

Cartels Uncovered

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Abstract

How many cartels are there, and what industry characteristics facilitate collusion? The answers to these questions are important in assessing the need for competition policy. We present a Hidden Markov Model that takes into account that often it is not known whether a cartel exists or not. We take the model to data from a period of legal cartels - Finnish manufacturing industries 1951 - 1990. Our estimates suggest that once born, cartels are persistent; by the end of the period, almost all industries were cartelized. Entry and exit rates, concentration, market size and variable costs are correlated with cartelization.

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“A nation built on cartels”

(Historian Markku Kuisma (2010) on Finland).

1 Introduction

This paper builds on two observations: First, there is little systematic evidence on the prevalence of cartels and, consequently, the need for competition policy. A key reason for this state of affairs is that important statistics, such as the proportion of industries (markets) that have a cartel under an existing competition policy regime, or would have a cartel if there was no competition policy, are unknown. These statistics are unknown primarily because of a lack of tools to deal with a peculiar feature of cartel data: Most of the time, it is not known whether there is a cartel in a given market or not.¹ Second, empirical research on how industry characteristics foster or impede cartels is surprisingly scant. We combine a statistical model that takes the central features of this data generating process into account - a so-called Hidden Markov Model (HMM) - with information on the existence of nationwide Finnish legal manufacturing cartels from 1951 to 1990 and with data on industry characteristics to shed light on these two questions.

We think there are two reasons why studying legal cartels is (still) of interest. First, for much of the twentieth century cartels were legal in many European countries and thus our analysis gives a better understanding of an important period of economic history. Second, at least since Stigler’s (1964) and Friedman’s (1971) seminal articles, much of the theoretical work on cartels and collusion has

¹The available data depend on the prevalence of cartels, the probability that cartels get exposed and the probability that the cartels’ (non)existence in the time periods prior or after to their exposure can be established. This data exposure process implies that a naïve comparison of the proportion of observed cartels to that of non-cartelized industries would yield a biased estimate of the prevalence of cartels.

concentrated on establishing the conditions under which collusion takes place, or breaks apart when there is no competition authority. Even those studies that worry about the illegality of the cartel have to consider the other determinants of the probabilities of forming and continuing a cartel. One way of summarizing this prior theoretical work on collusion is to say that in a given period, firms in a market either collude (are cartelized) or do not (there is no cartel) and that the likelihood of collusion depends on whether there was collusion in the previous period or not.² Our HMM can be viewed as a reduced form model capturing this central feature.

We estimate the probabilities of cartel formation and continuation, and their determinants. The link to modern illegal cartels is that we provide an upper bound estimate of the number of cartels - after all, while legal cartels' existence is not affected by competition policy, they are subject to many of the same internal incentive problems that illegal cartels face. We provide an estimate of the number of cartels in the (from a modern viewpoint counterfactual) state of no active competition policy. These results both strengthen the empirical basis for "factors facilitating collusion" and contribute to answering the question of whether competition policy is needed. The following main results emerge: First, without competition policy, the likelihood of an industrialized economy being cartelized is high: according to our estimates, nearly all of Finnish manufacturing was cartelized by the end of 1980s. This development is driven by the high probability of cartels continuing found here and elsewhere (see Ellison 1994, and Levenstein and Suslow 2006), as long as it is matched with even a moderate probability of cartels forming. Second, in Finland the probability of

²A defining feature of the game theoretic analyses of e.g. Green and Porter (1984), Abreu, Pearce and Stachetti (1986) and Rotemberg and Saloner (1986) is that the break-down of collusion is part of the industry equilibrium. More recently, Harrington and Chang (2009) and Chang and Harrington (2010) have studied a Markov model where a cartel actually breaks down, either because of exogenous reasons, detection by the CA, or whistleblowing due to a leniency program.

forming a cartel started to increase from the late 1960s onwards. This development, captured by our model and driven by shocks to GDP growth, matches well with the contemporaneous institutional changes in Finland. Taken at face value, our results suggest that strict competition policy is of first order importance. Third, some factors facilitating collusion affect both the formation and the continuation of cartels, others only one or the other. Concentrated and large markets, markets with high variable costs, as well as markets with infrequent exits are a fertile ground for establishing a cartel, whereas entry destabilizes cartels. These asymmetries may warrant attention in both theoretical and subsequent empirical work.

Textbooks in industrial organization (e.g. Belleflamme and Peitz 2010, Cabral 2000, Carlton and Perloff 2004, Motta 2004 and Scherer and Ross 1990 to name a few) routinely list factors that are thought to facilitate collusion. These lists seem to be based more on theoretical than empirical research. Besides qualitative evidence, the empirical backing for these lists comes largely from cartel research using inter-industry data (e.g. Hay and Kelley 1974, Asch and Seneca 1975 and Frass and Greer 1977) that predates the emergence of New Empirical Industrial Organization (NEIO; see Bresnahan 1989).³ More recently, Symeonidis' work on cartels has made use of the inter-industry variation in policy changes to identify the treatment effect of cartelization (see Symeoni-

³For example, the Jacquemin and Slade (1989) survey on collusion lists only two empirical papers when discussing factors facilitating collusion (Hay and Kelley 1974 and Jacquemin, Nambu and Dewez 1981). See also Connor (2007), which provides mostly qualitative evidence on factors facilitating collusion. Examples of the NEIO strand of the literature using data on individual markets are Porter (1983), Lee and Porter (1984), Ellison (1994), Pesendorfer (2000), Porter and Zona (1993, 1999), Genesove and Mullin (1998, 2001), Knittel and Stango (2003), Röller and Steen (2006) and Asker (2010). These papers describe the inner workings of an individual cartel and reveal a considerable amount of heterogeneity in how effective cartels are in sustaining collusive outcomes and in the welfare losses they generate. Another approach is used by List and Price (2005), who implement a framed field experiment in the sportscard marketplace to study collusion. More recent examples of the inter-industry approach include Miller's (2009) paper on the number of exposed U.S. cartels and Brenner's (2009) analysis of European Commission's leniency program. Bryant and Eckard (1991) use U.S. data on exposed horizontal price fixing agreements 1961-1988 and estimate the probability of detection by the Competition Authority (CA).

dis 2002), and determinants of cartel formation (Symeonidis 2003). The latter paper, together with Dick (1996), is to our knowledge one of the few recent papers addressing the issue of which factors facilitate collusion.⁴ Unfortunately, the prior studies suffer from the problem we seek to solve: that the industries that do not have a (registered legal) cartel actually have none. Our data and results challenge this assumption. To the best of our knowledge, we are the first to provide evidence on the factors facilitating collusion without assuming that in those industries where no cartels are observed, there is none.

Our most important precursors are Porter (1983), Lee and Porter (1984) and Ellison (1994) who all study the Joint Executive Committee, i.e., the Chicago-Atlantic seaboard railway cartel from the 1880s. Porter (1983) and Lee and Porter (1984) allow for two hidden states of the industry - collusion and price-war in their set-up - and utilize an imperfect indicator to identify the collusive state of the industry. Ellison (1994) extends their empirical work by bringing in a Markov structure for the hidden process (see also Cho and White 2007). These authors' objective is to estimate the collusive status of the industry and the effect of collusion on the supply relation. They utilize data on demand, cost, and collusive markers from a given market. Another important precursor is Knittel and Stango (2003), who allow for latent tacit collusion in the local U.S. credit card markets.

Unlike that of earlier empirical work, our objective is to estimate the prevalence of cartels and its macro- and industry-level determinants using data on the (non)existence of cartels. While not denying the importance of understanding

⁴Studying legal UK cartels, Symeonidis finds that capital intensity fosters collusion, advertising intensity impedes it, and that concentration has no effect. He also finds some evidence that market growth has a nonlinear effect on collusion. Dick (1996) studies legal U.S. export cartels and finds that capital intensity fosters collusion, as does the U.S. producer's market share in world export markets; product differentiation and concentration are found to hamper collusion. Levenstein and Suslow's (2011) study the determinants of the duration of international cartels, and find that firm-specific discount rates are associated with the duration. There is also an empirical literature studying the effects of multimarket contact: see e.g. Evans and Kessides (1994) and Ciliberto and Williams (2013).

how efficiently cartels work, we concentrate on their existence. Methodologically, the major difference to preceding work is that we introduce the HMM modeling structure. In particular, we allow explicitly for the possibility that the state of the industry is unknown to the researcher and the Competition Authority (CA), instead of allowing for regime classification mistakes. The observation process part of our HMM acts as a filter between the hidden process and what is observed by the econometrician, and allows identification of the economic parameters of interest.⁵

The possibility that the state of the industry is unknown means that our model can be readily applied to a cross-section (or panel) of markets; something one wants to do when studying prevalence of cartels. The higher the number of markets in the data, the more likely it is that the researcher faces the situation where she cannot with confidence assign a “cartel/no-cartel” status to some observation(s). Indeed, the CA actions may reveal demand and cost data on the investigated industries, but nothing about the remaining industries. We would thus think - and this definitely holds in our application - that most of the observations in a large, representative dataset on markets would be assigned the status “unknown”.

We take our HMM model to panel data on 193 Finnish manufacturing industries from 1951 to 1990. In 54% (105/193) of the industries in our data, there was at least one known nationwide horizontal cartel in existence some time between 1951 - 1990; for the remaining industries it is unknown whether a cartel ever existed. We have obtained the cartel data from the Registry established in 1958 after the first Finnish competition law was enacted. The forms of collu-

⁵Given the type of data typically available, the earlier models would require the researcher to assign either the status “cartel” or “no cartel” to each observation, while allowing for mistakes in this assignment. The previous models therefore assign probability zero to the event that the observed state of an observation is “unknown”. Our HMM can be related to the earlier models, as it can allow both for mistakes in labeling and the possibility that the state of the industry is not known.

sion varied and included e.g. agreements on prices, and/or market shares (see Hyytinen, Steen and Toivanen 2013). Similar registries on legal cartels existed e.g. in Austria, Germany, Switzerland, the Netherlands, all Nordic countries and Australia.

The rest of the paper is organized as follows. In the next Section, we first briefly discuss how to incorporate much of cartel theory into an empirical reduced form model of cartel formation and continuation. We then show how a HMM that matches the collusive dynamics of these models with the observed data can be specified and its parameters identified. In the third Section, we describe the Finnish institutional environment vis-à-vis cartels after WWII. Section four is devoted to the presentation of our data. There we also discuss how we match cartels to markets and what industry characteristics to include in the model, based on existing theoretical and empirical research. We present and discuss our results in Section five. Section six concludes.

2 A Hidden Markov Model for Cartel Formation and Continuation

2.1 The Reduced Form Model

We study the rate of cartelization among Finnish manufacturing industries during an era when, bar a few exceptions that we explain in greater detail in Section 3, cartels were legal.⁶ There are many dynamic models of cartel formation and dissolution in the literature that could suit our purposes: Most of them share the feature that there is an incentive compatibility constraint (ICC) that needs to be satisfied for the cartel to form and to continue operating. A

⁶The Finnish CA, or its predecessors, did not attempt to close cartels. Nor was there a leniency program in place.

shock (e.g. a high or a low demand state) may lead to a price war (as in Green and Porter 1984 and Rotemberg and Saloner 1986), or to a full break-down of the cartel (Harrington and Chang 2009).⁷

We model the probability of cartel formation, conditional on there being no cartel in the previous period, as $H1$. The continuation probability, i.e., the probability of a cartel continuing conditional on there being one, is $H2$ (see also Bradbury and Over 1982). Both of $H1$ and $H2$ will be functions of observable macro- and industry-characteristics, making our HMM non-homogenous. We assume that the shocks to these probabilities are i.i.d..

2.2 The HMM Structure

For our purposes, the above framework has an important feature: it suggests a Markov model for the collusive dynamics of a market and generates a sequence of cartel and non-cartel periods that is potentially unobserved by the econometrician and the CA. HMMs provide a means to study dynamic processes that are observed with noise. The evolution of a population of cartels matches this description, because we typically observe the collusive dynamics of a market only irregularly, if at all, and only for discovered cartels.

A HMM consists of an underlying hidden (“unobserved”) process and an observation process. We consider finite HMMs (e.g. Cappé, Moulines and Rydén 2005, pp. 6), in which the hidden process is the state of the market (i.e., whether or not there is a cartel) and in which the observation process is what the researcher knows about the state of the market in a given period (i.e., whether or not it is observed that there is a (no) cartel). More formally, the observed data, denoted O_{it} , for market $i = 1, \dots, N$ and periods $t = 1, \dots, T_i$ follow a

⁷While our model is reduced form, one can map a theoretical model of cartels to our empirical model. If the model and data included a competition authority (as e.g. in Harrington and Chang 2009), one could estimate the policy parameters, and conduct counterfactual analyses.

HMM if the hidden states, $\{Z_{it}\}_{t=1}^{T_i}$, follow a Markov chain and if, given Z_{it} , observation O_{it} at time t for i is independent of the past and future hidden states and observations (see the Appendix for a more detailed description). We next explain the state space of the hidden process and the observation process of our HMM.

2.2.1 The Hidden Process

Consider cartel formation and continuation in market i at time $t > 1$.⁸ If the market does not have a cartel at the beginning of a period, a cartel is formed with probability $H1_{it}$, where the subscripts indicate that the probability will in the empirical part depend on macro- and industry-characteristics. If the market has a cartel at the beginning of period t , then cartel the continues with probability $H2_{it}$. With probability $1-H2_{it}$, an existing cartel breaks down during period t .

This process for cartel formation and continuation means that in period t , market i either has (“ c ”) or does not have (“ n ”) a cartel. Treating these two outcomes as the states of hidden process for Z_{it} , the state space is $S_Z = (n, c)$. The associated transition matrix \mathbf{A}_{it} is⁹

$$\mathbf{A}_{it} = \begin{bmatrix} a_{it}^{nn} & a_{it}^{nc} \\ a_{it}^{cn} & a_{it}^{cc} \end{bmatrix} = \begin{bmatrix} (1 - H1_{it}) & H1_{it} \\ (1 - H2_{it}) & H2_{it} \end{bmatrix} \quad (1)$$

The elements of the matrix are the transition probabilities of a first-order Markov chain. The cell in the upper right hand corner, for example, gives the probability that in a market where there was no cartel in period $t - 1$, a cartel is formed in period t .

⁸Year $t = 1$ is dealt with through an initial condition, as we explain later.

⁹In the superscript, the first index refers to $Z_{it} = k$ and the second to $Z_{i,t-1} = m$, where k and $m \in S_Z = (n, c)$.

2.2.2 Observed Data and the Observation Process

Our cartel data are incomplete, meaning that we don't observe for each market in each year whether there is a cartel or not. We therefore postulate that in each period t , the state of market i is either not known to the econometrician (“ u ”), or the market is observed not to have a cartel (“ n ”) or to have a cartel (“ c ”). These three observed cartel outcomes give the state space of the observation process, $S_O = (n, c, u)$.

Our HMM links the observed data to the hidden process that governs the formation and dissolution of cartels. When the unobserved state of market i at time t is $k \in S_Z = (n, c)$, the probability of observing $w \in S_O = (n, c, u)$ is

$$b_{it}^k(w) = P(O_{it} = w | Z_{it} = k). \quad (2)$$

To derive the observation probabilities explicitly and to match them with the institutional environment, we make the following assumptions:

First, we assume that if a market does not have a cartel, its (true) state is observed with probability $b_{it}^n(n) = \beta_{it}^n$. If this event happens, $O_{it} = Z_{it} = n$. In words, we observe there to be no cartel ($O_{it} = n$), and this is the case in reality, too ($Z_{it} = n$). With the complementary probability $b_{it}^n(u) = 1 - \beta_{it}^n$, the state cannot be determined reliably and remains unknown. If a market is cartelized, its (true) state is observed with probability $b_{it}^c(c) = \beta_{it}^c$. In this case, $O_{it} = Z_{it} = c$. Again, with the complementary probability, the status remains unknown.

This formulation of the observation process relies on the assumption that if a market has (does not have) a cartel, the observed data never wrongly suggest that it is not (is). This assumption imposes $b_{it}^n(c) = b_{it}^c(n) = 0$. To us this does not seem that strong an assumption, because we are interested in whether the

firms had a cartel agreement in place or not (rather than in the efficiency of that agreement). We also stress that if and when one has reasons to suspect that there are such errors, the status of a market can be labeled “unknown”.¹⁰ The resulting observation probability matrix \mathbf{B}_{it} is

$$\mathbf{B}_{it} = \begin{bmatrix} b_{it}^n(n) & b_{it}^n(c) & b_{it}^n(u) \\ b_{it}^c(n) & b_{it}^c(c) & b_{it}^c(u) \end{bmatrix} = \begin{bmatrix} \beta_{it}^n & 0 & 1 - \beta_{it}^n \\ 0 & \beta_{it}^c & 1 - \beta_{it}^c \end{bmatrix}. \quad (3)$$

In equation (3), the upper left hand probability is the probability that the econometrician observes that there is no cartel when that really is the case. The zero in the middle column on the upper row embodies our assumption that the econometrician never thinks that there is no cartel in a given market when there actually is one. Finally, the probability in the upper right hand corner is the probability that the econometrician does not observe the state of the market (i.e., that there is no cartel) when there is no cartel. The lower row reads similarly, but now the true state is that there is a cartel in the market. Because $\beta_{it}^n \leq 1$ and $\beta_{it}^c \leq 1$, the model explicitly allows for the possibility that there are "holes" in our data. There are two primary reasons for such incompleteness: On the one hand, information about the state of a registered cartel can be incomplete over time. On the other hand, some cartels were never registered and some industries may not have had cartels. For these cases, our data conservatively assign state u , as we explain in greater detail below.

2.3 Identification and Estimation

2.3.1 Identification

The theoretical argument for the identification of the parameters of a general

¹⁰In addition to being conservative in labeling observations, this assumption can be relaxed if the data contain information about potential mistakes or mislabelings in the records. One can then introduce separate probabilities for making mistakes.

finite HMM follows from the identifiability of mixture densities (see Cappé, Moulines and Rydén 2005, pp. 450-457). The parameters of our HMM are identified for two further reasons: First, the theoretical framework describing the formation and dissolution of cartels allows us to circumvent the problem of identifying the dimension of the hidden process. It directly suggest that there are only two states of the world and hence $S_Z = (n, c)$. A second source of identification are the parameter restrictions that we impose on \mathbf{B}_{it} .

If the hidden process were observable, identification of the probabilities $H1_{it}$ and $H2_{it}$ would be standard. When that is not the case, we can write a (partial) transition matrix for the *observation* process as in Table 1.

Table 1: Partial transition matrix
of the observation process

$t - 1 / t$	n	c	u
n	$\beta_{it}^n(1 - H1_{it})$	$\beta_{it}^c H1_{it}$	$1 - \beta_{it}^n(1 - H1_{it}) - \beta_{it}^c H1_{it}$
c	$\beta_{it}^n(1 - H2_{it})$	$\beta_{it}^c H2_{it}$	$1 - \beta_{it}^n(1 - H2_{it}) - \beta_{it}^c H2_{it}$

The rows give the state that the econometrician observed in the previous period; the columns the state the econometrician observes this period. There are three possibilities for both: either a cartel was observed or not, or the econometrician didn't observe the true state. We have excluded from the table the third row for not having observed the true state in the previous period, because it is not needed for our identification argument. In the upper left hand cell of Table 1, the probability $\beta_{it}^n(1 - H1_{it})$ is the product of the probability that a market that did not have a cartel in the previous period (and was observed not to have one) does not establish one this period ($1 - H1_{it}$), and the probability of this (the fact of not having a cartel this period) being observed (β_{it}^n). Similarly, the probability that we observe a cartel this period when there was no cartel last period (and this was observed) is $\beta_{it}^c H1_{it}$. Concentrating on the four cells

in the upper left hand corner of Table 1, one notices that we have four moments and four unknown parameters $\{\beta_{it}^c, \beta_{it}^n, H1_{it}$ and $H2_{it}\}$. Using this information alone, the model is identified.

2.3.2 Estimation

To derive the likelihood of the HMM, we take two steps. First, we assume an initial distribution for Z_{i1} , i.e., the probability that market i is in the unobserved state $k \in S_Z$ in the initial period:

$$\tau_i^k = P(Z_{i1} = k). \quad (4)$$

Second, we let Θ denote the model parameters, \mathbf{D}_{i1} a (2×1) vector with elements $d_{i1}^k(w) = \tau_i^k b_{i1}^k(w)$, \mathbf{D}_{it} a (2×2) matrix with elements $d_{it}^{jk}(w) = a_{it}^{jk} b_{it}^k(w)$ for $t > 1$, and $\mathbf{1}$ a (2×1) vector of ones. The likelihood for the whole observed data can then be written as (see e.g. Zucchini and MacDonald 2009, p. 37 and Altman 2007)

$$L(\Theta; \mathbf{o}) = \prod_{i=1}^N \left\{ (\mathbf{D}_{i1})' \left(\prod_{t=2}^{T_i} \mathbf{D}_{it} \right) \mathbf{1} \right\} \quad (5)$$

where \mathbf{o} denotes the data (the realization of \mathbf{O}).¹¹

Four comments about the HMM and its estimation are in order: First, while the maximization of $L(\Theta; \mathbf{o})$ may be a non-trivial matter, (direct) numerical maximization methods can be used (Zucchini and MacDonald 2009, Chapter 3; Turner 2008). Typically, a normalization (scaling) is used to avoid numerical underflow. Second, because $\{\tau_i^c, H1_{it}, H2_{it}, \beta_{it}^c, \beta_{it}^n\}$ are all probabilities, a

¹¹Picking the appropriate elements from \mathbf{A}_{it} and \mathbf{B}_{it} , we can determine $d_{it}^{jk}(w) = a_{it}^{jk} b_{it}^k(w)$ for $t > 1$, i.e., the elements of matrix \mathbf{D}_{it} of the likelihood function that is given as equation (5). If, for example, $o_{it} = c$, the upper left-corner cell of \mathbf{D}_{it} is $d_{it}^{cn}(w) = a_{it}^{cn} b_{it}^n(c) = 0$. For $t = 1$, the elements of the vector \mathbf{D}_{i1} , $d_{i1}^k = \tau_i^k b_{i1}^k(w)$, in the likelihood function can be determined similarly.

simple way to parametrize them is to assume a standard probability model for each of them. Third, we estimate standard errors using the inverse Hessian, as is customary. Finally, the HMM summarized above can be extended to allow for unobserved heterogeneity. The HMM literature (see e.g. Altman 2007) has thus far introduced unobserved heterogeneity only to a limited extent, and thus there is no established best practice. As a robustness check, we estimate a finite mixture non-homogenous HMM (see e.g. Maruotti 2011), with two mixture classes.

3 The Institutional Environment and the Cartel Registry

The Finnish institutional environment vis-à-vis cartels mirrors wider European and especially Swedish developments both before and after WWII. Before the war there was no competition law. The apparent reason was the prevailing liberal view which held that contractual freedom entailed also the right to form cartels (see Fellman 2008, 2009).¹² This view started to change in 1948 when a government committee was set to provide a framework for competition legislation. We focus on the developments after 1950, because the heavy wartime regulations were mostly lifted by early 1950s.¹³

The first cartel law, effective from 1958, was built around the idea of making cartels public through registration. Registration, however, was to be done solely on authorities' request. Only tender (procurement) cartels became illegal, and even these were apparently not effectively barred from operation (Purasjoki and Jokinen 2001). Vertical price fixing could be banned if deemed "particularly

¹²Finland had a tradition of export cartels that started prior to WWII (Kuisma 1993, Fellman 2008).

¹³See e.g. Väyrynen (1990, pp. 69): "The wider public will remember 1954 as the year when the remaining [wartime] regulations were abolished".

harmful". The law embodied the prevailing thinking of cartels not (necessarily) being harmful. A Finnish CA was set up to register the cartels. Here Finland followed Norway and Sweden, which set up similar registers in 1954 and 1946.

The CA sent out 9750 inquiries by 1962 and registered 243 cartels (Fellman 2009). However, the fact that registration was dependent on authorities' activism was an issue. To tackle this, the law was slightly revised in 1964. Those cartels that established formal bodies, such as associations, now had to register, but cartels without formal organizations were still exempt from compulsory registration. The law was again revised in 1973. The single largest change appears to have been that the obligation to register was again widened. Finland finally edged towards modern competition law with a committee that started its work in 1985, resulting in a new law in 1988. This law gave the newly established Finnish Competition Authority (new FCA) the right to abolish agreements that were deemed harmful. The law also made void possible sanctions in the cartel agreement.¹⁴ The new FCA initiated a negotiation round with cartels where these were asked to provide reasons why they should be allowed to continue. In 1992 the law was again changed (and took effect in 1993): Only now did cartels become illegal.

Our understanding of the regime is that the costs of registering were minor, that there could have been costs of not registering (in terms of enforceability of the contract; see Fellman 2009), and there were potential benefits attached to entering the Registry. Reflecting this, the former and current Director Generals of the Finnish CA (Purasjoki and Jokinen, 2001) sum up the environment prior to the 1988 law: "Time was such that there seemed no need to intervene even in clear-cut cases, especially if they had been registered. Registration had been

¹⁴In principle, cartel agreements were legal until early 1993. However, firms seem to have been reluctant to enforce their contracts in court. We have found evidence of only one court case related to the enforcement of cartel contracts. The court case took place in the early 1980s and apparently was a major reason for the law change of 1988.

transformed into a sign of acceptability of the [cartel] agreement, at least for the parties involved [in the cartel]”.¹⁵ Based on this, we end our analysis in 1990.

4 Data

4.1 Defining the Dependent Variable

The sole source of cartel data is the Finnish Cartel Registry. Over the period of its existence the Finnish Cartel Registry registered 900 cartels, varying from nationwide to local. For each cartel, there is a folder containing the entire correspondence between the Registry and the cartel (members).¹⁶ The Registry assigned a 3-digit SIC code to each cartel, and gave a verbal description of what the cartel was active in. We have collected data on all nationwide cartels registered in manufacturing, totaling 135 registered manufacturing cartels. Our sample includes all forms of nationwide horizontal competition restrictions with the exception of contracts between two firms that pertain to one or the other firm ceasing production of certain goods (e.g. due to a sale of a production line: see Hyttinen, Steen and Toivanen 2013 for more detail).

The ideal data for studying cartels would consist of a number of well-defined markets over time where it was clear which firms are active in which market in a given period. Having such data, one would determine the observed cartel status (n, c, u) for each market-period observation. Our data do not quite

¹⁵Purasjoki and Jokinen (2001) mention a few cartels that were not registered, but they do not explain how these cartels were exposed (apart from them being exposed as part of the negotiation initiative set up by the new FCA in the late 1980s). This nevertheless confirms that the Registry was not complete.

¹⁶We have been through the folders using a “semi-structured” approach: After initial discussions on what it is that we want to record, we randomly chose 8 cartels and had 4 researchers (including two of us) go independently through the material to establish whether the information we sought was available, and if, how to record it. We then checked the 4 individuals’ records against each other, and decided on a common approach and interpretation of e.g. various wordings that we encountered. Based on this, we formulated a written protocol that was used in collecting the information.

reach this ideal: On the one hand, a given registered cartel may operate in more than one market. On the other hand, even the most disaggregated level of the industry classification does not map to actual markets, meaning that two registered cartels operating in different markets can be in the same industry.

To deal with these complexities, we resort to a three step process: We first assign the value of the observed state for each registered cartel in all years; this is similar to the exercise one would do with the ideal data. We then assign each registered cartel to one or more industries in step 2. Finally, we assign cartels to markets within each industry and use this information to assign a cartel status for each market-year observation. The outcome of this process is a dependent variable that is measured at the market-year level.

4.1.1 Step 1: Determining Observed States for Registered Cartels

For many cartels, the cartel contract is available. In addition to information on the entry into and exit from the Registry, this information allows us to pin down the actual birth and/or death dates of some cartels and/or their (non-) existence in certain years.

The Registry contains information on seven types of events that the registered cartels (may) have experienced between 1951-1990. First, we know for all the registered cartels the date when they entered the Registry ('register birth' - t^{rb}). For many cartels we know when they exited the Registry ('register death' - t^{rd}). The Registry also has occasionally information on a cartel changing its contract ('contract change' - t^{cc}), such as an addition of members. There can be many such events per cartel. For some cartels, we can establish their actual birth ('birth' - t^b) and/or the death date ('death' - t^d). In addition, there were incidences where a cartel was observed to be operational prior to the registered birth ('actually alive' - t^{aa}) and also some incidences where we found proof of

the cartel being alive after their registered birth and before their (registered) death ('still alive' - t^{sa}).

We use these events to define what the observed state of a cartel is in year t . We assign for each cartel one of the observation states $S_O = (n, c, u)$ for all years. How we do this for a single cartel is illustrated in Figure 1. We assign the value u for a given registered cartel in all those years where it is not known that either there was a cartel (c) nor that there was no cartel (n).

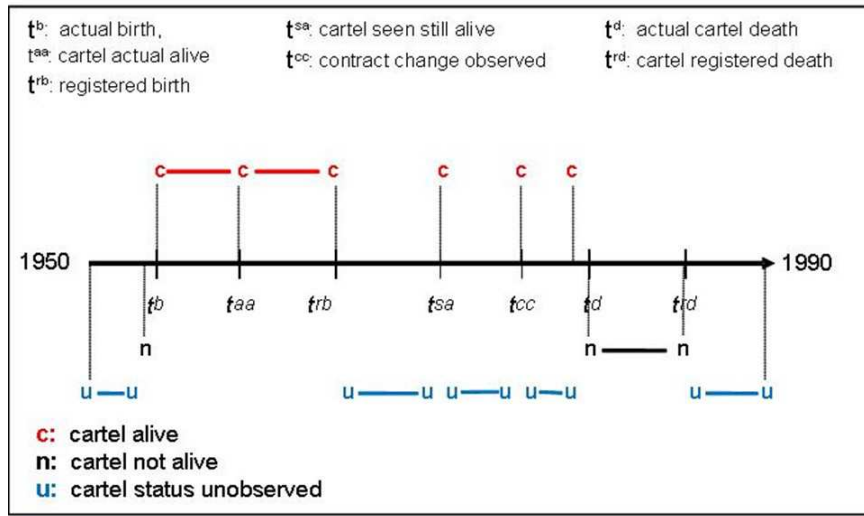


Figure 1 - Time-line for the state definition and observed cartel incidences

Cartels for whom we observe the actual birth date t^b or for whom we have information on the cartel being actually alive some year prior to register birth (t^{aa}) are assumed to be alive between t^b (t^{aa}) and the date of register birth (t^{rb}). Correspondingly, cartels for whom we know the actual death date (t^d) are presumed to be dead between t^d and the date of register death (t^{rd}). In addition, cartels are assumed to be alive every year where we observe an active move, i.e., a 'still alive' or a 'contract change' incidence. We assume that a

cartel for which we can pin down the actual death date is alive the year before. Finally, cartels are assumed dead the period prior to actual birth. For all the other periods, the state of the observation process is u (unobserved).

The definition of the observed states is in our view quite conservative. For instance, even though the Registry effectively assumed that the cartels were alive between t^{rb} and t^{rd} , we only assign an industry into state c when an event like t^{sa} or t^{cc} appears. The reason for including the periods between t^b/t^{aa} and t^{rb} as observed c -states is due to the assumption that when a cartel is asked to register (at t^{rb}), it had no reason to tell any other birth date but the latest. Correspondingly, when the Registry finds out that the cartel is dead (t^{rd}), there is no incentive for the cartel not to inform the Registry of an actual restart between t^{rb} and t^{rd} when confirming their death to the Registry. We hence record them as n . Note also that the way in which we define observed/unobserved states here removes the usual problem of right censoring for cartels where we do not know the ending date.

4.1.2 Step 2: Assigning Cartels to Industries

We use the SIC code and the qualitative information provided by the Registry to match each registered nationwide manufacturing cartel to one or more industries. Using the most disaggregated level of the 1979 Finnish equivalent of the SIC classification for manufacturing, we end up having 193 industries in our data, measured roughly at the 6-digit level.¹⁷ A cartel was assigned to multiple industries if we were unable to assign it to a single one. As an example, think of a 3-digit industry which comprises of two 6-digit industries. If the verbal description of the cartel did not provide information that would allow us to assign it only to one or the other 6-digit industry, we would assign it to both.

This step results in us assigning one or more cartels to 54% (105) of the

¹⁷We had to exclude a few industries because of missing data on industry characteristics.

193 industries. Out of these 105 industries, 40% (42) have only one registered cartel.¹⁸ We explain in the next step how we deal with those industries with more than one registered cartel.

4.1.3 Step 3: Assigning Cartels to Markets within an Industry

There are two reasons for us observing more than one registered cartel in a given industry. The first reason is that an individual entry into the Registry (a “registered cartel”) does not necessarily correspond to the economic definition of a cartel (“actual cartel”). In some cases, two registered cartels were clearly part of the same actual cartel. As an example, we compared the members of the registered cartels if they were assigned to the same industry by the Registry. If the members were the same and the purpose of the registered cartels interlined, we concluded them to be part of the same actual cartel. After taking these cases into account in our assignment process, we observe one actual cartel in 49.5% (52) of the 105 industries with one or more registered cartels.

The second reason, which we faced in the remaining industries, is that some registered cartels that operated in the same industry were clearly different entities. This became clear when comparing the verbal descriptions of some of the cartels assigned to the same industry.

To deal with the second issue, we assume that there is at most one actual cartel in a given market at any point in time. We therefore treat each industry as consisting of an exogenously determined number of markets to which we assign the cartels.¹⁹ We describe in the Appendix the process of assigning multiple registered cartels to markets within an industry. An outcome of this process is that we assign the value u for all years for those markets in a given industry

¹⁸17% (23) of the 135 registered cartels were assigned to more than one industry.

¹⁹We needed to assign at least as many markets to an industry as there are cartels. The maximum number of actual cartels/industry is 7. We arbitrarily chose the number of markets / industry to be 11, yielding us 2123 markets (as we have 193 6-digit industries).

for which there is no cartel. Robustness tests showed that neither changing the number of exogenously determined markets within an industry nor excluding the industries in this last group from the estimation sample had any effect on our results.²⁰

4.1.4 Descriptive Statistics

Table 2 shows the transition matrix of our dependent variable. We have 40 annual observations (1951-1990) for 2123 markets in 193 industries, yielding 84920 market-year observations. We have 360 observations for which we know for consecutive years that a cartel did not exist in a given market in either year. Similarly, we observe 641 cases where a cartel existed in two consecutive years. As can be seen, the vast majority of transitions are between two consecutive market-year observations where we do not know whether a cartel existed or not. All in all, the u observations account for 98% of the data. This is partly due to the fact that if no cartel in the Registry is assigned to a given industry, all market-year observations in the industry are assigned u . The table also shows that we have clearly more c than n observations. Using the formulas in Table 1 and the numbers in the first two rows of Table 2 allows us to calculate estimates of the probabilities of forming a cartel ($H1_{it}$) and of continuing a cartel ($H2_{it}$) which turn out to be 0.27 and 0.90. Our raw data thus suggests a moderate probability to form a cartel, but a high continuation probability.

²⁰The former result was expected, as increasing the number of markets only leads to a higher fraction of observations in the (u, u) - cell of the transition matrix of the observation process. As explained above, those observations do not contribute to identification.

Table 2: Transition matrix

$t - 1 / t$	n	c	u	total
n	360	113	142	615
	58.54%	18.37%	23.09%	100.00%
c	85	641	319	1045
	8.13%	61.34%	30.53%	100.00%
u	180	272	80685	81137
	0.22%	0.34%	99.44%	100.00%
total count	625	1026	81146	82797
total %	0.75%	1.24%	98.01%	100.00%

Notes: The number of observations in Table 2 is 2123 less than the number of observations in the data, as the transition cannot be calculated for the first year of the data.

4.2 Explanatory Variables

Our data for explanatory variables come from three sources: The Cartel Registry, the Research Institute of the Finnish Economy and Statistics Finland. The first provides us variables measuring workings of the Registry, which we use to model the observation process. The second source provides us with GDP and trade figures, and the third with plant level data that we use to generate industry level variables for 1974 - 1987. We use these data to model the hidden process. We display the descriptive statistics in the Appendix.

4.2.1 Registry Variables

The ability of the Registry to detect the births and deaths of cartels may have varied over time. There is a weak negative trend and a lot of variation over time in the total number of annually registered cartels, as calculated over all

the cartels in the Registry. There is an upward trend in the number of Registry exits.

To accommodate these patterns, we make the two observation probabilities (β_{it}^c and β_{it}^n) each a function of following two variables: First, we let β_{it}^c (β_{it}^n) vary with the number of cartels that entered (exited) the Registry in year $t - 1$. Second, we allow β_{it}^c (β_{it}^n) to be a function of the (once) lagged cumulative number of registered births (deaths). These variables are denoted (*Birth-flow*, *Birth-stock*, *Death-flow*, *Death-stock*) and they are computed using the data from the whole Registry with 900 cartels.

Further, to capture past cartel activity in a given industry, as observed by the Registry, we create a variable that counts the number of cartels that have been registered in a given industry by $t - 1$ (*Birth-count*). We assume that the observation probabilities are functions of this variable. We expect that having observed a cartel previously increases both observation probabilities.

4.2.2 Institutional and Macroeconomic Environment

We have a long panel with 40 years of data over a period in which the Finnish macroeconomy went through large business cycle changes. To utilize this variation, we include macroeconomic variables into the HMM. We detrend the GDP volume index using the Hodrick and Prescott filter (Hodrick and Prescott 1997), decomposing GDP into the long run growth trend (*HP-trend*) and deviations from the long run trend. We decompose the deviations into two variables, one capturing positive deviations from the long run trend (*GDP-pos*), and another capturing all negative deviations from the long run trend (*GDP-neg*), both measured in absolute terms. Both the formation and the continuation probabilities are functions of these variables.

To control for changes in the competition law, we introduce an index (*Law-*

index) that starts with value zero in the period prior to the first competition law, and increases by one every time the law is changed (including introduction in 1959).

4.2.3 Industry Characteristics

We next discuss industry characteristics that are frequently mentioned as factors facilitating collusion:

Number of firms and concentration: The textbook supergame theoretic model of collusion suggests that collusion is harder to achieve, the larger the number of firms in the industry (e.g. Peitz and Belleflamme 2010 ch. 14.2). Similarly, it is commonly asserted (e.g. Carlton and Perloff 1990, pp. 221) that high concentration facilitates collusion. We therefore include the Herfindahl-index (*HHI*).

Asymmetry of firm size: Most of the theoretical literature suggests that asymmetry between firms makes collusion more difficult (e.g. Lambson 1994, Davidson and Deneckere 1984, 1990). Compte, Jenny and Rey (2002) find that this result depends on how large aggregate capacity is relative to demand. To account for this we include the ratio of the sales of the second largest firm to the sales of the largest firm to capture the effects of (a)symmetry between the leading firms (*Ms – second – first*). In most models of collusion, cost asymmetries make collusion harder (see e.g. the survey of Jacquemin and Slade 1989). One can argue that the ratio of the market share of the largest and second largest firms partly captures cost asymmetries.

Cost structure: The responsiveness of cartel prices to costs may vary, affecting incentives to collude (Harrington and Chen 2006). We include the ratio of material expenses to sales to measure variable cost (*Material – share*).

Product differentiation: The empirical literature suggests that collusion

mostly occurs in homogenous goods industries (see e.g. Levenstein and Suslow 2006), but the theoretical literature addressing the same question portrays a more mixed picture. Chang (1991) and Ross (1992) find that differentiation makes collusion easier, while Raith (1996) and Häckner (1994) find the opposite. Thomadsen and Rhee (2007) show that costs of maintaining collusion increase the difficulty of sustaining collusion more for firms in industries with product differentiation. We allow for this by including a dummy for the product of an industry being homogenous (*Homog* – *d*). This was constructed following the existing literature (Rauch 1999, Foster, Haltiwanger, Syverson 2008) by utilizing the characterization of each industry, and the Registry’s description of the goods produced by the cartel (see also Hyytinen, Steen and Toivanen 2013).

Multimarket contact: Bernheim and Whinston’s (1986) theoretical analysis shows that under certain conditions, such as cost asymmetries and scale economies, multimarket contact may facilitate collusion. The existing empirical research (e.g. Evans and Kessides 1994, Ciliberto and Williams 2013 and Molnar, Violi and Zhou 2013) provide evidence supporting this. We measure multimarket contact as the share of sales of the two largest firms in industries where they are both present, excluding the industry for which we measure the variable (*Mm* – *share*).²¹

Industry growth: There is a large cartel literature focusing on the importance of demand fluctuations for cartels (see Levenstein and Suslow 2006 for a review). Most notable are Green and Porter (1984), whose model suggests that price wars will arise in response to unobserved negative demand shocks, and Rotemberg and Saloner (1986), whose model predicts price wars during booms (later discussed by e.g. Haltiwanger and Harrington 1991). The litera-

²¹The formula is the following: $Mm - share_{it} = \frac{\sum_{j \neq i} 1(sales_{ktjt} > 0)1(sales_{mjt} > 0)sales_{kjt}sales_{mjt}}{\sum_{j \neq i} [1(sales_{ktjt} > 0)sales_{kjt} + 1(sales_{mjt} > 0)sales_{mjt}]}$ where i, j index markets, t time, and k and m the largest and second largest firm in market i in year t .

ture suggests that cartel formation may be linked to the growth trend as well as to idiosyncratic changes in demand not anticipated by the cartel (Jacquemin, Nambu and Dewez 1981 and Suslow 2005). In addition to variables capturing the overall macroeconomic conditions, we also include industry growth to control for these effects (*Growth*).

Entry: The lower the entry barriers, the more likely it is that a cartel that manages to raise prices invites more entry. We measure the ease of entry and exit by using the entry and exit rates of a given industry (*Entry – share*, *Exit – share*).

Exports: While export cartels were not registered, they were both legal and in frequent use. The higher is the share of exports, the likelier it is that there is an export cartel in the industry, potentially facilitating cartelization also in the domestic market (Schultz 2002). We capture this by including the ratio of exports to turnover (*Export – share*).

Turnover: Finally, we include the industry level turnover to capture the effects of market size on cartelization (*Turnover*).

We allow all these variables to affect both the formation ($H1_{it}$) and the continuation ($H2_{it}$) probability.

5 Empirical Analysis

5.1 Parameterization and Estimates

5.1.1 Parameterization of the Model

We estimate the model with ML and parameterize the transition and observation probabilities and the initial probability of there being a cartel (τ^c) all as single index functions. This means, for example, that we impose $H_{j_{it}} =$

$\Phi(\mathbf{H}\mathbf{j}'\mathbf{x}_{it})$, $j \in \{1, 2\}$ where $\Phi(\bullet)$ is the c.d.f. of the normal distribution, \mathbf{x}_{it} denotes the explanatory variables and $\mathbf{H}\mathbf{j}$ is the parameter vector to be estimated.

We estimate two versions of the model. The first version (the ‘‘Macro model’’) includes only the institutional and macroeconomic variables and the dummy for homogenous goods as explanatory variables. The second version (the ‘‘Micro-macro model’’) adds the remaining industry characteristics to the first version.²² Our results concerning the dynamics of cartelization are essentially identical for these two versions of our HMM, but the latter allows us to study the factors facilitating collusion.

5.1.2 Parameter Estimates

Macro model: The first three columns of Table 3 presents the results from the Macro model. For $H1_{it}$, all the *HP – trend* polynomial terms obtain statistically significant coefficients, and both *Gdp – pos* and *Gdp – neg* shocks a positive and significant coefficient. However, *Homog – d* and *Law – index* coefficients are insignificant.

Looking at the $H2_{it}$ coefficients, we find that the homogenous goods dummy has no effect on the continuation probability. The *HP – trend* polynomial terms all carry highly significant coefficients, and both negative and positive GDP shocks have a positive and significant effect on the probability that a cartel

²² A complication that the introduction of these industry variables generates is that they are only observed for a subset of years. We want to simultaneously capture the rich dynamics embedded in the long time series and the cross-industry variation in industry characteristics. In order to be able to introduce industry characteristics into the model while preserving the long time-series of cartel behavior, we interact a subset of the macrovariables with a dummy taking value one for those years in which the industry characteristics are observed. We don't take interactions between the dummy and the polynomial terms for GDP as the polynomial is flexible enough on its own. The same is true for *Law – index* as changes in it are highly collinear with the dummy variable. Additionally, we don't interact the dummy with the indicator for homogenous goods. This approach allows the parameters of the macro shock variables to take on different values for the periods when we do and don't observe industry characteristics. Our results are robust to not adding these interactions, but it turned out that there is not enough variation in the data to estimate a model that includes all the possible interactions of the macrovariables with the dummy.

continues.

Our estimate of τ^c , the initial probability of being in a cartel is about 1%. The homogenous goods - dummy obtains a positive and marginally significant coefficient for the initial probability τ^c , suggesting that industries producing homogenous goods were more likely to have a cartel at the beginning of our observation period.

Turning to the coefficients for β_{it}^c and β_{it}^n in Table 4, we find that both are affected by the stock of past activity at the Registry, and β_{it}^n is affected by *Death-flow*. Having registered a cartel (*Birth-count*) in an industry increases both observation probabilities, meaning that prior information in a given market increases the probability by which the Registry observes the true state of a given market.

Micro-macro model: In columns 4-6 of Table 3 we present the coefficients of the Micro-macro model. We find that both for $H1_{it}$ and $H2_{it}$, the coefficients of the macrovariables are relatively close to those of the Macro-model.²³ The largest changes are that the coefficient of *Law-index* obtains now a marginally significant negative coefficient in $H1_{it}$ and that the coefficient on negative GDP shocks loses its significance in $H2_{it}$.

²³The *Gdp-pos-ia* and *Gdp-neg-ia* interactions (of *Gdp-pos* and *Gdp-neg* with the dummy for observing industry characteristics) both carry negative and significant coefficients.

Table 3 - Parameter estimates for $H1$, $H2$ and τ^c

	Macro model			Micro-macro model		
	$H1$	$H2$	τ^c	$H1$	$H2$	τ^c
<i>Hp - trend</i>	-1.409** (0.235)	-4.656** (0.675)		-1.806** (0.410)	-4.014** (0.747)	
<i>Hp - trend</i> ²	0.256** (0.035)	0.556** (0.075)		0.326** (0.071)	0.459** (0.088)	
<i>Hp - trend</i> ³	-0.011** (0.002)	-0.021** (0.003)		-0.014** (0.003)	-0.017** (0.003)	
<i>Gdp - pos</i>	0.067** (0.003)	0.008** (0.003)		0.067** (0.005)	0.018** (0.005)	
<i>Gdp - neg</i>	0.017** (0.003)	0.010** (0.003)		0.019** (0.004)	0.009 (0.009)	
<i>Law - index</i>	-0.084 (0.106)	0.902** (0.140)		-0.265* (0.158)	0.698** (0.156)	
<i>Gdp - pos - ia</i>				-0.071** (0.016)	-0.023** (0.008)	
<i>Gdp - neg - ia</i>				-0.018** (0.009)	-0.001 (0.010)	
<i>Homog - d</i>	0.072 (0.049)	-0.026 (0.058)	0.311* (0.171)	0.04 (0.052)	-0.04 (0.062)	0.312* (0.171)
<i>Growth</i>				0.23 (0.192)	0.139 (0.089)	
<i>Entry - rate</i>				0.111 (0.225)	-0.282** (0.091)	
<i>Exit - rate</i>				-0.667** (0.340)	0.067 (0.154)	
<i>HHI</i>				1.123** (0.428)	0.284 (0.176)	
<i>Mm - share</i>				-0.219 (0.206)	0.14 (0.095)	
<i>Ms - second - first</i>				-0.418 (0.313)	-0.07 (0.141)	
<i>Material - share</i>				0.452** (0.197)	0.245** (0.093)	
<i>Turnover</i>				1.426** (0.409)	-0.052 (0.077)	
<i>Export - share</i>				-0.231 (0.710)	-0.032 (0.307)	
<i>Constant</i>	-0.862* (0.502)	12.814** (1.798)	-2.509** (0.125)	-0.719 (0.733)	11.756** (1.893)	-2.509** (0.125)
N		84920			84920	
logL.		-5697.974			-5643.865	

Notes: Standard errors in parentheses. * p<0.10, ** p<0.05

Regarding the industry characteristics, we find that *Exit – rate* has a negative and statistically significant effect on $H1_{it}$, whereas *HHI*, *Material – share* and *Turnover* all have a positive and significant effect. These findings mean that cartels are more likely to be established in large, concentrated markets, and in periods where variable costs are high relative to sales. Cartels are less likely to be established in (following) periods when there is a lot of exit from the market. For continuation probability $H2_{it}$, we find that most of the industry characteristics do not obtain statistically significant coefficients: *Entry – rate* obtains a negative and *Material – share* a positive coefficient, which both are significant at better than the 5% level.

In terms of factors facilitating collusion, we thus find that concentration and variable costs are associated both with the formation and continuation probabilities. Concentration has always been an important item on the list of factors facilitating collusion and our results verify this; variable costs have played a smaller role, with most of the interest having been on demand shocks. Exit is (negatively) correlated with the formation but not the continuation probability, whereas entry is (negatively) associated with the continuation probability. While entry is often emphasized as a possible disruptive phenomenon, its asymmetric role may warrant further attention. The statistically significant coefficient of exit is indicative of the importance of market turbulence on collusion. Finally, the relation of market size with the probability of forming a cartel has received less attention in the literature.

A likelihood ratio tests suggest that the Macro model is rejected against the Micro-macro model. A Likelihood-ratio test obtains a value of 108.22 (with 22 d.f.) and is thus highly significant.²⁴

²⁴Two further points warrant discussion. First, the literature on testing the fit of HMM models is rather thin; see ch. 6 in Zucchini and MacDonald (2009). This applies in particular to models with a discrete observed state space, such as ours. One way to extend the model would be to allow for a higher-order Markov chain. However, according to Zucchini and McDonald (pp. 119), the number of parameters of such a model rapidly becomes prohibitively large.

Table 4: Parameter estimates for β s

	Macro model		Micro-macro model	
	β^n	β^c	β^n	β^c
<i>Death – stock</i>	-2.888** (0.337)		-3.067** (0.331)	
<i>Death – stock</i> ²	3.313** (0.293)		3.512** (0.293)	
<i>Death – flow</i>	0.013** (0.006)		0.014** (0.006)	
<i>Birth – count</i>	0.404** (0.024)	0.140** (0.011)	0.405** (0.025)	0.139** (0.011)
<i>Birth – stock</i>		-1.173** (0.044)		-1.152** (0.043)
<i>Birth – stock</i> ²		0.070** (0.004)		0.069** (0.004)
<i>Birth – flow</i>		0.001 (0.002)		0.001 (0.002)
<i>Constant</i>	-2.836** (0.037)	1.797** (0.115)	-2.834** (0.037)	1.752** (0.112)

Notes: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$

5.2 Cartel Dynamics

5.2.1 Dynamics of $H1_{it}$ and $H2_{it}$

We can calculate the probability of forming a cartel ($H1_{it}$) and the continuation probability ($H2_{it}$) for each industry-year observation in our sample. If we use the estimates from the Macro model (Micro-macro model), we find that $H1_{it}$ is on average 0.22 (0.24), i.e., close to what we calculated from the summary data in Table 2. The interpretation of this estimate is that an industry that was not in a cartel last year has a roughly 20% chance of being able to form a cartel this year.

The estimated continuation probability ($H2_{it}$) is on average 0.96 in both models (again close to the 0.90 calculated from Table 2). The implication of

Second, we performed a large number of experiments (using different starting values, and using slightly different parameterizations of the model) to establish that we reach a global optimum.

this is that when cartels are legal, i) industries form a cartel with a moderately high probability and ii) that cartels, once formed, are very durable. Other empirical cartel studies, such as Ellison (1994), have also found large continuation probabilities.

In Figure 2 we show the development of the predicted $H1_{it}$ and $H2_{it}$ from the Macro model (with confidence intervals displayed in the Appendix). The predicted probability of continuation is high, but exhibits a period of lower values between mid-1950s and early 1970s before returning to levels above 0.9. The probability of establishing a cartel varies more and exhibits a positive trend. The large increases in early 1970s, early 1980s and late 1980s seem at first glance to be due to the large positive shocks in the aggregate demand in these periods. Notice, however, that $H1_{it}$ is increasing trend-like, so even ignoring the effect of the positive GDP shocks, its value is significantly higher at the end of our sample period than at the beginning of it. The dynamics of the observation probabilities β_{it}^c and β_{it}^n are quite different: whereas β_{it}^c starts at a very high level and decreases quickly, exactly the opposite holds for β_{it}^n .

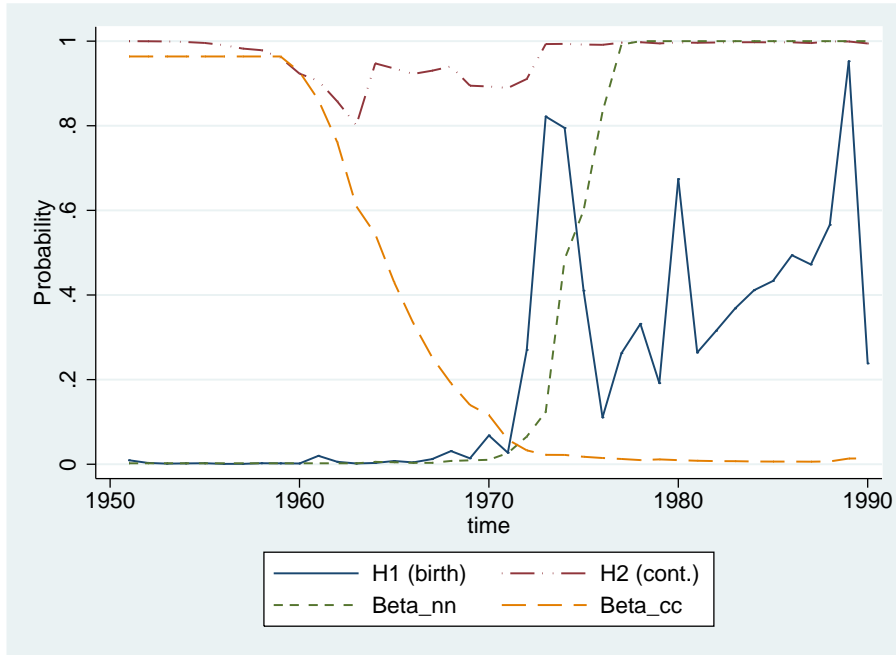


Figure 2 - Development of $H1_{it}$, $H2_{it}$, β_{it}^c and β_{it}^n

To look at how the levels and dynamics of the $H1_{it}$ and $H2_{it}$ vary across industries, we calculated them separately for industries with high and low concentration, and with a high and low level of "turbulence". The former we defined as the highest and lowest quartile of the HHI distribution, calculated in the first year in which we observe the industry variables. The latter we defined as the highest and lowest quartile of the distribution of the sum of entry and exit rates, calculated over the whole period over which we observe the industry variables. As can be seen from Figure 3, there is essentially no difference in the continuation probability $H2_{it}$ between industries with high and low concentration, but the highly concentrated industries have a clearly higher probability of a cartel being formed ($H1_{it}$). Similar differences can be seen between industries with high and low turbulence in Figure 4, but the difference is smaller. These

figures suggest that although we find that the formation probability $H1_{it}$ is affected by the exit rate and the continuation probability $H2_{it}$ by the entry rate, the latter has a limited impact, as the continuation probability is very high for both the high and the low turbulence groups.

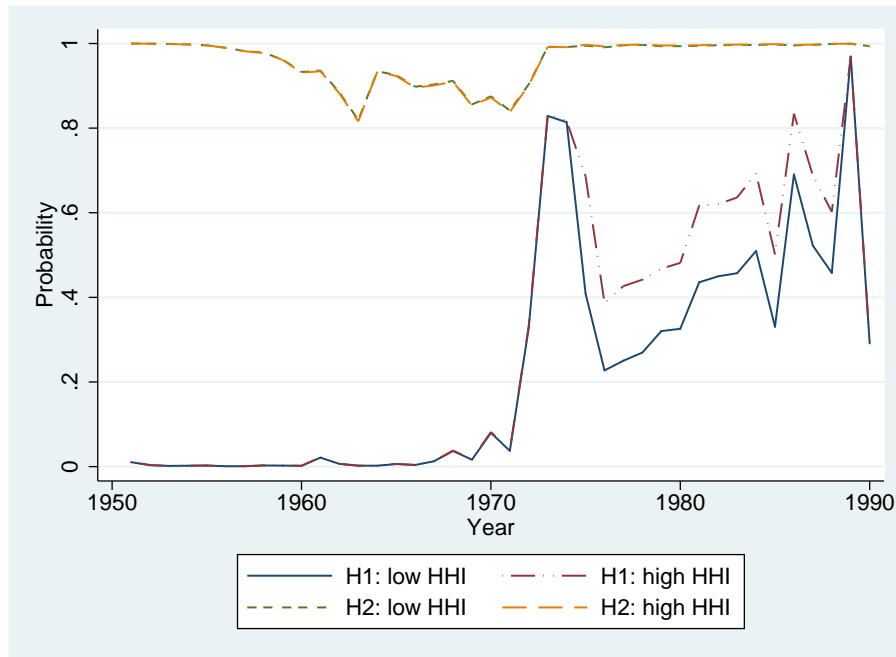


Figure 3 - Development of $H1_{it}$ and $H2_{it}$ - high and low HHI

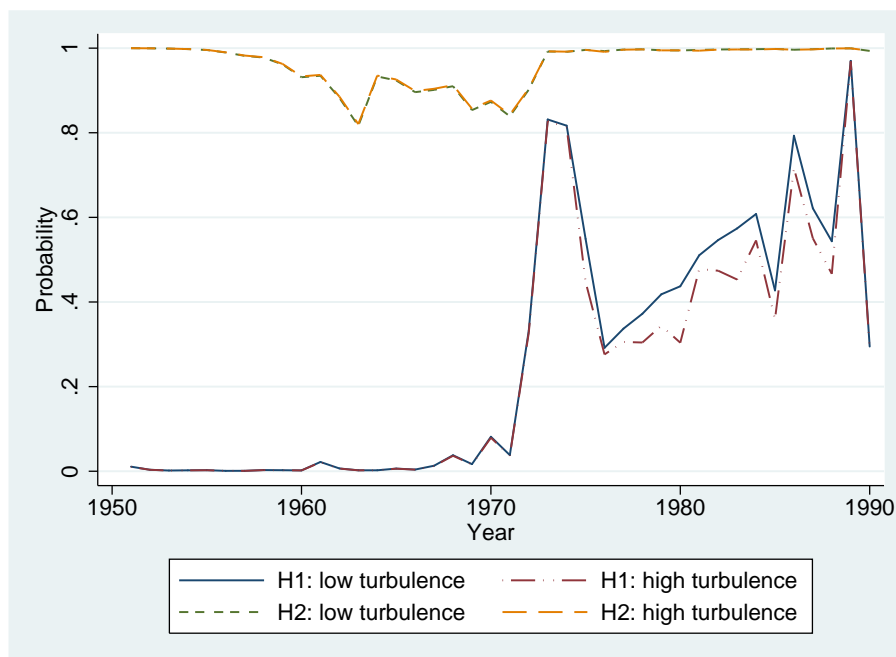


Figure 4 - Development of $H1_{it}$ and $H2_{it}$ - high and low turbulence

In sum, it seems that while a number of industry characteristics are statistically associated with $H1_{it}$ and $H2_{it}$, their economic significance varies and can be asymmetric.

5.2.2 Dynamics of the Degree of Cartelization

The above results suggest that the degree of cartelization may have increased over our sample period. We use the HMM structure of our model to illustrate this. We employ a recursive calculation of $Pr[Z_{it} = c]$ and estimate the proportion of manufacturing industries that had a cartel in a given year. The recursive calculation is made individually for each industry (see the Appendix).

The results of this exercise, averaged over the industries and years, show that the proportion of manufacturing industries that had a cartel is close to

50%. The time-series are displayed in Figure 5: The proportion of cartelized industries starts reasonably low at round 1%, reflecting the low values of τ^c and $H1_{it}$ in the early years. It then starts to increase, and jumps upwards in the early 1970s when $H1_{it}$ increases.

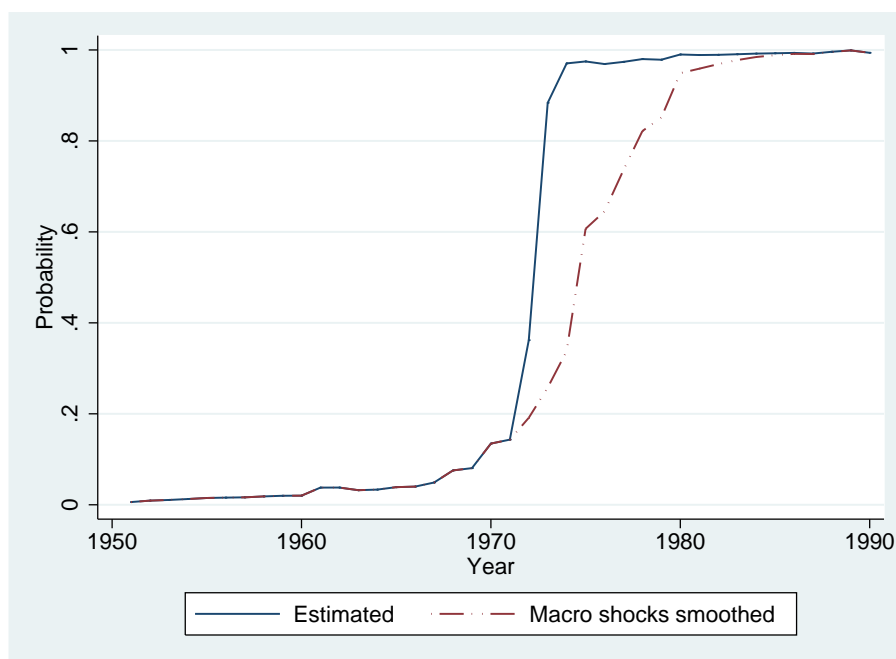


Figure 5 - Estimated proportion of cartelized markets: actual data, and smoothing the macro shocks

These findings suggest that inferring the dynamics of cartelization directly from the Registry data is nearly impossible (see also Figure A6 in the Appendix for the count of (n, c) over the sample period), as the degree of cartelization is not the same as the fraction of markets with an observed cartel: one has to take into account the probability of a cartel in each of the markets and the probability that the activities of the cartels are observed. Coupling Figure 5 with the development of the observation probabilities β_{it}^c and β_{it}^n (shown in Figure

2) explains the divergence between the raw data and the estimated proportion of cartelized industries. Our estimates imply that early on in the observation period, any market in hidden state c is almost surely observed to be in that state, as β_{it}^c is very high. This suggests that even though there were some concerns about the ability of the CA to get cartels registered during the early years of the Registry's existence, this was less of an issue for the nationwide manufacturing cartels. In the early 1960s, β_{it}^c starts to decline, meaning that a lower and lower proportion of observations in hidden state c are observed to be in that state. This means that the hidden and observed c -series start to diverge. A similar but reverse story holds for the n -states. These patterns of the observation process are consistent with the view that the nationwide manufacturing cartels had initially few reasons to hide their activity and that the atmosphere changed towards the end of our sample period, when the incentives of such cartels to disclose their activities diminished.

This description also makes clear why one cannot make inference on the degree of cartelization from the raw data alone and, in particular, why a naïve comparison of the proportion of observed cartels to that of non-cartelized industries is likely to yield a biased estimate of the prevalence of cartels: One needs both a model of cartel behavior and a model of the observation process, i.e., a HMM model like ours, to get a proper estimate.

In sum, Figure 5 suggests a rather dramatic story, with the degree of cartelization in Finnish manufacturing growing over time and reaching very high levels by the end of the 1980s. In addition, Figures 2 and 5 suggest that the rapid increase in the degree of cartelization may be driven by the spike in $H1_{it}$ in the early 1970s, and the upward trend in $H2_{it}$ during the same period.

The spike(s) in $H1_{it}$ and the trend in $H1_{it}$ beg three questions: First, to what extent do they drive the high level of cartelization reached by the end of

1980s? Second, are they due to misspecification of the model in one way or the other? Third, are there any economic explanations for them and, more broadly, for the high degree of cartelization toward the end of our sample period? We address all of these questions in the next section.

5.3 Discussion and Robustness

5.3.1 Role of GDP shocks

The estimated spike(s) in $H1_{it}$ are largely driven by the positive GDP shocks. To show that they do not drive our estimates, we return to Figure 5, which also displays the predicted proportion of cartelized markets from a calculation where we smoothed the positive GDP shocks to take the average value of that variable. As can be seen, this smoothing somewhat delays the rise in cartelization, but by the end of 1980s almost all markets are nonetheless cartelized. The early 1970s spike in $H1_{it}$ is therefore not driving our result on the degree of cartelization.

5.3.2 Robustness checks and model specification

Our robustness tests are mostly geared towards studying the dynamics of cartel behavior. As the simpler Macro model produces essentially identical dynamics with the Micro-macro model, we use it as the base for these tests. We display all the parameter estimates and the $H1_{it}$, $H2_{it}$ -figures in the Appendix.

Number of markets / industry: As explained, the number of markets per industry is exogenously determined and we chose that number to be 11. To check that our results are robust to this assumption, we re-estimated the Macro model by assuming that the number of markets per industry is 14. The results are unchanged.

Number of cartels: We executed two robustness tests. For 73% of industries (88 industries with no cartel, and 52 with one actual cartel out of a total of 193 industries), there is at most one actual cartel, and therefore little uncertainty that our classification procedure would bias the results. Re-estimating the Macro model using only these industries reproduced our results. We then additionally kept the main estimation sample intact, but used only information on the first cartel in each industry. Again, the results closely match our main results.

Time period: While we observe both instances of there being a cartel and instances of there being no cartel prior to the establishment of the Registry in 1959, we by definition cannot observe transitions from an industry having a cartel to it not having a cartel prior to 1959.²⁵ We have therefore re-estimated both the Macro and the Micro-macro model using data starting in 1959. While there are some differences in parameter estimates,²⁶ the temporal patterns of the $H1_{it}$, $H2_{it}$ -figures are very similar to those obtained using all the data.

Unobserved heterogeneity: There are several ways to allow for unobserved heterogeneity in a HMM (Altman 2007), but no established best practice in an application like ours.²⁷ We opted for a mixture model with two mixture classes in the latent model. This choice leads to a finite mixture (non-homogenous) HMM (see e.g. Maruotti 2011, Maruotti and Rocci 2012), where we allowed the constants in $H1_{it}$, $H2_{it}$, and τ^c to differ between the two classes. We find that 91% of our observations belong to one of the classes and the remaining to the other. The dynamics of the larger class, including the predicted fraction of markets with a cartel, closely resemble those obtained with our main

²⁵If there existed a cartel prior to 1959 which dissolved, it would not register and therefore we could not observe it.

²⁶One would not expect the coefficients of the macroparameters to stay the same; similarly one would expect that the initial probability changes (increases), which it indeed does.

²⁷It is also well known that such models may present severe computational challenges. We faced them as well.

specifications, although the estimated $H1_{it}$ is somewhat lower than previously. The smaller class had a lower $H1_{it}$ and a higher $H2_{it}$; particularly, the decrease in $H2_{it}$ in the 1960s is more pronounced for the smaller class. When predicting the fraction of markets with a cartel for this class, we found that cartelization increased initially faster in the smaller class. The large increase in the degree of cartelization in the larger class eventually leads to the order between the two classes being reversed. By the end of the estimation period, both groups are highly cartelized.

In sum, it seems that misspecification of the model do not drive the estimated dynamics of cartel behavior and thus the high level of cartelization reached by the end of 1980s.

5.3.3 Economic explanations for the Jump in the Probability of Cartel Formation in the 1970s

Are there any economic or institutional explanations for the large jump in $H1_{it}$ in the early 1970s and, more broadly, for the high degree of latent cartelization toward the late 1980s?

The trade with the former Soviet Union was very important for Finland (see Gorodnichenko, Mendoza and Tesar 2012) and the specific bilateral nature of this trade offers one explanation for the jump in $H1_{it}$. The jump coincides almost perfectly with the first oil crisis, which hit the open Finnish economy. The resulting export shock was however positive because it increased the bilateral trade: Finland paid its Soviet oil imports by exporting manufacturing goods. The growth in bilateral trade was accompanied by a diversification of trade from being mostly ships in the early 1950s to covering a wider set of manufacturing industries by the late 1970s.

The trade between the Soviet Union and Finland was based on a centralized

inter-governmental system, and was handled through bilateral clearing accounts (see Ollus and Simola, 2006 and Fellman 2008). The general terms of trade were agreed at the national level, but the final agreement was an interactive process involving the participating companies. Production alliances were also common (Ollus and Simola, 2006, pp. 20). The process seems to have been conducive for non-competitive behavior and (possibly) cartel formation also in domestic markets.²⁸

The Finnish arrangements of the time therefore provide a historical example of a specific mechanism through which export cartels may have facilitated collusion in the domestic market (Schultz 2002): The negotiations necessitated by the bilateral trade arrangements meant that representatives of Finnish manufacturing firms met more often than they would otherwise have met. Both the more frequent interaction and the encouragement for and use of productive alliances are conducive for cartel formation, as they lower for example the costs of monitoring of other members and make capacity allocation among the firms easier. These considerations are consistent with an increase in $H1_{it}$ and $H2_{it}$.²⁹

Another explanation for the increase in $H1_{it}$ in the early 1970s and, more broadly, for the higher degree of cartelization is a structural change in the Finnish economic environment that took place in 1968. That year, the first so-called General Incomes-Policy Settlement between the government, the labor unions and the industry (employers') associations was signed (see Fellman 2008). This may have enhanced cartel formation and stability, because it prohibited the indexation of prices to inflation, meaning that the returns to firms agreeing on

²⁸This has not gone unnoticed in the literature: Ollus and Simola (2006) conclude (pp. 21): "Finnish exporters to the Soviet Union were protected from external competition which made exporters lazy. The exports favored the less competitive industries and biased the production structure in Finland." For a similar argument, see Gorodnichenko, Mendoza and Tesar (2012).

²⁹To study this further, we re-estimated the Micro-macro model allowing for trade variables in $H1_{it}$ and $H2_{it}$. We included the ratio of total exports to GDP, and the ratio of exports to the Soviet Union and total exports. We find the same results as before: A strong jump in $H1_{it}$ in the early 1970s. Some of the export variables obtain significant coefficients.

prices rose. It is generally thought that the collective agreements also increased the strength of the labor unions. As a result, the need for firms to coordinate their labor market actions may have grown, meaning better opportunities to form a product market cartel.

More generally, the trend towards increasing corporatism, reached (according to Virtanen 1998) its apex in the early 1970s. Virtanen writes (pp. 254): “The 1973 [competition policy] legislation marked the culmination of post-World War II development. Competition policy in the committee report played a subsidiary role as a part of ‘public price policy’”. While cartels may have been a source of inflation, the committee viewed competition policy as complementary to price controls in containing inflation. This seems to have meant that the government either took a relaxed view, or even encouraged price coordination among firms.³⁰

Finally, the EEC free trade agreement negotiated from late 1960s onwards and signed in 1973 generated a large change in the institutional environment of Finnish manufacturing firms, creating the expectation of not only increased access to European markets, but also of increased foreign competition in the domestic market. The negotiation process again led to a series of discussions between the government and the industry, possibly leading to an increase in $H1_{it}$. The actual agreement may have also affected cartelization for example by the industry feeling the need to form “defensive” cartels whose purpose was to accommodate (foreign) entry.

We conclude that there are a number of economic and institutional explanations for the higher degree of cartelization toward the late 1980s. It is unlikely that a single event could explain the increase. However, taken together, the

³⁰ According to Virtanen (the Deputy Director General of FCA), “the execution of price controls strongly encouraged firms to establish industry associations entrusted with representing the firms in the price control process and filing common applications for increased prices to be assessed by the price control authorities” (private communication with Virtanen, March 10, 2011). This means that the price regulation authority encouraged firms in a given industry to file common instead of individual applications (for price increases) to the authority.

structural changes and institutional developments of the late 1960s and early 1970s are, in our view, significant enough to produce a major change in the incentives and opportunities of Finnish manufacturing firms to seek protection for competition in the domestic markets from various collaborative arrangements.

6 Conclusions

To understand how useful competition policy is, a counterfactual of what would happen in the absence of competition policy has to be constructed. This is difficult to do due to the nature of the process through which cartels can be observed: most of the time we don't know if there is a cartel in a given market or not. We couple data from an era - quite representative of much of the developed world after the second World War - when cartels were legal with both a reduced form model of cartel formation and continuation and a Hidden Markov Model that allows for the special observation process of cartels. For part of the observation period we observe industry characteristics that allow us to empirically study which of the "factors facilitating collusion", routinely listed in textbooks of Industrial Organization, enhance cartel formation and continuation.

We find that while early in our observation period the degree of cartelization was low due to both a low initial probability and a low probability of cartel formation, by the end of 1960s things started to change. Cartelization got under way through an increase in the probability of cartel formation and the constantly high probability of a cartel continuing. The large spikes in the probability of forming a cartel that coincide with the two oil shocks, and to which we give some potential explanations tied to both Finnish-Soviet trade and the increasing degree of corporatism in the Finnish society, are important but are not the main drivers of our finding that by the end of 1980s, essentially

all Finnish manufacturing was cartelized. This outcome is the result of a fairly high probability of cartel formation and a very high continuation probability. Our results suggest that competition policy is indeed of first order importance, as in the absence of it, much of manufacturing might be cartelized.

We also find that concentrated markets and entry and exit are associated with cartelization and that variable costs are positively correlated with the probability of both forming and of continuing a cartel. Finally, larger markets are more likely to see a cartel being formed. As far as we are aware of, no earlier study has provided evidence on whether factors like these facilitate collusion without having to assume that in those industries where no cartels are observed, there is none.

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Appendix (Online appendix, not intended for publication)

Finite HMM

To provide a formal definition for a HMM, let us assume that observations are recorded at equally spaced integer times $t = 1, 2, \dots, T_i$ for cross-sectional units $i = 1, \dots, N$. The observed data for i follow a HMM if the hidden states, $\{Z_{it}\}_{t=1}^{T_i}$, follow a Markov chain and if given Z_{it} , observation O_{it} at time t for unit i is independent of $O_{1t}, \dots, O_{i,t-1}, O_{i,t+1}, \dots, O_{iT_i}$ and $Z_{1t}, \dots, Z_{i,t-1}, Z_{i,t+1}, \dots, Z_{iT_i}$. This property means that in a standard HMM, the observations are independent conditional on the sequence of hidden states.

The general econometric/statistical theory and scope of applications of the HMMs is broad (see e.g. Cappé, Moulines and Rydén 2005, Zucchini and MacDonald 2009, on which this section builds), but for the purposes of our analysis, we can focus on the case in which Z_{it} takes on values from a finite set (state space), $S_Z = \{s_1, s_2, \dots, s_{\bar{Z}}\}$, where \bar{Z} is known. We also assume that O_{it} is a discrete (categorical) random variable, taking on values from a finite (observation) set, $S_O = \{o_1, o_2, \dots, o_{\bar{O}}\}$, where \bar{O} is known. We define \mathbf{O}_i to be the T_i -dimensional vector of observations on i and \mathbf{O} the $\sum_{i=1}^N T_i$ -dimensional vector of all observations. The vectors of hidden states, \mathbf{Z}_i and \mathbf{Z} , are defined similarly. Finally, we let \mathbf{x}_{it} denote the K -dimensional vector of covariate values of unit i at t , with $\mathbf{x}_i = \{\mathbf{x}_{i1}, \dots, \mathbf{x}_{iT_i}\}$.

The HMM is fully specified by the initial and transition probabilities of the hidden Markov chain and by the distribution of O_{it} , given Z_{it} . For a cross-sectional unit i , these three stochastic elements can be specified as follows:

First, the probability that unit i is at the unobserved state $k \in S_Z$ in the

initial period (i.e., $Z_{i1} = k$), given its contemporary covariate values. These initial state probabilities are denoted

$$\tau_i^k = P(Z_{i1} = k | \mathbf{x}_{i1}).$$

Second, the (hidden) transition probabilities give the probability that unit i is at state $k \in S_Z$ in period t , given that it was at state $j \in S_Z$ in period $t - 1$, and given its covariate values. These transition probabilities are

$$a_{it}^{jk} = P(Z_{it} = k | Z_{i,t-1} = j, \mathbf{x}_{it}).$$

This formulation shows that we allow the Markov chain to be non-homogenous (i.e., the transition probabilities can depend on a time index) and that conditional on \mathbf{x}_{it} , the current state depends only on the previous state (the Markov property).

The third stochastic element of the HMM are the observation (state-dependent) probabilities. The observation probabilities give the probability of observing $w \in S_O$ when the unobserved state is $k \in S_Z$ at t , i.e.,

$$b_{it}^k(w) = P(O_{it} = w | Z_{it} = k, \mathbf{x}_{it}).$$

This formulation shows that $b_{it}^k(w)$ can depend on covariates and that conditional on \mathbf{x}_{it} , the observation at time t depends only on the current hidden state and is independent of the previous observations (and states).

To derive the likelihood of the HMM, let Θ denote the model parameters, \mathbf{D}_{i1} the $(\bar{Z} \times 1)$ vector with elements $d_{i1}^k(w) = \tau_i^k b_{i1}^k(w)$, \mathbf{D}_{it} the $(\bar{Z} \times \bar{Z})$ matrix with elements $d_{it}^{jk}(w) = a_{it}^{jk} b_{it}^k(w)$ for $t > 1$, and $\mathbf{1}$ the $(\bar{Z} \times 1)$ vector of ones. As shown in e.g. MacDonald and Zucchini (2009, p. 37) and Altman (2007),

the likelihood for the whole observed data can be written as

$$L(\Theta; \mathbf{o}) = \prod_{i=1}^N \left\{ (\mathbf{D}_{i1})' \left(\prod_{t=2}^{T_i} \mathbf{D}_{it} \right) \mathbf{1} \right\}$$

where \mathbf{o} denotes the data (the realization of \mathbf{O}).

Assigning Cartels to Markets in Case of Multiple Registered Cartels

The issue here is that some registered cartels are assigned to the same industry and were not part of the same actual cartel. To deal with this, we determined whether registered cartels assigned to the same industry are in the same market and whether they are part of the same actual cartel, using qualitative information obtained from the Registry. The evidence consisted of the assignment of the registered cartels to SIC industries by the FCA, the qualitative description of the competition restriction by the FCA, and lists of members of the registered cartels. We then applied the following rules to industries with multiple registered cartels that were not part of the same actual cartel:

1. Those multiple registered cartels that were judged to be in different markets while in the same industry were each assigned to a separate market within the industry.
2. If the multiple registered cartels were found in the same market but were sequential,³¹ they were assigned to the same market.
3. If the multiple registered cartels were found in the same market and were simultaneous, we assigned them to different markets.

³¹We use information on the real and registry formation and continuation of cartels to determine whether they are simultaneous or sequential.

As to Rule 2, we proceed by first coding the observed states for all cartels in the same market separately. We then merge these as follows: If we observe "c" for one cartel but "n" or "u" for the others in a given year, we assign "c" to that year on the basis that we know that at least one of the cartels was active in that year. If we observe "u" for one and "n" for some of the others in a given year, we assign "u" to that year on the basis that while we know that one of the cartels did not exist in that year, we don't know the status of the others. Rule 3 stems from the identification of our model which requires us to have at most one cartel at a given point in time in a given market. Our reading of the qualitative evidence from the Registry suggests that this assumption is reasonable.

Descriptive Statistics

In Table A1 we report the descriptive statistics. For the industry characteristics (excl. *Homog - d*) these are measured for the years during which they are observed, rather than over the whole sample.

Table A1: Descriptive statistics

variable	definition	mean	median	sd
Macro and control variables				
<i>Hp - trend</i>	GDP volume index / 100, original series 100 = 1913	7.271	6.954	3.144
<i>Gdp - pos</i>	GDP vol. - <i>HP - trend</i> in year <i>t</i> GDP vol. > <i>HP - trend</i>	6.027	0	10.325
<i>Gdp - neg</i>	GDP vol. <i>HP - trend</i> in year <i>t</i> GDP vol. < <i>HP - trend</i>	6.082	0.920	9.556
<i>Law - index</i>	0 before 1959 law; increase by 1 at each law change	1.200	1	0.980
<i>Homog - d</i>	1 if homogenous goods, 0 otherwise	0.378	0	0.485
<i>Death - stock</i>	#exits from the Registry by <i>t - 1</i>	1.387	0.79	1.594
<i>Death - flow</i>	#exits from the Registry in <i>t - 1</i>	13.375	11.5	13.292
<i>Birth - stock</i>	#entries into the Registry by <i>t - 1</i>	4.007	3.93	3.181
<i>Birth - flow</i>	#entries into the Registry in <i>t - 1</i>	22.45	25	1.644
<i>Birth - count</i>	#entries into the Registry in industry <i>i</i> by <i>t - 1</i>	0.882	0	1.438
Industry characteristics				
<i>Growth</i>	(industry sales in <i>t - 1</i> - ind. sales in <i>t - 2</i>) / ind. sales in <i>t - 2</i>	0.153	0.025	0.471
<i>Entry - rate</i>	#new firms in industry <i>i</i> / (#firms in ind. <i>i</i> - #new firms in ind. <i>i</i>)	0.264	0.091	0.439
<i>Exit - rate</i>	#exiting firms in industry <i>i</i> / #firms in ind. <i>i</i>	0.158	0.059	0.273
<i>HHI</i>	$\sum_i (\text{Turnover}_{it-1} / \sum_i \text{Turnover}_{it-1})^2$	0.329	0.244	0.267
<i>Mm - share</i>	see fn. #21.	0.454	0.412	0.378
<i>Ms - second - first</i>	turnover of 2 nd largest firm / turnover of largest firm in ind. <i>i</i>	0.513	0.515	0.292
<i>Material - share</i>	material costs in industry <i>i</i> / gross output in ind. <i>i</i>	0.900	0.832	0.430
<i>Export - share</i>	exports in industry <i>i</i> in <i>t - 1</i> / turnover in ind. <i>i</i>	0.133	0.097	0.134
<i>Turnover</i>	turnover (total deliveries) in industry <i>i</i> , in Mio. 1990 FIM.	0.224	0.077	0.445

Notes: The descriptive statistics for the industry characteristics are calculated over 1975 - 1988 when they are observed.

Unless otherwise stated, industry characteristics are calculated in *t - 1*.

Detrending of *HP - trend* was done using a smoothing index of 100.

Robustness Tests

Table A2: Parameter estimates for $H1$, $H2$ and τ^c from robustness tests

	$N + 3$ markets			only industries with ≤ 1 cartels			only first cartel		
	$H1$	$H2$	τ^c	$H1$	$H2$	τ^c	$H1$	$H2$	τ^c
$Hp - trend$	-1.536** (0.232)	-4.689** (0.661)		-1.798** (0.443)	-2.444** (0.989)		-1.409** (0.236)	-4.657** (0.658)	
$Hp - trend^2$	0.274** (0.035)	0.560** (0.073)		0.315** (0.064)	0.286** (0.114)		0.256** (0.035)	0.556** (0.073)	
$Hp - trend^3$	-0.012** (0.002)	-0.021** (0.003)		-0.014** (0.003)	-0.011** (0.004)		-0.011** (0.002)	-0.021** (0.003)	
$Gdp - pos$	0.069** (0.003)	0.008** (0.003)		0.081** (0.006)	-0.005 (0.006)		0.067** (0.003)	0.008** (0.003)	
$Gdp - neg$	0.018** (0.003)	0.010** (0.003)		0.014** (0.006)	0.026** (0.010)		0.017** (0.003)	0.010** (0.003)	
$Law - index$	-0.061 (0.104)	0.921** (0.137)		0.145 (0.183)	0.942** (0.258)		-0.084 (0.106)	0.902** (0.138)	
$Homog - d$	0.067 (0.048)	-0.02 (0.057)	0.305* (0.168)	0.101 (0.095)	0.016 (0.110)	0.31 (0.228)	0.072 (0.049)	-0.026 (0.058)	0.311* (0.171)
$Constant$	-0.667 (0.493)	12.918** (1767.0)	-2.567** (0.122)	-0.594 (0.976)	7.477** (2.525)	-2.625** (0.170)	-0.862* (0.503)	12.818** (1.755)	-2.509** (0.125)
N	100360			61160			84920		

Notes: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$

Table A3: Parameter estimates for $H1$, $H2$ and τ^c from robustness tests

	1959- data only; macro model			1959- data only; micro-macro model		
	$H1$	$H2$	τ^c	$H1$	$H2$	τ^c
$Hp - trend$	0.54 (1371.0)	-2.950** (0.819)		0.408 (1767.0)	-1.720 (1306.0)	
$Hp - trend^2$	0.049 (0.149)	0.373** (0.089)		0.074 (0.210)	0.207 (0.149)	
$Hp - trend^3$	-0.004 (0.005)	-0.015** (0.003)		-0.005 (0.008)	-0.008 (0.006)	
$Gdp - pos$	0.064** (0.003)	0.009** (0.004)		0.064** (0.006)	0.020** (0.005)	
$Gdp - neg$	-0.001 (0.005)	0.008** (0.003)		-0.008 (0.007)	-0.002 (0.009)	
$Law - index$	-0.318 (0.306)	0.644** (0.155)		-0.377 (0.312)	0.386* (0.218)	
$Gdp - pos - ia$				-0.066** (0.016)	-0.023** (0.008)	
$Gdp - neg - ia$				0.006 (0.010)	0.008 (0.009)	
$Homog - d$	0.149** (0.060)	-0.023 (0.059)	-0.007 (0.106)	0.116* (0.065)	-0.047 (0.063)	-0.007 (0.106)
$Growth$				0.09 (0.197)	0.107 (0.092)	
$Entry - rate$				0.269 (0.219)	-0.274** (0.091)	
$Exit - rate$				-0.586* (0.340)	0.067 (0.153)	
HHI				1.062** (0.438)	0.322* (0.179)	
$Mm - share$				-0.226 (0.205)	0.132 (0.095)	
$Ms - second - first$				-0.413 (0.315)	-0.039 (0.144)	
$Material - share$				0.409** (0.196)	0.231** (0.091)	
$Turnover$				1.464** (0.413)	-0.044 (0.077)	
$Export - share$				0.168 (0.714)	0.042 (0.308)	
$Constant$	-6.274* (3680.0)	8.130** (2.231)	-1.793** (0.065)	-6.591 (4447.0)	5.569 (3.391)	-1.793** (0.065)
N	67936			67936		

Notes: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$

Table A4: Parameter estimates for the β s

	$N + 3$ markets		only industries with ≤ 1 cartels		only first cartel	
	β^n	β^c	β^n	β^c	β^n	β^c
<i>Death – stock</i>	-2.912** (0.331)		-3.125** (0.592)		-2.888** (0.337)	
<i>Death – stock</i> ²	3.332** (0.287)		3.229** (0.474)		3.313** (0.293)	
<i>Death – flow</i>	0.013** (0.006)		0.023** (0.011)		0.013** (0.006)	
<i>Birth – count</i>	0.392** (0.024)	0.137** (0.010)	0.603** (0.074)	0.160** (0.029)	0.404** (0.024)	0.140** (0.011)
<i>Birth – stock</i>		-1.186** (0.043)		-1.259** (0.082)	-1.173** (0.044)	
<i>Birth – stock</i> ²		0.071** (0.004)		0.081** (0.007)	0.070** (0.004)	
<i>Birth – flow</i>		0.001 (0.002)		0.002 (0.003)	0.001 (0.002)	
<i>Constant</i>	-2.888** (0.037)	1.786** (0.113)	1.776** (0.218)	-3.177** (0.070)	-2.836** (0.037)	1.797** (0.115)

Notes: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$

Table A5: Parameter estimates for the β s

	1959- data only; macro model		1959- data only; micro-macro model	
	β^n	β^c	β^n	β^c
<i>Death – stock</i>	-3.205** (0.337)		-3.274** (0.335)	
<i>Death – stock</i> ²	3.687** (0.309)		3.771** (0.310)	
<i>Death – flow</i>	0.014** (0.006)		0.014** (0.006)	
<i>Birth – count</i>	0.397** (0.026)	0.141** (0.011)	0.396** (0.026)	0.142** (0.011)
<i>Birth – stock</i>	-1.121** (0.048)		-1.114** (0.048)	
<i>Birth – stock</i> ²	0.067** (0.004)		0.066** (0.004)	
<i>Birth – flow</i>	0.002 (0.002)		0.002 (0.002)	
<i>Constant</i>	-2.782** (0.051)	1.584** (0.136)	-2.781** (0.051)	1.576** (0.136)

Notes: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$

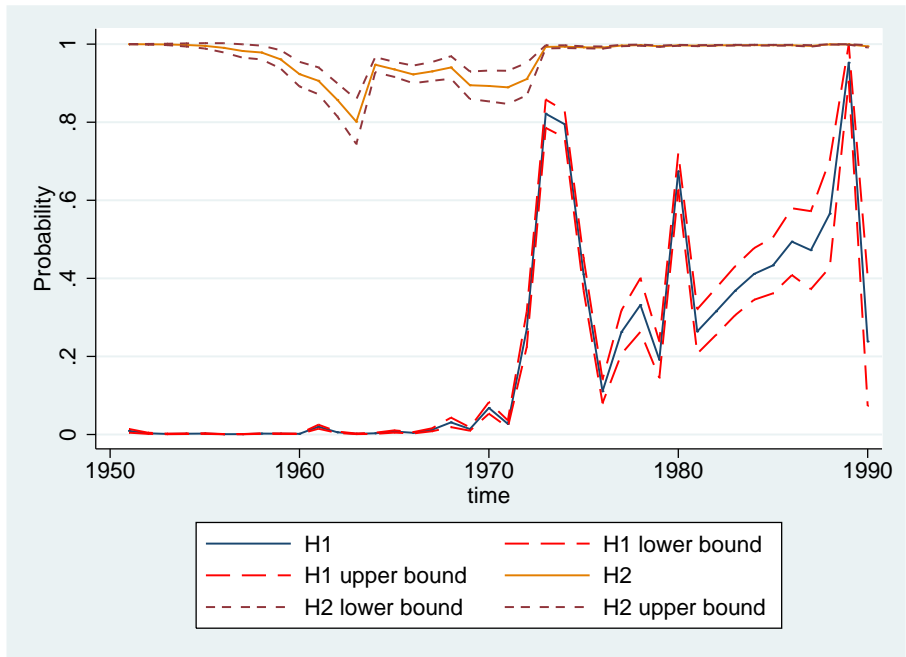


Figure A1: Macro-model's $H1_{it}$ and $H2_{it}$ with 95% confidence intervals

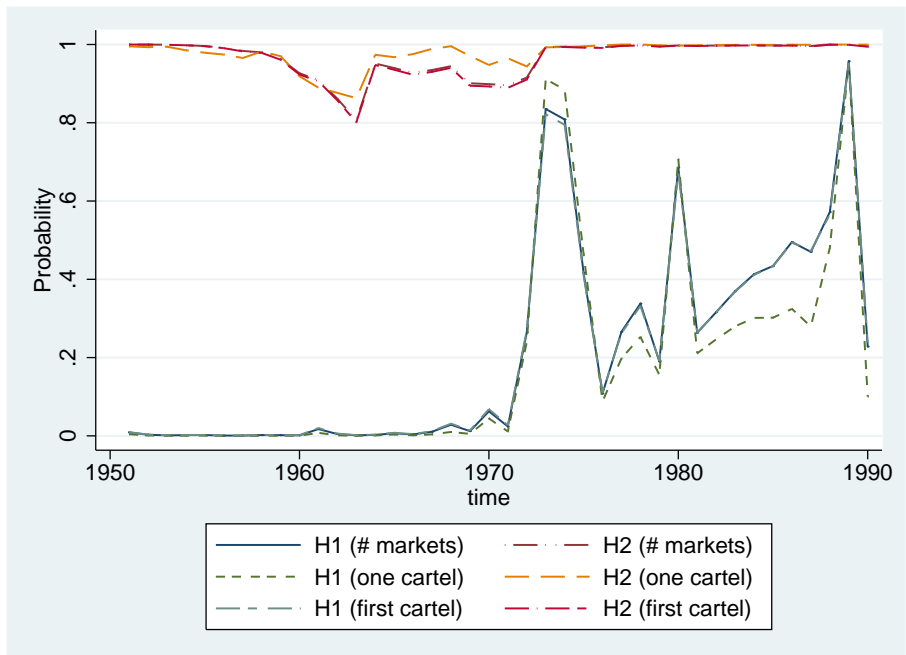


Figure A2: $H1_{it}$ and $H2_{it}$ using different cartel samples

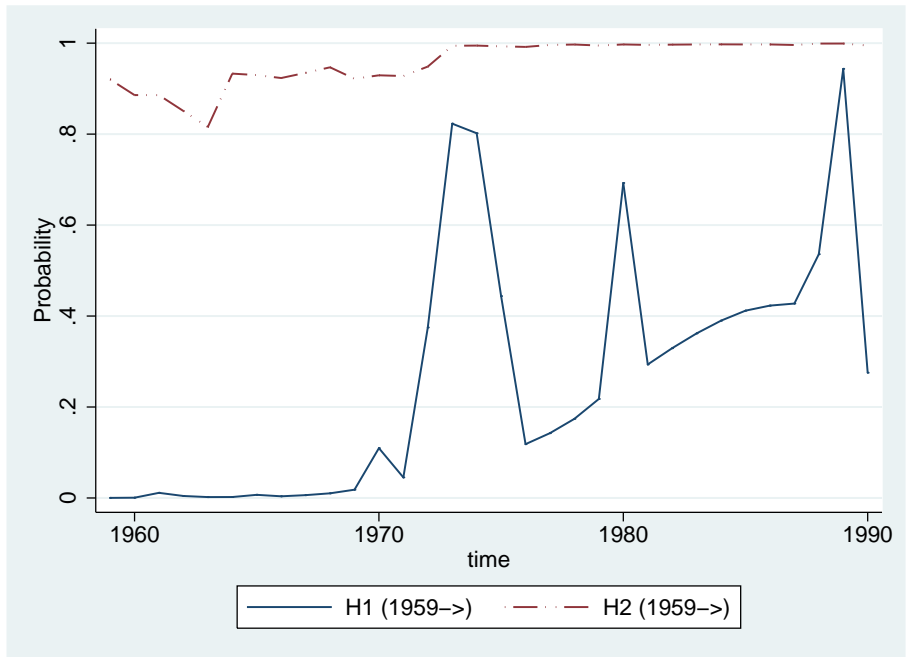


Figure A3: $H1_{it}$ and $H2_{it}$ using data from 1959 onwards only

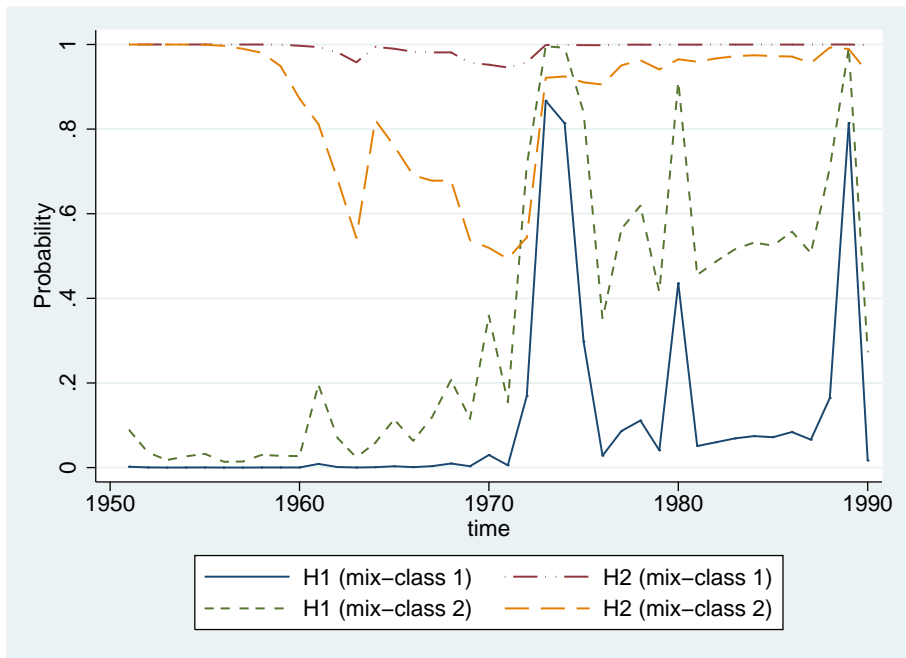


Figure A4: $H1_{it}$ and $H2_{it}$ using the mixture model

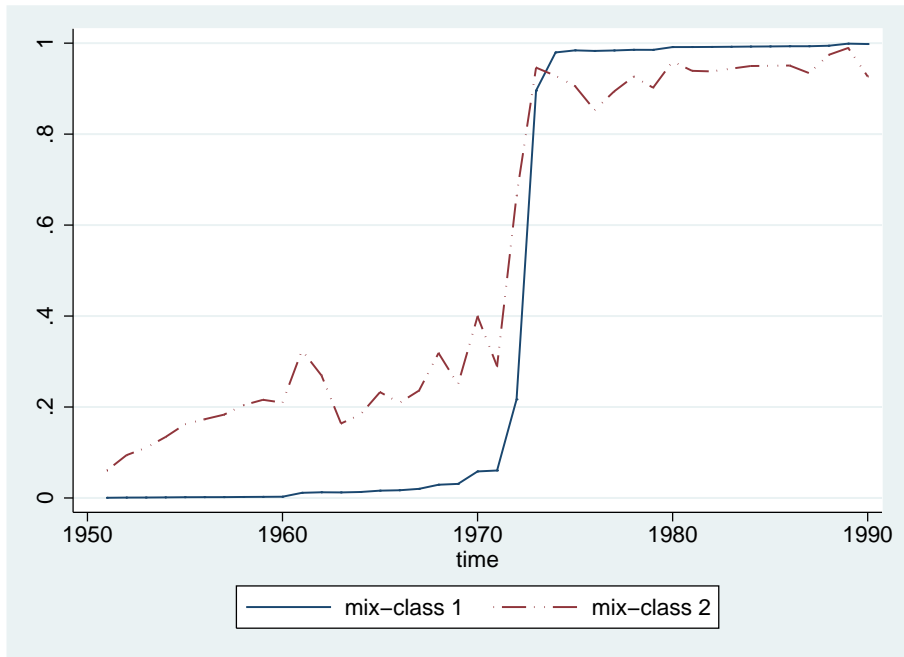


Figure A5: Predicted cartelization using the mixture model

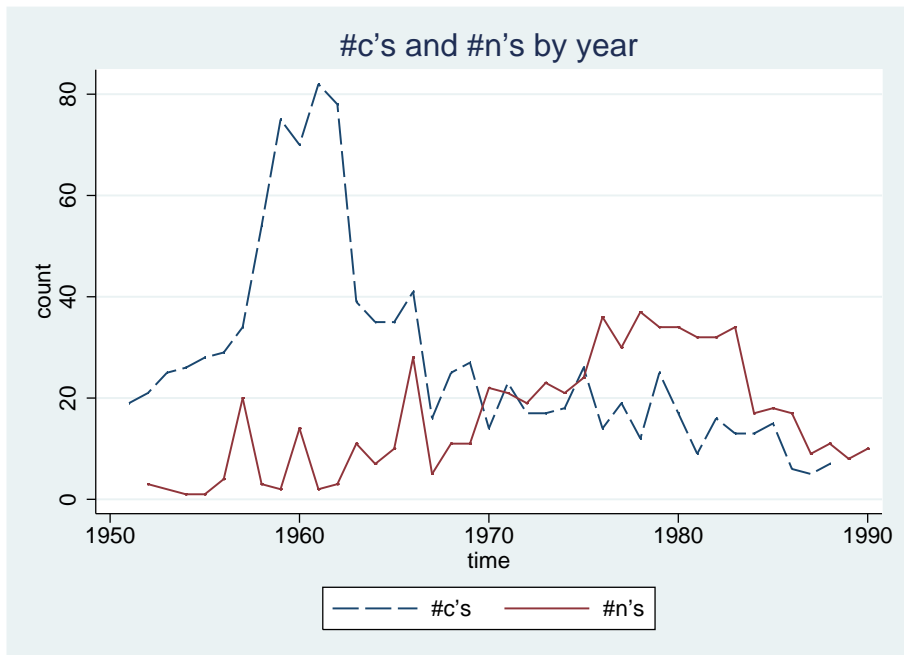


Figure A6: Count of c - and n - observations in the estimation data