Capacity Expansions timing patterns in the United Kingdom's petroleum refining industry between 1948 and 1998

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ABSTRACT

We try to get a handle on whether capacity expansion timing patterns in oligopoly among incumbents are followed. We study the United Kingdom ´s petroleum refining industry between 1948 and 1998. Using fixed-effects logit models, we find that U.K.´s refiners have not followed any definite capacity expansion-timing pattern.

Author Keywords: Capacity expansion timing; Mobility deterrence

JEL Classification: L11; L13; L71

Introduction

In high fixed costs industries where product homogeneity predominates, demand shocks happen at aggregate level. Since capital equipment is usually specific to this kind of industries, the costs of CEs tend to be irreversibly sunk, thus (very) expensive commitments are generated when CEs are made.

The petroleum refining is a high fixed cost industry especially characterised by irreversibility. This suggests trying to find out whether firms follow some type of CEs timing

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behaviour to optimise investment decisions when they expand capacity. We define a CE timing pattern as some kind of CE execution among competitors, which repeats (more or less) regularly.

In the Industrial Organisation literature, the most important published articles which have taken up timing issues at least tangentially when testing CEs as strategic tools among incumbents, have been Lieberman [1987a, b] and Gilbert and Lieberman [1987]. These articles study investment rivalry across the same sample of U.S. chemical processes industries (between twenty-four and thirty-nine industries), during two decades[1].

Gilbert and Lieberman [1987] study the use of CEs only among incumbents. Their goal is determining, in a non-co-operative framework, whether incumbents expand capacity in order to maintain their market shares, so that they "co-ordinate" CEs, or they do not expand capacity to maintain their market shares, but instead try to pre-empt each other's CEs. They find that capacity size differences generate maintenance of market shares amongst larger firms and pre-emption amongst smaller firms.

We are going to concentrate on CEs timing exclusively among incumbents. In this paper we re-state and adapt Gilbert and Lieberman (henceforth, GL) [1987], with the aim of testing for the existence of CEs timing patterns in the U.K.´s petroleum refining industry during the period 1948-1998. Surprisingly against the background, our results do not support the hypothesis that incumbents practised any CE timing pattern.

Hypothesys to test

It makes sense to conceive that incumbents firms time their CEs either in order to keep their market share or in order to enlarge it. Otherwise CEs would be unnecessary. This gives

[1] When we assert that Lieberman [1987a,b] and Gilbert and Lieberman [1987] treat timing tangentially, we are asserting that these articles are not testing models where time is the decision variable. Rather, they are explicitly proposing an exogenous timing of CEs. The special feature of their models consists, as we will see, of associating a given exogenous timing to the (pricing) models they test.

place to the possibility of spotting some type of CE execution among incumbents, which repeats (more or less) regularly, which we define as a CE timing pattern.

HYPOTHESIS: *If long term incumbents followed any CEs timing pattern in the U.K.'s petroleum refining industry, then either they have expanded capacity making round-robins, maintaining market shares and/or pre-empting each others. Otherwise no CEs timing pattern existed.*

Data and Variables

What we are searching for in this analysis is identifying the presence of CE timing patterns among incumbents in the U.K.'s petroleum refining industry during the period 1948-1998. It is worthy to note that U.K.'s refiners keep outstanding capacity size differences. We consider only firms which operated longer than 5 years in this industry.

We will study the CE timing behaviour of firms after they had settled in the U.K.'s petroleum refining industry throughout the reference period. In order to do so, we use fixed-effects logit models. This type of model allows us to take into account the capacity size differences existing among incumbents. We test the three hypotheses stated in the main hypothesis (and described below): The practice of round-robins, maintaining market-share and pre-emption.

The basic data consists of production capacity by firm and total industry output. We compute the data as follows:

$K_{i,t}$: Total capacity of firm i on January 1 of year t

Q_t: Total industry output during year t

We analyse CEs at firm level: There is one observation per firm and year in which the incumbent is a producer. We estimate investment behaviour by using fixed-effects logit models on the probability that a firm expanded capacity. We set a binary dependent variable equal to 1 for all observations where firm i increases primary capacity more than 5.00% in the observation year. Thus:

$$y_{i,t} = \begin{cases} 1 & \text{if} \quad \dfrac{K_{i,t+1} - K_{i,t}}{K_{i,t}} > 0.05; \\ 0 & \text{Otherwise} \end{cases} \qquad (1)$$

In the petroleum refining industry, like in other chemical processing industries, apart of expanding capacity through additions to existent refineries or new refinery construction, firms can expand capacity by eliminating bottlenecks, which in essence stems from learning-based improvements achieved at negligible investment costs. These usually do not reach more than 5.00% expansion rate. Hence, our choice of a (larger than) 5.00% threshold on expansion size is made to screen out incremental expansions of this nature.

We also choose a dichotomous measure for CEs in this part of the study, because with economies of scale in new capacity, the ratio in equation (1) may take on extremely large values for small, growing firms. Following GL [1987], defining investment as a dichotomous variable avoids this capacity scaling problem.

Building a new refinery may take up to two years, while expanding an existing refinery usually can be done more quickly. Completed CEs thus reflect the influence of firm and industry conditions prevailing from one to two years before the observed expansion date. We list the next explanatory variables, which are meant to describe these conditions:

- Capacity Utilisation (CU_t). Represents the average rate of capacity utilisation over the prior two-year period:

$$CU_t = \frac{Q_{t-1}}{\sum (K_{i,t} + K_{i,t-1})} + \frac{Q_{t-2}}{\sum (K_{i,t-1} + K_{i,t-2})}$$

- Output growth rate ($GROW_t$). Defines the historical rate of output growth over the prior four-year period:

$$GROW_t = \left(\frac{Q_t}{Q_{t-4}} \right)^{1/4} - 1$$

- Firm's capacity share ($SHARE_{i,t}$). Firm i's share of total industry capacity at the start of year t:

$$SHARE_{i,t} = \frac{K_{i,t}}{\sum K_{i,t}}$$

- Change in capacity share ($DELSHR_{i,t}$). The change in total industry capacity share of firm i from the start of year t-2 to the start of observation year t is[2]:

$$DELSHR_{i,t} = \frac{SHARE_{i,t}}{SHARE_{i,t-2}}$$

- "Bandwagon" effect ($BAND_{i,t}$). This is a variable that records rival´s CEs; we define the "bandwagon" variable in year t as follows:

[2] We select a two-year period to measure the changes in capacity shares, because this corresponds to the lag associated with the construction of new refineries.

$$BAND_{i,t} = \frac{\sum_{m \neq i} (K_{m,t+1} - K_{m,t})}{\sum_{m \neq i} K_{m,t}}$$

The variable *BAND* is the percentage by which all producers other than firm *i* collectively increased their capacity during the observation year. GL [1987] asserts that *BAND* is inversely related to the change in firm *i*'s capacity share during the observation year, which results from the actions of competing firms. This differs from the variable *DELSHR*, because *DELSHR* refers to changes in capacity share that results from own as well as rivals' investment and it is measured over the preceding two years.

GL [1987] holds that a positive coefficient for *BAND* implies that a firm's expansion tends to be correlated with expansions of other firms, after we control for the influence of historical growth and/or capacity utilisation. To the extent that each firm is knowledgeable of the investment plans of its rivals, a positive *BAND* coefficient suggests that firms have a tendency to invest simultaneously instead of staggering their investments over time. This is equivalent to state that firms tend to "hop on the wagon".

- Interaction terms

The major asymmetries across firms in this industry relate to their market shares. For detecting possible differences in CEs timing behaviour that vary systematically with market share, we compute multiplicative terms between the total industry capacity share of each firm (*SHARE*) and each one of the independent variables (excluding *SHARE* itself).

It is also plausible that the investment asymmetries attributed to market shares may result from differences in industrial concentration. Product markets for which firms have large share also tend to have high concentration levels. To differentiate the two possibilities we define a second set of multiplicative terms by using firms' Herfindahl-Hirschman ratios (*HERFIN*) as multiplicative variables. Recall,

$$HERFIN_t = \sum_i \left(\frac{K_{i,t}}{K_t} \right)^2$$

In contrast to GL [1987], we find them significant several times for our case study. Then we include these concentration interactions set along with the share interactions set in the models as explanatory variables.

Additionally, most firms in the sample are either multinational petroleum companies or local petroleum refining companies. Conceivably, these groups might differ in their CEs timing behaviour, basically because multinationals tend to be larger firms integrating operations from crude extraction to derivatives distribution.

To test this assertion we define a dummy variable for multinational companies (1) and non-multinational companies (0) and then multiply it by *CU*, *DELSHR* and *BAND* as part of the independent variables. Again in contrast to GL [1987], these have explanatory power in the U.K.'s petroleum refining industry case.

The interaction terms used can be summarised as follows:

$$GROWSH_t = GROW_t x\ SHARE_{i,t}$$

$$DELSHS_t = DELSHR_{i,t} x\ SHARE_{i,t}$$

$$BANDSH_t = BAND_{i,t} x\ SHARE_{i,t}$$

$$BAND_t^{MN} = BAND_{i,t} x \begin{cases} 1 & \text{if multinational} \\ 0 & \text{if non-multinational} \end{cases}$$

$$GROWHERF_t = GROW_t x\ HERFIN_t$$

$$BANDHERF_t = BAND_{i,t} x\ HERFIN_t$$

$$DELSHERF_t = DELSHR_{i,t} x\ HERFIN_t$$

$$CUSH_t = CU_t x\ SHARE_{i,t}$$

$$CUHERF_t = CU_t x\ HERFIN_t$$

Observe these interaction terms have basically the following root variables:

CU

GROW

DELSHR

BAND

Which are interacted with the following asymmetry variables:

SHARE

HERFIN

$$\begin{cases} 1 \text{ if multinational} \\ 0 \text{ if non-multinational} \end{cases}$$

We have to remark that these interaction terms impact on equation (1) will follow the effects the root variables are expected to have on the hypotheses tested.

- Lagged terms

All independent variables are computed in first and second differences, over the one-year capacity additions and two-year refinery construction periods. As a result, for any given firm, observations begin at least one year after the firm entered the industry. This excludes initial capacity investment by entrants. Consequently, the dependent variable registers expansions by incumbent firms only. Note lagged terms are not included in GL [1987]´s models.

- Other terms

Completing the specification of the dependent variable $y_{i,t}$ in equation (1), all independent variables are included in their quadratic and inverse forms. The quadratic-form coefficients are interpreted as the linear-form ones, since the underlying variable is the same. The inverse-form coefficients stand for multiplicative effects of the underlying variable.

Since some first attempts to fit prospect models show severe specification problems with the linear form of the independent variables, these terms are included with the aim of inductively determining better specifications for the dependent variable in equation (1). This certainly distinguishes our work from GL [1987].

We describe now the results we expect in order to contrast our main hypothesis.

Capacity Expansion Timing Patterns models

Round-robins

According to GL [1987], the Cournot-Nash model with identical firms predicts an investment round-robin, with no firm building its $(N+1)^{st}$ refinery until every other firm has at least N refineries. The assumptions according to which firms take rival expansions projects as given and have identical technologies and product characteristics are very restrictive. Hence, it would not be surprising if the round-robin investment behaviour predicted by the Cournot-Nash model were rarely observed in our data sample. Nevertheless, this hypothesis about firm’s CEs timing can be tested.

Although the round-robin hypothesis assumes that firms are symmetric in capacity, GL [1987] show that we may generalise this to allow for asymmetric installed capacity among firms[3]. Bearing this in mind, consider an industry with *M* competitors. Let r_{it} be an indicator variable that takes on a value of 1 if firm *i* invests at date *t*, *-1/(M-1)* if firm *j* invests at date *t*, and zero otherwise. Let us define the variable

$$R_{it} = \sum_{\tau=0}^{t} r_{i\tau} \qquad (2)$$

The start date ($\tau = 0$) corresponds to a point in time at which all firms have made an equal number of CEs (but with possibly unequal market shares). If firms invested following a round-robin pattern, then R_{it} would be bounded above by +1 and below by –1. If firms had unequal number of CEs (and possibly unequal market shares) at the start date, but followed a round robin, then the bounds on R_{it} would differ, but the difference between its upper and lower bounds would be at most two.

Then an examination of the frequency distribution of R_{it} permits us to assess empirically the presence of an investment round-robin. Any observations of R_{it} separated by more than two units cannot belong to a round-robin. Of course, even if firms followed a round-robin, mistakes in actions or observations may occur. We can incorporate this fact by allowing a confidence level for the fraction of observations of R_{it} in equation (2) that may lie outside a bound of two before this hypothesis can be rejected. We allow for a 5.00% (we contrast the round-robin hypothesis without stating any sub-hypothesis).

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[3] Observe firms that are clearly members of a competitive fringe may be excluded from the round robin.

Maintaining-market-share

We assert that the market share of any firm can be proxied through its share of total industry capacity. We follow this assertion when we examine the maintaining-market-share hypothesis. Capacity-sharing asymmetries among firms will play a major role in pursuing this CEs timing pattern, because the motivation to make CEs would be determined by refiners projecting to sustain their market stake.

The maintaining-market-share hypothesis is basically a generalisation of the round-robin hypothesis: If firms maintained their market shares, they should be willing to expand capacity all at the same rate each time, even if that rate were changed. Moreover, each firm would expand only until after every other firm has done so. However, under this hypothesis, decisions to expand capacity are more linked to market fluctuations in the sense that this type of behaviour stipulates that firms expand solely to protect their market stake, not for the mere aim of following each other, as in a typical round-robin.

In a maintaining-market-share CE timing regime, the average rate of investment of each firm over time should grow with the product of the growth rate and its market share or concentration index. Capacity utilisation rates per se should have no effect on this investment pattern. GL [1987] holds that firms should respond negatively to *DELSHR*, the measure of their change in capacity share and they should respond positively to *BAND*. If rival firms announce CE programmes corresponding to a high value for $BAND_{i,t}$, firm i must respond with a CE of its own to maintain its share of industry capacity. We extend these expected effects to any variables whose roots are *DELSHR* or *BAND*.

Excluded from this part of the modelling of equation (1) are variables *GROW*, *SHARE*, *HERFIN*, *CU* (and its multinational companies interaction terms), *CUxSHARE* and *CUxHERFIN*. The first three variables *GROW*, *SHARE* and *HERFIN*, are omitted from this model because in a system in which CEs are timed to maintain market share, and consequently industrial concentration, each firm's investment should be positively impacted by the product of its market share and the industry's growth rate.

Hence, variables *GROSH* and *GROWHERF* should completely capture the positive effects of market growth on industry investment in a maintaining-market-share regime. We omit *CU* and the interaction variables *CUSH* and *CUHERF*, because capacity utilisation should not be a determinant of CEs under maintaining market shares, since incumbents are rather "herding" instead of "planning strategically".

GL[1987] specify the following model on the maintaining market share hypothesis:

$$y_{i,t} = a_1 GROWSH_t + a_2 DELSHR_t + a_3 DELSHS_t + a_4 BAND_t + a_5 BANDSH_t + e_t$$

which using our data sample, turned out to be mis-specified.

Consequently, we specify the next model to test the expected relationships among variables and then assess the maintaining market share hypothesis in our data sample. The specification proposed is correct. Note building up to equation (1a) implied keeping in mind the underlying reasoning of the maintaining market share hypothesis as looking for the best econometrical quality of the model.

$$\begin{aligned} y_{i,t} = {} & w_1 GROWSH_t^2 + w_2 \frac{1}{DELSHR_t} + w_3 DELSHS_{t-1} + w_4 BAND_{t-1} + w_5 BANDSH_{t-2} \\ & w_6 BANDSH_t^2 + w_7 BAND_{t-1}^{MN} + w_8 GROWHERF_t^2 + w_9 BANDHERF_{t-1} \\ & w_{10} DELSHERF_{t-2} + e_t \end{aligned} \tag{1a}$$

Where we test

1) $\begin{array}{l} n.s.h: w_2, w_3, w_{10} < 0 \\ a.s.h: w_2, w_3, w_{10} > 0 \end{array}$ 2) $\begin{array}{l} n.s.h: w_4, w_5, w_6, w_7, w_9 > 0 \\ a.s.h: w_4, w_5, w_6, w_7, w_9 < 0 \end{array}$

3) $$n.s.h: w_1, w_8 > 0$$
$$a.s.h: w_1, w_8 < 0$$

Pre-emption

We define pre-emption as the act of making a CE before any other rival firm in order to render its CE less attractive by reducing the value of its investment opportunity. Successful pre-emptive investment should generate an increase in market share that lasts for some time and should not stimulate investment activities by competing firms.

In contrast to the behaviour pattern in a model in which firms maintain market shares, a reduction in any firm´s market share should not induce to invest when firms engage in effective pre-emptive strategies. Hence, the *DELSHR* variable (including its version restricted to multinational companies) and its interactions with *SHARE* and *HERFIN* should not have any explanatory value in the pre-emption model.

Following GL [1987], we can use industrial CU data to test whether a pre-emptive CE timing strategy is put in practice. When a firm invests, total capacity increases, and if there is no price reduction, CU declines. Therefore, if capacity utilisation has any effect on investment, it must be positive for pre-emption to be effective. Otherwise, pre-emption will only help to stimulate investment by other firms since they will perceive it as an empty threat. Hence, a positive correlation between CU and the probability of expanding capacity is a necessary condition for effective pre-emption.

Additionally, if all firms other than firm *i* announce a CE, the information should cause firm *i* to consider a delay in its own decision to expand capacity. This implies that *BAND* should be negatively correlated with CEs under pre-empting CE timing. Nonetheless, according to GL [1987], this correlation could be reversed if incumbents invested simultaneously for reasons that are not captured by other explanatory variables (for example, an innovation process could lower costs and trigger new investment by all firms in the industry).

GL[1987] specify the following model on the pre-emption hypothesis:

$$y_{i,t} = a_1 CU_t + a_2 CUSH_t + a_3 GROWTH_t + a_4 GROSH_t + a_5 BAND + a_6 BANDSH_t + e_t$$

which using our data sample, turned out to be mis-specified.

Consequently, we specify the next model to test the expected relationships among variables and then assess the pre-emption hypothesis in our data sample. Observe although in the fit of equation (1b) we will find opposite significant signs not only between $GROW_{t-1}$ and $GROW_{t-2}$, but also between $BAND_t$ and $BAND_{t-1}$, the specification proposed is correct. Note building up to equation (1b) implied keeping in mind the underlying reasoning of the pre-emption hypothesis as looking for the best econometrical quality of the model.

$$y_{i,t} = z_1 CUSH_t + z_2 CUHERF_t + z_3 GROW_{t-1} + z_4 GROW_{t-2} + z_5 GROWSH_t + z_6 GROWSH_{t-1}$$

$$(1b)$$

$$+ z_7 BAND_t + z_8 BAND_{t-1} + z_9 GROWHERF_t + z_{10} BANDHERF_{t-1} + e_t$$

Where we test

4) $\begin{array}{l} n.s.h: z_3, z_4, z_5, z_6, z_9 = 0 \\ a.s.h: z_3, z_4, z_5, z_6, z_9 \neq 0 \end{array}$

5) $\begin{array}{l} n.s.h: z_7, z_8, z_{10} < 0 \\ a.s.h: z_7, z_8, z_{10} > 0 \end{array}$

6) $\begin{array}{l} n.s.h: z_1, z_2 > 0 \\ a.s.h: z_1, z_2 < 0 \end{array}$

Analysis of results

We analyse the existence of CE timing patterns for both Greenfield refineries construction and capacity additions to Greenfield refineries executed during 1948-1998. In tables 1, 2 and 3 we examine, respectively, the three hypotheses related to our main hypothesis: The practice of round robins, maintaining-market-share and pre-emption.

Round-robins

The first of these hypotheses is the practice of round robins. In table 1 are listed the 21 petroleum refining companies in our sample. The fact that those firms had unequal number of investments after 1948 shows up in the bounds of the intervals in the lower part of table 1.

We find that, even allowing for a confidence level of 5.00% on the bounds of the round-robin interval, only a 19.05% of firms during 1948-1998 in the U.K.'s petroleum refining industry intended not to expand capacity until after every other firm had done so. Therefore, we can infer, examining the frequency distribution of R_{it} in equation (2), that the round-robin investment hypothesis has little support in this case study.

Maintaining-market-share

In a more realistic environment, market shares will fluctuate with random changes in factors that determine demand and supply, even if firms are investing with the objective of maintaining their market shares. Firms following a strategy of maintaining-market-share could be expected to expand capacity when (and only when) they detect reductions in their market shares that they consider substantial relative to historical random variations.

The fixed-effects logit model in table 2 is overall significant and well specified at 5.00%. According to this fixed-effects model, 53.31% of CEs variations in the industry can be explained through the relationships we have modelled. Note six out of the ten explanatory variables show contrary signs to the ones expected under the maintaining-market-share hypothesis: At a 5.00% significance level, we reject the null sub-hypotheses 1), 2) and 3) with respect to $w_1, w_3 w_5, w_6, w_9$ and w_{10}.

On the one hand, observe for every 1.00% increase, although *DELSHR* had a negative (but multiplicative) impact on the probability of expanding capacity of about 0.00000006% in year *t*, capacity differences on change in capacity share (*DELSHS*) had a positive influence in year *t-1* of 0.0000005%. Similarly, concentration differences on change in capacity share (*DELSHERF*) had a positive influence but in year *t-2* of 0.0000008%.

Thus, it is less likely that firms were expanding to change capacity share in current years, as expected under the maintaining-market-share hypothesis, instead, larger firms were expanding more probably to change capacity share one year before. Additionally, in periods of higher industrial concentration, all firms were prone to change capacity share two years before.

On the other hand, from the same fixed-effects model of equation (1a) in table 2, we note in year *t-1*, for every 1.00% increase of *BAND*, the CE probability rose 0.0000002% for any refiner and 0.0000003% for multinational companies only. However, for each 1.00% increment in the capacity differences of the percentage firms other than firm *i* expanded (*BANDSH*) in years *t-2* and *t*, the CE probability diminished, respectively, 0.000001% and 0.0003%. Concentration differences on the percentage firms other than firm *i* expanded (*BANDHERF*) had also a negative impact on the CE probability in year *t-1* of about 0.000006%.

Then, firms, multinationals or not, might have been trying to "band-wagon" CEs a year before current years, which would be (with delay) expected under the maintaining-market share hypothesis, but larger firms were not inclined to "band-wagon" their decisions either in the current year or two years before. Analogously, in periods of higher industrial concentration, one year before was characterised for a decreasing probability of "band-wagon" decisions.

Observe in year *t-1* each 1% increment of *BANDHERF* was diminishing the probability of expanding capacity more than each 1% increment of both *BAND* and $BAND^M$ were augmenting it, which does not support the maintaining market share hypothesis.

Besides, in spite of the result that for each 1.00% increase in the concentration differences on production growth (*GROWHERF*) in year *t* the probability of expanding capacity increased 0.014%, for each 1.00% rise in the capacity differences on production growth (*GROWSH*) in year *t*, the probability of expanding capacity dropped 0.0007%. This means, although higher concentration periods were more suitable for expanding when output grew, whenever output grew larger firms were not expanding capacity.

Then, what can we infer about the practice of maintaining market shares as a CEs timing pattern in the U.K.'s petroleum refining industry between 1948 and 1998? Analysing overlapping effects, we can infer that, in higher industrial concentration periods, no firm was expanding capacity to maintain its market share, and irrespective of industrial concentration levels, larger firms were not expanding capacity to maintain their market share. Therefore, the practice of this CE timing pattern does not sustain.

Pre-emption

The last hypothesis related to our main hypothesis is pre-emption. In table 3 we present the fixed-effects logit fit of the pre-emptive CEs model in equation (1b). This is significant and well specified at 5.00%, and its explanatory variables are all significant at 10.00%. However, only 23.74% of CEs variations in this industry can be explained through this model. In fact, at a 10.00% significance level, we reject the null sub-hypothesis in 4), in 5) only with respect to z_8, and in 6) only with respect to z_2.

We see from equation (1b) ´s model in table 3 that for each 1.00% increase in year *t* of the capacity differences on capacity utilisation (*CUSH*), the probability of expanding capacity rose 0.0000002%. Also, for each 1.00% increase in year *t* of the concentration differences on capacity utilisation (*CUHERF*), the probability of expanding capacity dropped 0.0000003%. This contradicts the pre-emption hypothesis, because in any case the negative effect of *CUHERF* was greater than the positive effect of *CUSH* on the probability of expanding capacity.

Besides, table 3 displays that for each 1.00% increment of *BAND* in year *t*, the probability of expanding capacity fell in year *t* 0.00000015%, which agrees with the pre-emptive hypothesis. However, in contrast with this hypothesis for every 1.00% increase in *BAND* from year *t-1* this probability increased 0.00000021%. Further, in year *t-1,* for each 1.00% rise in the differences of concentration on the percentage firms other than firm *i* expanded (*BANDHERF*), this probability fell 0.0000012%.

Additionally, we observe that output-growth related terms signs were mixed. For instance, while each 1.00% rise of output growth in year *t-2* raised the probability of expanding capacity in about 0.00000017%, a similar increment in year *t-1* reduced it around 0.00000022%.

Likewise, even though for every increase in 1.00% during year *t-1* and year *t* of the capacity differences on output growth (*GROWSH*), the probability of expanding capacity rose, respectively, 0.0000003% and 0.0000013%, this fell 0.0000029% for each 1.00% increase in the concentration differences on output growth (*GROWHERF*) in year *t*.

In consequence, we infer that the positive impact of capacity utilisation needed for pre-emption to be effective is not fulfilled. We also infer that the absence of “band-wagon” behaviour, required by the pre-emption hypothesis, is only partial. Besides, in higher industrial concentration periods, all firms were more prone to concede investment opportunities to competitors, as expected under the pre-emption hypothesis, but with a year delay.

Nevertheless, the mixed signs of output- growth related variables reveal that, even though larger firms were more willing to expand capacity in the current year and one year before, when output grew, this was not true for smaller firms. Thus, one year before, CEs were likely done by larger firms. However, two years before, CEs were undertaken with the same probability by any firm when output grew. During higher industrial concentration periods, in both one and two years before the current year, CEs were less likely done by anyone.

What shall we deduce then about the practice of pre-emptive CE timing in this industry during 1948-1998? We observe from the fixed-effects logit model of table 3 that according to equation (1b), the pre-emption hypothesis does not hold undoubtedly for our data. Therefore we infer that pre-emption does not sustain as a CEs timing pattern in the U.K.´s Petroleum Refining Industry during the reference period.

Conclusions

Evidence is against the maintaining-market-share hypothesis. We can state that evidence from the U.K.’s petroleum refining industry does not support the timing of CEs in order to maintain market shares, at least during the phase 1948-1998. This nullifies the possibility that round robins explain the observed CE timing behaviour. We are also unable to support the hypothesis that CEs were used pre-emptively in our case study. Evidence in the U.K.'s petroleum refining industry does not point out that pre-emptive timing of CEs was practiced during 1948-1998 either.

We have attempted to determine the existence of CE timing patterns in the U.K.'s petroleum refining industry between 1948 and 1998. Neither round robins, nor maintaining market-share, nor pre-emptive hypotheses resisted our scrutiny. Therefore, we assert that no CEs timing pattern is detected; consequently, we reject the main hypothesis.

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FIRM	R_{it}	DIFF. W.R.T MEAN
Amoco U.K. Ltd.-Milford Haven	-3.22	-4.47
Berry Wiggings & Co. Ltd.- All refineries	3.57	2.32
British Petroleum.- All refineries	12.61	11.36
Burmah Oil Trading.-All refineries	1.29	0.04*
Carless Solvents Ltd.-Harwich	-1.02	-2.27
Conoco Ltd.- South Killinghome	-1.01	-2.26
Continental Oil Co. Ltd.-Killingholme	-2.14	-3.39
Eastham Refinery Ltd.- All refineries	-3.20	-4.45
Elf Oil (G.B.) Ltd.-Milford Haven	-3.20	-4.45
Esso Petroleum CL- All refineries	7.99	6.74
Gulf Oil-GB.-Milford Haven	1.14	-0.11*
Lindsley Oil Refinery Ltd.- South Humberside	0.02	-1.22
Lobitos Oilfields,Ltd.-Ellsmere Port	-0.92	-2.17
Manchester Oil Refinery Ltd.- All refineries	-2.00	-3.25
Mobil Oil CL.-Corynton, Essex	10.05	8.80
Nynas U.K. AB.-Dundee	-4.30	-5.55
Phillips Imperial Petroleum Ltd.- Teesside	-2.10	-3.35
Philmac Oils Ltd.-Eastham, Cheshire	1.11	-0.13*
Shell U.K..Ltd.- All refineries	8.11	6.86
Texaco Ltd.-Pembroke, Dyfed	1.16	-0.09*
William Briggs & Sons Ltd.- Dundee	2.32	1.07
mean	1.25	
std	4.72	
Number of obs. in [0.24936,2.24936]	*4*	
Number of obs. in [0.19936,2.29936]	4	

*It is in both intervals

Table 1. Round-robin hypothesis test

	$y_{i,t}$
$GROWSH_t^2$	-115590.5
	(0.010)
$\frac{1}{DELSHR_t}$	-9.301189
	(0.000)
$DELSHS_{t-1}$	82.02417
	(0.002)
$BAND_{t-1}$	41.68089
	(0.005)
$BANDSH_{t-2}$	-197.4335
	(0.025)
$BANDSH_t^2$	-51447.7
	(0.023)
$BAND_{t-1}^{MN}$	50.60321
	(0.045)
$GROWHERF_t^2$	2307744
	(0.008)
$BANDHERF_{t-1}$	-965.0341
	(0.008)
$DELSHERF_{t-2}$	133.1216
	(0.036)
Log likelihood	-24.895189
Number of obs	158
LR χ^2	56.86*
Prob > χ^2	**0.0000**
Pseudo R^2	0.5331
P>|z| of hatsq	**0.889**

*Ten d.o.f

Table 2. Capacity Expansions under maintaining-market-share model

	$y_{i,t}$
$CUSH_t$	35.11789 0.001
$CUHERF_t$	-51.99578 (0.055)
$GROW_{t-1}$	-36.76154 (0.005)
$GROW_{t-2}$	28.18804 (0.019)
$GROWSH_t$	213.3346 (0.008)
$GROWSH_{t-1}$	53.28783 (0.002)
$BAND_t$	-25.93732 (0.000)
$BAND_{t-1}$	35.74431 (0.000)
$GROWHERF_t$	-487.1737 (0.040)
$BANDHERF_{t-1}$	-206.6739 (0.004)
Log likelihood	-196.46624
Number of obs	985
LR χ^2	122.30*
Prob > χ^2	**0.0000**
Pseudo R^2	0.2374
P>|z| of hatsq	**0.091**

*Ten d.o.f

Table 3. Pre-emptive Capacity Expansions model