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Author(s): D. Paraskevopoulos and C. N. Pitelis

Source: *Managerial and Decision Economics*, Nov. - Dec., 1995, Vol. 16, No. 6 (Nov. - Dec., 1995), pp. 619-632

Published by: Wiley

Stable URL: https://www.jstor.org/stable/2487844

MANAGERIAL AND DECISION ECONOMICS, VOL. 16, 619–632 (1995)

An Econometric Analysis of the Determinants of Capacity Expansion Investment in the West European Chemical Industry

D. Paraskevopoulos

IBM, Athens, Greece

and

C. N. Pitelis

Judge Institute of Management Studies, and Queens' College, University of Cambridge, UK

INTRODUCTION

Capacity expansion investments by oligopolistic firms is arguably one of their most important strategic decisions. It may have significant implications on the firms themselves as well as on their existing and potential competitors, the industry and the economy as a whole. Accordingly, it is no surprise that the determinants of such investments has been a most popular issue in industrial organization (IO) theory. Given the complexity of real life, it is unlikely, however, that answers of general applicability can be provided to this question. This necessitates empirical work which has not been forthcoming. Our objective in this paper is to fill this gap by providing an econometric analysis of the determinants of capacity expansion investments in a real-life case, the West European chemical industry. The paper is divided into six sections. The next section discusses the theory underlying investment decisions in general and capacity expansion investments in particular. The third section introduces the case under consideration. The fourth section has a discussion of the data and variables used in the study. The fifth section discusses our results and conclusions are presented in the final section.

CCC 0143–6570/95/060619-14

THE DETERMINANTS OF CAPACITY EXPANSION INVESTMENT DECISIONS

Investment decisions by oligopolistic firms represent choice of equipment type and size as well as commitment of resources based on conjectures about uncertain future quasi-rents. The magnitude of the latter depends on demand and supply forces, since the expected net revenues are a function of both the market price and the production cost. For a given demand trajectory, revenues depend on the supply structure, as the latter is determined by the state of technology and the type of competition characterizing the particular market.

The investment decision has two main components: one is noticing the investment opportunity; the second is committing resources to it (Spence, 1979). In this respect, the elements entering into an investor's decision may be categorized as follows (see Caves and Porter, 1977)[1]:

(1) The rents earned by the present market occupants
(2) Any comparative advantages that the investor will enjoy

(3) The irreversible costs of gathering information and making the decision
(4) Any considerations associated with entry and mobility barriers
(5) Other potential investors and their likely behaviour
(6) Competitor reactions to one firm's investment decision, as reflected in the changes observed in their market behaviour patterns.

All items in the above list are uncertain and highly interrelated in their values and effects. An investment decision influences future ones, while its attractiveness is heavily dependent on future investments to come; the latter influence the determination of short-run equilibrium and, in turn, price and profitability.

Item (4) in the above list is of particular interest here; it concerns anything which impedes the ability of firms to enter or leave an industry, or to move from one segment of the industry to another (Caves and Porter, 1977; Porter, 1979; Geroski, 1983; Geroski and Jacquemin, 1985). 'Entry barriers' are usually grouped into two classes: *structural*, which are exogenous and arise from basic characteristics of the industry, such as technology or demand; and *strategic*, which arise from strategic action adopted by incumbents and tend to enhance the effects of the former (see below).

Structural barriers are usually identified as economies of scale, product differentiation and absolute cost advantages.[2] Scale economists restrict the number of firms that can profitably compete in a market, while they raise the capital outlay required, for example, to erect a reasonably sized plant.[3] Product differentiation poses difficulties for entrants because it reduces the price elasticity of firms' contingent demand curves (see Shubik, 1984, pp. 68–74). Consequently the entrant is forced to make extra outlays in advertising, sales promotion, etc as prior consumption of incumbents' brands represents sunk costs by consumers (Schmalensee, 1982).[4] Absolute cost advantages arise whenever the entrant has a higher unit cost curve than the incumbent, because of unequal access to technology, raw material or distribution channels, government policies (see especially Scherer, 1980, pp. 141–5) or vertical integration.

Exit barriers are factors which discourage producers to withdraw from an industry. They mainly arise due to sunk costs (as, for example, in cases of large capital-intensive equipment with long pay-out times) and from operation of specialized assets (such as 'dedicated' equipment); high exit costs (e.g. penalties from terminating long-term contracts); vertically or horizontally integrated product lines; government pressures; or emotional barriers (see Porter, 1979). Exit barriers involve also strategic elements. In stagnating or declining industries, the exit of one firm might leave the others better off, so that exit decisions may be delayed because each firm expects its rivals to exit first (see also Ghemawat and Nalebuff, 1985; Geroski and Jacquemin, 1985).

Strategic interaction among firms occurs along several dimensions: capacity, pricing, product policy and R&D. Most of these involve substantial investments; the last represents largely irreversible commitments to the industry and are an integral part of the process of establishing the firms' relative positions in terms of market share, costs and products. In this respect, differences in the specific characteristics and the timing of entry put firms into asymmetrical positions with respect to investment (Spence, 1981). Such asymmetries frequently lead to *first-mover advantages*. First-movers are generally faster than entrants or small firms in noticing potential profit opportunities, they can act faster than entrants to capture the opportunity due to the lower uncertainty involved and by being insiders they have automatically overcome some entry barriers (e.g. establishing a market). In addition, first-movers are given opportunities for strategic behaviour in deterring entrants (Geroski and Jacquemin, 1985).

Strategic behaviour consists of deliberate actions which are intended to alter those perceived by the firm's competitors (entrants, small firms or rivals) and competition of the post-entry market (and in turn the profitability of their investment). Depending on market conditions and their characteristics, the firm can use strategically the price (or output) variable, investment or both. Strategic investment can be used to erect strategic barriers as well as for pre-emptive or predating purposes.

Strategic barriers represent incumbent pre-entry activity intended to enhance the structural barriers faced by the entrants and thus further discourage entry. Credible incumbent threats of fighting the prospective entrant in the post-entry market can play this role. The credibility of such threats is enhanced if the incumbent holds excess capacity that could be utilized if entry occurred (Spence, 1977; Bulow et al., 1985), especially if the incumbent holds a strong leading position in the post-entry market (Spulber, 1981); if it has established a 'reputation for toughness' by fighting previous entrants (Kreps and Wilson, 1982; Milgrom and Roberts, 1982), or if it responds to entry with an aggressive investment program designed to deter continued growth and 'mobility' of the entrant (Caves and Porter, 1977; Spence, 1979; Fudenberg and Tirole, 1983). Although there is little empirical support for the excess capacity entry-deterring argument (Hilke, 1984; Liebermen, 1987a; Smiley, 1988)[5], there is evidence that aggressive post-entry investment and pricing responses were common in concentrated markets of the US chemical industry (Lieberman, 1987b).

Pre-emptive behaviour consists of early investments which aim to capture opportunities before rivals do, thereby gaining an increased share of industry output and profits (Porter and Spence, 1982; Ghemawat, 1984; Reynolds, 1986; Lieberman, 1987c). Pre-emptive strategies are successful if, as Lieberman (1987c) observes,

- Parts of new capacity are large in relation to the total market and represent a largely irreversible commitment
- Demand is certain and grows fairly slowly (Ghemawat, 1984)
- The incumbent enjoys scale- or proprietary learning-advantages (Gilbert and Harris, 1981)
- The pre-emptor can run faster than its competitors or at least make the initial commitment faster[6].
- The pre-emptor's rivals are willing (or forced) to back up, so that pre-emption does not inspire rivalry and large new investment bandwagons. In particular, the announcement of a major expansion—especially by a large firm—may 'signal' that the firm has high expectations of future growth, and thereby stimulate additional expansions by other—especially the smaller—firms (Gilbert and Lieberman, 1987).

Pre-emptive expansions tend to increase excess capacity. However, Reynolds (1986) suggests that while such pre-emptive strategies were pursued by the large producers in the US aluminium industry, they explained a small part of the observed overcapacity in that industry.

The intricacies of real-life industry and firm behaviour suggest that some degree of inconclusiveness is not very surprising. Firm behaviour may also differ depending on, for example, its competitive position, and/or the industry 'generic environment' (see Porter, 1980). Further, it is not easy to discern whether, for example, observed excess capacity is due to strategic or non-strategic reasons (including erroneous forecasts) and/or irrational behaviour, or whether its use is aimed to prevent entry, pre-empt existing rivals and/or operate as a signalling device helping to coordinate industry investment behaviour. Lastly, a discussed but little-tested concept in the literature is that of plant announcements. Do firms actually build excess capacity or do they simply announce that they will? Can announcements play a similar role to that of physical investment in capacity? The aim of the following sections is to attempt to provide some answers to these questions by focusing on an examination of the determinants of the investment decision in a real-life case of oligopolistic interdependence, the West European chemical industry.

THE CASE STUDY

Our focus is the West European vinyl-chloride monomer (VCM) and poly-vinyl chloride (PVC) industries. These represent the first two stages of the PVC product line industry. The single product of the first stage (the monomer) is the sole raw material for the second stage (the polymer) (see Fig. 1). An advantage of the PVC product line industry is that it captures all the basic characteristics of the petrochemical industry of which it is a major sector (such as product homogeneity, technological redundance, large capital-intensive technology, virtually integrated chains) and, in addition, its market is almost free from external trade and interactions from other petrochemical processes and products. This makes it particularly useful case study material as it allows an easier exploration of the factors affecting the industry's evolution over time.[7] In addition, the PVC product line industry constitutes a 'typical' manufacturing stage of capital-intensive industries, such as metals and other large-volume petrochemicals,

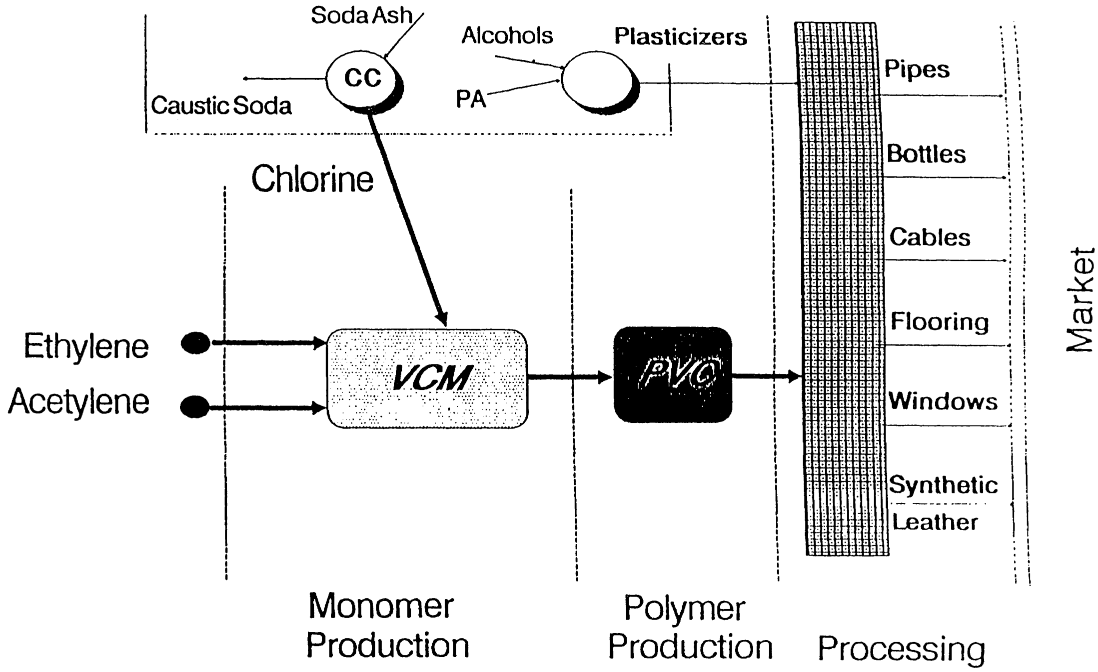

Figure 1. The PVC product-line industry.

suggesting scope for possible generalizations of any findings for other industries.

Another major advantage of the PVC–VCM industries in particular, and the petrochemical industry in general, is its rapid evolution from its growth phase to its maturity phase. Between 1965 and 1985 the industry had undergone three distinct phases. A high demand growth phase extending up to 1973; the mid-1970s to early 1980s period which was characterized by stagnant demand and high overcapacity, and the post-1982 period in which a capacity rationalization process was observed. These are shown in Fig. 2. Also shown in this figure is the persistent overcapacity

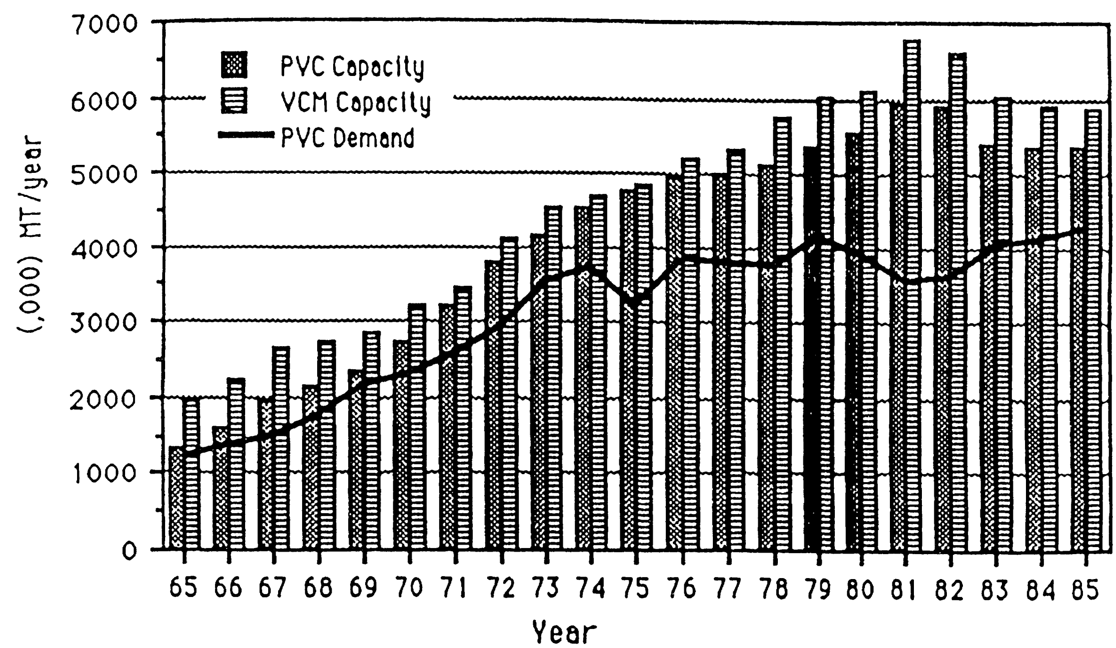

Figure 2. PVC–VCM industry demand and capacity evolution.

throughout the industry's development history. This makes it an interesting case study, particularly the pre-1982 period. The post-1982 period was one of rationalization rather than expansion, so that mergers and acquisitions became the predominant form of market conduct and it is analyzed in a separate work (see Paraskevopoulos and Pitelis, 1989). In the pre-1982 period, on the other hand, the possibility of strategic behaviour is very distinct, particularly so in the 1973–81 period when capacity and announcements for new expansions were well above what one would expect even on the basis of 'overoptimistic' forecasts (see Figure 3).

In the 1965–73 period the industries in question were structured as a relatively strong oligopoly. Each consisted of 15 firms, the two largest accounting for around 35% of the output, while the six largest were around 70%.[8] All were large transnationals with a strong R&D base and a high degree of diversification in other petrochemicals, and confirmed 'leaders' in their national markets. Nine new entries were recorded in the PVC and five in the VCM industries during this period and many there were considering entry (see Paraskevopoulos, 1988). This and the opening of the markets due to EU regulations led to an industry becoming more like a loose oligopoly in the second half of the 1970s, specifically the post-1973 period. The four largest firms accounted for about 45% of total capacity and the eight largest for about 65%. New plants were coming onstream during the period and announcements for new expansions were made.[9] In some cases investors undertook a small part of the project expenses (design, open bids, etc.) so that announcements looked more credible (see Smith, 1981). One entry took place in the PVC industry during this period, and two in the VCM industry (thus) increasing the number of players from 15 in 1965–73 to a total of 32, more than double the original industry population!

DATA AND VARIABLES

Our data sample consists of plant capacities and planned expansions by firm and technological process and potential industry output for each product by year. We have a total of 753 observations covering the 1965–81 period. The data are recorded in Paraskevopoulos (1988). Our estimated model is similar to that Gilbert and Lieberman (1987) but differs on a number of important respects. First, we adopt a 'general to specific' method in order to derive our preferred equations. As this method presupposes a knowledge of all potential factors affecting the dependent variable, we have a substantially more extensive array of independent variables than that

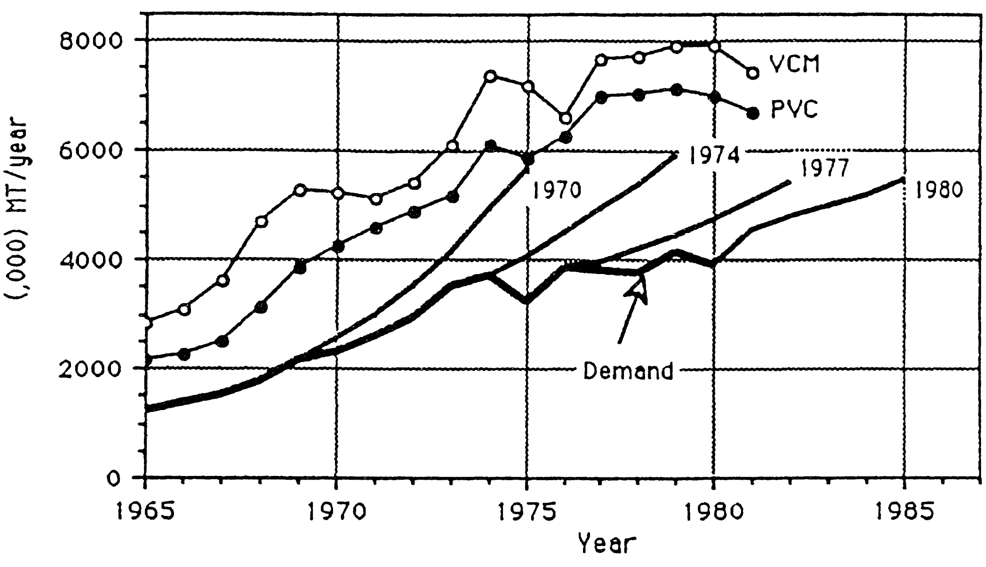

Figure 3. Demand forecasts and planned capacity; Western Europe, PVC–VCM industry. Demand forecasts are of the year indicated. Planned capacity in year t would be equal to the installed capacity in year t if all announcements went ahead; r is the construction time.

of Gilbert and Lieberman, notably announcements and structural factors such as scale economics and vertical integration (see below). Further, we are formulating our model in terms of installed capacities and also consider the effect of plant announcements in determining the participants' expansion policies. For estimation we use a Logit model of firm capacity investment in which the probability of capacity expansion is taken to be a linear function of observable characteristics of the industry and firm.

We define the following variables:

$K_{i,j,t}$ = total installed capacity of firm i to produce product j at year t

$EK_{i,j,t}$ = the sum of installed and announced capacity for product j or firm i at time t

$Q_{j,t}$ = total industry demand for product j at year t

The variable EK represents the potential capacity for firm i in year $(t+r)$ where r denotes the gestation lag (design and construction time) for the commissioning of new capacity. For PVC industries we have taken $r=2$ and for VCM industries $r=3$. *Ceteris paribus*, this difference arises mainly due to the differences in the optimal plant size. Obviously EK includes announcements for projects which are in the construction phase and are expected to start up during the period to $(t+r-1)$.

Planned capacity is estimated from expansion announcements which have gone public, so that they involved some expenses for the firm who undertook them. Accordingly, this variable is particularly convenient for consideration of the strategic investment game, as it considers only *explicitly stated* and thus relatively more *credible threats*.[10]

The general estimated form of our estimated equation can be written as

y = f $(X, Z, X \times Z) + u$, where y = a dependent variable (see below)

X = a set of independent variables describing competitive behaviour

Z = a set of independent variables of structural factors

$X \times Z$ = interaction terms

u = an error term.

The variables are described below.

Dependent Variables

We set the binary dependent variable $y_{i,j,t}$ equal to 1 if firm i decided (and actually committed the resources) to increase its net production capacity for product j (j denotes PVC or VCM) during the observation year t, and to 0 otherwise.

$$y_{i,j,t} = \begin{cases} 1 \text{ if } \dfrac{K_{i,j,t+r} - K_{i,j,t+r-1}}{K_{i,j,t+r-1}} > 0 \\ 0 \text{ otherwise} \end{cases} \tag{1}$$

Due to the existence of a gestation lag of r periods for the commissioning of new capacity, we identify an expansion by the change in capacity r years after the time t at which the resources have been committed. Thus completed expansions reflect conditions prevailing about two (for PVC) to three (for VCM) years before the observed expansion date. Obviously, the form of Eqn (1) suggests that the dependent variable excludes entrants' investment, and registers expansions only by firms which were present in the industry at time t. Due to scale economies, the ratio in Eqn (1) takes extremely large values for small growing firms; defining investment as a dichotomous variable avoids this capacity scaling problem which justifies our use of the Logit model.

In the chemical industry, capacity can be expanded in three ways (in decreasing order of project expense): by constructing a new greenfield plant; by adding additional units at an existing plant site; or by expanding existing units incrementally (for example, by 'debottlenecking'). The last type is the fastest and it can result in a capacity increase of about 20% for plants of both products (for typical 100 000 metric tonnes per year (MT/y), PVC and 300 000 MT/y, VCM plants, respectively). However, incremental expansion of VCM plants is more time consuming, and the expenses involved are substantial. Usually, even such incremental expansions are publicized—especially the larger ones, so that firm intentions are known one or two years before the completion of the expansion (see *European Chemical News*, various issues).

Large Expansions

The variable in Eqn (1) includes all three types of expansions. In an attempt to screen out small and incremental expansions, we have defined a variable which is intended to capture only expansions of the first two types. Instead of identifying an expansion by seeking cases in which the ratio in Eqn (1) is greater than zero, the new variable $Y_{i,j,t}$ is defined to be equal to 1 if the next expansion (PS) is greater than 20 000 MT/y for PVC and 50 000 MT/y for VCM and equal to 0 otherwise[11]. Thus:

$$Y_{i,j,t} = \begin{cases} 1 \text{ if } K_{i,j,t} - k_{i,j,t+r-1} > PS \\ 0 \text{ otherwise} \end{cases} \quad (2)$$

Complete and Incomplete Expansions

Both the above variables record only completed expansions. They do not include projects which, although planned, were not eventually implemented because either another competitor pre-empted the expansion or the market conditions deteriorated. Consequently, they cannot account for the signalling-announcement game and its effect on firm behaviour. Thus, we define a third variable, $SY_{i,j,t}$, which takes into account what firm *i's* capacity would be in year $(t+2)$ if the expansion that the firm was planning at year t went ahead;

$$SY_{i,j,t} = \begin{cases} 1 \text{ if } EK_{i,j,t} - K_{i,j,t+r-1} > PS \\ 0 \text{ otherwise} \end{cases} \quad (3)$$

where again PS = 20 000 MT/y for PVC and 50 000 MT/y for VCM. We have included only in the expansions here because in the announcement game these would be the ones to have more impact on competitor behaviour. Obviously Y is a subset of SY as the latter includes both completed and incomplete expansion announcements. In a total number of 753 observations, we had 203 cases of both incremental and new plant investment (the non-zero elements of the y variable), 110 cases of only new plant investment (the Y variable) and 291 cases of plant announcements (the SY variable). The last is inflated and does not always represent different projects, because some postponed investments appeared as announcements in later years as well (albeit arguably correctly reflecting firms' intentions to invest).

Independent Variables

We have a total of 14 independent variables, mainly intended to capture the effects on firm investment behaviour and market conditions, as well as of structural factors.

Competitive Factors

Competitive Behaviour
We consider the following six variables.

(1) *Growth of Rivals* ($BAND_{i,j,t}$)

This variable records rival capacity expansion. It is defined as:

$$BAND_{i,j,t} = \frac{\sum\limits_{m=1} (K_{m,j,t+r} - K_{m,j,t+r-1})}{\sum\limits_{m=1} K_{m,j,t+r-1}} \quad (4)$$

We divide *BAND* in two; *BANDNE*, the capacity expansion by new entrants, and *BANDEP*, the capacity expansion of existing producers, so as to be able to distinguish between entry deterrence *per-se* expansions and attempts to pre-empt competitors. *BAND* measures the growth of firm *i*'s competitors due to expansions decided in year *t*. If the coefficient of *BAND* variables proves positive, it means that expansions of firm *i* were correlated to those of its competitors, i.e. that the firm expanded simultaneously with its competitors. If it is negative, the probability of firm *i* expansion during the observation year is inversely correlated with expansion of its rivals, so that firm *i* holds investment and in a way accommodates the expansions of its competitors. In this context a negative coefficient for *BAND* variables provides an indication of entry-accommodating behaviour.

(2) *Perceived growth of rivals* ($StrBAND_{i,j,t}$)

In order to infer the effect of the strategic signalling game on firm expansion investment, we have also defined a variable similar to *BAND*, *StrBAND*, recording both completed and unfinished projects. This is defined as follows:

$$StrBAND_{i,j,t} = \frac{\sum\limits_{m=1} (EK_{m,j,t} - K_{m,j,t+r-1})}{\sum\limits_{m=1} K_{m,j,t+r-1}} \qquad (5)$$

Again we distinguish between *StrBAND* of new entrants (*StrBANNE*) and existing rivals (*StrBANEP*). The *BAND* variables constitute a subset of *StrBAND*, as the latter includes also project announcements which were not eventually implemented. The interpretation of *StrBAND* variables is conceptually similar to that of *BAND*. A positive coefficient suggests that a firm's actual or announced investment follows a firm's *n-i*'s announcements, i.e. firms tend to invest in an attempt to pre-empt or deter their rivals. A negative coefficient for *StrBAND* implies that rivals' announcements make firms postpone investment (probably fearing total industry expansion in excess of demand).

(3) *Firm capacity share* ($SHARE_{i,j,t}$)

In the chemical industry this measure is used as a proxy for the firm's market share, for which accurate information is not available (Shaw and Shaw, 1983; Lieberman, 1987):

$$SHARE_{i,j,t} = \frac{K_{i,j,t}}{\Sigma K_{i,j,t}} \qquad (6)$$

(4) *Change in market share* ($DELSHR_{i,j,t}$)

The change in capacity share of firm i, between time t and time $(t+r-1)$ represents the anticipated change in the market share of firm i, accounting also for expansions already in the construction phase (to be completed during years $t+1,\ldots,t+r-1$). Thus:

$$DELSHR_{i,j,t} = \frac{SHARE_{i,j,t+r-1}}{SHARE_{i,j,t}} \qquad (7)$$

If firms were investing in an attempt to maintain market share, the coefficient of the *DELSHR* term would have to be negative, indicating that firms invest in order to counteract changes in their market share.

The following two variables are intended to capture the influence of market conditions on capacity expansion behaviour.

(5) *Capacity utilization* ($CU_{j,t}$)

This represents the average rate of capacity utilization over the observation year:

$$CU_{j,t} = \frac{Q_{j,t}}{\Sigma K_{i,j,t}} \qquad (8)$$

(6) *Output growth rate* ($GROW_{j,t}$)

This represents the historical growth rate of output for product j. In determining *GROW* we have taken into account that, in forecasting future output, present as well as past demand observations are considered. However, in estimating this variable, we have assigned more weight to recent observations to reflect their higher importance with respect to planning. We expect a positive sign.

Structural Factors

Technology Change and Technological Obsolescence

Technology change and investment for replacement of obsolete plants form an integral part of the capacity expansion process. We define two variables:

(1) *Firm obsolete capacity* ($REPLACE_{i,l,t}$)

This variable was defined as the proportion of firm i's capacity based on an old or obsolete process:

$$REPLACE_{i,l,t} = \frac{K_{i,l,t+r-1}}{\Sigma K_{i,l,t+r-1}}$$

where l is the type of process technology used. A negative coefficient for *REPLACE* would be an indication that the firm is particularly sluggish in increasing capacity because it needs to replace its old plants and, in the meantime, enjoys lower profits.

(2) *Rival obsolete capacity* ($StrREPLACE_{i,l,t}$)

Next we have defined a variable which reflects expansions attracted by advantages conferred upon the firm which operates new plants after we have controlled for the influence of market growth and capacity utilization. If a firm operates old or obsolete plants, opportunities are created for its rivals to expand at its expense; such investments involve pre-emption, as the firm's rivals pre-empt the firm from undertaking the replacement itself. This variable is defined as:

$$StrREPLACE_{i,l,t} = \frac{\sum_{m=1} K_{m,l,t+r-1}}{\sum_{m=1} K_{i,l,t+r-1}} \quad (10)$$

and represents the capacity of the firm's rivals which is based on obsolete plants. If strategic pre-emption of this type is involved we expect a positive coefficient for this variable.

Scale Economics Effects

In order to take into account considerations related to the optimal plant size in relation to market size, we have defined two more variables which capture the 'percentage' and the 'absolute capital requirements effects' of new plant size (Geroski, 1983):

(1) *The percentage effect (MES)*

This measures the proportion of a minimum-optimal scale (*MOS*) plant in relation to the total industry capacity; it was simply estimated as the ratio of *MOS* over the total installed capacity.

(2) *The absolute capital requirement effect (MOS)*

This represents the monetary value of the absolute size of the minimum-optimal scale plant $MOS_{j,t}$. As a proxy for this measure we have used the average size of installed plants (excluding very small plants).[12] The higher the *MES* variable, the less the probability of firm investment in new plants, because the more the price will be depressed and the lower the capacity utilization when the plant will come onstream (Scherer, 1980). To this end, a negative coefficient for *MES* would suggest that as *MES* increases, firms consider more seriously the impact that an expansion would have in the market and reduce the rate of investment. A positive coefficient provides an indication of intense rivalry, as competitors do not care for the effects of expansions on profitability but they simply expand in order to avoid being pre-empted by their rivals. On the other hand, the higher the *MOS*, the more the investment required to build an appropriate-sized plant, and thus the more probable is that financial constraints will start binding.

Vertical Integration

The desire for vertical integration was pronounced throughout the industry's development history (see Paraskevopoulos, 1988). Differences between the minimum optimal scales (*MOS*) of PVC and VCM plants suggest that some producers might have achieved this target after following a phased expansion policy, operating for some time partly forward integrated. In this way, PVC-plant announcements by partially forward-integrated VCM producers might be more credible.

Partial Integration (VERT)

In order to take into account the higher activity of these partly integrated VCM producers, we have defined the variable *VERT* as the proportion of firm *i*'s VCM capacity in comparison to its PVC one (we have alternatively used a dummy set equal to one when the excess VCM capacity of a firm was more than sufficient to supply a medium-scale PVC plant; both formulations provided similar results). We have not considered such an effect for the VCM plants. Access to raw materials was a necessary condition for participation in the VCM business, while the large size of a VCM unit practically prohibited VCM expansion in order to supply partially backward integrated PVC units.

Interaction Terms

In order to allow for possible asymmetries depending on market share and in order to obtain a genuinely 'general' starting Eqn, we computed multiplicative interaction terms between the capacity share of each firm (*SHARE*) and the level of some of the explanatory variables where such asymmetries might arise. Very few firms in the industry have shares large enough to significantly affect their marginal revenues, however, which would suggest that one would not expect significant coefficients for most of these terms.

RESULTS AND DISCUSSION

Our main results are summarized in Tables 1 and 2. We report only our results for large expansions (Table 1 dependent variable, *Y* Eqn 2) and plant announcements for such expansions (Table 2, *SY* variable, Eqn 3) to economize on space and facilitate the presentation and comparisons of the results. Results for all expansions (dependent variable *Y*, Eqn 1) are available from the authors on request (all results were supported). In the first column of the tables we report the general equation which includes all the independent variables as well as the interaction terms. Column 2 reports the more parsimonious equation obtained by dropping the non-significant variables. The Wald test was used throughout to test the validity of these restrictions. In column 3 we report the 'specific' equation obtained by the same procedure from a 'general' equation also including all our interaction terms. One-tailed *t* tests for significance are reported. For each model the parameter estimates are the partial derivatives of the logit probability of expansion with respect to the independent variable, calculated at the sample mean (Fomby *et al.,* 1984).

Focusing on our preferred 'specific' Eqns 2 and 3 in Table 1, we observe the following picture. Capacity expansion is positively correlated with expansion announcements of competitors, obsolete capacity of competitors, share and capacity utilization and negatively correlated with increasing scale of operations (*MOS*) and market growth. The results are broadly in line with expectation

Table 1 Logit Analysis of Expansion Probability: Actual Expansions

Independent variables	1	2	3
CONSTANT	−8.45[a]	−8.21[a]	−7.93[a]
	(2.27)	(3.30)	(3.16)
BANDNE	−8.91	–	–
	(0.93)		
BANDEP	−0.58	–	–
	(0.15)		
STRBANNE	−0.11	–	–
	(0.04)		
STRBANEP	2.86	2.59[a]	2.68[a]
	(1.49)	(2.05)	(2.09)
SHARE	15.77[a]	15.63	8.97[a]
	(6.19)	(6.38)	(1.96)
DELSHR	−0.06	–	–
	(0.13)		
REPLACE	−0.54	–	–
	(1.11)		
STRREPLA	2.19[a]	1.22[b]	1.32[b]
	(2.30)	(1.67)	(1.64)
CU	9.04[a]	9.03[a]	9.16[a]
	(2.31)	(3.03)	(3.05)
GROW	−5.68	−6.13[a]	−10.05[a]
	(1.46)	(1.98)	(2.73)
MOS	−0.07	−0.07[a]	−0.07[a]
	(1.34)	(2.26)	(2.25)
MES	1.31	–	–
	(0.05)		
VERT	0.27	–	–
	(1.24)		
GRSHA	–	–	66.95[b]
			(1.79)

t Ratios in parentheses.
[a]Significance at the 5% level.
[b]Significance at the 10% level.

Table 2. Logit Analysis of Capacity Expansion Probability: Plant Announcements

Independent variables	1	2	3
CONSTANT	6.71[a]	3.70[a]	5.18
	(2.41)	(−2.09)	(2.69)
STRBANNE	−1.79	–	–
	(1.02)		
STRBANEP	2.48[a]	2.17[a]	2.25[a]
	(2.27)	(2.03)	(2.09)
SHARE	19.82[a]	19.74[a]	42.94[a]
	(7.92)	(7.99)	(3.67)
DELSHR	−0.21	–	–
	(0.57)		
REPLACE	−1.32[a]	−1.33[a]	−1.35[a]
	(3.48)	(3.56)	(3.58)
STRREPLA	3.03[a]	2.40[a]	2.37[a]
	(3.95)	(3.63)	(3.52)
CU	6.66[a]	2.67[b]	2.87[b]
	(2.31)	(1.78)	(1.90)
GROW	−4.76[b]	–	–
	(1.64)		
MOS	0.05[b]	0.05[b]	0.10[a]
	(1.71)	(1.90)	(2.77)
MES	−55.99[a]	−75.95[a]	−72.62[a]
	(2.63)	(4.59)	(4.41)
VERT	0.63[a]	0.65[a]	0.67[a]
	(3.73)	(3.90)	(3.88)
MOSHA	–	–	−1.00[a]
			(2.06)

t Ratios in parentheses.
[a] Significance at the 5% level.
[a] Significance at the 10% level.

and empirical evidence (see Gilbert and Lieberman, 1987). It would appear counterintuitive that high growth limits investment. Yet this paradox is solved when we look at column 3. In there the (only) significant interaction term is the growth term, and it is positive and significant. This would imply that for large firms growth affects investment positively, but for small firms, negatively. An explanation is that high market growth requires heavy investments to sustain market shares and this makes small firms fall behind (for example, due to capital access difficulties).

The positive signs of *StrBANDEP* and *StrREPLACE* suggest that firms invested in an attempt to prevent competitor announcements for expansion and also to capitalize on competitor weaknesses due to obsolete plants (respectively). We consider this as a strong indication of pre-emptive behaviour.

In Table 2, the plant announcement results, three more variables appear in our final column 2. The vertical integration variable with a positive sign, the *REPLACE* variable with a negative sign, and the *MES* variable also with a negative sign. On the other hand, the growth term (as well as its interaction term with *SHARE* in column 3) drops out. In this latter equation the interaction term of *MOS* and *SHARE* now appears with a negative sign.

Limiting our discussion to its bare essentials, the disappearance of the growth terms in columns 2 and 3 would suggest that, unlike real expansions, announcements may not be affected by market growth. The signs and significance of the vertical integration variable, the negative effect of the *REPLACE* variable (negative expansionary projects of firms possessing a large amount of obsolete capacity) and the relative scale effect can all be seen to affect the credibility of plant announcements. The most interesting results though, from the point of view of this paper, come from the *(Str)BAND* type variables.

In all our reported (and unreported) equations the one variable which was consistently found to affect expansions and expansion announcements by existing rivals. This suggests that incumbents' plans to expand capacity and announcements to do so are strongly affected by the announcements of existing competitors.

To summarize, our data and analysis of the industry in question suggest that incumbents were concerned to pre-empt existing rivals by undertaking expansions when existing rivals announced to do so. Also a strategic signalling game was observed whereby incumbents announced expansions, following announcements by existing rivals.

Before concluding, the following are worth noting. First, although our framework here appears largely static, dynamics have been incorporated in terms of the *DELSHR* variable. Its insignificance in all cases suggest that (announcements of) expansions were not affected by market share considerations. That potential reactions to past failures to expand are covered in the *DELSHR* variable, which suggests that one should include the *StrBAND* type variable concurrently (and not lagged) as we did. A possible extension would be to include industry forecasts as an explanatory variable to test whether the observed overoptimistic forecasts also played a role in explaining expansions (announcements). Unfortunately such a series was not available. Existing forecasts for the years reported are not published annually and/or on a regular basis.

CONCLUSIONS AND POLICY IMPLICATIONS

We have tested for the first time the relationship between capacity expansion and plant announcements by industry incumbents and their rivals and/or potential entrants. Our results lend support to the idea that incumbents were interested in pre-empting existing rivals. Although the extent to which results such as ours are conclusive is limited by inherent problems with data and their interpretation, we hope we have gone a step towards throwing some light on these totally unexplored empirical issues. Further research is obviously needed.

Concerning policy, our results appear to support the idea that incumbents are strongly interested in *actual* competition. To the extent that their (announcements of) capacity expansions are intended to deter entry, this appears to be through pre-empting existing rivals and/or signalling to existing rivals intentions to fight, with an eye to achieving industry coordination.

Acknowledgements

We are grateful to J Gabsevitz, N Ireland, S Martin, T Nilssen, A Silberstorn, S Thompson, M Waterson and D Ulph for helpful comments and discussion on earlier drafts. We also thank three anonymous referees of this journal.

NOTES

1. They suggest that these elements influence a new entrant's decision. However, they can be viewed as more general, underlying also the investment decisions of already existing producers.
2. For a review of the various aspects of entry barriers see Geroski (1983).
3. For example, the prospective entrant in the presence of scale economies has two options: enter with a sub-optimal scale plant, thus incurring a cost disadvantage relative to incumbents; or enter with an optimal scale plant but under-utilize it at least for some time or cut prices. Barriers similar in effect to those by ordinary static scale economies are also created by dynamic economies (learning); these are higher for moderate rates of learning (Spence, 1981).
4. See, for example, Schmalensee (1978) for an example in the ready-to-eat cereals industry.
5. This argument has also been questioned on theoretical grounds. See, for example, Dixit (1980) and Spulber (1981)
6. For examples in which pre-emption was not successful because the incumbent could not run fast enough, see Lieberman (1978a) for the magnesium industry.
7. The product homogeneity and the absence of external trade justifies the treatment of VCM–PVC as a single market.
8. This makes it important to see how large firms reacted.
9. There were no indications or allegations of a cartel during this period. Some such allegations appeared in the post-1981 period (see *European Chemical News*, various issues, for more details).
10. One might think of secret expansions intended to avoid rival reactions. Secret expansions were very few and consisted only of incremental ones. In fact it is difficult for major expansions not to be detected, at least by the industry participants, because of the high diffusion of information through consulting and contracting companies. Thus, even if an expansion is not publicized in the press, it can practically remain confidential only for a very short

time, and almost certainly cannot after construction has begun.

11. This is the specification of the dependent variable of Gilbert and Lieberman (1987). In particular, they estimate the value of *PS* as 5% of total firm capacity. Although according to our definition the value of *PS* is still within this range for large firms, for small ones it implies very small expansions. Although perfect distinction between incremental and large expansions cannot be claimed with such a rough measure, the values chosen for *PS* represent addition of at least one polymerization vessel for PVC, or another ethylene-dichloride unit (or major incremental expansion of the EDC, pyrolysis unit) or a major revamp of the plant which makes necessary a feasibility study, consulting advice, etc.
12. We have also used an alternative formulation for *MOS* in order to take into account the differences between the capital intensity of the production process of the two products and the nonlinearity of the scale effect. Obtained results, however, were very similar.

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