# Cartels Uncovered[†]

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*How many cartels are there, and how long do they live? 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.* (*JEL* D43, K21, L12, L13, L41, L60)

> *"A nation built on cartels."*
>
> Historian Markku Kuisma (2011) on Finland.

Antitrust policy rests on limited evidence on two key questions: how common
are cartels?; and how long do they live? Data on discovered cartels from juris-
dictions where cartels are illegal cannot easily be used to address the first question
and provide a biased (selected) sample to address the second. To our knowledge,
we are the first to provide evidence addressing the first question. We also believe to
be the first to provide evidence on the second question using an unbiased sample
of cartels that did not have to actively hide from authorities' oversight. During our
observation period 1951–1990, cartels in Finland were legal, could voluntarily reg-
ister with a government registry when they formed and de-register when they died,
and in between they may or may not have been observed to be active. Thus, while
we work with a comparatively representative sample of cartels, our data are incom-
plete in a manner that is similar—but not identical—to data on illegal cartels. We

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build a Hidden Markov Model (HMM) that addresses this problem. Because cartels in our data are legal, we provide a baseline estimate determined solely by the internal stability requirement of a cartel that is at the center of the theory of collusion. Our estimate of the number of cartels and their duration in the regime of no active competition policy serves thus as a counterfactual to the current regime where cartels are illegal.

We take our HMM to panel data on 193 Finnish manufacturing industries from 1951 to 1990. In 69 percent (134/193) 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.[1] The forms of collusion varied and included agreements that, for example, fixed prices, allocated markets, and/or set quotas (see Hyytinen, Steen, and Toivanen forthcoming, HST henceforth). While the regime we study may sound idiosyncratic at first, cartels were legal and registers common in a large number of countries, especially for the post-World War II part of the twentieth century. At least Australia, Austria, Denmark, Germany, India, Israel, Japan, the Netherlands, New Zealand, Norway, South Korea, Spain, Sweden, and the United Kingdom had cartel registers of some form during the era (see Shanahan and Fellman 2016).[2] Finland is quite representative of this post-World War II regime. We find that if horizontal agreements were not forbidden, 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 the 1980s. This development is driven by the high probability of cartels continuing to be found here (and elsewhere; see Ellison 1994, Levenstein and Suslow 2006; and Harrington and Wei 2017), matched with a moderate and increasing probability of cartels forming. Taken at face value, our results suggest that deterring harmful cartels through strict competition policy is of first-order importance.

Our most important precursors are Porter (1983), Lee and Porter (1984), and Ellison (1994) who all study the Joint Executive Committee (JEC), 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 setup—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 US credit card markets. Harrington and Wei (2017) study the related problem of what the duration of discovered illegal cartels reveals about the duration of all cartels.[3]

Methodologically, the major difference to preceding work is that we introduce the HMM modeling structure. The literature studying the JEC starts from a given

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[1] As we expain in more detail in Section I, we have obtained the cartel data from the registry established in 1958 after the first Finnish competition law was enacted.

[2] Even the United States allowed cartels in the 1930s under the National Recovery Act (see, e.g., Taylor 2007).

[3] Other relevant work includes Bryant and Eckard (1991), Porter and Zona (1993, 1999), Genesove and Mullin (1998, 2001), Pesendorfer (2000), Symeonidis (2002), Harrington and Chen (2006), Röller and Steen (2006), Brenner (2009), Miller (2009), and Asker (2010).

observed quantity-price pair and uses distributional assumptions, an econometric model, and collusion theory to classify a given observation as collusive or not, allowing for classification mistakes (see the previously mentioned papers and Reiss and Wolak 2007 on the required identifying assumptions). Our approach does not require observing the market outcome (prices and quantities), but relies on the researcher having information of the collusive status of a market for some markets and some years. In particular, our approach does not require one to take a stand on what happens in industries or markets where no cartels are detected. Our HMM is complementary to the misclassification approach adopted by the earlier papers; both approaches build on the relative strengths of the data the econometrician observes. A strength of our approach is that it can be more readily applied to a cross section or panel of markets when the researcher doesn't have consistent data on prices and quantities.

In the next section, we describe the Finnish institutional environment vis-à-vis cartels after World War II and provide evidence that the legal cartels indeed engaged in collusive activities. Section II is devoted to the presentation of our data. There we also discuss how we match cartels to industries. In Section III, we first briefly discuss how to incorporte 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. We present and discuss our results in Section IV. Section V concludes. A number of additional details and analyses are reported in an online Appendix (henceforth Appendix) that supplements this paper.

## I. The Institutional Environment and the Cartel Registry

### A. *Development of Competition Law*

The Finnish institutional environment vis-à-vis cartels mirrors wider European and especially Swedish developments both before and after World War II. 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 2015). 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 the early 1950s.[4]

The first cartel law, effective from 1958, was built around the idea of making cartels public through registration. Registration was initially 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). Resale price maintenance (RPM) could be banned if deemed "particularly harmful." The law embodied the prevailing thinking of cartels not necessarily being harmful. A registry was set up to register the cartels. The registry was an early incarnation of

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

the Finnish competition authority (CA), which was to be established. Here, Finland followed Norway, Denmark, and Sweden, which set up similar registers in 1920, 1937, and 1946 (Shanahan and Fellman 2016).

Despite its limited resources, the registry was fairly active immediately after it was founded. The registry started systematic investigations concerning individual firms, specific branches (= industries), and trade associations already in 1958. By 1962, 9,539 inquiries had been sent, 235 industry investigations had been conducted, and 310 cartels had been registered (Fellman 2015, table 6.2). 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 on their own initiative, but cartels without formal organizations were still exempt from this kind of compulsory self-initiated registration. The motivation behind this change was the fact that many cartels, particularly those involving large firms, were organized as associations. Retail price maintenance (RPM) became illegal; the manufacturer could still propose suggested retail prices, but retailers could choose to set lower prices. The new law also introduced the so-called negotiation principle, according to which the registry could initiate negotiations to adjust the cartel contract with a cartel that was deemed particularly harmful. Throughout these years, the registry remained active. By 1966, it had conducted 17,543 inquiries, 565 investigations, and 500 registrations (Fellman 2015, table 6.2). It is important for our econometric modeling that conditional on the law regime and the registry's scale of operations, its activities appear "… *to have been done in a fairly random manner*" (Fellman 2015, 106).

The law was again slightly revised in 1973. According to Fellman (2010, 2015), the most important change was the reorganization of the relevant public sector bodies. In terms of substance, the single largest change appears to have been that the obligation to register was widened to apply to the self-employed, merchants, and small businesses who were part of a price-fixing cartel. Another addition to the law was the requirement to inform the registry of a cartel ceasing its activities. The law change made it possible to sue cartels for failing to register; this seems to have been rare in practice. However, no new prohibitions were introduced (Fellman 2010, 2015). A partial reform took place in 1985, which further expanded the notification requirements.

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, and the definition of what constitutes a harmful cartel was widened. The law also made void possible sanctions in the cartel agreement. The new FCA initiated a negotiation round with some of the 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 era is that the compliance requirements for registering became gradually tighter, but new outright prohibitions besides that of RPM in 1964 were not introduced before the end of the 1980s (Fellman 2010, 2015). There were benefits to registration both in terms of potential enforceability of the contract (at least initially) and perceived legitimacy of the collaborative activities. As cartels

typically struggle with stability, writing out an agreement and registering it probably helped to stabilize collusion. Moreover, during the first decades of our sample period, it is plausible that some colluding firms believed that they could enforce the contract if it was registered.[5] The ground for holding such a belief probably eroded over time.[6] Nevertheless, the environment seems to have encouraged registration up to the 1988 law. Testifying this, the former and current director generals of the FCA (Purasjoki and Jokinen 2001) concluded that "[t]ime was such that there seemed no need to intervene even in clear-cut cases, especially if they had been registered. Registration had been transformed into a sign of acceptability of the [cartel] agreement, at least for the parties involved [in the cartel]."[7] Based on these considerations, we end our analysis in 1990.

## B. Nature of Registered Cartels

Over the period of its existence the registry registered some 900 cartels, varying from nationwide to local. Of these, 364 were manufacturing and 534 nonmanufacturing cartels (HST forthcoming). Out of the registered manufacturing cartels, 80 percent were nationwide. A relevant question is whether the registered cartels in general and, particularly, the nationwide manufacturing cartels that we study were actually harmful.

One piece of evidence supporting the view that the registered cartels were indeed harmful is that the various associations of manufacturing industries opposed the introduction of the original law and its subsequent adjustments to, e.g., expand the obligation to register. Similarly, consumer organizations supported the law and suggestions to tighten it further. The available contemporary written documents, such as various committee reports, draft proposals for new legislation, or writings of the contemporary economists, provide little support for the view that the registered cartels would have been just harmless industry associations (Fellman 2010, 2015).

In terms of quantitative evidence, we can report that of all legal manufacturing cartels in the Finnish Registry, 73 percent of engaged in market allocation and 37 percent in fixed prices; these figures contain also cartels doing both.[8] The respective

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[5] Several of the cartel agreements stated that conflicts were to be solved by the parties meeting for arbitration at the Finnish Chamber of Commerce. Since these arbitrations are not known to the public, in retrospect, we do not know to which extent this option was used. Enforcement in the court of law was, according to the then-prevailing law, also an option (but apparently very rarely used). We stress that despite these possibilities, the cartels had to rely mostly on self-policing, in line with what was the case elsewhere in Europe. In line with this, Suslow (2005, 709) writes: "[…] although European law took a tolerant attitude towards cartels during this period, the legal tolerance did not translate into cartel enforceability; cartel contracts were still self-enforcing."

[6] Firms seem to have been reluctant to enforce their contracts in court. In particular, the primary motivation for the law change in 1988 was the only known lawsuit based on a cartel contract from the early 1980s that led to damages being awarded. This incident suggests that there was, similar to the case of the US Sugar Institute (Genesove and Mullin 1998, 2001), ex ante uncertainty as to the enforceability of these contracts in court. Taking your fellow cartel member to court seems to have carried the risk of affecting the legal environment, especially during the latter part of our sample period.

[7] Purasjoki 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.

[8] Market allocation refers to the cartel using quotas, agreeing on geographic market allocation, or allocating the market in some other way (e.g., through specialization in particular product lines; see HST forthcoming). Fixing prices implies that the cartel agreed either on prices, pricing rules, and/or payment rules.

numbers for the cartels in our estimation sample containing only nationwide manufacturing cartels are 46 percent for market allocation and 71 percent for fixing prices. The data in HST further show that manufacturing cartels were heavily engaged in activities designed to ensure compliance of cartel members, such as monitoring, enforcement, and fines. Of the manufacturing cartels in our estimation sample, 30 percent had clauses related to monitoring, 17 percent to enforcement, and 18 percent to fines as a part of their cartel contract.[9] HST (forthcoming) also report illustrative cases of how the registered cartels concretely divided markets and fixed prices.

When the cartels eventually became illegal by the early 1990s, the FCA initiated (around 1988) a special, large-scale project that was targeted at the registered cartels. The aim of the project was to ensure that the cartels in the registry would be abolished and that they would cease to exist by the time the new law forbidding them became effective. Had the authorities thought that the registered cartels were harmless and not real competition restrictions, launching such a project with the limited resources of the bureau would not have been necessary. Despite these efforts, some of the largest cartels that have been exposed since cartels became illegal in 1993 appear to have had their roots in the era of legal cartels (e.g., road pavement and raw wood).

Our final piece of evidence leverages industry-level data for 1974–1988 matched with our cartel data (see Section IV, subsection F, for details). Using these data we find that the more likely an industry is to have a cartel, the higher its price-cost margin, suggesting that these legal cartels indeed raised prices.

## II. Data on Cartel Activity

In this section, we explain what we observe about cartels' activities and define our dependent variable. We postpone the discussion of our explanatory variables, their data sources, and how we use them in Section IV.

### A. *Defining the Dependent Variable*

The sole source of cartel data is the Finnish Cartel Registry. For each registered cartel, there is a folder containing the entire correspondence between the registry and the cartel (members).[10] The registry assigned a three-digit SIC code to each cartel and gave a verbal description of what the cartel was active in. The registry did not follow the registered cartels on a regular basis over time (as, e.g., the Norwegian Registry did). Subsequent entries into the registry were made either when the cartel

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[9]Building on HST (forthcoming), we observe this information for 71 cartels in our estimation data.

[10]We 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 eight cartels and had four researchers (including two of us) go independently through the material to establish whether the information we sought was available and, if so, how to record it. We then checked the four 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.

contacted the registry (e.g., to register a change in cartel rules or membership), or on the basis of a registry's enquiry.

We have collected data from the registry 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 or a specialization agreement; see HST forthcoming for more detail).

The ideal data for studying the prevalence and birth and death of 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 for each market-period observation. Our data do not quite 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. We take a straightforward approach in the main body of the paper and treat each industry as an individual market. We have also used an alternative procedure that deals with the issue of observing more than one (simultaneous) cartel in a given industry in a more elaborate way by creating markets within each industry. We used the data generated by this more elaborate procedure as one of our robustness tests (see Section IV, subsection E). We also execute further tests to check that our results are robust to how we allocate cartels to markets.

Our main and alternative processes consist of three steps each, with both processes sharing the first two. We first assign the value of the observed state for each registered cartel in all years in step 1; 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 deal with those cases with multiple cartels in the same industry in step 3.

**Step 1** (Determining Observed States for Registered Cartels)**:** To determine whether or not a given industry had an active cartel in a given year, we use information on the entry into and exit from the registry and the information available from the folder that contains the correspondence between the registry and the cartel. For many cartels, the cartel contract or some parts of it are also available. This additional information allows us to pin down the actual birth and/or death dates of some cartels and/or their (non)existence in certain years. We assign for each cartel one of the observation states $(n, c, u)$ for each of the years: $n$ stands for no cartel, $c$ for cartel, and $u$ for the collusive status being unknown to the researcher.

The registry contains information on seven types of events that a registered cartel may have experienced between 1951–1990 and that may reveal that the cartel is active either at the time of the event or just before it. Some events also reveal that a cartel did not exist at a given point in time. 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 occasionally obtained information on a cartel changing its contract ("contract

$t^b$: Actual birth
$t^{aa}$: Cartel actual alive
$t^{rb}$: Registered birth

$t^{sa}$: Cartel seen still alive
$t^{cc}$: Contract change observed

$t^d$: Actual cartel death
$t^{rd}$: Cartel registered death

$c$: Cartel alive
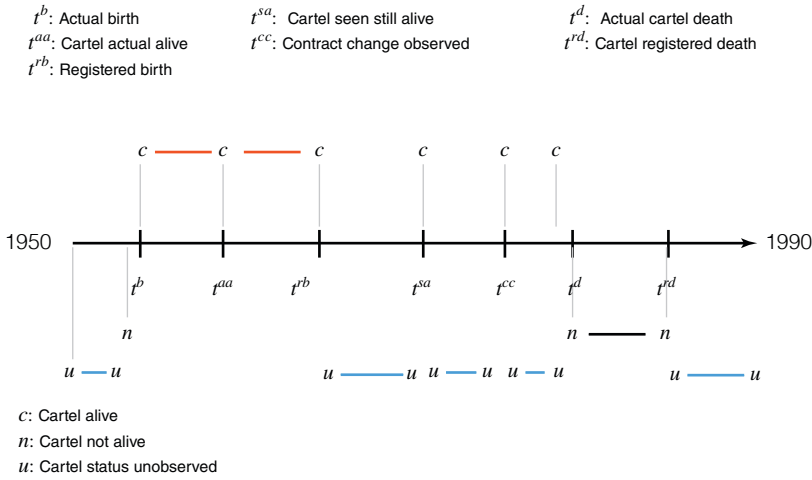$n$: Cartel not alive
$u$: Cartel status unobserved

FIGURE 1. TIME LINE FOR THE STATE DEFINITION AND OBSERVED CARTEL INCIDENCES

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 $t$.

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 $(n)$. If we were to follow the (misclassi- fication) approach used by Porter (1983) and others, we would have to assign each of the observations we assign $u$ either an $n$ or a $c$.

Cartels for whom we observe the actual birth date $t^b$ or for whom we have infor- mation 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 $(t^{rb})$. The reason for including the periods between $t^b$ and $t^{rb}$ as observed $c$-states is due to the assump- tion that had a cartel not been alive between those dates when it is asked to register (at $t^{rb}$), it would have informed the registry of a later birth year. This data coding assumption means that conditional on a cartel informing the registry about its birth year, the number of periods revealed as cartelized is minimized. This assumption guarantees that we are conservative in assigning $c$s. Correspondingly, cartels for whom we know the actual death date $(t^d)$ are presumed to be dead from $t^d$ to the date of register death $(t^{rd})$, i.e., we record them as $n$. When the registry found out and was convinced that the cartel was dead, it removed the cartel from the registry $(t^{rd})$. In some cases, it then obtained information on the actual death date $(t^d)$ of the cartel, which must have happened prior to $t^{rd}$. Our assumption essentially is that in the time interval between these two dates, the cartel was not operational.

In addition, we make the following assumptions: cartels are assumed to be alive every year where we observe another active move, i.e., a still alive or a contract

change incidence. We further 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 conservative because we only assign an $n$ or a $c$ in years where the cartel reveals itself through some action (e.g., writing a letter to the registry or news in the press) or during periods where we can safely infer the status of the cartel. For instance, although 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 during the time the cartel was registered.

**Step 2** (Assigning Cartels to Industries)**:** We use the SIC code and the qualitative information provided by the cartel folders of the registry to match each of the registered 135 nationwide manufacturing cartels to one or more industries. To determine the population of industries, we use the most disaggregated level of the 1979 Finnish equivalent of the SIC classification for manufacturing. Using this classification, we end up having 193 industries, measured at the six-digit level when possible. A cartel was assigned to a single industry if we were able to do so. If not, it was assigned to multiple industries: as an example, think of a three-digit industry which comprises two six-digit industries. If the verbal description of the cartel did not provide information that would allow us to assign it to only one or the other six-digit industry, we would assign it to both.

This step results in us assigning one or more cartels to 69 percent (134) of the 193 industries. Out of these 134 industries, 26 percent (35) have only one registered cartel.[11] We explain in the next step how we deal with those industries with more than one registered cartel.

**Step 3** (Assigning Cartel Status to Industries with Multiple Cartels)**:** In our main approach, the last step consists of rules on assigning $n$, $c$, or $u$ to the industry-year observations for the industries where we observe more than one cartel. The rules are as follows: first, we assign $c$ to each industry-year observation where we observe at least one cartel alive; second, we assign $n$ when all observed individual cartels are assigned $n$ (in step 1), as only then can we be sure that none of the observed cartels are operational; and third, in all other cases, we assign the dependent variable the value $u$.

Our robustness tests show that using only industries with one observed cartel and using data only on the first registered cartel in a given industry had minor effects on our results (see Section IV, subsection E). Moreover, the more elaborate process, to which we previously alluded, imposes exogenously the number of markets within an industry and then assigns some of the observed (simultaneously active) cartels to those markets. This procedure produces similar but starker dynamics. These results were as expected, as the procedure of increasing the number of markets mostly leads

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[11] In addition, 17 percent (23) of the 135 registered cartels were assigned to more than one industry.

to a higher fraction of observations in the $(u, u)$-cell of the transition matrix of the observation process. As we will explain later, such observations do not contribute to identification.

## B. *Descriptive Statistics*

After assigning the value of the observed state for each registered cartel for each year (step 1), assigning each registered cartel to one or more industries (step 2), and dealing with multiple cartels in the same industry (step 3), we have a panel data of 7,720 observations, consisting of a time series of $n$, $c$, and $u$ for each industry from 1951 to 1990 ($N = 193$, $T = 40$). We have relatively more $c$ observations during the first decades of our sample period and $n$ observations during the latter part of the sample (see Figure A1 in online Appendix A, which displays $c$ and $n$ time series, aggregated over industries).

Identification and estimation of Markov models typically rely on the observed transitions from one state to another. In our data, the observed transitions are $(n \rightarrow n)$, $(n \rightarrow c)$, $(n \rightarrow u)$, $(c \rightarrow n)$, $(c \rightarrow c)$, $(c \rightarrow u)$, and $(u \rightarrow n)$, $(u \rightarrow c)$, $(u \rightarrow u)$. As we explain later, the identification of our HMM does not require using all types of possible transitions in the data, but the maximum likelihood (ML) estimation makes use of all of them. To illustrate the transitions we observe, Table 1 shows the transition matrix of our dependent variable. The table shows, for example, that we have 313 observations for which we know for consecutive years that a cartel did not exist in a given market in either year $(n \rightarrow n)$. Similarly, we observe 564 cases where a cartel existed in two consecutive years $(c \rightarrow c)$. 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 $(u \rightarrow u)$ transitions account for 95 percent of the data; this high number corresponds with the observation that most of the time, we don't know whether or not a given market has a cartel. In our 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 $u$.

## III. A Hidden Markov Model for Cartel Formation and Continuation

In this section, we outline a HMM for cartel formation and continuation and discuss how its parameters can be identified and estimated.

## A. *The Model*

There are several 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 (for early work, see Stigler 1964 and Friedman 1971). A 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 breakdown of the cartel (Harrington and Chang 2009).

TABLE 1—TRANSITION MATRIX

| $t - 1/t$ | $n$ | $c$ | $u$ | Total |
|---|---|---|---|---|
| $n$—Count | 313 | 102 | 111 | 526 |
| $n$—Percent | 59.51 | 19.39 | 21.10 | 100.00 |
| $c$—Count | 100 | 564 | 228 | 892 |
| $c$—Percent | 11.21 | 63.23 | 25.56 | 100.00 |
| $u$—Count | 123 | 207 | 5,779 | 6,109 |
| $u$—Percent | 2.01 | 3.39 | 94.60 | 100.00 |
| | | | | |
| Total—Count | 536 | 873 | 6,118 | 7,527 |
| Total—Percent | 7.12 | 11.60 | 81.28 | 100.00 |

*Note:* The number of observations in Table 1 is 193 less than the number of observations in the data, as the transition cannot be calculated for the first year of the data.

Motivated by the prior work on cartels, we denote 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 denoted $H2$ (see also Bradburd and Over 1982). For our purposes, this framework has an important feature: it suggests a two-state Markov model for the collusive dynamics of a market and generates a sequence of cartel and non-cartel periods. Our approach takes seriously the possibility that the collusive state is unobserved by the registry and hence also by the econometrician in a systematic way.

While our model is a 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. We illustrate how to incorporate one of the candidate theoretical cartel models (that of Harrington and Chang 2009; see also Harrington and Chang 2015) into our modeling framework in online Appendix B. Matching such a model with data from an era of illegal cartels and modern competition policy (including leniency; see, e.g., Brenner 2009 and Miller 2009) would yield estimates of structural parameters, including those measuring the efficiency of competition policy and the harm caused by the cartel.

## B. *The HMM Structure*

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, 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 $i = 1, \ldots, N$ and periods $t = 1, \ldots, T_i$ 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 $i$ is independent of the past and future hidden states and observations.

*The Hidden Process.*—Consider cartel formation and continuation in market $i$ at time $t > 1$.[12] 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 are needed because the probability in the empirical part will depend on macro- and industry characteristics. If the market has a cartel at the beginning of period $t$, the cartel 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 $\mathbf{A}_{it}$ is[13]

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

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 $t$.

*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

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

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)

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

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

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) cartelized. This assumption imposes $b_{it}^n(c) = b_{it}^c(n) = 0$. This is not a strong assumption because we are interested in whether the firms had a cartel agreement in place or not. Furthermore, our coding of $c$ and $n$ is based on the registry's information on the cartel being active in one way or the other or not being active. If one has reasons to suspect that there are errors in coding either $n$ or $c$, the status of a market can conservatively be labeled "unknown."[14] The resulting observation probability matrix $\mathbf{B}_{it}$ is

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

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.

The observation probabilities can be less than one (i.e., $\beta_{it}^n \leq 1$, $\beta_{it}^c \leq 1$) and need not be equal (i.e., $\beta_{it}^c \neq \beta_{it}^n$). As we discuss in more detail later, the former feature means that the model explicitly allows for the possibility that there are "holes" ($u$s) in our data, whereas the latter feature allows the observed transitions to be a selected set of all hidden transitions. There are two primary reasons for the incompleteness of our data: on the one hand, information about the state of a registered cartel can be incomplete over time. For example, some cartels were born years before they were registered, but we only observe the actual birth years for some cartels. Another example is cartels that ceased activities years before they were removed from the registry; again, we only observe the actual death year for a subset of all registered cartels. 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 explained earlier).

## C. Identification and Estimation

The identification of the parameters of a general finite HMM follows from the identifiability of mixture densities (see Cappé, Moulines, and Rydén 2005, 450–57). The parameters of our HMM are identified for two further reasons: first, the economic theory of cartels allows us to circumvent the problem of identifying the

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[14] The approach of Porter (1983) and others would result in an observation probability matrix where we allow $b_{it}^n(c)$ and $b_{it}^c(n)$ to be nonzero, but impose $b_{it}^n(u) = b_{it}^c(u) = 0$.

dimension of the hidden process. The theory directly suggests that there are only two states of the world; hence, $S_Z = (n, c)$. A second source of identification is the parameter restrictions that we imposed on $\mathbf{B}_{it}$.

Identification of the probabilities $H1_{it}$ and $H2_{it}$ would be straightforward, if the hidden process was observable (i.e., if $\beta_{it}^c = \beta_{it}^n = 1$ in our notation). If this was the case, $c$ and $n$ would be observed for all industries in all years. With such data, the parameters of a standard Markov model could be identified in two ways. First, assuming as a first cut that the transition parameters are constant across industries (see also Harrington and Wei 2017), we could imagine having two consecutive observations for each industry, for a large number of industries. The resulting transition matrix would allow one to estimate the shares for transitions $(n \rightarrow n)$, $(n \rightarrow c)$, $(c \rightarrow n)$, and $(c \rightarrow c)$ and thus to calculate the probability of cartel birth $(H1_{it})$ and a cartel staying alive $(H2_{it})$. Alternatively, we could imagine having a very long time series from a single industry. Again, the resulting transition matrix would enable identification of the transition probabilities, assuming they stay constant over time. In a panel context, what one needs is a sufficiently large $N \times T$.

The identification argument presented above extends to the case of collusive status of a given industry in a given year being missing completely at random (Rubin 1976). If this was the case, the observed data are representative of the underlying population. This case corresponds to the observation probabilities being less than one and equal to each other (i.e., $\beta_{it}^c = \beta_{it}^n < 1$).

When an observation is missing at random (Rubin 1976), the likelihood of it being missing is allowed to be related to observed covariates. In our HMM context, this case allows the observation probabilities to be the same or different, conditional on covariates. In particular, if $\beta_{it}^c \neq \beta_{it}^n$, the observed transitions are not representative, and a naïve (non-hidden) Markov model would yield biased estimates of the transition probabilities

Our HMM allows for $\beta_{it}^c \neq \beta_{it}^n$ and thus for the observed transitions to be a selected set of the hidden transitions. To clarify how the parameters are identified in this more general case, consider the (partial) transition matrix for the *observation* process displayed in Table 2.

The rows give the state that the econometrician observed in the previous period; the columns give the state that 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 $(\beta_{it}^n)$. 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 left-most cells of Table 1, one notices that we have four moments and four unknown parameters $\{\beta_{it}^c, \beta_{it}^n, H1_{it}, \text{ and } H2_{it}\}$. Using the population shares of the corresponding transitions $(n \rightarrow n, n \rightarrow c, c \rightarrow n, \text{ and } c \rightarrow c$; see Table 1 for their empirical counterparts), one can solve for these four unknown

TABLE 2—PARTIAL TRANSITION MATRIX OF THE OBSERVATION PROCESS

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

parameters. Had we data on infinitely many industries, we could solve for the four unknowns for each $t$ for $t > 1$.[15] These arguments illustrate that our HMM is (non-parametrically) identified.

In practice, the datasets on cartels are sparse on transitions and have a limited cross-sectional dimension, meaning that one cannot solve for the four unknowns for each $t$ and then estimate the time-specific parameters using rolling transition matrices. A standard solution to this problem is to model the transition and observation probabilities as single index functions of the explanatory variables. This is what we do. We specify, in particular, the single index functions of the observation probabilities to include variables that capture the functioning of the registry over time, changes in the institutional (legal) environment, and the observed cartel history of each industry. This specification allows past (registration) activity to affect the subsequent probability of observing the cartel status of the industry. It also matches the view that conditional on its past activities and current scale of operations, the registry conducted industry investigations and sent inquires to firms and associations in a fairly random manner (Fellman 2015).

*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:

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

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

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

where $\mathbf{o}$ denotes the data (the realization of $\mathbf{O}$).[16]

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[15] Alternatively, if the data included a sufficient number of time-series observations and thus transitions in each cell for each industry, one could in principle identify industry-specific parameters.

[16] Picking 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 by equation (5). If, for example, $o_{it} = c$, the upper left-corner cell of $\mathbf{D}_{it}$ is $d_{it}^{nn}(w) = a_{it}^{nn} b_{it}^n(c) = 0$. For $t = 1$, the elements of the vector $\mathbf{D}_{i1}$, $d_{it}^k = \tau_i^k b_{i1}^k(w)$, in the likelihood function can be determined similarly.

Four comments about the HMM and its estimation are in order: first, while the maximization of $L(\Theta; \mathbf{o})$ may be a nontrivial matter, (direct) numerical maximization methods can be used (Turner 2008, Zucchini and MacDonald 2009, ch. 3). Typically, a normalization or scaling is used to avoid numerical (i.e., floating point) underflow. Second, because $\{\tau_i^c, H1_{it}, H2_{it}, \beta_{it}^c, \beta_{it}^n\}$ are all probabilities, a 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, our HMM can be extended to allow for unobserved heterogeneity. However, 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 nonhomogenous HMM (see, e.g., Maruotti 2011), with two mixture classes.[17]

## IV. Empirical Analysis

In this section, we present how we parametrize our HMM, discuss our explanatory variables, and report the point estimates. We then demonstrate what the estimated models suggest about the dynamics of cartel formation and dissolution. Finally, we discuss the robustness of the uncovered dynamics and give economic and institutional explanations for it.

### A. *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 ($\tau^c$) all as single index functions. This means, for example, that we impose $Hj_{it} = \Phi(\mathbf{Hj}'\mathbf{x}_{it})$, $j \in \{1, 2\}$ where $\Phi(\,\cdot\,)$ is the c.d.f. of the normal distribution, $\mathbf{x}_{it}$ denotes the explanatory variables, and $\mathbf{Hj}$ is the parameter vector to be estimated.[18] We treat the observation probabilities and the initial probability similarly.

We have two main approaches for the specification of the index functions. In the first one, we use variables describing the workings of the registry, the macroeconomic and legal environments, and the nature of the industry. Given that our primary interests are the transition probabilities and the implied degree of cartelization, our second approach uses a polynomial of time as the only explanatory variable in the index functions. These two specification approaches complement each other. We use them to deal with model uncertainty, i.e., to make sure that our findings are not driven by arbitrary choices of explanatory variables (see, e.g., Leamer 1983).

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[17] Two further points warrant discussion. First, the literature on testing the fit of HMM models is rather thin; see Zucchini and MacDonald (2009, ch. 6). 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 MacDonald (2009, 119), the number of parameters of such a model rapidly becomes prohibitively large. 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.

[18] For simplicity, we omit the *it* subscript from here on.

B. *Data on Explanatory Variables*

Our data for explanatory variables come from two main sources. The first one is the registry. It provides us variables measuring the workings of the registry, which we use to model the observation process. The second source is the Research Institute of the Finnish Economy. We obtain from its database macroeconomic data, such as GDP and trade figures. We use these data to model the hidden process. We display the descriptive statistics of the explanatory variables in online Appendix A.[19]

*Specifying the Observation Probabilities.*—The ability of the registry to detect and register the births and deaths of cartels may have changed over time because of, e.g., learning-by-doing, changes in the registry's resources and the gradual tightening of the registration requirements over time. To accommodate these patterns, we specify the single index functions of the observation probabilities ($\beta^c$ and $\beta^n$) to include variables that capture the functioning of the registry over time, changes in the institutional (legal) environment, and the observed cartel history of each industry.

The two observation probabilities are assumed to be a function of the following two registry variables: first, we let $\beta^c$ ($\beta^n$) vary with the number of cartels that entered (exited) the registry in year $t - 1$. These numbers measure the current scale of operations of the registry. Empirically, there is a weak negative trend and a lot of variation over time in the number of annually registered cartels, as calculated over all the cartels in the registry, and an upward trend in the number of registry exits. Second, we allow $\beta^c$ ($\beta^n$) to be a function of the (once) lagged cumulative number of registered births (deaths) and its square. The total number of registered births and deaths capture the cumulative experience of the registry. These variables are denoted ($Birth - flow$, $Birth - stock$, $Death - flow$, $Death - stock$), and they are computed using the data from the whole registry with circa 900 cartels, thereby exploiting mostly variation that comes from outside our estimation data.

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 two observation probabilities are functions of this variable. An implication of including $Birth - count$ in the observation probabilities is that the model allows for the possibility that the cartel status of an industry is observed with a higher probability in an industry with a registered cartel than in an industry without.

To control for changes in the competition law, we introduce an index into the two observation probabilities 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 its introduction in 1959 ($Law - index$). This index measures the main changes in the competition law, which mostly had to do with the gradual tightening of the requirements for registration and information provision duties of cartels (rather than limiting the possibilities to collude). For example, the 1973 law change that introduced a (potential) punishment for not informing the registry about a cartel ceasing

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[19] For a robustness test, we obtained plant-level data from Statistics Finland that we used to generate industry-level variables for 1974–1988; see Section IV, subsection E for details.

activities may have lead to a higher probability to observe $n$. Although the law did not become stricter in terms of what type of collusion was allowed, it may have been the case that the environment became more hostile towards collusion over time. This may have had the effect that cartels were less likely to register and/or more likely to leave the registry. Such changes would show up in the observation probabilities of our model and are modeled using *Law − index*.

The identification of the transition probabilities rests on the assumption that conditional on the included variables, the observation probabilities capture variation in the observation process. In particular, our specification of the observation probabilities allows the past (registration) activity of an industry to affect the subsequent probability of observing the cartel status of the industry. The specification of the observation probabilities also matches with the view that conditional on its past activities (cumulated experience) and current scale of operations, the registry conducted industry investigations and sent inquires to firms and associations in a fairly random manner (Fellman 2015).

*Specifying the Transition Probabilities.*—We specify the transition probabilities (*H*1, *H*2) to be functions of three types of variables: first, variables capturing the macroeconomic conditions; second, variable(s) capturing the law regime; and finally, a variable capturing the nature of the products in the industry in question.

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 capture 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 use a third order polynomial of *HP − trend* to capture the nonlinearities, if any, in how the long run growth trend is associated with the birth and death of cartels. 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.

We allow *H*1 and *H*2 to depend on the law regime, as it is possible that the changes in the competition law affected the behavior of cartels beyond registration, affecting the transition probabilities. While the content of the law changes were often linked to registration requirements, the legal environment, and possibly also the general attitudes towards cartels, as perceived by the involved colluding firms, became gradually less lenient. To accommodate this, we introduce the *Law − index* previously described also into *H*1 and *H*2.

To capture some of the cross-industry variation, we introduce an indicator for the product of an industry being homogenous (*Homog − d*). We followed the existing literature (Rauch 1999; Foster, Haltiwanger, Syverson 2008) by utilizing the verbal characterization of each industry, the SIC3 industry code, and the registry's description of the goods produced by the cartel. 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

TABLE 3—PARAMETER ESTIMATES FOR $H1$, $H2$, AND $\tau^c$

|  | $H1$ (birth) | $H2$ (continued) | $\tau^c$ |
|---|---|---|---|
| *Homog − d* | 0.200 | −0.102 | 0.477 |
|  | (0.072) | (0.073) | (0.252) |
| *HP − trend* | 0.698 | −6.401 |  |
|  | (0.327) | (0.742) |  |
| *HP − trend²* | −0.056 | 0.739 |  |
|  | (0.044) | (0.083) |  |
| *HP − trend³* | 0.002 | −0.027 |  |
|  | (0.002) | (0.003) |  |
| *GDP − pos* | 0.029 | 0.010 |  |
|  | (0.005) | (0.005) |  |
| *GDP − neg* | 0.008 | 0.012 |  |
|  | (0.004) | (0.004) |  |
| *Law − index* | −0.049 | 0.897 |  |
|  | (0.1340) | (0.159) |  |
| *Constant* | −4.033 | 17.174 | −1.501 |
|  | (0.753) | (1.962) | (0.176) |
| Observations |  | 7,720 |  |
| log likelihood |  | −2,992 |  |

*Note:* Standard errors are in parentheses.

more mixed picture.[20] We introduce *Homog − d* into $H1$ and $H2$, as well as into the initial probability of an industry being cartelized in the first year of our data, $\tau^c$.[21]

## C. *Parameter Estimates*

Before discussing our ML estimates, we use the HMM structure (i.e., the formulas in Table 2) and the numbers in the first two rows of the transition matrix (i.e., the numbers in Table 1) to calculate a (nonparametric) estimate for the probabilities of forming a cartel ($H1$) and of continuing a cartel ($H2$). Using only this subset of the transitions, we find that the estimate for the probability of forming a cartel is 0.26 (CI 95 percent: [0.22, 0.31]) and that of continuing a cartel is 0.86 (CI 95 percent: [0.83, 0.89]). These estimates thus suggest a moderate probability to form a cartel, but a high continuation probability.

Tables 3 and 4 present the parameter estimates from the ML estimation of our HMM model. These point estimates are not of key interest to us, as we care more about what they imply for the prevalence of cartels, the stability of cartels, and the broad dynamics of the cartelization of the economy. We therefore only point out three things here. First, as Table 3 shows, the initial probability of being in a cartel is higher for the manufacturing industries, which produce homogenous goods

[20] Chang (1991) and Ross (1992) find that differentiation makes collusion easier, while Häckner (1994) and Raith (1996) 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.

[21] Other industry data are not consistently available for our observation period for the level of industry classification we use.

TABLE 4—PARAMETER ESTIMATES FOR $\beta$s

|  | $\beta^n$ | $\beta^c$ |
|---|---|---|
| $Law - index$ | 0.171 | −0.542 |
|  | (0.135) | (0.133) |
| $Death - stock$ | −2.054 |  |
|  | (0.570) |  |
| $Death - stock^2$ | 2.383 |  |
|  | (0.507) |  |
| $Death - flow$ | −0.008 |  |
|  | (0.011) |  |
| $Birth - count$ | 0.688 | 0.272 |
|  | (0.056) | (0.020) |
| $Birth - stock$ |  | −0.756 |
|  |  | (0.095) |
| $Birth - stock^2$ |  | 0.041 |
|  |  | (0.008) |
| $Birth - flow$ |  | 0.001 |
|  |  | (0.003) |
| $Constant$ | −2.067 | 2.356 |
|  | (0.062) | (0.206) |

*Note:* Standard errors are in parentheses.

($p$-value 0.058).[22] Second, the two types of GDP shocks ($GDP - pos$, $GDP - neg$) tend to obtain significant and positive coefficients in the single index functions of $H1$ and $H2$ (albeit their magnitudes seem to vary a little from one specification to another; see the robustness tests). Third, turning to the single index functions of $\beta^c$ and $\beta^n$ in Table 4, we find that as expected, having registered a cartel ($Birth - count$) in an industry increases both observation probabilities. This finding means that prior information on cartelization activities in a given industry increases the probability by which the registry observes the industry's state.

We can use the estimated HMM (Table 3) to predict $H1$ and $H2$ for each industry-year observation in our sample. We find that $H1$ is 0.23 and that $H2$ is 0.88 on average. These averages are close to those we calculated nonparametrically from the transition matrix (using Tables 1 and 2). The economic implication of these findings is that when cartels are legal, industries form a cartel with a moderately high probability and that cartels, once formed, are very durable.

The results reported in Tables 3 and 4 are based on the first of our two main approaches for the specification of the index functions. Our second approach uses a polynomial of time as the only explanatory variables in the index functions. After some experimentation, we settled on using a fourth-order polynomial in time in all the index functions; a third order polynomial would do as well. Given that we are primarily interested in the transition probabilities and the implied degree of cartelization and that the individual polynomial coefficients cannot be meaningfully interpreted, we do not report the point estimates here. Suffice it to note that even though

[22] The estimates imply that the average initial probability of being in a cartel at the start of our sample period is about 10 percent. We do not want to put too much emphasis on this estimate, as it is in essence a nuisance parameter that is estimated from a single cross section of industries and that is not of direct interest to us.

this alternative specification uses a completely different set of explanatory variables and was estimated using a different set of starting values, the implied $H1$ and $H2$ are very similar. According to the alternative specification, $H1$ and $H2$ are on average 0.26 and 0.94, respectively. Other empirical cartel studies, such as Ellison (1994) and Harrington and Wei (2017), have also found high continuation probabilities. To the best of our knowledge, there are no comparable estimates of $H1$ in the prior literature.

It is difficult, if not impossible, to determine when an economy would be in a steady state. In spite of this, it is of interest to ask the question of how common cartels would be in the steady state of a hypothetical economy that does not forbid them. When the probability of forming a cartel is about 0.26 and that of continuing a cartel is about 0.88,[23] the steady-state degree of cartelization would be 0.87, provided that the Markov chain governing cartel births and deaths reaches its stationary distribution. In this steady state, the implied duration of legal national manufacturing cartels would be 8.5 years.[24]

We explore the implied cartel dynamics of the two single index specifications, as well as the robustness of our findings, in the next section.

### D. *Cartel Dynamics*

*Dynamics of $H1$ and $H2$.*—We show the development of the predicted $H1$ and $H2$, averaged over the manufacturing industries, in Figure 2 (with confidence intervals displayed in online Appendix C). The figure reveals two key findings. First, the probability of establishing a cartel, $H1$, exhibits a positive trend. Notice, in particular, that the estimated $H1$ is increasing trend-like, so even ignoring the upward spikes, its value is significantly higher at the end of our sample period than at the beginning of it. Second, the probability of cartel continuation, $H2$, is persistently high, even though it exhibits a period of lower values between the early 1960s and mid-1970s. As we later show, these broad dynamics, i.e., the trend in $H1$ and the persistently high level of $H2$, are robust and have an important implication for the degree of cartelization in our data. We note, in particular, that while the displayed variation in the estimated series for $H1$ and $H2$ is a relatively robust feature, too, the exact magnitude and timing of the upward and downward spikes vary somewhat from one specification to another. In any event, neither the magnitude nor the timing of the estimated spikes drive the key findings that we report.

The dynamics of the observation probabilities $\beta^c$ and $\beta^n$ are quite different: whereas $\beta^c$ starts at a very high level and decreases quickly, exactly the opposite holds for $\beta^n$. The time-series patterns of $\beta^c$ and $\beta^n$ are not of key interest to us. However, it is useful to note two things about them. First, the estimated patterns are at least partly explained by how we observe $c$s and $n$s over time (see online

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[23] Harrington and Wei's (2017) results imply an annual continuation probability of 0.83 for illegal cartels.

[24] Harrington and Wei's (2017) analysis shows that the average duration of discovered cartels is an unbiased estimate of the true duration only in specific circumstances and can be biased either way. Levenstein and Suslow (2011) report an average duration of 8.1 years for discovered international cartels but do not adjust for the potential bias. Harrington and Wei (2017) adjust for the bias and report a duration range of 5.3–6.8 years for cartels convicted by the Antitrust Division of the US Department of Justice.
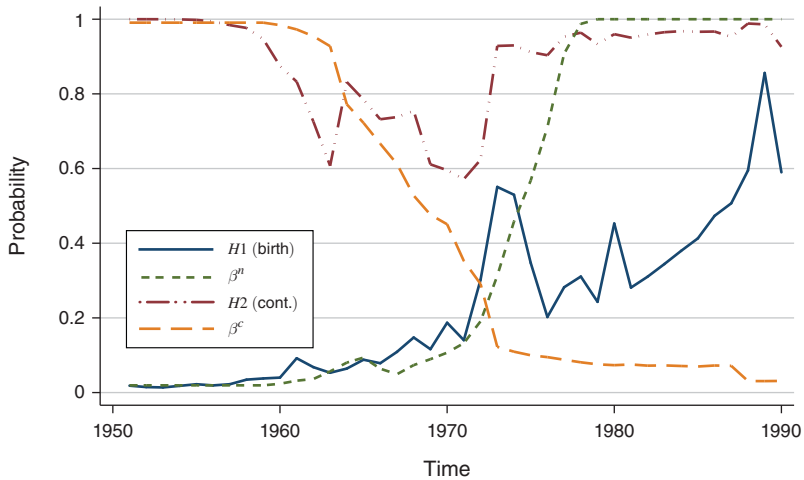
FIGURE 2. DEVELOPMENT OF $H1$, $H2$, $\beta^c$, AND $\beta^n$

Appendix A, Figure A1). Second, the estimated patterns allow highlighting how our HMM model works: the estimated time-series patterns of $\beta^c$ and $\beta^n$ imply that early on in the observation period, any manufacturing industry in hidden state $c$ is almost surely observed to be in that state, as $\beta^c$ is very high. These data patterns are in line with the description of Fellman (2015), reporting that during the early years of the registry, the legislation was on purpose lenient on cartels so as to facilitate registrations (see online Appendix A for further discussion).

*Dynamics of the Degree of Cartelization.*—The results mentioned earlier suggest that the degree of cartelization may have increased over our sample period. To explore this, we make use of the estimated parameters of the hidden transition process and perform a recursive calculation of $\Pr[Z_{it} = c]$ (i.e., we use the Chapman-Kolmogorov equation). This calculation allows us to recursively estimate the proportion of manufacturing industries that had a cartel in a given year. The calculation is first made individually for each industry and then as an average over the industries.

To show that our cartelization findings are not driven by arbitrary choices of the explanatory variables or model specification, we display four versions of the estimated time series of the degree of cartelization. First, we display the series calculated on the basis of the point estimates displayed in Table 3. Second, we take a closer look at the role of GDP shocks. The reason for doing so is that the estimated spike(s) in $H1_{it}$ are largely driven by the positive GDP shocks (see Figure 2 and Figure A2 in online Appendix A). To show that they do not drive the dynamics of cartelization, we redo the baseline calculation using the estimates of Table 3, but so that we counterfactually smooth the largest positive GDP shocks to take the average value of that variable. Third, we display the alternative specification which uses the fourth-order polynomial of time as the only explanatory variable in all four single index functions. Finally, we display a model-averaged version of the time series for the cartelization. The weighted average is calculated using the
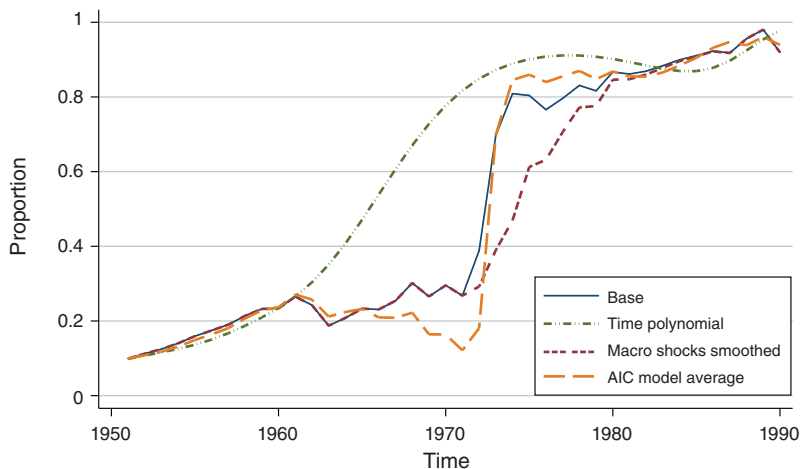
implied cartelization time series generated by a subset of the robustness checks that we report later in this paper.[25] To calculate the model average, we use weights based on Akaike's information criterion (see Burnham and Anderson 2002; see also Buckland, Burnham, and Augustin 1997).

The four time series are displayed in Figure 3. For the baseline specification, the figure shows that the proportion of cartelized industries starts reasonably low, reflecting the low values of $\tau^c$ and $H1$ in the early years. The degree of cartelization then starts to increase, reflecting the persistently high $H2$ and the trend in $H1$. The other models confirm these patterns. Understandably, given the polynomial structure of the alternative specification, the time-series pattern of cartelization is smoother than those produced by other models. Taken together, these results suggest that the dynamics we capture are not an artifact of the included macroeconomic variables. In particular, the early 1970s spike in $H1$ or the other shorter term variations in $H1$ or $H2$ are not driving our result on the degree of cartelization.

How do the HMM-based time-series patterns of the degree of cartelization compare to the (admittedly intuitive, but potentially naïve) estimate of the prevalence of cartels that one could have derived from the raw data (on registrations)? To address this question, we display in Figure 4 the share of industries that had a registered cartel over the sample period. A comparison of Figures 3 and 4 suggests that inferring the dynamics of cartelization directly from the registry data is not reliable (see also Figure A1 in Appendix A for the count of $n$, $c$ over the sample period). The reason is that such an estimate is based on a biased data: the degree of cartelization is not the same as the fraction of industries with an observed cartel. One has to take into account both the probability of a cartel in each of the industries and the probability that the activities of the cartels are observed (for a related point, see Harrington and Wei 2017).

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[25] We include all but the following robustness checks in the model averaging: the mixture model, models estimated using the larger data, and the model estimated using data post-1959. For weights used in model averaging, see online Appendix C.
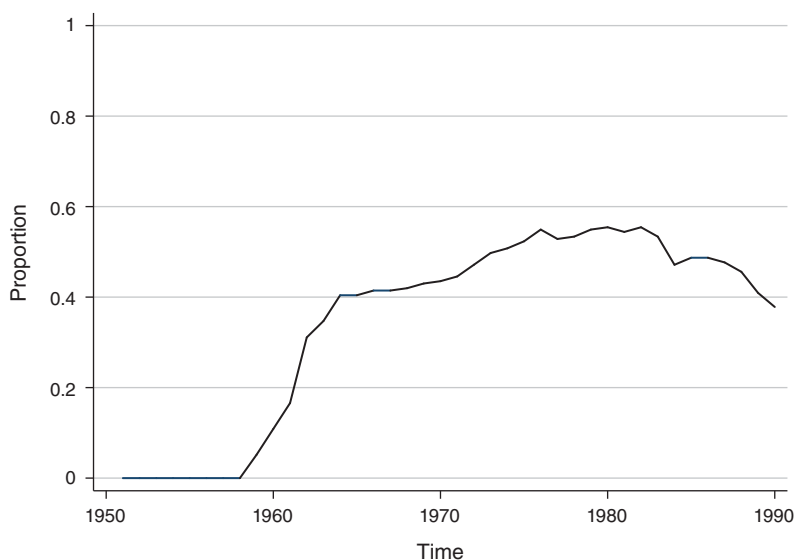
FIGURE 4. PROPORTION OF INDUSTRIES WITH A REGISTERED CARTEL

## E. *Robustness*

Our robustness tests are mostly geared towards establishing that the means reported for $H1$ and $H2$ and the broad dynamics of $H1$, $H2$ and the degree of cartelization are robust to reasonable alternative modeling choices. We report the means of $H1$ and $H2$ implied by all the estimated models in Table 5 and display figures on dynamics in Appendix C. We also perform the counterfactual of removing the GDP shocks for each estimated model. The only exception to this is the mixture model for which we display the $H1$, $H2$-figure and the predicted cartelization later in this paper.

**Robustness Test #1, Number of Cartels:** The number of cartels utilized in our estimation depends on how we deal with industries with more than one observed cartel. For 49 percent of industries (59 industries with no cartel, and 35 with 1 actual cartel out of a total of 193 industries), there is at most 1 actual cartel, and therefore little uncertainty that our classification procedure would bias the results. To verify that this is the case, we reestimated the model excluding industries with more than one observed cartel. This exercise reproduced our results.[26]

**Robustness Test #2, 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.[27] We have therefore reestimated the

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[26] In an early version of our paper (HST 2010), we used only information on the first cartel in each industry. The dynamics closely match those reported here.

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

Table 5—Estimates of $H1$, $H2$, $\beta^n$, and $\beta^c$

| Specification | Baseline | Time polynomial | One cartel | 1959 | Law spline | *Law − index* 1985 |
|---|---|---|---|---|---|---|
| Robustness test # | | | 1 | 2 | 3a | 3b |
| **Parameter:** | | | | | | |
| $H1$ | 0.234 | 0.264 | 0.153 | 0.234 | 0.229 | 0.234 |
| $H1 \mid year \leq 1970$ | 0.062 | 0.122 | 0.022 | 0.062 | 0.057 | 0.062 |
| $H1 \mid year > 1970$ | 0.406 | 0.407 | 0.285 | 0.406 | 0.401 | 0.406 |
| $H2$ | 0.882 | 0.944 | 0.877 | 0.882 | 0.852 | 0.882 |
| $H2 \mid year \leq 1970$ | 0.849 | 0.928 | 0.810 | 0.849 | 0.807 | 0.849 |
| $H2 \mid year > 1970$ | 0.915 | 0.960 | 0.943 | 0.915 | 0.896 | 0.915 |
| $\beta^n$ | 0.429 | 0.544 | 0.376 | 0.429 | 0.431 | 0.429 |
| $\beta^c$ | 0.474 | 0.403 | 0.431 | 0.474 | 0.502 | 0.474 |

| | | | | | Large data | |
|---|---|---|---|---|---|---|
| Specification | Observed heterogeneity | Exports | Unobserved heterogeneity | | Baseline | Observation heterogeneity |
| Robustness test # | 4 | 5 | 6 | | 7a | 7b |
| | | | Group 1 | Group 2 | | |
| **Parameter:** | | | | | | |
| $H1$ | 0.259 | 0.228 | 0.124 | 0.346 | 0.217 | 0.242 |
| $H1 \mid year \leq 1970$ | 0.059 | 0.060 | 0.024 | 0.140 | 0.010 | 0.009 |
| $H1 \mid year > 1970$ | 0.459 | 0.395 | 0.224 | 0.552 | 0.424 | 0.475 |
| $H2$ | 0.872 | 0.864 | 0.977 | 0.856 | 0.961 | 0.955 |
| $H2 \mid year \leq 1970$ | 0.834 | 0.810 | 0.973 | 0.844 | 0.938 | 0.930 |
| $H2 \mid year > 1970$ | 0.909 | 0.918 | 0.981 | 0.867 | 0.985 | 0.981 |
| $\beta^n$ | 0.430 | 0.433 | 0.447 | | 0.387 | 0.387 |
| $\beta^c$ | 0.486 | 0.497 | 0.437 | | 0.351 | 0.355 |

*Notes:* The displayed figures are means of the parameters over the whole sample otherwise and over the sample up to 1970 and after 1970 if so indicated. In the mixture model, the estimated probability of an industry being in mix-class 1 (group 1) is 60 percent.

model using data starting in 1959. While there are some differences in parameter estimates, the temporal patterns of the $H1$, $H2$-figures and cartelization are very similar to those obtained using all the data.

**Robustness Test #3, Modeling of Law Changes:** The effect of the law changes on $H1$ and $H2$ may have been nonlinear. To allow for this, we modeled the law changes as a spline in $H1$ and $H2$, but kept the linear law index variable in the observation probabilities. The implied degree of cartelization is very similar to that obtained with our main specification. To further inspect the effects of law changes, we redefined our law index to incorporate the partial law reform of 1985 by allowing the index to increase by one-half from 1985 until the law change in 1988. Our results are largely intact.[28]

**Robustness Test #4, Observed Heterogeneity:** To gauge the robustness of our results on observed industry heterogeneity, we resort to data from Statistics Finland, which is available for 1974–1988 (see Appendix D for details on the data). Using

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[28] A further implication of a more hostile environment could have been that existing cartels change their contract to appear less harmful.

these plant-level data, we generate industry-level variables and match them to industries in our estimation sample. We reestimated our model including several industry characteristics into $H1$ and $H2$. We find that the estimated dynamics are not changed by the introduction of observed heterogeneity.

**Robustness Test #5, Role of Export Cartels:** Finland had a tradition of export cartels that started prior to World War II (Kuisma 1993, Fellman 2015); the largest manufacturing sectors were and are heavily export oriented. As we discuss in more detail later in this paper, the Finnish trade arrangements post-World War II were such that export cartels may have facilitated collusion in the domestic market; see also Schultz (2002) who has argued for the importance of such a mechanism. To study whether export activities explain our findings, we reestimated the baseline model allowing for trade variables in $H1$ and $H2$. 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.

**Robustness Test #6, Unobserved Heterogeneity:** There are ways to allow for unobserved heterogeneity in a HMM (Altman 2007), but no established best practice in an application like ours.[29] We opted for a mixture model with two mixture classes in the latent model. This choice leads to a finite mixture (nonhomogenous) HMM (see, e.g., Maruotti 2011 and Maruotti and Rocci 2012), where we allowed the constants in $H1$, $H2$, and $\tau^c$ to differ between the two classes. The resulting dynamics are displayed in Figures 5 and 6. The estimates imply that 60 percent of our observations belong to the larger mixture class, denoted mix-class 1 in Figures 5 and 6, and the remaining to the smaller mixture class, denoted mix-class 2. As the figures show, allowing for unobserved heterogeneity does not change the estimated dynamics. When predicting the fraction of industries with a cartel, we find that cartelization increases initially faster in the smaller mixture class. However, by the end of the estimation period, both latent classes are highly cartelized.

**Robustness Test #7, Definition of Markets:** We have estimated our base model and the model including industry characteristics using data generated by the more elaborate procedure assigning cartels to markets (see Section II and online Appendix E). Both specifications reproduce our dynamics, but with a slightly more pronounced spike in $H1$ in the early 1970s and a smaller decrease in $H2$ in the 1960s.

**Summary:** Summing up all models, Table 5 shows that the average $H1$ and $H2$ are relatively stable across models. This observation holds both when calculating these parameters over the sample period and when splitting the sample period into pre- and post-1970 subperiods. We also observe that the average $H1$ is clearly lower in the first than the second subperiod, as already indicated by Figure 2 (see also Figure 5 and online Appendix C). The average $H2$ is somewhat lower in the first than the second subperiod, but is persistently high. Our estimated average observation

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[29] It is also well known that such models may present severe computational challenges. We faced them as well.
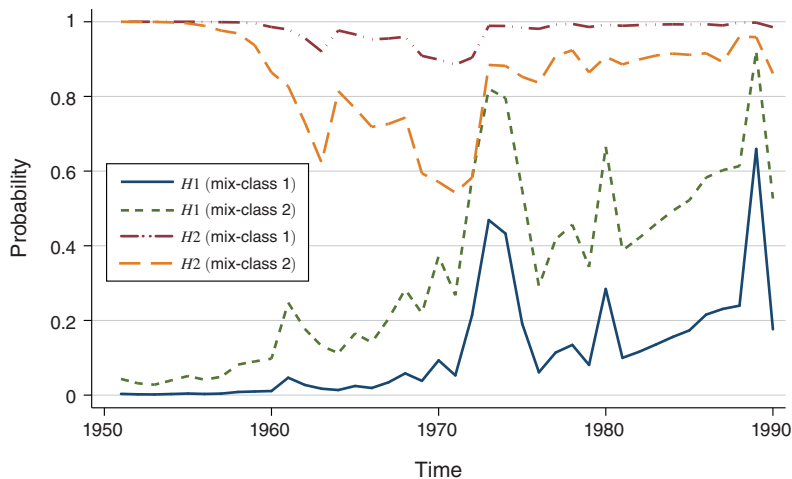
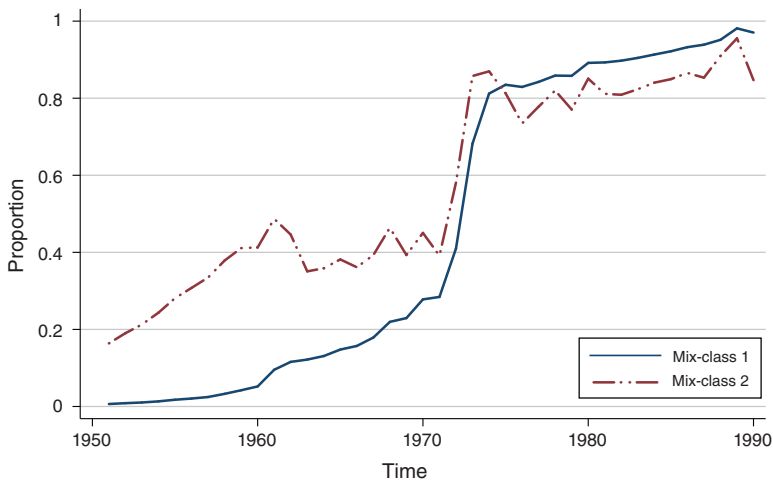FIGURE 5. DEVELOPMENT OF $H1$, $H2$ USING THE MIXTURE MODEL



FIGURE 6. ESTIMATED PROPORTION OF CARTELIZED MARKETS USING THE MIXTURE MODEL

probabilities $\beta^n$ and $\beta^c$ are stable across the models and close to each other. While not reported, the dynamics of these parameters over time are also very similar across the models.

### F. *Discussion*

We have shown that, save for some short-term fluctuations, the probability of establishing a cartel exhibits a positive trend and the probability of cartel continuation is persistently high. Combined with a relatively low initial probability of cartelization,

these estimates imply that the proportion of cartelized industries starts reasonably low but then starts to increase, leading eventually to an economy that is very cartelized. Misspecification of the model does not seem to drive these estimated dynamics.

This leaves us with two open questions: first, if cartelization was so widespread, were the registered manufacturing cartels actually harmful? Second, are there economic or institutional explanations for the increased cartelization in the 1970s and 1980s, especially in manufacturing? We address these questions here.

*Industry Profitability and Cartelization.*—We have already argued that there is qualitative and quantitative evidence supporting the view that the registered cartels were more than just harmless industry associations (see Section I and also HST forthcoming and Fellman 2015). To complement this evidence, we use the estimated HMM and industry data to show that the cartelization of industries is associated with better industry profitability.

To investigate whether the Finnish legal nationwide manufacturing cartels had an effect on profitability, we resort both to the industry data for the years 1974–1988 and our HMM, estimated using those industry data (see robustness test #4). A challenge we face goes to the heart of our exercise: we do not observe the cartel status for most of our industry-year observations. We overcome this challenge by resorting to the probability of cartelization generated using the parameters of the hidden process of our HMM. This probability is our prediction that a given industry in a given year actually has a cartel.

We calculate a proxy for the profitability of an industry (price-cost margin = value added/turnover), which we then regress on industry fixed effects, a linear time trend, and the estimated probability of the industry being cartelized. We obtain a positive and significant (at the 1 percent level) coefficient of 0.33 for the cartel variable (see online Appendix D).

While this exercise is not conclusive, it does suggest that these legal cartels were able to raise prices and is in line with our qualitative and other quantitative evidence that they were harmful.

*Economic Explanations for the Increased Cartelization in the 1970s and 1980s.*— Are there any economic or institutional explanations for the large jump in $H1$ in the early 1970s (seen in many but not all figures) and, more broadly, for the high degree of latent cartelization toward the late 1980s? There are several events that in our view are complementary and contributed to the observed jump and the increase in cartelization. One part of the explanation is events that increased firms' chances of communicating with each other. Another part increased the collusive benefits of communication. A third part of the explanation builds around increased threat of import competition, which further strengthened the incumbents' incentives to collude. We elaborate on these next.

**Increased Chances of Communication:** 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 potential explanation for the increase in cartelization and the spike in $H1$.

The trade between the Soviet Union and Finland was based on a centralized intergovernmental 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. This arrangement meant that more or less all firms interested in exporting to the Soviet Union had to participate in these meetings. Production alliances were also common (Ollus and Simola 2006, 20). The process seems to have been conducive for noncompetitive behavior and (possibly) cartel formation also in domestic markets.[30]

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 other members and make capacity allocation among the firms easier. These considerations are consistent with the estimated increase in cartelization in manufacturing.

The spike in $H1$ 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. However, as robustness test #5 showed, adding export variables to HMM does not change our main findings and does not remove the spike in $H1$.

**Collusive Benefits of Communication:** In 1968, 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 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, providing 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 (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'*" (see also Fellman 2010). While cartels may have been a source of inflation, the committee viewed competition policy as complementary to

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[30] This has not gone unnoticed in the literature. Ollus and Simola (2006, 21) conclude: "*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).

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.[31]

**Threat of Import Competition:** Finally, the EEC free trade agreement negotiated from the 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 lead to a series of discussions between the government and the industry, possibly leading to an increase in $H1$. 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. Shanahan and Fellman (2016) suggest that already the EFTA agreement, to which Finland became an associate member in 1961 and which imposed free trade in 1966, may have had similar consequences.

We conclude that these complementary economic and institutional events partly explain the higher degree of cartelization toward the late 1980s.

## V. Conclusions

Many cartels, including legal ones (e.g., Porter 1983 and Ellison 1994), are considered to be socially harmful. 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 an economic model of cartel formation and continuation and a Hidden Markov Model that allows for the special observation process of cartels. Our approach could be extended to allow the estimation of a structural model.

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. Over our sample period, the average annual probability of cartel formation is approximately 0.2–0.3 and that of cartel continuation approximately 0.8–0.9. Our estimates imply a cartel duration of 8.5 years and a steady-state degree of cartelization of 0.8–0.9. We give some potential explanations tied to both Finnish-Soviet trade and the increasing degree of corporatism in the Finnish society for the trend-like increase in cartelization and for the finding that by the end of 1980s, almost all Finnish manufacturing was cartelized. Our results suggest that deterring harmful cartels by competition policy is indeed of first-order importance

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[31] 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.

as our HMM estimates suggest that, in the absence of it, much of manufacturing would be cartelized.

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