Analyse the factors that facilitate or hinder the formation and stability of collusive agreements among firms (e.g. cartels).

Third Year Project

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Abstract

This paper examines the factors which influence collusion both positively and negatively. The econometric analysis tests the power of industry factors to predict the existence of domestic and/or international cartels in an industry via a multinomial logistic model. The dataset has observations over eight years from 2000 to 2007 and consists of UK industry data at the per firm level, domestic cartel data from the Office of Fair Trading(OFT) and international cartel data from the European Commission. The regression results imply that concentration has a concave effect on international cartelisation while growth in demand has a concave effect on domestic cartelisation. Both are highly significant for industries where both types of cartelisation exist, together with standard deviation of demand which is a proxy for demand uncertainty. However, this separation of impact could be due to the level of disaggregation of the utilised data rather than limitations in the explanatory power of the factors which are proxied. The model is also used to create estimates for the probability of a certain type of cartel existing in given industry and identifies several cases where international or domestic cartelisation is predicted and yet no such cartels have been detected.

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Section 1. Introduction

The question of which factors affect the formation and stability of collusive agreements is important not only from an academic standpoint, but also for policy reasons such as maximising consumer welfare and market efficiency. Furthermore, a better understanding of these factors can assist in assessing how to best tailor competition policy. This paper aims to examine the factors which according to the main theoretical and empirical sources affect collusion using UK industry data at the firm level as firms are the entities responsible for forming and sustaining collusive agreements. The main factors analysed are concentration, growth in demand, uncertainty of demand and entry barriers. The multinomial logistic model is utilised in this study in order to split cartelisation into four categories: industries where there are no cartels, industries where there are only domestic cartels, industries where there are only international cartels, and industries where there both types exist.

The paper is structured as follows. Section 2 is composed of a comprehensive review of the literature, Section 3 describes the constructed dataset and issues with the data, Section 4 examines the multinomial logistic model. Section 5 analyses the findings of econometric regression, how robust they are to variations of the model, how they relate to other similar studies and their consistency with the broader theoretical and empirical literature. Section 6 provides a brief conclusion of the paper and Section 7 suggests areas of improvement and further research.

Section 2. Review of the Literature

This section is split into several subsections which examine the main theoretical and empirical investigations into how various factors are considered to affect collusive agreements. While the literature review looks at the broad range of factors which influence collusion, the parts particularly relevant to the empirical regression analysis are where concentration, entry barriers and market demand are discussed.

Section 2.1 Effects of Homogeneity

Section 2.1.1 Theoretical literature

The main factor most theoretical papers discuss is homogeneity of the product produced by the colluding firms, or of the costs these firms face. It is generally accepted that when products are similar there is less uncertainty over demand and profits. Jacquemin and Slade(1989) argue that when the opposite is the case and there is heterogeneity, whether in products or in costs, firms need to negotiate on more factors (such as varying prices, outputs and division of profits) which complicates the formation of collusive agreements. Additionally, when conditions change there is likely to be uncertainty about how other firms are affected by such changes, which further complicates renegotiating the terms of collusion. The model Jacquemin and Slade(1989) use is static and considers collusion to be costless. If negotiation costs are also included in the analysis this would only strengthen the negative effects heterogeneity is expected to have on collusion, as if heterogeneity increases the length and difficulty of agreeing on the collusion terms then estimated benefits of collusion are further reduced which in turn lowers the probability of successful collusion.

However, the effect of homogeneity on collusion is not one-sided. Levenstein and Suslow(2006) argue that asymmetries such as heterogeneity have two contrasting effects on collusion. They state that product heterogeneity increases the benefits of collusion, but it also increases the incentive to deviate from a collusive agreement as the profits from cheating are also larger. Symeonidis(2002) further investigates this prediction by creating a model with multiproduct firms, where firms can produce more than one variety of a good, which implies product heterogeneity. He concludes that under both quantity and price competition an increase in the varieties produced by firms hinders the incentives for collusion. The only exception is under price competition when the number of firms in the industry is small and products are similar. His intuition is that with multiproduct firms in the industry, when the number of products increases, the profit from deviation increases more than the profits from

collusion. He believes that the existence of such multiproduct firms in industries may be why empirical and theoretical literature often arrive at different results as they are usually not considered in theoretical models, but may affect results of empirical studies and skew the predictions for the effect of other factors such concentration and number of firms in the industry. Symeonidis(1999) also develops a model to explain the low incidence of cartels in R&D intensive and advertising intense industries, both of which are sometimes used in empirical literature to estimate product heterogeneity. His model predicts that such product differentiation, which may be considered as reflecting variable product quality or brand image, hinders collusion.

Section 2.1.2 Empirical literature

Hay and Kelley(1974) estimate a positive relationship between homogeneity and collusion. However, in their sample most of the products fall in the category of high homogeneity and they subjectively assign the value of homogeneity, both of which may skew the results. Asch and Seneca(1975) estimate product differentiation by classifying firms in their sample by belonging to either producer or consumer-goods industry. They believe that producer-goods industries generally exhibit homogeneity. Nevertheless, they do not find that homogeneity on its own has a statistically significant effect on collusion. Symeonidis(2003) empirically investigates the effect of advertising-intensity on collusion. As mentioned above advertising intensity in an industry can be used as a proxy of product heterogeneity as products can be differentiated in the eye of consumers due to heavy advertising. He concludes that overall advertising-intensive industries are less likely to be collusive than low-advertising-intensive industries. Therefore, it seems that the pro-collusive effects of homogeneity generally tend to outweigh its negative effects, as even though theoretical arguments may be ambiguous, empirical evidence tends to confirm such positive correlation or fail to confirm a relationship, rather than find a negative relationship.

Section 2.2 Effects of Industry Concentration and Number of Firms

Section 2.2.1 Theoretical literature

In theoretical models industry concentration is thought to facilitate collusion as it is expected to reduce the number of negotiating partners and increase the potential per firm profits from collusion**.** In contrast, higher numbers of firms in a given industry are believed to hinder collusion, especially its duration. Jacquemin and Slade(1989) and OFT(2005) (Office of Fair Trading) expect collusion to be easier when there is a small number of firms in a market as deviation by one firm is more noticeable and detecting cheating is considered as one of the major problems of cartels. The OFT(2005) argue that a high number of firms in the industry increase the probability that firms have different costs which, as mentioned when discussing product differentiation, is expected to hinder collusion. In addition, each firm's share of the collusive profits is lower when there are more firms in the cartel. Furthermore, the OFT(2005) argue that when not all firms in the industry are members of the cartel, an increase in the number of firms in the industry which then proceed not to join the cartel threatens cartel stability by decreasing the total market share and profits that the cartel captures.

Section 2.2.2 Empirical literature

Empirical studies by both Hay and Kelley(1974) and by Zimmerman and Connor(2005) conclude that concentration is a factor facilitating collusion. However, other empirical papers fail to conclude that concentration has a statistically significant effect (as in Asch and Seneca(1975). Notably, Symeonidis(2003) concludes that overall concentration has an unclear link to collusion as it is not statistically significant once capital intensity is added to the model. However, in the sample he reviews collusion was not illegal which may have affected the results. Nevertheless, it may be the case that in models where capital intensity is not accounted for, the effect of concentration is biased and in part reflects the degree of entry barriers in the industry. On the other hand, Levenstein and Suslow(2006) remark that papers

by Dick(1996), Marquez(1994), and Suslow(2005) all find that cartel duration increases with the share of the market controlled by cartel members. This implies that factors which concern the characteristics of the firms in the cartel may have more impact on the formation and sustainability of collusion than the overall degree of concentration in the industry.

Additionally, Symeonidis(2003) finds a concave association between cartel occurrence and concentration by including a squared term for concentration in his analysis(although as mentioned above concentration is not statistically significant). Symeonidis(2003) suggests that this may be the case because if concentration is sufficiently high the large level of profits when there is no collusion significantly diminishes the incentives for engaging in a collusive agreement. Alternatively, the OFT(2005) note that most antitrust cases in the EU include large firms, and as the size of firms maybe correlated with high industry concentration, this may skew the results of empirical research into the effects of concentration on collusion. Levenstein and Suslow(2006) discuss other reasons why concentration in empirical papers seems less significant than in theoretical papers. First, high concentration may reflect firm asymmetry, which makes collusion more difficult. Second, collusion alters the optimal number of firms in the industry so other things being equal in collusive and non-collusive industries the equilibrium level of concentration varies, which complicates estimating a ceteris paribus relationship among collusion, concentration and number of firms in the industry. These reasons suggest that when attempting to assess how industry concentration and the number of firms in the industry affect collusion prevalence and duration, one must be cautious to estimate the unbiased ceteris-paribus relationship.

Section 2.3 Effects of Entry Barriers

Section 2.3.1 Theoretical literature

Entry barriers are thought to have a positive effect on collusion as in their absence the threat of entry decreases the level of expected future collusive profits (Levenstein and Suslow (2006)). However, most theoretical models estimating collusion usually assume no possibility of entry. Consequently, this may lead to incomplete results about the effect of other factors on collusion. For example, Vasconcelos(2008) estimates the effect of market growth in a model where entry is possible and concludes that when entry is taken into account, collusion may be completely unsustainable in a growing market, which is contrary to what most studies of collusion under moderate market growth conclude(see section on market demand). This is because in his model when firms expect entry to occur, this reduces their estimated future streams of profits if they do not deviate from the collusive agreement and therefore increases their incentives to cheat. On the other hand, theoretical literature considers excess capacity by firms in a given industry as a way of deterring entry by making punishment strategies credible (also noted in Levenstein and Suslow(2006)). Dixit(1979) discusses the role of excess capacity in deterring entry in a duopoly model where the incumbent threatens to exercise a predatory output increase if entry occurs, and concludes that excess capacity increases the probability that entry is successfully prevented. However, while this can help model situations where entry is less likely, it does not imply that this is often the case.

Section 2.3.2 Empirical literature

When Symeonidis(2003) includes capital intensity in his model, which he uses as a proxy of entry barriers, this causes the industry concentration variable to become statistically insignificant. Capital intensity, however, is highly statistically significant, which makes the case for considering entry barriers both in theoretical and empirical literature. In contrast, the OFT(2005) create a model where the level of R&D per firm in an industry, gross capital expenditure per firm, and the level of stocks per firm are all included to estimate entry

barriers, and are all seen to have little effect on how collusion-prone an industry is. In their empirical study the cost-disadvantage ratio (which is also a measure of economies of scale) is the only variable approximating entry barriers which is found to be statistically significant. However, they note that as their data are on cartels which have been detected by an Antitrust Authority, if entry barriers in the industry are low, cartels may have been caught while trying to prevent entry, which may introduce bias in the results and cause some estimators to be insignificant. In conclusion, it is important to note that both empirical and theoretical literature predict entry barriers are expected to facilitate collusion, whether this effect is considered to be significant or not.

Section 2.4 Effects of Market Demand

Section 2.4.1 Theoretical literature

Jacquemin and Slade (1989) argue that unstable market conditions hinder collusion as they can cause frequent renegotiations of the collusive agreement which increases the costs of collusion. Additionally, differences in opinion about future conditions and the particulars of optimal cartel agreements become more likely. Moreover, when market demand is uncertain firms may not be able to distinguish if their partners are deviating or if they are experiencing an unrelated low demand, which may result in price-wars and the breaking-up of the cartel, as in the model of Green and Porter(1984). This is consistent with the findings of Rotemberg and Saloner(1986), who construct a cyclical model and assume that observable demand shocks are identically distributed and therefore it is optimal for firms to deviate when ”times are good” than when there is a temporary slump, as the future costs of deviation are similar, but the current profits from deviation are higher when demand is high then when it is low.. However, if we relax their assumption as in the model of Haltiwanger and Harrington(1991), where demand shocks are cyclical, then collusion is more likely to break when demand is falling or expected to fall. Similarly, according to Bagwell and Staiger(1997) collusion is

hard to sustain during transitionary shocks, whether it is high or low, but when the expected duration of booms is high or that of slumps is low, collusion is easier to sustain (as quoted in the OFT (2005)). Therefore, when measuring changes in demand it is optimal to consider the level, direction and future expectations of market demand.

Section 2.4.2 Empirical literature

Symeonidis(2003) finds and inverted U-shaped relationship between growth and collusion(his model also accounts for entry barriers as a proxy for capital intensity). He concludes that while moderate growth facilitates collusion, stagnant or declining demand or excessive growth hinder collusive agreements. It may be the case that moderate growth is easier to predict, while excessive and declining growth may be more volatile and therefore, more uncertain. In contrast, Zimmerman and Connor(2005) find that economic downturns facilitate collusion and hypothesize that the illegal profit opportunities during downturns can sustain collusive agreements. However, as mentioned above, in theory, when there is a threat of entry, the effect of market growth may be nullified(see Vasconcelos(2008)). Therefore, while neither empirical nor theoretical literature have given a conclusive prediction of how the level and direction market demand affects collusion, it is generally expected that uncertainty in demand hinders collusive agreements.

Section 2.5 Effects of Antitrust and Communication

Section 2.5.1 Theoretical literature

Most theoretical papers (such as Jacquemin and Slade(1989)) argue that the existence of legal restrictions on collusion hinders collusive agreements by decreasing the benefits of collusion due to the threat of prosecution and fines if firms are caught colluding. Furthermore, firms must communicate in secret which additionally increases collusion costs. However, the effect of leniency programs (where a firm is not punished if it reveals the existence of a collusive agreement it is participating in) is rather ambiguous from a theoretical perspective. On one

hand, they increase the probability that collusion is discovered which reduces cartel duration. However, they also reduce the expected cost of collusion which increases incentives to engage in collusion. Motta and Polo(2003) argue that leniency programs increase the efficiency of antitrust policy even in cases where firms are allowed to join them after an investigation has commenced and therefore conclude that they hinder collusion. Aubert et al(2006) go further and construct a model where giving positive rewards to colluding firms which cooperate hurts collusion more than when only leniency programs are implemented. Additionally, they conclude that positive rewards targeted at individuals have an unambiguously adverse effect on collusion. This implies that when analysing the effect of antitrust laws focus should be placed not only on the fines for collusion, but also on the specific leniency and reward programs in place.

Section 2.5.2 Empirical literature

Most empirical models also estimate that with stricter the antitrust law environment cartel duration is shorter. In the study of Zimmermann and Connor(2005) this is true even under leniency programs. However, Andersson and Wengstörm(2007) undertake an experimental study with duopoly pricing-games under three levels of communication costs, where higher communication costs suggest stricter antitrust, and find that more costly communication enhances the stability of collusive agreements, even though it also reduces the frequency of communication. This hints that the relationship between communication and collusion may not be as straightforward as most theoretical models assume and that there may be cases when lack of communication helps sustain collusion. This implies that while antitrust laws hinder collusion, if they have the effect of reducing communication among cartel members it may be the case that they also affect collusion positively through this mechanism. However, any such effect seems to be far outweighed by their strongly adverse effects to collusion which were discussed above.

Section 2.6 Summary of the Literature Review

This literature survey reviewed the main factors which according to theoretical and empirical studies have an effect on the formation and sustainability of collusive agreements. The factors which are generally expected to facilitate collusive agreements according to both the theoretical and empirical literature are homogeneity, entry barriers and antitrust laws. Although homogeneity is predicted to have two opposite effects on collusion in theoretical models, empirical studies suggest that the positive effect of homogeneity on collusion prevails. This is similar to what empirical studies conclude for leniency programs in antitrust policy. While uncertain demand is expected to hinder collusion by both empirical and theoretical studies, how the direction and growth level of demand affect collusion is ambiguous as theoretical and empirical studies arrive at a range of conclusions. On the other hand, other things being equal, a higher number of firms in an industry is expected to hinder collusion and vice versa, higher industry concentration is expected to facilitate it. However, although industry concentration is considered to be a major factor affecting collusion in theoretical literature, empirical studies are not so definitive and often fail to determine a strong correlation between the two. Having reviewed the main factors which affect collusion according to theoretical and empirical literature, the next section of this paper proceeds to describe the data and model utilised in the econometric analysis in this particular study. As mentioned before not all factors discussed in the literature review are tested. This is mainly due to lack of publicly available data at the appropriate level of industry desegregation and compatibility with the unit of analysis.

Section 3. The Data and the Dataset

Section 3.1 Degree of emulation of previous studies

The econometric analysis in this paper draws substantially on the methodology employed in OFT(2005) where industry characteristics at the per firm level are used to predict the level of

cartelisation in a given industry. However the data in this study are collected for a broader time period albeit at a lower disaggregation level due to time constraints. The OFT study investigates cartelisation at the 3 digit industry level(SIC 3) while this study does so at the NACE 1.1 revised code which is one level lower than the SIC 3. This paper concentrates on the UK by investigating cartels affecting the UK in particular rather than EU and USA cartels as in the OFT(2005) study. Additionally there is not a complete overlap of the type of data collected due to lack of publicly available data. Furthermore, this study employs a multinomial logistic model (described in Section 4) while the OFT(2005) study uses a series of logit, ordered logit and OLS estimations. Finally, this study attempts to provide an insight into the differences between domestic and international cartels(where participant firms are from the UK or/and the UK industry is affected) and to what extent domestic industry characteristics determine cartelisation at the domestic and international level and can therefore be used to predict whether in a given industry there is a domestic, international or both types of cartels.

Section 3.2 Dataset used and data collected

Several data sources were used to compile the dataset. The data were collected at the per firm level and variables are measured in thousands of pounds, quantity or as a percentage where appropriate (for more precise estimates and to ease interpretation of the coefficients the percentage variables were multiplied by 100). They were collected for each industry in the UK using the NACE1.1 revised industry classification (correspondent to the SIC 2003-2007 classification employed in the UK) and several industries had to be excluded from the analysis due to lack of data(a complete list of all industries is provided in Appendix A, excluded industries are in bold). The primary data source was the Annual Business Inquiry compiled by the Office for National Statistics (ONS' ABI). The data collected were from 2000 to 2007 and the variables were number of enterprises in the industry, total turnover in

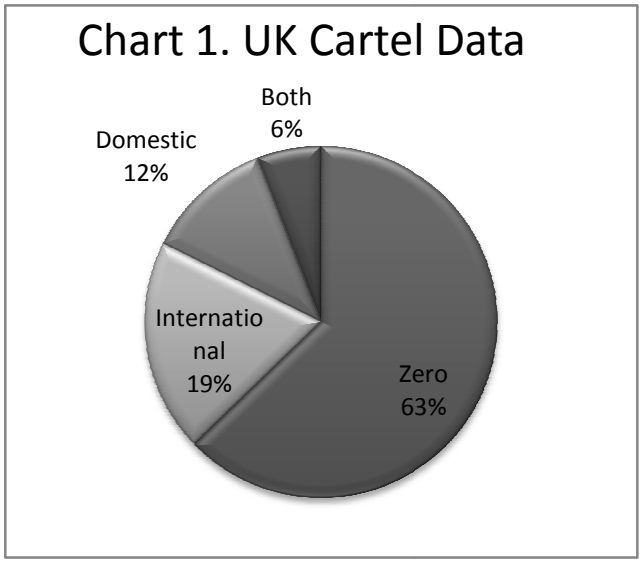
the industry, approximate gross value added at basic prices, total employment - average during the year, total employment costs, total net capital expenditure, and total stocks and work in progress - value at end of year. These were then used to create average values at the per firm level. Additionally data on total turnover per firm over the eight years was used to calculate a proxy for uncertainty of demand which was the standard deviation in total turnover over the eight years. A variable reflecting the growth in demand was created as the growth in turnover per firm from 2000 to 2007. Both variables were measured in a percentage form multiplied by 100 (1.3% is measured as 1.3 in the data).

Secondly the financial database Orbis was used to collect data on entry barriers and gross added value. Entry barriers were proxied by the variables capital per firm and fixed assets per firm. These were used in the primary regressions but were excluded from the final model. Gross added value was collected for the three firms with the largest values each year in each industry and was then divided by the total approximate gross added value at basic prices variable from ONS' ABI (and multiplied by 100) to create a proxy for concentration in the industry. This was done due to the lack of another publicly available measure of concentration at the industry level. Squared terms for concentration and growth of demand were also constructed to test for concavity of their relationship with collusion. Where these variables were negative in the linear term the squared term was also imputed to be negative.

To create a variable measuring cartelisation a dummy was composed using data for cartels detected from 2000 to 2007 from the UK Office of Fair Trading(OFT) for domestic cartels[2] and European Commission data for international cartels affecting the UK market[3]. The constructed variable(mcartels) had a value of 0 if there was no cartel discovered in the industry, a value of 1 if there was only an international cartel discovered in the industry, a value of 2 if there was a domestic cartel discovered in the industry and a value of 3 if in the

[2] Available at: http://www.oft.gov.uk/advice_and_resources/resource_base/ca98/decisions/?Order=Date
[3] Available at: http://ec.europa.eu/competition/cartels/cases/cases.html

industry there were discovered both an international and a domestic cartel. Chart 1 provides a graphical expression of the composition of the cartelisation variable by type of cartel detected. Industries are included where firms in the industry have been fined for engaging in collusion by the respective Antitrust Authority(OFT or European Commission). Cases where UK firms have escaped fines due to participation in leniency schemes are also included. There are 33 industries with no cartels, 10 industries with international cartels, 9 with domestic and 3 with both types of cartels present. The value of the cartel dummy(mcartels) is not affected by the number of domestic or international cartels discovered i.e. an industry with 5 domestic cartels and 0 international would still generate a dummy of 2. The specific advantages and drawbacks of this are discussed further later in the paper. Additionally dummies for each year of observations (from 2000 to 2007) were created to account for specific shocks which may have taken place in a given year.



Section 3.3 Issues with the data

The cartel data have a measurement problem. As the data used in the study are by necessity that of cartels which have already been discovered these do not reflect the full set of cartels existing in each industry as there may be cartels in existence which have not been discovered. If a large proportion of industries have existing cartels which are undetected then even if industry characteristics explain cartelisation this may not be reflected in the fitted model. Consequently, it may be difficult to find statistically significant estimates. For a ceteris paribus estimation the missing cartelisation data must be missing in a way not correlated with

the explanatory variables so that their coefficients are unbiased. Unfortunately, it is not immediately clear if this is the case. Similarly, there may be omitted variable bias if other factors not included in the regression which influence cartelisation (such as those discussed in the literature review) are correlated with the included explanatory variables.

As the data are collected for 8 years for each industry and industry characteristics are expected to remain similar across the period there exists the problem of overestimating the standard errors of the explanatory variables and thus overestimating the significance of these variables. To avoid this the observations have been clustered (51 clusters) by industry in all regressions. The year 2000 is excluded from regressions to evade multicollinearity. Therefore, the dummies for the other years show effects on probabilities of cartelisation as a result of being in that year compared to being in the year 2000.

The variables total turnover in an industry and total turnover per firm were included in the final regression similarly to the model in OFT(2005) for scaling purposes. As OFT(2005) notes, industry classification may split markets arbitrarily and as collusion is expected to occur at the market level if a certain industry is too large it may encompass several markets and thus have a higher incidence of cartelisation. In order to account for that an industry size proxy must be included, which is what these variables are meant to capture. One of the three variables total turnover, turnover per firm and number of firms had to be dropped as each one can be reconstructed from the other two. In the final model number of firms was excluded. The variable was included in some preliminary regressions at the expense of one of the other two variables but it did not improve the fit of the model and its coefficients were often not significant and predicted positive and negative relationship equally often all of which unfortunately did not add value to the analysis.

Not all of the collected variables are used in the final regression but all were included in preliminary regressions. Most were excluded for collinearity reasons and some because

they were insignificant in most of the regressions. For example, capital per firm and fixed assets per firm tended to be highly correlated with concentration as in the database they were collected from (Orbis) large companies are more likely to be listed. These were also mostly insignificant in regressions. Having reviewed how the dataset was compiled and specific issues related to the data we continue to examine the regression model.

Section 4. The Model

The regression analysis employs a multinomial logistic model, following the formula:

$$Prob\ (Y_i = j) = \frac{e^{\beta'_j x_i}}{\sum_{k=0}^{3} e^{\beta'_k x_i}}, \quad j=0,1,2,3 \quad [4]$$

Where Yi = j represents the specific outcome of the dependent dummy variable(Y_i = mcartels, j = 0, 1, 2 or 3) and encompasses the different possibilities about the type of cartelisation in an industry. If there are no existing cartels in an industry it takes the value 0, if there are only international cartels in the industry (one or more) it takes the value of 1, if there are only domestic cartels in the industry (one or more) it takes the value of 2 and if there are both international and domestic cartels in the industry the value is 3. The explanatory variables x_i capture the characteristics of each industry, such as concentration, variability of demand, growth in demand, proxies for entry barriers and others (discussed in more detail in the dataset description section). This model was selected in favour of a more simplified logit model as it provides an insight into how domestic industry characteristics influence the existence of cartels both domestically and internationally.

There are drawbacks to the model. It assumes independence from irrelevant alternatives(IIA) where the introduction of a new alternative, or alterations of the properties of an existing alternative, should not change the relative odds ratios between the other

[4] Formula adapted from Greene, William H.(2003) , Econometric Analysis, 5th Edition, pp 721

existing alternatives. Relative odds ratios are defined as OR $=\frac{p(1-q)}{q(1-p)}$ where p is the probability of a cartel occurring in the target group (for example for mcartels = 1, where there are only international cartels in the industry) and q is the probability of the event occurring in the control group (where mcartels = 0). On the other hand, relative risk-ratios(rrr) which are used in the description of the regression results are defined as RR $=\frac{p}{q}$ [5].

Whether the relative odds ratios are independent from other alternatives is not immediately clear. Therefore the IIA assumption of the multinomial logistic model is not a particularly attractive one. This is relaxed in the multinomial probit model where the IIA assumption is dropped and coefficients across outcomes are allowed to correlate. Regressions ran for the multinomial logistic model in this paper were also ran for the multinomial probit model to check for consistency and this did not affect the overall results. The multinomial logistic model is the presented model because coefficients can be interpreted more easily when transformed into relative risk ratios(rrr), which is not possible for the multinomial probit model.

The cartel dummy variable is not sensitive to the exact number of cartels discovered in an industry. It is created to reflect the type of cartels, not their quantity. Therefore the value of the dummy will be 2 whether there is 1 domestic cartel in the industry or 3. While this could have been at least partially corrected using an ordered logit model, the multinomial logistic model was selected as it allows for focusing the research into different types of cartels (international domestic or both) which provides originality to the study and a better fit of the model. Additionally, as mentioned above, the exact number of discovered cartels may be misleading in predicting the real number of cartels in the industry. From that point of view a less "precise" measure of cartelisation which only considers whether a specific type of

[5] Adapted from http://www.numberwatch.co.uk/rr&or.htm, page on the differences between relative odds and risk ratios, written by John Brignell

cartel has been discovered in the industry or not, may be better at approximating the distribution of cartelisation across industries. Having discussed the main characteristics of the multinomial logistic model this paper proceeds to examine the results of the regression analysis.

Section 5. The Results

The base category in the model is mcartels = 0 where there are no cartels in the industry. Therefore the reported relative risk ratios(rrr) represent the change in the relative probability of a given outcome(p(mcartels = k)/p(mcartels = 0), k = 1,2 or 3) , i.e. the probability of being in the respective outcome(mcartels = 1, 2 or 3) compared to the probability of being in the base outcome due to a point increase in the explanatory variable. When the term relative probability is used in the results section it refers to the probability of the outcome for the respective section(where mcartels = 1, 2 or 3) compared to the probability of the base outcome (mcartels = 0).

A rrr of 1 would imply no change in a given relative probability due to a change in the variable. The tool most employed in the interpretation of rrr different from 1 is to subtract 1 from the rrr and report the result as the percentage change in the relative probability. For example a rrr of 0.8205 implies that if the variable increases by 1 the probability of being in the given outcome compared to the probability of being in the base outcome(p(mcartels = k) / p(mcartels = 0)) changes by 0.8205 – 1 = - 0.1795, i.e. decreases by 17.95 per cent.

The interpretation of the rrr(relative risk ratios) is further complicated by the fact that there are two variables which have squared terms included in the model. These are industry concentration and growth in demand. The reason for the inclusion of these terms is to test for concavity in their relationship with cartelisation. They are included in the final model because they are statistically significant in some categories which is robust across variations of the model. Moreover, they add to the explanatory power of the model . However this complicates

the interpretation of their rrr as it is not as straightforward to compute as in an OLS regression. Therefore when interpreting the rrr their significance and direction will be emphasised rather than their quantitative interpretation.

To help interpret the magnitude of the impact of the studied factors their effects are also computed at the median both for a marginal change in the variable(derivative dy/dx, y = p(mcartels = k) where k = 1, 2 or 3, x = studied variable) and for a discrete change[6]. For the discrete effects the coefficient is the change in the individual probability of the given outcome(not the relative probability) when the variable changes from -0.5 points below the median to 0.5 points above the median(a change of 1 point) and all other variables are at their median. The marginal and discrete effects have the advantage of predicting changes in terms of the individual probability of a certain type of cartelisation but they have the disadvantage of showing the picture only at the estimated point. It needs to be noted that the magnitude and direction of the estimated effects can differ depending on the point where they are estimated. Indeed at the mean of all variables the probability of no cartels was practically 1 causing probabilities for the other outcomes to be very close to zero and thus the marginal and discrete effects to be zero or close to zero. This was the main reason why these estimates are presented at the median where although the probability of zero cartels is still high(64%) the probability of international cartelisation is 33% and the probability of domestic cartelisation if 3%. The probability of both types of cartels existing in a single industry is again very close to zero which causes small marginal and point estimates for this category. To compensate for this they are presented up to a higher decimal point level. The paper now proceeds to examine the results across the different cartelisation categories.

[6]Estimates produced using prchange, stata command which is part of the SPost package by J. Scott Long and Jeremy Freese

Section 5.1 International Cartels

Table 1. Multinomial logistic Regression Results for International Cartels (mcartels = 1)				
Pseudo R2 = 0.4558	rrr	robust SE	dy/dx(median)	dy/dx=1 (median)
year 2001	0.9610	*0.0839*	-0.0086	0.0044
year 2002	0.8067*	*0.1044*	-0.0470	0.0235
year 2003	0.7553*	*0.1251*	-0.0610	0.0307
year 2004	0.9234	*0.1510*	-0.0164	0.0097
year 2005	1.0976	*0.1937*	0.0215	0.0107
year 2006	0.8040	*0.1437*	-0.0468	0.0245
year 2007	0.8321	*0.1415*	-0.0394	0.0207
total turnover in the industry	1.0000	*0.0000*	0.0000	0.0000
total turnover per firm	0.9999	*0.0001*	0.0000	0.0000
industry concentration	1.0534*	*0.0332*	0.0113	0.0057
industry concentration squared	0.9997*	*0.0002*	-0.0001	0.0000
standard deviation of demand	0.8205	*0.1070*	-0.0421	0.0225
growth in total turnover per firm(2000 to 2007)	0.9703	*0.0306*	-0.0074	0.0037
growth in total turnover per firm squared	1.0004	*0.0003*	0.0001	0.0001
total net capital expenditure per firm	0.9976	*0.0022*	-0.0006	0.0003
total stocks per firm	1.0008	0.0014	0.0003	0.0001
***significant at 0.01 per cent	51 Clusters			
**significant at 0.05 per cent	Number of Observations:397			
*significant at 0.1 per cent	Log pseudolikelihood = -224.69402			

*rrr (relative risk ratios), if variable increases by 1 then p(mcartels =1)/mcartels=0) changes by (rrr - 1)*100 percentage change; where p(mcartels = 0) is the probability of no cartels existing in the industry, p(mcartels = 1) is the probability of only international cartels existing in the industry*

dy/dx(median) is marginal change at the median, dy/dx =1 is discrete change at -0.5 to +0.5 around the median, both reflect changes to the probability of mcartels= 1 (probability of the existence of an international cartel)

First, we turn our attention to how economic factors affect international cartelisation (Table 1). Of the dummy variables for the years only 2002 and 2003 have statistically significant negative effect on the relative probability of international cartelisation at the 10% significance level (as opposed to being in the control group (year 2000)). 2005 is the only year which has a predicted, albeit not statistically significant, positive effect on the relative probability of international cartelisation. This is a result that holds only for international cartels as for all other categories the predicted effect of year dummies on relative probabilities is negative. The marginal effects have similar predictions to those for the relative probability with all years except 2005 having a negative effect on the individual probability of international cartelisation at the median**.** In contrast, the discrete effects are all predicted to have a positive effect on the individual probability of international cartelisation. However, as the median value of the year dummies is 0, the discrete changes estimates

provide predictions for the variables going from -0.5 to 0.5 which are values not observed in the data and thus the estimates are not very useful.

Total turnover in the industry and total turnover per firm have relative risk ratios (rrr) of 1 or very close to 1 which implies no effect on the relative probability of international cartelisation. This is consistent with the marginal and discrete effects on the individual probability of international collusion which are predicted to be 0 at the median. This is not particularly unexpected as their inclusion in the model is mainly to account for the scale of the industry so that the other estimated coefficients are unbiased.

The effect of industry concentration on the relative probability of international cartelisation is concave and statistically significant at the 10% level(linear term larger than 1, squared term lower than 1). Similarly, the marginal effect of concentration on the individual probability of international concentration is also predicted to be concave (positive coefficient for the linear term and negative for the squared term). At the median a point increase in the concentration proxy implies a 0.57 percentage points increase in the individual probability of international cartelisation while the squared term is predicted to have a small positive impact close to zero. This is not incompatible with the concavity prediction as at -0.5 points from the median the effect of concentration could still be positive for both terms, while it turns negative for higher levels of concentration. This suggests that, as Symeonidis(2003) hypothesizes, while concentration facilitates international cartelisation extremely high levels can hinder collusion perhaps by reducing the potential payoff from colluding. The concavity of the relationship is consistent with the estimates in Symeonidis(2003).

Demand factors such as deviation in demand and growth in demand do not have statistically significant coefficients. A percentage point increase in standard deviation(proxy for demand uncertainty) is predicted to reduce the relative probability of international cartelisation by 17.95% but this is significant only at the 12.9% error level and the point and

marginal effects at the median have opposing signs for the predicted effect on the individual probability of international cartelisation. However, demand data used in this paper reflects mostly domestic demand factors which may not be so important for international cartelisation where international demand factors can be more essential. This can cause the variables to be insignificant in this outcome and does not imply than demand factors in general have no effect on international cartelisation.

Entry barrier measures such as total net capital expenditure per firm and total stocks per firm also do not have a statistically significant effect on international cartelisation. However this may reflect the fact that as pointed out by OFT(2005) firms which have been caught colluding may have been in the process of fighting off entrants as this increases the probability of being caught colluding. But for entry to have occurred in the first place entry barriers are likely to have been low. This may complicate the effect entry barriers appear to have on collusion and render it insignificant or even negative as opposed to what theory predicts (positive effect). However, it may simply be the case that the average per firm entry barriers are pushed down by low levels for small firms which are less likely to participate in international cartels than large firms. This can have the result of skewing the figures for international cartelisation.

Section 5.2 Domestic Cartels

For domestic cartelisation (Table 2) all year dummies have a negative effect on the relative probability of domestic collusion (as opposed to being in the control group (year 2000)). However, this effect is not significant for any specific year. The scale variables total turnover in the industry and total turnover per firm have coefficients 1 or close to 1. Additionally, the marginal and discrete effects at the median have values of 0 which suggests the variables have no effect on the individual and relative probability of domestic collusion similarly to the predictions for international collusion.

Table 2. Multinomial logistic Regression Results for Domestic Cartels(mcartels = 2)					
Pseudo R2 = 0.4558		**rrr**	**robust SE**	**dy/dx(median)**	**dy/dx=1 (median)**
year 2001		0.9843	*0.0634*	-0.0001	-0.0086
year 2002		0.9508	*0.0742*	0.0006	-0.0470
year 2003		0.8927	*0.1085*	-0.0005	-0.0609
year 2004		0.8776	*0.1193*	-0.0029	-0.0164
year 2005		0.9104	*0.1310*	-0.0036	0.0215
year 2006		0.8584	*0.1734*	-0.0022	-0.0467
year 2007		0.8752	*0.2113*	-0.0020	-0.0393
total turnover in the industry		1.0000**	*0.0000*	0.0000	0.0000
total turnover per firm		0.9988	*0.0008*	0.0000	0.0000
industry concentration		1.0185	*0.0587*	0.0000	0.0113
industry concentration squared		0.9998	*0.0003*	0.0000	-0.0001
standard deviation of demand		0.8462	*0.1554*	-0.0028	-0.0421
growth in total turnover per firm(2000 to 2007)		1.0803	*0.0639*	0.0025	-0.0074
growth in total turnover per firm squared		0.9981**	*0.0008*	-0.0001	0.0001
total net capital expenditure per firm		1.0025*	*0.0014*	0.0001	-0.0006
total stocks per firm		0.9921	0.0140	-0.0002	0.0003
***significant at 0.01 per cent		51 Clusters			
**significant at 0.05 per cent		Number of Observations:397			
*significant at 0.1 per cent		Log pseudolikelihood = -224.69402			
*rrr(relative risk ratios), if variable increases by 1 then p(mcartels =2)/mcartels=0) changes by rrr - 1)*100 percentage change; where p(mcartels = 0) is the probability of no cartels existing in the industry, p(mcartels = 2) is the probability of only domestic cartels existing in the industry*					
dy/dx(median) is marginal change at the median, dy/dx =1 is discrete change at -0.5 to +0.5 around the median, both reflect changes to the probability of mcartels= 2(probability of the existence of a domestic cartel)					

Industry concentration again has a predicted concave effect on the relative probability of domestic cartelisation but here it is not statistically significant. This may be the case as some domestic cartels in the dataset and in practice are regional and regional concentration of the industry rather than that for the whole of the UK may be more relevant in estimating the impact of concentration on domestic cartelisation.

Standard deviation of demand is again not statistically significant at 10% level. Its predicted effect on the relative probability of domestic collusion is negative and similar in magnitude to that for international cartels with 1 percentage point increase reducing the relative probability of domestic collusion by 15.38%. The marginal and discrete changes at the median predict a negative impact on domestic collusion with a percentage point increase in standard deviation reducing the individual probability of domestic collusion by 4.21 percentage points.

The predicted effect of growth in demand on the relative probability of domestic collusion is concave which similarly to the results for concentration is consistent with the estimates in Symeonidis(2003). Nevertheless, although the rrr are more significant than for international cartels, and the squared term is significant at the 5% level, the linear term is still insignificant. This may be the result of both terms being significantly collinear(correlation coefficient of 0.88) which pushes up their standard errors. The high correlation may also have the effect of skewing the predictions for the individual probability of domestic cartelisation as at the median although the marginal effect is predicted to be concave(positive linear term and negative squared term), the discrete effect coefficients have opposite signs(negative linear and positive squared term).

On the other hand, total net capital expenditure per firm has a statistically significant rrr above 1 which in accordance with theory predicts a positive effect on the relative probability of domestic cartelisation. However, this is only at the 10% significance level and the marginal and discrete changes at the median have alternative signs for the effect on the individual probability of domestic cartelisation. Additionally, this is the only outcome where the rrr is higher than 1 and significant.

Section 5.3 Domestic and International Cartels

This outcome has predictions for industries where both international and domestic cartels exist (Table 3). Only 3 industries in the dataset fall into this category which raises questions about the validity of the estimates. However, when these cases are excluded from the regressions the conclusions for the other two categories remain the same so including it can only be beneficial to the model. Additionally, the results have been tested for consistency and when this category was switched in order with another outcome (i.e. the category was number 1 instead of number 3) the results were still the same. As the individual probability of this

Table 3. Multinomial logistic Regression Results for Both Types of Cartels (mcartels = 3)				
Pseudo R2 = 0.4558	rrr	robust SE	dy/dx(median)	dy/dx=1 (median)
year 2001	0.6975	*0.6965*	-3.88E-15	-0.0000655
year 2002	0.6608	*0.6537*	-3.88E-15	0.0006391
year 2003	0.2059	*0.2520*	-1.03E-14	-0.0005081
year 2004	0.0470	*0.1068*	-1.26E-14	-0.0029280
year 2005	0.0788*	*0.1115*	-1.22E-14	-0.0035538
year 2006	0.0131**	*0.0225*	-1.3E-14	-0.0022179
year 2007	0.0007***	*0.0013*	-1.32E-14	-0.0020026
total turnover in the industry	0.9997***	*0.0000*	0	-0.0000343
total turnover per firm	1.0051***	*0.0008*	6.93E-17	0.0000000
industry concentration	1.2958***	*0.1019*	3.25E-15	0.0000168
industry concentration squared	0.9986***	*0.0005*	-2.04E-17	-0.0000024
standard deviation of demand	0.0003***	*0.0004*	3.21E-13	-0.0028192
growth in total turnover per firm(2000 to 2007)	2.43e+10***	*1.04E+11*	-5.35E-15	0.0024765
growth in total turnover per firm squared	0.6966***	*0.0464*	-1.26E-13	-0.0000558
total net capital expenditure per firm	0.9942	*0.0036*	-7.19E-17	0.0000946
total stocks per firm	0.9855***	0.0028	-2.19E-16	-0.0002310
***significant at 0.01 per cent	51 Clusters			
**significant at 0.05 per cent	Number of Observations:397			
*significant at 0.1 per cent	Log pseudolikelihood = -224.69402			
*rrr(relative risk ratios), if variable increases by 1 then p(mcartels =3)/mcartels=0) changes by (rrr - 1)*100 percentage change; where p(mcartels = 0) is the probability of no cartels existing in the industry, p(mcartels = 3) is the probability of both international and domestic cartels existing in the industry*				
dy/dx(median) is marginal change at the median, dy/dx =1 is discrete change at -0.5 to +0.5 around the median, both reflect changes to the probability of mcartels= 3, probability of the extstence of both international and domestic types of cartels in an industry)				

type of cartelisation is very low at the median, the marginal probabilities have been reported up to more decimal points.

All year dummies have negative predicted effects on the relative probability of collusion, which are statistically significant for years 2005, 2006 and 2007. The marginal and discrete changes also predict a negative effect on the individual probability of collusion, except for the year 2002 where the predicted discrete effect is positive which may be a result of the aforementioned drawback of the discrete effects for dummy variables.

As in the other two outcomes the scale variables(total turnover and total turnover per firm) are again significant but close to 1 implying no effect on the relative probability of cartelisation. Similarly, the marginal and discrete effects are 0(or extremely close to 0) suggesting no effect on the individual probability.

Unlike in the other two cases here both concentration and growth in demand are strongly significant(both the linear and squared terms) and predicted to have a concave effect on the relative probability of collusion. The effect of concentration is also concave for the individual probability of collusion, as predicted by the marginal and discrete changes at the median. For growth in demand a concave effect on the individual probability of cartelisation is predicted by the discrete changes but not by the marginal changes which predict a negative effect of both linear and squared terms.

Additionally, the linear rrr term for growth in demand is extremely large (2.43E+10). However, there is particularly low variability of growth in demand in the third category (the values are 30.3, 31.4 and 41.1) with a standard deviation in the variable of only 5 percentage points which is significantly less than the 14.4 percentage points standard deviation for domestic cartels, 44.6 for international and 50 percentage points for industries with zero cartels(base category). Also the mean value of growth in demand is highest for this category (34%) while it is 25% for international cartels, 24% for domestic and 30% for industries with no cartels. Therefore, among all categories the last one (mcartels = 3) has the least observations, the highest average value for growth in demand and the lowest variation in the variable. The combination of these three factors may have caused the extremely high rrr for the linear effect of growth in demand on the relative probability of cartelisation because a point increase in growth in demand is "a low probability high impact event" for the third category when it is compared against the zero cartels category. The squared term for growth in demand on the other hand has a larger variability so it does not suffer from such skewing of the estimates. There is an alternative explanation where the rrr is so large because in this outcome there is no concave effect between cartelisation and demand but only a strong positive effect and thus the positive linear rrr term has a much higher magnitude than the negative squared rrr term so that the net effect of both terms never becomes negative within

the possible values of growth in demand. Indeed, when only the linear term is included n the regression the rrr is only 1.09 and still statistically significant at 0.01%. The real reason may well lie somewhere in the middle of both explanations and is mainly a concern for the relative probability as predictions for the effect of the variable on the individual probability are not excessive. The standard error of the linear term appears to be excessively large too (1.04E+11) as Stata uses the delta rule to compute standard errors of transformed coefficients so that $se(rrr_b) = exp(b)*se(b)$, where the rrr are the exponential of the estimated coefficients b (rrr = exp(b)) (See Appendix A for the model reported with the b coefficients).

On the other hand, standard deviation of demand which is a proxy for uncertainty of demand is also statistically significant and 1 percentage point increase reduces the relative probability of cartelisation by 99.97%, again a strong effect which could perhaps be traced back to the low number of observations in this category and the fact that the standard deviation of the variable in this outcome is 1.43 percentage points (lowest across all categories) compared to 9.5 points for the reference category of no cartels. This makes the case for an increase in uncertainty in demand also being a "low probability high impact event" for the relative probability of this type of cartelisation(when the base category is zero cartels). Similarly to growth in demand, when the coefficients for discrete increase in standard deviation of demand are considered the effect on the individual probability of collusion at the median is much more modest, a decline of 0.28 percentage points for a percentage point increase in the variable. The marginal effect estimate has a positive coefficient but as in the case for growth in demand it has a very small magnitude and may be a result of a statistical error.

Stocks per firm is also statistically significant and together with total net capital expenditure (not significant) are predicted to have negative effect on relative cartelisation,

which is contrary to theory. Similar results appeared for international cartels and potential reasons were discussed in that section.

The fact that industry factors seem to have a more statistically significant effect in this category may be because some variables explain the existence of domestic cartels better and some explain international cartelisation better. Consequently, when in an industry both types of cartel exist the overall effect may be for all variables to be significant. For example, industry concentration seems to affect more international cartelisation while growth in demand seems to matter more when predicting the existence of domestic cartels(magnitude issues of the rrr coefficients were discussed earlier). However, as discussed before, this division in the impact of the factors may be mainly due to the level of disaggregation of the data. Domestic demand factors while useful for explaining domestic cartelisation may be less relevant for international cartelisation than international demand factors. Furthermore, regional cartelisation may be better at explaining domestic cartels which can often be regional. International cartelisation is mainly conducted by large firms which perhaps find it easier to start/join an international cartel if they have a considerable market share domestically, which could be captured by overall industry concentration. Therefore it is probable that both concentration and growth in demand may influence both types of cartelisation when measured at the appropriate level of disaggregation.

Section 5.4 Probability estimates

Additionally, probability predictions for all industries were run to estimate the probability of there being no cartels, only international cartels, only domestic cartels or both types of cartels in the industry(Table 4). Similarly to the OFT(2005) paper the probabilities for each industry were calculated as the average of the probabilities for each year for the industry. Interesting conclusions can be drawn for industries where the prediction of existing cartels does not correspond with the evidence up to date. This is the case for four industries: Publishing,

NACE	Table 4. Probability Estimates		predicted probabilities for cartels			
1.1	Industry	mcartels	no cartels	international	domestic	both
1	Agriculture, hunting and related service activities	0	0.61	0.34	0.05	0.00
2	Forrestry, logging and related service activities	0	0.74	0.07	0.19	0.00
5	Fishing, fish farming and related service activities	0	0.73	0.13	0.14	0.00
10	Mining of Coal and Lignite; Extraction of Peat	0	1.00	0.00	0.00	0.00
11	Extraction of Crude Petroleum and Natural Gas; Service Activities Incidental to Oil and Gas Extraction Excluding Surveying	0	0.99	0.00	0.00	0.01
14	Other Mining and Quarrying	0	0.98	0.02	0.00	0.00
15	Manufacture of Food Products and Beverages	0	0.69	0.30	0.00	0.01
16	Manufacture of Tobacco Products	0	1.00	0.00	0.00	0.00
17	Manufacture of Textiles	1	0.57	0.43	0.01	0.00
18	Manufacture of Wearing Apparel; Dressing and Dyeing of Fur	1	0.43	0.55	0.03	0.00
19	Tanning and Dressing of Leather; Manufacture of Handbags, Saddlery, Harness And Footwear	0	0.55	0.45	0.00	0.00
20	Manufacture of Wood And Products of Wood And Cork, Except Furniture; Manufacture of Articles of Straw and Plaiting Materials	0	0.51	0.16	0.09	0.24
21	Manufacture of Pulp, Paperand Paper Products	3	0.17	0.06	0.00	0.77
22	**Publishing, Printing and Reproduction of Recorded Media**	0	0.35	0.51	0.15	0.00
23	Manufacture of Coke, Refined Petroleum Products and Nuclear Fuel	0	1.00	0.00	0.00	0.00
24	Manufacture of Chemicals and Chemical Products	3	0.11	0.04	0.00	0.84
25	Manufacture of Rubber and Plastic Products	1	0.60	0.39	0.01	0.00
26	Manufacture of Other Non-metallic Mineral Products	1	0.75	0.25	0.00	0.00
27	Manufacture of Basic Metals	1	0.69	0.31	0.00	0.00
28	Manufacture of Fabricated Metal Products, Except Machinery and Equipment	3	0.14	0.05	0.05	0.76
29	Manufacture of Machinery and Equipment Not Elsewhere Classified	1	0.43	0.57	0.00	0.00
30	Manufacture of Office Machinery and Computers	0	0.79	0.20	0.01	0.00
31	Manufacture of Electrical Machinery and Apparatus Not Elsewhere Classified	1	0.57	0.42	0.00	0.00
32	Manufacture of Radio, Television and Communication Equipment and Apparatus	1	0.52	0.48	0.00	0.00
33	**Manufacture of Medical, Precision and Optical Instruments, Watches and Clocks**	0	0.45	0.55	0.00	0.00
34	Manufacture of Motor Vehicles, Trailers and Semi-trailers	0	0.78	0.20	0.00	0.02
35	**Manufacture of Other Transport Equipment**	0	0.34	0.48	0.00	0.18
36	Manufacture of Furniture; Manufacturing Not Elsewhere Classified	2	0.67	0.19	0.14	0.00
37	Recycling	0	0.86	0.14	0.00	0.00
40	Electricity, Gas, Steam and Hot Water Supply	0	1.00	0.00	0.00	0.00
41	Collection, Purification and Distribution of Water	0	1.00	0.00	0.00	0.00
45	Construction	2	0.16	0.02	0.82	0.00
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Automotive Fuel	0	0.67	0.10	0.23	0.00
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	0	0.93	0.02	0.05	0.00
52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Personal and Household Goods	2	0.09	0.02	0.89	0.00
55	**Hotels and Restaurants**	0	0.20	0.14	0.66	0.00
60	Land Transport; Transport Via Pipelines	2	0.36	0.26	0.33	0.04
61	Water Transport	0	0.94	0.06	0.00	0.00
62	Air Transport	0	0.89	0.11	0.00	0.00
63	Supporting And Auxiliary Transport Activities; Activities Of Travel Agencies	0	0.72	0.08	0.02	0.17
64	Post and Telecommunications	1	0.87	0.12	0.01	0.00
71	Renting of Machinery and Equipment Without Operator and of Personal and Household Goods	0	0.83	0.05	0.12	0.00
72	Computer and Related Activities	0	0.63	0.37	0.00	0.00
73	Research and Development	0	0.58	0.42	0.00	0.00
74	Other Business Activities	2	0.05	0.02	0.93	0.00
80	Education	2	0.74	0.08	0.18	0.00
85	Health and Social Work	0	0.62	0.10	0.28	0.00
90	Sewage and Refuse Disposal, Sanitation and Similar Activities	0	0.83	0.12	0.05	0.00
91	Activities of Membership Organisations Not Elsewhere Classified	0	0.58	0.09	0.33	0.00
92	Recreational, Cultural and Sporting Activities	1	0.66	0.34	0.00	0.00
93	Other Service Activities	0	0.62	0.12	0.26	0.00

Printing and Reproduction of Recorded Media, (NACE code 22, p(mcartels = 1) = 0.51); Manufacture of Medical, Precision and Optical Instruments, Watches and Clocks(NACE code 33, p(mcartels =1) = 0.55); Manufacture of Other Transport Equipment(NACE code 35, p(mcartels = 1) = 0.48); and Hotels and Restaurants(NACE code 55, p(mcartels =2) = 0.66)). The first three industries have a probability of around a half of having an international cartel and yet there have been no detected cartels in the industry. The fourth industry has two thirds predicted probability of having a domestic cartel and there too no cartels have been detected so far. It may be the case that such regression analysis could serve to highlight industries where a certain type of cartelisation is more likely. Nevertheless, the measurement problem with the data on cartels must be taken into account. By necessity the predictions are based on data for cartels which are already discovered which may skew all probability predictions. Also, the relatively low level of industry disaggregation may be too broad to narrow down areas where investigation needs to be undertaken.

Section 5.5 Regression issues and comparisons with other models

Table 5 presents the results for relative probability using the rrr(relative risk ratios) across the three categories together, which is how the model predictions were produced and presented by Stata. The model was tested for collinearity and while the score for all variables together is high (mean VIF of 4.83, 5.04 when mcartels, the dependent variable, is excluded) this is primarily due to the squared terms for concentration and growth in demand. Once these are removed from the test the score is within norms (mean VIF of 2.45, 2.53 when mcartels is excluded) and the only parameters with a VIF above 2 were total turnover per firm and stocks per firm both of which have VIF around 7 but their tolerance parameter is not below 0.1 [7]. The coefficients were also tested for equivalence across the categories and that hypothesis

[7] estimates produced using the collin command for stata, developed by the UCLA ATS Statistical Consulting Group for data analysis

Table 5. Multinomial logistic Regression Pseudo R2 = 0.4558	**rrr(relative risk ratios) and robust standard errors type of cartel:**		
variables:	**international**	**domestic**	**both**
year 2001	0.9610	0.9843	0.6975
(SE)	*0.0839*	*0.0634*	*0.6965*
year 2002	0.8067*	0.9508	0.6608
(SE)	*0.1044*	*0.0742*	*0.6537*
year 2003	0.7553*	0.8927	0.2059
(SE)	*0.1251*	*0.1085*	*0.2520*
year 2004	0.9234	0.8776	0.0470
(SE)	*0.1510*	*0.1193*	*0.1068*
year 2005	1.0976	0.9104	0.0788*
(SE)	*0.1937*	*0.1310*	*0.1115*
year 2006	0.8040	0.8584	0.0131**
(SE)	*0.1437*	*0.1734*	*0.0225*
year 2007	0.8321	0.8752	0.0007***
(SE)	*0.1415*	*0.2113*	*0.0013*
total turnover in the industry	1.0000	1.0000**	0.9997***
(SE)	*0.0000*	*0.0000*	*0.0000*
total turnover per firm	0.9999	0.9988	1.0051***
(SE)	*0.0001*	*0.0008*	*0.0008*
industry concentration	1.0534*	1.0185	1.2958***
(SE)	*0.0332*	*0.0587*	*0.1019*
industry concentration squared	0.9997*	0.9998	0.9986***
(SE)	*0.0002*	*0.0003*	*0.0005*
standard deviation of demand	0.8205	0.8462	0.0003***
(SE)	*0.1070*	*0.1554*	*0.0004*
growth in total turnover per firm(2000 to 2007)	0.9703	1.0803	2.43e+10***
(SE)	*0.0306*	*0.0639*	*1.04E+11*
growth in total turnover per firm squared	1.0004	0.9981**	0.6966***
(SE)	*0.0003*	*0.0008*	*0.0464*
total net capital expenditure per firm	0.9976	1.0025*	0.9942
(SE)	*0.0022*	*0.0014*	*0.0036*
total stocks per firm	1.0008	0.9921	0.9855***
(SE)	0.0014	0.0140	0.0028
***significant at 0.01 percent **significant at 0.05 percent *significant at 0.1 percent	51 Clusters Log pseudolikelihood = -224.69402	Number of Observations:397	

*rrr(relative risk ratios), if variable increases by 1 then p(mcartels =k)/p(mcartels=0), k = 1,2 or 3) changes by (rrr - 1)*100 percentage change; where p(mcartels = 0) is the probability of no cartels existing in the industry, p(mcartels = k) is the probability of a given other outcome(mcartels = 1, 2 or 3)*

was rejected (Prob > chi2 = 0.0002 was the highest recorded with the majority being Prob > chi2 = 0.0000).

The main results in the multinomial logistic model are also similar to those achieved using a different combination of variables in the model. Industry concentration, growth and deviation of demand all tend to be very significant for the last category where there are both

international and domestic cartels. Additionally, concentration tends to be significant for international cartels while growth of demand is significant for domestic cartels (in some regressions for both terms). Standard deviation is also sometimes significant for international cartels and sometimes for domestic cartels. The entry barriers presented too tend to have the same signs across categories for variations of the model, although when other entry barriers are introduced into the model, their rrr can become negative for all categories. However additional entry barriers have been excluded from the final model mostly due to high collinearity with the other variables in the model and low significance of the estimated coefficients. For example, this was the case for employment costs per firm, a variable intended to capture whether there was an effect on collusion connected to the level of pay received by employees.

The model was also run as a multinomial probit model to test how it compares when we relax some of the assumptions made in the multinomial logistic model such as the coefficients along the categories being uncorrelated and the previously mentioned IIA assumption.(see Appendix A for the multinomial probit model results). That model strongly resembles the one presented here and several variables are even more statistically significant than the ones presented here. Standard deviation, for example, is statistically significant for international cartels (at 9.3%) whereas in the multinomial model it was not. Additionally, for domestic cartels the linear term is more significant than previously (at 12.7%). In the category where there are both international and domestic cartels in an industry the only substantial difference is that the year 2004 dummy is also statistically significant at the 6.8% level.

In the model presented here we have included a case of tacit collusion in the domestic education industry as evidence of collusion. The participating private schools were fined by the OFT for disclosing information on charges to pupils. As this choice may be contested the

results were also tested for robustness to the exclusion of the specific case and this did not affect the main results(direction of the effect of the variables and their statistical significance).

As part of the alternative regressions run to determine the optimal model, a simple logistic model was run separately for domestic cartels and for international cartels. The main results remained the same. In the model for international cartels concentration (both the linear and squared terms) was significant at the 10% level and the year 2005 again had a positive albeit insignificant effect on the relative probability of international collusion. Additionally the negative effect of uncertainty of demand was statistically significant at the 5.1% level. The other variables also had similar signs to before with the years 2002 and 2003 having again a statistically significant negative effect. In the model for domestic cartels all variables were insignificant with the exception of the linear and squared terms for growth in demand which were both statistically significant at the 10%. As these separate models did not add more insight than the multinomial logistic model which was chosen in favour of them. That also has the benefit of introducing a new category where there are both domestic and international cartels in an industry.

The relatively small number of clusters in the model (51) may cause doubt whether clustering is optimal in this case. Nevertheless, Kezdi(2004) maintains that clustering provides good estimates for moderate sized samples and presents a model where 50 clusters are enough to estimate accurate standard errors. However, his conclusions are for a different model than the one presented here. Therefore, this model was tested by excluding some variables (most often the year dummies, this special case model is presented in Appendix A) to increase the degrees of freedom. Another regression was also run with all the variables in the final model without the clustering option. In both cases the main conclusions remained the same although without clustering the standard errors were smaller as expected.

As this study partially emulates a paper by OFT(2005) the results have been compared to those in OFT(2005). One major difference is that in this paper employment variables such as employment costs per employee and per firm were always insignificant unlike in OFT(2005) so they were excluded from the final model. Employment costs per firm also significantly increased collinearity whenever it was included in the model. Furthermore, in the OFT(2005) models there were no squared terms for concentration and growth in demand. However, the direction if their effect was positive and thus consistent with the estimates in our study. Standard deviation of demand had a predicted negative impact. All three variables were statistically significant in almost all presented regressions unlike in our study where different variables were significant in different outcomes. Additionally total turnover for the industry and per firm were also very significant across the regressions with coefficients predicting no relationship or positive relationship with collusion. Entry barriers such as total stocks per firm and total net capital expenditure per firm were predicted to have positive albeit statistically insignificant effect on collusion which is more consistent with theory than in our model. Where a constant is reported it has a statistically significant negative impact on collusion which is similar to our model although in our case the term is only significant for the last outcome (both types of cartels). The constant term in our regression is not reported in Stata when the relative risk ratio option(rrr) is selected. However, it can be viewed as a normal b coefficient when the option is not selected(see Appendix A for model without the rrr).

It is encouraging to see that the regression analysis here gives similar results to that in OFT(2005) despite the different time period, level of industry disaggregation and set of tested variables (the full set of variables was not replicated here due to lack of publicly available data). The model analysed here has a higher pseudo R-squared by the OFT(2005) model, 0.4558 compared to between .14 and .24 in the OFT model, which may be because here

different types of cartels are sorted into categories (domestic, international, both) while the OFT(2005) employ an opposite approach. Although they too use only UK industry data their cartel data is pooled from cartels in the EU and the USA, which is highly correlated (0.678 per cent although less than 20% of the EU and USA cases are common). Our data on international and domestic cartels has a much smaller overlap with a correlation of 0.088 and only 5.77 per cent of industries which have both types of cartelisation. It is most likely that the utilisation of a multinomial logistic model is what improves the fit of the model the most as when only international or only domestic cartels were tested with a logit model the pseudo R-squared was around 20 percent which is similar to the regressions in OFT(2005).

Section 6. Conclusion

The aim of this paper was to analyse the factors which facilitate or hinder collusion. It utilized UK industry and cartel data from 2000 to 2007. An innovative method employed in the paper was using a multinomial logistic regression to separate industry cartelisation into different categories depending on the type of cartels present. This allowed for optimal use of the existing data for prediction purposes and enhanced the explanatory power of the model. Industry concentration was shown to have a concave effect on international cartelisation, while growth in demand was predicted to have a concave effect on domestic cartelisation. Standard deviation was predicted to reduce cartelisation mainly in industries where both types of cartels were present. Nevertheless, these factors do not necessarily only affect a particular type of cartelisation as the results could be due to the level of disaggregation in the data. Overall concentration in the industry may be effective in predicting international cartels but for domestic cartels regional concentration may be more important. Similarly, growth in demand for the UK industry may reflect domestic demand conditions better than international ones which could be why they seem to affect domestic cartelisation while not international. Furthermore, probability estimates were created for each industry to predict what types of

cartels are expected to exist there. This was done in an attempt to produce estimates which could help optimise antitrust investigations by providing ex-ante information on which industries are likely to be cartelised and what type of cartelisation is likely to exist.

Section 7. Suggestions for further research

The analysis presented in this paper is innovative but there are limitations to its scope and quality. There are four main areas of further improvements. First, collecting data for explanatory variables at different levels of disaggregation(international, regional) could help improve the fit of the model for both international and domestic cartels. Nevertheless, this may not be possible at this time. Second, conducting research at a deeper level of industry disaggregation can be used increase the number of clusters in the regressions and thus allow for better estimates and perhaps more useful predictions for industries which may be cartelised. This was not done in this study due to time constraints but is a suggestion which given the available time can be implemented. Third, conducting the research for other countries will help compare whether the results hold for industries in other countries or not. Finally, developing a way to measure the level of communication among firms in an industry and the characteristics of the Antitrust Authority responsible for detecting the specific cartel case can help incorporate those factors in empirical regressions.

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Appendix A

Table 6. NACE 1.1 list of industries (industries in bold have no predictions in the model due to lack of data)	NACE 1.1 code
Agriculture, hunting and related service activities	1
Forrestry, logging and related service activities	2
Fishing, fish farming and related service activities	5
Mining of Coal and Lignite; Extraction of Peat	10
Extraction of Crude Petroleum and Natural Gas; Service Activities Incidental to Oil and Gas Extraction Excluding Surveying	11
Mining of Uranium and Thorium Ores	**12**
Mining of Metal Ores	**13**
Other Mining and Quarrying	14
Manufacture of Food Products and Beverages	15
Manufacture of Tobacco Products	16
Manufacture of Textiles	17
Manufacture of Wearing Apparel; Dressing and Dyeing of Fur	18
Tanning and Dressing of Leather; Manufacture of Handbags, Saddlery, Harness And Footwear	19
Manufacture of Wood And Products of Wood And Cork, Except Furniture; Manufacture of Articles of Straw and Plaiting Materials	20
Manufacture of Pulp, Paperand Paper Products	21
Publishing, Printing and Reproduction of Recorded Media	22
Manufacture of Coke, Refined Petroleum Products and Nuclear Fuel	23
Manufacture of Chemicals and Chemical Products	24
Manufacture of Rubber and Plastic Products	25
Manufacture of Other Non-metallic Mineral Products	26
Manufacture of Basic Metals	27
Manufacture of Fabricated Metal Products, Except Machinery and Equipment	28
Manufacture of Machinery and Equipment Not Elsewhere Classified	29
Manufacture of Office Machinery and Computers	30
Manufacture of Electrical Machinery and Apparatus Not Elsewhere Classified	31
Manufacture of Radio, Television and Communication Equipment and Apparatus	32
Manufacture of Medical, Precision and Optical Instruments, Watches and Clocks	33
Manufacture of Motor Vehicles, Trailers and Semi-trailers	34
Manufacture of Other Transport Equipment	35
Manufacture of Furniture; Manufacturing Not Elsewhere Classified	36
Recycling	37
Electricity, Gas, Steam and Hot Water Supply	40
Collection, Purification and Distribution of Water	41
Construction	45
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Automotive Fuel	50
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	51
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Personal and Household Goods	52
Hotels and Restaurants	55
Land Transport; Transport Via Pipelines	60
Water Transport	61
Air Transport	62
Supporting And Auxiliary Transport Activities; Activities Of Travel Agencies	63
Post and Telecommunications	64
Financial Intermediation, Except Insurance and Pension Funding	**65**
Insurance and Pension Funding, Except Compulsory Social Security	**66**
Activities Auxiliary to Financial Intermediation	**67**
Real Estate Activities	70
Renting of Machinery and Equipment Without Operator and of Personal and Household Goods	71
Computer and Related Activities	72
Research and Development	73
Other Business Activities	74
Public Administration and Defence; Compulsory Social Security	**75**
Education	80
Health and Social Work	85
Sewage and Refuse Disposal, Sanitation and Similar Activities	90
Activities of Membership Organisations Not Elsewhere Classified	91
Recreational, Cultural and Sporting Activities	92
Other Service Activities	93
Activities of Households as Employers of Domestic Staff	**95**
Undifferentiated Goods Producing Activities of Private Households for Own Use	**96**
Undifferentiated Services Producing Activities of Private Households for Own Use	**97**
Extra-territorial Organisations and Bodies	**99**

Table 7. Multinomial logistic Regression (no year variables)	**rrr coefficients and robust standard errors**		
Pseudo R2 = 0.4413	**type of cartel:**		
variables:	**international**	**domestic**	**both**
total turnover in the industry	1.0000	1.0000*	0.9998***
(SE)	*0.0000*	*0.0000*	*0.0000*
total turnover per firm	0.9999	0.9987	1.0035***
(SE)	*0.0001*	*0.0008*	*0.0007*
industry concentration	1.0535 (sign at 10.3 %level)	1.0196	1.1775***
(SE)	*0.0337*	*0.0588*	*0.0720*
industry concentration squared	0.9997*	0.9998	0.9991**
(SE)	*0.0002*	*0.0003*	*0.0004*
standard deviation of demand	0.8200	0.8466	0.0048***
(SE)	*0.1063*	*0.1520*	*0.0073*
growth in total turnover per firm(2000 to 2007)	0.9707	1.0802	2.50e+07***
(SE)	*0.0306*	*0.0630*	*6.95E+07*
growth in total turnover per firm squared	1.0004	0.9982**	0.7749***
(SE)	*0.0003*	*0.0008*	*0.0338*
total net capital expenditure per firm	0.9976	1.0026*	0.9968
(SE)	*0.0022*	*0.0014*	*0.0055*
total stocks per firm	1.0009	0.9921	0.9892***
(SE)	0.0015	0.0140	0.0042
***significant at 0.01 percent	51 Clusters	Number of Observations:397	
**significant at 0.05 percent			
*significant at 0.1 percent	Log pseudolikelihood = -230.69764		

*rrr (relative risk ratios), if variable increases by 1 then p(mcartels =k)/p(mcartels=0) changes by (rrr - 1)*100 percentage change; where p(mcartels = 0) is the probability of no cartels existing in the industry, k is the value of mcartels different from 0 (1,2 or 3)*

Table 8. Multinomial logistic Regression(b coefficients)	**coefficients and robust standard errors**		
Pseudo R2 = 0.4558	**type of cartel:**		
variables:	**international**	**domestic**	**both**
year 2001	-0.0397	-0.0158	-0.3602
(SE)	*0.0873*	*0.0644*	*0.9985*
year 2002	-0.2148*	-0.0505	-0.4142
(SE)	*0.1294*	*0.0780*	*0.9893*
year 2003	-0.2806*	-0.1135	-1.5805
(SE)	*0.1656*	*0.1216*	*1.2239*
year 2004	-0.0797	-0.1305	-3.0580
(SE)	*0.1636*	*0.1359*	*2.2740*
year 2005	0.0931	-0.0938	-2.5406*
(SE)	*0.1765*	*0.1439*	*1.4141*
year 2006	-0.2181	-0.1526	-4.3327**
(SE)	*0.1787*	*0.2020*	*1.7171*
year 2007	-0.1837	-0.1333	-7.3181***
(SE)	*0.1701*	*0.2414*	*1.9048*
total turnover in the industry	0.0000	0.0000**	0.0000***
(SE)	*0.0000*	*0.0000*	*0.0000*
total turnover per firm	-0.0001	-0.0012	0.0051***
(SE)	*0.0001*	*0.0008*	*0.0007*
industry concentration	0.0521*	0.0183	0.2591***
(SE)	*0.0315*	*0.0576*	*0.0786*
industry concentration squared	-0.0003*	-0.0002	-0.0014***
(SE)	*0.0002*	*0.0003*	*0.0005*
standard deviation of demand	-0.1978	-0.1670	-8.2466***
(SE)	*0.1303*	*0.1837*	*1.3969*
growth in total turnover per firm(2000 to 2007)	-0.0301	0.0772	23.9146***
(SE)	*0.0316*	*0.0592*	*4.2900*
growth in total turnover per firm squared	0.0004	-0.0018**	-0.3615***
(SE)	*0.0003*	*0.0008*	*0.0666*
total net capital expenditure per firm	-0.0024	0.0025*	-0.0058
(SE)	*0.0022*	*0.0014*	*0.0036*
total stocks per firm	0.0008	-0.0079	-0.0146***
(SE)	0.0014	0.0141	0.0028
constant	0.0685	0.0843	-359.9525***
(SE)	1.3479	2.0299	64.4059
***significant at 0.01 percent	51 Clusters	Number of Observations:397	
**significant at 0.05 percent			
*significant at 0.1 percent	Log pseudolikelihood = -224.69402		

Table 9. Multinomial Probit Regression	**coefficients and robust standard errors**		
	type of cartel:		
variables:	**international**	**domestic**	**both**
year 2001	-0.0572	-0.0104	-0.3116
(SE)	*0.0703*	*0.0481*	*0.4492*
year 2002	-0.1881*	-0.0449	-0.3047
(SE)	*0.1062*	*0.0469*	*0.4693*
year 2003	-0.2411*	-0.0936	-1.2084*
(SE)	*0.1338*	*0.0785*	*0.6569*
year 2004	-0.0989	-0.1049	-2.2800**
(SE)	*0.1252*	*0.0934*	*0.9458*
year 2005	0.0539	-0.0606	-2.0481***
(SE)	*0.1378*	*0.0957*	*0.7706*
year 2006	-0.1792	-0.0989	-3.3148***
(SE)	*0.1455*	*0.1233*	*0.9792*
year 2007	-0.1435	-0.0660	-5.6790***
(SE)	*0.1402*	*0.1479*	*1.0882*
total turnover in the industry	0.0000	0.0000**	0.0000***
(SE)	*0.0000*	*0.0000*	*0.0000*
total turnover per firm	-0.0001	-0.0010**	0.0039***
(SE)	*0.0001*	*0.0005*	*0.0005*
industry concentration	0.0455*	0.0153	0.1912***
(SE)	*0.0237*	*0.0359*	*0.0412*
industry concentration squared	-0.0002*	-0.0001	-0.0010***
(SE)	*0.0001*	*0.0002*	*0.0002*
standard deviation of demand	-0.1580*	-0.1383	-6.3313***
(SE)	*0.0952*	*0.1408*	*1.1189*
growth in total turnover per firm(2000 to 2007)	-0.0249	0.0621	18.2106***
(SE)	*0.0227*	*0.0385*	*2.9412*
growth in total turnover per firm squared	0.0003	-0.0015*	-0.2753***
(SE)	*0.0002*	*0.0006*	*0.0456*
total net capital expenditure per firm	-0.0018	0.0021**	-0.0045*
(SE)	*0.0014*	*0.0009*	*0.0023*
total stocks per firm	0.0006	-0.0051	-0.0111***
(SE)	0.0010	0.0092	0.0016
constant	-0.0933	0.1143	-273.7437***
(SE)	0.9745	1.3811	43.4507
***significant at 0.01 percent	51 Clusters	Number of Observations:397	
**significant at 0.05 percent			
*significant at 0.1 percent			
mprobit coefficients reported are compared against the base outcome of there being no cartels in the industry			