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Peer-reviewed & Open access journal
ISSN: 1804-1205 | www.pieb.cz
BEH - Business and Economic Horizons
Volume 4 | Issue 1 | January 2011 | pp. 88-107

Polish cement industry cartel - preliminary examination of collusion existence

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The paper is devoted to a case of a cartel in Polish cement industry. Short description of the industry and characteristics of the cartel with its fundamental illegal practices, market sharing and price fixing have been done. We focused on examination of possibility of detection of a cartel-like behavior of players in an industry on a basis of cartel markers' evaluation, using statistical data we can actually obtain. On a basis of examination of market shares of players and price/supply processes we found distinctive, theoretically motivated patterns characteristic for collusive equilibrium in an industry.

JEL Classifications: L13; L41; L60

Keywords: Cartel detection, collusion markers, industry studies, cement market.

Introduction

On 10th of December 2009 the Polish Office of Competition and Consumer Protection (OCCP) announced in press release the existence of a cartel in Polish cement industry[1]. This statement was a consequence of three-year investigation. The President of the OCCP noted that 7 companies were engaged in the market sharing and price fixing practices in 1998-2009 period. Fines amounting to PLN 411 million (approximately EUR 100 million) have been imposed on the members of cartel[2]. The central evidence against the cartel was information furnished by the two cartel members which had decided to participate in the leniency program. In a body of the OCCP President's Decision functioning of cartel is described in many details; so that is one of those rare cases when researchers find out that collusion in the industry was a fact. Such a situation gives us a chance to examine of functioning of a cartel and to answer to many important questions dealing with behavior of the players. The first question we would like to answer in current paper refers to possibility to detect a cartel-like behavior of players on a basis of various cartel markers' evaluation (ex post examination) using statistical data we can actually obtain.

An answer to above question seems to be useful from theoretical and empirical point of view. Taking into account the fact how harmful collusion is, it seems natural that it should be quickly and properly detected. At first, every case of a prosecuted cartel, especially with testimonies of some cartel members, makes possible an empirical verification of the various theoretical methods of cartel detection. At second, a study of a cartelized industry may be compared with the researches of the same industry in different countries, looking for similarities in players' behavior. And at last, but not least there is a very important question for competition policy: how effective, and in consequence how harmful, a cartel really was. If there are strong evidences of abusing the law (document, data files, testimonies of the members of a cartel), does it really mean that those prohibited practices led to creation of substantial market power and impediment of the industry development?

In the present paper we would like to do preliminary research of polish cement cartel in periods of 1998-2006 and 2000-2008 (availability of data had determined the length of a sample). Our first objective is to answer to above stated question using methods which are called markers of collusion (Harrington, 2005, p.25), specific patterns in economic

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[1] See press release of Spokesperson for the OCCP from 10.12.2009.

[2] See Decision of the President of the Office of Competition and Consumer Protection number Dok -7/2009, Warsaw, Republic of Poland, further: Decision 7/2009.

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processes that distinguish collusion from competition. Such patterns should be theoretically motivated by a profile of equilibrium strategies and/or payoffs of properly constructed games. In section A we characterize the methods used and review related literature. In section B short description of a Polish cement industry and the data is presented. Section C contains an empirical analysis. Last section concludes an article.

Section A - Methodology and related literature

In our research we want to use specific patterns, which concern:

- the relation between players' prices and market demand changes (Green and Porter, 1984; Rotemberg and Saloner, 1986; Haltiwanger and Harrington, 1991; Bejger, 2010);
- market shares volatility (Albeak et al., 1997; Athey, Bagwell, and Sanchirico, 2004; Athey and Bagwell, 2004; Bejger, 2010).

According to above mentioned researches in collusion (cartel) phase player's price and market supply are negatively correlated; it becomes possible that price leads a demand cycle or is insensible (sticky) to seasonal changes of demand. Theoretical motivations of those conclusions are based on standard supergame models. In a case of market shares theoretical basis is more unclear. Some conclusions are contained in Albeak et al. (1997), Harrington (2006); analysis of particular case have been done in Bejger (2010).

TABLE 1.RECENT PROSECUTIONS OF A CEMENT INDUSTRY IN VARIOUS COUNTRIES

Year	Country / firms / type of illegal behavior
1994	EUROPEAN UNION; EUROPEAN CEMENT ASSOCIATION (CEMBUREAU),8 NATIONAL CEMENT ASSOCIATIONS, 33 EUROPEAN CEMENT PRODUCERS; CARTEL
1998	DENMARK; AALBORG PRTLAND A/S; ABUSE OF DOMINAT POSITION
2002	GERMANY; ALL OF THE MAIN PLAYERS IN THE INDUSTRY; CARTEL
2005	AGENTINA; FIVE COMPANIES; CARTEL
2005	ROMANIA; THREE COMPANIES; CARTEL
2005	TAIWAN; ALL OF THE MAIN PLAYERS IN THE INDUSTRY; CARTEL
2006	TURKEY; TWO COMPANIES; PRICE INFORMATION SHARING
2007	FRANCE; TWO COMPANIES; LIMITING THE SUPPLY
2007	EGYPT; ALL OF THE MAIN PLAYERS IN THE INDUSTRY; CARTEL
2008	INDIA; ALL OF THE MAIN PLAYERS IN THE INDUSTRY; CARTEL
2009	POLAND; ALL OF THE MAIN PLAYERS IN THE INDUSTRY; CARTEL
2009	PAKISTAN; ALL OF THE MAIN PLAYERS IN THE INDUSTRY; CARTEL

Source: National competition authorities web sites, global competition review web site, UN (2005).

Generally speaking, in a cartel phase market shares should exhibit very small volatility and are more stable under collusion phase. This is especially true when players do not use sophisticated methods of market sharing, using instead of these very simple "historical precedence" rule. As Harrington (2006) observed on an example of a few hard core cartels[1], members of a cartel can agree to use market shares they enjoyed at the moment of initiating of a cartel (or to use some historical scheme they all agree to) and maintain these cartel quotas throughout the conspiracy period. It is perfectly true characteristic in a case of a cartel in Polish cement industry[2]. To summarize methodological side of our research, we focused on testing of market shares' volatility and a behavior of a market price in connections with supply (demand).

The grey cement industry is a frequent subject of empirical studies connected with market power assessment and/or collusion detection. It is not a surprise because the cement industry in various countries is a synonym of oligopoly with huge tendency to

[1] de Roos (2004) noticed the same on a basis of Lysine cartel example.

[2] See Decision 7/2009, pp.28-29.

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uncompetitive behavior. There are at least twelve recent cases where some market players were found guilty of abuse of competition law. Table 1 lists those cases.

Such "ability" to uncompetitive behavior causes interest of economists (and competition authorities). There are few papers which analyze cement industry from a point of view of market power abusing and/or cartel detection. We can point to most representative works, namely: Allen, 1993 ; Jans and Rosenbaum , 1996; Kleit and Palsson, 1996; Steen and Sørgard, 1999; Rosenbaum and Sukharomana, 2001; LaCour and Møllgaard, 2002; Röller and Steen, 2006; Lorenz, 2008; O'Farrell and de Pino, 2009; von Blanckenburg and Geist, 2009; Zeidan and Resende, 2009. One of the most comparable in different aspects to our work is the paper of Rosenbaum and Sukharomana (2001) that tested Haltiwanger and Harrington (1991) price hypothesis. Authors found evidences that collusive prices are influenced by deterministic demand cycles. Röller and Steen (2006) using a unique institutional set-up in the Norwegian cement industry (legal cartel, approved by government) have studied the working of cartel in detail. They found cartel to be inefficient by using "production" sharing rule, which creates an incentive to overinvest. Consumers were better off in that scheme. Zeidan and Resende (2009) used so called CPM method of Bresnahan and Lau (1982); they estimated dynamic version of CPM model applied to regional cement markets. They found significant evidences of market power in most of the markets. The works of von Blanckenburg and Geist (2009) and Lorenz (2008) used so called CFD method to verify hypothesis of cartel existence in German cement market. In both papers authors detected strong evidences of cartel behaviour.

Section B - The cement industry in Poland and a cartel description

When we talk about cement we usually think about gray (sometimes called Portland) cement, which dominates world production and consumption. All over the world, cement is one of the most important building materials. World cement production in 2008 was about 2800 Mt, where majority was grey cement.

The grey cement production's technology is very mature and unified all over the world. There had been no important technological changes except transfer to dray process of production (described below). The most important raw materials for making cement are limestone, clay and marl. The raw materials are crushed in crushing installations. The desired raw mix of crushed raw material and the additional components required for the type of cement, e.g. silica sand and iron ore, is prepared using metering devices. In a dry method of production roller grinding mills or ball mills grind the mixture to a fine powder at the same time as drying it by gases from kiln installation. In a wet method ball mills grind the mixture, which consists about 32% - 38% of water before burning. Then the burning of the raw meal at approximately 1450°C is carried out in kilns (kiln is a great rotating cylinder, few meters in diameter and even 200 meters of length in wet method). By chemical conversion, a process known as sintering, a new product is formed: clinker. The dry process (especially with preheater) is far more energy efficient, heat consumption is about 3140 -3780 kJ/kg of clinker (in a wet method heat consumption is about 5230 - 5660 kJ/kg of clinker). After burning, the clinker is cooled down and stored in clinker silos. From there the clinker is conveyed to ball mills or roller presses, in which it is ground down to very fine cement, with the addition of gypsum and anhydrite, as well as other additives, depending on the use to which the cement is to be put. Despite of various types of grey cement[1] there is common material, clinker, which must be used in

[1] European norm EN 197 -1 divides cements into two groups: traditional construction cements, based on mixing cement clinker with additives, and special cements (white cement or clay cement) which have very special applications. Polish construction norm PN - EN 197-1:2002 describes five main types of traditional construction cements: CEM I, CEM II, CEM III, CEM IV, CEM V. For more information see: Polish Cement (2005).

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production of every kind of cement[1]. Because of that we can treat grey cement as homogenous producer good. Most of cement production is used in production of concrete, some amount is used as raw material (mostly in road construction, stabilization of ground), so there are no close substitutes of it.

Polish cement industry

The development[2] of the cement industry in Poland started in 1884. In that year the "Wysoka" cement plant in Łazy started production. Next plants were built, reached 15 plants in total, including 10 in the annexed Russian territory. During World War I the cement industry in the area of the former Russian rule was severely destroyed but other cement plants were not affected by the war.

After independence regaining in 1918 the capacity of the cement industry in Poland started to grow. Following a short slump in sales in 1924 there was an acceleration of growth, so that production and sales exceeded one million tons. The big world economic crisis caused a drop in cement sales to a very low level, about 400 000 tons in 1932. As of that year, cement consumption and production in Poland grew systematically reaching nearly 2 million tons just one year before the outbreak of World War II. The capacity in 1939 was 1.98 million tons. After the war cement production grew fast and in 1948 it exceeded the year 1939 level reaching 1.8 million tons. Industry output exceeded 3.8 million tons in 1955. The most dynamic development of the cement industry was in the decade 1965-1975, when production increased from 8 to 16 million tons. The cement industry reached its highest output in 1979, at the level of nearly 23 million tons. The crisis of socialist system countries after 1980 seriously affected the cement industry. The demand for cement in 1981 fell down to 14 million tons, and in the following years it was in the range of 15-16 million tons. At the same time organizational changes in the industry were performed: the liquidation of the Federation in 1981, establishment of the obligatory Association of Cement Producers in 1982 and then the voluntary Association of Construction Materials Producers in 1987, which gathered all cement plants. In 1990 important event took place: the Polish Cement Association (PCA further in text) was established. In 1993 PCA joined the CEMBUREAU - the European Cement Association.

After 1991 Polish economy was transformed to free market economy, mostly by privatization of many industries. The privatization process of the cement industry started in 1992 with the purchase of two plants: "Górażdże" and "Strzelce Opolskie" by the Belgian company CBR. In the beginning of privatization there were 26 productions plants, after consolidation and restructure 13 plants left. The structure of Polish cement industry in 2009 is given in Table 2.

Till 2009, all cement plants operating in Poland have been practically completely modernized. About 90% of clinker production's capacity has been rebuilt, replacing the old installations. During the modernization, the newest technological innovations were applied at all installations. Polish cement plants operate 15 modern dry process kilns and 6 using the wet process. The share of the wet method in cement production in 2009 was approximately 3.4%. The production capacity of dry methods' kiln in the cement industry is approximately 14.7 million tons of cement clinker per year, potential production capacity of the existing wet methods' kilns is about 0.9 million tons per year. It totals to industry capacity of 15.6 million tons of clinker or approximately 21 million tons of cement. In 2009, the average value of the heat consumption index on clinker burning amounted to 3.692 kJ/kg of clinker.

[1] Cements contain from 100% (Portland cement, CEM I) to 5% (foundry cement, CEM III/C) of clinker in mixture.

[2] Content of this subsection is based mostly on information and data from: Polish Cement Association (2007) and Polish Cement Association's cement industry year summary, various years.

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TABLE 2. OWNERS OF POLISH CEMENT PLANTS

Plant	Cement company/Owner
GÓRAŻDŻE CEMENT S.A.. - CEMENTOWNIA GÓRAŻDŻE - EKOCEM SP. Z O.O.	HEILDERBERG CEMENT
LAFARGE CEMENT S.A. - ZAKŁAD KUJAWY - ZAKŁAD MAŁOGOSZCZ	LAFARGE
GRUPA OŻARÓW S.A. - GRUPA OŻARÓW - ZAKŁAD REJOWIEC	CEMENT ROADSTONE HOLDING
CEMEX POLSKA SP. Z O.O. - ZAKŁAD CHEŁM - ZAKŁAD RUDNIKI	CEMEX
CEMENTOWNIA NOWINY	DYCKERHOFF
CEMENTOWNIA WARTA S.A.	POLEN CEMENT
CEMENTOWNIA ODRA S.A	MIEBACH
CEMENTOWNIA NOWA HUTA S.A.	RUMELI
GÓRKA CEMENT SP. Z O.O.	MAPEI

Source: Polish Cement Association, Cement industry summary 2010.

TABLE 3. RESULTS OF CEMENT SECTOR IN POLAND in 2006-2009 (kilotons)

Year	Clinker production	Cement production	Domestic deliveries	Cement consumption	Cement export	Clinker export
2006	11 163.10	14 630.90	14 409.20	14 522	417.1	676.6
2007	13 109.40	16 796.70	16 691.40	16800	305.6	181.7
2008	12 380.20	16 973.50	16 861.10	17120	370.1	177.4
2009	10 650.80	15 197.30	15 096.70	15500	423.4	143.9

Source: : Polish Cement Association, Cement industry summary 2010.

Table 3 shows basic characteristics of production and consumption in recent years.

As we can notice, recent cement production was well below estimated capacity. Export states about two percent of production and has no important influence on producer supply. Import of cement has no important impact on market situation, either. Structure of total production by types of cement was as follow (data from 2009): CEM I - 33.26%; CEM II - 57.84%; CEM III - 8.81%; CEM IV - 0.01%; CEM V - 0.04%; others - 0.07%. As we can notice majority of production are the most common Portland cements, CEM I and CEM II. Important feature of a market is structure of demand for bagged and bulk cement. Evolution of this structure was from 55.5% share of bulk cement in 1998 to 73.6% share of bulk cement in 2009. We thus can observe, typical for growing economy, substitution of bagged cement by bulk one. This is due to growing investments (the investment rate, investment to GDP ratio, increased from 18.1% in 2004 to over 22% in 2007) and as a consequence rising share of professional, industrial concrete producers in the construction market. Important role in this tendency play road investments.

To identify main players in a grey cement industry we have to add some comments to Table 2. At first Cementownia Nowa Huta is in liquidation process and their market share always have been marginal (It produced CEM V type cement, which has marginal share in national consumption). At second, Górka Cement is a producer of special cements, not commonly used in construction. At third, German company Polen Zement Beteiligungsgesellschaft mbH is an owner of Cementownia Warta S.A. (99.84% of Warta's shares). Another German Company, Miebach Projektgesellschaft mbH, is an owner of

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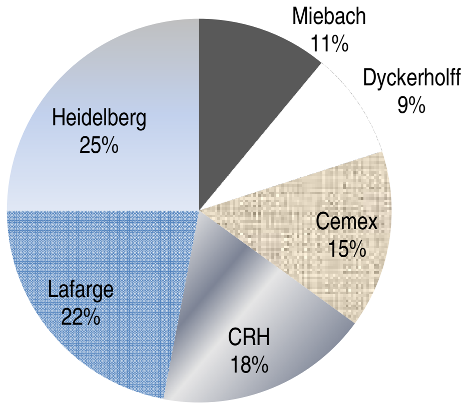
Cementownia Odra S.A. (99.94% of Odra's shares). An owner of 33.33% of shares of Polen Zement Beteiligungsgesellschaft mbH and 51% of shares of Miebach Projektgesellschaft mbH is Mrs. Jutta Miebach. Mrs. Miebach is only member of Board of Directors of Warta and Odra and she holds real strategic control on these companies[1]. For these reasons we can treat Warta and Odra together as plants with the same owner.

FIGURE 1. CEMENT COMPANIES' MARKET SHARES IN DOMESTIC MARKET IN 2008



Source: Polish Cement Association, Cement industry summary 2010.

To summarize, Polish cement industry in the year of cartel detection (cited data mostly encompass years 2009 or 2008) was technologically modern oligopolistic industry, producing below capacity, mostly for domestic market. We have to finally add that all main players in an industry are members of PCA. It is very significant (and typical for such an industry in various countries or even in international scale, see CEMBUREAU) that players organize themselves in that type of associations.

The Cartel - short description of functionality

While detailed description of history and functionality of the cartel contains Decision 7/2009 and some aspects of cartel story are very interesting (forthcoming papers will be devoted to them), we describe some of the most important factors of cartelists' activity at present.

On the 28th of December 2006 the President of the Office instituted antimonopoly proceedings and examined alleged anticompetitive agreement concluded by the producers of grey cement - Lafarge Cement, Górażdże Cement (Heidelberg), Grupa Ożarów (CRH), Cemex, Dyckerhoff, Cementownia Warta and Cementownia Odra (Miebach) - the combined market share of which amounted to almost 100 percent (Figure 1). As a result of the 3-year long investigation, robust evidence had been collected, which was subsequently completed by the information furnished by the undertakings involved in the agreement. Two leniency applications were filed in the case, one from Lafarge Cement and second from Górażdże (CRH).

On the basis of collected evidences and information from two former cartel members, the President of the Office concluded in his Decision 7/2009 that at least from 1998 the players were sharing the national market for grey cement, when agreeing on freezing the market shares of each company, as well as fixing minimum prices of the cement, the timetables, the amounts and the order of applying the increases in prices for cement. The

[1] We can add, that in 2009 the same four persons were members of Supervisory Boards of these companies.

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detected cartel practices violate both national competition law and European law (article 81 Treaty of Rome). The investigation showed that the cartelists did realize that the practices they were engaged in were illegal. Remaining cartelists - Grupa Ożarów, Cemex, Dyckerhoff, Cementownia Warta and Cementownia Odra - were fined with the maximum penalties possible, totaling to PLN 411 586 477. This is the highest fine ever imposed in the 20 years history of the OCCP.

The most important collusive practices from a point of view of this research were market sharing and price fixing, and we will focus on them further.

Illegal agreements among gray cement's producers took place at least from 1998. Above mentioned producers called themselves as "the club" or "group7" [1]. When privatization process of Polish cement sector had finished, main players focused on stabilizing market shares in the industry, and hence to eliminate competition. This kind of activity is dated from 1998 either. All of the producers agreed that the base for market sharing should be "historical" market shares (from years before privatization)[2]. This structure evolved slightly (mostly because of takeover of Ekocem plant by Lafarge) and stabilized itself about 2003. From evidences collected in Lafarge (mostly computer files) the local structure is known (Table 4). If we compare Table 4 and Figure 1, the similarity is obvious.

TABLE 4. LOCAL MARKET SHARES OF CEMENT PRODUCER
(status for year 2003)

Company	Share
HEIDELBERG	26.42%
LAFARGE	21.49%
CRH	18.13%
CEMEX	14.5%
DYCKERHOFF	8.88%
MIEBACH	10.58%
TOTAL	100%

Source: Decision 7/2009, p.32, Table 8.

This market structure was a nominal one. During cartel activity there were several changes in that structure but players informed themselves about higher shares they had reached in particular year. For such a case a system of next year compensations was created. Confidential market information was exchanged in many ways, the most important were direct contacts between players and reports for third parties - PCA and after 2002 for private Law Office "Optimas" (which had an agreement with PCA). Nevertheless, there was an important case of false information sharing. In 2001-2005 period Cemex reached substantially larger market share than "historical" one and that reported to other players or PCA/"Opitmas". In connection with that we use in present paper real (except one case noticed in text), reported to President of OCCP during investigation, market shares.

Price fixing took place at least 1998 and can be divided into two periods: years 1998-2000 and after. System of price fixing was created on a meeting of main players, which took place at the end of 1998 near city Kielce[3]. The first period's system was a system of minimum district prices[4]. It functioned as follow: Territory of Poland was divided into three regions (west, central and east), each region had a representative cement plant (Górażdże, Małogoszcz, Ożarów or Chełm accordingly). Criterion of inclusion of

[1] See: Decision 7/2009, p.22.

[2] See: Decision 7/2009, p.28.

[3] See: Decision 7/2009, p.44.

[4] Territory of Poland is divided into 379 administrative districts, district is a medium- level administrative unit, smaller than province and bigger than commune.

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particular district to region was distance from representative plants - the shortest distance determined the plant and the region. At first, for the representative plants price of cement[1] CEM I 32.5 R bulk was fixed at the same level (in Polish złoty, PLN per ton). Next, to this value transportation cost from regional plant to particular district in region was added. That sum determined a minimum district price. As a consequence, every market player should use district price as a base price for that district and correct it of their own transportation's cost to the district. The prices of other types o cement were fixed on basis of correction of price of CEM I 32.5 R bulk. The values of corrections (in PLN per ton) were agreed among cartelists, and were add to or subtract of base price. Those values were the same for all players. For example, in 2004 price of CEM I 52.5 bulk was a base price (in a particular district) plus 26 PLN and price of CEM III 32.5 bulk was base price minus 29 PLN[2]. The most important factor for this paper is that the same mechanism regulated price of a bagged cement. New (higher than previous) minimum district prices were usually introduced in a first quarter of each year, after consultations in "the club". Subjects of those consultations were value of increase of base price and an order of introducing new price list by players (exact date of increase of prices was different among players).

After year 2000 system of district prices collapsed. Instead of it in a new mechanism of price fixing producers established one, common for whole country, value of increase in price of CEM I 32.5 R bulk (given in percentage). Prices of other types of cement were created in a way described above. Subjects of consultations remained percentage value of increase of base price and an order of introducing new price list by players (usually all of companies increased prices in a period of one month)[3].

Summarizing cartel activity in a part devoted to market shares' and prices' fixing, described mechanisms (which existence was confirmed by evidences and explanations of two cartel members) seem to be uncompetitive and should create characteristic patterns of a kind we list in a section A.

The empirical analysis

Market shares

We decided to use annual data from period 1998-2006. This is determined by availability of unique information about market shares and quantities sold by cartel members. We use true data (corrected by Cemex management) which has been evidenced to President of OCCP[4]. Figure 2 depicts annual market shares of players in comparison with annual sale in domestic market (from previous conclusions we can omit export and import).

In our research we wanted to check:

- stability of market shares;
- connections of market shares with market size;
- minimum market share that ensures stability of the cartel.

Table 5 contains descriptive statistics of market shares and total sale in domestic market. We used total sale as a proxy of market size. As we can see from coefficients of variations, variability of market shares is low[5]. Empirical distributions are fairly symmetric which means that shares are oscillating around a mean. To confirm stability we could utilize one of unit root tests, but for 9 observations such a test would be very week. Instead of this

[1] It is a subtype of cement CEM I type with the greatest share in sale.
[2] See: Decision 7/2009, p.45, table 17.
[3] See: Decision 7/2009, p.48 - 49.
[4] Data are from Decision 7/2009, pp.39 - 40.
[5] Unfortunately, there are no clear limit of stability/unstability of shares. For example, in p. 22 of Harrington (2006) we can read: "market shares are highly stable over time" (in collusion). We still need theoretical motivation of market shares' stability limit, as we tried to determine for particular assumptions in Bejger (2010).

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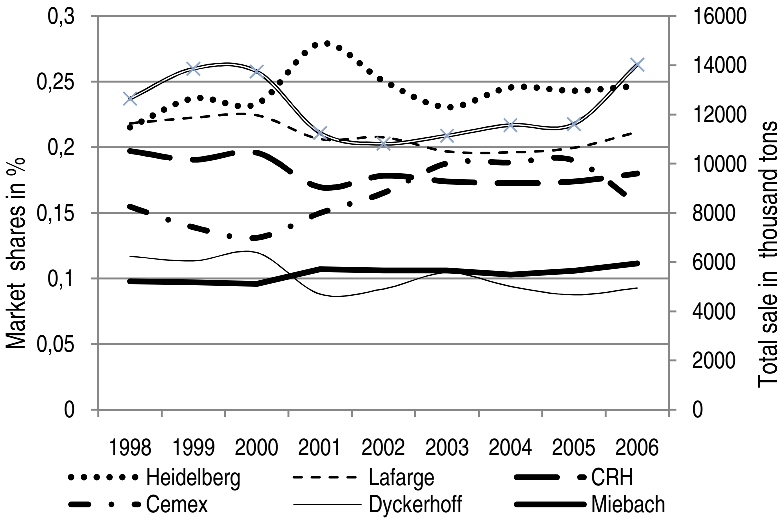
we applied very simple procedure. At first we took firs difference of all series of shares and examined them graphically (Figure 3).

FIGURE 2. CEMENT COMPANIES' MARKET SHARES AND TOTAL SALE IN DOMESTIC MARKET



Source: Author's own preparation based on data from Decision 7 (2009).

TABLE 5. DESCRIPTIVE STATISTICS - MARKET SHARES AND TOTAL SALE

	HEIDELBERG	LAFARGE	CRH	CEMEX	DYCKERHOFF	MIEBACH	Total sale (thousand tons)
Mean	0.242	0.209	0.181	0.162	0.100	0.103	12294.56
Median	0.243	0.207	0.178	0.157	0.093	0.105	11604.84
Maximum	0.279	0.224	0.197	0.190	0.119	0.111	14026.74
Minimum	0.215	0.196	0.169	0.131	0.087	0.095	10812.79
Std. Dev.	0.017	0.010	0.010	0.021	0.012	0.005	1289.29
Skewness	0.687	0.156	0.539	0.088	0.396	-0.167	0.338
Kurtosis	3.641	1.608	1.694	1.651	1.483	1.822	1.411
Observations	9	9	9	9	9	9	9
Coefficient of variation	7.20%	5.12%	5.76%	13.50%	12.69%	5.16%	10.48%

Source: Author's own calculations.

Analysis of Figure 3 suggests that market shares' changes are really small (mostly smaller than one std. dev). We can observe two interesting patterns, either. Firstly, changes in shares are of opposite signs year after year (especially true for Heidelberg, CRH, and Dyckerhoff). This pattern depicts, earlier mentioned system of compensations (if particular player enlarge slightly his market share in one year, he was obliged by cartel to reduce it next year). At second, in 2001 some disturbance in system of cartel quotas had happened.

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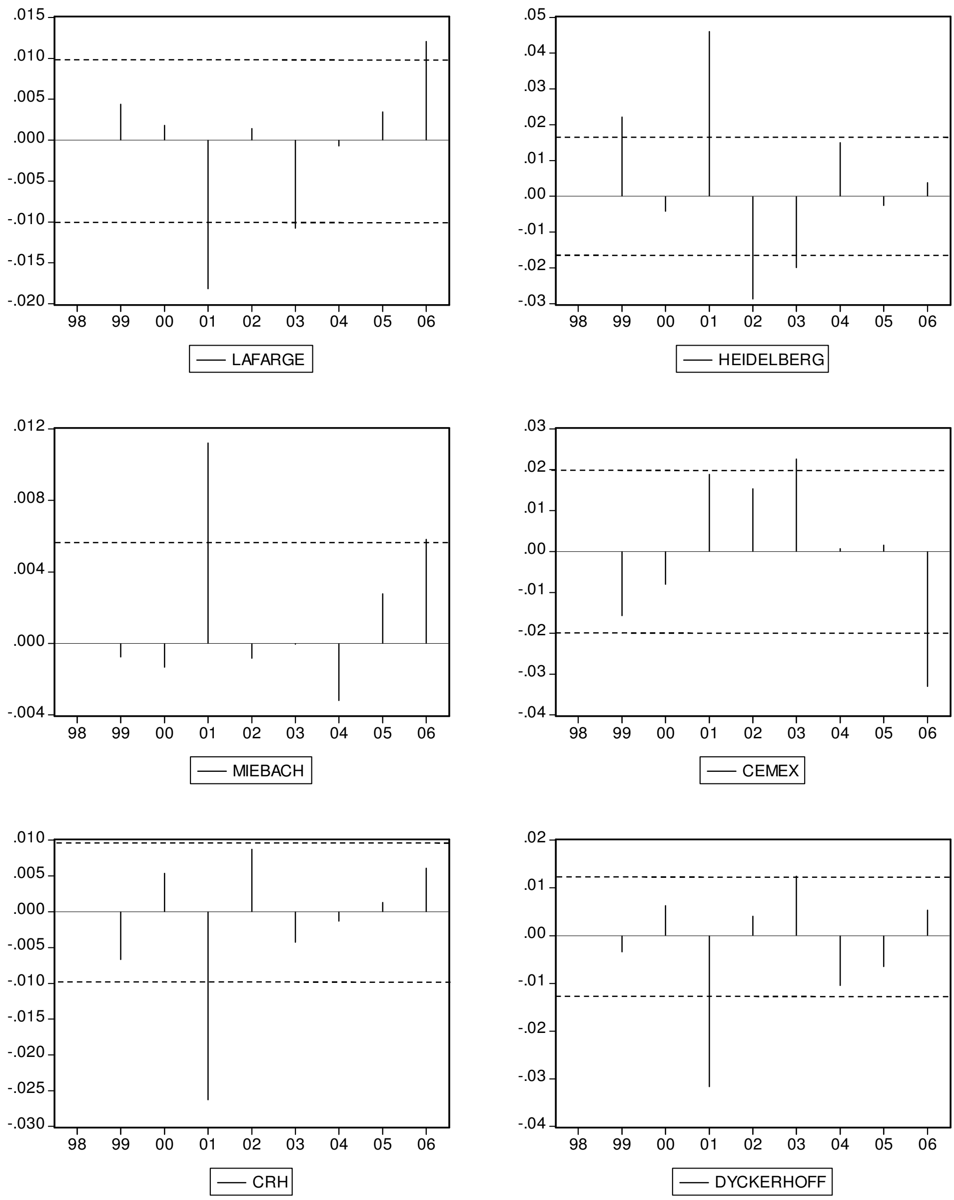
In last step of our simple procedure we carried out the test of the null hypothesis that the mean of the differentiated series is equal to zero against the one-sided alternative that it is greater than zero. Results of the tests are shown in Table 6.

FIGURE 3. SERIES OF FIRST DIFFERENCES OF MARKET SHARES



Source: Author's Own preparation.

Note: Plus/minus one std. dev. bands are marked by dashed lines.

TABLE 6. THE VALUE OF STATISTICS FOR THE 0 - VALUE OF THE MEAN TEST

Series	t-statistic	p-value
HEIDELBERG	0.471	0.32
LAFARGE	-0.243	0.40
CRH	-0.545	0.30
CEMEX	0.041	0.48
DYCKERHOFF	-0.617	0.27
MIEBACH	1.023	0.17

Source: Author's own calculations.

We have no reasons to reject the null hypothesis for all series, so we can say that there are no significant tendencies in market shares' level and they seem stable over the test period.

To finalize examination of market shares' variability we calculated indicator VMV - variance of market share volatility.

It is calculated as[1]:

$$VMV_k^{jm} = Var_j^m\left(\sum_i^n\left|\frac{\Delta MS_i}{2}\right|\right) \qquad (1)$$

where: VMV_k^{jm} - variance of volatility of market shares for industry *k* for period from *j* to *k*; *n* - number of companies; ΔMS_i - increase or decrease of market share of company *i* in particular year.

It is mostly used when information about market shares is unknown (Lorenz, 2008) but we can use it in our research for comparability purpose. It is common practice to use a threshold 0.05% of VMV as a marker of collusion. For a Polish cement industry in sample period 1998-2006 the calculated VMV is 0.0441%.

To conclude examinations of stability of market shares we have to state that:

- volatilities of market shares are low, individually or on average for industry (VMV);
- stability of market shares for all of the players is high.

TABLE 7. PAIRWISE CORRELATION MATRIX

	HEIDELBERG	LAFARGE	CRH	CEMEX	DYCKERHOFF	MIEBACH	Total sale
HEIDELBERG	1	-0.312	-0.698 *	-0.012	-0.741 *	0.552	-0.349
LAFARGE		1	0.884 **	-0.929 **	0.728 *	-0.641	0.778 *
CRH			1	-0.683 *	0.895 **	-0.782 *	0.697 *
CEMEX				1	-0.568	0.498	-0.672 *
DYCKERHOFF					1	-0.849 **	0.567
MIEBACH						1	-0.380

Source: Author's own calculations.
Note: * - significant on 5% level, ** - significant on 1% level.

Second characteristic pattern we want to check is connection between changes in market size and market shares of players. If there was substantial competition in an industry, shifts in demand should cause some changes in market shares' structure. We could not use Chi-square independence test (small sample size - the small sample distribution of the test statistic under the null hypothesis may deviate considerably from the asymptotic chi

[1] See: Lorenz (2008), p. 225.

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square distribution); so we started from testing correlations (linear) between market shares and total sale (used as a proxy of market size). Table 7 summarizes this step.

As we can see, there are no significant correlation between market shares and market size in a case of a half of the players' set. The rest of the companies' shares are correlated with market size at 5% significance level only, additionally sign of correlation coefficient in Cemex case reflects cartel-like mechanism (non competitive) of supply regulation of this producer. In year 2005 industry players noticed that Cemex had distributed false information about his market sale. In reaction, all cartel members agreed that Cemex's market share should went back to "historical" level in 2006. As a consequence, Cemex did not follow market growth in 2006 (in spite of unused capacity, capacity utilization in 2006 in Cemex is confidential, but it is known that it was not totally used (Decision 7. 2009, p.43).

Pearson's correlation coefficients could be biased because of small size of sample. We wanted to confirm above results using alternative measures of independence, namely Spearman rank correlation coefficient and Gamma correlation coefficient. Table 8 contains results.

TABLE 8. SPEARMAN AND GAMMA CORRELATION COEFFICIENTS OF COMPANY'S MARKET SHARE AND TOTAL SALE

Company	Spearman R	p-value	Gamma	p-value
HEIDELBERG	-0.250	0.516	-0.167	0.532
LAFARGE	0.633	0.067	0.389	0.144
CRH	0.567	0.112	0.278	0.297
CEMEX	-0.450	0.224	-0.222	0.404
DYCKERHOFF	0.400	0.286	0.222	0.404
MIEBACH	-0.317	0.406	-0.333	0.211

Source: Author's own calculations

TABLE 9. THE VALUE OF STATISTICS FOR THE EQUALITY OF VARIANCES TEST

Company	F-test	p-value	Bartlett	p-value
HEIDELBERG	1.287	0.748	0.103	0.748
LAFARGE	6.379	0.026	4.952	0.026
CRH	3.675	0.107	2.591	0.108
CEMEX	1.068	0.933	0.007	0.933
DYCKERHOFF	1.255	0.772	0.084	0.772
MIEBACH	5.387	0.041	4.170	0.041

Source: Author's own calculations.

Note: value of F and Chi - square statistics for 5% and 10% sig. levels are: 3.787; 2.784 and 3.841; 2.705.

The two statistics show clearly that we can't say about significant statistical dependence between market shares and market size. Only one R coefficient (Lafarge) is significant at 10% level and neither in Gamma case.

In second step, we want to check if market shares and market size have similar volatilities. At first, we compared descriptive statistics (Table 5) and stated that market size has greater volatility than 4 of 6 market shares' samples. Next, we tested null hypothesis that variance in series of chain index[1] of market shares of particular company and chain index of market size are equal against alternative that they are not. We used F-test and Bartlett

[1] Indices of series have homogenous variances and approximately Normal distributions.

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test. We found that (at 5% and 10% significance level) we should reject the null in a case of Miebach, Lafarge and CRH and there were no reason to reject the null hypothesis for the rest of companies. Table 9 presents these results. To summarize shares - market size dependence examination, we can conclude that there are no strong evidences of statistical dependence between market shares and market size and scale of variability is smaller in 3 of 6 cases. So we stated that market shares' structure is fairly independent of market size and more stable than market size.

The last problem dealing with market shares' system is approximation of theoretical minimum market share supporting collusion in an industry. In Bejger (2010) we developed simple supergame model of partial collusion that focuses on the role of fixed (exogenous to game) system of market shares. As one of the conclusions of the model we estimated limit market share below which collusion is not stable (the game switch to competition phase) or could not be started. We found that collusion in an industry could be started or sustained only if the smallest market share s_i of some player i is greater than (2).

$$
\begin{aligned}
s_i \geq & \frac{1}{(\sqrt{\delta}-1)(\sqrt{\delta}+1)(n+1)(-2a+ar+cr)}(-2c-2\sqrt{\delta}(4a^2\delta+4c^2\delta+8c^2n- \\
& -4c^2r+4c^2n+a^2r^2+c^2r^2+8ac-4a^2+a^2r^2n^2+c^2r^2n^2+2acr^2-8c^2nr+ \\
& +2a^2nr^2+2c^2nr^2-4c^2n^2r-8ac\delta-4acr+4acrn^2-4acn^2r+2acn^2r^2- \\
& -8acnr)^{1/2}-2c\delta-2cn+ar+cr-2c\delta n+a\delta r+c\delta r+anr+cnr+a\delta nr+ \\
& +c\delta nr
\end{aligned}
\qquad (2)
$$

As we have not enough data to estimate market and cost parameters of the industry for now, we use (2) with assumption that it is full collusion in an industry (in our model average market price in collusive equilibrium is given as r part of monopoly price, so we assume now that $r = 1$). With that assumption we can reduce expression for limit market share to (3) below:

$$
s_i \geq -\frac{1}{(\delta-1)(n+1)}(\delta+n-2\sqrt{\delta}\sqrt{4\delta+2n+n^2-3}+\delta n+1) \qquad (3)
$$

As we can see, it depends on number of players and discount factor only, so we can do first approximation of minimum market share on this basis. We recall that discount factor $\delta < 1$ is given as:

$$
\delta = \frac{1}{(1+r)} = \mu e^{-r\Delta} \qquad (4)
$$

where: r - discount rate; μ - hazard rate - probability of o continuation of the game in a period $t+1$; Δ - length of a period (detection delay).

We simulated limit market share for a few combinations of discount rate and detection delay, assuming $\mu = 1$ and $n = 6$. Simulation's result is shown in Table 10.

We assumed various detection delays but one year delay seems unrealistic. Evidences contained in Decision 7/2009 imply that companies' authorities contacted each other more frequent and sales monitoring was done monthly rather than yearly. So the most plausible delay was between half a year and one month. We assume that the most probable discount rate level was in range 8% to 14% (macro data from the sample period suggest that). As we see from Table 10, combinations of such values of parameters give us discount factor from a range 0.96-0.98. For these values of δ we have minimum market share that support collusion in a level from a range 0.090-0.085.

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TABLE 10. SIMULATION'S RESULTS - MINIMUM MARKET SHARE SUSTAINING COLLUSION

r	Δ year	Δ half a year	Δ two months	δ (rounded)	MINIMUM THEORETICAL MARKET SHARE FOR DISCOUNT FACTOR δ	MINIMUM MARKET SHARE OF INDUSTRY MEMBER NOTED IN PERIOD 1998 - 2005 *
8%	0.923	0.980	0.987	0.88	0.1080	0.0963 (1998)
9%	0.914	0.978	0.985	0.90	0.1039	0.0951 (1999)
10%	0.905	0.975	0.983	0.92	0.0993	0.0957 (2000)
11%	0.896	0.973	0.982	0.94	0.0947	0.0975 (2001)
12%	0.887	0.970	0.980	0.95	0.0925	0.0923 (2002)
14%	0.869	0.966	0.977	0.96	0.0903	0.0940 (2003)
16%	0.852	0.961	0.974	0.97	0.0881	0.0935 (2004)
20%	0.819	0.951	0.967	0.98	0.0858	0.0966 (2005)

Source: Author's own calculations, Data (*) from decision 7/2009, p.37.

To compare with real industry market share's structure we used data on market shares from reports of companies that were annually delivered to PCA (similar information players exchange bilaterally)[1]. These data exhibit market situation, which was seen and considered true by all players, expect Cemex. The levels of market shares in this sample are than natural reference point for comparison to our theoretical findings. Last column of Table 10 contains minimum level of market share of some player in an industry (Miebach in a first three years of a sample, Dyckerhoff afterwards). If we compare these levels with our theoretical range, we can see that empirical minimal market share was always greater than necessary theoretical collusive level. So even if our approximation is very rough, we can say that, from a point of view of fixed cartel quotas, no cartel members had incentives to cheat or break unilaterally cartel agreement.

Price and demand

The content and a length of sample period of price/demand collusive patterns research were determined by monthly data available in Polish public statistics. Data subject and source of data are listed below.

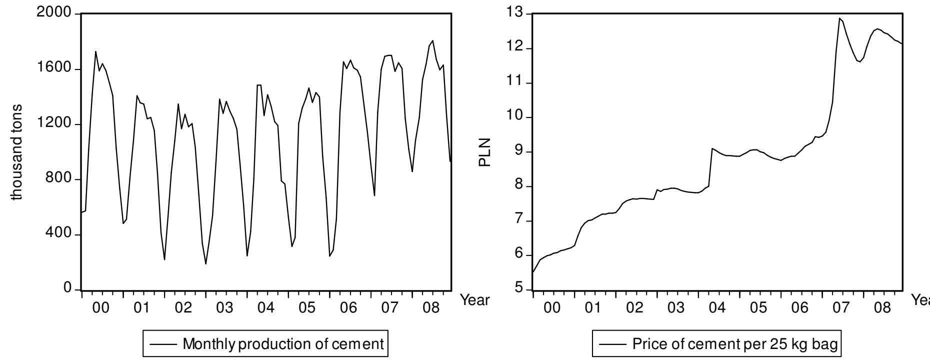
Price of cement - we were only able to collect retail price of Portland cement/ bagged/ 25 kg bag in PLN, years 2000-2008, frequency - monthly, source: Prices in the national economy, Central Statistical Office of Poland Statistical Information and Elaborations, years 2001-2009. We could not reach any type of information about wholesale/producer's prices; so we use average retail price of 25-th kg bag as a proxy of market cement price. We hope that it is justified procedure because of strong dependency between producer's base price of bulk cement and price of bagged cement, as it was described earlier in this paper.

Demand for cement - Polish public statistics does not provide monthly data on demand for cement, we did not estimate demand equation either (lack of proper data for the moment). Instead of quantity demanded we used the best we could obtain, i.e. monthly production of cement industry. Hence proxy for demand is production of cement in domestic market in thousand tons during 2000-2008, frequency - monthly, source - Production of major products, Central Statistical Office of Poland, Department of an Industry, source materials issued monthly, years 2001-2009.

The most detailed data on production have PCA, but publically available are data from period 2004 - 2008 only.

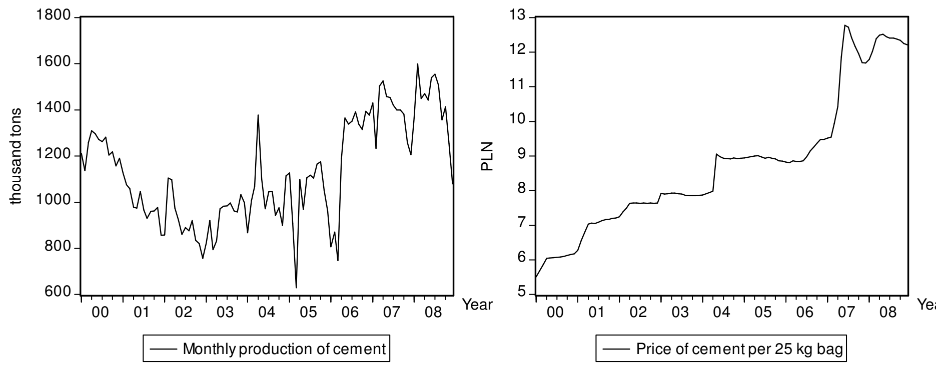
[1] See: Decision 7/2009, p. 37. Notice that sample is one period shorter.

FIGURE 4. PRODUCTION AND PRICE OF CEMENT - RAW DATA



Source: Author's own preparation

FIGURE 5. PRODUCTION AND PRICE OF CEMENT - SEASONALLY ADJUSTED DATA



Source: Author's own preparation

TABLE 11. BASIC STATISTICS AND TESTS

	SERIES	
STATISTIC/TEST	PRICE	PRODUCTION
SKEWNESS	0.651	0.195
KURTOSIS	2.545	2.066
JARQUE-BERA NORMALITY TEST	8.560 (0.013)	4.612 (0.099)
LJUNG - BOX TEST FOR LEVELS - Q(5)	359.38 (0.000)	271.62 (0.000)
ADF TEST*	-2.944** (0.153)	-3.486** (0.045)
KPSS TEST*	0.167***	0.246***

Source: Author's own calculations.

Note: p - values given in parenthesis, *test include trend and intercept; **value of t statistics (critical values for 1%; 5%; 10% sig. levels: (-4.046); (-3.452); (-3.151), *** value of LM statistics (asympt. critical values for 1%; 5%; 10% sig. levels: 0.216; 0.146; 0.119).

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On the beginning, we examined both time series visually and checked the basic statistic properties. Raw data are on Figure 4. At first, we examined stationarity of the series. From graphics we could expect that both series are nonstationary. To check that we corrected both series for seasonality (by Census X12 method), at first[1]. Seasonally adjusted series are depicted in Figure 5.

Next, we used unit root test ADF and KPSS to test hypothesis about stationarity of the series. Results of the tests together with basic statistics are shown in Table 11.

The series are weekly skewed, do not follow normal distribution, strong autocorrelation exists in both of them. Unit root tests with different configuration of hypotheses confirmed nonstationarity of the series. In next step we eliminated existence of second unit root in both series[2].

Further, we wished to explore dependences between price and production (supply). We checked correlation of original series, detrended series[3] and first differences of the series (stationary processes). Pearson correlation coefficients were as follow (*t* - statistics in parenthesis): 0.365 (4.036); 0.248 (2.635); -0.064 (-0.66). Critical value of *t*-statistic for 106 df and 0.01% significance level is 2.623 what implies that first two coefficients are significant. Nevertheless, correlation is very weak (we should focus on detrended series). We additionally calculated measures of association: Contingency coefficient (value = 0.244); Cramer's V coefficient (value = 0.178). To summarize, we could detect very weak dependency between price and production so far. In a last step we wanted to check if we would be able to detect any causality relationship between series. We used Granger causality test with 12 lags for first differences of the series (to impose stationarity). Calculated F-statistics were: 1.27 (*p*-value = 0.352) in production -> price direction of causality and 1.440 (*p*-value = 0.168) in price -> production direction. Values of *F*-statistics suggest that we do not reject hypothesis that one series do not Granger cause the second one in both directions.

Another pattern characteristic for collusive equilibrium may be rigidity of prices regarding to seasonal shifts in demand. From theoretical model (Bejger, 2010) market price is rigid when market is getting smaller. We can describe such a shift in demand as a seasonal fluctuation (we can consider it deterministic). If some industry exhibits seasonal fluctuations of demand (which is an exogenous fact, know from economic theory) we can use seasonal price movement to detect or confirm cartel behavior of the players. Demand for cement has strong seasonal fluctuation and production series (our proxy for demand) exhibits the same property. We would like to explore if price movements correspond with this fluctuations. On a basis of Figure 4 we assumed monthly seasonality in production series. At first we examined visually means by seasons of both series (Figure 6).

On seasonal stacked graphs we could see strong seasonality in production and rather weak in price. To estimate seasonal factors and check for statistical significance of them we estimated following equations for production and price.

$$\hat{price}_t = \alpha_1 price_{t-1} + \alpha_2 price_{t-2} + \beta_1 HPtrend + s_1 D_{1t} + s_2 D_{2t} + s_3 D_{3t} + s_4 D_{4t} + s_5 D_{5t} + s_6 D_{6t} + s_7 D_{7t} + s_8 D_{8t} + s_9 D_{9t} + s_{10} D_{10t} + s_{11} D_{11t} + \lambda_1 may04 + \lambda_1 may07 + u_t \quad (5)$$

[1] We will shortly name seasonally adjusted series as: price and production.

[2] Both series seem to be non stationary in mean an variance. After detrending of the both series, we still could not (on 1% sig. level) confirm stationarity of the residual procesess (by ADF, PP KPSS tests) so the procesess are not of TS type rather. Moreover, we estimated a few data generating models for first differences of the procesess (of AR(p) type) and could not eliminat heteroscedatisiti of residuals (significan autocorrelation o squared residuals, significant LM statisticst in LM ARCH test). In depth analysis of the structure of the procesess will be desribed in further paper devoted to market power analysis.

[3] We use Hodrick - Prescott filter to detrend both series and obtain filtered data.

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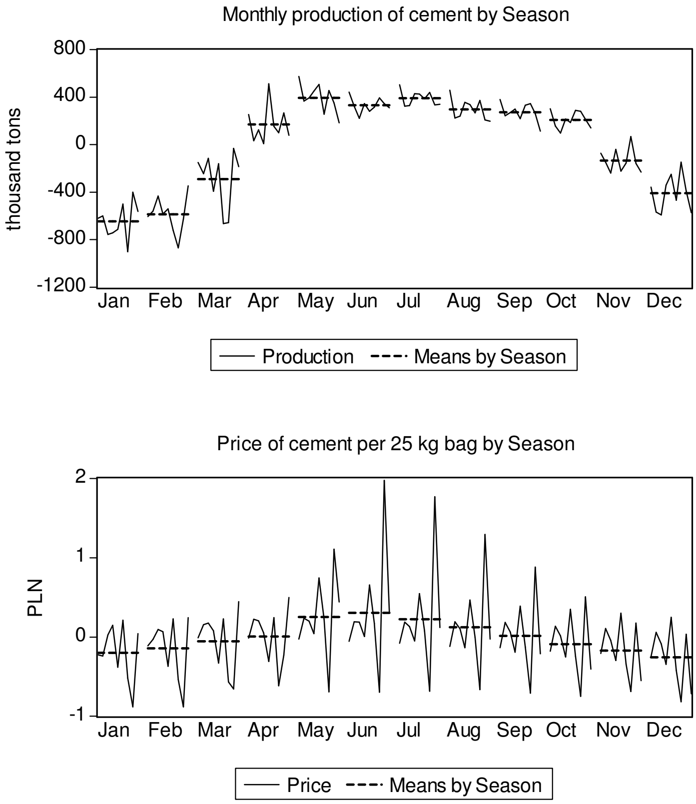
where: $\hat{price}_t$ - price of cement per 25 kg bag, level in PLN; $price_{t-p}$ - lagged of *p* periods price of cement per 25 kg bag, level in PLN; *HPtrend* - trend component from Hodrick - Prescott filtration; $D_{1t},..., D_{11t}$ - seasonal dummies, January - November; may04, may07 - dummies which accommodate shifts in price caused by VAT tax increase from 7% to 22% in may of 2004 (may04) and boom for construction materials in summer of 2007.

FIGURE 6. PRODUCTION AND PRICE OF CEMENT - SEASONAL STACKED LINE GRAPHS



Source: Author's own preparation

As (5) implies, we treat December as the reference month so coefficients attached to the seasonal dummies are differential intercepts, showing by how much the average price in the month with dummy value of 1 differs from December. To remove autocorrelation in residuals we introduce autoregressive structure with two lagged dependent variables. Table 12 contains estimation results. The most important observation is that significant seasonal factors we have for February and March only[1].

Next we estimated production equation of the form:

$$\hat{prod}_t = const. + \alpha_1 prod_{t-1} + \beta_1 HPtrend + s_1 D_{1t} + s_2 D_{2t} + s_3 D_{3t} + \\ + s_4 D_{4t} + s_5 D_{5t} + s_6 D_{6t} + s_7 D_{7t} + s_8 D_{8t} + s_9 D_{9t} + s_{10} D_{10t} + s_{11} D_{11t} + u_t \quad (6)$$

[1] We confirmed that conclusion by Wald coefficinet test. Both factors are significant in 5% level.

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where: $\hat{prod}_t$ - monthly production of cement, level in thousand tons; $prod_{t-1}$ - lagged of 1 period monthly production of cement, level in thousand tons; *HPtrend* - trend component from Hodrick - Prescott filtration; $D_{1t},..., D_{11t}$ - seasonal dummies, January - November.

As (5) implies, we treat December as the reference month again. Table 13 contains estimation results.

TABLE 12. REGRESSION RESULTS FOR SEASONAL FACTORS IN PRICE

Coefficient	Value	Std. Error	t-Statistic	p - value
α_1	1.326	0.052	25.09	0.000
α_2	-0.43	0.053	-8.16	0.000
β_1	0.105	0.023	4.551	0.000
D1	0.064	0.045	1.422	0.158
D2	0.090	0.045	1.961	0.052
D3	0.106	0.044	2.419	0.017
D4	0.072	0.044	1.630	0.106
D5	0.036	0.047	0.770	0.442
D6	0.030	0.046	0.648	0.518
D7	-0.01	0.045	-0.23	0.816
D8	0.017	0.044	0.397	0.691
D9	0.010	0.044	0.231	0.817
D10	0.002	0.044	0.053	0.957
D11	0.016	0.044	0.371	0.711
λ_1	1.017	0.111	9.160	0.000
λ_2	1.176	0.114	10.28	0.000
R-squared 0.997; Durbin-Watson stat 1.975				
Ljung - Box test for Residuals - Q(5) 4.17 (0.524)				

Source: author's own calculations.

TABLE 13. REGRESSION RESULTS FOR SEASONAL FACTORS I IN PRODUCTION

Coefficient	Value	Std. Error	T-Statistic	P - value
Const.	-346.5	79.91	-4.33	0.000
α_1	0.530	0.088	6.010	0.000
β_1	0.478	0.107	4.430	0.000
D1	-101.0	58.55	-1.72	0.087
D2	92.628	69.02	1.341	0.182
D3	361.20	65.90	5.480	0.000
D4	661.96	54.15	12.22	0.000
D5	640.69	58.88	10.88	0.000
D6	460.28	70.02	6.573	0.000
D7	552.99	66.48	8.317	0.000
D8	427.69	69.83	6.123	0.000
D9	454.88	64.66	7.034	0.000
D10	402.36	63.51	6.335	0.000
D11	94.577	60.46	1.564	0.121
R-squared 0.942; Durbin-Watson stat. 1.923				
Ljung - Box test for Residuals - Q(5) 1.60 (0.90)				

Source: Author's own calculations.

As we can see, almost all of the seasonal parameters are significant in this case. Comparing to results for price we can conclude that price do not follow seasonal shifts in production (demand). Moreover, one of seasonal factors (for February), which are significant in price series, is insignificant in production series. Additional interesting question is if there is any

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seasonal pattern in price's changes. To detect this we estimate similar to (5) equation for first difference of a price. It turned out that in fact only significant, positive seasonal parameters (in 1% level) were those for February and March. That is consistent with previously described price scheme of a cartel in which players introduced price's rises on the beginning of the year, in automatic way (without connection with actual market situation).

Concluding our preliminary research of price/supply patterns distinct for collusion we found that:

- price and supply (demand) of grey cement were weakly correlated in a sample period (cartel phase);
- preliminary examination eliminated Granger causality dependence between price and production;
- price do not follow deterministic shifts in demand, exhibits some kind of stickiness (it is downward sticky probably, but precise estimation of scale and direction of asymmetry is more complex task, we live it for another paper);
- price exhibits regular (seasonal) rise in first quarter of each year, which is not connected with market demand.

Conclusion

This paper is devoted to a case of a cartel in Polish cement industry. We described the industry (its history and actual status) and characterized the cartel with its fundamental illegal practices, market sharing and price fixing. Our main task for this paper was examination of possibility of detection a cartel-like behavior of players in a cement industry on a basis of cartel markers' evaluation (ex post examination) using statistical data we can actually obtain. We have done preliminary research of Polish cement cartel in a periods of 1998-2006 and 2000-2008 (availability of data had determined the sample) searching for specific patterns in market shares', price and supply processes that distinguish collusion from competition. We have found that both market shares of players and price/supply processes exhibits theoretically motivated, distinctive for collusion patterns such as: stability, low volatility and independence of market size of market shares' system, seasonality smoothing of prices and weak correlation with market supply (demand). Additionally we have detected market price regular annual rise periods and estimated theoretical minimum level of market share of particular cartel member that sustain collusion. Our conclusions are partly similar to these of Rosenbaum and Sukharomana (2001), Röller and Steen (2006), Zeidan and Resende (2009), von Blanckenburg and Geist (2009), and Lorenz (2008). However, our work is not fully comparable with other papers, mostly because of specific situations we are dealing with (we know exactly schemes of price fixing /market sharing in one hand, in the other hand we have very small data set so far) and different questions we wished to answer in current work. As this paper is the first one connected with quantitative examination of Polish cement cartel we signaled some topics of further research we would undertake in further research.

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