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Discussion Papers

1030

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Berlin, July 2010

IMPRESSUM

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Fax +49 (30) 897 89-200
http://www.diw.de

ISSN print edition 1433-0210
ISSN electronic edition 1619-4535

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Empiricism Meets Theory–
Is the Boone-Indicator Applicable?

Alexander Schiersch and Jens Schmidt-Ehmcke

Abstract:

Boone (2008a) proposes a new competition measure based on Relative Profit Differences (RPD) with superior theoretical properties. However, the empirical applicability and robustness of the Boone-Indicator is still unknown. This paper aims to address that question. Using a rich, newly built, data set for German manufacturing enterprises, we test the empirical validity of the Boone-Indicator using cartel cases. Our analysis reveals that the traditional regression approach of the indicator fails to correctly indicate competition. A proposed augmented indicator based on RPDs performs better. The traditional Lerner-Index is still the only measure that correctly indicates the expected competitive changes.

Keywords: Competition, Boone-Indicator, Cartels, Census Data
JEL Classification: L12, L41, D43

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1. Introduction

The study of competition is hampered by the scarcity of appropriate data and, in particular, by the lack of good indicators for the competitive environment that have wide coverage. Researchers and policy-makers, for instance in antitrust authorities, usually rely on traditional measures like the price cost-margin (PCM) to assess the competition levels in industries. However, theoretical research raises doubts on the robustness of PCM. Amir (2003), Bulow and Klemperer (1999), Rosenthal (1980), and Stiglitz (1989) show that there are theoretically possible scenarios in which PCM increases with more intense competition. However, the practical importance of these counterexamples is still unknown. Despite these drawbacks, the PCM is still a popular measure in empirical research (see, for example, Pruteanu-Podpiera et al., 2007; Maudos and Fernandez de Guevara, 2006; Aghion et al., 2005; Nevo, 2001; Klette, 1999).

Boone (2008a) extends the existing set of competition measures by suggesting an indicator that relies on Relative Profit Differences (RPD). This approach is based on the notion that competition rewards efficiency. In industries with increasing competition inefficiently operating firms are punished more harshly than more efficient ones. Hereby, efficiency is defined as the possibility to produce the same output with lower costs or, rather, lower marginal costs. Thus, comparing the relative profits between some arbitrarily efficient firm and a firm with greater efficiency contains information about the level of competition within that industry. The more competitive the market is, the stronger is the proposed relationship between efficiency differences and performance differences. Two properties make the so called Boone-Indicator (BI) appealing: First, it has a robust theoretical foundation as a measure of competition, meaning that it depicts the level of competition correctly both when competition becomes more intense through more aggressive interaction between firms and when entry barriers are reduced. Second, it has the same data requirements as the PCM.

The goal of this paper is to evaluate the empirical robustness of the Boone-Indicator using a newly constructed data set for German manufacturing enterprises. We proceed in three steps: First, we present the established parametric approach of estimating the BI. Second, we calculate the RPDs, as theoretically defined, using real world data and propose an augmented indicator correcting for firm size. Finally we use cartel cases as natural experiments to evaluate the performance of the Boone-Indicator and compare it to the traditional PCM measure. The intuitive idea behind the cartel cases as a natural experiment is that we expect fiercer

competition in the aftermath of its uncovering. This should be observed in our data and affect the competition measures.

The empirical literature on the effects of efficiency on firm performance and the positive impact of competition on efficiency somewhat supports the assumed cohesion between efficiency, firm performance, and competition needed for the Boone-Indicator. One of the earliest studies examining the influence of competition on productivity is Nickell (1996). Using firm level data from EXSTAT, he finds evidence that higher competition leads to higher productivity. A number of papers try to identify the effect of competition on wage levels (Nickell, 1999) or innovative activity by firms (e.g., Porter, 1990; Geroski, 1995; Nickell, 1996; Blundell et al., 1999).

Despite theoretical robustness few studies apply the Boone-Indicator to real world data to date. The only paper published in a refereed journal, to our knowledge, is Bikker and Leuvensteijn (2008). Using data for the Dutch life insurance market, they calculate the Boone-Indicator using three different approximations of the marginal costs: average variable costs, defined as management costs as a share of the total premium; marginal costs derived from a translog costs function; and scale adjusted marginal cost. Using a least-square dummy variable approach, they regress these variables first one by one on logarithmized relative profits, then, in a second step, on the market share of insurance companies as an outcome variable. Their results point to a weak competition in the Dutch life insurance industry when compared to other industries. However, the robustness of their results is unclear.

Additionally, the Boone-Indicator is used in a number of reports and discussion papers. Griffith et al. (2005) investigate the empirical usefulness of a slightly modified BI based on relative profits. Using data from the annual report and accounts filed by firms listed on the London Stock Exchange over the period 1986-1999, they compare the relative profit measure with the PCM and the Herfindahl index. Their main results show a positive correlation between the new measure and PCM but no correlation with Herfindahl, which raises questions about the usefulness of the Herfindahl index as a measure of competition. Furthermore, they provide evidence that the relative profit measure is less affected by cyclical changes than the PCM. However, they can not derive recommendations on which might be the "correct" measure of competition because "without a prior information about the 'true' degree of competition … it is difficult to say whether the relative profit measure is empirically better than the price-cost-margin" (Griffith et al. 2005: 14). Creusen et al. (2006) use a similar method to examine the competition in Dutch market sectors during the years 1993-2001 based on firm level data finding a slight decline in the intensity of competition during that time. More re-

cently, the Finnish Ministry of Trade and Industry studied trend changes in the intensity of competition across Finnish business sectors (Malirante et al. 2007). The report focuses on the service sector and reports the results of nine different measures of competition including traditional measures like Herfindahl, PCM and the four-firm concentration index as well as six different parameterizations of the Boone-Indicator. Their results suggest an increase in competitive pressure in Finland in the analyzed time interval. However, the outcomes vary a lot with respect to the different parameterizations of the BI and they state that "…the optimal specification and estimation of the Boone indicator remains an open question and should thus be debated." (Malirante et al. 2007: 23)

We organize this paper as follows: In Section 2 we present the Boone-Indicator and compare its theoretical robustness to the traditional PCM measure. In Section 3 we list the relevant cartel cases in the power cable sector, the cement sector, and the ready mix concrete sector. In Section 4 we give a detailed description of the dataset and present first descriptive statistics. In Section 5 we discuss the Boone-Indicator and propose a modification to control for firm size and present the main results of our analysis. Finally, in the last section we collect the main findings and conclude the paper.

2. Measuring Competition

A common competition measure is the Lerner-Index or Price Cost Margin (PCM). It is based in neoclassic theory where under perfect competition prices (p) equal marginal costs (c). Hence, the PCM, calculated as $(p_i - c_i)/p_i$, takes values greater than zero if competition is not perfect and firms are able to enforce prices above marginal costs. As competition becomes fiercer PCM approaches zero. To evaluate competition on markets or in industries, the industry PCM is calculated as a simple or weighted mean of individual PCMs. The latter is usually derived by calculating it with firm market shares. This ensures that the market power of big firms is adequately captured. The common interpretation is as with firm individual PCM. It decreases with fiercer competition and increases with weaker competition.

However, it is not a robust competition measure. Amir (2003) shows that, under certain conditions, an increase in competition through an increase in the number of firms in a market can result in an increasing average PCM. Given certain circumstances Stiglitz (1989) shows that profits per unit sales can rise in a recession. Thus, even though competition among firms increases during recessions, industry PCM also increases. Another potential source of error can be the reallocation effect. As a result of fiercer competition, the market share of the more efficient firms increases while that for less efficient firms decrease. Thus, the weighted

average PCM can increase if the increase in the market share of the more efficient firms over-compensates the decrease of the respective individual PCMs. Therefore, the Lerner-Index is, at least theoretically, potentially misleading.

Against this background and the fact that the interpretation of popular concentration indices like Herfindahl is also not straightforward in terms of competition, Boone (2008a) proposes a new competition measure. Termed Relative Profit Differences (RPD), its main idea is that competition rewards efficiency. To get the measure working, Boone postulates some assumptions of which the most important ones are outlined here. First, firms under consideration act in a market with relatively homogeneous goods. Secondly, we assume symmetry. Hence, firms act on a level playing field that ensures that changes in competition affect firms directly and not indirectly through changes in that playing field. It also implies that "…firm i's profits are the same as firm j's profits would be if firm j was in firm i's situation." (Athey/Schmutzler 2001: 5). Thus, within the theoretical framework of the indicator, this implies equal profit level for two equally efficient companies. Thirdly, we are able to rank firms with respect to their efficiency (n_i). Thereby the efficiency index (N) needs to be one dimensional to ensure transitivity. Given that the production costs are captured by $C(q,n)$ with q as output quantity, the relationship between efficiency and cost is assumed to be:[1]

$$\frac{\partial C(q,n)}{\partial q_l} > 0 \qquad \frac{\partial C(q,n)}{\partial n} \leq 0 \qquad \text{and} \qquad \frac{\partial \left[\frac{\partial C(q,n)}{\partial q_l} \right]}{\partial n} \leq 0 \quad \text{for } l \in \{1,2,\ldots,L\}$$

The proposition of the first two quotients on the left-hand side is clear-cut. The first states that firms have positive marginal costs. The second quotients defines that costs are lower the more efficient firms are. Finally, the quotient at the right-hand side states that marginal costs are lower for more efficient firms. Given these assumptions, firms play a two stage game. In the first stage, they decide whether or not to enter. This is determined by the entry costs and the expected profit. Only firms enter that are able to recoup entry costs. In the second stage, the remaining firms simultaneously choose their actions to maximize profits. This gives a subgame equilibrium for each competitive state.

[1] Boone (2008a)

Boone uses two parameters to model changes in competition. One is the conduct parameter θ, which mirrors the aggressiveness of firms. The second is the change in entry costs ε.[2] Then, the output reallocation effect works in the following way:[3]

$$\frac{d\ln q(n)}{d\theta} \text{ and } \frac{d\ln q(n)}{d(-\varepsilon)} \text{ are increasing in } n$$

Given these conditions, while an increase in competition can decrease the output of firms, this decrease will be smaller for more efficient firms. As a result the market share for the more efficient firms increases while that for the less efficient firms shrinks. Hence, competition rewards efficient firms. Given these setting, the RPD is calculated as a quotient of profit level differences:[4]

$$RPD(n,N,I,\theta) = \frac{\pi(n'',N,I,\theta) - \pi(n',N,I,\theta)}{\pi(n,N,I,\theta) - \pi(n',N,I,\theta)}$$
$$\text{with } n'' \geq n \geq n' \text{ and } \pi(\ldots) \text{ as firms profit}$$

Increasing competition raises this measure for any three firms with $n'' \geq n \geq n'$. As Boone (2008a) proves, his measure of competition is robust to distortions out of the reallocation effect. The following example will illustrate how the reallocation effect works and how it affects both RPD and PCM. We have a simple linear demand function, three firms with constant marginal costs and no entry costs.[5] As shown in Table 1 fiercer competition, simulated by an increase in substitutability of products, results in a rise of the weighted average PCM while the respective RPD is decreasing. Hence, PCM signals a fall of competition while RPD correctly signals fiercer competition.

< insert Table 1 about here >

However, if there are more than three firms, comparing RPDs over time for each company is impractical. One convenient way, proposed by Boone (2008a), is to plot the RPDs. Using a firm's normalized efficiency for the x-coordinates gives a function that is always bounded at one on both axes. Figure 1 presents an example. As in the previous example, we model changes in competition via substitutability of products. The increase in competition leads to lower firm specific RPDs. To measure the change in competition one now calculates

[2] For a detailed discussion see Boone (2004).
[3] Boone (2004)
[4] Boone (2008a). Hereby N is the efficiency index of n_i and I is the set of firms in the market.
[5] This is a modified example from Boone (2008b).

and compares the area under both curves. Since we have normalized values the area is bounded between zero and one, with zero implying perfect competition and one the complete absence of competition. The area in our example shrinks and thus correctly indicates fiercer competition.

< insert Figure 1 about here >

3. Cartel Cases

In order to evaluate the robustness of the Boone-Indicator we use a natural experiment of three major cartel cases in different sectors. A cartel is defined as an explicit contractual agreement between legally independent companies in order to restrict competition and increase profits. Such contracts define the prices, quantities, markets, etc., for each participating firm. Further the contracts also implement a system of sanctions to ensure that deviant behavior by cartel members is properly punished. Sometimes establishing a cartel includes the formation of an organization that coordinates and monitors participating firms.

In addition to explicit cartels, there is also collusive behavior. This is characterized by the absence of contractual agreements or any form of record. Instead it often relies on informal and mostly oral agreements. Although it has the same objective as a cartel, it usually cannot restrict competition as effectively since firms have incentives to deviate from the collusion strategy and the sanction mechanism is missing.[6] However, since this way of restraining competition is hard to detect we only focus on cartels.

For the purpose of our analysis cartels have to meet three criteria. Firstly, the cartel must be nationwide. This ensures that it was able to restrict competition all over Germany. Second, it must have been a cartel case of significant size. Hence, the cartel actually must have gained a significant control over the national market. Both criteria ensure that the effect can be found in the data. We take the size of the cartel fine as a proxy for the level of the distortion of competition. Finally, the product of a cartel should be as homogenous as possible, leaving as little room for product diversification and, thusly, price discrimination.

When such cartels are uncovered and terminated, we expect fiercer competition in subsequent periods. This assumption does not imply that competition changes to perfect competition, nor does it neglect the possibility of future informal oral agreements by the involved companies. However, as previously noted, collusive behavior is less effective than explicit cartels. Moreover, it would not be rational to take the risk of an explicit cartel in the first place

[6] However, there are of course gaming strategies which lead to similar results, given certain well specified condition. See for instance Bester (2004).

if collusion could restrict competition at the same extent from the very beginning. Therefore we impose the weak assumption that competition is significantly higher in the aftermath of a legal cartel case compared to the cartel period.

Power cable cartel

The first cartel that appears to be suitable for our analysis is the cartel of German power cable producers. It was constructed as a price- and quota-cartel, where producers agreed not only on global market shares but also on shares for every big customer within a precisely defined period and on the respective price range. In order to govern the cartel the "Elektro-Treuhand GmbH" (ETG) was founded as a joint venture of all involved producers. The mechanism worked in the following way: Every customer query was reported to the ETG. Since ETG also did the cartel accounting, it knew which firms already were at quota during any given time period, and which were not. They passed price- and discount-information to the companies involved to ensure that in the following negotiations those companies scheduled to get the job succeeded at the defined price. The cartel controlled the entire power cable market for several decades. (Fleischhauer, 1997; Drucksache 14/1139).

The cartel ended in September 1996 in a nationwide search and seizure by the Federal Cartel Office. By the end of 1997 the cartel office had charged 16 companies, two cable industry organizations and 28 individuals with a fine of 280 million Deutsch Mark (143 million Euros) in total, the largest fine in German history at that time. All companies, except one, accepted the fine and thus acknowledged having participated in an illegal cartel in order to avoid competition. The organizational structure of the cartel was terminated, including the closure of the ETG and the two cable industry organizations (Drucksache 14/1139).

Cement cartel

The second cartel in our analysis is the German cement cartel. It was created in the aftermath of the German unification in the early 1990s as a price-, quota- and regional cartel covering the entire German market for cement including importation (Pressemitteilung 19/09). All major players and also medium sized producers took part in the cartel. Due to the physical properties of cement, which leads to excessively high transport costs over 300 kilometers, the market for cement is regional. However, all players agreed on a nationwide organization of regional cartels with explicit organizations for each regional market. The German market was divided into an east, west, north and south submarkets. At this level the organizational structure varied. However, in each submarket contractual agreements were made (VI-2a Kart 2 - 6/08 OWi). The nationwide monitoring was done by the umbrella association of the German cement producers ("Bundesverband der Deutschen Zementindustrie e.V."). In the event that

cement was delivered outside a firm's home market, compensatory payments were arranged during ad hoc meetings held in Munich, the so-called "Money-Karussell" (money-carousel).

The cartel ended in July 2002 in a nationwide search and seizure of 30 companies. By the end of 2003 the Federal Cartel Offices levied twelve companies and several persons with a cartel fine of 702 million Euros in total (Drucksache 15/5790). However the companies under suspicion, save for the company acting as principal witness, protested the amount of the fine. The legal disputes lasted until June 2009 when the court finally confirmed all allegations but reduced the fine to 330 million Euros. However, with respect to market effects we can state two things. First, as stated by the court, witnesses, and various experts in the legal case, the consequence of the uncovering of the cartel was a price war that lasted at least until 2005. Second, to gain more information for the court, a second national seizure was carried out in 2004. There was no evidence whatsoever that the cartel still operated. Hence, the market condition changed toward more competition. Blanckenburg and Geist (2009), confirm this, finding fiercer competition after 2002.

Ready-mix concrete cartel

The last cartel case used in this study is that of the ready-mixed concrete industry. This was actually not one cartel but many regional cartels. This is because the physical properties of ready-mixed concrete limits transport time to roughly 60 minutes after a truck is filled.[7] However, the entire German market was governed by regional cartels. The cartels were organized as quota-cartels that specified the share for each participating firms within the regional market. As typical for illegal cartels, regular meetings were established in order to monitor and govern the activities of all involved parties, as for instance proved in the case of the Berlin ready-mixed concrete cartel (KRB 2/05). As established by the courts, most cartels in the West were formed around 1990, the ones in East Germany around 1995 (Drucksache 14/6300; Drucksache 15/1226).

The first cartel was uncovered in May 1999 in Greater Berlin. Additional cartel inquests were opened against companies in the federal states of Sachsen-Anhalt and Niedersachsen. Consequently the Federal Cartel Office initially charged 69 companies in 29 consortiums with a cartel fine of 370 million Deutsch Mark (189 million Euros). With evidence found in these cases and additional information, the cartel office carried out a nationwide search and seizure of 48 companies in March 2000. Moreover, as a result of the cartel inquiry on the cement market, some of the cement companies cooperated with cartel offices and

[7] This information comes from the umbrella association of German ready-mix concrete industry. For further information on the specifics of ready-mixed concrete market see also Syverson (2008)

passed further information about the ready-mixed concrete regional cartels to the authorities. This allowed the authorities to open new cases against 70 ready-mixed concrete companies all over Germany. The legal dispute lasted until 2005 when the Federal Supreme Court followed the Federal Cartel Office in all main cases and stated that the participating companies had established and operated illegal cartels, with the last cartel uncovered in 2001. (Drucksache 16/5710; KRB 2/05). Thus, roughly 140 companies were convicted with a fine of approximately 167 million Euros.

In the meantime the sector saw major changes. On the one hand, due to high overcapacity many companies closed (Drucksache 16/5710). Two major players, Larfarge and Hanson, completely stopped its market engagement. Moreover, the Cartel Office approved 136 mergers between 2002 and 2006, which were seen as a result of a fierce competition while the market struggled with overcapacities and declining sales. Moreover, State and Federal Cartel Offices approved structural-crisis-cartels or cartels of small and medium-sized enterprises under supervision of the cartel authorities ("Mittelstandskartell") in some regional market in order to support the regular capacity reduction and the process of adjusting to the new market conditions (Drucksache 15/1226; Drucksache 15/5790; Drucksache 16/5710).

These three cartels meet our defined analysis needs. Each was large enough to influence competition at the national level and included all major suppliers and producers while producing homogenous goods. All three cartels had illegal organizational structures and formal cartel agreements needed to coordinate participating firms. Hence, it is expected that collusion without such a structure is not as effective. Therefore, we expect fiercer competition without such an organizational structure. Finally, all were heavily fined due to the extent of the distorted competition.

4. Data

The data is taken from the German Cost Structure Census (*Kostenstrukturerhebung)* and the German Production Census (*Produktionserhebung*). Each dataset was gathered and complied by the German Statistical Office (*Statistisches Bundesamt*) over the period 1995-2006. Plant level data is merged to firm level data using a common identifier. The strength of the dataset is its sample coverage and reliability of information. It covers almost all large German manufacturing firms with 500 or more employees over the entire time span. Firms with fewer than 500 employees are included as a random subsample that is designed to be representative for

the small firm segment as a whole in every industry.[8] Only firms with 20 or more employees are covered.[9]

The Cost Structure Census contains information on several input categories, namely payroll, employer contributions to the social security system, fringe benefits, expenditures for material inputs, self-provided equipment, goods for resale, energy costs, external wage-work, external maintenance and repair, tax depreciation of fixed assets, subsidies, rents and leases, insurance costs, sales tax, other taxes and public fees, interest on external capital as well as "other" costs such as license fees, bank charges and postage, or expenses.[10] Finally, the German Production Census gives detailed information about the number of products produced, approximated by the nine-digit product classification system (*Güterverzeichnis für Produktionsstatistiken*) of the Federal Statistical Office. This variable gives us as an important element to identify the relevant sectors.

All previously mentioned studies followed Boone (2008a) and analyzed the competition based on three digit sector classification. With our rich dataset we are able to focus on a four digit sector and goods classifications, defining the respective markets even more detailed than any previous analysis. As discussed above, these are the power cable sector (WZ 3130), the cement sector (WZ 2651) and the ready-mix concrete sector (WZ 2663). Each of these sectors is characterized by a relatively homogeneous good. In order to guarantee relatively comparable companies, we only look at companies which have at least 75 percent of their overall turnover in one of these sectors. All other companies are dropped.

The sample contains a number of observations with extreme values that proved to impact the calculation of the PCM and the estimation of the Boone-Indicator. Therefore, we exclude observations from the analysis for which the cost for a certain input category in relation to gross value added fall in the upper or lower one percentile of the sample per year.

According to Boone, we calculate profit by subtracting variable costs from revenue. Hereby, we define revenue as revenue out of self produced goods. Hence, it does not include revenues out of other activities like renting or trading operations. The variable costs contain 'consumption of raw materials', 'energy', 'gross wages', 'legal and additional social insurance contributions', 'costs for contract workers' and 'costs of repairs'. Following Boone (2008a) we calculate two different measures for efficiency, i) average variable costs, which we define as total variable costs per sales and ii) labor productivity, defined as gross value

[8] Samples are drawn in 1995, 1997, 1999 and 2003.
[9] In some particular industries, even firms with less than 20 employees are included as a random draw.
[10] For more information about the Cost Structure Census surveys in Germany, we refer the reader to Fritsch et al. (2004).

added per employee. Additionally we also use sales per employee as a third measure for efficiency. Descriptive statistics for the variables are presented in Table 3.

5. Empirical Investigation

We present our analysis in three steps. First, we present the parametric approach to apply Boone's idea and discuss its main drawbacks. In a second step we apply the Boone-Indicator as theoretically defined on real data. We discuss its drawbacks and propose an augmented indicator correcting for firm size. Finally, we use the above described cartel cases as natural experiments to test for the empirical applicability of the Boone-Indicators and compare its performance with that of the traditional PCM.

5.1. Discussion and Modification of the Boone-Indicator

Before the indicators are tested using the cartel cases, we briefly discuss the applicability of the indicator on real word data. Griffith et al. (2005) was the first to propose a regression of average variable costs on logarithmized profits. This is based on the idea behind the Boone-Indicator that the more efficient a company becomes the greater the profit should be, *ceterus paribus*. Since marginal costs are unobservable, average variable costs (AVC), defined as total variable costs divided by sales, are taken as a crude proxy for marginal costs. They are also used to assess firm efficiency. The estimated beta-coefficient measures the profit elasticity of the respective firms. More precisely, "…it measures the percentage decrease (increase) in firm *i*'s profit if its variable costs (i.e. marginal costs relative to price) increase (decrease) by one percentage *point*." (Griffith et al. 2005: 6). Since the relationship between profits and average variable costs must be negative, the estimated coefficient needs to be negative. As competition intensifies, the slope of the regression should become even more steeply negative, following the idea that inefficient firms are punished more harshly by fiercer competition.

Although we will calculate RPDs, we also adopt this approach for comparative purpose. However, we follow Creusen et al. (2006) and estimated the elasticity by means of yearly log-log regressions: $\ln(\pi_{ijt}) = \alpha - \beta_{jt} \ln(AVC_{ijt}) + \varepsilon_{ijt}$ with $t = \text{year}$, $i = \text{firm}$ and j=market . Then the coefficient plainly gives the percentage change in profits due to a one percent change in average variable costs. As shown by Boone et al. (2007) with simulations within his theoretical framework, changes in competition are correctly identified by this model.

However, measuring competition this way can cause the usual problems for regression analysis. The problems are well known and therefore we just want to mention one problem directly related to the desired analysis. One task in that analysis is the definition of markets.

The more precisely we can capture a market, the less other factors or markets influence the outcome and the better the subsequent competition estimates should be. On the other hand, the more precisely we size a market, the fewer observations we will have. Moreover, markets with few players are of special interest for competition analysis, but fewer observations decrease stability of regressions. An outlier can have a significant impact on the slope and the significance of the coefficient (Urban and Myerl 2008).

A second problem is related to firm size. As long as we operate under the model's assumptions, the most efficient firm must become the biggest firm in terms of market share and consequently, due to its efficiency level, it also must make the greatest profit. With respect to linear regression analysis we must consider that in reality big firms are not necessarily the most efficient ones and thus, it is possible to find a nonnegative beta-coefficient.[11]

In addition to the regression analysis that is usually used to apply the Boone idea on real data, this paper tries to estimate the RPDs. Initially we assess the efficiency of firms in a one-dimensional and transitive way. Following Boone (2008a) we use the average variable costs, defined as total variable costs per sales $(TVC/sales)$ and labour productivity, defined as gross value added per employee $(VA/employee)$ as efficiency index N. We add sales per employee $(sales/employee)$ as a third measure. Than the RPDs are calculated for each market (j) and each firm (i) in every year (t) as:

$$RPD_{ijt}(n) = \frac{\pi_{ijt}(n) - \pi_{ijt}(n')}{\pi_{ijt}(n'') - \pi_{ijt}(n')} \quad \text{with } t = 1,\ldots,T,\ j = 1,\ldots,J \text{ and } i = 1,\ldots,I\ ,$$

where profits are defined as sales minus total variable costs $(\pi_{ijt} = S_{ijt} - TVC_{ijt})$. The RPD can only take values between zero and one, with one for the most efficient and zero the least efficient firm. The efficiency of the firms is normalized via $(n - n')/(n'' - n')$.

As the example in Figure 2 reveals, which depicts the RPDs for the cable industry (4 digit classification) in 2006, plainly applying this model on real world data is not sufficient.[12] The RPDs are located between roughly 30 and -1, while we should see a scatter plot within the boundaries of zero and one. We do have the most efficient firm located at the coordinate (1,1) as it should be. However that firm has a profit below many of its competitors and it follows $(\pi_{ijt}(n) - \pi_{ijt}(n')) \geq (\pi_{ijt}(n'') - \pi_{ijt}(n'))$. Thus, the RPD can take values above one for less effi-

[11] That both, size and few observations can have an impact is not just a theoretical problem as the results of Griffith et al. (2005) show.

[12] In this example the efficiency is defined by average variable costs. However, we can show further examples with labour productivity.

cient firms. At the same time we have a least efficient firm, which has a profit above that of other firms, resulting in negative numerators for these observations.

< insert Figure 2 about here >

This happens due to firm size. Obviously in the real world there are firms that are really efficient, no matter of how efficiency is captured, but they can be small, at least at certain point in time. On the other hand, large companies may not be as efficient, but because of the larger size, the firms make larger profits. To overcome this problem the RPD must be calculated taking firm size into account. This can be done by means of number of employees or sales. However, applying workforce to normalize profits does not give a good fit. We still have RPDs significantly below zero and above one (Table 2), regardless of the efficiency index used. This might be caused by a weakness of the data set. It lacks information about the number of temporary workers and for how long they stayed in the company, but we know through a costs category that some firms used temporary workers. This biases the profits for the respective firms as well as the efficiency if labour productivity and sales per employee is applied. Therefore we do not use workforce in the calculation of the efficiency or to normalize profits. Instead, in the subsequent analysis profits will by normalized by sales, which is turnover out of the core business without trading or other activities. Thus, the RPD is calculated as:

$$RPD_{ijt}(n) = \frac{\pi_{ijt}(n)/sales_{ijt} - \pi_{ijt}(n')/sales_{ijt}}{\pi_{ijt}(n'')/sales_{ijt} - \pi_{ijt}(n')/sales_{ijt}}$$

For the efficiency index we apply the average variable costs. In order to estimate the area under each curve we use the Data Envelopment Analysis (DEA). It is a nonparametric method that envelops the scatter plot at its outer boundary. We abstain from presenting the method here and refer the interested reader to Canter et al. (2007) for a concise introduction and to Simar and Wilson (2005) for a detailed discussion. Given the estimated curve we are able to derive the corresponding area by integration.

5.2. Results

Given the above defined RPD we proceed with testing the validity of the Boone-Indicator using the cartel cases. For this end we estimate the PCM of each firm as proposed by Boone (2008a), and aggregate them into yearly industry PCMs using market share as the weight. The market share is derived as the share of the firm sales on industry sales in a year. Further, we

estimate the BI as beta coefficients of the above outlined regression approach (afterwards also called parametric indicator). Finally, we calculate the modified RPDs and the respective areas as discussed above (also called nonparametric indicator). The change in competition is measured by subtracting the respective indicator in the base period from itself in the reference period. Regardless of the indicator under consideration, a positive result shows an increase in competition between the periods. A negative result on the other hand indicates decreasing competitive pressure over time.

We used Welch's t-test for evaluating the significance of changes in PCM since it accounts for unequal variances in two samples. The same test is applied when comparing the beta coefficients. However, the test can only be applied if both of the beta coefficients are significant on there own. Otherwise, we depict just the difference labelling it as not significant. Since the level of competition by means of RPDs is measured as area, tests based on means and variances can not be applied. Therefore, the significance of differences between the areas is calculated applying the nonparametric Wilcoxon rank-sum test on the underlying RPDs.

Given the estimates and tests, we can use the cartel events to derive the validity of the indicators. As discussed in section 3 we expect fiercer competition in the aftermath of the uncovering of a cartel. Hence, we look at the estimated changes in competition after such an event compared to periods before the event. When possible, we look at the three years after and the three years before the cartel case. The year of the event is not taken into consideration, because the effect on the competition level in that year is not straightforward since we only have annual data. The relevant biannual differences are presented in Table 4 to Table 6.

The first cartel we take a look at is the cable cartel. The cartel was uncovered in 1996. Due to time limitations in our dataset we can only compare the changes in competition between 1995 and 1997 to 1999. Looking at the Lerner Index (Table 6), in all of the respective biannual comparisons we see positive differences where two out of three of these differences are significant. Thus, the PCMs indicate the expected increase in competition. The nonparametric measure (Table 5) also indicates fiercer competition in the years 1997 to 1999 compared to 1995, although just one of the differences is significant. The differences in elasticities (Table 4) on the other hand are positive and negative, thus signalling decrease and increase in competition after the cartel was terminated. However, the betas are not significantly different. This is caused by the fact that the beta coefficient in 1995 is not significant at a 10 percent level. Even if we ignore this fact and test for significant differences in betas, we find all changes to be significant, not only the positive difference. Thus with respect to the aim of this paper we must state that PCM and the nonparametric indicator behaved as expected, indicating

fiercer competition in the aftermath of the termination of a cartel. In contrast, the parametric indicator did not behave as expected.

Looking at the cement cartel, we find similar results as for the cable cartel. As discussed above, the cartel was uncovered in 2002, thus, we evaluate the changes in competition of the period 1999 to 2001 against 2005 to 2006.[13] Again, the weighted PCMs signal fiercer competition after the event, where all results are significant. Yet, it is now the parametric indicator signaling fiercer competition without exception and with all changes significant. To a certain degree the area changes also indicate fiercer competition. Unfortunately none of the changes are significant. Thus, although we only find positive values indicating fiercer competition, with the absence of significance we must record that the nonparametric indicator shows no change in competition after the cement cartel was terminated.

Finally we look at the ready-mixed concrete cartels, where the first one was uncovered in 1999 while the last one stopped its activity in 2001 as discussed before. We therefore define the period 1996 to 1998 as base period and 2002 to 2004 as reference period. As presented in Table 6, the PCMs differences again show the expected sign and are all significant. The parametric indicator on the other hand is pointing to the opposite direction. All differences are negative and at least two are significant. If we overlook the insignificants of the 2003 and 2004 betas and test for differences, six out of nine negative differences would be significant. The parametric indicator actually suggests weaker competition in the aftermath of the termination of the ready-mixed concrete cartels. The nonparametric indicator is not performing better. Although seven out of nine biannual comparisons are positive, pointing toward fiercer competition, two are negative and no change is found to be significant.

< insert Figure 3 about here >

Figure 3 summarizes the main findings, depicting the direction of changes in competition with and without taking the significance of the changes into account. Here it is especially interesting that the parametric Boone measure points just once in the expected direction, regardless of significance. The nonparametric indicator, on the other hand, fails just once if we ignore significance. Indeed, if we look closely at that unexpected outcome we find seven biannual differences out of nine signalling fiercer competition, thus pointing into the expected direction.

[13] There are to few observations in 2003 and 2004 after running the outlier detection, so that we could not use this years due to the data protection rules of the FDZ.

6. Conclusion

Using a rich newly built data set for German manufacturing enterprises, we test the empirical validity of the Boone-Indicator. This is a new competition measure that, from its theoretical properties, proved to be more robust than the Lerner-Index (also called PCM). The proof of its empirical practicability and robustness is missing, however. This paper aims to shed light on that question. To this end we use large cartel cases as events to compare the indicated competition levels before and after a cartel was uncovered and stopped operating. Since all of the chosen cartels significantly restricted market competition, we expected fiercer competition in the aftermath of the debunking of a cartel.

In the actual analysis we compare the performance of three competition measures. The first is the Lerner-Index as a classical measure of competition. The second is the Boone-Indicator calculated as beta coefficient of a log-log regression, as proposed by Boone et al. (2007) and various other authors. Finally the Boone-Indicator derived by means of Relative Profit Differences (RPD) is calculated using real data for the first time.

Our analysis reveals that the latter cannot be applied to real data as theoretically defined. This is because the relationship between the efficiency of a firm and its profit level is not as designed in Boone's theoretical framework, where the most efficient company is always, by design, the biggest firm in terms of market share. Our results suggest that this relationship does not hold in reality. Therefore we propose a way to account for firm size in the calculation of RPDs.

With respect to the performance of the indicator in the face of uncovered cartels we note that the Lerner-Index performed as expected. In every case it indicated fiercer competition in the aftermath of a cartel case with almost all biannual comparison to be significant. Hence, although not theoretically robust, in this analysis it proved its empirical usefulness. This we cannot state for the two Boone-Indicators, in particular the regression approach. Regardless of whether or not we account for the significance of changes and betas, the indicator just once indicates fiercer competition. This supports our doubts regarding this approach. The Boone-Indicator based on RPDs also does not perform as well as the Lerner-Index. This is mainly because the changes are often not significant. Leaving significance aside, the Boone-Indicator by means of RPD and taking firm size into account perform almost as well as PCM.

Based on our findings we conclude that the Boone-Indicator, although theoretically superior, is, at least at this stage, not an empirically robust indicator. The Lerner-Index on the other hand indicates changes in competition as expected. However, the results of the RPD

based Boone-Indicator are promising. Future research should focus on alternative methods to account for firm size while keep the original variation of the profit levels.

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Appendix

Figure 1: Fiercer competition and RPD[14]

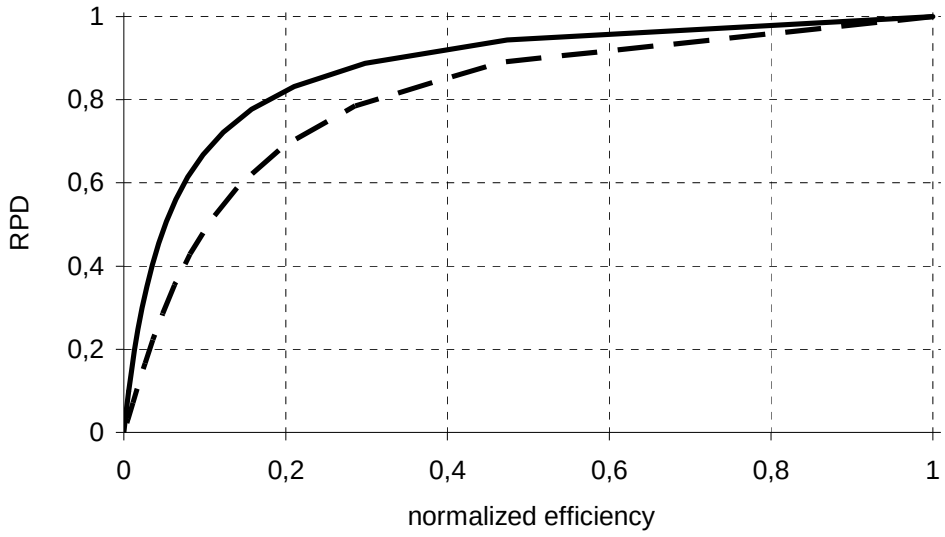
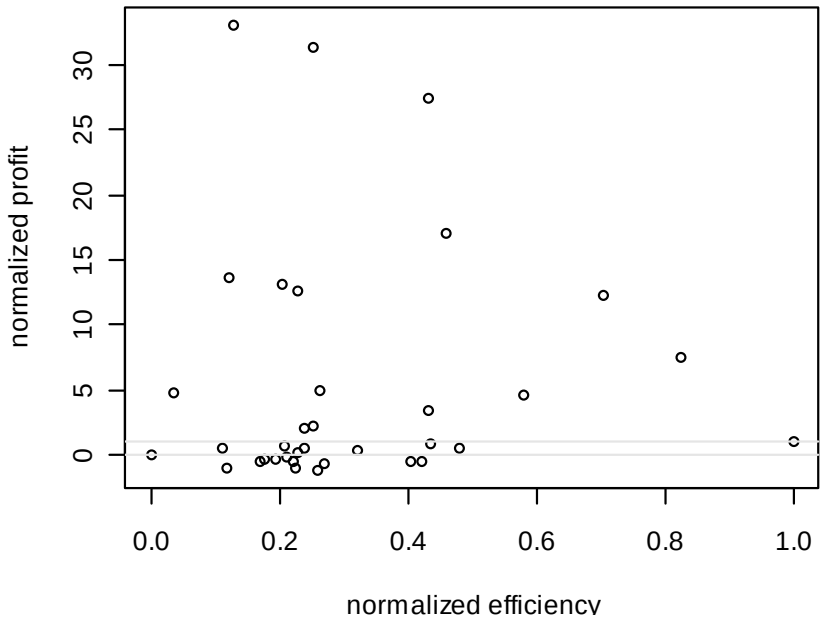


Figure 2: RPDs for cable industry in 2006[15]



[14] We apply the same demand function as in the example of table 1. We have 20 firms in the beginning with constant marginal costs of $c_i = i/10$. There are no entry costs, $a = 20$, $b = 2$ and d increases from 0.1 to 2. The solid line captures the RPDs in situation one, hence with low intense competition due to a d of 0.1, while the dotted line is with $d = 2$. To overcome the problem that appears if the least efficient firm is assessed, which means dividing by zero, we calculate inverse RPDs, hence: $\left(\pi(n,\theta) - \pi(n',\theta)\right) / \left(\pi(n'',\theta) - \pi(n',\theta)\right)$. The normalized efficiency is calculated as: $\left(n - n'\right) / \left(n'' - n'\right)$ with $n'' \geq n \geq n'$

[15] The efficiency was measured by average variable costs.

Figure 3: change in competition after the termination of the cartels[16]

Industry (4-digit classification)	Event	PCM	Boon-Indicator log. regression	RPD	PCM	Boon-Indicator log. regression	RPD
power cable (3130)	1996	↑*	→*	↑*	↑	→	↑
cement (2651)	2002	↑*	↑*	→*	↑	↑	↑
ready-mixed concrete (2663)	1999-2002	↑*	↓*	→*	↑	↓	→

[16] * marks the direction changes in competition that take significance into account.

Table 1: The reallocation effect and how it affects PCM and RPD[17]

	PCM1	PCM2	PCM3	Weighted Industry PCM	RPD3
d=0.1	0.950	0.587	0.465	0.680	0.262
d=2	0.939	0.385	0.139	0.717	0.149

Table 2: Mean absolute deviation of RPDs form the boundaries of One and Zero for different efficiency measures and normalized profits[18]

	labor productivity			sales per employee			total average variable cost		
sectors	2651	2663	3130	2651	2663	3130	2651	2663	3130
years	profit normalized by number of employees								
1995	0.15	0.144***	0.122*	0.372**	0.068***	0.128*	-	0.293***	0.03
1996	0.081	0.002	0.27	0.129	0.002	0.27	-	0.031	0.006
1997	0.389	0.027	0.139***	0.389	0.027	0.139***	-	0.226***	0.063
1998	0.041	0.39***	0.348***	0.041	0.39***	0.348***	0.124	0.045**	0.509***
1999	0.411	0.014**	0.258	0.411	0.014**	0.258	-	0.026***	0.881***
2000	0.531	0.062**	0.154***	0.531	0.062**	0.154***	0.062	0.082	1.88***
2001	0.158	0.02	0.316***	0.158	0.02	0.316***	0.126**	0.199**	1.214***
2002	0.236	0.085**	-	0.236	0.085**	-	-	0.04	0.088***
2003		-	0.008**		0.02	0.008**		0.052	0.233*
2004		0.062**	0.084**		0.062**	0.088		0.53**	0.11**
2005	0.094	0.067**	0.065*	0.094	0.067**	0.075*	0.163	0.351**	0.071***
2006	0.554*	0.03	0.011	0.554*	0.03	0.011	2.225*	0.326*	0.353***
years	profit normalized by sales								
1995	4.326***	1.8***	0.517***	4.326***	5.191***	0.783***	-	-	-
1996	0.45**	0.477***	1.018***	0.45**	0.477***	1.018***	-	-	-
1997	0.169	0.303***	0.27***	0.169	0.303***	0.27***	-	-	-
1998	0.222***	0.064***	0.605**	0.222***	0.064***	0.605**	-	-	-
1999	0.903**	0.541***	13.839***	0.903**	0.375***	13.839***	-	-	-
2000	7.21***	24.66***	0.544***	0.052	24.66***	0.544***	-	-	-
2001	1.176***	0.321***	5.213***	1.176***	0.321***	5.213***	-	-	-
2002	0.787**	6.764***	0.759***	0.787**	6.764***	0.759***	-	-	-
2003		0.541***	32.276***		0.61***	32.276***		-	-
2004		2.585***	0.292***		2.585***	1.615***		-	-
2005	2.035	0.862***	6.725***	2.035	0.862***	8.964***	-	-	-
2006	0.661	0.211	0.488***	0.661	0.308	0.488***	-	-	-

Note: *** 1% significance level, ** 5% significance level, * 10% significance level, - no observation below

[17] The demand function is $p(x_i, x_{-1}) = a - bx_i - d\sum_{j \neq i} x_j$ and is taken from Boone (2008b). We apply a=20, b=2 and marginal costs are c_1=0.5, c_2=5 and c_3=7. The substitutability is captured by d, where the quotient $d/b = 1$ for perfect substitutes.
We do not report the RPD for the most and the least efficient firm since they have to be one and zero at both times by definition.

[18] The table shows the absolute mean deviation of observed RPDs. The t-test was applied to test the significance of the deviation.

Table 3: descriptive statistics of applied variables

	years	labor productivity			sales per employee			average variable cost			profit per employee			profit			profit per sales		
		N	mean	stdev	N	mean	stdev	N	mean	stdev	N	mean	stdev	N	mean	stdev	N	mean	stdev
cement (2651)	1995	12	275941.51	129813.93	12	250929.88	135268.84	12	0.649	0.098	10	83120.21	28026.36	10	24654701.55	17453737.68	10	0.357	0.072
	1996	14	265036.62	127948.35	14	249585.34	130711.21	14	0.629	0.105	12	88773.66	32464.45	12	22778734.13	15832666.98	12	0.377	0.076
	1997	12	276189.53	145353.94	12	261612.75	150995.23	12	0.687	0.137	10	74634.88	39439.96	10	16802487.80	16717070.01	10	0.307	0.123
	1998	15	278276.44	156382.50	15	270103.39	156462.29	15	0.698	0.168	13	76120.76	46540.80	13	14735482.19	15604300.49	13	0.303	0.155
	1999	11	274748.10	134320.53	11	270853.22	131465.84	11	0.642	0.117	9	88671.80	41351.98	9	14200256.44	5614375.85	9	0.354	0.088
	2000	10	288927.17	146704.66	10	282349.24	148575.94	10	0.636	0.128	8	88255.96	32752.75	8	13883868.00	6443732.38	8	0.365	0.102
	2001	11	270489.54	119815.39	11	263364.86	119862.98	11	0.621	0.087	9	90750.26	36495.89	9	14446138.39	5230236.09	9	0.373	0.046
	2002	10	245045.22	121731.84	10	236704.63	114060.71	10	0.697	0.143	8	67226.60	32639.25	8	11084038.59	5612858.25	8	0.295	0.118
	2003	5	300541.35	149883.91	5	296174.19	140902.28	5	0.806	0.127	3	-	-	3	-	-	3	-	-
	2004	6	309138.85	164345.12	6	302090.05	155287.22	6	0.750	0.109	4	-	-	4	-	-	4	-	-
	2005	8	294208.58	130545.15	8	290029.69	131093.51	8	0.774	0.082	6	66548.27	36666.66	6	6636015.96	2810269.67	6	0.229	0.052
	2006	9	324927.22	146052.86	9	316989.06	140402.72	9	0.789	0.092	7	65738.91	26572.20	7	6262759.34	4123335.23	7	0.212	0.063
ready-mixed concrete (2663)	1995	54	251117.62	129036.76	54	233626.90	101980.56	54	0.747	0.109	52	60371.38	38170.91	52	2616140.67	1988239.08	52	0.251	0.100
	1996	53	254805.13	113837.36	53	244309.09	111584.94	53	0.753	0.093	51	61082.96	39192.39	51	2814139.71	2323074.70	51	0.246	0.085
	1997	49	273992.96	123699.78	49	255339.73	120220.88	49	0.753	0.099	47	66414.15	42546.41	47	3313806.18	4237861.19	47	0.247	0.091
	1998	48	279176.87	124248.85	48	261529.14	118127.47	48	0.765	0.090	46	64148.75	42623.48	46	3771510.86	4739668.24	46	0.233	0.081
	1999	52	274033.77	116433.09	52	253774.86	107210.53	52	0.760	0.102	50	63797.39	38075.43	50	3210729.85	3239263.76	50	0.240	0.092
	2000	42	251756.12	102335.12	42	233123.35	92110.32	42	0.789	0.086	40	46870.18	21091.43	40	2815013.48	2825058.13	40	0.208	0.075
	2001	41	244960.06	98983.09	41	225744.35	85260.38	41	0.828	0.090	39	36569.27	19329.71	39	1822365.37	1883094.22	39	0.172	0.083
	2002	34	241576.69	103036.93	34	225902.39	91855.19	34	0.810	0.089	32	40494.91	19379.63	32	2089801.49	1478034.08	32	0.188	0.080
	2003	33	261039.86	162679.94	33	241767.11	159280.52	33	0.791	0.115	31	47589.03	32841.38	31	2120169.47	1820009.56	31	0.207	0.102
	2004	28	264242.60	159316.55	28	245730.82	153393.66	28	0.771	0.101	26	55913.14	42054.17	26	2660461.54	2640251.05	26	0.227	0.089
	2005	27	248869.77	160936.75	27	231151.24	156099.15	27	0.793	0.107	25	47970.41	35245.75	25	2294912.86	2396800.51	25	0.205	0.095
	2006	25	262554.37	151372.94	25	243909.69	140061.37	25	0.776	0.101	23	52561.25	34258.02	23	2930521.63	3296418.43	23	0.222	0.082
power cable (3130)	1995	27	137050.79	81077.73	27	131736.93	77630.07	27	0.793	0.137	25	27518.89	25609.48	25	2837311.25	3734492.90	25	0.198	0.110
	1996	32	125834.14	70994.28	32	122574.71	71751.78	32	0.800	0.130	30	24678.87	22063.71	30	2748478.84	4123596.11	30	0.193	0.109
	1997	27	157486.33	112253.24	27	155005.09	112373.79	27	0.804	0.134	25	25687.72	17474.33	25	3780242.70	5024262.03	25	0.188	0.111
	1998	27	175971.06	108371.88	27	171222.35	104395.73	27	0.804	0.119	25	28747.07	15826.69	25	3900144.49	4740320.96	25	0.191	0.099
	1999	40	135041.67	95481.60	40	127359.11	91574.56	40	0.823	0.097	38	20127.21	14699.69	38	2613762.00	4875401.33	38	0.174	0.085
	2000	46	143254.13	109120.80	46	134039.37	104077.61	46	0.809	0.109	44	22639.76	17189.35	44	3048404.80	6402232.59	44	0.183	0.079
	2001	43	156818.27	112995.34	43	141924.92	103674.28	43	0.810	0.121	41	24764.81	20117.29	41	7958490.43	23292462.10	41	0.180	0.076
	2002	39	120835.79	85302.58	39	113354.50	78258.16	39	0.813	0.089	37	20792.55	14417.71	37	2635375.63	5314750.34	37	0.187	0.083
	2003	32	185344.88	113356.04	32	172921.88	108741.88	32	0.823	0.092	30	28691.09	20712.85	30	4294877.94	6179956.47	30	0.172	0.076
	2004	33	184921.04	127967.38	33	169483.13	116443.65	33	0.839	0.083	31	24552.29	17225.56	31	3314602.39	4756077.99	31	0.157	0.068
	2005	35	201946.92	145788.62	35	179365.03	128275.93	35	0.826	0.098	33	28986.68	21380.44	33	3395725.65	4787847.22	33	0.171	0.089
	2006	37	221277.66	195301.91	37	197897.10	180639.40	37	0.827	0.092	35	28875.81	21964.10	35	3297811.57	4226426.49	35	0.171	0.080

Table 4: differences in beta over time

	years	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
cement (2651)	1995	-1.039**	-0.538	-0.521	-2.293***	-2.149***	-2.587***	-1.851***	-	-	-0.723	2.611***
	1996	-	0.501*	0.518*	-1.254***	-1.11***	-1.548***	-0.812*	-	-	0.316	3.65***
	1997	-	-	0.017	-1.755***	-1.612***	-2.049***	-1.313***	-	-	-0.185	3.149***
	1998	-	-	-	-1.772***	-1.628***	-2.066***	-1.33***	-	-	-0.202	3.132***
	1999	-	-	-	-	0.144	-0.294	0.442	-	-	1.57**	4.904***
	2000	-	-	-	-	-	-0.437	0.298	-	-	1.426**	4.76***
	2001	-	-	-	-	-	-	0.736*	-	-	1.864***	5.198***
	2002	-	-	-	-	-	-	-	-	-	1.128*	4.462***
	2003	-	-	-	-	-	-	-	-	-	-	-
	2004	-	-	-	-	-	-	-	-	-	-	-
	2005	-	-	-	-	-	-	-	-	-	-	3.334***
ready-mixed concrete (2663)	1995	0.361***	1.409***	2.009***	1.291***	-1.271	1.284***	0.228	-1.13	-0.065	-0.144	-3.32
	1996	-	1.049***	1.648***	0.931***	-1.632	0.924***	-0.132	-1.491	-0.426	-0.504	-3.68
	1997	-	-	0.6***	-0.118	-2.68	-0.125	-1.181***	-2.539	-1.474	-1.553	-4.729
	1998	-	-	-	-0.718***	-3.28	-0.725***	-1.78***	-3.139	-2.074	-2.152	-5.329
	1999	-	-	-	-	-2.562	-0.007	-1.063***	-2.421	-1.357	-1.435	-4.611
	2000	-	-	-	-	-	2.555	1.499	0.141	1.206	1.127	-2.049
	2001	-	-	-	-	-	-	-1.056***	-2.414	-1.349	-1.428	-4.604
	2002	-	-	-	-	-	-	-	-1.358	-0.294	-0.372	-3.548
	2003	-	-	-	-	-	-	-	-	1.065	0.987	-2.19
	2004	-	-	-	-	-	-	-	-	-	-0.078	-3.255
	2005	-	-	-	-	-	-	-	-	-	-	-3.176
power cable (3130)	1995	1.081	-0.859	-1.499	1.364	1.218	3.591	2.131	0.575	-0.53	0.677	-0.612
	1996	-	-1.94	-2.58	0.283	0.137	2.51***	1.05***	-0.506	-1.611	-0.404	-1.694
	1997	-	-	-0.64	2.223	2.077	4.050	2.989	1.434	0.329	1.536	0.246
	1998	-	-	-	2.863	2.717	5.090	3.629	2.074	0.969	2.176	0.886
	1999	-	-	-	-	-0.146	2.227***	0.767*	-0.789	-1.894	-0.687*	-1.977
	2000	-	-	-	-	-	2.373***	0.912**	-0.643	-1.748	-0.541	-1.831
	2001	-	-	-	-	-	-	-1.461***	-3.016	-4.121	-2.914***	-4.204
	2002	-	-	-	-	-	-	-	-1.555	-2.661	-1.453***	-2.743
	2003	-	-	-	-	-	-	-	-	-1.105	0.102	-1.188
	2004	-	-	-	-	-	-	-	-	-	1.207	-0.083
	2005	-	-	-	-	-	-	-	-	-	-	-1.29

Note: *** 1% significance level, ** 5% significance level, * 10% significance level

Table 5: spread between areas over time

	years	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
cement (2651)	1995	-0.011	-0.016	-0.041	-0.01	-0.003	0.024	-0.015	-	-	0.044	0.026
	1996	-	-0.005	-0.03	0.001	0.008	0.035	-0.004	-	-	0.055	0.037
	1997	-	-	-0.025	0.005	0.013	0.04	0	-	-	0.06	0.042
	1998	-	-	-	0.031	0.038	0.065	0.026	-	-	0.085	0.068
	1999	-	-	-	-	0.007	0.034	-0.005	-	-	0.054	0.037
	2000	-	-	-	-	-	0.027	-0.012	-	-	0.047	0.029
	2001	-	-	-	-	-	-	-0.04	-	-	0.02	0.002
	2002	-	-	-	-	-	-	-	-	-	0.06	0.042
	2003	-	-	-	-	-	-	-	-	-	-	-
	2004	-	-	-	-	-	-	-	-	-	-	-
	2005	-	-	-	-	-	-	-	-	-	-	-0.018
ready-mixed concrete (2663)	1995	0.007	0	0.02	0.014	0.015	0.022	0.029	0.011*	0.016	0.01	0.011
	1996	-	-0.006	0.013	0.008***	0.009	0.015	0.022	0.005	0.009	0.003	0.005
	1997	-	-	0.02	0.014**	0.015	0.022	0.029	0.011	0.016	0.01	0.011
	1998	-	-	-	-0.006**	-0.004	0.002	0.009	-0.008	-0.004	-0.01	-0.008
	1999	-	-	-	-	0.001***	0.008	0.015	-0.003**	0.001**	-0.005	-0.003**
	2000	-	-	-	-	-	0.007*	0.014	-0.004	0	-0.006	-0.004
	2001	-	-	-	-	-	-	0.007	-0.011*	-0.006	-0.012	-0.011
	2002	-	-	-	-	-	-	-	-0.018	-0.013	-0.019	-0.018
	2003	-	-	-	-	-	-	-	-	0.004	-0.002	0
	2004	-	-	-	-	-	-	-	-	-	-0.006	-0.004
	2005	-	-	-	-	-	-	-	-	-	-	0.002
power cable (3130)	1995	-0.014	0.01	0.014	0.041**	0.041	0.036	0.043*	0.052	0.052	0.032	0.031
	1996	-	0.024	0.028	0.055***	0.056***	0.05**	0.058***	0.066***	0.066***	0.047	0.045**
	1997	-	-	0.004	0.031**	0.031*	0.026	0.033**	0.042*	0.042*	0.022	0.021
	1998	-	-	-	0.027***	0.027**	0.021	0.029***	0.038**	0.038**	0.018	0.017**
	1999	-	-	-	-	0	-0.005**	0.002	0.011	0.011	-0.009**	-0.01*
	2000	-	-	-	-	-	-0.006	0.002	0.011	0.01	-0.009	-0.01
	2001	-	-	-	-	-	-	0.008*	0.016	0.016	-0.003	-0.005
	2002	-	-	-	-	-	-	-	0.009	0.008	-0.011*	-0.012*
	2003	-	-	-	-	-	-	-	-	0	-0.02	-0.021
	2004	-	-	-	-	-	-	-	-	-	-0.02	-0.021
	2005	-	-	-	-	-	-	-	-	-	-	-0.001

Note: *** 1% significance level, ** 5% significance level, * 10% significance level

Table 6: changes in PCM over time

	years	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
cement (2651)	1995	-0.018	-0.003	0.006	-0.008	-0.016	-0.007	0.05	-	-	0.13***	0.137***
	1996	-	0.015	0.024	0.01	0.002	0.011	0.068	-	-	0.148***	0.155***
	1997	-	-	0.009	-0.005	-0.014	-0.004	0.053	-	-	0.132***	0.139***
	1998	-	-	-	-0.014	-0.022	-0.013	0.044	-	-	0.124**	0.13**
	1999	-	-	-	-	-0.008	0.001	0.058	-	-	0.138***	0.144***
	2000	-	-	-	-	-	0.01	0.066	-	-	0.146***	0.153***
	2001	-	-	-	-	-	-	0.057	-	-	0.136***	0.143***
	2002	-	-	-	-	-	-	-	-	-	0.08*	0.086*
	2003	-	-	-	-	-	-	-	-	-	-	-
	2004	-	-	-	-	-	-	-	-	-	-	-
	2005	-	-	-	-	-	-	-	-	-	-	0.007
ready-mixed concrete (2663)	1995	-0.004	-0.018	-0.008	0.006	0.047***	0.093***	0.079***	0.08***	0.042**	0.053***	0.044**
	1996	-	-0.015	-0.005	0.009	0.051***	0.096***	0.082***	0.084***	0.045**	0.057***	0.047***
	1997	-	-	0.01	0.024	0.066***	0.111***	0.097***	0.098***	0.06***	0.072***	0.062***
	1998	-	-	-	0.014	0.056***	0.101***	0.087***	0.088***	0.05**	0.062***	0.052***
	1999	-	-	-	-	0.042***	0.087***	0.073***	0.074***	0.036*	0.048**	0.038**
	2000	-	-	-	-	-	0.046***	0.031*	0.033*	-0.005	0.006	-0.003
	2001	-	-	-	-	-	-	-0.014	-0.013	-0.051**	-0.039**	-0.049***
	2002	-	-	-	-	-	-	-	0.001	-0.037*	-0.025	-0.035*
	2003	-	-	-	-	-	-	-	-	-0.038*	-0.027	-0.036**
	2004	-	-	-	-	-	-	-	-	-	0.011	0.002
	2005	-	-	-	-	-	-	-	-	-	-	-0.009
power cable (3130)	1995	-0.024	0.055*	0.057*	0.042	0.031	-0.017	0.041	0.053*	0.087***	0.064**	0.087***
	1996	-	0.079**	0.081**	0.066**	0.056*	0.007	0.065**	0.077**	0.112***	0.088***	0.112***
	1997	-	-	0.002	-0.013	-0.024	-0.072***	-0.014	-0.002	0.032*	0.009	0.032
	1998	-	-	-	-0.015	-0.026	-0.074***	-0.016	-0.004	0.03	0.007	0.03
	1999	-	-	-	-	-0.011	-0.059***	-0.001	0.011	0.045***	0.021	0.045***
	2000	-	-	-	-	-	-0.049***	0.009	0.021	0.056***	0.032*	0.056***
	2001	-	-	-	-	-	-	0.058***	0.07***	0.105***	0.081***	0.105***
	2002	-	-	-	-	-	-	-	0.012	0.047***	0.023	0.047***
	2003	-	-	-	-	-	-	-	-	0.035**	0.011	0.035**
	2004	-	-	-	-	-	-	-	-	-	-0.024	0
	2005	-	-	-	-	-	-	-	-	-	-	0.024

Note: *** 1% significance level, ** 5% significance level, * 10% significance level