Semicollusion in the Norwegian cement market

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Abstract

A model of semicollusion, where firms collude on prices and compete on capacities, is tailor-made to the characteristics of the Norwegian cement market and tested on this particular market for the period 1927–1982. The results indicate that the rapid increase in capacity and thereby in exports in the period 1956–1967, the late phase of the price cartel, best can be explained by the market-sharing agreement: each firm overinvested in capacity to receive a large quota in the domestic market. © 1999 Elsevier Science B.V. All rights reserved.

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One might ask how the production of cement in a small country such as Norway became so much larger than the domestic consumption… Gartmann (1990, p. 247).

1. Introduction

According to conventional wisdom, collusion on prices benefits the colluding firms (see, e.g., Tirole, 1988, Chapter 6). Fershtman and Gandal (1994) question

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this conclusion. They argue that collusion on prices triggers more aggressive competition along other dimensions. Such behaviour, referred to as semicollusion, may yield lower overall profits than if no collusion at all.\(^1\) The purpose of this paper is to extend the capacity model presented in Fershtman and Gandal (1994) and test it on the Norwegian cement market.

There are several empirical studies focusing on non-price competition.\(^2\) Roberts and Samuelson (1988) investigate advertising competition in the American cigarette industry. In contrast to our work, they do not test for the relationship between the firms’ pricing policy and the nature of non-price competition. Rosenbaum (1989) tests this relationship for the U.S. aluminium industry. He finds that excess capacity has a positive impact on price–cost margins. Our focus, though, is on the opposite mechanism: how price collusion affects capacity investments. As far as we know, there are no empirical studies of the investment effects of price collusion. However, anecdotal evidence suggests that price collusion do have a pro-competitive effect along other dimensions.\(^3\)

This is what we have set out to test.

In 1923 cement producers in Norway established a common sales office. The sales office determined the domestic sale, and it set quotas according to each firm’s capacity. The residual production was exported to the world market. The domestic demand grew substantially after World War II. The increase in total capacity was even larger, and led to an increase in exports. In the late 1960s 40% of the domestic production was exported. The cartel agreement lasted until 1968, when the three firms merged and established the firm Norcem. During the 1970s Norcem gradually closed down capacity, and in the early 1980s the domestic capacity was equal to domestic demand.

To tailor the model to the characteristics of the Norwegian cement market, we extend the capacity model in Fershtman and Gandal (1994). We allow the firms to sell at an export market. They are price takers at the export market, and price setters in the domestic market. Non-cooperative capacity setting is followed by

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\(^1\) All the studies of semicollusion assume collusion in the product market (either on prices or quantity) and competition along other dimensions. Competition on capacity is analysed in Fershtman and Muller (1986), Osborne and Pitchik (1987), Davidson and Deneckere (1990), Matsui (1989) and Fershtman and Gandal (1994); competition on R&D is analysed in Katz (1986), D’Aspremont and Jacquemin (1987), Kamien et al. (1992) and Fershtman and Gandal (1994); competition on location is analysed in Friedman and Thiss (1993). For a survey of the literature, see Fershtman and Gandal (1994) or Philips (1995, chapters 9 and 10).

\(^2\) For a survey, see Bresnahan (1989) or Slade (1996).

\(^3\) According to Scherer (1980), in the 1920s and 1930s price collusion led to intense rivalry on advertising in the American cigarette industry while it led to the installing of excess capacity in the German cement industry. The existence of cartels in the domestic Japanese market, where quotas were allocated according to relative capacity, led to excess capacity in many Japanese industries during the 1950s and 1960s (see Matsui, 1989).
cooperative price setting domestically, and the residual production is exported. Each firm’s domestic quota is determined by its share of total capacity. It is shown that the size of the domestic market, as well as costs and the export price, is decisive for whether the price cartel results in a domestic capacity in excess of domestic demand and thereby export or not. For example, a large domestic demand will make it profitable to install a large capacity and thereby to receive a larger share of that large domestic market. This counterintuitive effect – an increase in domestic demand results in an increase in exports – is labelled the semicollusion effect. We test whether this effect has been present in the Norwegian cement cartel.

We exploit a unique annual data set for the period 1927–1982. The overall econometric results of the models are good. The export-supply models account for important effects as the World War II and Norwegian post war regulations, and the results are shown to be robust with regard to different specifications of marginal costs. The results indicate that the semicollusion effect is present in the late cartel phase (1956–1967), and thus triggered by the large size of the domestic market. Furthermore, the tests suggest that marginal cost has no or a less significant impact on exports in the early cartel period and in the post-merger monopoly period than in the late cartel period. This is in line with our predictions, since costs have no effect on the distribution of sale between the domestic market and the export market in periods with capacity above the equilibrium level.

In the next section, we formulate the model. In Section 3 we construct the industry hypotheses, while we in Section 4 formulate the econometric models and report the results from the empirical tests as well as discussing the results. Section 5 concludes the paper. The proofs of the propositions are relegated to Appendix A, the data sources and the variable definitions used are described in detail in Appendix B.

2. The model

Let us consider three firms, located in one domestic market, offering an identical product. They can sell the product in the domestic market, as well as exporting it to the world market. The three firms are price takers at the world market. We let $W$ denote the net export price, i.e., f.o.b. export price, and $D(P)$ the domestic demand as a function of the domestic price $P$. The inverse demand function in the domestic market is

$$P = A - Q.$$  \tag{1}

$Q$ denotes total quantity delivered in the domestic market, defining $Q = \sum_{i=1}^{3} Q_i$. The $A$ can be interpreted as the parameter determining the market size. The
firms have symmetric cost characteristics, where $C_S$ denotes the short-run marginal costs, $C_L$ the marginal costs of installing capacity, and $F_i, K_i$ and $E_i$ firm $i$’s fixed costs, capacity and exports, respectively.

We assume that $A > C_S + C_L > W > C_S$. $C_S + C_L > W > C_S$ implies that the export price is higher than short-run marginal costs but lower than long-run marginal costs. $A > C_S + C_L$ implies that there is positive domestic demand at a price equal to long-run marginal costs. To simplify, we let $C_L + C_S = C$. We assume that $F_i$ is sufficiently small to ensure that all three firms earn positive net profit. $\pi$ denotes gross profit, i.e., profit exclusive of the fixed costs.

Let us assume the following sequence of moves in each period:

Stage 1: The firms set capacities $K_i$ non-cooperatively.
Stage 2: The firms set price(s) $P_i$ cooperatively.
Stage 3: The firms set export quantities $E_i$ non-cooperatively.

Our setting is identical to the model with cooperative price setting in Fershtman and Gandal (1994), except that we (i) assume three rather than two firms, (ii) assume constant rather than increasing marginal cost, and (iii) allow the firms to export to a world market.

At stage three, the firms set export quantities. Since $W > C_S$ and $K$ is exogenous at stage three, it is unprofitable to have idle capacity. It produces a quantity equal to $K_i$, and exports the quantity that is not delivered on the domestic market. Hence, $E_i = K_i - Q_i$.

At stage two, the firms set the prices in the domestic market cooperatively. The maximization problem for the cartel is then the following:

$$
\sum_{i=1}^{3} \pi_i = \max_P (P - C_S)Q + (W - C_S)E - K \cdot C_L,
$$

where $E = \sum_{i=1}^{3} E_i$. If $K < (A - W)/2$, the marginal revenue in the domestic market exceeds the export price $W$. Hence, the cartel sets the domestic price so that the entire production is offered at the domestic market. Then $P = A - K$ in the domestic market.

It can easily be shown that for $K \geq (A - W)/2$, it is optimal at stage 2 to set $P = (A + W)/2$. The firms will then sell $Q = (A - W)/2$ in the domestic market. If $K > (A - W)/2$, it remains to determine the sharing rule in the domestic market – each firm’s quota in the domestic market. In that case we assume that

$$
Q^K = \frac{K_i}{K} D(P).
$$

Each firm’s domestic market share is thus identical to its share of total capacity.
At stage 1, the firms set capacity non-cooperatively. Firm $i$ has the following maximization problem:

$$\pi_i = \max_{K_i} (P - C)Q_i + (W - C)[K_i - Q_i]$$

subject to:

(i) if $K_i \leq \frac{A - W}{2}$, then $Q_i = K_i$ and $P = A - K$,

(ii) if $K_i > \frac{A - W}{2}$, then $Q_i = Q^K_i$ and $P = \frac{A + W}{2}$.

Proposition 1. If $A > 3C - 2W$, then $K_i > Q_i$ and $E_i > 0$. Otherwise, $K_i = Q_i$ and $E_i = 0$.

We thus see that the parameters $A$, $C$ and $W$ determine whether the price cartel results in excess domestic capacity and thereby export or not. A large demand potential in the domestic market (large $A$), a low cost of installing capacity or producing the product (low $C$), and a high export price (high $W$) will all encourage each firm to install a large capacity. The reason is straightforward. The price cartel’s market sharing rule implies that a large capacity will result in a large domestic sales quota. The larger the domestic demand, the more profitable is it to receive a larger share of the domestic market. Furthermore, the lower the costs and the higher the export price, the less costly is it to install excess capacity that is being exported.

When $A \leq 3C - 2W$, then there is no export. If $A > 3C - 2W$, we have that the equilibrium export quantity for each firm is as follows:

$$E_i = \frac{(W - A)(A + 2W - 3C)}{18(W - C)}.$$ (5)

If the capacity, for whatever reason, is larger than the equilibrium capacity, then the exported quantity for firm $i$ is as follows:

$$E^0_i = K^0_i - \frac{A - W}{6},$$ (6)

where $K^0_i$ denotes the actual capacity of firm $i$.

Note that from Eq. (6) we can also find the exported quantity of a monopoly with excess capacity initially. It is equal to the sum of each of the three firms exported quantity, i.e. $3 \cdot E^0_i$.

Proposition 2. If $A > 3C - 2W$ initially and each firm sets its equilibrium capacity, then $\partial E_i/\partial A > 0$, $\partial E_i/\partial W > 0$, and $\partial E_i/\partial C < 0$. If the firm(s) are (is) exporting initially and (i) the actual capacity is larger than the equilibrium capacity for the price cartel or (ii) there is a monopoly, then $\partial E^0_i/\partial A < 0$, $\partial E^0_i/\partial W > 0$ and $\partial E^0_i/\partial C = 0$. 

First, note the effect of an increase in domestic demand. Intuitively, we expect that an increase in domestic demand causes a reduction in exports. The reason is that the firms will reshuffle sales from the export market to the domestic market. This is what we observe, except for the case of a price cartel facing a large domestic demand initially. In that latter case an increase in domestic demand will increase exports. The reason is that an increase in domestic demand will encourage the firms to install a larger capacity and thereby to capture a larger share of the large domestic demand. We label this the semicollusion effect.4

Second, note that costs may have no effect on the exported quantity. If there exists a larger capacity than the equilibrium capacity, then the question is how to allocate sales between the domestic market and the export market. In such a case a cost increase (or reduction) will have no effect on the distribution of sales between the domestic and the export market.

Finally, note that in Proposition 2 we present comparative statics for a – per definition – static (one-period) model where the firms set the monopoly price domestically and compete on capacity. We know that in a repeated game, one subgame perfect equilibrium path is that the firms act in accordance with the static equilibrium outcome in each period. If we let the durability of the capacity investment define the period length, then we could interpret our model as one where firms collude on prices but compete on capacity in each period. We will interpret a period with low demand as an early period of the price cartel and a period with high demand as a late period of the price cartel.

3. Constructing industry hypotheses5

In Norway, the first cement plant, A/S Christiania Portland Cementfabrikk, called CPC, was established in 1892. At the end of World War I, three new plants were established in Norway: A/S Dalen Portland-Cementfabrikk (1916) (called DPC), CE-NO Portland Cement A/S (1917) and a firm in Northern Norway, Nordland Portland Cementfabrikk A/S (1918) (called NPC). This

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4 We have to be careful with the interpretation of $\partial E/\partial A$, because a shift in $A$ changes the demand and domestic monopoly price. An increase in exports due to an increase in $A$ could therefore be the result of a higher domestic price and thus a reshuffling of sales from the domestic to the export market. To rule out this possibility, we have also undertaken comparative statics with the demand function $Q = \alpha(A - P)$. A change in $\alpha$ can be interpreted as a pure shift in demand, since the domestic monopoly price is unaffected. It can be shown that $\partial E/\partial \alpha > 0$ if $A > 3C - 2W$. Hence, the results derived in Proposition 2 are not sensitive to such an alternative specification of the demand shift.

5 Unless otherwise stated, all cement figures refers to the dataset collected by the authors. Precise variable definitions and data sources are presented in Appendix B.
resulted in a large increase in domestic capacity. The capacity expansion, combined with the recession in Norway from 1920, led in the early 1920s to a domestic capacity amounting to almost twice the domestic demand (see Gartmann, 1990, p. 114). The mismatch between capacity and demand triggered the establishment of A/S Norsk Portland Cementkontor in 1923, a joint sales office for the three firms in Southern Norway (CPC, DPC and CE-NO). Five years later, NPC became a member of the common sales office as well, ‘after a short price war in the market in Northern Norway’ (Gartmann, 1990, p. 189).6

The sales office set quotas in Southern Norway according to each firm’s capacity: 51% to CPC, 18% to CE-NO and 31% to DPC (see Gartmann, 1990, pp. 116, 188). In 1927, DPC acquired CE-NO, obtaining a total quota of 49% in Southern Norway. According to Gartmann (1990), ‘the quotas were set according to each firm’s capacity’ (p. 185). When NPC joined the sales office in 1928, the firm should supply Northern Norway and 85% of the demand in the counties Northern and Southern Trøndelag (in Mid Norway).

Furthermore, the export prices were low (Gartmann, 1990, p. 115). The three firms’ exports fell gradually during the 1930s, from more than 50% of total domestic production to approximately 10% of domestic production at the beginning of World War II. In the mid 1950s the export again grew rapidly, and in the late 1960s over 40% of the domestic production was exported (see Reve et al., 1992, Chapter 10). In 1968 the three firms merged and established the firm Norcem. During the 1970s Norcem gradually closed down capacity, and in the early 1980s its capacity was approximately equal to domestic demand. Aggregated Norwegian export and Norwegian consumption are shown in Fig. 1.

We can use our theoretical predictions to construct industry hypotheses on how export will be affected by the changes in costs \(C\), export price \(W\) and the domestic demand \(A\). Ideally, we should test each firm’s export performance. However, we observe that in some years the firms have used transfer payments to correct for any deviations from the market sharing rule, for example, to compensate a firm that sold a lower share than its quota in the domestic market.7 Therefore, we test how the cartel’s aggregated export is affected by the

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6 There has been imports to Norway, for example from Germany in the last century. However, in 1895 Norwegian, Swedish and German producers agreed not to sell in each others home markets, which eliminated any competition from foreign firms in the Norwegian market (see Gartmann, 1990, p. 91). In addition, they coordinated their exports in order to eliminate the temptation to sell in each others home markets. As late as in the 1990s, there were market sharing agreements in the European cement market (see EU, 1994).

7 In the 1964 annual report for CPC we can read the following: CPC’s deliveries to its ordinary, domestic market increased from 464,000 tonnes in 1963 to 484,000 tonnes in 1964. In addition, it delivered 54,000 tonnes to DPC’s customers, which implied that DPC’s export increased with an identical amount. For this indirect export, CPC compensated DPC according to the ordinary export prices’ (p. 13).
variables $A$, $C$ and $W$. We will, for reasons explained below, distinguish between three phases: early cartel, late cartel and monopoly. Table 1 summarises our hypotheses. The relationship between export price and exports is straightforward. The higher the export price, the higher the exported quantity, all else equal. Hence, the three plus signs in Table 1.

With an equilibrium capacity level, we expect that an increase in costs is followed by a reduction in exports. However, with a capacity above the equilibrium level, Proposition 2 predicts that changes in costs will not influence the exported quantity. Due to the large investments in the early post World War I years, we expect that the industry had a sub-optimal capacity level in the early cartel phase. Therefore, the zero with the minus sign in the parenthesis. In the

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8 We have data for each firm’s annual production in the period 1913–1982. It shows a very parallel development in production for all three firms in the cartel period. In particular, all three firms expand production substantially from 1955 on. This is consistent with a hypothesis where all three firms had incentives to expand capacity to have a large quota in the domestic market (see below).
long run, however, the cartel could close down (not renew) capacity. As we approach the late cartel phase, we expect the ordinary relationship between costs and export to dominate: the higher the costs are, the lower is the exported quantity. In the monopoly phase – after the merger in 1968 – the capacity was very high, and export was not profitable (Gartmann, 1990, p. 246). It is thus reasonable to assume that the capacity was above the equilibrium level for the monopoly, and that costs had no effect on the exported quantity. Hence, the zero with the minus in the parenthesis.

To pin down the relationship between exports and domestic demand, we distinguish between three time periods (phases). In the monopoly phase, an increase in domestic demand is expected to reduce the exported quantity. Thus, the last minus sign in all three outcome paths. In the cartel period, the situation is more complicated. We know from Proposition 2 that the semicollusion effect is triggered if the domestic demand is sufficiently large, the costs sufficiently low, or the world market price sufficiently high, i.e., if \( A > 3C - 2W \). Except for World War II, and the year 1953, there are no dramatic changes in the measure \( 3C - 2W \).\(^9\) By inspection of a drawing (of the size of \( 3C - 2W \)) we observe that if there is any trend, then it is a negative time trend. We know from Fig. 1 that the domestic consumption increased substantially in the cartel period, especially after World War II. Technically speaking, we therefore expect \( A \) to cross \( 2C - 3W \) from below (if any crossing at all). Hence, our hypothesis is that it is more likely that each firm overinvests in capacity in the late than in the early cartel. Then there are three possible empirical results which all are consistent with our model. They are all shown in Table 1.

\(^9\) In 1953, the export price was very high. It could be due to the fact the exported quantity was quite low that particular year, and special cement was exported at a high price.
The next problem is to determine what is *early* and *late* in the cartel period. After World War II the cement industry was regulated. The firms had to ask for permission to undertake capacity investments, and this regulation lasted until the mid 1950s.\(^{10}\) The 1953 annual report for CPC, the largest domestic cement producer, states (p. 14): ‘...the negotiations about increased production capacity have still not succeeded ...’. However, the 1956 annual report states: ‘As is well known, the Norwegian producers have maintained an agreement on market sharing, but two of the producers have in the post-war period not been able to exploit their quotas. These circumstances have now changed ...’ Hence, we conclude that the early cartel phase lasts until 1956, and that the later phase runs from 1956 onwards.\(^{11}\)

4. The empirical tests

In this section we specify the empirical model, describe the data, and present and discuss our empirical results.

4.1. A testable model

According to our predictions, exports are determined by three factors. This allows us to define the export-supply equation as

\[
E = f(W, C(\cdot), A).
\]

where \(E\) is Norwegian exports, \(W\) is the export price, \(C(\cdot)\) is the marginal costs of production and \(A\) measures the size of the domestic market. We assume that Eq. (7) has a log-linear form.

We use annual data for the period 1927–1982 (see Appendix B). The left-hand side variable, \(E\), is measured as total yearly Norwegian cement export in tonnes.\(^{12}\) The export price \(W\) is calculated as the average yearly unit export price per ton cement.\(^{13}\) To represent the size of the domestic market, \(A\), we use

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\(^{10}\) This suggests that even if the semicollusion effect was triggered in the post-war period, the firms’ export opportunities were constrained. Later on we test for this by including a post-war regulation dummy.

\(^{11}\) We have also used statistical tests to uncover the break (see Harvey, 1990). CUSUM and CUSUMQ endogenous structural break tests we have undertaken indicate a break between 1955 and 1956.

\(^{12}\) We have also tested a model with lags, but the model performed worse than the one we report. The reason could be that the producers have rational expectations, i.e., anticipate how large the demand will be \(t\) years from now and then start installing capacity in due time.

\(^{13}\) Note that \(W\) is exogenously given at the world market.
the yearly Norwegian gross national product (GNP). The data set allows us to calculate a very precise short run marginal cost figure. However, to make our conclusions robust with regard to the measuring problem, we also estimate a model where \( C(\cdot) \) enters as a composite of input prices. Hence, we formulate two models, one in which \( C(\cdot) \) enters as a calculated figure based on the yearly expenses of labour (excluded permanent clerical staff), materials, fuel and electricity per ton produced cement, and one in which \( C(\cdot) \) enters as a composite of input prices on labour, materials and fuel/electricity. All values are in real terms. The Norwegian consumer price index is used as deflator.

To test the hypotheses concerning the effect of costs on exports, we include two \( C \) variables. One cost variable runs for the entire data period, and one is multiplied by a dummy that takes the value one in the period from 1956 to 1967, and zero otherwise. To test the semicollusion hypothesis we include three \( A \) variables, all multiplied by dummy variables that correspond to one of the phases. Hence, we obtain individual parameter estimates on \( A \) for each phase. Furthermore, we include a dummy variable to account for the effect of World War II. The econometric models can be written as:

\[
\text{Model A: } C(\cdot) \text{ enters as a calculated figure}
\]

\[
\ln E_t = \alpha + \beta_w \ln W_t + \beta_C \ln C_t + \beta_{C56-67} D_{t,56-67} \ln C_t + \beta_{A27-55} D_{t,27-55} \ln A_t + \beta_{A56-67} D_{t,56-67} \ln A_t + \beta_{A68-82} D_{t,68-82} \ln A_t + \lambda D_{t,40-44} + \epsilon_t;
\]

\[
\text{Model B: } C(\cdot) \text{ enters as a composite of input prices}
\]

\[
\ln E_t = \alpha + \beta_w \ln W_t + \beta_C \ln C_t^L + \beta_{C56-67} D_{t,56-67} \ln C_t^L + \beta_{C56-67} D_{t,56-67} \ln C_t^M + \beta_{C56-67} D_{t,56-67} \ln C_t^{EF} + \beta_{A27-55} D_{t,27-55} \ln A_t + \beta_{A56-67} D_{t,56-67} \ln A_t + \beta_{A68-82} D_{t,68-82} \ln A_t + \lambda D_{t,40-44} + \eta_t.
\]

The \( Ds \) are dummy variables that take the value one according to the period defined by the subscript, e.g., \( D_{t,56-67} \) takes the value one in the period from 1956 to 1967, and zero otherwise. The input prices in Model B is denoted as; labour, \( C_t^L \), materials, \( C_t^M \), and electricity/fuel, \( C_t^{EF} \). The World War II effect is captured by the dummy variable \( D_{t,40-44} \).

\footnote{See Sutton (1991) for a discussion of definitions of market size variables in empirical IO studies.}

\footnote{See Schmalensee (1989) and Martin (1993, Chapter 17) for a survey on the problems using accounting data to measure marginal cost.}

\footnote{In an earlier version of the paper, we included a trend parameter to capture technical change. However, it turned out that the model performed better without the trend parameter.}
through the $D_{t,40-44}^\text{war}$ dummy. The error terms, $\varepsilon$ and $\eta$, have by assumption the standard properties. In Table 2 the model predictions and the implied parameter restrictions (null hypotheses) are summarised. When it is sufficient to investigate the sign and the significance of a single parameter an ordinary $t$-test is applied, and when joint restrictions are imposed, an $F$-test is used.

### 4.2. The empirical results

The results and model statistics are presented in Table 3. The statistical properties of both model A and B are good. The overall explanatory power are 0.89 for both models. In models A, seven out of eight parameters are significant at a 0.05 level or higher, while in model B it is eight out of 12. The autocorrelation statistics, Durbin–Watson and Ljung–Box $Q$-statistics (Ljung and Box, 1979) show no first-order, or higher-order autocorrelation.
Table 3
Empirical results – models A and B

<table>
<thead>
<tr>
<th></th>
<th>Model A</th>
<th>Model B</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>$15.511^a$ (2.340)</td>
<td>$16.791^a$ (5.117)</td>
</tr>
<tr>
<td>$\beta_W$</td>
<td>$0.870^a$ (0.153)</td>
<td>$0.857^a$ (0.153)</td>
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<tr>
<td>$\beta_C$</td>
<td>$1.225^b$ (0.527)</td>
<td>$5.005^a$ (1.195)</td>
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<tr>
<td>$\beta_{C56-67}$</td>
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<td>$1.740$ (3.352)</td>
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<tr>
<td>$\beta_{t}$</td>
<td></td>
<td>$0.350$ (1.152)</td>
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<td>$\beta_{tr}$</td>
<td></td>
<td>$-1.847^a$ (0.807)</td>
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<tr>
<td>$\beta_{t56-67}$</td>
<td>$-24.709^a$ (10.05)</td>
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</tr>
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<td>$-4.016^c$ (2.722)</td>
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<td>$0.613$ (1.695)</td>
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<tr>
<td>$\beta_{A27-55}$</td>
<td>$-2.198^b$ (1.174)</td>
<td>$-3.538^b$ (1.764)</td>
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<td>$\beta_{A56-67}$</td>
<td>$4.183^a$ (1.096)</td>
<td>$26.959^a$ (10.67)</td>
</tr>
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<td>$\beta_{A68-82}$</td>
<td>$-0.244$ (0.929)</td>
<td>$-2.144$ (1.887)</td>
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<td>$\lambda$</td>
<td>$-4.503^a$ (0.783)</td>
<td>$-3.824^a$ (1.001)</td>
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<td>$R^2$</td>
<td>0.88</td>
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<td>$DW$</td>
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<td>$Q(1)_{h,jung.Box}$</td>
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<td>$Q(2)_{h,jung.Box}$</td>
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<td>$Q(3)_{h,jung.Box}$</td>
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<td>7.39</td>
</tr>
<tr>
<td>F-test</td>
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<td></td>
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<tr>
<td>$H_0$: $\beta_{C56-67} = \beta_C$</td>
<td>6.07$^d$</td>
<td></td>
</tr>
<tr>
<td>F-test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$H_0$: $\beta_{t56-67} = \beta_{t} \lor \beta_{t56-67} = \beta_{tr} \lor \beta_{t56-67} = \beta_{t}$</td>
<td>2.29$^a$</td>
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</tr>
<tr>
<td>F-test</td>
<td></td>
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</tr>
<tr>
<td>$H_0$: $\beta_{A27-55} = \beta_{A56-67} = \beta_{A68-82}$</td>
<td>22.22$^d$</td>
<td>7.92$^d$</td>
</tr>
</tbody>
</table>

* Significant at a 0.025 level.

b Significant at a 0.05 level.

* Significant at a 0.10 level.

* Significant at a 2.5% level.

* Significant at a 10% level.

The World War II dummy is significant at a 0.025 level in both models, suggesting a negative effect on export.

The remaining parameters can be used to test our predictions. We find that the export price has a positive impact on exports, and that it is significant at a 0.025 level.

Five out of eight cost parameters in the two models predict a negative relationship between exports and costs. However, there are differences between the cost effect in the late cartel phase versus the early cartel phase and the monopoly phase. In model A, the parameter measuring the cost effect on exports is is larger in magnitude in the late cartel phase than in the other two time
In addition, it is significant on all interesting significance levels only in the late cartel phase. The same pattern can be seen in model B. This result is confirmed when we undertake two joint tests where we impose that there are no differences between the three phases (see Table 2). Thus, our results suggest that the cost is of larger importance in the late cartel phase than in the other two phases. This is consistent with our predictions (see Table 1).

The last predictions to be tested are the effect of changes in domestic demand on exports, i.e., the semicollusion hypothesis. Both models suggest that we are in a situation (ii), where the semicollusion effect is triggered in the late cartel phase. The semicollusion effect is found to be strongly significant in the late cartel phase. It is consistent with the cost parameter results, where the late cartel phase was found to be significantly different from the other two phases. Finally, we undertake a joint test where we require all three market-size parameters to be the same. Using an $F$-test we reject the null hypothesis at a 2.5% significance level in both models (see Table 3). Thus, there is a significant difference between the three phases. In conclusion, we find that there is a semicollusion effect in the late cartel phase: higher domestic demand triggers investments in capacity and thereby an increase in export.

4.3. Discussion of the results

There are some issues that should be addressed regarding our results. First, one could argue that the Norwegian GNP is exposed to the same business cycle movements as their neighbouring countries. If this is the case, our market-size parameters might pick up something more than only the domestic market size. However, when investigating the export destinations during this period, from 1927 and every 10 years onwards until 1977, only between 5% and 6% of the Norwegian export was sold in Europe. The rest was sold to the US (26%) and the ‘rest of the world’ (68%), which in this case mainly were South-America and Africa.

Second, one could argue that GNP is a too aggregate measure of the market size of cement. To check the robustness of our results to the market size variable, we have estimated models A and B using a Norwegian construction and

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Note that in model B the magnitude of $\beta_{458.67}$ is considerably larger than in model A. However, the models are not directly comparable since the costs are represented in two different ways. Furthermore, the cost parameters in model B show the same pattern, with large differences in magnitudes. Finally, since both $\beta_{457.55}$ and $\beta_{458.82}$ also are larger in magnitude in model B, the relative difference between the market-size parameters are not as pronounced as the difference in magnitude.
building index to represent the market size. This index will not be exposed to the same problems as the GNP measure. On the other hand, it might be too disaggregated to capture the total Norwegian cement demand. Even though the predictions from model B change in the sense of suggesting a non-significant parameter for $\beta_{AB-67}$ and fewer significant parameters in general, the main predictions hold. In particular, all predictions from model A are the same using the construction index. Hence, the aggregation level on the market-size variable seems not to be critical to our main results. See Appendix C, where the results are reported.

Third, due to the post-war regulations in Norway, one might argue that also in 1945–1955 the industry was exposed to restrictions that reduced their production possibilities. Models A and B have been reformulated to include a post-war regulation dummy. As expected, the post-war regulation has a negative impact on exports. All our principal results remain unchanged. We still conclude with statistical differences between the periods regarding costs and the importance of the domestic market size, and the semicollusion effect is still triggered in the late cartel phase. However, the results are less clear than in the models presented; fewer significant parameters and not as good statistical properties on autocorrelation.\footnote{The results are available upon request to the authors.}

Fourth, changes in costs could affect the domestic cartel price and thereby affect exports. To take into account such an effect we should have tested a structural model, where we explicitly modelled domestic demand and supply. However, we observe from the data that real-costs are quite stable until World War II and steadily decreasing after World War II. A decline in real costs results in a lower monopoly price which, in turn, leads to a higher domestic consumption. All else equal, it dampens the growth in exports in the late cartel phase. This effect – which we have not captured in our empirical test – cannot explain the observed growth in exports in the late cartel phase. Hence, this effect is not an alternative to the semicollusion effect as an explanation of the observed export pattern.

Finally, the capacity expansion could have been undertaken for other reasons than the one we have focused on. Firms could have built excess capacity (1) in anticipation of future domestic demand, (2) to preempt its rivals from building capacity or (3) to facilitate price collusion in the domestic market. The observed export pattern in the late cartel seems to be inconsistent with the first argument. In the late 1960s, 40% of the production was exported. It seems unlikely that the firms overestimated the future demand to such a degree. Moreover, the incentive to preempt its rival and to facilitate collusion was present in other countries than Norway. An investigation done by the European Commission suggests
Fig. 2. The development in export in Norway and Europe the period 1927–1989 (in 1000 tonnes).

that there has been a secret cement cartel in Europe for many decades (see EU, 1994). Accordingly, there are no a priori reasons to expect an excess capacity pattern in the Norwegian cement industry that is different from other European cement industries. However, we observe from Fig. 2 that the excess capacity in Norway in 1955–1967, measured through the development in exports, is distinctly different from the pattern in other European countries.\textsuperscript{19}

5. Some concluding remarks

The purpose of this paper has been to analyse theoretically and test empirically the effect of the price cartel in the Norwegian cement market, a price cartel

\textsuperscript{19} We see that the growth in European exports accelerated in the early 1970s. A plausible explanation is the oil crisis. It dampened the economic growth in Europe, and the cement producers’ continued growth in capacity forced them to expand their exports.
which lasted for 45 years. We find that what we have labelled the semicollusion effect became significant in the Norwegian cement industry in the late cartel phase: each member of the price cartel increased its investment in capacity to capture a larger share of a growing domestic market. The driving force was the market sharing rule. Each firm was given a quota in the domestic market according to its share of total domestic capacity. Fershtman and Gandal (1994) show that collusion on prices and competition on capacity can be unprofitable for the firms, because the costs associated with capacity expansion more than offsets the gains from price collusion. This suggests that a capacity expansion that according to traditional theory of collusion could have been a virtue – for example, an instrument to facilitate collusion – might instead become a problem in this particular industry.

Did the firms actually regard the capacity expansion as a problem? The apparent success of the price cartel for many years – according to our empirical study it was successful for more than 30 years – may explain why they underestimated or simply neglected the potential problem which the growth in the domestic market triggered in the mid 1950s. Moreover, for a given capacity the firms are always better off colluding than not colluding. So any decision not to collude is not credible (see Fershtman and Gandal, 1994, p. 142). In the 1960s – a decade too late – they finally thought of an alternative solution to the problem, as the following description from cartel negotiations in the 1960s indicates: ‘During the opening round of negotiations for a new cartel agreement there appeared to be much dissatisfaction with the apparent lack of industry coordination when it came to capacity expansion…. It consequently did not take the parties long to see large potential benefits from a full merger’ (Lorange, 1973, p. 33). In 1968, the three firms finally merged.

The welfare implications of such a merger is straightforward. Domestic prices are not affected, while the foreign consumers will no longer purchase cement produced in Norway at a price below long-run marginal costs. The elimination of the excess investments in capacity has therefore been beneficial for domestic welfare. So in this particular case a monopoly is more beneficial for the Norwegian society than a price cartel.

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20 As shown in Kreps and Scheinkman (1983), the game they have specified with non-cooperative rather than cooperative price setting at stage 2 can yield a Cournot outcome. By comparing the price cartel outcome with the Cournot outcome, Fershtman and Gandal reach the conclusion referred to in the text. However, other assumptions may give the opposite result. For example, Davidson and Deneckere (1986) show that random rather that efficient rationing results in a more competitive outcome than the Cournot outcome, which may be enough to reverse the conclusion. Moreover, as far as we know, there are no studies showing that the Kreps and Scheinkman (1983) result is valid in industries with more than two firms. We should therefore be careful in concluding that the price cartel is always unprofitable in the setting we are investigating.
Acknowledgements

With the usual disclaimer, we thank Tore Ellingsen, Joe Harrington Jr., Jan Tore Klovland, Kjell Gunnar Salvanes, two anonymous referees and seminar participants at our home institution, the University of Oslo, the Stockholm School of Economics, Warwick Summer Research Workshop 1996 on modelling firm behaviour, 11th Annual Congress of the European Economic Association 1996 in Istanbul and the 23rd Annual Congress of the European Association for Research in Industrial Economics 1996 in Vienna for helpful discussions and suggestions. Our research has been partly financed by the Research Council of Norway through SNF.

Appendix A. Proofs of propositions

Proof of Proposition 1. \((A - W)/6\) is each firm’s domestic sales quota when the domestic price cartel is in force, while \((A - W)^2/[18(C - W)]\) is the equilibrium capacity for each firm when capacity exceeds its domestic sale [condition (ii) in Eq. (4)]. Then we have that if

\[
\frac{(A - W)^2}{18(C - W)} < \frac{A - W}{6}, \tag{A.1}
\]

the installed capacity at stage 1 is so low that no export takes place after the cartel price is set at stage 2. Rearranging Eq. (A.1), we have that the members of the price cartel will not export if \(A \leq 3C - 2W\). A sufficient condition for \(K_i > Q_i\) and \(E_i > 0\) is then that \(A > 3C - 2W\). \(\Box\)

Proof of Proposition 2. From Eq. (5) we have that

\[
\frac{\partial E_i}{\partial A} = \frac{A - W}{9(C - W)} - \frac{1}{6}. \tag{A.2}
\]

By setting \(A = 3C - 2W\), we have that \(\partial E_i/\partial A = \frac{1}{6}\). Then for \(A > 3C - 2W\), we have that \(\partial E_i/\partial A > 0\). From Eq. (5) we have that

\[
\frac{\partial E_i}{\partial W} = \frac{2W^2 + A(A - 2C) + C(3C - 4W)}{18(W - C)^2}. \tag{A.3}
\]
By setting $A = 3C - 2W$, we have that $\partial E_i / \partial W = \frac{1}{2}$. Thus, $\partial E_i / \partial W > 0$ when $A > 3C - 2W$. From Eq. (5) we have that

$$\frac{\partial E_i}{\partial C} = -\frac{(A - W)^2}{324(W - C)^2} < 0.$$  \hspace{1cm} (A.4)

From Eq. (6) it can easily be verified that $\partial E_i^0 / \partial A = -\frac{1}{6}$, $\partial E_i^0 / \partial W = +\frac{1}{6}$ and $\partial E_i^0 / \partial C = 0$. \hspace{1cm} \square

**Appendix B. Data description and variable definitions**

The data is collected from four main sources; the Norwegian industry statistics (NIS), the norwegian trade statistics (NTS), the norwegian historical statistics (NHS), and the national accounts statistics (NAS), all published annually by the Central Bureau of Statistics Norway (SSB). The bureau started its publications of the Norwegian Industry Statistics in 1927, as is the first year of observation utilised in this study.

The Norwegian export figures are from NTS, containing the commodity numbers: 35.22, 25.23 and 2523.1000. Export ($E$) is measured in tonnes and the export price ($W$) is the unit price measured as NOK per ton. The latter is calculated as the yearly export value divided by the yearly export quantity. The European export figures (Fig. 2) are from CEMBUREAU’s production, trade and consumption statistics; ‘World Cement Market in Figures. 1913–1981’, *World Statistical Review No. 4*, and yearly CEMBUREAU publications from 1982 to 1989.

The cost observations are from NIS; ISIC code 3340 prior to 1970 and ISIC code 3692 from 1970 onwards. The calculated figure $C(\cdot)$ is yearly expenses of the three input factors, labour (excluded permanent clerical staff), materials, and fuel and electricity divided by the yearly production. Hence, the calculated cost figure $C(\cdot)$ is a NOK per ton measure. Yearly production is also found in NIS, but is checked against production figures provided by Norcem, and production figures from CEMBUREAU. The labour price ($c^L$) is labour expenses (excluded permanent clerical staff) per hour, the material price ($c^M$) is calculated as material expenses per ton produced, and the electricity and fuel price ($c^{EF}$) is also a per ton price.

The export price, and the four cost measures are all deflated using the Norwegian consumer price index (CPI), which is found in NAS and NHS.

To construct the gross national product (GNP) series, several sources were used. SSB does not publish official figures for GNP during the World War II; the years from 1940 to 1945. However, SSB published figures for GNP for the years from 1940 to 1943, in the publication ‘Le revenu national en Norvège 1935–1943, Capital effectif en 1939 et la réduction du capital pendant la guerre.”
Table 4
Summary statistics main variables (the period from 1927–1982)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export in tonnes</td>
<td>56</td>
<td>2.82E+05</td>
<td>3.71E+05</td>
<td>1.37E+11</td>
</tr>
<tr>
<td>Export price</td>
<td>56</td>
<td>412.380</td>
<td>262.53</td>
<td>68922.00</td>
</tr>
<tr>
<td>Marginal costs</td>
<td>56</td>
<td>325.980</td>
<td>83.194</td>
<td>6921.300</td>
</tr>
<tr>
<td>Input price materials</td>
<td>56</td>
<td>123.050</td>
<td>31.683</td>
<td>1003.800</td>
</tr>
<tr>
<td>Input price electricity and fuel</td>
<td>56</td>
<td>122.730</td>
<td>48.303</td>
<td>2333.100</td>
</tr>
<tr>
<td>Wage per hour (blue collar workers)</td>
<td>56</td>
<td>42.209</td>
<td>21.716</td>
<td>471.600</td>
</tr>
<tr>
<td>GNP</td>
<td>56</td>
<td>36.044</td>
<td>22.643</td>
<td>512.720</td>
</tr>
<tr>
<td>Building and construction index</td>
<td>56</td>
<td>1193.40</td>
<td>541.97</td>
<td>293730.00</td>
</tr>
</tbody>
</table>

*Coutus de l’occupation*. Figures also for 1944 and the first four months of 1945 were estimated by Aukrust and Bjerve (1945) in their book; ‘What the costs of the war were to Norway’, (Table 12, p. 45). Using these sources, we were able to construct an unbroken series of GNP figures from 1927 to 1982. (The 1945 GNP figure from Aukrust and Bjerve was multiplied by 3 to obtain a proxy for the whole year.)

The construction index we use as a measure of market size is a volume index of gross domestic product in the construction industry. It is derived from NOS National Accounts Statistics [National Accounts 1865–1960 (Table 45), Historical Statistics 1968 and 1984]. Estimates for 1927–1929 and 1940–1945 is based on hours worked in construction, from NOS Manufacturing Statistics (see Table 4). Data for the various time periods are spliced by the simple ratio method to form a consistent time series. The index is collected and constructed by Jan Tore Klovland, Norwegian School of Economics and Business Administration.

Appendix C. Empirical results for models A and B when market size is measured by a construction index

<table>
<thead>
<tr>
<th></th>
<th>Model A</th>
<th>Model B</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>26.169* (4.682)</td>
<td>28.880* (5.135)</td>
</tr>
<tr>
<td>$\beta_W$</td>
<td>0.871* (0.149)</td>
<td>0.852* (0.152)</td>
</tr>
<tr>
<td>$\beta_C$</td>
<td>$-0.704^* (0.483)$</td>
<td>$-0.140^* (1.775)$</td>
</tr>
<tr>
<td>$\beta_{C56-67}$</td>
<td>$-8.140^* (1.775)$</td>
<td></td>
</tr>
<tr>
<td>$\beta_{C56-67}$</td>
<td></td>
<td>2.003 (2.491)</td>
</tr>
<tr>
<td>$\beta_{C67}$</td>
<td></td>
<td>$-0.064 (1.142)$</td>
</tr>
<tr>
<td>$\beta_{C67}$</td>
<td></td>
<td>$-1.418^* (0.845)$</td>
</tr>
<tr>
<td>$\beta_{C56-67}$</td>
<td></td>
<td>2.078 (9.176)</td>
</tr>
<tr>
<td>$\beta_{C56-67}$</td>
<td></td>
<td>$-0.672 (3.286)$</td>
</tr>
<tr>
<td>$\beta_{C56-67}$</td>
<td></td>
<td>$-1.295 (2.139)$</td>
</tr>
</tbody>
</table>
### Appendix C. Continued

<table>
<thead>
<tr>
<th></th>
<th>Model A</th>
<th>Model B</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_{127-55}$</td>
<td>$-$2.883* (0.889)</td>
<td>$-$3.551* (1.077)</td>
</tr>
<tr>
<td>$\beta_{156-67}$</td>
<td>2.075b (1.082)</td>
<td>3.994 (7.121)</td>
</tr>
<tr>
<td>$\beta_{168-82}$</td>
<td>$-$1.879b (0.827)</td>
<td>$-$2.917* (1.154)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>$-$2.971* (0.896)</td>
<td>$-$1.908* (1.230)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td>$DW$</td>
<td>2.42</td>
<td>2.35</td>
</tr>
<tr>
<td>$Q(1)_{h,jung-Box}$</td>
<td>3.54</td>
<td>3.40</td>
</tr>
<tr>
<td>$Q(2)_{h,jung-Box}$</td>
<td>3.89</td>
<td>4.18</td>
</tr>
<tr>
<td>$Q(3)_{h,jung-Box}$</td>
<td>5.62</td>
<td>6.14</td>
</tr>
<tr>
<td>$F$-test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$H_0: \beta_{56-67} = \beta_c$</td>
<td>14.06d</td>
<td></td>
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<tr>
<td>$F$-test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$H_0: \beta_{156-67} = \beta_{cr} \vee \beta_{c56-67} = \beta_{cr}$</td>
<td>0.02</td>
<td></td>
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<tr>
<td>$F$-test</td>
<td></td>
<td></td>
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<tr>
<td>$H_0: \beta_{127-55} = \beta_{156-67} = \beta_{168-82}$</td>
<td>53.48d</td>
<td>2.52e</td>
</tr>
</tbody>
</table>

* Significant at a 0.025 level.

b Significant at a 0.05 level.

Significant at a 0.10 level.

d Significant at a 2.5% level.

Significant at a 10% level.

### References

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