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Live Cartels

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Prosjektet har mottatt forskningsmidler fra det alminnelige prisreguleringsfondet.

LIVE CARTELS

Determinants of cartel efficiency[1]

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Abstract:

We analyze the efficiency of a legal voluntary and active agricultural cartel in Norway, which major means of collusion are information gathering and public announcement of recommended cartel prices to its cartel members. We are interested in what determines the cartel's efficiency in terms of achieving the recommended cartel prices. We find that the cartel is surprisingly efficient given that local producers can choose to deviate, and that there is no real enforcement mechanisms in place. We find only deviations between recommended and market prices in between 12 and 20% of the weeks over 16 years of data. We also find that the cartels efficiency increase over time. We focus on three factors that have received attention in the literature and that are believed to affect collusion and cartel efficiency: Capacity utilization, predictable demand variation and import competition. We find that all three factors matters to cartel efficiency, high storage numbers, and in particular unanticipated high storage numbers mirroring excess capacity in this sector will increase cartel efficiency, whereas cartel breakdown is more frequent in high demand periods. Reduced likelihood of import competition seems to stabilize the cartel.

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1. Introduction

Norwegian primary producers of agricultural products have exemption from Norwegian competition law. In principle, this means that primary agricultural producers and their organizations can freely collude on prices and restrict output on the markets. At the same time, the Norwegian government subsidizes Norwegian farmers directly over the state budget, and the Norwegian market has high tariffs protecting primary producers from competition from abroad.

We analyze the efficiency of an active agricultural cartel in Norway. "The Green Growers' Cooperative Marked Council" (GCC) is the organizer of the cartel, and the major means of collusion are information gathering and public announcement of recommended cartel prices to the cartel members. The operation of GCC and the associated producers is interesting because the producers operate like a cartel with GCC as the coordinating body. However, unlike most other cartels, this cartel is legal and alive, and offers a unique opportunity to study the dynamics of the cartel. A central feature of the organization of the cartel is that all the producers weekly get a price recommendation of what they should charge for each product the upcoming week.

In this paper, we are interested in what determines the cartel's efficiency in terms of achieving the recommended cartel prices. For instance, what are the most important factors that influence defection from the agreed-upon prices? When do we observe market prices diverging from the recommended prices of the cartel? What factors are decisive for these price differences, and how does exogenous factors such as storage conditions, weather, import competition and business cycles affect pricing behavior? Do we see any systematic changes in efficiency over time, in particular, do cartels get better in suppressing competition over time? To perform an empirical analysis of the working of the cartel we have collected a unique dataset containing weekly information for several products for 20 years from 1995 to 2015 on an active cartel.[4]

The regulation regime surrounding the agricultural markets in Norway is extensive and complex, and different agricultural sectors may have different regulatory regimes. The most important ingredients are as follows. Each year the farmers' associations negotiate an agreement with the government. In the agreement, the parties negotiate direct subsidies, target prices for a subset of the products and tariffs. A target price is the price that the farmers and their organizations should aim at obtaining from the market for the products in question. When target prices are in force, the market price should not supersede the target price as an average over the year, and if it does, the producers will get a reduction in the target price the following year. In addition, if the market price supersedes the target price with more than 12 % for a given period within the year, import tariffs will be lowered administratively to allow for import

[4] There are a number of case studies of historical cartels (e.g. by Porter 1983, Ellison 1994, Genesove and Mullin 2001, Röller and Steen 2006, and Clark and Houde 2013). Our study has the advantage of observing an active cartel allowing us both detailed data and knowledge about its functioning.

and to bring the domestic prices down. The policy with respect to tariffs is to some extent constrained by international agreements, e.g. the WTO agreement.

For some products, an appointed market regulator has the responsibility to balance the markets. The market regulator is mostly the major cooperative in each sector. For a subset of the products, the market regulator will collect a production tax from each farmer, and spend the revenue from the tax on different market balancing activities. The aim is to stabilize market prices as close as possible to the agreed-upon target price. The revenue from the tax can finance the removal of produce from the market (storage or export), and it can be used to subsidize output limitation or to relocate produce to alternative usage.

In the green-growing sector, the set of regulatory instruments is more limited. The sector still has exemption from competition law, but cannot use production taxes to finance balancing of the market (except for a couple of products). There are still target prices on most of the products, and import tariffs will be lowered if national market prices get too high. However, as opposed to many other products, the green-growing sector is allowed to obtain higher market prices than the target prices without being penalized with lower future target prices. In this sector, producers will try to sustain collusion on the target prices solely by communication and exchange of information between producers of the different products (mainly vegetables and fruit). The body, formally named "The Green Growers' Cooperative Marked Council" which functioning we will present in more detail below, organizes the coordination and communication within the cartel.

Typically, illegal cartels have to rely on volunteerism among its members since binding contracts cannot be written. Even though the GCC-cartel is legal, it has decided to have a system built on volunteerism. Thus, the cartel resembles modern illegal cartels more than older legal cartels. Old legal cartel could write contracts, and as such obtain an even tighter cartel structure, though enforceability in contracts differed.[5] Here, we will focus on in several factors that have received attention in the literature and that are believed to affect collusion and cartel efficiency, in particular capacity utilization, demand variation and import competition.

We find that the cartel is surprisingly efficient given that it is voluntary in the sense that local producers can choose to deviate, and that there is no real enforcement mechanisms in place. We find only deviations between recommended- and market prices in between 12 and 20% of the weeks over 16 years of data.

[5] Lately we have seen several new studies of historical legal cartels, see Fink et al (2017) and Hyytinen et al (2014, 2018). Older studies of legal cartels are surveyed both in Levenstein and Suslow (2006) and more lately in Hyytinen et al (2014). Some of these cartels had contracts that even were enforceable in court (e.g. Fink et al (2017), some had to rely on self-polishing (see e.g. Genesove and Mullin 2001, and Hyytinen et al 2014). For a discussion on the legal cartels' status in Europe in terms of enforceability, see also Dick (1986) and Suslow (2005).

We also find that the cartel's efficiency increases over time. Over the sample period, controlling for a number of industry characteristics the cartel improves its efficiency between 2.7 and 5.4%. During this period, several things have happened that might improve cartel efficiency. First, due to a downward trend in the number of farms there are fewer farmers, and second improved communication over internet and the use of smart phones have created more transparancy. The positive efficiency trend can also be attributed to learning-by-doing over time, as the skills of interpreting the market may have improved.

We find that high storage numbers, in particular unanticipated high storage numbers, mirroring excess capacity in this sector, increase cartel efficiency. This result is in line with most of the literature on capacity utilization where increased capacity will increase collusion (see e.g., Osborne and Pitchik, 1987, Brander and Harris, 1984 and Davidson and Deneckere, 1990). In line with the predictions of Rotemberg and Saloner (1986) and Haltiwanger and Harrington (1991), cartel breakdown is more frequent in high demand periods. Finally, reduced likelihood of import competition seems to increase the willingness for the individual producers to stick to the cartel price.

The cartel we analyze is legal and politically accepted to protect Norwegian domestic agricultural industry, suggesting that the usual welfare discussion is not relevant in this case. The cartel has however, the same challenges as any illegal cartel when it comes to achieving efficiency over time. By analyzing its functioning we can both learn about how cartels work, and understand and test how theoretical predictions on factors as capacity utilization and demand changes affect collusion. Our findings seem to verify that such factors do indeed affect cartel efficiency. This means that our results have bearings for competition policy.

For instance, the finding on storage seems to suggest that in industries with excess capacity one will anticipate more efficient collusion, than in industries without excess capacity. Likewise, we find that even self-polishing cartels without any formal contracts and ties can achieve collusion through sharing communication and signaling, suggesting skepticism for competition authorities towards more detailed information sharing systems.

In the following, we will present in more detail the organization of the cartel, and the working and the available instruments for the GCC. Next, we will present theory on cartel efficiency. In Section 4, we present our data with focus on the subset of cartel products that we will work with in this paper. In Section 5, we undertake a descriptive analysis and define our empirical variables, before we undertake econometric analysis in Section 6. Section 7 concludes and points at future research.

2. The GCC cartel, information and communication.

The GCC's main task is to coordinate production and pricing behavior in the markets for potatoes, vegetables, fruit and berries. The GCC is the market regulator for potatoes and apples, and in these markets, GCC may directly regulate supply. Our focus in this paper is on the products where GCC does not have these regulatory instruments, but instead must rely on communication and information to achieve its price goals.

Until recently, most of the producers were organized in four major producer groups, each supplying one of the four major retail grocery chains in Norway. A retail merger in 2015 reduced the number independent grocery chains to three, and consequently the number of producer groups to three.

The coordinating body GCC previously had four members, one from each producer group, but due to the above-mentioned merger, there are now three members. The most important instrument of the GCC is the so-called steering groups. There is a steering group for each individual product, and it consists of producers selected from the different producers groups that are relevant for the product in question. For instance, there is a steering group for "onion" consisting of eight producers of onions selected from different producer groups and geographical areas in Norway. The steering groups may also include independent farmers that are not member of one of the producer organizations.

Locally in the major agricultural production areas in Norway, GCC organizes weekly meetings for the local producers. This is done both to gather micro information on the local supply situation (anticipations on harvest etc.), but also to be able to communicate more general information to the local producers. These meetings take place prior to the central market meetings. With this setup, GCC gathers a lot of information both locally and centrally prior to pricing decisions, and are able to communicate directly with a surprisingly high number of producers.

Every week, the GCC publishes detailed information on prices and quantities from past weeks for every product. For each product, they publish the weekly traded quantity, the average market price and GCC's recommended price (which we later will refer to as the cartel price). In addition GCC reports the price that will induce reductions in tariffs (called the upper price limit), the target price that defines the upper price limit, the import price included tariffs and transportation costs, the tariff, the total quantity sold per season, and the estimated storage of each individual product. This information is available for every week, for every product and back in time for several years.

The GCC organizes its week in the following regular way. Monday or Tuesday each week GCC posts import prices for all products on the GCC website. Every Tuesday, the Norwegian Agriculture Agency[6] collects last week's market prices from the traders, transfers this information to GCC, and GCC posts the prices on its webpage. Tuesday afternoon and Wednesday morning all steering groups have telephone meetings and agree on recommended prices for each product for the upcoming week. Before noon on Wednesday, GCC sends out the recommended prices to the producers and producer groups, and posts the recommended prices on their webpage. Every Thursday there is a central "market meeting"

[6] "Statens landbruksforvaltning," a governmental agency.

at 8 am in Oslo, where both GCC and representatives from the ministry are present. GCC suggests their recommended prices to the “market meeting”, and the meeting decides the final price recommendations for the upcoming week, and sends out this information to the producers before 9 am Thursday. The final recommended prices then appear on the GCC webpage. Finally, GCC updates its webpage with traded quantities from the last week with information from Norwegian Agriculture Agency.

We will name the final recommended price as the cartel price. We assume that this price is the price that will maximize the joint profit for the relevant product, taking into consideration the target price and the supply and demand circumstances of the market. After trade has occurred, the market price is revealed, and most times the market price is very close to the cartel price. Given that the market price is an average price based on transactions from a number of farmers, the price will almost never exactly match the cartel price. However, there will be a systematic pattern in the sense that as long as market prices are close enough to the recommended cartel price, GCC has succeeded to maximize cartel profits. However, when the market price falls short of the cartel price, this might be due to defection from some farmers. When a substantial number of farmers defect, the average market price will fall below the cartel price. The major aim of our study is to uncover what determines deviations between cartel- and market prices.

Hence, the study does two things; we evaluate the efficiency of the cartel, and we determine which factors that affect cartel efficiency.

3. Cartel theory

The theory on cartel stability is extensive and focuses on factors that facilitate tacit collusion. Three strands of this literature are particularly relevant for our study in this paper. First, there is the literature initiated by Brock and Scheinkman (1985) that studies the relationship between capacity and collusion. Many of our products in this study are products that can be stored, and variation in storage can potentially influence the ability to collude. Second, we have the business cycle theories that analyze the relationship between demand fluctuations and collusion. Finally, there is the literature that focuses on the role of rules and communication and how this may effect cartel stability. Below we will briefly review the main insights from the most central contributions within each strand.

The literature on capacity and collusion. Brock and Scheinkman (1985) were the first to model the relationship between capacity and collusion. They did that by examining the stability of collusive agreements in a specific example of a price-setting game with capacity constraints (rather than a quantity-setting game). At more or less the same time, a series of papers appeared that studied the influence of the timing of investments on equilibrium outcomes in oligopolistic markets (Spence, 1977; Dixit, 1980; Eaton and Lipsey, 1981; Gelman and Salop, 1983; Kreps and Scheinkman, 1983; and Fudenberg and Tirole, 1983). Benoit and Krishna (1987) integrated the two ideas and made a model where firms could choose their capacity and then engage in an infinitely repeated game with price competition. The Benoit-Krishna model is in fact a combination of Kreps and Scheinkman (1983) and Brock and Scheinkman (1985). It extends Brock and Scheinkman by allowing capacity constraints to be determined endogenously, as well as Kreps and Scheinkman by considering an infinitely repeated price game, making it possible to sustain collusive equilibria.

Following up on some specific equilibria of Benoit and Krishna (1987), Davidson and Deneckere (1990) analyze the relationship between the level of excess capacity and the degree of price collusion that can be sustained in a market. They look at a game where firms tacitly collude on price, but compete in capacity. They show that equilibria exist where firms will carry excess capacity in order to support collusive outcomes (see also Osborne and Pitchik, 1987). They do not explain why firms cannot collude in capacity, but rather cite a number of examples of where firms are in such a situation of "semi-collusion" (or "mixed games", see Brander and Harris, 1984).

Based on the level of excess capacity, Davidson and Deneckere (1990) identify three types of equilibria. When the cost of capital is low, firms would hold large excess capacity and could sustain the unconstrained collusive outcome. When the cost of capital is intermediate, some level of collusion could be sustained, and when the cost of capital is high, there will be no collusion. Hence, the empirical implication of this for our setting is that higher capacity should entail higher prices in equilibrium, all else equal.

Business cycle – seasonal variation (deterministic – not random). There is a large cartel literature focusing on the importance of demand fluctuations for cartels (see Levenstein and Suslow 2006 for a review). Most notable are Green and Porter (1984), whose model suggests that price wars will arise in response to unobserved negative demand shocks, and Rotemberg and Saloner (1986), whose model predicts price wars during booms. Later also Haltiwanger and Harrington (1991) show that a pricing cartel becomes less stable when current demand is strong (making secret price cuts more profitable). The literature suggests that cartel formation may be linked to the growth trend as well as to idiosyncratic changes in demand not anticipated by the cartel (Jaquemin et al, 1981 and Suslow, 2005). Harrington and Chang (2009) show how cartels birth and death is linked to (unanticipated) demand shocks.

Rules and communication. Competition authorities are suspicious against inter-firm communication. In spite of this, many famous cartel cases reveal that cartel members often organize regular meetings. As we demonstrated above, the organization of the GCC cartel in focus here, also have regular weekly meetings and structure the communication during each week in a regular way. An intriguing question is why cartels find it useful to meet, and why they meet so often?

Genesove and Mullin (2001) study a sugar-refining cartel and report that the cartels member in this case met weekly for almost a decade. Also in other famous cartels as the vitamin A and E, citric acid, and lysine cartels, the members met on a regular basis (see Harrington, 2006). Theory seems to suggest that communication is important for collusion. Both Athey and Bagwell (2001) and Cooper and Kühn (2014) show that explicit communication can help sustain collusion. In a recent and very interesting paper, Awaya and Krishna (2016) study the role of cheap talk communication within a situation where firms may make secret price cuts and where firms cannot observe each other's prices or sales. They find that even cheap talk may result in near-perfect collusion in a repeated pricing game with a prisoners' dilemma structure. The authors show that unverifiable communication about past sales can indeed facilitate collusion. In the model, firms cannot observe the rivals' prices, but each firm can observe its own sales. Own sales are however noisy signals of other firms' actions. When firms try to collude, imperfect monitoring of sales limits the potential for collusion because defection from a collusive agreement cannot be detected with certainty. If a firm observes a drop in its sales, it could be due to a drop in demand, or it could be because a competitor defected with a low price. However, what Awaya and Krishna (2016) show is that when firms are allowed to report unverifiable information of past sales, collusion can be sustained. The intuition is as follows. As long as no firm defects from a collusive equilibrium, past sales of the cartelists will be correlated because they are subject to the same demand conditions. On the other hand, if a firm defects and the other cooperates, past sales will be uncorrelated, and this will be the case even if the defector tries to manipulate its sales report. Hence, even if sales reports are unverifiable cheap talk, such reporting will help the firms to sustain collusion by enabling the firms to discover defection.

4. The data

Our data consists of weekly prices for the period 1995 to 2015 on major vegetables and green products managed by GCC. In addition, we have collected quantity numbers and the relevant target prices (which indirectly also defines the upper price limit that will induce reductions in tariffs). Files on recommended (cartel) prices do not exists prior to 1999.[7]

We have matched these data with data on imports, import prices, toll size and toll size changes for these products. Most of these data comes from the Norwegian Directorate of Agriculture and the Norwegian Customs and Excise Directorate.[8] We obtained the recommended prices for some years directly from GCC, whereas the older cartel prices were obtained from the Norwegian Directorate of Agriculture. All import figures come from Statistics Norway (SSB).

For some of the products, significant quantities are stored throughout the year. This is mainly due to the asymmetry between consumption and production cycles over the year. Storage is obviously only possible for products that can sustain long-term storage without deteriorating its quality too much. The Norwegian Directorate of Agriculture produces and provides storage numbers for the vegetables.

[7] We have also received comments and information from the cartel body, GCC.
[8] We also downloaded these data from the GCC webpages, but to the extent that data also existed from public directories, we used the latter.

Finally, we collected regional weather data for the whole period, together with detailed regional production information. The weather data is from the Norwegian Meteorological Institute (eKlima) whereas the regional production data is from Statistics Norway (SSB). By creating regional production weights over time, we were able to create product specific weather variables that vary over time. Summary statistics for our variables are provided in Appendix C.

The study focuses on products that are not subject to the system of production tax and balancing programs, and where GCC only acts on behalf of the farmers to maximize profits. All values and prices are in real terms, deflated using the monthly Norwegian Consumer Price Index from SSB. We analyze nine products, whereof five are storage products and four are non-storage products. Table 1 shows the products we use in this study.

Table 1. Average market-, and cartel prices for the studied products where information on both market- and cartel price is available

	# weeks	Market price	Cartel price	First observation year	Last observation year
Storage products					
Carrots	783	680	687	1999	2015
Cabbage	633	482	466	1999	2015
Celeriac	594	1429	1468	1999	2015
Onion	734	565	572	1999	2015
Leeks	498	1673	1703	1999	2015
Total storage	3242				
Non-storage products					
Cucumber	550	676	684	1999	2015
Cauliflower	311	763	784	1999	2014
Iceberg Salad	358	794	825	1999	2015
Tomato	374	1786	1797	1999	2015
Total non-storage	1593				

We have 4835 weekly observations where we both know the market and the cartel prices. We have more information on the storage products, both due to the longer periods of sale and production, but also because we have one more storage product than none-storage products. For carrots, we nearly cover every week in the 16-year period, and for this product, we observe prices for 94% of all weeks (783 out of 835). For storage products, we observe prices 78% of the weeks, whereas for the non-storage products with shorter production season we only observe prices for 48% of the weeks over these 16 years.

If we look at the product-price averages, we see that in most cases market and cartel price averages are very close. On average, the difference is between 1 and 4% of the cartel price.

With the exception of the storage and the import price variables, we have been able to match all our other variables to the price variables. As can be seen from Tables C1 and C2 in Appendix C, we know storage numbers for 4 483 weeks, and import prices for 4 666 weeks.

The dataset thus comprises very rich information on prices, quantities, import figures, regulative information (toll and target prices), storage numbers and weather conditions for a long time span.

In the next section, we will take a closer look at the data and look at the dynamics in prices and other variables.

5. Descriptive analysis and variable definitions

In this section, we will define the variables used in the econometric analysis, and we will examine the dynamics of these variables. Appendix C gives a full description of our data.

Cartel efficiency: Left hand side variable definitions

In order to define cartel efficiency, we need to define what constitutes a defection. We will denote the cartel as efficient when the weekly average product market price being ‘equal to’ or above the cartel price. However, a requirement that the average product market price is exactly equal to the cartel price is very strict. The market price is an average over a large number of transactions. Hence, we operationalize efficiency in the following way: Whenever the market price is no more than 5% below the recommended product cartel price, we say that the cartel is efficient. Whenever the market price falls short of 5% of the cartel price, we will define this as a cartel break. This is measured through our cartel break variable that takes the value one whenever this is the case (*Cartelbreak*=1), otherwise the variable is equal to zero. In Table 2, we have tabulated the cartel break variable across products.

On average, the cartel is efficient in 83% of the time for the analyzed products. It seems to be more efficient for the non-storage products where the cartel price is within the 5% threshold 88% of the time. For storage products, this happens for 80% of our weeks. Turning to the product level, cabbage and iceberg salad have most cartel breaks; for more than 29% of the weeks the market price is below the 5%-threshold. For Leeks, Cucumber and Tomato the cartel is very efficient, where market prices are below the 5%-threshold for only 3-9% of the weeks over 16 years.

Obviously, these are raw numbers, and in the econometric section, we will see whether these patterns are significant when controlling for other factors.

Table 2. Cartel breaks across products and product categories 1999 to 2015.

	N	Cartelbreak=1
All products	4835	0.17
Storage products	3242	0.20
Non-Storage products	1593	0.12
Storage products		
Carrots	783	0.19
Cabbage	633	0.29
Celeriac	594	0.22
Onion	734	0.18
Leeks	498	0.09
Non-storage products		
Cucumber	550	0.05
Cauliflower	311	0.16
Iceberg Salad	358	0.30
Tomato	374	0.03

Right hand side variables

Storage

From Tables 1 and 2 we see that there is a difference between storable and non-storable products, both in terms of the length of production and sales seasons and to what extent the GCC cartel is able to sustain cartel prices.

Storage increases the farmers' capacity level, and as we discussed in the theory section above, excess capacity can support collusion. Storage mostly takes place at the farms, which also implies that when local farmers have large storage volumes they can choose to supply large quantities to the market.

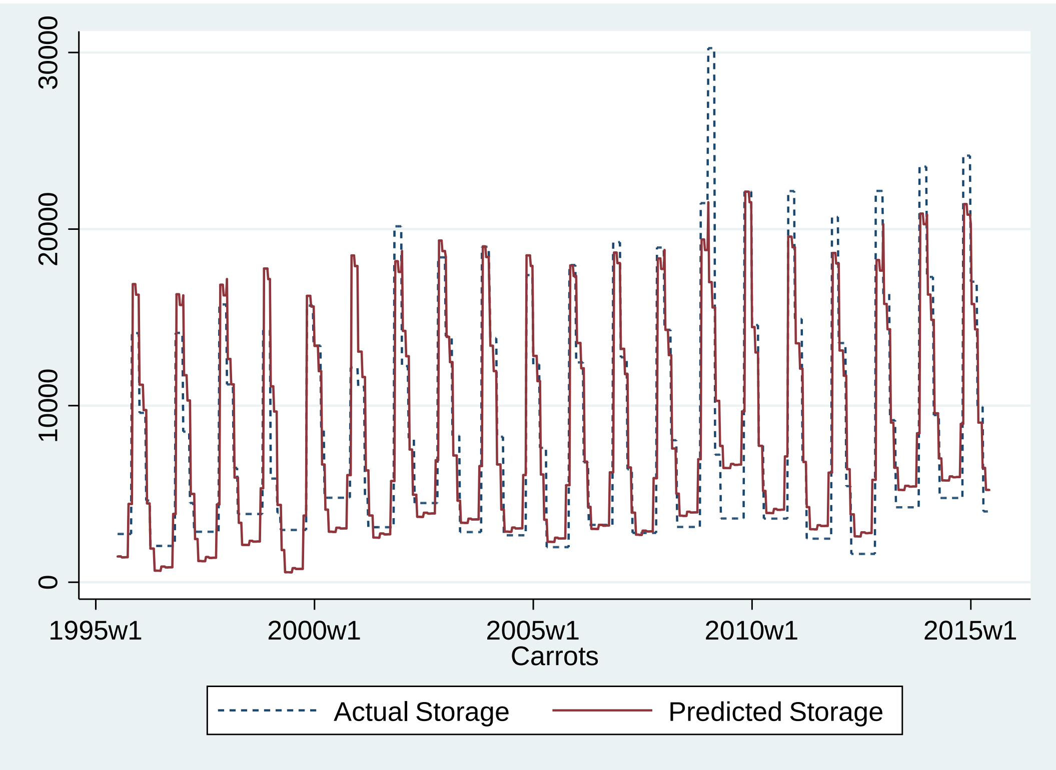
To investigate the effects from storage we will include two different storage variables in our models. The first is simply last week's storage numbers (*Storage*). We also create a second storage variable intended to pick up unanticipated changes in storage volumes. The idea is that a farmer would not only look at the storage when considering his offered price, but also to what extent the storage volumes depart from some notion of the normal situation.

To say something about the 'normal' storage situation we have estimated separate storage models for the five storage products using ordinary least squares (OLS). We use data from the whole period 1995 to 2015. In each model, we explain storage as a function of a full set of monthly and yearly dummies. Generally, we explain the development of storage volumes quite well. Four models have adjusted R-squares between 76 and 81%, and for leeks where we only use data after 2005, the figure is as high as 72%.

In Figure 1, we show actual and predicted storage numbers for carrots. The remaining four storage predictions are shown in Appendix A, figures A1 to A4.

Assuming that our predicted storage volumes are reasonable estimates of the normal storage situation, we look at the difference between predicted and actual storage for product *i* at time *t*: $DiffStorage_{i,t} = Actual\ storage_{i,t} - Predicted\ storage_{i,t}$. If $DiffStorage_{i,t}$ is positive, actual storage is higher than normal storage as predicted by our OLS models. However, this is a too strict definition of unanticipated storage volumes. Instead, we look at storage deviations that are so large that they represent situations where the farmers clearly believe that storage is unanticipated higher than normal. We operationalize this in the following manner: If the actual storage volume is higher than the predicted storage volume by more than 5% of the average of the difference ($DiffStorage_{i,t}$) in absolute terms, we assume that the storage for the relevant product is unanticipated higher than normal. More formally: If $Actual\ storage_{i,t} > Predicted\ storage_{i,t} + 0.05 \cdot ABS[DiffStorage_{i,t}]$, the storage level for product *i* at time *t* is higher than normal. Whenever this happens, our *Storage5%* variable is equal to one, otherwise it is zero.

Figure 1. Development in actual and predicted storage volumes for carrots the period 1995 to 2015



In Table 3, we show the average for the *Storage5%* variable for the different products.

Table 3. Predicted unanticipated storage (*Storage5%*) across products and product categories 1999 to 2015 for all observations where both market and cartel price and storage are known.

	N	**Storage5%**
Storage products	2 780	0.41
Carrots	764	0.36
Cabbage	600	0.37
Celeriac	489	0.62
Onion	709	0.32
Leeks	218	0.48

On average, 41% of the periods have unanticipated high storage levels as defined above. For three of the products we observe *Storage5%* to be equal to one in one third of the cases. For celeriac and leeks, the shares are 48% and 62%. This suggests that our storage predictions for these products fit less well than for the others, and consequently the explanation power is low for these two products.

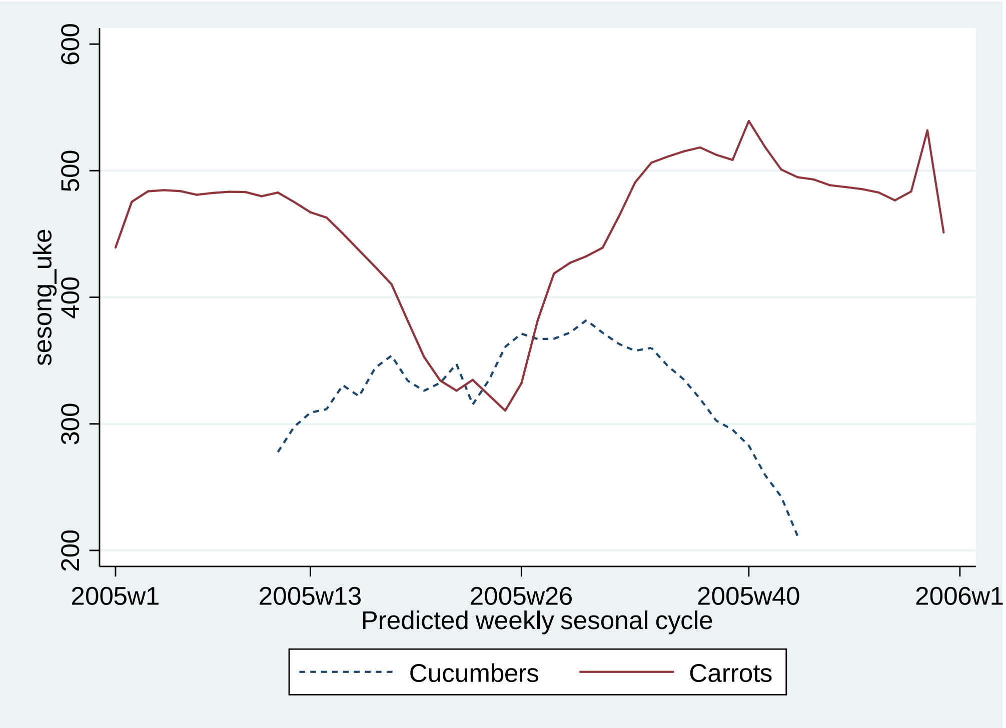
Business cycle: Seasonal changes in demand

As we discussed in the theory section above, the empirical cartel literature has been concerned with the effect of demand shocks and business cycle changes on cartel stability. The GCC cartel is to very limited extent exposed to business cycles between years. However, despite some stochastic variation due to varying weather conditions, *within-year* variation of sales is relatively deterministic. For some periods, the market is in a 'high demand' situation, and in others, we have a 'low demand' situation. This implies that the short-term payoff for cartel member deviations differs over the yearly cycle.

To model this seasonality in demand we have estimated OLS models over all years to identify this cycle. Since the cycle typically differs for storage and non-storage products, we have estimated a seasonal cycle for each product group. The two models include a full set of weekly dummies, relevant product dummies and a time trend. The product dummies shift the cycle whereas the time trend adjusts for demand changes over time: Negative for storage products, positive for non-storage products. The adjusted explanation power is 0.85 and 0.40 for the two groups respectively. We use the whole sample back to 1995 in these estimations.

In Figure 2, we show the estimated seasonal cycle for cucumbers and carrots. The graphs are typical also for the demand pattern for the other products, higher demand during the summer season for non-storable products, lower for the storable products, and vice versa during the winter season. Even though the predictions for the seasons are based on all years and are averages, we lag the variable in the econometric section to prevent potential endogeneity.

Figure 2. Predicted weekly seasonal demand cycle for cucumbers and carrots based on the OLS estimations for the period 1995-2015 for storage and non-storage products, respectively. The cycle shown here is for the year 2005.



Import prices, toll changes and target prices

We use product level monthly import quantities and import values from Statistics Norway to generate weekly data for import prices ($Pimp_{(i,t)}$). The level of the import price together with the product tariffs may discipline domestic prices. In some periods, the import price is lower than the domestic market price. However, most of the time high tariffs block foreign competition. Only when the product tariff is reduced or removed, which may be due to lack of Norwegian production or that domestic prices reach the upper price limit for two weeks in a row, we see significant imports. Still, the import price has a potential disciplining effect also in periods when product tariffs are in force. In periods when the import price is very low (for a given tariff), the foreign products become more attractive for Norwegian buyers.

The target prices ($Ptp_{\ (i,t)}$) are determined *ex ante* annually by (negotiations with) the Ministry, and consequently they are known for the producers when production takes place. If the market price exceeds the target price by 12% or more (defined as the upper price level) for two consecutive weeks, the tariff is reduced on the relevant product. If we look closer at tariff removals due to domestic shortage or too high domestic prices in our sample, the tariff falls on average with between 69% (Storage products) and 78% (also including non-storage), implying that even in these occasions, some tariffs remain in force.

To account for this we have made a dummy variable that indicate that a tariff change is implemented ($Tariffchange_{(i,t)}=1$), otherwise this variable is zero.

To account for the effect of a change in the target price we do three things. As the target price is an exogenous variable that affects the competitive framework by defining the upper price limit, we include the target price in the models. Furthermore we include two differences, the difference between the target price and the import price lagged one week [$(Ptp\text{-}Pimp)_{(i,t-1)}$] and the previous week's difference between the target price and the market price [$(Ptp\text{-}Pmarked)_{(i,t-1)}$]. These variables are relevant for both how the cartel sets its recommended cartel prices the following week, and how the individual farmers evaluate the market situation when deciding which price to charge.

We illustrate some of the dynamics of differences in prices, and imports in Figure 3 (carrots in 2005). In the second quarter, the import price is very close to the market price and imports grow. Note that carrots sold in Norway at this time mostly come from storage. After June 20th the market price doubles, and stays high and above the import price until August. In this period, imports are very high, but falls again when the domestic market price fall. Note that there are some imports all the time, even in periods when import prices are high. This is primarily imports for restaurants. The average import share of total consumption of carrots in 2005 was 17%. During the weeks in June, the import share was as high as 94%.

Figure 3. Development in prices and imports for Carrots in 2005

Weather

The production of vegetables outdoor depends on the weather. To account for the effects of exogenous changes in the weather we have made a substantial data effort in calculating product and time specific weather variables. This has been possible by computing regional production weights for all products together with regional data for weather across counties in Norway.[9] We ended up using two major variables that we also interact: Rainfall [$Rainfall_{(i,t)}$], a Pretty Weather index [$PrW_{(i,t)}$] and the interaction [$PrWxRainfall_{(i,t)}$]. Rainfall is measured in millimeters and the Pretty weather indicator is an indicator that say something about the extent of the cloudiness.[10] The variables varies by product, but have naturally larger variance within products than between products.

6. Empirical model and results

We estimate several models. In particular, we estimate separate models for the storage products and models including all products. Our focus is on cartel efficiency in terms of achieving the recommended cartel price. In our main models, we analyze cartel efficiency as a discrete phenomenon, using *Cartelbreak* as our left-hand side variable.

We specify two models:

Storage-products model

$$
\begin{aligned}
Cartelbreak_{i,t} = {} & a_0 + \beta_1 \cdot Pimp_{i,t-1} + \beta_2 \cdot (Ptp - Pimp)_{i,t-1} + \beta_3 \cdot (Ptp - Pmarket)_{i,t-1} \\
& + \beta_4 \cdot Ptp_{i,t} + \beta_5 \cdot Storage5\%_{i,t-1} + \beta_6 \cdot Storage_{i,t-1} \\
& + \beta_8 \cdot PrW_{i,t} + \beta_9 \cdot Rainfall_{i,t} + \beta_{10} \cdot PrW \cdot Rainfall_{i,t} + \beta_{11} \cdot Tariffchange_{i,t} \\
& + \beta_{12} \cdot Season_{i,t-1} + \gamma \cdot Trend_t + \rho_p \cdot \sum_{p=1}^{3} package_{p,i} + \delta_m \cdot \sum_{m=2}^{12} Month_{m,t} + \theta_i \\
& + \varepsilon_{i,t}
\end{aligned}
$$

[9] There are more than 600 measuring points in Norway. Daily figures from these are aggregated to week and regional county level.

[10] The Pretty weather index is based on the so-called Birkeland formula and say something about how much clouds are seen from the measuring point as the share of the area observed. It is measured three times during a day (06:00, 12:00 and 18:00). If the weather is good (the cloudy area is sufficient small) the index=1. We average the index over all measuring points in each county for each week.

All-products model

$$
\begin{aligned}
Cartelbreak_{i,t} = {} & a_0 + \beta_1 \cdot Pimp_{i,t-1} + \beta_2 \cdot (Ptp - Pimp)_{i,t-1} + \beta_3 \cdot (Ptp - Pmarket)_{i,t-1} \\
& + \beta_4 \cdot Ptp_{i,t} + \beta_5 \cdot Storage5\%_{i,t-1} + \beta_6 \cdot Storage_{i,t-1} + \beta_7 \cdot HasStorage_i \\
& + \beta_8 \cdot PrW_{i,t} + \beta_9 \cdot Rainfall_{i,t} + \beta_{10} \cdot PrW \cdot Rainfall_{i,t} + \beta_{11} \cdot Tariffchange_{i,t} \\
& + \beta_{12} \cdot Season_{i,t-1} + \gamma \cdot Trend_t + \rho_p \cdot \sum_{p=1}^{3} Package_{p,i} + \delta_m \cdot \sum_{m=2}^{12} Month_{m,t} + \theta_i \\
& + \varepsilon_{i,t}
\end{aligned}
$$

The subscript *i* refers to product, *t* to week. In addition to the variables defined in the previous section we include a linear trend ($Trend_t$), three dummy variables for packaging size and type ($Package_{p,i}$),[11] 11 monthly indicators ($Month_{m,t}$)[12] and product dummies (θ_i). We assume that the error term $\varepsilon_{i,t}$ has the standard properties. a_0, $\beta_1 - \beta_{12}$, γ, ρ_p, δ_m, θ_i are all parameters to be estimated. As we saw above, storage products seem to have a different pattern in terms of cartel breaks than the non-storage products. Hence, in the *All-products model* we include an indicator for all products that have storage ($HasStorage_i$) which pick up the overall effect on *Cartelbreak* for storage products. Note that to be able to include the other two storage variables also in the model where we include non-storage products, we assume the storage variables to be zero for all non-storage products. The subscripts *i* and *j* for the *Season* variable make reference to the average *height* of the cycle changes for all products (*i*), and the *form* of the cycle changes across product groups (*j*=storage, non-storage).

We estimate three specifications of our models, one including all variables (1), one including all variables but *Storage5%* (2), and one were we also leave out *Storage* (3).

Since our left-hand side variable is a zero-one variable, we estimate logit models.[13] For all models, we report robust standard errors. The logit model parameters are not easy to interpret directly, and therefore a standard practice is to report marginal effects.[14] For the continuous right-hand side variables, these are interpreted as the percentage change following a one percent increase of the relevant variable.

The marginal effects for the major variables for the *storage-models* are tabulated in Table 4 and for the *all-products models* in Table 5. The total marginal effects from import price changes and changes in the target prices involves several of the marginal effects from Tables 4 and 5 since these variables enters several places. The import price enters twice, first through the import parameter itself ($Pimp_{(i,t-1)}$) and then through the parameter for the price difference ($(Ptp\text{-}Pimp)_{(i,t-1)}$), the target price entering both by

---

[11] We have three packaging indicators, indicating whether the product is sold by the unit ($Pieces_i$), in kilos (Kg_i) or by size ($Size_i$). The reference category is products sold in bundles.
[12] January is the reference month.
[13] We have the option of using logit- or probit models. As long as the distribution of the left-hand side variable is not particularly skewed, the two approaches provide very similar results.
[14] The parameters themselves do not provide any additional information regarding significance or signs.

itself ($Ptp_{(i,t)}$) and in the two price differences ($(Ptp\text{-}Pimp)_{(i,t-1)}$) and ($(Ptp\text{-}Pmarket)_{(i,t-1)}$).[15] The total marginal effects of the import price and the target price are tabulated for all models in Table 6.

Table 4. Margin estimates of logit models for cartel breaks, storage products for the period 2000-2015

	(1)	(2)	(3)
$Pimp_{(i,t-1)}$	0.00027*	0.00026*	0.00014
	(0.00015)	(0.00015)	(0.00012)
$(Ptp\text{-}Pimp)_{(i,t-1)}$	0.00030**	0.00030**	0.00017
	(0.00015)	(0.00015)	(0.00012)
$(Ptp\text{-}Pmarket)_{(i,t-1)}$	0.00030***	0.00030***	0.00019***
	(0.00009)	(0.00009)	(0.00007)
$Ptp_{(i,t)}$	-0.00004	-0.00004	-0.00004
	(0.00016)	(0.00016)	(0.00011)
$Storage{+}5\%_{(i,t-1)}$	-0.08940***	-0.09217***	
	(0.01669)	(0.01584)	
$Storage_{(i,t-1)}$	-1.84e-06		
	(2.90e-06)		
$Trend_{(t)}$	-0.00006***	-0.00006***	-0.00004***
	(0.00001)	(0.00001)	(0.00001)
$PrWxRainfall_{(i,t)}$	0.05115	0.05125	0.04478
	(0.03891)	(0.03895)	(0.03612)
$Rainfall_{(i,t)}$	-0.01781***	-0.01787***	-0.01563***
	(0.00537)	(0.00537)	(0.00484)
$PrW_{(i,t)}$	-0.04894	-0.04907	-0.05309
	(0.08189)	(0.08189)	(0.07623)
$Tariffchange_{(i,t)}$	0.02682	0.02773	0.02721
	(0.02647)	(0.02655)	(0.02499)
$Season_{(t-1)}$	0.00069*	0.00069*	0.00066*
	(0.00041)	(0.00041)	(0.00037)
N	2721	2721	3100
Pseudo R2	0.1016	0.1016	0.0813
Product, packaging and monthly dummies	Yes	yes	yes

Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[15] For instance will the total marginal effect of the import price be given as: $\partial Cartelbreak/_{\partial Pimp} = \beta_1 - \beta_2$

Table 5. Margin estimates of logit models for cartel breaks, all products for the period 2000-2015

	(1)	(2)	(3)
$Pimp_{(i,t-1)}$	0.0002^{*}	0.0002^{*}	0.0001
	(0.0001)	(0.0001)	(0.0001)
$(Ptp\text{-}Pimp)_{(I,t-1)}$	0.0002^{*}	0.0002^{*}	0.0001
	(0.0001)	(0.0001)	(0.0001)
$(Ptp\text{-}Pmarked)_{(i,t-1)}$	0.0003^{***}	0.0002^{***}	0.0002^{***}
	(0.0001)	(0.0001)	(0.00004)
$Ptp_{(i,t)}$	-0.0001	-0.0001	-0.0001
	(0.0001)	(0.0001)	(0.0001)
$Has\ Storage_{(i)}$	0.3623^{***}	0.3701^{***}	0.2611^{***}
	(0.0761)	(0.0753)	(0.0611)
$Storage{+}5\%_{(i,t-1)}$	-0.0790^{***}		
	(0.0151)		
$Storage_{(i,t-1)}$	-2.37e-06	-5.96e-06 **	
	(2.58e-06)	(2.50e-06)	
$Trend_{(t)}$	-0.00003^{***}	-0.00003^{***}	-0.00003^{***}
	(4.16e-06)	(4.11e-06)	(3.67e-06)
$PrWxRainfall_{(i,t)}$	0.0210	0.0215	0.0201
	(0.0272)	(0.0273)	(0.0260)
$Rainfall_{(i,t)}$	-0.0052	-0.0049	-0.0049
	(0.0037)	(0.0037)	(0.0035)
$PrW_{(i,t)}$	-0.0155	-0.0158	-0.0218
	(0.0625)	(0.0626)	(0.0602)
$Tariffchange_{(i,t)}$	0.0286	0.0222	0.0314
	(0.0207)	(0.0205)	(0.0199)
$Season_{(t-1)}$	0.0007^{***}	0.0007^{***}	0.0006^{***}
	(0.0002)	(0.0002)	(0.0002)
N	4180	4240	4559
Pseudo R2	0.1218	0.1140	0.1066
Product, packaging and monthly dummies	Yes	yes	yes

Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6. Total margin estimates for import price and target price, logit models for cartel breaks, storage and all-products models for the period 2000-2015

	(1)	(2)	(3)
Storage products models			
Total marginal effect *Pimp*	-0.000031	-0.000033	-0.000025
	(0.00002)	(0.00002)	(0.00002)
Total marginal effect *Ptp*	0.00056***	0.00055***	0.00033***
	(0.00009)	(0.00009)	(0.00007)
All products models			
Total marginal effect *Pimp*	0.00001	0.00001	0.00001
	(0.00001)	(0.00001)	(0.00001)
Total marginal effect *Ptp*	0.00036***	0.00034***	0.00025***
	(0.00006)	(0.00006)	(0.00005)

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

First, we note that the results are similar across all models. Mostly the parameters are marginally more significant in the *all-products*, which is reasonable given the higher number of observations. This is also true for the explanation power, which is highest for the *all-products models*. The indicator for storage products *($HasStorage_{(i)}$*) is significant and positive mirroring what we found in the descriptive analysis in Table 2. In general, storage products have more cartel breaks. Typically, for both the *storage* and *all-products* models (1), including storage variables performs best. These are our preferred models.

Price effects and import competition

We start by looking at the price effects. Both the lagged import price and the two price differences are significant, but only when we include one or two storage product variables, and more so for the storage-models. The parameter for the target price is not by itself significant in Tables 4 and 5. However, since both the import price and the target price enter several variables it is difficult to interpret these single marginal effects directly. Thus, we start by looking and interpreting the total marginal effects from Table 6. The total marginal effect of changes in the target price is positive and significant across all models, whereas the total marginal effect of import price changes is non-significant and close to zero in all models. Generally, magnitudes for all price effects are very small suggesting very low marginal effects from price changes.

The target price seems to be most important overall. The total marginal effect is also low, but higher than all other effects, suggesting that a 10% increase in the target price increases the number of cartel breaks with 0.6%. Market price is highly correlated with target price (0.96 for our estimation sample, all-products), the latter being set to maximize the revenues from the market. When target price (and market price) is high, imports will be relatively more profitable, (import price and tariffs stay the same ceteris paribus) and we see more cartel breaks.

Similarly, in the storage model we find (non-significant) negative effects for the total marginal effect of the import price. This suggests that when imports become more expensive, import competition is reduced, and we see less cartel breaks. A likely reason for not finding import price effects very significant is the fact that tariffs most of the time are prohibitive, between 45% (Storage products) and 64% (also including Non-storage) of the market price on average. The import price plus the tariff is often substantially higher than the domestic market prices, on average the market price is lower for 69% (Storage products) and 80% (also including Non-storage) of our estimation observations. Changes in import prices are thus most relevant for the cartel in periods when tariff barriers are reduced. When we look at the occasions where tariffs are reduced due to domestic shortage or too high domestic prices, the tariff on average falls with between 69% (Storage products) and 78% (also including Non-storage), implying that even in these occasions, some tariffs are still imposed.

Thus, the lack of an effect from the import price probably means that the tariff barrier is the most important factor for the cartel. This also suggests that the positive (but small) marginal effect of an increase in the price difference between the target price and the import price (*Ptp-Pimp*), is dominated by changes in the target price. When the target price increases, the price difference (*Ptp-Pimp*) also increases, Likewise, if import prices increase – import competition decreases – the difference gets smaller and cartel breaks are reduced.

Turning to the lagged price difference between the target price and the market price (*Ptp-Pmarked*), this also comes in with a small positive and significant marginal effect, suggesting that the number of cartel breaks increases when this price difference increases. This may seems contra-intuitive, but as noted above, the interpretation of the marginal effects in isolation is not straightforward.

Before we turn to the remaining results, we estimate two more versions of our preferred model (1) for both storage- and all-products where we exclude the price differences. The results are presented in Tables B1 and B2 in Appendix B. We here confirm the findings from Table 6 in the sense that the target price estimates suggest significant positive marginal effects that are somewhat lower (0.0002-0.0003) for both samples. The import price effect is now negative and significant at 10% level in the storage model, but still insignificant in the all-product model.

Storage effects

Storage volumes turn out to matter a lot. When including the variable measuring unanticipated high storage (*Storage+5%*) we find both a large, and a significant negative effect. The other storage variable is significant and negative in some models, but has a very small marginal impact on cartel breaks. The finding that unanticipated high storage disciplines the cartel is in line with the cartel literature suggesting that excess capacity helps discipline collusion, and increase profits (see e.g., Osborne and Pitchik, 1987, Brander and Harris, 1984 and Davidson and Deneckere, 1990). In our case, the GCC-cartel more often achieves the cartel price when storage numbers are high: An increase in unanticipated storage of 1% reduces cartel breaks by between as much as 7 and 8%. The results from the models in Table B1 in the Appendix B suggest very similar storage results, both signs and magnitudes.

Time trend

We find a negative trend across all models, cartel breaks diminish over time. Since we are using weekly data, even a modest marginal effect is large over the sample period of 17 years. The marginal effect differs between -0.00003 and -0.00006. If we scale it by the 888 weeks over the sample period between 1999 and 2015, the GCC cartel improves its efficiency between 2.7 and 5.4% over the period. During this period, several things have happened that might improve cartel efficiency. To name two, fewer farmers due to a downward trend in the number of farms, and more easily available information an improved communication over internet and the use of smart phones. Alternatively, the trend can be due to learning-by-doing, in the sense that the skills of interpreting the market have improved over time. The models where we exclude the price interactions in Table B1 in the appendix B also suggests negative trend in the same range (-0.00004, -0.00006).

How cartels learn to collude over time is not particular well explored in the theory, exceptions are (Mookherjee and Ray, 1991, and lately Asmat, 2016). Here we only include a trend, often the literature look at accumulated production over time, a measure that make less sense in our market where the yearly growth volumes clearly are independent across years. A natural assumption, as argued also by Mookherjee and Ray (1991), is that learning-by-doing through lower costs increases concentration (competition) over time, but when they later make firm concentration endogenous in their model, they find no effect from learning. In his study of the DRAM market, Asmat (2016) look at learning along the production cycle. The model, and his empirical results, show that collusion is harder to sustain in the early stage of a product life cycle, when learning is high, than in the later stage of a life cycle, as learning declines. We also find evidence of improved efficiency over time, though our industry is very different from his ‘product cycle’ industry where new products replace older ones.

Weather

We have included weather variables in our analysis. However, it is not obvious how changes in weather affect the cartel. On the one hand favorable weather increases growth and productivity, on the other hand it might also affect demand for some of the products. In particular, the consumption of non-storage products can be exposed to weather changes, e.g., when the weather turns out good, people use more barbeque food that often involves salads etc. Obviously, shifts in productivity due to changes in weather also affect storage. Thus, it is not possible to make any clear predictions on how differences in weather should affect collusion. Rainfall comes in negative and significant for the storage products. The two other weather variables are both non-significant. A one percent increase in rainfall (which for storage products amounts to 0.03 mm of an average of 3 mm rainfall) increases cartel breaks with close to 2%. The interaction term is positive and suggests that the combination of pretty weather and rain increases the likelihood of cartel breaks, but is non-significant. If we exclude the interaction term, rainfall is still significant with a marginal effect of -1.41% in our most preferred model (Table 4, model 1) for the storage products. We also impose joint tests for all three weather variables. In the three storage models, they are always jointly significant, whereas in the *all-products* models they are not jointly significant.[16] Again, the models in Appendix B predict similar results.

Business cycle

The variable used to capture changes in demand over the yearly cycle ($Season_{(t-1)}$) is significant and positive in all models. The marginal effect is small and very similar across models (0.0007). This suggests that cartel breaks marginally increase in the high demand periods. Note that since we include also monthly indicators (see results Table 7 and 8), the Season variable captures the marginal effect of the demand cycle. The result that cartels are more difficult to discipline in high demand periods is in line with Rotemberg and Saloner (1986), whose model predicts price wars during booms. This is also in line with Haltiwanger and Harrington (1991) predictions that show that a pricing cartel becomes less stable when current demand is strong (making secret price cuts more profitable). The models in Appendix B suggest the same effects as we observe from Tables 4 and 5.

Product controls and seasonal effects

The controls for packaging, product indicators and monthly dummies are presented in Tables 7 and 8. If we look closer at the monthly indicators, some are significant, in particular in the *all-products* models. Except for the first quarter, the pattern is similar over the year. There is a negative peak in June and July

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[16] A joint Chi-square test with three degrees of freedom is performed for all six models. For the Storage models we obtain 15.21 (model 1), 15.34 (Model 2) and 13.74 (Model 3) clearly rejecting the null hypothesis of no weather effects. For the models including all products we obtain 2.95 (model 1), 2.67 (Model 2) and 2.66 (Model 3), suggesting no weather effect across models.

Table 7. Margin estimates of logit models for cartel breaks, product, packaging and monthly dummies, storage products for the period 2000-2015

	(1)	(2)	(3)
Kg(i)	0.10494	0.10117	0.08996
	(0.07896)	(0.07817)	(0.05619)
Size(i)	1.84435***	1.84620***	1.96044***
	(0.08174)	(0.08243)	(0.07345)
Cabbage	0.26069**	0.27137**	0.24961**
	(0.11604)	(0.11446)	(0.10468)
Celeriac	0.12289	0.14715	0.19685
	(0.20308)	(0.19929)	(0.17954)
Onion	-1.63022***	-1.62934***	-1.75382***
	(0.13412)	(0.13395)	(0.11643)
Leeks	-0.25669	-0.22353	-0.05235
	(0.20673)	(0.20035)	(0.17243)
February	-0.00730	-0.00636	-0.02621
	(0.03256)	(0.03255)	(0.03066)
March	-0.15456***	-0.14895***	-0.14852***
	(0.03732)	(0.03639)	(0.03535)
April	-0.11079***	-0.10236***	-0.10656***
	(0.04036)	(0.03740)	(0.03596)
May	0.00109	0.01162	0.02491
	(0.05483)	(0.05178)	(0.04733)
June	-0.12972	-0.11793	-0.05917
	(0.08482)	(0.08276)	(0.07350)
July	-0.05346	-0.04404	-0.01024
	(0.06455)	(0.06278)	(0.04901)
August	-0.04536	(0.04528)	-0.04771
	(0.04948)	0.02040	(0.03838)
September	0.00874	(0.04112)	0.00164
	(0.04496)	(0.04432)	(0.03642)
October	0.00804	0.01703	0.02468
	(0.03855)	(0.03600)	(0.03313)
November	0.05264*	0.04972	0.02212
	(0.03158)	(0.03111)	(0.02958)
December	0.03756	0.03449	0.00405
	(0.03117)	(0.03099)	(0.02947)

Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

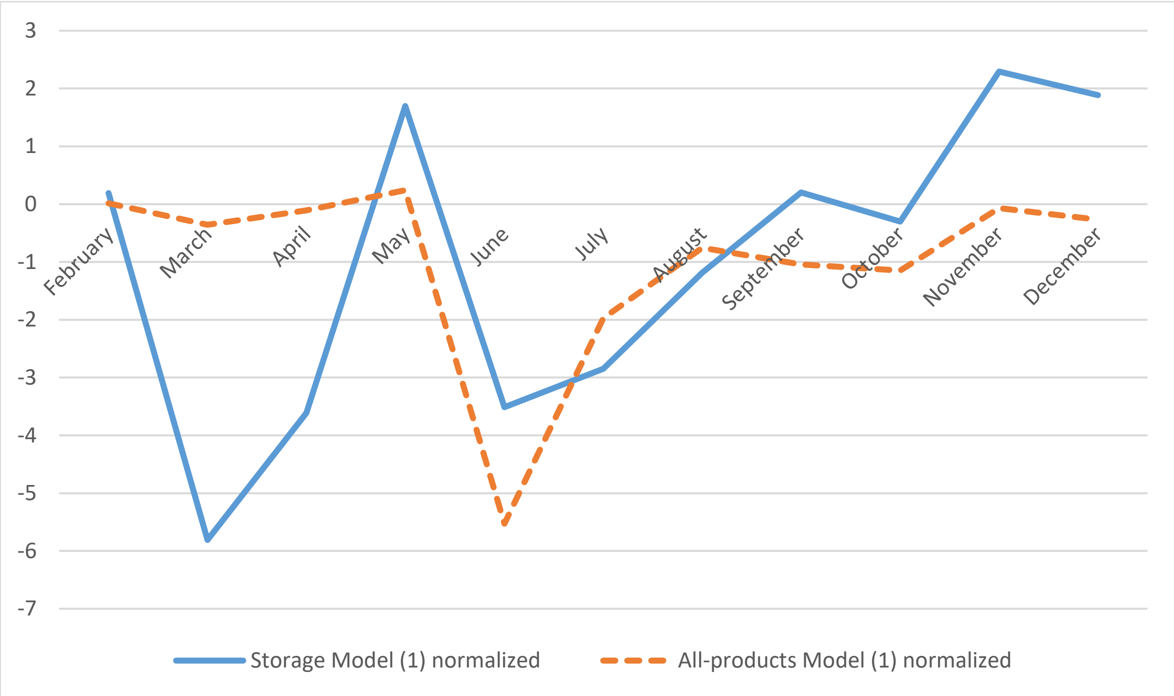
Table 8. Margin estimates of logit models for cartel breaks, product, packaging and monthly dummies, all products for the period 2000-2015

	(1)	(2)	(3)
Pieces(i)	1.6427	1.8704	1.8782
	(91.1214)	(174.5790)	(170.4882)
Kg(i)	0.0371	0.0443	0.0330
	(0.0534)	(0.0496)	(0.0403)
Size(i)	1.7048	1.8898	1.8942
	(82.8283)	(139.0739)	(139.3292)
Cucumber	-1.4134	-1.6242	-1.7242
	(91.1214)	(174.5790)	(170.4882)
Cauliflower	-1.2350	-1.4390	-1.5437
	(91.1214)	(174.5790)	(170.4882)
Iceberg green salad	-1.1524	-1.3593	-1.4521
	(91.1214)	(174.5790)	(170.4882)
Cabbage	0.2421***	0.2325***	0.2192***
	(0.0544)	(0.0539)	(0.0481)
Celeriac	0.2751***	0.2307***	0.2519***
	(0.0832)	(0.0821)	(0.0710)
Onion	-1.5353	-1.7172	-1.7410
	(82.8283)	(139.0739)	(139.3292)
Leeks	-0.0113	-0.0593	0.0414
	(0.0957)	(0.0949)	(0.0726)
February	0.0037	-0.0202	-0.0150
	(0.0275)	(0.0270)	(0.0265)
March	-0.1117***	-0.1359***	-0.1110***
	(0.0316)	(0.0315)	(0.0301)
April	-0.0695**	-0.0988***	-0.0722**
	(0.0328)	(0.0324)	(0.0301)
May	0.0326	0.0137	0.0407
	(0.0337)	(0.0333)	(0.0293)
June	-0.0675*	-0.0926**	-0.0370
	(0.0391)	(0.0390)	(0.0327)
July	-0.0548	-0.0740**	-0.0271
	(0.0361)	(0.0353)	(0.0300)
August	-0.0228	-0.0554*	-0.0243
	(0.0333)	(0.0329)	(0.0272)
September	0.0039	-0.0261	0.0018
	(0.0315)	(0.0312)	(0.0257)
October	-0.0058	-0.0178	0.0100
	(0.0293)	(0.0293)	(0.0245)
November	0.0441*	0.0291	0.0206
	(0.0266)	(0.0263)	(0.0254)
December	0.0363	0.0177	0.0082
	(0.0269)	(0.0266)	(0.0256)

Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

where cartel breaks are a lot less frequent, then a reduction towards the end of the year. We illustrate this for our two most preferred models (1) in Figure 4. We have normalized the set of indicators from Tables 7 and 8 to be able to compare across models. The pronounced difference is that during March and April (both indicators being significant), the storage product model predicts significant fewer cartel breaks. In this model cartel breaks are 4-6 less common than the average (=-1). The June effect is in the same magnitude, whereas during July we see half as many breakdowns as the average month. May and the fall has the highest numbers of breakdowns.

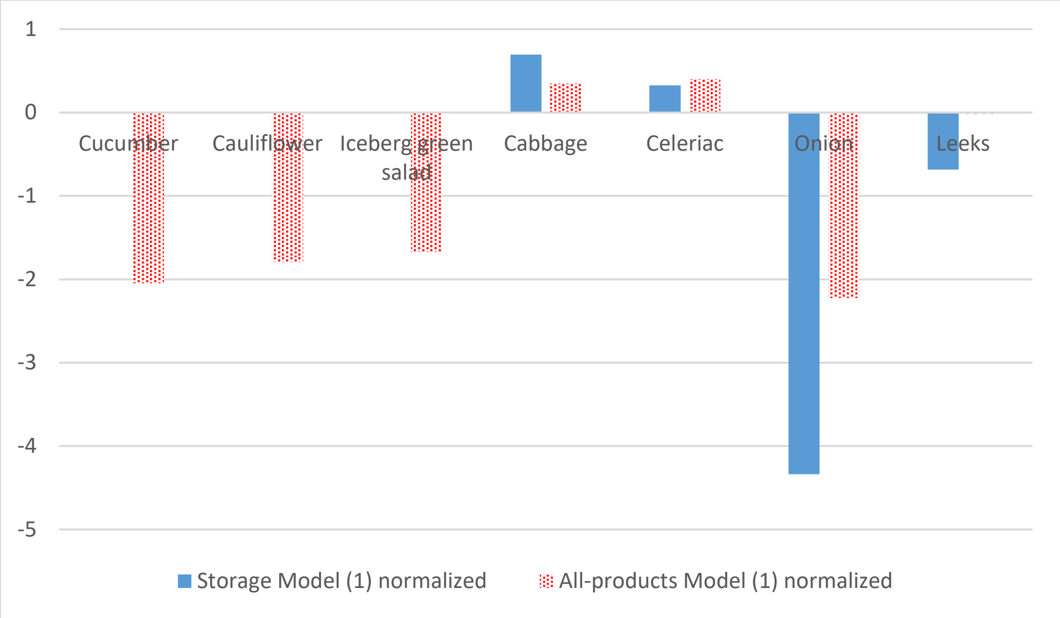
Figure 4. Normalized marginal effects for monthly indicators for our preferred models (1) from Table 7 and 8



Finally, we look at the product indicators. Here we have carrots as our reference category, implying that all the differences are compared to carrots. (Note that the indicator for tomatoes is thrown out due to collinearity.) Figure 5 illustrates the normalized product indicators.

We see that even after controlling for the product group effect for the storage products (*Has Storage*) the cartel breaks are less pronounced for the non-storage products. We do not find big differences within this group. None of these indicators turns out to be significant (see Table 8). Within the storage group cabbage, celeriac and onions obtain significant indicators. Whereas cabbage and celeriac have more cartel breaks than the average, onion has significantly (2-4 times) less cartel breaks. The models in Table B2 in Appendix B are quite similar, in particular for the product controls.

Figure 5. Normalized marginal for product indicators for our preferred models (1) from Table A1 and A2



Comparing this to the raw averages from Table 2, we see that when controlling for all other effects, the differences in cartel breaks across products change. There are no significant differences between the non-storage products, but in the raw data, cucumber had only 5% cartel breaks, whereas iceberg salad had as many as 30% over the 1999 to 2015 period. Looking at the storage products, numbers also change. Whereas leeks had the lowest average in the storage group (0.09) onions had the double (0.18). Even though both products are still among those with the lowest numbers of cartel breaks, controlling for all other factors the relationship between the two changes. Now onions have a much higher number than leeks. The result that celeriac and cabbage has more cartel breaks than carrots is in line with our raw averages; carrots (0.19), cabbage (0.29) and celeriac (0.22). In sum, this shows that the raw numbers can be misleading in terms of predicting differences on product level. Controlling for other exogenous factors determining the cartel's efficiency show a somewhat different picture across products.

7. Discussion and conclusions

We analyze the efficiency of a legal agricultural cartel in Norway; "The Green Growers' Cooperative Marked Council", which major means of collusion is information gathering and public announcement of weekly recommended cartel prices. The cartel is surprisingly efficient given that it is voluntary in the sense that local producers can choose to deviate from the recommended cartel price, and that there is no real sanctions in place. We find deviations only in between 12 and 20% of the weeks over 16 years of data. If some producers consistently deviate over time, the cartel management may contact them, but there are no further enforcement mechanisms in place.[17] As such, this cartel has similarities to the type of cartels discussed by Awaya and Krishna (2016), who study the role of cheap talk communication within a situation where firms may make secret price cuts and where firms cannot observe each other's prices or sales. They find that cheap talk may result in near-perfect collusion in a repeated pricing game with a prisoners' dilemma structure. Our cartel matches this description, and shows indeed to be quite efficient in its operation.

We estimate logit models that measure cartel breaks over time, controlling for exogenous variables that affect import competition (import prices, tariff reductions and predetermined target prices), storage variables, demand cycle variables and seasonality, weather variables and product related effects and time trends.

Interestingly enough, we find that after controlling for all these variables, the cartel improves over time in terms of cartel efficiency. This result can be explained by factors as a negative trend in number of members over time (which usually increase cartel discipline) and learning-by-doing effects. The result could however be due to the fact that the technology for information transfer has improved tremendously over the period from 2000 to 2015. The cartel we look at is mostly about information gathering and how information is given to producers, and the improved information technology is likely to have sustained more collusion.

In line with the theory on capacity utilization and collusion, we find clear evidence that storage (excess capacity) matters for cartel efficiency, see e.g., Osborne and Pitchik, 1987, Brander and Harris, 1984 and Davidson and Deneckere (1990). When storage is high, in particular unanticipated higher than the normal, the cartel is more efficient and less cartel breaks by the production members take place. The results shows that a one percent increase in unanticipated storage reduce cartel breakdowns with as much as 8%.

Another much discussed topic when it comes to collusion and cartel efficiency is to which extent demand changes affect the level of collusion. The analyzed industry does not experience traditional business cycle over time, but due to growth seasons and demand patterns, demand shifts with a predictable pattern over the year. We find clear evidence suggesting that cartel breakdowns are more frequent in high demand periods, a result that is in line with the predictions by Rotemberg and Saloner (1986) and Haltiwanger and Harrington (1991), whose models predicts price wars or more defection during booms. When demand increases by 10%, cartel breakdowns increase by nearly 1%.

The government and the industry negotiate target prices that also defines an upper price limit. When the market price exceeds the upper price limit for two consecutive weeks, the regulator will remove

[17] From interviews with the manager of GCC, we learned that he would invite himself for 'coffee' sometimes to explain the importance of being loyal to the recommended cartel price. He also told that he organized seminars where the producers were explained the prisoners' dilemma game to motivate the producers to cooperate.

tariff barriers. We find clear evidence that the higher this target price is, the more likely they are to sell below the cartel price. Due to the strong positive correlation between the market- and the target price, we attribute this result to increased import competition: The higher the target price, the more tempting imports become (for given import prices and tariffs) and the more likely the cartel members are to deviate from cartel prices. We find a corresponding less clear effect for the import prices, in the models where we find significant import-price effects, these are negative. This suggests that when these increases and foreign competition gets less likely, marginally less deviations takes place.

The cartel analyzed here is legal and politically accepted to protect Norwegian domestic agricultural production. This is also the case in many other countries. Hence, the usual welfare discussion is not relevant in this case. The cartel has however, the same challenges as any illegal cartel when it comes to achieving efficiency over time. By analyzing its functioning we can both learn about how cartels work, and understand and test how mostly theoretical predictions on factors as capacity utilization and demand changes affect collusion. Our findings seem to verify that such factors do indeed affect cartel efficiency. This means that our results have bearings for competition policy. For instance, the finding on storage seems to suggest that in industries with excess capacity one will anticipate more efficient collusion, than in industries without excess capacity. Likewise, we find that even self-polishing cartels without any formal contracts and ties can achieve collusion through sharing communication and signaling, suggesting skepticism for competition authorities towards more detailed information sharing systems.

References

Asmat, D., 2016, “Collusion Along the Learning Curve: Theory and Evidence from the Semi-conductor Industry”, manuscript: http://www.cresse.info/uploadfiles/2016_pa9_pa4.pdf , downloaded 28.02.2018.

Athey, S. C. and K. Bagwell, 2001, “Optimal Collusion with Private Information,” RAND Journal of Economics, Vol. 32, No. 3, pp. 428-465.

Awaya, Y. and V. Krishna, 2016, “On Communication and Collusion”, American Economic Review, 106(2), 285-315.

Benoit J.P. and V. Krishna, 1987, "Dynamic Duopoly: Prices and Quantities", Review of Economic Studies, 54, 23-35.

Brander H. and R. Harris, 1984, "Anticipated Collusion and Excess Capacity", mimeo, University of British Columbia.

Brock W. and J. Scheinkman, 1985, "Price-setting Supergames with Capacity Constraints," Review of Economic Studies, 52, 371-382.

Clark, R. and J-F. Houde, 2014, “The Effect of Explicit Communication on Pricing: Evidence from the Collapse of a Gasoline Cartel," Journal of Industrial Economics, Vol. 62, No. 2, pp. 191-227.

Cooper, D. and K-U. Kühn, 2014, “Communication, Renegotiation, and the Scope for Collusion,” American Economic Journal: Microeconomics, Vol. 6, No. 2, pp. 247-278.

Davidson and Deneckere, 1990, "Excess Capacity and Collusion", International Economic Review, 31(3), 521-541.

Dixit, A. 1980, "The Role of Investment in Entry Deterrence," Economic Journal, 90, 95-106.

Dick, Andrew R., 1996, “When are Cartels Stable Contracts?” Journal of Law and Economics, Vol. 39, No. 1 pp. 241-283.

Eaton, B.C. and R.G. Lipsey, 1981, "Capital, Commitment, and Entry Equilibrium," Bell Journal of Economics, 12, 593-604.

Ellison, G., 1994, “Theories of Cartel Stability and the Joint Executive Committee,” RAND Journal of Economics, Vol. 25, pp. 37-57

Eswaran, M. 1997, "Cartel Unity over the Business Cycle", Canadian Journal of Economics, 30(3), 644-672.

Fink N., P. Schmidt-Dengler, K. Stahl, and C. Zulehner, 2017, “Registered Cartels in Austria – Overview and Governance Structure”, European Journal of Law and Economics, July 2017

Fudenberg, D. and J. Tirole, 1983, "Capital as a Commitment: Strategic Investment in Continuous Time," Journal of Economic Theory, 31, 227-250.

Gelman, J.R. and S.C. Salop, 1983, "Judo Economics: Capacity Limitation and Coupon Competition," Bell Journal of Economics, 14, 315-325.

Genesove, D. and W.P. Mullin, 2001, "Rules, Communication, and Collusion: Narrative evidence from the sugar institute case," American Economic Review, 91(3), 379-398.

Green, E. J. and R.H. Porter, 1984, “Non cooperative Collusion under Imperfect Price Information,” Econometrica, 52, 87-100.

Haltiwanger, J. C. and J.E. Harrington, 1991, “The Impact of Cyclical Demand Movements on Collusive Behavior,” RAND Journal of Economics, 22, 89-106.

Harrington, J.E., 2006, “How do cartels operate?” Foundations and Trends in Microeconomics 2(1), 1-108.

Harrington, J E. and C. Myong-Hun, 2009, “Modelling the Birth and Death of Cartels with an Application to Evaluating Antitrust Policy”, Journal of the European Economic Association, 7(6), 1400-1435.

Hyytinen, A., F. Steen and O. Toivanen (2018) “Uncovering Cartels”, 2017, American Economic Journal Microeconomics, in press.

Hyytinen, A., F. Steen and O. Toivanen (2014) “The anatomy of cartel contracts”, DP, Aalto University - Department of Economics.

Jacquemin, A. T. Nambu and I. Dewez, 1981, “A Dynamic Analysis of Export Cartels: The Japanese Case”, https://econpapers.repec.org/article/ecjeconjl/, 91 (363), 685-96.

Jacquemin, A. and M. Slade, 1989, “Cartels, Collusion and Horizontal Mergers”, in Handbook of Industrial Organization Vol. 1, Richard Schmalensee (ed.), North-Holland.

Kreps, D.M. and J.A. Scheinkman, 1983, "Cournot Pre-commitment and Bertrand Competition Yields Cournot Outcomes," Bell Journal of Economics, 14, 326-337.

Levenstein, M.C. and V.Y. Suslow, 2006, “What Determines Cartel Success?” Journal of Economic Literature, Vol. XLIV, 43-95.

McCutcheon, B., 1997, "Do meetings in smoke filled rooms facilitate collusion?" Journal of Political Economy, 105(2), 330-50.

Mookherjee, D. and D. Ray, 1991, Collusive Market Structure Under Learning-By-Doing and Increasing Returns, The Review of Economic Studies, Volume 58, Issue 5, 1 October 1991, Pages 993–1009

Osborne, D. K. and C. Pitchik, 1987, "Cartels, Profits and Excess Capacity", International Economic Review, 28(2), 413-428.

Porter, R. H., 1983, “A Study of Cartel Stability: The Joint Executive Committee, 1880-1886,” Bell Jour-nal of Economics, 14, pp. 301-314

Rotemberg, J.J., and G. Saloner 1986, "A supergame-theoretic Model of Business Cycles and Price Wars During Booms" American Economic Review, 76, 390-407.

Röller, L-H. and S. Frode, 2006, “On the Workings of a Cartel: Evidence from the Norwegian Cement Industries,” American Economic Review, Vol. 96, pp. 321-338.

Spence, A.M. 1977, "Entry, Capacity, Investment and Oligopolistic Pricing," Bell Journal of Economics, 8, 534-544.

Suslow, V.Y., 2005, “Cartel Contract Duration: Empirical Evidence from Inter-War International Cartels”, Industrial and Corporate Change, 14(5), 705-44.

Appendixes

Appendix A - Storage predictions

Figure A1: Development in actual and predicted storage volumes for cabbage the period 1995 to 2005

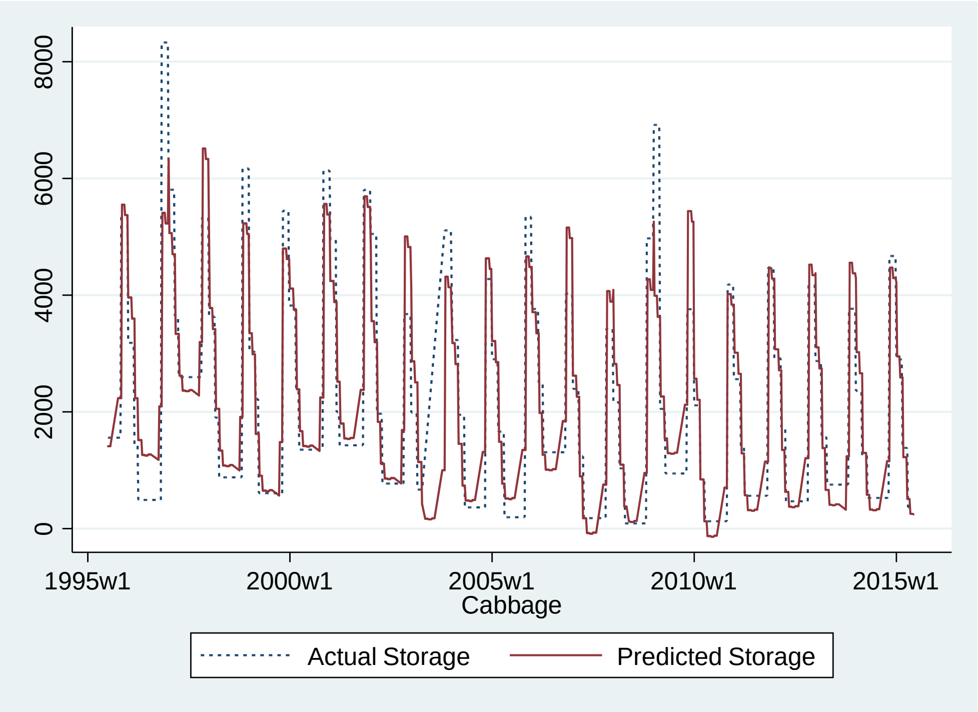


Figure A2: Development in actual and predicted storage volumes for celleriac the period 2006 to 2005

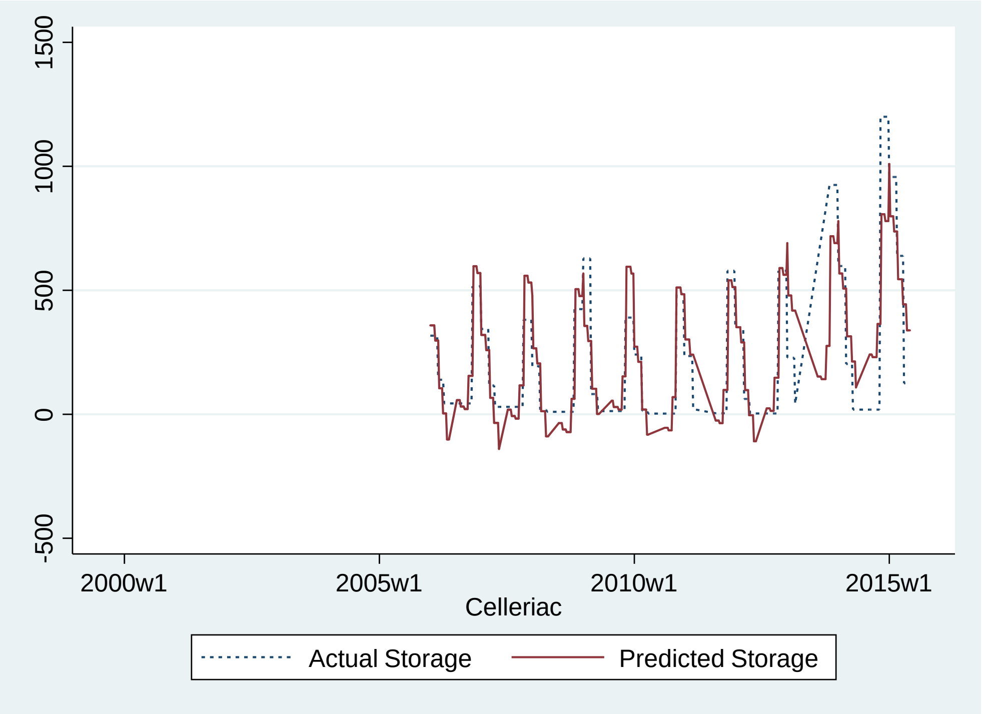


Figure A3: Development in actual and predicted storage volumes for onions the period 1995 to 2005

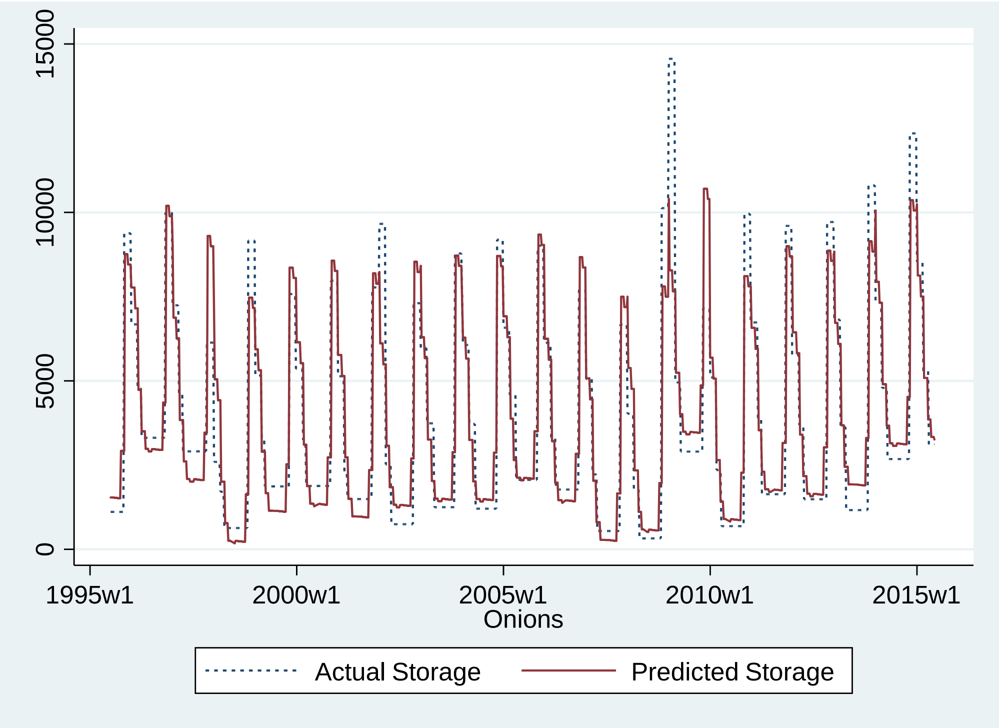
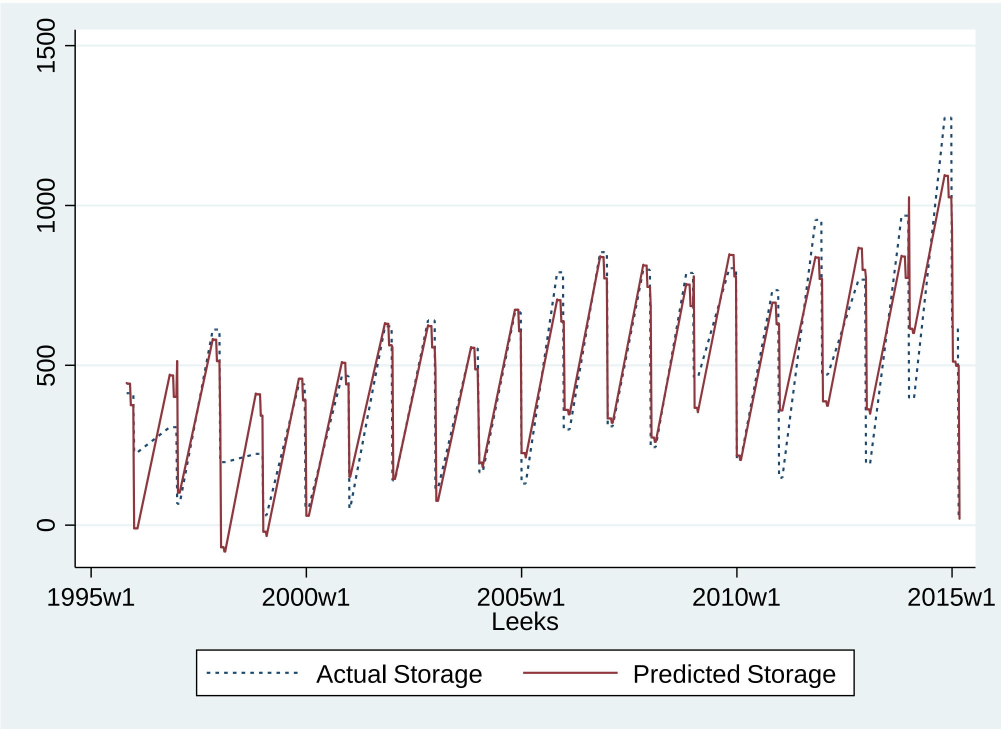


Figure A4: Development in actual and predicted storage volumes for leeks the period 1995 to 2005



Appendix B: Cartel break models without price differences

Table B1 Margin estimates of logit carte break models for storage-, and all-products, major parameters for the period 2000-2015

	Storage- Excluded price differences	All products Excluded price differences
$Pimp_{(i,t-1)}$	-0.00004* (0.0000)	9.54e-06 (0.00002)
$Ptp_{(i,t)}$	0.00031*** (0.0001)	0.0002*** (0.00005)
Has Storage$_{(i)}$		0.3686*** (0.0748)
Storage+5%$_{(i,t-1)}$	-0.0858*** (0.0169)	-0.0760*** (0.0152)
$Storage_{(i,t-1)}$	-9.61e-07 (2.88e-06)	-1.89e-06 (2.58e-06)
$Trend_{(t)}$	-0.00006*** (6.20e-06)	-0.00004*** (4.16e-06)
$PrWxRainfall_{(i,t)}$	0.0577 (0.0388)	0.0252 (0.0271)
$Rainfall_{(i,t)}$	-0.0179*** (0.0053)	-0.0051 (0.0037)
$PrW_{(i,t)}$	-0.0582 (0.0823)	-0.0238 (0.0627)
$Tariffchange_{(i,t)}$	0.0044 (0.0254)	0.0037 (0.0189)
$Season_{(t-1)}$	0.0008* (0.0004)	0.0009*** (0.0002)
N	2721	4180
Pseudo R2	0.0934	0.1130
Product, packaging and monthly dummies	Yes	yes

Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

To test for exclusion of the weather variables we also here impose a joint Chi-square test with three degrees of freedom for both models. For the Storage models we obtain 15.34 clearly rejecting the null hypothesis of no weather effects. For the models including all products we obtain 2.65, suggesting no weather effect across models.

Table B2 Margin estimates of logit cartel break models, storage-, and all-products, product, packaging and monthly dummies, for the period 2000-2015

	Storage-Excluded price differences	All products Excluded price differences
Pieces$_{(i)}$		2.0280
		(165.25)
Kg$_{(i)}$	0.1397*	0.0666
	(0.0813)	(0.0540)
Size$_{(i)}$	2.0273***	1.9074
	(0.0871)	(155.12)
Cucumber		-1.7349
		(165.25)
Iceberg green salad		-1.4637
		(165.25)
Cauliflower		-1.5371
		(165.25)
Cabbage	0.3101***	0.3194***
	(0.1177)	(0.0535)
Celeriac	0.1454	0.3313***
	(0.2069)	(0.0822)
Onion	-1.7515***	-1.6589
	(0.1370)	(155.12)
Leeks	-0.2423	0.0255
	(0.2106)	(0.0946)
February	-0.0107	-0.0004
	(0.0327)	(0.0276)
March	-0.1570***	-0.1149***
	(0.0376)	(0.0319)
April	-0.1035**	-0.0611*
	(0.0407)	(0.0331)
May	0.0141	0.0534
	(0.0558)	(0.0338)
June	-0.1437	-0.0427
	(0.0898)	(0.0382)
July	-0.0310	-0.0344
	(0.0640)	(0.0358)
August	-0.0307	-0.0235
	(0.0473)	(0.0333)
September	0.0239	0.0022
	(0.0440)	(0.0316)
October	0.0159	-0.0054
	(0.0385)	(0.0293)
November	0.0467	0.0387
	(0.0317)	(0.0267)
December	0.0344	0.0324
	(0.0313)	(0.0271)

Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix C - Descriptive statistics

Table C1 Descriptive statistics for variables used in the econometric analysis for the period 1999-2015

	All products					**Storage products**				
Variabel	*N*	*Mean*	*Std.Dev*	*Min*	*Max*	*N*	*Mean*	*Std.Dev*	*Min*	*Max*
Cartel break	4835	0.17	0.38	0	1	3242	0.20	0.40	0	1
Pimp	4666	1054.18	534.94	198.7	3185.8	3144	851.23	447.30	198.7	3037.6
(Pplcl-Pimp)	4666	-105.92	697.93	-2455.1	1658.1	3144	46.30	700.29	-2145.3	1658.1
(Pplcl-Pmarket)	4835	20.54	157.65	-1429.5	1277.3	3242	0.53	147.07	-1429.5	1277.3
Pplcl	4835	950.35	528.99	231.8	2576.7	3242	905.53	538.09	231.8	2576.7
Pcartel	4835	943.03	511.63	162.4	4028.7	3242	916.80	518.90	240.0	4028.7
Pmarket	4835	929.81	501.52	240.1	3148.6	3242	905.00	507.97	240.1	3148.6
Has storage	4835	0.67	0.47	0	1					
Storage	4483	2595.72	4587.27	0	30247	2890	4026.50	5184.89	3	30247
Storage5%	4483	0.26	0.44	0	1	2890	0.41	0.49	0	1
Trend (stata)	4835	17295.16	1707.68	14248	20247	3242	17306.31	1713.35	14248	20240
Rainfall	4835	3.18	2.43	0.00	18.25	3242	2.95	2.23	0.01	14.66
Pretty weather	4835	0.15	0.13	0.00	0.88	3242	0.15	0.13	0.00	0.84
Tariff change	4835	0.10	0.30	0	1	3242	0.13	0.33	0	1
Season	4835	253.71	151.33	-143.2	543.9	3242	214.06	167.26	-143.2	543.9
Pieces	4835	0.25	0.43	0	1	3242	0.00	0.02	0	1
Kg	4835	0.57	0.50	0	1	3242	0.73	0.44	0	1
Size	4835	0.15	0.35	0	1	3242	0.22	0.41	0	1

Table C2 Descriptive statistics for variables used in the econometric analysis for the period 1999-2015

	All products					**Storage products**				
Variabel	*N*	*Mean*	*Std.Dev*	*Min*	*Max*	*N*	*Mean*	*Std.Dev*	*Min*	*Max*
Cucumber	4835	0.11	0.32	0	1					
Cauliflower	4835	0.06	0.25	0	1					
Iceberg Salad	4835	0.07	0.26	0	1					
Tomato	4835	0.08	0.27	0	1					
Carrot	4835	0.16	0.37	0	1	3242	0.24	0.43	0	1
Cabbage	4835	0.13	0.34	0	1	3242	0.20	0.40	0	1
Celeriac	4835	0.12	0.33	0	1	3242	0.18	0.39	0	1
Onin	4835	0.15	0.36	0	1	3242	0.23	0.42	0	1
Leeks	4835	0.10	0.30	0	1	3242	0.15	0.36	0	1
January	4835	0.07	0.26	0	1	3242	0.11	0.31	0	1
February	4835	0.06	0.24	0	1	3242	0.09	0.29	0	1
March	4835	0.07	0.25	0	1	3242	0.09	0.28	0	1
April	4835	0.06	0.24	0	1	3242	0.07	0.26	0	1
May	4835	0.08	0.27	0	1	3242	0.07	0.25	0	1
June	4835	0.08	0.27	0	1	3242	0.04	0.19	0	1
July	4835	0.09	0.29	0	1	3242	0.05	0.21	0	1
August	4835	0.11	0.31	0	1	3242	0.08	0.27	0	1
September	4835	0.11	0.32	0	1	3242	0.09	0.28	0	1
October	4835	0.11	0.32	0	1	3242	0.11	0.31	0	1
November	4835	0.07	0.26	0	1	3242	0.10	0.31	0	1
December	4835	0.07	0.26	0	1	3242	0.11	0.31	0	1