on prices of pharmaceuticals. He finds that the reform has led on average to 10% price decrease. One caveat to the paper is that he assumes same price elasticity of all generic drugs, whereas it is quite unlikely that a painkiller will have same price elasticity as an antibiotic. Moreover, price elasticity can differ even among same substance (see the discussion in chapter VI.2.). The recent report of TLV[5] also claims that prices of generic drugs in Sweden are low compared to 19 other European countries. However, since pharmaceutical companies have global presence, it is highly likely that if they collude in Sweden, they might do so in other countries as well. In that case price comparison with other countries does not mean that there is no collusion in Sweden; just that there is no more collusion than in other countries. Moreover, the report focuses on prices with high sales volumes that usually have many bidders and are not subject to collusion. The report notes that prices on medicines with few bidders are higher than in other countries. Another report, conducted by Bergman, Granlund and Rudholm (2012), shows that the prices of the "product of the month" have increased in the recent years in Sweden and that the reforms have led to less companies competing per product.

Since I suspected collusion within the market (based on the discovery of bid rotation patterns), I had to turn to the literature on collusion detection. Harrington (2008) provides summary of cartel detection papers and lists some collusive markers, among them low price variance, which shall be used in the empirical part of the thesis. According to his classification, detecting collusion can be done in four ways:

1) Checking if behaviour is consistent with competitive models by creating a competitive model and checking if it fits the data. The disadvantage is that we don't know if the model does not fit because of collusion or because of misspecification.

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[5] http://www.tlv.se/press/ovriga-nyheter/Svenska-priserna-pa-generiska-lakemedel-bland-de-lagsta-i-Europa/

2) Discovering structural breaks: when a cartel is formed price should increase suddenly and we should be able to observe it. However, smart cartels might try to make the transition stage look smooth so as to avoid being detected.

3) Finding significant difference in behaviour of suspect firms in comparison with behaviour of other firms- this method is stronger than the first one, since we can defend the idea that the model is not misspecified if some firms bidding behaviour fits the model. However, it is applicable only if we are able to distinguish between colluding and competing firms and if there are any firms not belonging to the cartel. This method was used by Porter and Zona (1993).

4) Specifying two models: collusive and competitive and checking which one fits the data better. This strategy was used by Bajari and Ye (2003).

One of the early empirical studies of bid rigging was done by Porter and Zona (1993). They examine bidding behaviour patterns for highway construction contracts. In their case cartel members used to meet before the procurement auction and decide who was going to submit the lowest bid. Other firms were supposed to submit complementary bids, soundly higher. Porter and Zona estimate reduced bid equations and prove that for non-cartel members the bidding behaviour of the lowest bidder is indistinguishable from others, i.e. all the coefficients of demand and cost shifters are significant and have same sign. For cartel members, on the other hand, the lowest bid is a function of cost and demand shifters, whereas other bids are random, independent of bid determinants for the lowest bid. The explanation Porter and Zona give for it is that cartel members choose the company who should submit the lowest bid before the auction. That firm calculates its bids so that it would maximise its pay-off, hence it depends on its costs. On the other hand, other cartel members are just supposed to submit higher bids which would give an impression of competition. These bids do not depend on their costs.

Porter and Zona (1993) model the auction as Independent Private Value, which means that product can present different value (or cost) for each firm and the value it represents for firm A is independent from the value it represent for firm B and companies don’t know each other’s costs. They furthermore estimate probability of observing a given bid rank using multinomial logit. In their case cartel firms compete with other, non-cartel companies for the same contract. The problem with using this methodology is that one needs to know cartel members beforehand, which we do not. Moreover, one needs to have precise information about the cost and demand shifters, which would be difficult to obtain for over 1900 pharmaceuticals over 5 years' time.

The second important article for this study is Bajari and Ye (2003). They develop a model of procurement auctions with asymmetric firms. Firms differ particularly in their costs. They argue that competitive bids should be independent and exchangeable. Bids are independent if there is no correlation between bids after controlling for publicly known cost drivers. The reliability of the method depends however on whether one includes all cost factors. Otherwise, the results might be misleading. Exchangeability, on the other hand, means that firms bid solely based on their cost and demand estimation and not based on which competitor they face on the market. In the first stage they check which firms bids are correlated (in particular, if the residuals from the bid equations are correlated). In that way they identify potential cartels. Then they proceed to calculate probability of observing the actual mark-ups given a particular model (competitive or collusive). The structural model of bidding is a function of firm's costs and other firms' bids. Estimating the distribution of bids one can back out firm's cost and in that way get the estimate of the mark-up. Afterwards, they compare it with the industry experts' prediction. The collusive model performs well at the average but very badly at the distribution tails. As a result, in total, the competitive model seems to fit the reality better. The method is interesting but there are numerous caveats. The advantage of this method over Porter and Zona (1993) is that they do not know cartel members beforehand. However, they need precise information about demand and cost shifters and omission of a significant factor can lead to incorrect results. If there is a cost that is correlated among firms and we do not include it in the equation, then we shall reject the hypothesis of independence without collusion really taking place. The application for our work would be difficult, since there would be need to obtain data about cost and demand shifters. Moreover, one can be dubious as to whether industry experts are able to predict mark-ups that should occur if the market is competitive. Finally, it can happen that costs are homogenous across firms. In that case there is no independence between bids even without collusion.

Another relevant article was written by S.G. Güllen (1996). The paper aims at determining whether OPEC is a cartel. The method she uses is unit root and cointegration tests. The unit root tests take into consideration possibility of structural breaks, using the methodology of Perron (1989). The cointegration tests are based on Engel and Granger (1987), Gregory and Hansen (1996) and Johansen (1988) methodologies. Güllen argues that if OPEC is a cartel, then the production of each country with the total output of OPEC should be cointegrated, i.e. there should be a long-run relationship between outputs. A cartel like OPEC operates through production restrictions. The members communicate on how much they should produce in each period and through that they control prices. If the members abide by their quota, their production should constitute some percentage of total OPEC production and be quite stable over time. In the time-series language that would mean cointegration.

The results obtained by Güllen (1996) suggest that there was indeed cointegration, but only in one period: 1982-1993. Secondly, the paper examines whether OPEC has the power to impact prices by its production without the reverse causality (i.e. prices on production). She tests it with the Granger causality tests and confirms that there was indeed such effect in 1982-1993. OPEC was able to control world oil prices in that period with its output quotas, whereas prices had no impact on the production. I used the cointegration test also on the data about monthly prices of drugs, but since cointegration can also occur if the companies have homogenous costs, I decided not to include it in the thesis.

Another paper using time-series methodology for cartel analysis was written by Bolotova, Connor and Miller (2008), where they use GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model to estimate difference of the first two moments of the price distribution during collusion and after cartel discovery (when it was dissolved). In the GARCH model current price and its variance are functions of its past values. The purpose of using this model is to incorporate the fact that cartel has impact not only on the price levels but also on price variance. As mentioned in the Introduction, it is commonly observed that price variance is lower if firms collaborate. Abrantes-Metz, Froeb and Taylor (2004) show that the variance of price in a cartel for frozen perch was a few times lower than after the cartel has been discovered and dismantled. There could be a few reasons for that. Athey et al (2004) suggest that the reason is the difficulty in sharing the cost information of each cartel member between them. As a result they do not notify the other cartel member if their costs have increased/decreased and keep fixed prices instead.

Harrington and Chen (2004) propose that cartels avoid passing through changes in cost shifters in order to avoid detection. LaCasse (1995) on the other hand argues that bid variance is lower due to presence of phantom bids ("fake" bids, which only intend to create impression of competition). The cartels analysed by Bolotova, Connor and Miller (2008) are the citric acid cartel (1991-1995) and the lysine cartel (1992-1995). The paper confirms prediction of significant decrease in average price and increase in variance as the cartels have been dissolved. Again however, it is a post-factum analysis, where the cartels have been identified and punished. In our case however, we shall analyse a market where there is no detection of collusion so far. Instead, I shall compare price variation on the suspicious and non-suspicious markets, identified by the test that I have designed to check its reliability (see chapter V).

None of the papers analysed above performs a test on multiple products or markets. In most of the cases also the analysis is post-factum, i.e. after the cartel has been discovered. Hence, cartel members, operating time and even the pattern in which the cartel was working were known. None of this is known in this case. Potentially, Bajari and Ye (2003) methodology could be used but that would require gathering information about demand and cost shifters for each of nearly two thousand products, which would be very difficult. Moreover, the biggest caveat is the possibility that generic producers have similar cost structure. In that case neither Bajari and Ye (2003) method nor cointegration would be a suitable test for detecting collusion. As a result I designed a test of a sequence of winners focusing on checking for existence of bid rotation and parallel bidding. There might be more sophisticated patterns that I do not test for in this thesis and designing tests for those would be a possible future topic for a paper.

III. Theoretical Framework

This part contains a basic model of competition in an Independent Private Value auction. In the next step we shall look at what happens if there is collusion instead and what might impact the choice of collusive bidding pattern (bid rotation or parallel bidding). Finally, I shall present a graphical model of demand and supply that would explain why we might observe lower price variation under collusion.

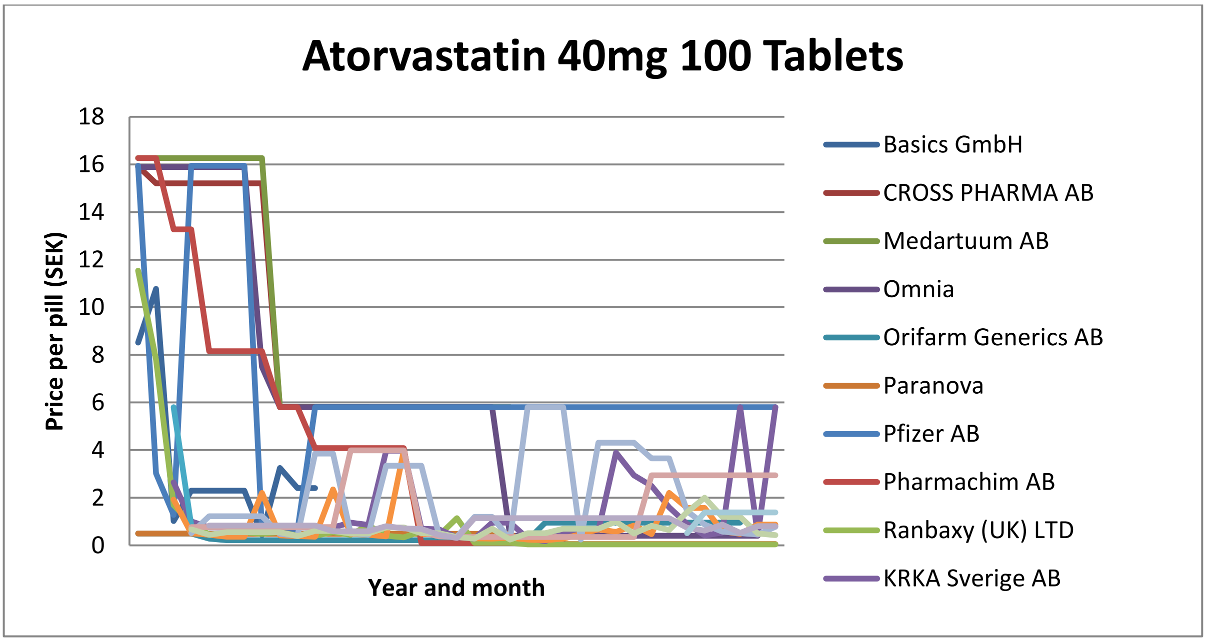
III.1. Competition

Following Bajari and Ye (2003) I will use an Independent Private Value model to represent how companies are predicted to behave under competition. According to this model companies know their own costs estimates but not the costs of other firms (only their distribution). The profit of company i on product j depends on the probability that it will win the "product of the month" status ($p_{ij} = PV$). And that in turn depends on the probability that the firm's costs (c_{ij}) are lower than its competitors.

$$P\left[p_{ij} = PV\right] = P\left[c_{ij} < c_{in}\, for\ all\ companies\ n \neq j\right]$$

As a result, I expect that the firms will charge prices close to their marginal cost and it will vary from month to month together with their costs. It seems that this is indeed the case on markets with many bidders, as we see on the graph below. We can also observe that the price of original producer is a "ceiling" for generic substitutes; nobody bids above it. It can be viewed as a monopolist price that a company would wish to bid had they been alone on the market.

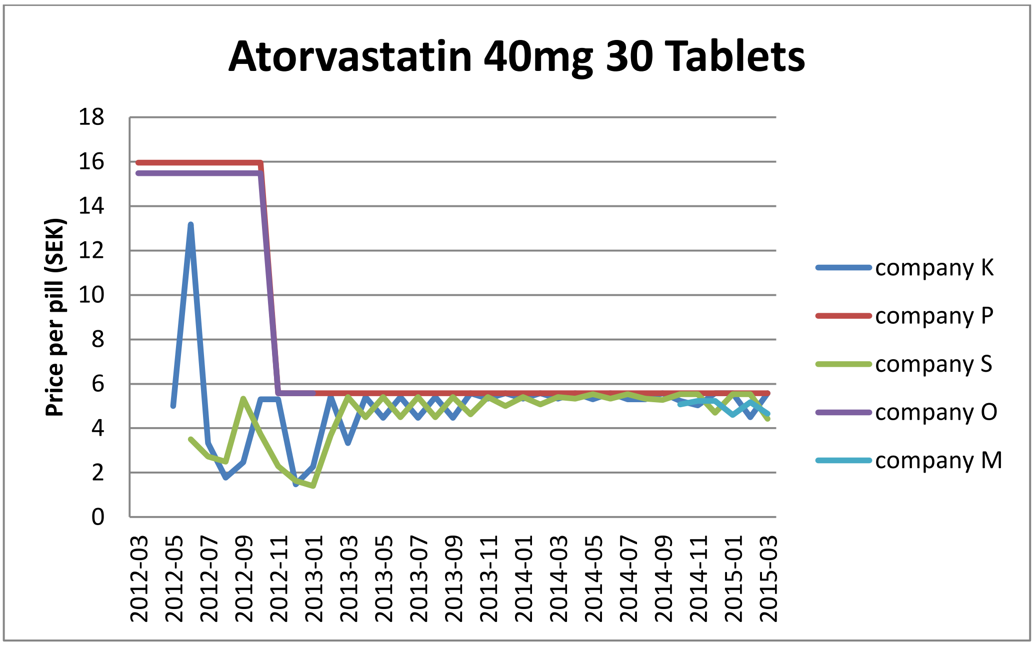
Graph III.1. Example of competition



III.2. Taking Turns or Sharing Market Every Month?

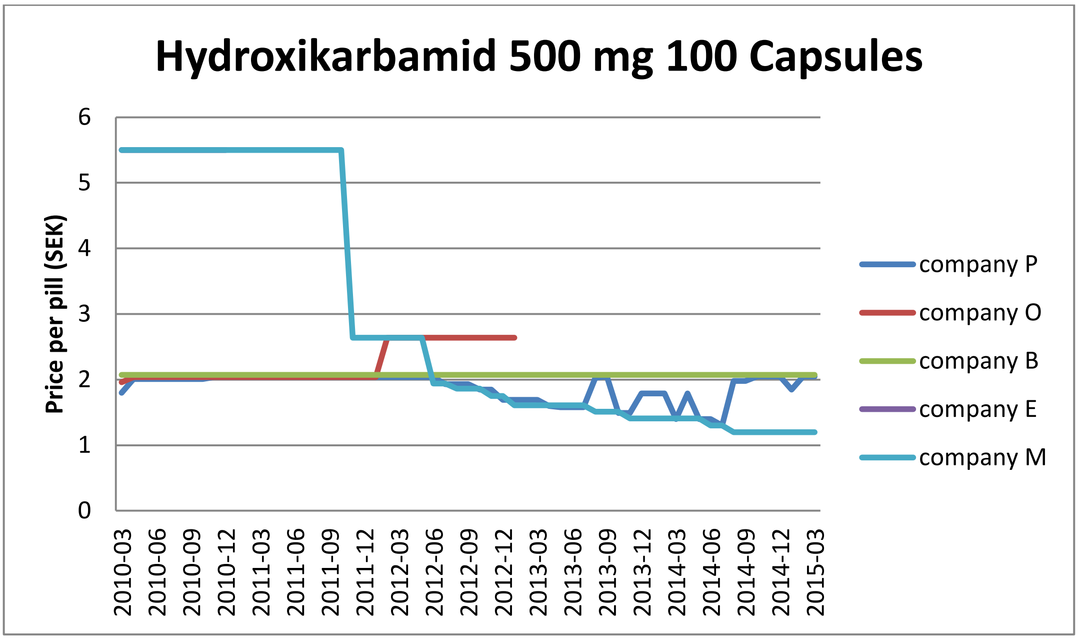
However, some markets do not seem to follow that prediction. In the example below, after an initial period of competition, firms start rotating their bids from 2013. Two companies (S and K) take turns to charge a price just a unit below the price of the original producer (which could be viewed as the monopoly price) and win the market.

Graph III.2. Example of bid rotation



The second pattern that is present on some markets is parallel bidding. In that case companies consistently charge the same price month after month, as in the example below (Graph III.3.), where companies P and O initially charge the same price and share the "product of the month" status (charging price just below the price of company B). From mid-2012 company M enters price competition and the pattern disappears. Company P seems to try to establish collusion with firm M but without success.

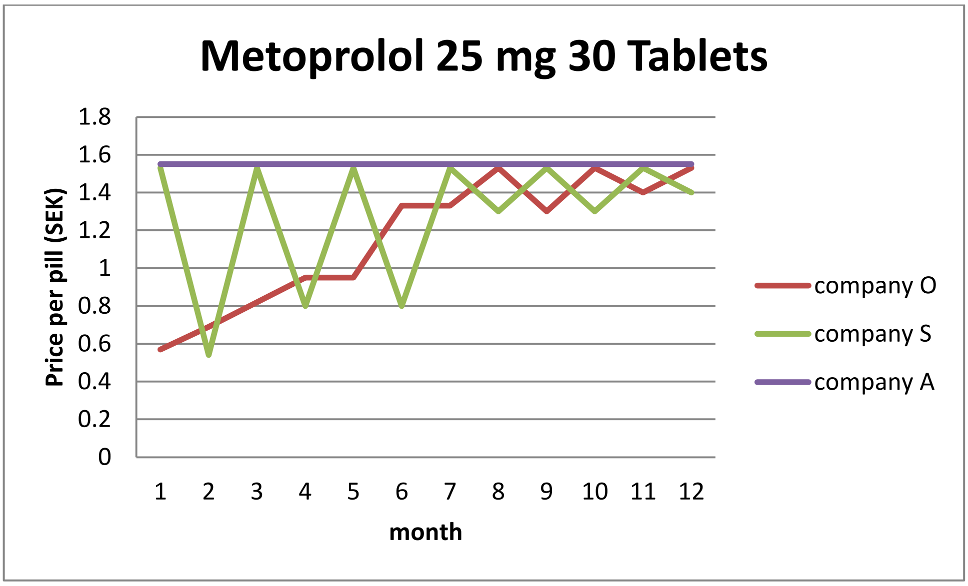
Graph III.3. Example of parallel bidding



So far we have identified two collusive patterns: bid rotation and parallel bidding. It is interesting to consider what impacts the choice of a particular pattern when firms decide to collude. I have not found any papers on that topic, perhaps since usually there is only one form of collusion occurring at a given market.

There are a few issues to consider: one is the expected profit. The other is how easy it is to establish and maintain collusion with other companies, preferably without explicit communication, since tacit collusion is not illegal. Intuitively, bid rotation seems to be easier to start and maintain without explicit communication. We can imagine that if a company wishes to communicate through its bids that it is willing to start bid rotation it will start bidding the same, high price every second month and very low in the periods between. The bid rotation scheme appears almost immediately, irrespective of the other companies' bids. As soon as company B observes it, it can pick up the scheme and both firms will increase their price also in their "low price" period. Below we can see a perfect example of how bid rotation can be achieved.

Graph III.1. Example of starting bid rotation



It would be much harder to communicate willingness to share the market just through bids as bidding same price every month doesn't necessarily mean one is willing to collude. Even if there are only two bidders and one starts bidding always higher, constant price, what motivation is there for the other company to enter collusion, rather than bid slightly below what his competitor bids? We can imagine that company A would be willing to start parallel bidding, but others prefer to bid slightly below and obtain market for themselves.

Another advantage of bid rotation is that it gives more flexibility in setting prices. An individual firm i would like to maximize its expected profit on product j, which is equal to price p minus cost c times the estimated demand $Q(p_{ij})$[6]:

$$\max E\,\pi_{ij} = (p_{ij} - c_{ij})Q(p_{ij}) \qquad (3.1)$$

We need not use the Independent Private Value model, since companies collude and they are sure of winning. The only unknown is the exact demand. The above maximization problem is solved by taking the derivative with respect to price, which leads us to the following result:

$$\frac{p_{ij} - c_{ij}}{p_{ij}} = \frac{Q(p_{ij})/p_{ij}}{\partial Q(p_{ij})/\partial p_{ij}}$$

[6] Using a static model.

This tells us that the price margin is equal to the inverse elasticity. The first thing we notice is that if the firms decide to collude by setting same price (assuming same demand elasticity for their products), that price will be profit-maximizing only if they have same costs.

$$p_{ij} = p_{in} = p_{eq} \leftrightarrow c_{ij} = c_{in} \qquad \text{for any firm } j \text{ and } n$$

This suggests that firms with heterogenous costs should prefer bid rotation, since it gives them flexibility to set the price equal to their own equilibrium price.

Another issue is the exogenous demand shift. The solution to optimization problem (3.1.) could be also expressed as:

$$p_{ij}^* = c_{ij} - \frac{Q(p_{ij})}{\partial Q(p_{ij})/\partial p_{ij}}$$

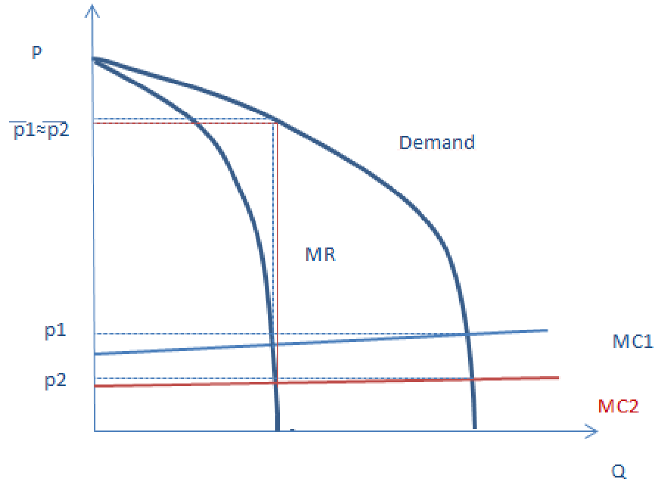
From this equation we see that with cost and demand changes, the equilibrium price (p_{ij}^*) will change as well. In case of parallel bidding, companies would need to communicate and coordinate their price changes. Such communication would make them face risk of being discovered and punished by authorities for setting a cartel. With bid rotation, company can adjust its price without communicating with the other company (especially if it is a downward change). In chapter VI.3 I test the hypothesis that bid rotation occurs on markets with higher demand volatility (compared to markets where we observe parallel bidding).

III.3. Price Variation Under Collusion and Competition

In the literature we often come across results that price variation is smaller under collusion (Harrington (2008)). Hence, price variation comparison among different products could be a signal for collusion. In this section I present a simple explanation why it is so. The following analysis is graphical and not formal.

First we need to start with understanding how companies set their prices. Most important to note is that it depends on the number of competitors. If the number of competitors is large and products are homogenous, companies set their prices close to the marginal cost (because of fear of losing the market if their price is higher than the competitors). This means that with cost fluctuations, price will fluctuate proportionally (as we can see on the graph: cost change from MC1 to MC2 brings price change from p1 to p2).

Graph III.4. Demand and supply graph



The situation is completely different if the firms collude. In that case they can maximize their joint profit. The profit maximization rule is equivalent to saying that the marginal cost should be equal to the marginal benefit. On the graph above I have drawn the marginal revenue line (MR). The price set in this case (called the equilibrium price) will be way higher than when the companies competed (p̄1 compared to p1). When the individual firm's cost changes from MC1 to MC2, the equilibrium price will not change much (from p̄1 to p̄2). That is why in many papers they observe much lower price variation under cartel (Abrantes-Metz, Froeb and Taylor (2004), Athey et al (2004), LaCasse (1995), Bolotova, Connor and Miller (2008)).

IV. Data and Descriptive Statistics

The analysis is based on monthly data on bids for generic drugs from March 2010 to March 2015, provided by the Swedish dental and medical authorities (TLV). The dataset contains 263 active substances and 1946 products. According to TLV's specification, a product is a medicine with a given active substance, strength, package group and form (example: Paracetamol 500 mg, 100 Tablets). Only for 1173 of those products there is data for at least 30 periods (which is needed for having a reasonable sample for statistical inference), others were discontinued or went off-patent only after 2013. It is only this data that I use for the estimations in order to be able to make sensible statistical inference.

Table IV.1. Descriptive statistics

Variable	Number of variations		
Substance	*263*		
	Number of variations per one active substance		
Variable	**Mean (Std. Dev.)**	**Min**	**Max**
Strength	*2.3 (2.2)*	*1*	*21*
Package	*4.3 (4.85)*	*1*	*45*
Form	*1.2 (0.62)*	*1*	*4*

In the analysed period, there are 263 different substances subject to tendering. Most of them are available only in one form (ex: tablets). However, 56 substances are available in 2 to 4 different forms (ex: normal tablet or dissolving tablet). Each substance appears on average in two different strengths (ex: 10 mg and 20 mg), with the maximum of 21. Each substance and strength, in turn, has on average nearly 3 package sizes available (maximum 41). This is an important feature that will be used for price comparison, since products with the same active substance, strength and form but of different package size will have many common characteristics.

The number of firms bidding at the same time has been changing and was on average around 3. In over 30% of cases there is a monopoly. In further 25% we observe a duopoly and in 11%- a triopoly. Only in 32% of cases there are at least four bidders. Hence the conditions are favourable for collusion (low number of competitors increases chances of collusion[7]).

[7] Levenstein and Suslow (2008)

Table IV.2. Average number of bidders (monthly)[8]

Average no of competitors bidding simultaneously	No of products	Percentage
1	374	32%
2	295	25%
3	134	11%
4	86	7%
5	76	6%
6	63	5%
7	33	3%
8	38	3%
9	26	2%
10	17	1%
11	8	1%
12	7	1%
13	4	≈0%
14	4	≈0%
15	1	≈0%
16	6	1%
17	1	≈0%

Table IV.3. Number of winners

Winners	Occurrences	Frequency
1	57864	88.3
2	7102	10.8
3	420	0.6
4	79	0.12
5	16	0.02
6	16	0.02
7	6	0.009

In 12% of cases there is more than one producer who wins the status of the "product of the month" (because of offering the same price). These are the possible suspects for parallel bidding (if the behaviour has been persistent over time).

V. Empirical Strategy

V.1. Overlapping Permutations Test

The purpose of this thesis is to identify products with suspicious bidding patterns in the form of bid rotation or parallel bidding. I haven't found any such test in the literature. One can claim that it is quite obvious to observe: if two firms continuously charge the same price, it is parallel bidding and if they take turns, it is bid rotation. However, if we deal with thousands of products, one does not have a possibility to look at each product and check if there is any pattern in the winning companies. So in order to find products where there is bid rotation or parallel bidding when we deal with "big

[8] The numbers presented in Table IV.2. are rounded (since we take average of 61 numbers).

data", I have created a test inspired by the Overlapping 5-Permutations Test. That test was invented to check if number generators produce truly random numbers. In our case it is however more useful to check if permutations of four or six (rather than five) consecutive numbers is random[9]. The identifying assumption is that competition will not result in taking turns by firms or bidding the same price for a longer time period[10]. However, if there is some agreement between firms (possibly even unspoken), we shall observe some patterns to appear unusually frequently, for example if we create a sequence of winners over time, it will look like: firmA, firmB, firmA, firmB, firmA, firmB…

For this purpose I create a string of numbers for each company and product equal to 1 if the firm won the "product of the month" status in a given month and 0 otherwise[11]. For example for Amoxicillin 750 mg, 100 tablets for company S we have:

1111111110111010111011111111111111111011111011101111001111

In each case we shall have a string of 61 binary outcomes, since I have data for 61 months. I further divide this string into groups by four (and drop the last month):

1111 1111 1101 1101 0111 1011 1111 1111 1111 1110 1111

First, I test for bid rotation among 2 firms, which is equivalent to repetition of sequence 0101 or 1010. There are 16 possible combinations of 0 and 1 in a sequence of four digits. So if all these combinations were equally probable (more on this below), on average we should observe that each combination appears with a probability of 1/16. The null hypothesis is that there is competition on the market and if we observe string 0101 or 1010, it is just random. The alternative is that there is collusion and firms rotate their bids. I could check if the observed frequency of each combination does not differ significantly from the expected frequency with the chi square frequency test. However, since there is only a maximum of 60 observations for each company and product that means there are maximum 15 combinations of a 4-digit string. Since each should theoretically appear with a probability of 1/16, it would mean that we should observe each of the possible combinations once. That is an extremely small frequency and the test would not perform well. Moreover, I am not particularly interested in the repetition of 1111 or 0000 combination (always winning or always losing). Therefore, I decided to limit the test to

[9] Since then we have repetitive sequence for 2 or 3 bidders.
[10] That would be statistically significant. See later explanation on the statistical test.
[11] In case of multiple winners I denote it as 0.5 in case of being one of two winners or 0.33 being one of 3 winners etc

two alternatives: collusive and non-collusive pattern. Collusive pattern 1010 for example can appear randomly with a probability of 1/16.

The *real* probability of a firm i winning depends on the other firm(s) bids. If we use the Independent Private Value model, it is equal to:

$$\Pr(c_j > \varphi_j(b_i) for\ all\ j \neq i)$$

Which is the probability that all other firms have costs higher than the inverse bid function of firm i $\varphi_j(b_i)$. In this paper however I shall use the simplifying assumption that firms' costs are identically and independently distributed and that all firms have equal probability of winning. In that case the probability of winning of firm i will only depend on the number of bidders. The probability of observing string 0101 or 1010 will in turn also be given as a product of probability of winning twice and losing twice:

$$\Pr(0101, 1010) = (1 - Pr_{win}) * Pr_{win} * (1 - Pr_{win}) * Pr_{win}$$

Table V.1. Probability of observing bid rotation pattern randomly[12]

Number of bidders	Probability of (single) winning	Probability of observing 0101
2	0,5	0,0625
3	0,33	0,0489
4	0,25	0,0352
5	0,2	0,0256
6	0,17	0,0199
7	0,14	0,0145
8	0,13	0,0128

I proceed to verify the null hypothesis (that there is competition and if we observe 1010 or 0101 it is random) using the **asymptotic equality test for the binomial proportion**. The test provides asymptotic statistics z that the binomial proportion equals p:

$$Pr(0101, 1010) = p$$

It is equal to:

$$z = (\hat{p} - p)/se$$

where standard error se is equal to $\sqrt{p(1-p)/n}$

In fact I am interested in one-sided statistics, since only bigger than expected proportion of 1010 or 0101 would mean collusion.

I test also for bid rotation among 3 firms dividing the 60-digit sequence into ten 6-

[12] Number are rounded

digit strings:

111111 111101 110101 111011 111111 111111 111011 111011 101111 001111

In this case I check if there is unusually frequent repetition of 010010 or 100100 or 001001. The expected frequencies are based on the same assumptions and provided in the table below.

Table V.2. Probability of observing 001001 (or 100100 or 010010) randomly[13]

Number of bidders	Probability of (single) winning	Probability of observing 001001 (or equivalent)
3	0,33	0,0219
4	0,25	0,0198
5	0,2	0,0164
6	0,17	0,0137
7	0,14	0,0107
8	0,13	0,0097

I use the same test for detecting parallel bidding. In that case I check if there is frequent repetition of sequence 0.5 0.5 0.5 0.5, which means there are constantly two winners. Similarly, I test for possibility of 3 winners (0.33 0.33 0.33 0.33) or 4 winners (0.25 0.25 0.25 0.25). The exact probability of observing this combination is challenging to compute. In the calculations for bid rotation I excluded possibility of multiple winning. This will however only result in conservative outcome, since I *overestimate* observing bid rotation pattern *randomly*. I used similar logic here and overestimate the probability of observing multiple winners by equalling its probability to observing 1 (single winning):

$$\Pr(0.5\ 0.5\ 0.5\ 0.5) = Pr_{win} * Pr_{win} * Pr_{win} * Pr_{win}$$

The hypothetic probabilities in this case are given in table V.3.

[13] Number are rounded

Table V.3. Probability of observing parallel bidding randomly[14]

Number of bidders	**Probability of (single) winning**	**Probability of observing 0.5 0.5 0.5 0.5 or 0.33 0.33 0.33 0.33 or 0.25 0.25 0.25 0.25**
2	0,50	0,0625
3	0,33	0,0123
4	0,25	0,0039
5	0,20	0,0016
6	0,17	0,0008
7	0,14	0,0004
8	0,13	0,0002

The probabilities in the tables V.1. – V.3. are overestimated, hence I predict to obtain conservative results. I also add additional restriction to the test, that the periods of collusion should be consecutive (at least 2 of them[15]). If we identify one sequence of bid rotation in 2010, one in 2013 and one at the end of 2014, it is not a very strong evidence of collusion. Moreover, if one company has a collusive pattern in 2012 and the other in 2013, it does not give evidence for collusion between them. Hence, I eliminate these results from conclusions.

V.2. Difference-in-Difference

I use two robustness checks: price level and price variation comparison. In price level comparison there are two possible sources of endogeneity: number of bidders and demand elasticity. Both collusion and number of bidders are likely correlated with price elasticity of demand, which I am not able to estimate due to lack of sufficient data (sales data available from TLV only from year 2014). To overcome this difficulty I use difference-in-difference identification strategy. I compare the price before and after collusion within the suspected product with the prices of a comparable product at the same time periods. The estimated equation takes the form:

[14] Number are rounded

[15] I set the limit to 2, since 3 repetitions of a collusive pattern is enough to reject the null hypothesis and I allow for a one period misfit, since the test does not perfectly correctly identify beginning and end of collusion (more on that see: Discussion)

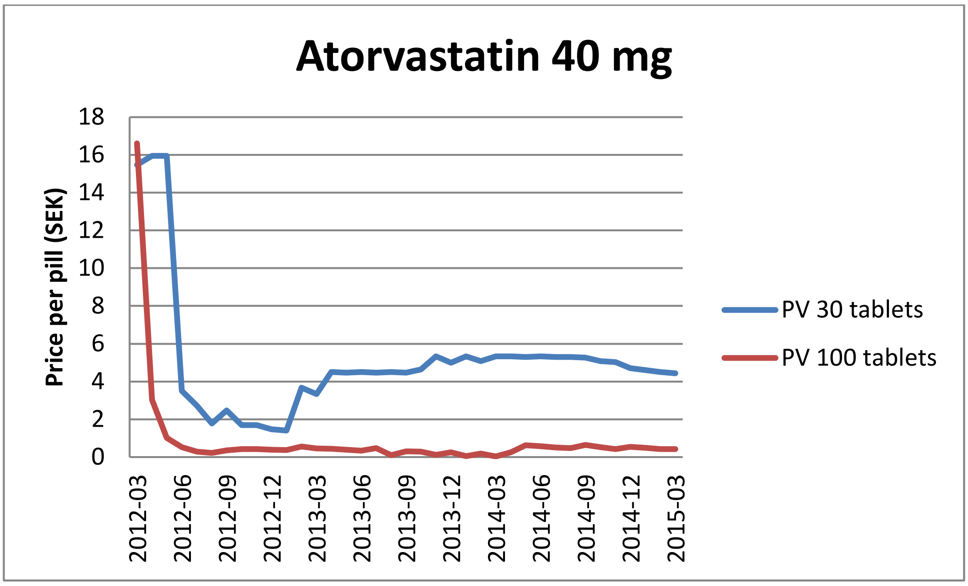
$$log\, p_{it} = \alpha_i + \beta * T_i + \gamma * suspected\_product + \delta * T_i * suspected\_product + \vartheta * no\_of\_bidders_{it} + \partial * package\_size_i + \varepsilon_{it} \qquad \text{(VI.1.)}$$

where p_{it} is the price of the "product of the month" on medicine i at time t; T takes value 0 in time where there was no collusion and 1 otherwise and *suspected_product* is a dummy that takes value 1 if the product is identified as suspicious. I include also control variables $no\_of\_bidders_{it}$ and $package\_size_i$ and substance-specific fixed effects (α_i). The error term ε_{it} is likely correlated across products with the same active substance, hence I cluster them at the substance level in order to obtain correct standard errors. The coefficient of interest is δ, since it captures the effect of price during collusion within suspicious products.

The identification strategy is that, absent collusion, prices on the products marked as suspicious would have developed in the same way as prices on similar non-collusive product. Since I compare products with the same active substance, this regression is robust to random changes to prices of the main ingredient. In this specification I also avoid the possible endogeneity from demand elasticity, since it impacts estimate of γ, and not the coefficient of interest, δ. Demand elasticity can influence decision whether to collude on a certain product but it is unlikely that it impacts the time of collusion. The price sensitivity should be fairly constant over time; hence I do not expect big changes in it before or after the collusion has started.

The identification strategy could also be illustrated by the example below. We see that price of Alendronat 40 mg 30-pills package has increased suddenly in 2013, whereas price of a similar product, Alendronat 40 mg 100-pills package has remained quite steady. In equation (VI.1), Alendronat 30-pills will have value 1 of variable *suspected_product,* whereas Alendronat 100-pills will have value 0. Both products will have T equal to 0 until 2013 and 1 afterwards. The idea is to compare the price before the collusion has started to the price after, eliminating the impact of changes in cost factors (which should be represented in the price of a comparable product). The graph confirms also that there is parallel trend in the prices of products that are being compared, which is required for the difference-in-difference strategy to be valid.

Graph V.1. Difference-in-difference example



The estimate of the impact of the number of bidders will likely be biased, since (from theory) both the number of bidders and price depend on demand elasticity, which will be included in the error term. It could be possible to instrument for the number of bidders using the market size, however the numbers are not available. Nevertheless, number of bidders is not the main variable of interest and the .

V.3. Coefficient of Variation

As literature suggests that collusion is correlated with lower coefficient of variation, I shall use it as a method to verify if that is also true for the products identified by the Overlapping Permutations Test. In particular I shall compare coefficient of price variation of the products identified by the previous test as suspicious with a comparable product (medicine with the same active substance, dosage and form, just another package size), including comparison between different number of bidders. Coefficient of variation (CV) is simply standard deviation divided by the average. It can be interpreted as a percentage by which price deviates from its average. In our case we shall consider variation of the price of the “product of the month”:

$$CV = \frac{standard\ deviation\ (PV\ price)_i}{mean\ (PV\ price)_i}$$

The coefficient of variation is unit-free and hence it can be compared between different products. However, we have to remember that the more bidders, the wider spectrum of costs and hence prices (assuming that different companies have different costs). Therefore the coefficient of price variation can be higher as the number of competitors increases (and it is indeed so, as we shall see in chapter VI.3.).

VI Results

VI.1. Overlapping Permutations Test

With the Overlapping Permutations Test, I have identified 96 products where the frequency of 1010 or 0101 pattern in winning is higher than predicted (out of 1173 products tested). In case of 2 bidders, if there are at least 3 repetitions of such a sequence, the asymptotic equality test for the binomial proportion gives us 95% confidence that it did not happen randomly. For sharing the market in consecutive months (parallel bidding) among 2 firms I find 127 products. But there are only 8 products where 3 firms would win simultaneously for many consecutive periods. Bid rotation among 3 firms has been found on 11 products. There is also one product where 4 firms won simultaneously for 4 months[16].

Table VI.1. Number of suspected products according to the Overlapping Permutations Test

	Number of suspected products
2 firms rotation	96
3 firms rotation	11
2 firms parallel bidding	127
3 firms parallel bidding	8
TOTAL (distinct)	231

In total there are 231 products identified as suspicious but only 104 different active substances, which means that usually there are at least two product groups that are under collusion for the same active substance. The most common package group under collusion

[16] That product had also periods of collusion between 2 firms.

is T23, which corresponds to 100 pills. It is important to notice that it is a common package size prescribed by doctors for long-term treatment.

Package group	Number of cases with collusion
T23	52
T18	32
T28	22
OL50	20
TN100	12
T20	12

The average period of collusion is 36 months, which corresponds to three years. The duration of collusion is similar under parallel bidding and bid rotation. The average starting point of collusion was in mid-2011.

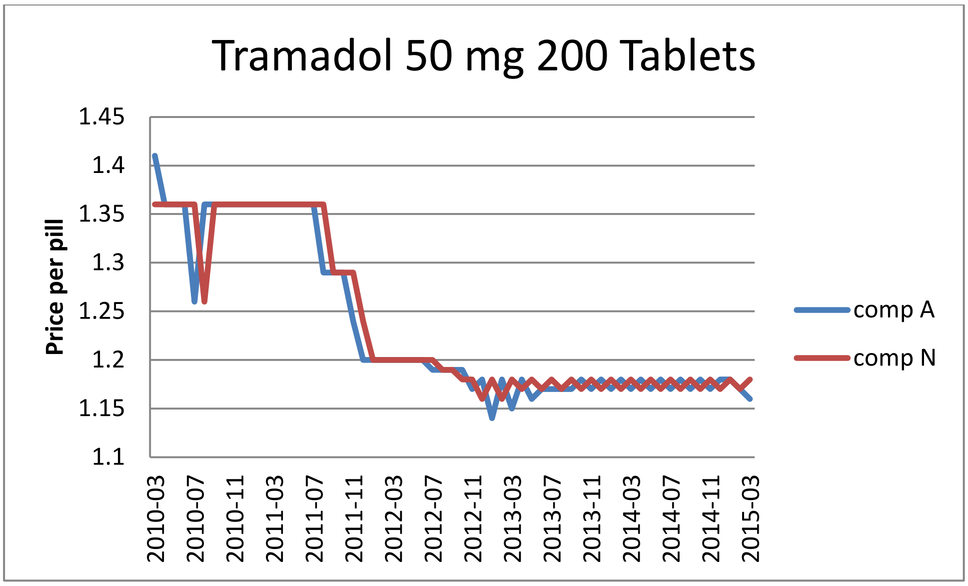
An interesting issue is that in 60% of cases of bid rotation company S is one of the colluding partners. Other companies do not exceed 26% share. We can therefore suspect that it is company S that facilitates collusion. There is no similar pattern in parallel bidding. Original producers usually don't involve in bid rotation (except for a few cases).

Table VI.2. Companies involved in bid rotation

company	frequency
company S	60%
company T	26%
company K	24%
company A	18%
company M	15%

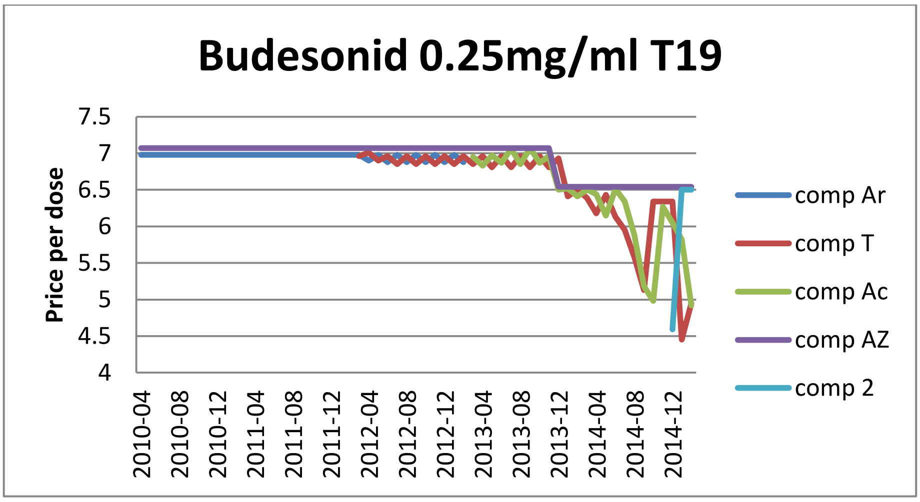
There are several cases in which there is a change from one bid rigging pattern to another. In most of the cases transition follows from parallel bidding to bid rotation and is associated with a slight price decrease. In one case the colluding partner changes and one might guess that this is the reason for the change in the bidding pattern. However, in the remaining examples the colluding partners stay the same. Usually there is also a few months period between where there seems to be no collusion. So it seems that in these cases companies used to bid the same price every month but one of them started charging lower price and then price competition started. However, after a few months companies switched to collusion again; only that this time in the form of bid rotation.

Graph VI.1. Example of a bidding pattern change



There are also a number of cases of a change in a bid rotating partner. Usually one of the colluding firms stays the same. The example is presented below. In this example first we have the original producer (company Az) and one generic producer (company Ar), who slightly undercuts the price of the original producer and in that way gets the "produce of the month" status. In 2012 enters a new generic producer, company T and he immediately starts bid rotation with company Ar. In 2013 the first generic producer exits the market and is replaced by company Ac. Company T continues rotating with company Ac until 2014 when collusion seems to crash.

Graph VI.2. Change of bid rotation partner



There are also several products that have changed bid rotation from two to three firms.

VI.2. Robustness Checks

VI.2.1. Price Level Comparison

If bid rotation or parallel bidding are manifestations of (possibly tacit) collusion, then the price level should be higher than for a comparable product[17]. The simple average price comparison confirms this prediction; products where I suspect bid rotation are on average over 3 times more expensive than comparable products (medicine with the same active substance, dosage and form, just different package size). The highest price difference is **26 times** on Ramipiril 2.5 mg. The average price difference is higher under parallel bidding: over 7 times.

The first problem in this comparison is that there is different number of bidders in different markets and it is naturally expected that the price will decrease with the number of bidders, even if there is no collusion. The number of bidders on colluding markets is on average around two, whereas a comparable product can have six or more bidders. In most of the cases it is impossible to find a comparable product with the same number of bidders.

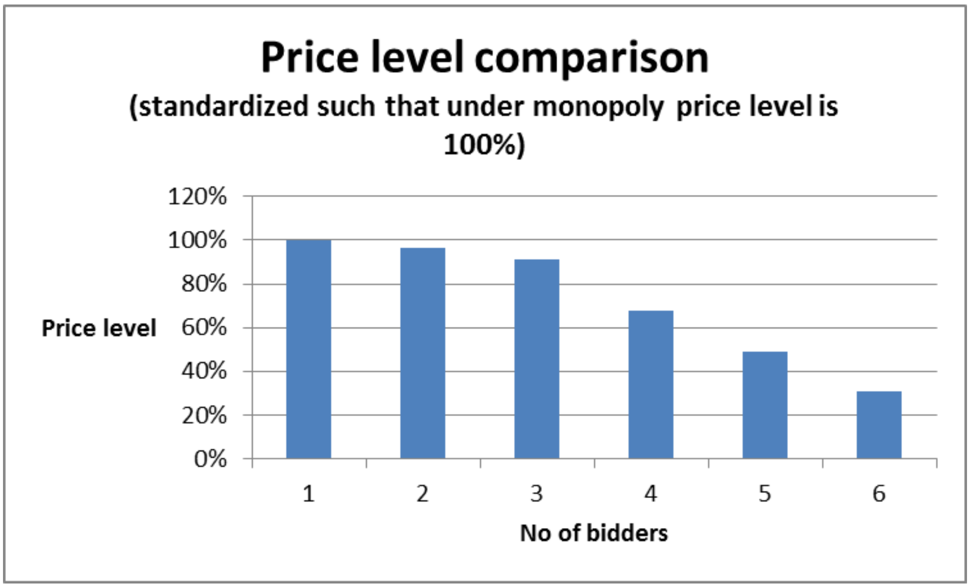
When we compare price differences among non-suspicious products with different number of bidders, we see that there is a huge price difference between monopoly and product with 6 bidders (3 times). Interestingly, duopoly and triopoly have prices close to

[17] For the price comparison I use data on prices during the period of collusion (information obtained from the overlapping permutations test, see chapter VI.1.). I do not include monopolists in price comparison.

the monopoly price. Classical economic models expect drastic decrease of price already under duopoly[18]. It seems however that competition is not so strong if there are only two or three bidders. The possible reason is that there might be also other forms of collusion when the number of bidders is small. Another reason is that the original producer is often not particularly interested in obtaining the status of "product of the month" and hence in case of only two bidders (one original and one generic), the generic substitute needs to be only slightly cheaper than the original producer in order to obtain the "product of the month" status.

Since the marginal cost shouldn't differ much between these products, it shows that firms on concentrated markets are able to extract substantial economic profit. And that means that the tendering system in Sweden does not drive the prices even close to the marginal cost for over 68% of products (since this many products have 1 to 3 bidders). However, products with the highest sales levels have on average many bidders and low prices[19].

Graph VI.3. Relationship between price and the number of bidders in non-suspicious markets



The price comparison becomes even more interesting when we consider products

[18] Bertrand model would predict even decrease of price to the marginal cost level already at the level of duopoly (without product differentiation).

[19] http://tlv.se/press/ovriga-nyheter/Omprovningar-av-lakemedel-har-sankt-priserna/Lankar-och-dokument-pdf/Internationell-prisjamforelse-av-lakemedel-2015-pdf-1-MB/ (accessed 8.04.2016)

with two bidders that are marked as suspicious according to the Overlapping Permutations Test. In that case the average price is 10% **higher** than under monopoly[20]. The reason why a price under duopoly could be higher than under monopoly is perhaps that the particular market is more price-insensitive.

In order to avoid the endogeneity from number of bidders as well as price elasticity of demand, I use difference-in-difference strategy (see chapter V.3.). The estimated isolated impact of collusion is around 47%. It is higher under parallel bidding (56% price increase due to collusion) than under bid rotation (35%). The results are significant at 1% level. The estimated impact of increasing the number of bidders by one is on average 18% price decrease. We have to bear in mind however that this estimate is likely biased (downward bias, see chapter V.3.). The general trend is a slight price decrease.

Table VI.2. Price comparison results difference-in-difference

	Difference-in-difference estimate		
Variable	**All collusive products**	**Parallel bidding**	**Bid rotation**
Time of collusion within suspected product	**0.468*** **	**0.556*** **	**0.352*** **
	(0.0882)	(0.124)	(0.116)
Time of collusion	-0,0492	-0.253***	0.164**
	(0.0558)	(0.0619)	(0.0776)
Suspected product	0.114**	0.371***	0,0814
	(0.0472)	(0.0747)	(0.0618)
Time trend (t)	-0.0137***	-.00968***	-0.0159***
	(0.00131)	(0.00165)	(0.00169)
Number of bidders	-0.185***	-0.137***	-0.244***
	(0.00402)	(0.00495)	(0.00695)
Observations	5619	1911	3708
R-square	0.82	0.85	0.79

Significance levels: *** : 1%, ** 5%, * 10%

Based on the price comparison, I estimate the cost of collusion to the society to be over 148 mln SEK. The estimation is based on only 78 drugs for which there exists an alternative without collusion. By an alternative I mean medicine with the same active substance, dosage and form. I did not include drugs with a different strength in the

[20] Comparison based on 45 products. No significant difference between parallel bidding and bid rotation. There are not enough products with 3 or 4 bidders to make a reasonable comparison (only two).

comparison, since sometimes same active substance but of different dosage is used for different therapeutical purposes. The cost to the society has been estimated according to the following equation:

$$Cost = [\max(p_{suspected\ product} - p_{comparison\ product})] * number\_of\_pills\_in\_the\_package * sales\_volume$$

Where p is the price per pill and $sales\_volume$ is the average sales from 2014 (the only sales data available from TLV). Some products have a few cheaper alternatives. In that case I use the cheapest as a reference. Since I estimate it for only 78 out of 231 suspected drugs, the possible cost to the society can be even three times higher, which would mean over 500 mln SEK (during 5 years' time).

VI.2.2. Price Variation Comparison

As noted before, there is ample evidence in the literature that price variation is smaller under collusion. Hence, if I have correctly identified collusive markets, I should be able to see a similar pattern in my data. I perform two types of comparison of the price variation: first I compare price variation of suspicious products with a comparable product (medicine with the same active substance, dosage and form, just different package) and secondly, I take into account possible systematic price variation differences depending on the number of bidders.

The coefficient of price variation (CPV) of suspicious products is over 3 times lower than the CPV of comparable products. The price variation under collusion is only 6%, compared to 20% on non-suspicious products. However, the average number of competitors is also smaller under collusion. Among non-suspicious products average coefficient of price variation is 0.1 in case of 2 bidders, whereas for 3 bidders it is 0.23. Among the products identified as suspicious by the Overlapping Permutations Test the average coefficient of variation is 0.04 in case of 2 bidders and 0.13 in case of 3 bidders. As we see, price variation is substantially smaller under collusion, even taking into account the number of competitors on the market. It is in line with the literature prediction that price variation is smaller under collusion. In fact, price variation under collusion is even lower than average price variation under monopoly (products with only one bidder), which is equal to 0.07.

Table VI.2. Coefficient of price variation comparison

	Suspicious products	**Non-suspicious**
2 bidders	0.04	0.1
3 bidders	0.13	0.23

VI.3. Bidding Pattern Choice

Results obtained from the Overlapping Permutations Test suggest that parallel bidding is more or less equally common as bid rotation. In the theoretical section I tried to answer the question why should a company choose one or the other. One hypothesis is that if costs and demand variate, the equilibrium (monopoly) price also does and it is easier to change price under bid rotation rather than under parallel bidding where firms would need to communicate and agree on common price. Hence, we should observe bid rotation on products with higher demand volatility.

I have tested the relationship between bidding patterns and sales volatility. I have obtained data from TLV on sales of the "product of the month" only for year 2014. For products where I suspect bid rotation in 2014 the average variation in quantity is 22%[21], whereas for parallel bidding it's 20%. Therefore we can say that on average bid rotation occurs on products with slightly higher variation of quantity sold, however it is not statistically significant (using t-test). Moreover, we cannot say if the variation in quantity is exogenous or whether it is caused by price changes. In order to estimate this we would need to estimate price elasticity of demand. That is beyond the scope of the paper. However, I shall just note that on average price variation under bid rotation is 4% (with no variation under parallel bidding). So if the price elasticity is above 0.5, we might even have higher exogenous demand variation on products under parallel bidding.

To sum up, I have not found evidence supporting the hypothesis that bid rotation is chosen due to exogenous demand variation. Hence, it would be interesting to conduct

[21] How much standard deviation varies from the average.

further study that would aim at identifying the reasons why companies choose one bid collusion pattern or the other. There are a few possibilities that I have identified (some of them have been discussed in chapter III.2.):

1) Cost variability: if costs change much from month to month, the profit maximising price will change also, hence bid rotation gives higher chances of maximising profit
2) Differences between firms: if firms have different marginal costs, agreeing on a common price means loss of profit for at least one of them
3) Legal consequences: tacit collusion is not illegal and it is arguably easier to maintain with bid rotation
4) Pharmacies' behaviour: which product will they dispose in case of two winners of the "price of the month" status
5) Individual firm's preferences

The analysis of products marked as suspicious has led to the discovery of yet one more possible reason: number of bidders. It seems that companies involve in parallel bidding if they are the only two bidders and in bid rotation if there are competitors not involved in collusion. Closer analysis is beyond the scope of this paper and is left for a separate research.

Conclusions

The aim of the thesis was to investigate whether there were suspicious bidding patterns on the Swedish generic drugs market in years 2010-2015. The empirical strategy is developed specially for the purpose of this thesis. It involves statistical check of the sequence of winners in order to find if there are some patterns. In particular, I check if there is bid rotation or parallel bidding. Unlike most of the previous literature, there is no information about the colluding companies beforehand. Moreover, unlike most papers dealing with bid rigging, I suspect that only some of over a thousand products in the dataset are under collusion. The advantage of the method I have used is that it requires very little information: only about the winner. The method does not require gathering data about demand or cost shifters that could be difficult or costly and in case of omission of one important factor would give misleading results. Hence data collection is easier and method more robust.

The test I designed has identified 231 products with suspicious bidding patterns[22]. In particular, there are 127 products with two firms submitting continuously same bids, 96 products with bid rotation among two firms, only 8 products with three firms bidding parallel and 11 products with bid rotation among three firms. Comparing the average prices of suspected products with non-suspected ones has revealed substantial differences: over 5 times on average with extreme value of 26 times (see chapter VI.2.). The price difference is hugely affected by the number of bidders. Even on markets without suspicious bidding patterns but with just two or three bidders, the price is close to monopoly price and a few times higher than a price of a comparable product[23] with six or more bidders. To account for this I use difference-in-difference specification. The estimated isolated impact of collusion is 47% price increase.

I perform also another check of reliability of the test for suspicious bidding patterns that I have developed. Literature has pointed to the fact that under collusion price variation is substantially smaller (see chapter II). Therefore I compared coefficient of price variation on products identified as suspicious with comparable products and obtained over 3 times difference. Price variation under collusion is on average only 6%, whereas on comparable products it is 20%. Moreover, price variation on suspicious products is even

[22] The number is not exactly the sum of products with different suspicious patterns, because there are a few products where for two years there was bid rotation among three firms and then bid rotation among two firms.

[23] Medicine with the same active substance, dosage and form, just different package size.

lower than under monopoly (7% on average). This is understandable, since companies need to coordinate their prices and therefore are not free to vary them as they would individually wish. That in turn confirms that the test is reliable and it identifies suspicious markets correctly.

The analysis has revealed the weakness of the monthly tendering system for generic drugs in Sweden, which makes collusion viable. First of all, 32% of products have only one bidder and another 36% have only two to three bidders. Average price level of products with up to three bidders is no more than 10% lower than that of a monopoly, whereas with six bidders the price drops to around 30% that of a monopoly price. This reveals that companies are able to exert substantial profit from price inelasticity. Moreover, having markets with only two or three bidders makes collusion feasible[24]. A possible solution to this problem would be to extend the reference group at least to all package sizes[25] in order to increase the number of competitors.

Another characteristic of the Swedish system that makes collusion easier is revealing the bidding prices. As shown by Skrzypacz and Hopenhayn (2004) this makes tacit collusion possible. Furthermore, frequent (monthly) interactions allow companies to rotate bids without putting pressure on their discounting rate. This would not be so easy with yearly interactions (as in the US vaccination bidding)[26]. Finally, in the Swedish subsidy system patients who have reached highest subsidy limit do not pay anything at the pharmacy and this makes them unaware of the prices. Perhaps the French system, where the customer first pays and then seeks reimbursement could improve the situation as it would make the patients aware of the prices, which eventually all the citizens pay from their taxes.

There is ample space for further analysis of the topic. First, it would be interesting analyse specific reasons for choice of a particular bidding pattern; especially its correlation with the number of bidders (see chapter VI.3.). Another issue detected while conducting the test was that there are many products with two bidders but only one winner ever. This brings about suspicion of phantom bidding and dividing markets between companies. An additional test would be needed to investigate if the companies interchange on who is the winner and if they split the number of products equally. Finally, one could try to see if

[24] As we know from literature, the possibility of collusion decreases with the number of competitors.
[25] Possibly also to all dosages, with the possibility of even including therapeutical substitutes, like in Germany
[26] Though it might be more difficult if marginal costs vary monthly. The issue would need to be thoroughly investigated.

similar patterns have been present elsewhere. Companies involved in bid collusion in Sweden have world-wide presence and if they were able to coordinate their prices in Sweden, they could have done it in other countries as well. In that case comparison among countries which shows that Sweden does not have high price levels of medicine does not tell us that there is no collusion. It would just mean there is no more collusion than in other countries.

Discussion

In the Overlapping Permutations Test I used two simplifying assumptions that allowed me to calculate probability of randomly observing a collusive pattern, namely:

-probabilities of winning do not depend on the past information (are independent over time)

-probability of winning is the same for each firm

The first assumption allows us to calculate a probability of a sequence as a multiplication of individual probabilities:

$$\Pr(0101, 1010) = (1 - Pr_{win}) * Pr_{win} * (1 - Pr_{win}) * Pr_{win}$$

The second one allows me to calculate probability of individual firm winning as a function of the number of firms bidding:

$$Pr_{win} = \frac{1}{no\ of\ bidders}$$

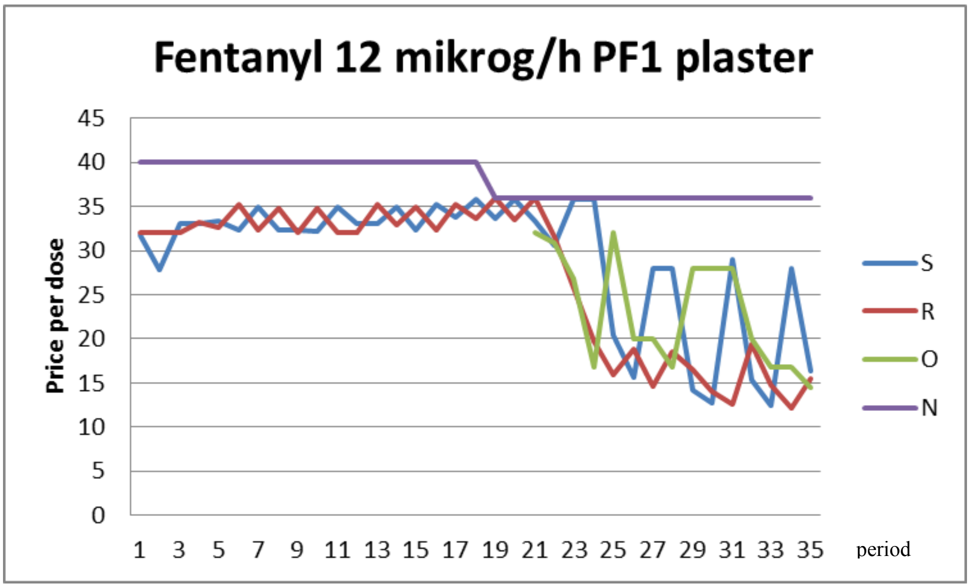
Obviously, both of these assumptions are not very realistic. However, they only lead to *under*estimation, not *over*estimation of collusion. What we could fear is that the test marks as collusive a pattern that was merely random, which would correspond to error type I: rejecting the null hypothesis of randomness when it was true. It would happen if I underestimate the probability of randomly observing a collusive pattern (ex. 0101). The function $(1 - Pr_{win}) * Pr_{win} * (1 - Pr_{win}) * Pr_{win}$ has its maximum at $Pr_{win} = 0.5$, which I assume as a probability of randomly observing single winning in case of two bidders. So if one company has a probability of winning higher than 0.5 and another lower than 0.5, the probability of observing 0101 for one firm and 1010 for another, randomly, is only *lower* than the one I estimated. Hence the only error I could have done is error type II: not finding enough collusive products.

I also computed exact probabilities that *P(0101)>p* (see chapter V.1.) using the binomial probability function:

$$Prob(X = x|p_0) = \binom{n}{x} p_0^x (1 - p_0)^{(n-x)}\ for\ x = 0, 1, 2, \ldots, n$$

However the test seemed to underestimate the confidence. For example a product with a bidding pattern like on graph below was not considered as suspicious with 95% confidence, whereas it was marked as suspicious using the asymptotic test. In general, for the asymptotic test 3 repetitions of a suspicious pattern were enough to reject the null hypothesis of randomness[27], whereas for the exact test 4 repetitions were required. I consider that one year of collusive pattern is enough to mark product as suspicious, especially since there might be periods of "error" in bidding pattern (like period 11 and 12 in the graph below). Therefore I decided to use the results from the asymptotic test.

Graph D.1. Example of test results



As we see on the graph above, it is difficult to exactly mark periods of collusion using the Overlapping Permutations Test. From graphical inspection we can say that it looks like bid rotation started in the third period. However, in the test I have divided the 60 digit string into 15 strings, each containing 4 digits. So I am not able to find the exact month when collusion started, only an approximation by a few months. In the example from Graph D.1. we will have a string: 1101 0101 0101 0101 … In that case the test will tell us that collusion started in the fifth month, because this is the beginning of the period when we have first full sequence of a bid rotation pattern. However, collusion has in fact started already in the third month.

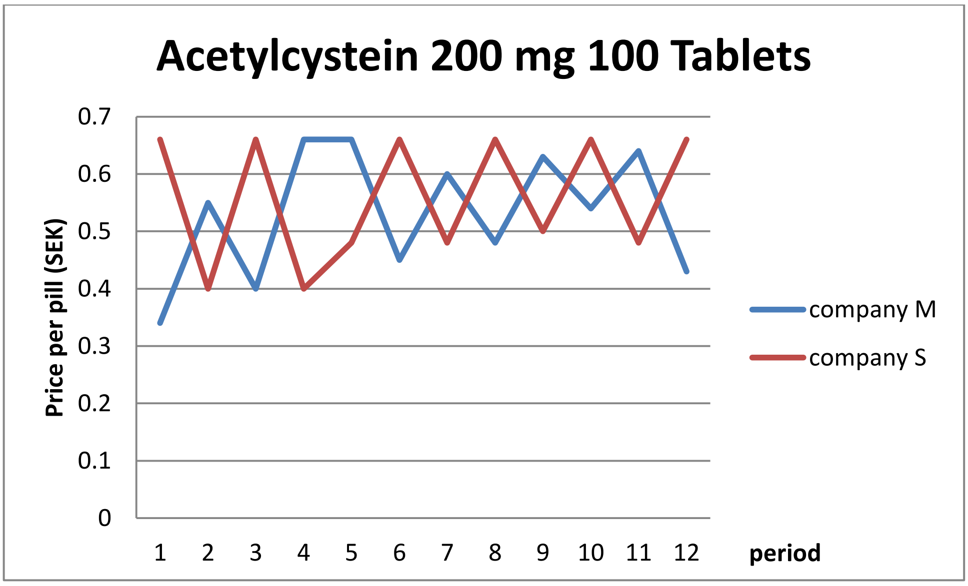
Because of the above mentioned reasons, it is hard to estimate the price impact of starting collusion. Moreover, it could be that before the collusion has started there was another form of collusion or a monopoly. In that case the price before collusion could be

[27] In case of two bidders

even higher than after it has been established. In any case the difference-in-difference estimate will have a downward bias, which means that the presented 47% price increase is *under*estimated.

Price level comparison is very complicated due to periods that are seemingly non-collusive in between collusive periods. For example if the sequence of winners is as in Graph D.2. Bid rotation has been seemingly interrupted in period 5 when company S won, though it was company M's turn. However, the only thing that happened was that the companies changed order in which they win[28]. Therefore I decided that if there is only one non-collusive chunk in between collusive ones, it is marked as collusive for the difference-in-difference price comparison.

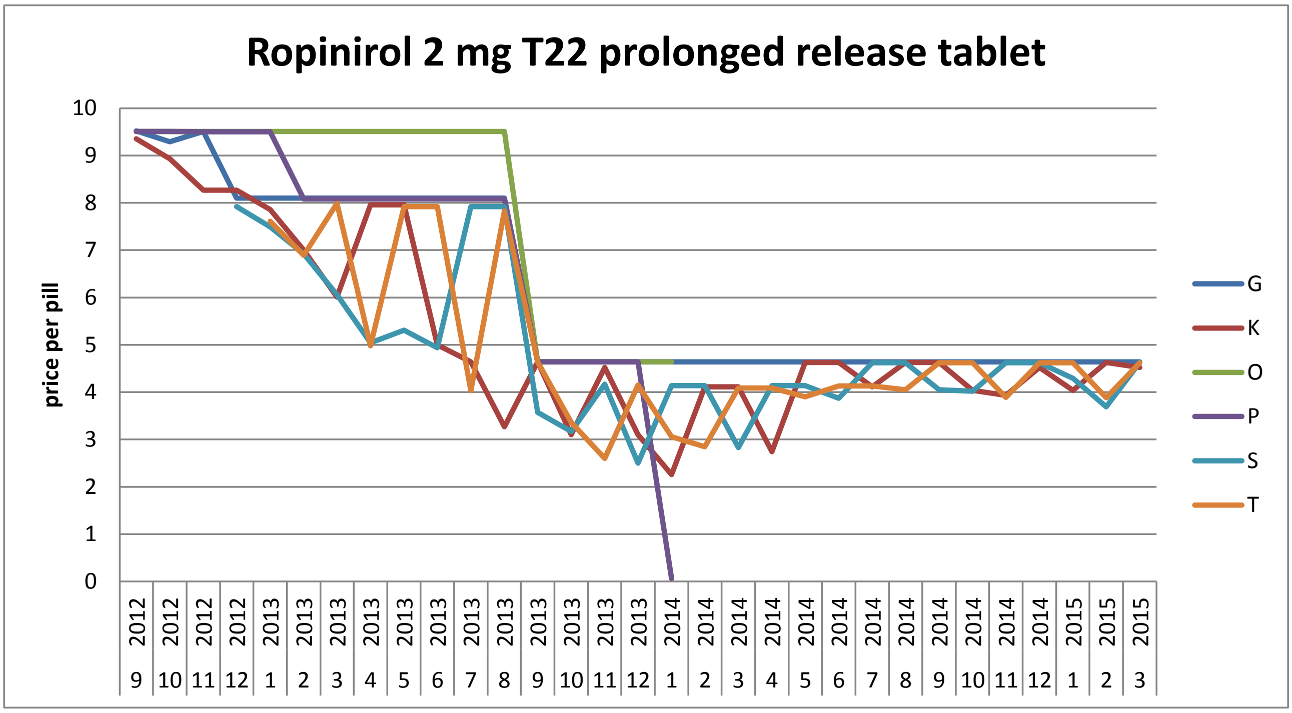
Graph D.2. Bidding pattern interruption



I checked also for frequent repetitions of 0011 and 1100 but it does not seem to be a common pattern that could be suspected as collusive. There might be however other patterns. In the example below three firms rotate their bids (company S, T and K). In 2013 they rotate in a "classical" form: 100100. From 2014 however the pattern becomes less clear. Nevertheless companies seem to exchange low and high bids and share the market evenly across periods. Interestingly, the price has even increased and remains just below the price of the original producer[29].

[28] The purpose of such exchange is unknown; it could be done in order to avoid detection, however that is unsure.
[29] This example shows also the disadvantages of difference in difference methodology: it is hard to estimate the correct beginning and end of collusion time and in this particular example we would conclude that collusion leads to price

Graph D.3. Other bidding patterns



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decrease.

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Appendix

Table1. Products identified as suspicious based on the Overlapping Permutations Test

Substance	Strength/Dosage	Package group	Form
Acetylcystein	200 mg	T17	effervescent tablet
Aciklovir	200 mg	T17	tablet
Aciklovir	3%	K5	eye ointment
Alendronat	10 mg	T23	tablet
Alendronat	70 mg	T23	tablet
Alfakalcidol	0.5 mikrog	T23	tablet
Allopurinol	100 mg	T23	tablet
Allopurinol	100 mg	T31	tablet
Alprazolam	0.25 mg	TN20	tablet
Alprazolam	0.5 mg	TN100	tablet
Alprazolam	1 mg	TN100	tablet
Alprazolam	1 mg	TN20	tablet
Amilorid + hydroklortiazid	2.5 mg/25 mg	T28	tablet
Amlodipin	10 mg	T18	tablet
Amlodipin	10 mg	T28	tablet
Amlodipin	5 mg	T28	tablet
Amoxicillin	1 g	T14	tablet
Amoxicillin	500 mg	T18	tablet/capsule
Amoxicillin	750 mg	T16	tablet/capsule
Amoxicillin + klavulansyra	875 mg	T16	tablet
Atorvastatin	20 mg	T28	tablet
Atorvastatin	40 mg	T18	tablet
Azatioprin	50 mg	T20	tablet
Azitromycin	500 mg	T2	tablet
Baklofen	10 mg	T23	tablet
Baklofen	10 mg	T27	tablet
Bisoprolol	2.5 mg	T18	tablet
Brimonidin	2 mg/ml	ÖM2	eye drops
Budesonid	0.25 mg/ml	T19	suspension
Buprenorfin	2 mg	TN7	sublingual tablet
Buspiron	10 mg	T23	tablet
Buspiron	10 mg	T28	tablet
Buspiron	5 mg	T23	tablet
Buspiron	5 mg	T28	tablet
Cefadroxil	500 mg	T14	capsule
Cefadroxil	500 mg	T16	capsule
Cefadroxil	500 mg	T18	capsule
Citalopram	30 mg	T23	tablet
Citalopram	40 mg	T18	tablet
Cyanokobalamin	1 mg	TT1000	tablet
Diklofenak	100 mg	SU3	suppository
Diklofenak	25 mg	T18	enterotablet
Diklofenak	25 mg (Grupp A)	T23	tablet

Diklofenak	50 mg	T16	enterotablet
Diklofenak	50 mg	T18	enterotablet
Diklofenak	50 mg	T20	enterotablet
Dimetikon	200 mg	T23	capsule
Dimetikon	200 mg	T28	capsule
Donepezil	10 mg	T28	tablet
Donepezil	5 mg	T28	tablet
Enalapril	10 mg	T28	tablet
Enalapril	2.5 mg	T18	tablet
Enalapril	2.5 mg	T20	tablet
Enalapril	20 mg	T18	tablet
Enalapril	20 mg	T28	tablet
Enalapril	5 mg	T28	tablet
Enalapril+hydroklortiazid	20 mg/12.5 mg	T18	tablet
Entakapon	200 mg	T23	tablet
Esomeprazol	20 mg	T18	enterotablet
Esomeprazol	20 mg	T20	enterotablet
Esomeprazol	40 mg	T23	enterotablet
Estriol	1 mg	T23	tablet
Felodipin	10 mg	T18	prolonged release tablet
Felodipin	2.5 mg	T23	prolonged release tablet
Felodipin	5 mg	T18	prolonged release tablet
Fenoximetylpenicillin	1 g	T16	tablet
Fenoximetylpenicillin	800 mg	T19	tablet
Fentanyl	12 mikrog/timme	PF1	transdermal patch
Fentanyl	12 mikrog/timme	PF4	transdermal patch
Fentanyl	75 mikrog/timme	PF2	transdermal patch
Flukloxacillin	500 mg	T18	tablet
Flukloxacillin	500 mg	T23	tablet
Flukonazol	100 mg	T7	capsule
Flukonazol	200 mg	T7	capsule
Fluoxetin	20 mg	T28	tablet
Folsyra	5 mg	T23	tablet
Folsyra	5 mg	TT1000	tablet
Furosemid	40 mg	T28	tablet
Furosemid	40 mg	TT1000	tablet
Granisetron	1 mg	T10	tablet
Granisetron	2 mg	T5	tablet
Hydrokortison + mikonazol	10 mg/g 20 mg/g	K50	cream
Hydroxikarbamid	500 mg	T23	capsule
Ibandronsyra	50 mg	T18	tablet
Ibandronsyra	50 mg	T22	tablet
Ibuprofen	200 mg	T23	tablet
Ipratropium	0.25 mg/ml (endos)	T24	solution
Irbesartan	150 mg	T18	tablet

Isosorbidmononitrat	20 mg	T27	tablet
Isosorbidmononitrat	60 mg	T23	prolonged release tablet
Itrakonazol	100 mg	T14	capsule
Itrakonazol	100 mg	T4	capsule
Kabergolin	2 mg	T18	tablet
Karvedilol	25 mg	T23	tablet
Kinapril + hydroklortiazid	10 mg/12.5 mg	T18	tablet
Klaritromycin	500 mg	T23	tablet
Klindamycin	150 mg	T19	capsule
Klomipramin	25 mg	T27	tablet
Klopidogrel	75 mg	T20	tablet
Laktulos	670 mg/ml	OL500	oral suspension
Lamotrigin	100 mg (grupp D)	T20	tablet
Lamotrigin	200 mg (grupp D)	T20	tablet
Lamotrigin	200 mg (grupp D)	T23	tablet
Lamotrigin	25 mg (grupp D)	T20	tablet
Lamotrigin	25 mg (grupp D)	T23	tablet
Lamotrigin	50 mg (grupp D)	T20	tablet
Lamotrigin	50 mg (grupp D)	T23	tablet
Lansoprazol	15 mg	T23	gastro-resistant capsule
Lansoprazol	30 mg	T20	gastro-resistant capsule
Levodopa + karbidopa	100 mg/25 mg	T23	prolonged release tablet
Levodopa + karbidopa	200 mg/50 mg	T23	prolonged release tablet
Levofloxacin	500 mg	T5	tablet
Loperamid	2 mg	T19	tablet/capsule
Loperamid	2 mg	T23	tablet/capsule
Losartan	50 mg	T28	tablet
Makrogol. kaliumklorid. natriumbikarbonat. natriumklorid		T16	powder for oral suspension
Makrogol. kaliumklorid. natriumbikarbonat. natriumklorid		T20	powder for oral suspension
Makrogol. kaliumklorid. natriumbikarbonat. natriumklorid		T23	powder for oral suspension
Meloxikam	15 mg	T18	tablet
Meloxikam	15 mg	T23	tablet
Meloxikam	7.5 mg	T18	tablet
Meloxikam	7.5 mg	T23	tablet
Metadon	10 mg	OL50	oral suspension
Metadon	100 mg	OL50	oral suspension
Metadon	110 mg	OL50	oral suspension
Metadon	120 mg	OL50	oral suspension
Metadon	130 mg	OL50	oral suspension
Metadon	140 mg	OL50	oral suspension
Metadon	15 mg	OL50	oral suspension

Metadon	150 mg	OL50	oral suspension
Metadon	20 mg	OL50	oral suspension
Metadon	25 mg	OL50	oral suspension
Metadon	30 mg	OL50	oral suspension
Metadon	35 mg	OL50	oral suspension
Metadon	40 mg	OL50	oral suspension
Metadon	45 mg	OL50	oral suspension
Metadon	50 mg	OL50	oral suspension
Metadon	55 mg	OL50	oral suspension
Metadon	60 mg	OL50	oral suspension
Metadon	70 mg	OL50	oral suspension
Metadon	80 mg	OL50	oral suspension
Metadon	90 mg	OL50	oral suspension
Metoprolol	25 mg	T18	prolonged release tablet
Metoprolol	50 mg	T18	prolonged release tablet
Metotrexat	2.5 mg	T23	tablet
Mianserin	10 mg	T23	tablet
Mikonazol	20 mg/g	K30	cream
Mirtazapin	45 mg	T18	tablet
Mometason	1 mg/g	K100	ointment
Mometason	1 mg/g	K30	ointment
Naproxen	250 mg	T17	tablet
Nitrazepam	2.5 mg	TN100	tablet
Nitrazepam	5 mg	TN100	tablet
Nitrazepam	5 mg	TN50	tablet
Norfloxacin	400 mg	T18	tablet
Olanzapin	10 mg	T28	tablet
Olanzapin	5 mg	T28	tablet
Olanzapin	7.5 mg	T23	tablet
Omeprazol	20 mg	T14	enterotablet
Omeprazol	20 mg	T28	enterotablet
Omeprazol	20 mg	T31	enterotablet
Ondansetron	4 mg	T10	tablet
Ondansetron	8 mg	T20	tablet
Oxazepam	10 mg	TN100	tablet
Oxazepam	10 mg	TN25	tablet
Oxazepam	15 mg	TN100	tablet
Oxazepam	15 mg	TN25	tablet
Oxazepam	25 mg	TN100	tablet
Oxazepam	25 mg	TN25	tablet
Oxazepam	5 mg	TN100	tablet
Oxazepam	5 mg	TN25	tablet
Pantoprazol	20 mg	T18	enterotablet
Paracetamol	500 mg	T23	tablet
Paracetamol + kodein	500 mg/30 mg	TN100	effervescent tablet
Paracetamol + kodein	500 mg/30 mg	TN100	tablet

Paracetamol + kodein	500 mg/30 mg	TN20	tablet
Paracetamol + kodein	500 mg/30 mg	TN50	tablet
Paroxetin	10 mg	T23	tablet
Pivmecillinam	200 mg	T16	tablet
Pivmecillinam	200 mg	T18	tablet
Pivmecillinam	200 mg	T23	tablet
Prednisolon	2.5 mg	T23	tablet
Quetiapin	200 mg	T28	tablet
Quetiapin	25 mg	T28	tablet
Ramipril	1.25 mg	T18	tablet/capsule
Ramipril	2.5 mg	T18	tablet/capsule
Ramipril	5 mg	T18	tablet/capsule
Ramipril + hydroklortiazid	5 mg/25 mg	T23	tablet
Risperidon	0.25 mg	T23	tablet
Risperidon	0.5 mg	T31	tablet
Risperidon	1 mg	T31	tablet
Risperidon	1 mg/ml	OL100	oral suspension
Risperidon	2 mg	T31	tablet
Ropinirol	2 mg	T22	prolonged release tablet
Ropinirol	4 mg	T22	prolonged release tablet
Ropinirol	8 mg	T22	prolonged release tablet
Salbutamol	1 mg/ml	T26	solution
Selegilin	10 mg	T23	tablet
Selegilin	5 mg	T23	tablet
Sertralin	100 mg	T18	tablet
Simvastatin	10 mg	T28	tablet
Simvastatin	40 mg	T28	tablet
Spironolakton	100 mg	T23	tablet
Spironolakton	25 mg	T23	tablet
Spironolakton	50 mg	T23	tablet
Sumatriptan	50 mg	T12	tablet
Temozolomid	20 mg	T5	capsule
Terazosin	2 mg	T23	tablet
Timolol	2.5 mg/ml	ÖE60	eye drops
Timolol	2.5 mg/ml	ÖM1	eye drops
Timolol	2.5 mg/ml	ÖM2	eye drops
Timolol	5 mg/ml	ÖE60	eye drops
Timolol	5 mg/ml	ÖM1	eye drops
Timolol	5 mg/ml	ÖM2	eye drops
Tolterodin	1 mg	T21	tablet
Torasemid	10 mg	T23	tablet
Torasemid	5 mg	T23	tablet
Tramadol	100 mg	TN500	prolonged release tablet
Tramadol	150 mg	TN500	prolonged release

			tablet
Tramadol	50 mg	TN20	tablet/capsule
Tramadol	50 mg	TN200	tablet/capsule
Tramadol	50 mg	TN250	tablet/capsule
Trimetoprim	100 mg	T23	tablet
Trimetoprim	160 mg	T23	tablet
Valsartan + hydroklortiazid	320 mg/12.5 mg	T23	tablet
Valsartan + hydroklortiazid	320 mg/25 mg	T23	tablet
Valsartan + hydroklortiazid	80 mg/12.5 mg	T18	tablet
Zolpidem	10 mg	TN500	tablet
Zopiklon	5 mg	TN100	tablet
Zopiklon	5 mg	TN500	tablet
Zopiklon	7.5 mg	TN100	tablet