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The Hidden Life of Cartels:
An Empirical Study on the Impact of Trade Liberalisation on Cartel Stability

Tove Forsbacka Karlsson (22880) Paula Höhne Tarragona (41347)

Abstract: Trade liberalisation is often argued to generate welfare gains by increasing competition. Market competition incentivises firms to develop new technologies and to streamline their productions, and forces inefficient firms out of the market. However, this effect risks being offset if firms increase collusion when trade barriers are removed. In this paper, we examine how a firm's ability to form and sustain a cartel is affected by a shock to trade liberalisation. We use data from the Swedish cartel register, which contains all registered cartels in Sweden during the period the register was active, 1947-1993. We use a hidden Markov model to estimate the probability that a cartel is formed and, once formed, the probability that a cartel manages to survive. To estimate the effect of trade liberalisation on cartel stability, we use a difference-in-difference model to analyse the impact of Sweden's accession to the General Agreement on Tariffs and Trade (GATT) in 1950. Our results show that cartels have a high probability of surviving, which increases with trade liberalisation. This highlights the importance of complementing trade policies with effective competition legislation.

Keywords: cartels, competition, trade liberalisation, hidden Markov model

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1 Introduction

Trade liberalisation is often argued to increase competition and thereby to improve welfare. Market competition is widely seen as a cornerstone in ensuring economic growth, efficiency and innovation. When competitive pressure increases, firms are incentivised to develop new technologies and to streamline their production, and inefficient firms are forced out of the market (Hellwig and Hüschelrath, 2017). However, reduced trade barriers may also incentivise firms to join efforts to create cartels in order to protect themselves from competition. Increased collusion could then potentially offset the expected benefits from trade liberalisation. In this paper, we examine the effect of a shock to trade liberalisation on cartel stability, by studying how the probabilities that cartels are formed and sustained are affected.

Cartels have been difficult to study empirically (Connor and Bolotova, 2006). Today, cartels are prohibited due to the adverse economic effects they have on competition, and therefore they have to act in secret. Much of the current knowledge on cartels is consequently based on studies of discovered illegal cartels, which could potentially be very different from cartels that manage to escape unnoticed. The discovered cartels might be overrepresented by the more harmful ones, since competition authorities are likely to focus their effort on finding these (Levenstein and Suslow, 2011), or by the least capable ones, if these are less able to hide from authorities (Harrington and Chen, 2006). In this paper, we overcome the bias that illegal cartel data contains by using data on legal cartels. Not long ago cartels were looked upon with more benign eyes, and were allowed to operate freely. In Sweden, cartels were prohibited in 1993 and between 1947 and 1993, cartels had to be recorded in an official cartel register. We use the cartel register's data (the Le Coq and Marvão dataset) and are thereby able to study the behaviour of Swedish cartels to a more detailed and broader extent than has previously been done.

To examine the effects of trade liberalisation on cartel stability, we first need a reliable measure of stability. Cartel stability can generally only be observed with some noise. For example, based on the register data it is sometimes hard to observe at what time a cartel breaks apart, since this may have happened before the cartel was recorded to have ended. Therefore, we use a hidden Markov model which allows us to take into account that there are periods where we cannot observe whether there were any active cartels in a particular industry. By applying this model, and estimating it with a maximum likelihood estimation, we determine the probability that a cartel is formed and, once formed, the probability that a cartel manages to survive. We then use these estimated probabilities to study the effects of trade liberalisation on cartel formation and survival, using a difference-in-difference model to analyse the impact of Sweden's accession to the General Agreement on Tariffs and Trade (GATT) in 1950, today part of the World Trade Organisation (WTO). As a result of Sweden joining the GATT, tariffs across a wide number of industries were lowered simultaneously, exposing Swedish firms to a sudden increase in international competition, and at the same time, enabling Swedish firms to reach a larger international market. We study how cartelisation in the industries where tariffs were lowered was affected by the shock, contrasting the change to the industries that remained protected.

We find that there is a relatively low probability that new cartels are formed in industries where no cartel existed before, but once formed, cartels have a high probability of persisting. Our results show that trade liberalisation is associated with an increase in the probability of cartel survival of 2.8 percentage points, while the probability of new cartels forming is not notably affected. This implies that integration with international markets strengthened incentives for firms to maintain their cartel contracts. This stands in contrast to the expectation that trade liberalisation increases competition.

Our contribution to the literature is threefold. Firstly, we are the first to study cartel stability in Sweden. By estimating the probability of cartels forming and surviving, we contribute with insights into the behaviour of cartels. Secondly, by using a larger and richer dataset, we are able to study a greater share of the economy compared to previous studies. Thirdly, we empirically show that cartel stability increased when trade barriers were greatly reduced. Our analysis provides important insights into the inherent stability of cartels in a changing economic environment. As our results suggest that cartelisation had been high in the absence of competition policy, antitrust efforts are of vital economic importance, especially in internationally integrated economies. Considering that cartel stability increases with trade liberalisation, trade policy cannot be used as a substitute for competition policy. Rather, effective competition policy needs to be in place to ensure that the benefits of trade liberalisation are realised.

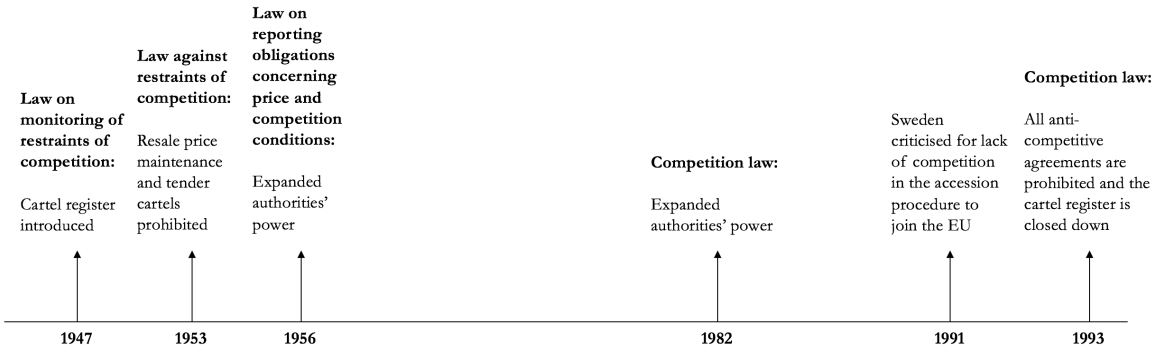
Our paper is structured as follows. In *Section 2*, we outline the evolution of Swedish competition policy in the second half of the 20th century and describe the Swedish cartel register. In *Section 3*, we review the previous literature on cartel stability. We draw from the existing theory in *Section 4*, where we construct our theoretical framework, in which we assess the constraints that must hold for a cartel to form and survive. *Section 5* outlines our empirical method, and describes our estimation strategy. We present our results in *Section 6*, and discuss implications and limitations in *Section 7*. Finally, *Section 8* concludes.

2 Competition policy in Sweden 1947-1993

2.1 Legal and economic environment

Over the course of the 20th century, the view on cartels changed remarkably in Sweden. Before the world wars, there were no restrictions on anti-competitive agreements between firms. Cartels were even considered to have a positive impact on the economy, in particular with regards to large scale production. Firms with high capital costs would find it hard to cancel production when demand was low, resulting in overproduction and falling prices. Some, therefore, argued that by colluding, firms could regulate production to better meet demand, which would be beneficial for society at large (Konkurrensverket, 2004). Over time, however, the notion that market competition generates efficiency and economic growth steadily took hold, and competition legislation was gradually implemented and tightened. *Figure 1* shows the development of competition policy in Sweden. This development was by no means specific to Sweden, rather it reflected a larger shift in market economies

Figure 1: Development of competition policy in Sweden 1947-1993



all over Western Europe and North America (Sandberg, 2016).

The Swedish government started to take an interest in the impact of cartels on the economy in the beginning of the 20th century. The government ordered several investigations on the market impact of monopolistic organisations and on collaborations between firms. In 1919, the Customs Duties and Treaty Committee found that essentially all industries of economic importance were affected by cartels and, in 1920, the Trust Legislation Committee concluded that the impact of monopolistic organisations on prices and turnover was so great that the Commission urged the government to intervene (Trustlagstiftningskommittén, 1921). As a result of these investigations, the *Law on investigation of monopolistic enterprises and associations* was introduced in 1925. The government was given the power to investigate the economic impact of monopolistic organisations and to suggest measures to address the issues they found. The law did not, however, include any restrictions on competition-restrictive practices. In 1940, a committee consisting of industry organisation experts concluded that cartels accounted for 39 percent of all production in Sweden and that profitability was significantly higher in cartelised industries (SOU 1940:35).

Registration and monitoring of cartels began after World War II. In 1945, the Commission for Planning of the Post-War Economy proposed that a public register of all active cartels should be introduced, to increase the understanding of how common cartels were and what impact they had on the economy (SOU 1945:42). As a result, the *Law on monitoring of restraints of competition*[1] was introduced in 1947 and an official cartel register was established. The objective of the register was to monitor and deter anti-competitive agreements through self-regulation (Berg, 2012). Upon request, firms were required to register all anti-competitive agreements they had entered into, concerning prices, production, and turnover. Failing to register was punishable with fines or imprisonment.

In the 1950s, legislation on cartels was gradually tightened. By 1951, the Commission of New Establishment concluded that competition was heavily restricted by private actors, even though the number of anti-competitive agreements had decreased since the introduction of the cartel register

[1] Lag om övervakning av konkurrensbegränsning inom näringslivet (SFS 1946: 448)

(SOU 1951:27-28). The restrictions against cartels were tightened when the *Law against restraints on competition*[2] was implemented in 1953. Two types of anti-competitive agreements were banned: tender cartels and retail price maintenance. Prior to the prohibition, retail price maintenance had been common while tender cartels had been very rare. Additionally, authorities were given more power to counteract restraints on competition. They were given the right to intervene by negotiating with cartels if the agreement was found harmful to society, for example if the agreement affected prices in an abusive way, restricted other firms' operation or hindered technological development. Furthermore, the law allowed firms to report anti-competitive agreements that they were not a part of to the cartel register, enabling firms to report cartels that were competing in the same industry. Two years after the law was implemented, the Price Control Commission concluded that competition was a more efficient tool to fight inflation than price regulations, which were widely used in Sweden at the time. This resulted in the implementation of new laws in 1956, with the objective to replace price controls with competition. The new legislation included the *Law on reporting obligations concerning price and competition conditions*[3], which built on the legislation from 1953.

In 1982, the *Competition law*[4] was implemented and resulted in a more restrictive policy towards anti-competitive agreements. In particular, authorities were given the power to intervene in competition-restricting agreements that were considered harmful, for example if the agreement inhibited efficiency, affected prices or prevented other businesses from operating on the market. Hence, even though there was no ban on price, quota and market sharing cartels, the Market Court could counteract and even dissolve cartel agreements through negotiation (Konkurrensverket, 2004). As a consequence, the cartels registered after the *Competition law* was introduced were of a more harmless character, mainly taking the form of exclusive agreements or transfer agreements with a competition clause. The number of agreements that were registered between 1983 and 1988 was also significantly lower compared to the decade before (Konkurrensverket, 2004).

Sweden applied to become a member of the European Union (EU) in 1991. In the accession process, Sweden was criticised by the European Commission for having weak competition legislation. By introducing the second *Competition law*[5] in 1993, Sweden fully incorporated the European competition law and prohibited all types of anti-competitive agreements. Thereby, Sweden went further in the implementation of the EU competition law than any member country. Fines were raised but imprisonment was removed as a potential sanction, since it was no longer considered adequate. At the same time as cartels were banned, the cartel register was closed down.

[2]Lagen om motverkande I vissa fall av konkurrensbegränsning inom näringslivet (SFS 1953:603)
[3]Lag om uppgiftsskyldighet rörande pris och konkurrensförhållanden (SFS 1956:245)
[4]Konkurrenslag (SFS 1982:729)
[5]Konkurrenslag (SFS 1993:20)

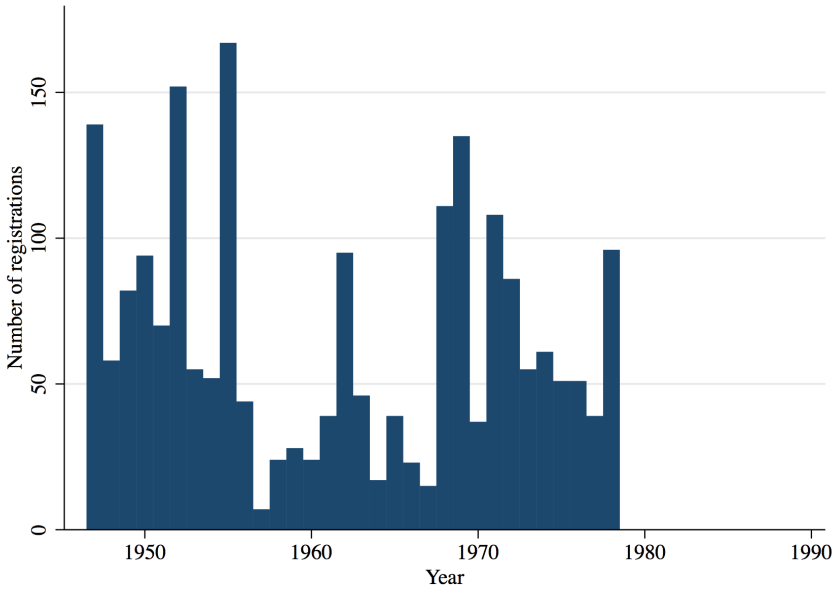
2.2 The Swedish cartel register

The Swedish cartel register and the agreements it contains provide a unique opportunity to study cartels in Sweden in the 20th century. Between 1947 and 1993, collusive agreements between firms were recorded in the official Swedish cartel register. There were four ways in which an anti-competitive agreement could be identified and recorded. Firstly, general requests were sent to firms and industry organisations. Secondly, the authority could identify anti-competitive agreements based on information in newspapers and industry journals. Thirdly, special industry investigations were conducted where the register investigated firms in certain industries. Lastly, from 1953 onwards, individual firms, usually firms that were not part of any cartel, could inform the authorities of collusive agreements between other firms (Sandberg, 2016). Once identified, the register authority sent out a standardised form to the involved firms, asking whether they were part of any anti-competitive agreement. The form contained questions about the agreements, price lists, meetings, minutes, and members. The register required firms to inform them if the agreement had been cancelled, to keep the information in the register up to date, and they also regularly approached firms in the registered cartels directly. Firms were also required to inform the register of any modifications, for example, if a new firm joined an agreement. This implies that if a cartel was modified, it did not need to register as a new cartel. Today, the agreements are archived and kept in the Swedish National Archive in Arninge (Konkurrensverket, 2004).

The cartel register contained a wide variety of contracts. The term "anti-competitive agreement" was never defined, nor did the register evaluate whether a registered contract actually should be defined as a cartel. Consequently, the register includes agreements whose economic impact was limited. In our analysis, we are only interested in agreements that fulfil the definition of a cartel: "any horizontal agreement on pricing (including margins and discounts), market sharing (including quotas, discounts and margins) or other restrictive practices, at local, national or international level" (Le Coq and Marvaõ, 2019). Based on this definition, 2,100 agreements are classified as cartels. For instance, agreements concerning vertical collusion or agreements with no identifiable competition-hindering clause are not included in the data we use.

During the first year that the register was active, we find that 139 cartel agreements were recorded. Out of these agreements, 70 had been active long before the register was introduced. The earliest cartel in the register was a transportation and distribution cartel that started in 1906. Over the whole period of the register's activity, on average 44 cartels were registered every year, although the number of registrations varied greatly over time: in 1955 there were 167 registrations, while two years later, in 1957, only 7 cartels were registered. Registration was particularly high in the early 1950s and the early 1970s. The last recorded cartel was registered in 1978. *Figure 2* shows the number of registrations over time. When the register closed down in 1993, it contained 18 cartel agreements that were still active. The industry investigations led to many cartels in a particular industry being registered at once. However, the pattern of initial registrations suggests that "authorities undertook investigations more or less randomly" (Sandberg, 2016).

Figure 2: Registration activity of the Swedish cartel register



Note: Annual number of cartels registered in the Swedish cartel register. Authors' own based on the Swedish cartel register (Le Coq and Marvão dataset).

Once a cartel agreement was terminated, firms were generally inclined to deregister the agreement from the register as soon as possible after they had been terminated. Firms did not want to appear in the register longer than necessary as there was a general uncertainty about whether cartels would remain legal, particularly during the 1950s when the competition law was gradually tightened. Nevertheless, many agreements remained in the register after the agreement was cancelled, for example if there had been a merger or an acquisition, or if the contractors had gone out of business.

Most cartels appeared in the manufacturing industry. Within the manufacturing sector, cartels regulating dairy products were the most common, with a total of 136 cartels operating in the dairy industry over the period. Manufacturing is followed by wholesale and retail, and the manufacturing and retail cartels were often closely linked (Sandberg, 2016). Cartels were also common in construction, agriculture, and personal services. For example, the cartel register includes various cartel agreements among hairdressers, driving schools, and funeral services providers.

The registered cartels vary greatly in size and scope (for an example of an actual cartel agreement, see *Appendix A*). The median number of firms in a cartel was three, and the majority of the agreements included four firms or less. However, there were also some much larger cartels containing thousands of firms. Most of these large cartels appeared in markets with industry organisations that often would negotiate and arrange cartel contracts for their members (Sandberg, 2016). One hundred cartels had more than 1,000 members and only three out of these were not part of an industry organisation. The largest cartel included over 30,000 firms (a honey cartel), while some of the other larger cartels were found in the forestry industry and hairdressing.

International cartels and agreements solely concerning the Swedish export market did not have to register. However, if an international cartel had any agreement that concerned the Swedish market they were subject to registration (Sandberg, 2016). The register did not include cartels in the banking and insurance sector, since those industries were monitored by the Bank and Insurance Inspection, respectively (Konkurrensverket, 2004).

Table 1: Summary statistics for registered cartel agreements

	Count	Percent	Total
Price clause	1,110	53%	2,100
Quota clause	929	44%	2,089
Market division clause	1,633	78%	2,097
Sanctions	382	43%	892
Voting system	496	24%	2,093
Dispute resolution system	1,210	56%	2,090
Meetings	531	25%	2,087
Industry organisation	846	46%	2,100

Note: Summary statistics over the most common clauses in the cartel agreements in the Swedish cartel register. Note that there are 2,100 cartels in total, meaning that information on some clauses is missing. Author's own based on the Swedish cartel register (Le Coq and Marvão dataset).

The content of the agreements registered display great diversity, and we present some summary statistics in *Table 1*. When it comes to the type of collusion, we distinguish between three main types: market division, prices, and quotas. Most cartels used a combination of different anti-competitive agreements, with 70 percent using a combination of at least two of the three types of collusion. Market division includes dividing markets according to regions, products or customer groups, and it was by far the most common type, with 78 percent of all cartel agreements including a market division clause. This was followed by collusion based on price fixing and quota setting. The agreements would also often describe how firms within the cartel would regulate their actions, and especially how to deal with violations of the contract. Almost 400 of the registered cartels explicitly stated how violations should be handled. If a firm broke the contract, the most common forms of punishment were fees to be paid by the defecting firm or suspension from the cartel. Furthermore, firms in the cartels often attempted to ensure their stability by having regular meetings or formal voting systems. Over 60 percent of the registered cartels used such coordinating mechanisms. Overall, the agreements found in the register reveal the wide scope and variety of competition-restricting agreements that existed in Sweden.

3 Previous literature

A cartel constitutes a clear-cut coordination problem and various economists have studied the stability of cartels. Bain (1959) notes that from its formation, a cartel continuously has to overcome challenges in the form of internal coordination and entry of new firms on the market. Stigler's (1964) seminal paper provides the first rigorous model showing that to sustain a cartel, the member firms must be able to detect when a firm deviates and punish free-riding. Modelling the inherent incentive problem the cartel faces, Stigler distinguishes between different types of collusion, arguing, for instance, that collusion based on market shares is the easiest to sustain. Green and Porter (1984) capture Stigler's model of collusion in a game theoretical framework. They show how collusion can be sustained if deviations are punished with price wars. Tirole (1988) contributes with a simpler and more accessible version of the Green and Porter model. Motta (2004) uses Tirole's model to analyse how cartel stability is affected by structural factors, price transparency and coordination mechanisms.

A number of theoretical studies have analysed how cartels are affected by international competition and trade liberalisation. Davidson (1984), Fung (1992), and Rotemberg and Saloner (1986) all examine the effects of trade liberalisation on cartel stability in a setting where foreign firms compete with domestic firms on the domestic market. These models deal primarily with changes in trade barriers that protect the domestic market (e.g. import tariffs). Davidson (1984), for example, models cartel stability in a repeated game, and finds that low tariffs lead to market structures where cartels are more likely to appear. Other studies examine cartel stability in a setting where rivalling firms compete on several markets. This is known as multimarket contact. Bernheim and Whinston (1990) find that cartel stability increases when firms compete on several markets, since deviations will be punished on all markets. While this literature initially focused on different product markets, it has also been applied to different geographical markets. Lommerud and Sørgard (2001) and Schröder (2007) build on the multimarket contact theory and consider a domestic firm colluding with a foreign firm, where both firms agree to stay out of each other market. Either firm breaking the agreement will result in intense cross-border competition. The extent to which each firm can gain access to the other's market in the punishment phase depends on the level of trade barriers. They find that lower trade barriers increase the incentives to deviate, but also that the severity of punishment increases. Similarly, Bond and Syropoulos (2005), in a setting where both domestic and foreign firms are exporting to each other, find that decreases in trade barriers can reduce welfare as a result of increased collusion.

The extent to which firms manage to form and sustain cartels in reality is an empirical question. The empirical literature on this is thin due to the lack of available data on cartels (Connor and Bolotova, 2006). Data on illegal cartels that have been uncovered and prosecuted by competition authorities risk being a small and unrepresentative sample of the cartel population, implying potential biases in results. There is no consensus regarding the direction of this bias, although some authors have tried to estimate it (e.g. Harrington and Wei, 2017). Regardless of the direction of the bias, one should be careful to draw strong implications from studies on discovered illegal cartels.

The datasets on legal cartels generally stem from two sources. Early studies use data from cartels exempted from prohibition, usually export cartels (see e.g. Dick, 1996, and Suslow, 2005 using an exemption in the US in the inter-war period). More recently, researchers have begun to use data from official national cartel registers at times when cartels were legal but monitored by authorities. The availability of datasets on legal cartels is limited, and conditioned by the existence of cartel registers in times when countries had a more permissive attitude towards cartels. The literature on cartel stability using legal cartel data has sprung to life recently, with data from some cartel registers becoming available as confidentiality issues regarding these registers cease to be important in the new era of stricter competition policy (Petit, 2017). Although cartel registers existed in all Nordic countries, to date there has been surprisingly little research on them. Only a few descriptive studies have been carried out on the Swedish cartel register, highlighting some of the features of the registered cartels (see e.g. Sandberg,2016; Konkurrensverket, 2004). Fölster and Peltzman (1997) study the effect of cartels on productivity, prices, and output, using a subset of manufacturing industries in the Swedish cartel register.

Besides data availability issues, estimating cartel stability empirically may not be straightforward. Some authors examine cartel stability through the lens of cartel duration, while others use departure from the collusive equilibrium to estimate cartel stability. Surveying the literature based on reported contract duration, Levenstein and Suslow (2006) find that there is great variation in how long cartels manage to survive. Using data on both legal and illegal cartels in Germany, Haucap, Heimeshoff and Schultz (2010) find that legal cartels on average last longer than illegal ones. A number of studies have also used hazard probability models to identify determinants of cartel breakdown (see e.g. Dick, 1996; Suslow, 2005; Hellwig and Hüschelrath, 2017). Among these empirical studies, Dick (1996) and Connor and Zimmerman (2005) find cartels involving foreign firms to be longer-lasting than purely domestic cartels.

A few studies use Markov models to estimate the collusive status of an industry. Porter (1983), Lee and Porter (1984), and Ellison (1994) all study the Joint Executive Committee, a railroad cartel in the US in the 1880s. Porter and Lee (1984) and Porter (1983) use a set up with two hidden states: there can either be collusion or price war. Extending on these studies, Ellison applies a model of hidden regimes with Markov transitions to identify secret price cuts. Hyytinen, Steen and Toivanen (2018) use a hidden Markov model to examine the behaviour of cartels and the cartelisation of the Finnish manufacturing industry. The hidden Markov model allows them to account for the fact that there are gaps in their data in terms of actual cartel activity. They find that there is a 23 percent average probability that a cartel is formed, given that no cartel existed the previous period, and that there is a 88 percent average probability that a cartel continued to exist, given that a cartel existed the previous period. Harrington and Wei (2017) find a similarly high probability that a cartel survives another year (83 percent) on a study of illegal discovered cartels in the US.

In this paper we follow the approach of Hyytinen, Steen and Toivanen (2018), and use a hidden Markov model to estimate cartel stability in Sweden. We use these estimates to study the effect

of trade liberalisation on cartel stability. To our knowledge, there have been no previous empirical studies examining how cartel stability is affected by trade liberalisation. We bridge this gap in the literature by studying how cartel formation and survival were affected by a large shock to trade liberalisation, which signified tariff cuts across a large number of sectors.

4 Theoretical framework

We model the incentives to collude as a repeated game with infinite horizon, considering an industry with n active firms. The firms can increase profits by cooperating to charge a higher price (ideally the monopoly price), produce a lower quantity or divide markets between them, and then split the revenues. If the firms collude, each firm can get a share of profits that exceeds what they would get under unrestricted competition. Whether a cartel is formed or not will depend on the *Participation Constraint*. We base this constraint on Bigoni et al. (2015). Once a cartel is formed, the *Incentive Compatibility Constraint* must hold for the cartel to survive. This constraint is based on the model by Motta (2004), although we adapt it to better fit the legal environment in Sweden between 1947 and 1993.

4.1 Cartel formation

A firm decides whether to form a cartel by evaluating the gains from colluding, π_i^m, and comparing that to the profits it would get under unrestricted competition, π_i^n. The discount factor is denoted $\delta \in [0, 1]$, defined as $\delta = \frac{1}{1+r}$ where $r \geqslant 0$ is the real interest rate which is assumed to be constant over time. To this framework, we add a transaction cost, $\tau \geqslant 0$, which represents the coordination and negotiation costs associated with reaching an agreement. This yields the following Participation Constraint:

$$\sum_{t=0}^{\infty} \delta^t \pi_i^m - \tau \geqslant \sum_{t=0}^{\infty} \delta^t \pi_i^n, \quad i = 1, ..., n. \tag{1}$$

A firm will participate in a cartel if the present value of profits under collusion is greater than the present value of profits under unrestricted competition. It is easier for firms to form a cartel if they are patient and if transaction costs are low. Based on the Participation Constraint we deduce the impact of trade liberalisation on cartel formation.

Increased transaction costs: When trade barriers are high, primarily domestic firms will operate on the domestic market. Trade liberalisation implies that the domestic market will be opened up to foreign competitors, implying that cartels will be harder to form. The higher the number of firms on the market, the higher the transaction cost, τ , to reach an agreement. Additionally, the transaction cost will be higher for cartels consisting of firms from different countries.

Collusion as a protective measure: At the same time, the increased competition implies that the profits under unrestricted competition, π_i^n, decrease. Hence, firms have higher incentives both to form cartels with other domestic firms to protect themselves from foreign entrants, and to form

cartels with foreign firms to stay out of each others' markets and avoid cheap imports undercutting domestic prices.

4.2 Cartel survival

Once a cartel has been formed, the cartel will only survive if the incentives to collude are stronger than the incentives to deviate. In essentially all collusive solutions, firms face an incentive to unilaterally deviate from the collusive equilibrium. By undercutting its competitors, a firm can capture a larger market share and increase its individual profit. Hence, for collusion to be sustained, cheating must be retaliated. The ability to retaliate differs between legal and illegal cartels. Most theoretical frameworks focus on illegal cartels and their need to create credible punishment strategies. In illegal cartels, the cartel members need to enforce the contracts themselves, which is usually done with aggressive market behaviour, such as price wars (Bigoni et al, 2015). Legal cartels have the important advantage that cartel agreements are enforceable in court. We construct a model of legal cartels with the payoff from collusion on the left hand side and the payoff from deviation and subsequent punishment on the right hand side. We let π_i^d represent the one-time profit firm i would get from deviating, given that all other firms collude. Punishment can take three forms. $F(\pi_i^d)$ represents a fee the deviating firm would have to pay for cheating and is a function of how much harm the deviating firm caused the other firms. Punishment can also take the form of expulsion from the cartel. When a firm is excluded, it earns the profits from unrestricted competition, π_i^d. c represents the litigation costs if the contract is enforced by arbitration or in courts. A collusive equilibrium should fulfil the requirement of a *Nash equilibrium*, such that no firm has any unilateral profitable deviation. Thus, collusion will only occur if the following Incentive Compatibility Constraint holds:

$$\sum_{t=0}^{\infty} \delta^t \pi_i^m \geqslant \pi_i^d + \delta \left[\sum_{t=0}^{\infty} \delta^t \pi_i^n - F(\pi_i^d) - c \right], \quad i = 1, ..., n, \tag{2}$$

where $F(\widetilde{\pi}_i^d) > F(\pi_i^d)$ for $\widetilde{\pi}_i^d > \pi_i^d$.

Cartel stability in the Incentive Compatibility Constraint is affected in two ways by trade liberalisation, going in opposite directions.

Increased competition on the domestic market: Trade liberalisation reduces the entry barriers for foreign firms to operate on the domestic market, which can hurt cartel stability in two ways. Foreign firms can undercut the domestic cartel and take market shares, decreasing the domestic cartel's collusive profit π_i^m, or the foreign firms can join a domestic cartel, increasing the number of firms, n, and thus decreasing each firms' collusive profit. Either action would destabilise the domestic cartel, threatening cartel survival.

Multimarket contact: While all firms on the domestic market are affected by the tightened competition on domestic markets, firms with cross-border activities will also see increased opportunities to interact and collude with foreign firms. When trade barriers are removed on both exports and imports, more domestic firms will start competing on foreign markets and more foreign firms will enter the

domestic market. Hence, the probability that two firms, from the same or different countries, compete against each other on several markets increases. To illustrate how multimarket contact increases the incentives to collude, consider two firms competing on two different markets. If the markets were treated separately, the Incentives Compatibility Constraint from *Equation 2* would hold. However, any deviation on one market would be met by retaliation on both markets in a multimarket contact equilibrium. Hence, any firm conspiring to deviate would do so on both markets simultaneously. This yields the following Incentive Compatibility Constraint, where firms either collude on both markets or deviate on both markets:

$$\sum_{t=0}^{\infty} \delta^t (\pi^m_{i,dom} + \pi^m_{i,for}) \geqslant \pi^d_{i,dom} + \pi^d_{i,for} + \delta \left[\sum_{t=0}^{\infty} \delta^t (\pi^n_{i,dom} + \pi^n_{i,for}) - F(\pi^d_{i,dom} + \pi^d_{i,for}) - c \right] \quad (3)$$

Once the two markets are pooled together, this results in a more relaxed Incentive Compatibility Constraint, thereby increasing the incentives to collude (Bernheim and Whinston, 1990).

5 Empirical analysis

To study cartel stability, the ideal data would have been a dataset on the state of collusion for each industry in each year. Based on the Swedish cartel register we can only observe the activity of some cartels for some years. Firstly, the number of registered agreements is likely to be an underestimation of the number of cartels, since cartels only had to be registered upon request by the authorities. Hence, we need to take into account that cartels might have existed that are not included in the data. Secondly, the collusive state of a cartel might not be obvious from the information in the register. In particular, it is hard to observe when a cartel broke apart, implying that it might not have been active during the whole period that the contract spanned. We are interested in the years that the cartel was operative and actually colluded, i.e. when the Incentive Compatibility Constraint held. To overcome these issues, we make use of a hidden Markov model.

In this section, we first describe the method we use to map cartel activity to different industries over time. We analyse for each cartel and for each year whether it was active or inactive based on the Le Coq and Marvão dataset on the Swedish cartel register, and then we map each cartel to an industry. We largely follow the approach by Hyytinen, Steen and Toivanen (2018) but due to differences in data we construct cartel birth and death slightly differently. Second, we present the hidden Markov model that we use to estimate the probability of cartel formation and survival, again following Hyytinen, Steen and Toivanen (2018). Third, we describe the maximum likelihood estimation that we use to find these probabilities. Finally, we outline the difference-in-difference approach that we use to analyse how trade liberalisation during Sweden's accession to the GATT affected cartel formation and survival.

5.1 Cartel activity

For each cartel, we identify six different types of events. We have information about the registration and deregistration year for each cartel. For some cartels, we also have information about when the cartel contract actually started and when it ended. Sometimes we also have information on when the cartel was known to be active otherwise (first known to be active or last known to be active), e.g. through some communication with the register regarding contract changes or through news press. To map the collusive states, we assign each cartel in each year either C for cartel activity, N for no cartel activity, or U for unknown.

Cartel birth: We denote the birth of the cartel as the earliest out of the year the contract started and the year the cartel was first known. In case both are missing, the cartel is assumed to be born the year it was registered. The cartel birth is marked by C. If cartel birth takes place before it is registered, we assume that there was cartel activity during all years between these years and we mark this period by C. This is motivated by the fact that the cartel would have stated a later date for the contract starting if the cartel had not been active during this period. In case the registration occurs before the contract start, the firm registers an agreement that is about to start in the future and that has not yet been activated. The registration date for these observations are marked by N, and so is the period until the year the contract starts. The year before a cartel birth, the cartel is assumed to be non-operative, N.

Cartel death: We denote the death of the cartel as the earliest out of the year the contract ended and the deregistration year. If a cartel contract is terminated a different year than it is deregistered, we assume that the cartel is not operative during the period between the two events and we mark this period by N. The year before the cartel's death, the cartel is assumed to be operative, C.

Any other period a cartel was known to be active is marked by C. For all other periods, we assign the state U, for unknown. This approach first results in a panel of year-cartel pairs for the years between 1946 to 1993. A few cartels were born before the register started. We include them in the analysis but we only consider their activity from 1946 onwards.

After mapping the activity for each cartel, we assign each cartel and its activities to one of the industries in the Swedish economy. Using NACE code classifications at the four digit level, we consider 578 industries in total, excluding industries such as civil service, defence, and public education, since there were no cartels in these industries due to the lack of private businesses. We also exclude the financial and insurance sectors, since these industries were regulated by a separate authority. We map each cartel to an industry by classifying each cartel with a four digit level NACE code based on the qualitative information about the products covered by each cartel in the register.

If a cartel colluded on products in more than one industry, we classify it to all industries it was active in. For example, a cartel that had an agreement regarding both plastic goods and industrial chemicals is mapped to both the plastics and the industrial chemicals industry. If there is at least one cartel active in an industry in a given year, we mark the industry as cartelised, C, that year. An industry is only marked to have no cartels, N, if all existing cartels in that industry were observed to be inactive that year. In all other cases, the cartelisation status of the industry is marked as unknown, U. The cartels in the register cover 279 industries, almost half of the studied industries. We also include the industries where we have no observed cartel, totalling 306 industries, in order to include both industries where cartels were formed and industries where, potentially, no cartel was ever formed. Once we have mapped cartel activity to each industry, we obtain a balanced panel dataset of industry-year observations, containing 27,744 observations (578 industries over 48 years).

As an example, consider the toy industry, which had two cartels appearing in the cartel register. We illustrate our mapping procedure in *Figure 3*. One of the two cartels was registered in 1968, the same year as the contract started. The contract ended and the cartel was deregistered in 1984 and there was no information about any other cartel activity. This results in the cartel birth in 1968 and cartel death in 1984 being clearly observable. The birth year is marked by C and the year before the birth is marked by N. The death year is marked by N, succeeding a C-state. The second cartel is considered to be born in 1966, since its contract started in 1966 and there was no information about when the cartel was first known. The cartel was registered in 1968. Hence, the years 1966-1968 are marked as C and the year before birth, 1965, is marked by N. The contract ended and was deregistered in 1968, implying that 1968, normally, would have been an N-state. However, since registration and deregistration took place in the same year, this coincides with a C-state and when this happens we let the C-state supersede. The cartel was last known to exist in 1982, long after it was deregistered. This year is marked by C. The rest of the years are marked by U. In the second step, when we map cartels to industry level, years that contain any C-state are marked by C. In this particular industry, there were no years where both cartels were known to be inactive, resulting in no N-states. All other years are marked by U.

Figure 3: An illustrating example of how we map cartel activity to industry level

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Cartel 1	U	U	**N**	**C**	U	U	U	U	U	U	U	U	U	U	U	U	U	U	**C**	**N**
Cartel 2	**N**	**C**	**C**	**C**	U	U	U	U	U	U	U	U	U	U	U	U	U	**C**	U	U
Industry	U	**C**	**C**	**C**	U	U	U	U	U	U	U	U	U	U	U	U	U	**C**	**C**	U

Based on this panel data of industry-year pairs, a number of transitions can be observed, on which the identification and estimation of Markov models typically rely (Hyytinen, Steen and Toivanen, 2018). Since each observation can take on three possible values: C, N, and U, there are nine possible transitions. Our parameters of interest are cartel formation and cartel survival. We measure cartel formation as the probability that a cartel is formed in an industry, conditional on there being no

cartel activity in the previous period (an $N - C$ transition), and we measure cartel survival as the probability of a cartel continuing to exist in an industry, conditional on there being cartel activity in the previous period (a $C - C$ transition).

5.2 Hidden Markov model

We follow the approach of Hyytinen, Steen and Toivanen (2018) and use a hidden Markov model, consisting of an underlying *hidden process* and an *observation process*. A Markov model consists of a stochastic sequence of events with changing states, where the probability of future event depends only on the current state. In a hidden Markov model the states of the sequence are only partially observed. The hidden process is assumed to follow a Markov chain, while the observed process is independent, conditional of the hidden sequence (Altman, 2007). Hidden Markov models are used when the actual state is not directly observable. Considering our case, the cartel register only provides limited information that allows us to conclude whether a cartel was active or not during some years, while, for other years, we cannot draw any conclusions about cartel activity. The hidden Markov model allows us to study the dynamic process of cartels forming and continuing to exist, despite the fact that the data on the real activity of cartels is limited. We use a second order hidden Markov model that considers the current and the preceding period. A model of the second order is necessary to identify cartel formation (a cartel exists this period but no cartel existed in the industry the preceding period) and cartel survival (a cartel exists this period and it also existed the preceding period).

The hidden process is the actual state of the industry: whether there is an active cartel or not. The hidden state, Z_{it}, can take on two different values: an active cartel, C, or no active cartel, N, giving the state space $S_Z = \{C, N\}$. This results in four possible transitions. We let $P1_{it}$ denote the probability that a cartel is formed, conditional on there being no cartel in the previous period, and $P2_{it}$ is the probability that a cartel continues to exist conditional on there being a cartel in the previous period. $(1 - P1_{it})$ and $(1 - P2_{it})$, which we do not focus on in this paper, are the probabilities that no cartel is formed, conditional on there being no cartel in the previous period, and the probability that there is no cartel, conditional on a cartel existing the period before. The transition probabilities are denoted:

$$a_{it}^{s_z} = Prob(Z_{it} = s_{z,t} | Z_{it-1} = s_{z,t-1}, \mathbf{x_{it}}). \tag{4}$$

$\mathbf{x_{it}}$ is a vector of covariates of unit i at time t, showing that conditional on the covariates, the current state depends only on the previous state, fulfilling the Markov property. This formulation also shows that the transition probabilities can vary over time (the Markov chain can be non-homogenous) (Altman, 2007). These four transitions, and respective probabilities, are illustrated by the following transition matrix. Each element of the matrix represents the transition probability of a first-order Markov chain:

$$A_{it} = \begin{vmatrix} a_{it}^{NN} & a_{it}^{NC} \\ a_{it}^{CN} & a_{it}^{CC} \end{vmatrix} = \begin{vmatrix} (1 - P1_{it}) & P1_{it} \\ (1 - P2_{it}) & P2_{it} \end{vmatrix} \tag{5}$$

The observation process is the observed state of the industry: whether we observe a cartel or not. We denote the observed data O_{it}. Based on the cartel register, we can only observe the actual state of the industry, C or N, with noise. Hence, an industry will be observed to have a cartel, C, to not have a cartel, N, or the state of the industry will be unknown, U. This gives the state space $S_o = \{C, N, U\}$. If the hidden state is $s_z \in S_z = \{C, N\}$, the probability to observe $s_o \in S_o = \{C, N, U\}$ is:

$$b_{it}^{s_z}(s_o) = Prob(O_{it} = s_o | Z_{it} = s_z, \mathbf{x_{it}}) \tag{6}$$

We assume that if a cartel is active in an industry, the actual collusive state is observed with probability $b_{it}^{C}(C) = \mu_{it}^{C}$. In other words, we observe a cartel in an industry and the industry is indeed cartelised, $O_{it} = Z_{it} = C$. Likewise, if there is no cartel activity, the true state is observed with probability $b_{it}^{N}(N) = \mu_{it}^{N}$: we observe that there is no active cartel and this is the reality, $O_{it} = Z_{it} = N$. With probabilities $b_{it}^{C}(U) = (1 - \mu_{it}^{C})$ and $b_{it}^{N}(U) = (1 - \mu_{it}^{N})$ the true states cannot be determined and are denoted unknown. We make the assumption that when the register observes cartel activity, it will never be wrong: the register will never observe that a cartel is active when the truth is that it is not active, $b_{it}^{N}(C) = 0$, nor will the register observe that a cartel is not active when the truth is that it is active, $b_{it}^{C}(N) = 0$. This implies that when the cartelisation state of the industry is observed, the observation will never be incorrect. This gives the following observation probability matrix:

$$B_{it} = \begin{vmatrix} b_{it}^{N}(N) & b_{it}^{N}(C) & b_{it}^{N}(U) \\ b_{it}^{C}(N) & b_{it}^{C}(C) & b_{it}^{C}(U) \end{vmatrix} = \begin{vmatrix} \mu_{it}^{N} & 0 & (1 - \mu_{it}^{N}) \\ 0 & \mu_{it}^{C} & (1 - \mu_{it}^{C}) \end{vmatrix} \tag{7}$$

In our case, we might be more likely to observe either C-states or N-states, meaning that the observation probabilities would differ, $\mu_{it}^{C} \neq \mu_{it}^{N}$. If this is the case, the observed transitions would not be representative of the actual transitions. As discussed in *Section 2.2*, the activity of the register was "more or less random". This implies that observations of cartel activity should be missing at random. As long as the observations are missing at random, the likelihood of the observation being missing is allowed to correlate with observed covariates. Hence, the observation probabilities are allowed to differ, $\mu_{it}^{C} \neq \mu_{it}^{N}$, conditional on covariates. It is, thus, not an issue that the observed transitions are a selected sample of the hidden transitions. Moreover, the observation probabilities can be lower than one, $\mu_{it}^{C} \leqslant 1$ and $\mu_{it}^{N} \leqslant 1$, which allows us to take into account that there are years where we do not observe whether there were any active cartels in a specific industry.

We can identify the parameters of our hidden Markov model based on the identifiability of mixture densities, the restrictions we impose on the observation probabilities, and the fact that in our setting there are only two hidden states (C or N). *Table 2* displays the transitions for the observed process. Each column denotes the state observed in the current period and each row denotes the state observed the period before. For example, the $N - C$ cell denotes the probability that we correctly observe that there exists a cartel in this period and that no cartel existed in the previous period ($P1_{it}$), multiplied by the probability of observing the existing cartel in this period, μ_{it}^{C}. We have four transitions and four unknowns: $P1_{it}$, $P2_{it}$, μ_{it}^{C}, μ_{it}^{N} that we solve for.

Table 2: Partial transition matrix

$t-1/t$	No cartel (N)	Cartel (C)
No cartel (N)	$\mu_{it}^{N}(1-P1_{it})$	$\mu_{it}^{C}P1_{it}$
Cartel (C)	$\mu_{it}^{N}(1-P2_{it})$	$\mu_{it}^{C}P2_{it}$

Note: Transition matrix for the observation process. The corresponding observed transitions in the register data can be found in *Appendix B*. The table is adapted based on Hyytinen, Steen and Toivanen (2018).

5.3 Maximum likelihood estimation

We estimate the probability of a cartel forming in an industry ($P1_{it}$) and the probability of a cartel continuing to operate in an industry ($P2_{it}$) by parameterising the hidden Markov model using a maximum likelihood estimation, as is common in the literature. To estimate the likelihood function of our hidden Markov model characterised by $P1_{it}$, $P2_{it}$, μ_{it}^{C}, μ_{it}^{N} we first assume a distribution for each state in the hidden process. The probability that industry i is in the true state $s_z \in S_z$ in the first period is:

$$\alpha_i^{s_z} = Prob(Z_{it} = s_z|\mathbf{x_{i1}}). \tag{8}$$

The likelihood that the hidden Markov model parameters describe the whole observed data is given by the following likelihood function:

$$L(\Theta;\mathbf{o}) = \prod_{i=1}^{N}\left((\mathbf{D_{i1}})'(\prod_{t=2}^{T_i}\mathbf{D_{it}})\mathbf{1}\right). \tag{9}$$

The first element, $\mathbf{D_{i1}}$, is a (2×1) vector representing the probability of industry i being in state C or N in the first period multiplied by the probability of observing this state. The second element, $\mathbf{D_{it}}$, represents a (2×2) matrix representing the probabilities that in the second period, industry i has transitioned to C or N multiplied by the probability of observing this change. The detailed matrix form of the likelihood function is shown in *Appendix C*.

We parametrise the transition probabilities ($P1_{it}$ and $P2_{it}$), the observation probabilities (μ_{it}^{C} and μ_{it}^{N}), and the initial state ($\alpha_i^{s_z}$) to be functions of a number of explanatory variables. For instance, we model the probability of cartel formation as $P1_{it} = \Phi(\mathbf{P1}'\mathbf{x_{it}})$, where $\mathbf{P1}$ is the parameter vector to be estimated. We parametrise the model twice. We first include all industries, and the second time we parametrise the model separately for the industries that were exposed to trade liberalisation and for those that remained protected. Following the literature in this field, we assume a standard probability model for each parameter that we want to estimate and we use the inverse Hessian to estimate standard errors (Hyytinen, Steen and Toivanen, 2018). Below we motivate our explanatory variables based on the theoretical framework in *Section 4*.

Explanatory variables for the transition probabilities:

We base our motivation for the explanatory variables on the Participation Constraint (*Equation 1*) and the Incentive Compatibility Constraint (*Equation 2*). Based on the these, we model the transition probabilities $P1_{it}$ and $P2_{it}$ as functions of four macroeconomic or industry based explanatory variables: product homogeneity, gross value added per industry, interest rates, and a law index. We only include industry characteristics and macroeconomic variables in the maximum likelihood estimation. If we had included cartel specific information from the register data, we would have lost all the industries without registered cartels in the estimation. Since we are interested in the probability of cartels forming in all industries of the economy, we do not want to limit our study to the industries where cartels were observed to be formed. In these industries the probability of forming a cartel is by construction higher than in the industries with no cartel formation being observed. In *Appendix D*, we explain how we construct our explanatory variables, and in *Appendix E* we display the descriptive statistics of the explanatory variables and graph the trends of our macroeconomic variables.

First, the theory suggests that the similarity of products in a cartel can affect the ease of collusion. If the product the cartel members produce is differentiated, each firm's action will have less impact on its competitors' sales and profit. A firm selling a differentiated good is able to charge higher prices without the risk of losing all its customers to competitors - collusion is not necessary to charge a higher price. In *Equation 1*, the difference between π_i^m and π_i^n is lower when goods are differentiated, and thereby the incentives to form a cartel is also lower. In terms of cartel survival, high product homogeneity implies that the potential benefit from cheating, π_i^d, is higher. If products are homogenous, consumers will be more prone to switch to the firm offering the lowest price, implying that the deviating firm can capture a larger market. Therefore, high product homogeneity can make cartels less stable (Levenstein and Suslow, 2006). Product homogeneity data comes from the classification in Rauch (1999), as is commonly used.[6]

Second, real interest rates, r, affect the probabilities of cartel formation and survival by influencing how patient firms are (in our theoretical framework the discount rate, δ). The discount rate therefore determines how tight the Participation Constraint and the Incentive Compatibility Constraints are. Higher interest rates, for instance, imply that the present incomes are valued higher than future ones, and thus firms have a higher incentive to cheat today, making them less stable (Bó, 2007). We use data from Sveriges Riksbank (2014).

Third, since competition law changed over the period we study, we construct an index for competition law, based on the approach by Hyytinen, Steen and Toivanen (2018). The probabilities of forming

[6]The industry classification for product homogeneity is based on the SITC (rev. 2) classification while our cartel data is classified based on NACE codes. To apply the Rauch classification, we first convert the SITC codes to into ISIC codes and then turn these into NACE codes. There are two versions of the classification scheme - we use the more liberal one. The Rauch classification only covers goods, but using the same classification all service trade is classified as differentiated products (Gaisford and Kerr, 2008).

a cartel and the cartel surviving are surely influenced by these law changes, which increasingly put regulatory pressure on collusive practices. The period 1946-1953 is indexed by 0, 1953-1956 is indexed by 1, 1956-1982 is indexed by 2, and 1982-1993 is indexed by 3.

Fourth, we model our transition probabilities on gross value added, and the growth of gross value added, per industry.[7] We decompose gross value added into a trend and a cyclical component and use a third order polynomial of the trend to account for any non-linearities in the long run growth trend,[8] following the approach of Hyytinen, Steen and Toivanen, (2018). Cartels might be more likely to form in periods of high industry growth as there is more to gain from collusion, π_i^m. However, given perfectly observable demand changes, cheating is more likely during growth periods as the potential profits from deviating, π_i^d increase (Rotemberg and Saloner, 1986). Cartels are also less stable during unexpected recessions as colluding firms cannot distinguish between the effects of members cheating and growth shocks (Green and Porter, 1984). Gross value added data on industry level comes from historical national accounts by Edvinsson (2005).

Explanatory variables for the initial state:

As in Hyytinen, Steen and Toivanen (2018), we model the initial probability of a cartel existing in an industry in the first year on product homogeneity, based on the same motivation as for $P1_{it}$ and $P2_{it}$.

Explanatory variables for the observation probabilities:

The observation probabilities, μ_{it}^C and μ_{it}^N are also modelled as functions of explanatory variables. Following Hyytinen, Steen and Toivanen (2018), we assume that the skills of the cartel register to observe cartels changed over time with the increased experience of the register. To allow for changes in observation probabilities due to learning by doing, or changes in the resources of the register, we model our observation probabilities based on the number of cartels that were registered and deregistered throughout its active years. The probabilities of observing a cartel are functions of the number of cartels that entered the register each year (birth flow) and the cumulative number of registered cartels at a given year (birth stock), as well as on the number of exits from the register each year (death flow) and the cumulative exits (death stock). We also model the observation probabilities on the number of cartels that were registered in each industry (industry birth count) to allow for the fact that the register might be better at requesting cartels to register in an industry where it already had registered cartels before. Lastly, the observation probabilities are also functions of the aforementioned law index, as the changes in legislation likely affected the way in which the register was requesting information from firms. In 1953, for example, the *Law against restraints of competition* allowed firms to report restrictive business practices by other firms to the register, likely increasing the register's ability to observe cartels.

[7] We use data on gross value added only at the most aggregated industry level and assign each sub-industry the same gross value added data.

[8] Gross value added is detrended using a *Hodrick-Prescott (HP) filter*, resulting in the trend and cyclical components.

5.4 Difference-in-difference estimation

Once the Participation Constraint and the Incentive Compatibility Constraint are fulfilled, a cartel should be stable and sustainable - unless something changes. One of the main threats to cartels are changes in the macroeconomic environment. Having parametrised the hidden Markov model and derived the probability of cartel formation, $P1_{it}$, and cartel survival, $P2_{it}$, over time, we study how these probabilities are impacted by a shock to trade liberalisation. In order to study this, we apply a difference-in-difference model, using Sweden's accession to the GATT as a natural experiment.

The GATT is a legal agreement between countries worldwide with the aim to increase international trade by reducing trade barriers. The majority of GATT provisions are today still in effect under the WTO framework. The GATT was founded in 1947 and by the time Sweden joined in 1950, it consisted of 34 signatory countries that had jointly agreed to lower tariffs on 50,000 products, affecting USD 10 billion of trade worldwide. Therefore, Sweden joining the agreement resulted in a significant shock in the form of trade openness to the Swedish economy. Sweden got increased access to international markets as it now faced the reduced GATT tariffs on exports to all other signatory countries. Swedish import tariffs were also reduced across industries. In total, 37 percent of Swedish imports were estimated to be affected by the tariff cuts (Prop. 1950:52).

We make use of the fact that some sectors were excluded from the GATT or given special treatment. In particular agriculture, fishing, forestry, and services remained protected. Agriculture, fishing and forestry were addressed separately under a number of headings that allowed governments to uphold trade barriers on these industries. Most importantly, subsidies and import quotas were still allowed, so the sectors largely escaped the normal trade rules other industries faced, heavily distorting trade in agriculture, fishing and forestry products. These exceptions meant that trade in these industries was effectively outside the normal scope of the GATT, until the GATT's Uruguay Round in 1995. Moreover, GATT only covered trade in goods and an agreement on trade in services was first introduced in 1995 under a separate agreement, the General Agreement on Trade in Services (GATS). This allows us to apply a difference-in-difference approach where the excluded industries are used as a control group, while we use the rest of the economy as the treated group.

The difference-in-difference model compares the changes in cartel stability in the industries where tariffs were cut, relative to the changes in cartel stability in the industries that remained protected. We study the average effect of trade liberalisation on cartel formation and cartel survival across all treated industries. This is due to the fact that we cannot identify exactly which cartels were affected by the trade liberalisation as the tariff cuts in the GATT agreement were specified on very detailed product descriptions, while the cartel agreements in the Swedish cartel register are defined on a broader product level. This implies that the reduction of trade barriers varied within the treated industries. Therefore, we capture the effect of the treated industries' overall exposure to trade liberalisation.

We study the period from 1946 until 1960, ten years after the accession took place, as it may have taken time before the cartels adapted their behaviour following the intervention. However, Sweden signed the GATT agreement in 1948, two years before the actual accession took place. Thus, there is a risk of an anticipation effect. Cartels might have changed their behaviour already before, for example to be prepared to protect themselves when foreign competition increased. We test for this in our robustness checks (see *Section 6.3*). Furthermore, we limit the post-intervention period to the 1950s, since Sweden joined the European Free Trade Association (EFTA) in 1960.

Two assumptions need to hold for the difference-in-difference model to produce unbiased estimates. The first assumption is that the control group and the treated group should have common trends, implying that absent the intervention, the trends for the two groups should have been parallel (Angrist and Pischke, 2009). In our setting, this implies that the probability of cartel formation and survival for the protected industries and the liberalised industries should have followed the same trends if Sweden had not joined the GATT. In an ideal setting, the liberalised and protected industries would have been randomly assigned, which would have ensured that the protected industries had been a good counterfactual for the treated group. By graphically studying the trends for the two groups before Sweden joined the GATT, we show that the common trend assumption is likely to hold (see *Section 6.3*), despite the fact that trade liberalisation was not randomly assigned.

The second assumption is that the studied intervention needs to be exogenous to ensure that there is no reverse causality (Angrist and Pischke, 2009). Here, it is important to highlight that Sweden joined an already existing multilateral agreement. The choice of industries that were excluded arose from negotiations among the original GATT signatories, and the sectors remained protected in all countries, including Sweden. Sweden, thus, had little influence over which industries were exposed to trade liberalisation. Overall, there was a large consensus and little public debate that Sweden should join the GATT. Therefore, interest groups likely had little impact on the timing and the conditions of the accession (Karlsson, 2004). Based on this we argue that the reduction in trade barriers can be seen as an exogenous shock.

In order to compare the probability of cartel formation and cartel survival between the treated and the control group, we estimate these parameters separately for each group. The treated group contains 275 industries (13,200 observations), while the control group contains 303 industries (14,544 observations). Having estimated $P1_{it}$, $P2_{it}$ and the observation probabilities separately, we combine the two datasets, now covering all 578 industries again (27,744 observations).

Our empirical difference-in-difference specifications are the following:

Cartel formation:

$$P1_{it} = \beta_0 + \beta_1 treated + \beta_2 post1950 + \beta_3 treated \times post1950 + \beta_4 controls + \varepsilon \tag{10}$$

Cartel survival:

$$P2_{it} = \beta_0 + \beta_1 treated + \beta_2 post1950 + \beta_3 treated \times post1950 + \beta_4 controls + \varepsilon \tag{11}$$

For both specifications, the difference-in-difference estimator for each Pj for $j \in \{1, 2\}$ is:

$$\beta_3 = (\bar{Pj}_{post1950,treated} - \bar{Pj}_{post1950,control}) - (\bar{Pj}_{pre1950,treated} - \bar{Pj}_{pre1950,control}). \tag{12}$$

All fixed, time-invariant characteristics are controlled for by the difference-in-difference estimates, implying that potential differences in the level of cartel characteristics between the two groups are not a threat to the model's validity (Strumpf, Harper and Kaufman, 2017). We control for a number of industry level factors to reduce the error variance in the estimation (Angrist and Pischke, 2009) and use clustered standard errors at the industry level. Alternatively, fixed effects could be included to further filter out any unobserved factors affecting the error term. The limitation of using fixed effects is that these models only make use of within variation for an observation. This increases standard errors and reduces efficiency (Angrist and Pischke, 2009). In our analysis it is important to capture the variation generated by the GATT accession between the two groups, which is why we do not use a fixed effect model as our main estimation.

Our control variables are based on the data from the Swedish cartel register (Le Coq and Marvão dataset). Since the original data specifies these characteristics for each cartel within an industry, if there is more than one cartel in an industry we use the average across the cartels. We include different controls for cartel formation and cartel survival motivated by either the Participation Constraint or the Incentive Compatibility Constraint. For both, we also control for GDP growth since a boom or recession in the economy affects the overall demand, altering potential profits from colluding, π_i^m, or deviating, π_i^n. GDP data from 1950 to 1993 is provided by Statistics Sweden, while data on GDP before 1950 comes from Sveriges Riksbank (2014). In *Appendix F* we display the descriptive statistics of the dependent and control variables.

Control variables for cartel formation

We control for the average number of firms in a cartel by industry and the presence of industry organisations. The transaction costs, τ, for reaching a cartel agreement increases if there are many firms involved, as this makes coordination and negotiation harder (see e.g. Bradburd and Over, 1982). The higher the transaction costs, the lower the incentives to negotiate a cartel agreement. In decentralised markets with many active firms, industry organisations and similar networks can also facilitate coordination and collaboration, thereby decreasing the transaction costs of forming a cartel.

Control variables for cartel survival

The estimated probability of cartel survival is also affected by the number of firms and the presence of industry organisations and, additionally, by the existence of coordinating mechanisms and sanctions, and the type of collusive agreements. First, collusion becomes harder if the number of firms in a cartel, n, increases, since the benefits from collusion decrease as each individual firm gets a smaller share of the collusive profits, π_i^m (Tirole, 1988). Second, if firms in a cartel are part of an industry organisation, this facilitates information sharing and market transparency, thereby making punishment more credible and collusion more stable. Third, cartels often set up mechanisms to monitor and coordinate their behaviour to prevent members from cheating. The more insight firms have into each others' activities and the more centralised cartels are, the more stable cartel agreements seem to be (Levenstein and Suslow, 2006). Fourth, when sanctions for deviating are explicitly set in the agreement, firms are deterred from cheating. Fifth, whether firms collude on prices, on quantities or by dividing markets will affect cartel stability. In particular, market sharing cartels have been argued to be the most stable, since it is relatively easier to detect a rival entering the market. Price setting cartels are the most prone to induce individual firms to cheat, since prices can be hard to monitor (Stigler, 1964).

While the difference-in-difference specification controls for time-invariant factors, there is a still a risk that variables that change over time are omitted. For example, one variable that could potentially affect collusion is changes in market concentration. On a market with only a few firms, for instance, it is easier for the firms to form a cartel that covers all actors on the market, than on a market with many small firms. If the cartel can cover the whole market, the collusive profit, π_i^m, increases as they can charge a higher price, divide markets or set lower production quotas, without facing any competition from firms outside the cartel. Thus, the incentives to both form and sustain a cartel increase (Bain, 1951). Another factor that could affect cartel stability is a change in entry barriers. A decrease in entry barriers would destabilise cartels since new entrants can charge lower prices and take market shares, decreasing the cartel's collusive profits π_i^m (Motta, 2004). Decreases in entry barriers can be driven by technological change, regulation or taxes. Due to data limitations we cannot control for these variables. Omitting any of these variables could potentially confound our estimation if they changed over the period we study in either the treated or the control group, since this would imply that the common trend assumption is violated. For instance, if market concentration increased in the treated industries around the same time as Sweden joined the GATT, the resulting change in cartel survival would be misattributed to trade liberalisation.

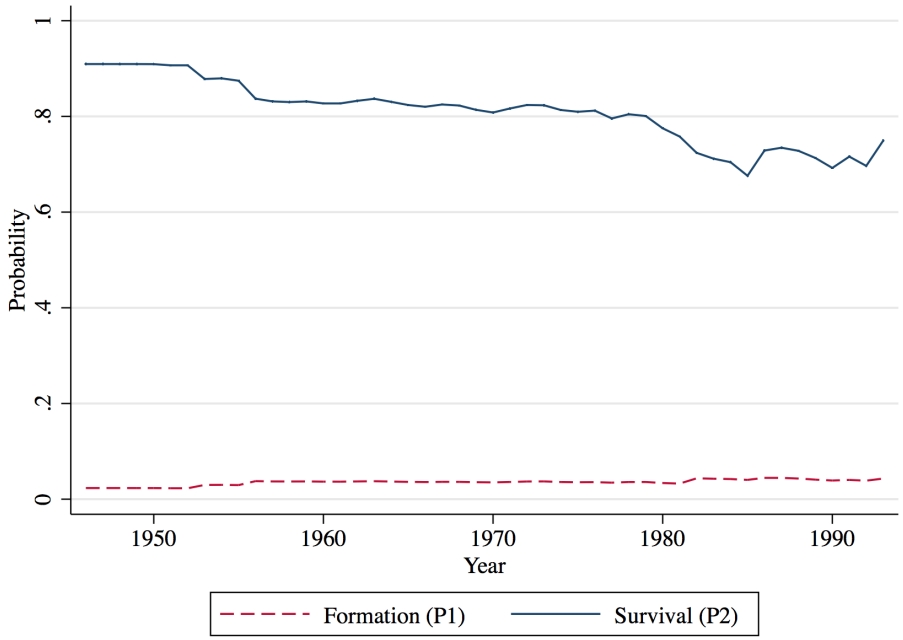
A further risk when studying a policy intervention is that another change is taking place at the same time that only affects one of the two groups. Given that the GATT was such a large shock to the Swedish economy, impacting 37 percent of Swedish imports, we find it unlikely that any other simultaneous political or economic shock could have impacted cartel stability to a similar extent.

6 Results

6.1 Cartel formation and cartel survival

The estimated probabilities of cartel formation and survival over time are shown in *Figure 4*. The probability of a cartel forming is stable over the period, averaging 3.5 percent. In 1947, the average probability of forming a cartel was 2.4 percent, and when the register closed in 1993, the probability was 4.3 percent. The average probability of cartel survival over the whole period was 80.8 percent and decreased over the studied period. In 1947, the probability of cartel survival was at its highest point, 91.0 percent, and in the 1950s, there were two stepwise decreases. The probability remained stable until the late 1970s, after which it decreased and fluctuated more. When the register closed in 1993 the probability of cartel survival was at 74.9 percent. In comparison to Hyytinen, Steen and Toivanen (2018), the probability of cartel formation that we find is lower than their result of 23.4 percent, while we find a probability of cartel survival similar to theirs (88.2 percent).

Figure 4: Cartel formation and survival



Note: Estimated probability of cartel formation and cartel survival for the whole period. We display the average probability across all industries.

Our aim is to study the development of $P1_{it}$ and $P2_{it}$ over time and how they are affected by trade liberalisation. The marginal impact of the explanatory variables (displayed in *Table 3*) are not our main focus and, therefore, we only discuss them briefly. The law index obtains a significant and positive coefficient for cartel formation, and a significant and negative coefficient for cartel survival. Periods of high interest rates are associated with a decrease in the probability of cartel survival, but have no significant effect on the probability of cartel formation. The gross value added of an industry has significant coefficients only for the probability of cartel formation. Positive value added shocks are associated with a lower probability of forming a cartel, while negative shocks indicate a higher

formation probability. Product homogeneity does not have any significant impact at a five percent significance level for either of the transition probabilities. In *Appendix G*, we display the parameter estimates for the observation probabilities and the initial state.

Table 3: Parameter estimates for cartel formation and cartel survival

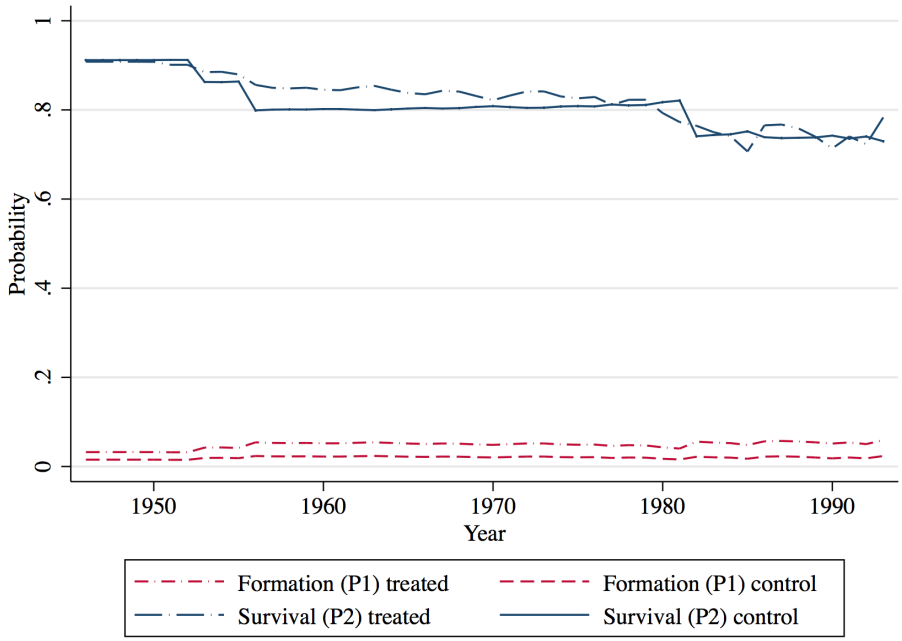
VARIABLES	Formation ($P1_{it}$)	Survival ($P2_{it}$)
Product homogeneity	0.082	-0.135*
	(0.059)	(0.076)
Interest rates	-0.010	-0.033*
	(0.012)	(0.017)
Law index	0.116***	-0.158***
	(0.041)	(0.058)
Value added (trend)	-5.432**	-0.716
	(2.131)	(3.624)
Value added (trend^2)	15.325***	-2.690
	(4.653)	(7.746)
Value added (trend^3)	-10.180***	3.527
	(2.797)	(4.615)
Value added (positive shock)	-8.267***	0.067
	(1.180)	(2.014)
Value added (negative shock)	8.743***	-6.147
	(2.577)	(4.267)
Constant	-1.760***	1.513***
	(0.193)	(0.336)
Observations	27,744	27,744
Likelihood	-6990.5405	

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

6.2 Trade liberalisation

We estimate the hidden Markov model on the treated and control groups separately, and use the estimated $P1_{it}$ and $P2_{it}$ parameters as the dependent variable in our difference-in-difference model. In the treated group, we find the estimates for average cartel formation and cartel survival to be 4.8 percent and 82.5 percent, respectively. For the control group, we find a probability of cartel formation of 2.0 percent and a probability of cartel survival of 80.8 percent on average. *Figure 5* displays the development of $P1_{it}$ and $P2_{it}$ over time for both groups. The parameter estimates for the treated and control groups are shown in *Appendix H*.

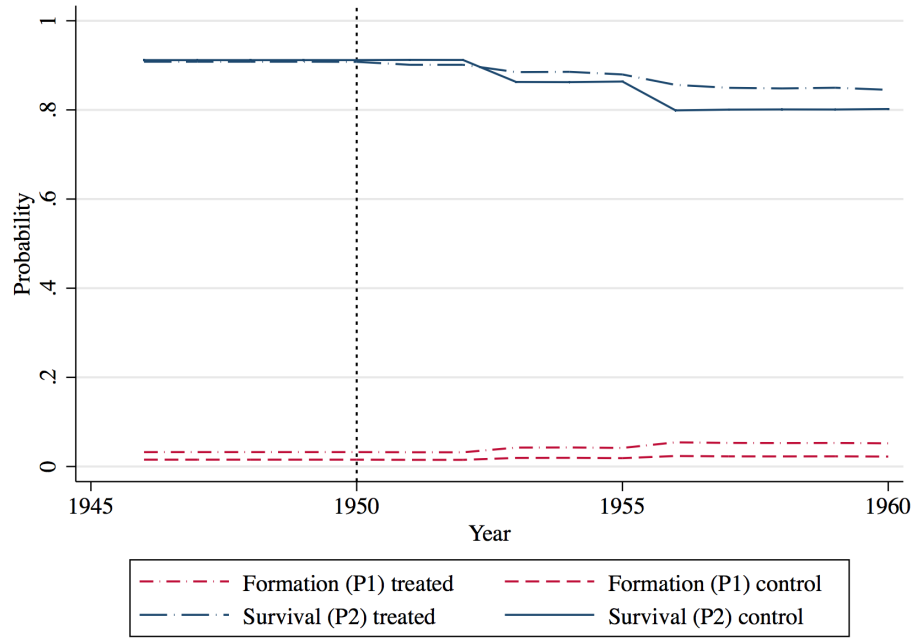
Figure 5: Cartel formation and survival for the treated and control groups separately



Note: Estimated probability of cartel formation and cartel survival over time for the treated and control groups separately. We display averages across all industries for the two groups.

The main underlying assumption for the difference-in-difference model to yield unbiased estimates is that the trend of the control group should be an adequate counterfactual of how the trend in the treatment group would have developed in the absence of the intervention. The identifying assumption therefore rests on the treated and control group following parallel trends before the intervention. Examining the trends before 1950 for $P1_{it}$ and $P2_{it}$ we find very similar trends for the treated and control groups, as shown in *Figure 6*. Hence, we find it plausible to assume that the trends would have continued to be parallel if the treated group had not been affected by lower trade barriers.

Figure 6: Cartel formation and survival for the treated and control groups 1946-1960



Note: Estimated probability of cartel formation and cartel survival 1946-1960 in the treated and control industries. We display averages across all industries for the two groups. The dotted line marks the year Sweden joined the GATT.

Table 4 displays the results from the difference-in-difference regression. The first column shows the coefficient estimates for cartel formation, while the second column shows the coefficients for cartel survival. The impact of trade liberalisation on cartel formation is statistically significant but economically very small (0.8 percentage point). For cartel survival, on the other hand, trade liberalisation is associated with a significant increase. Comparing the probability of cartel survival before and after the intervention, the industries in the control group experienced an increase in survival by, on average, by 3.2 percentage points. The change in the probability of cartel survival was 2.8 percentage points higher in the treated group than in the control group. This implies that the treated industries, on average, experienced an increase in the probability of cartel survival of 5.9 percentage points. Most of our control variables are insignificant. However, a one percent increase in GDP is associated with a 0.026 percentage point increase in the probability of cartel formation and a 0.123 percentage point decrease in the probability of cartel survival. The number of firms has a statistically significant impact on cartel formation but the effect is too small to have any meaningful impact. The existence of an industry organisation has a small but significant, negative impact on cartel formation at a five percent significance level.

Table 4: Difference-in-difference estimation

VARIABLES	Formation ($P1_{it}$)	Survival ($P2_{it}$)
post1950	-0.0150***	0.0316***
	(0.000684)	(0.00214)
Treated	0.0180***	-0.0114***
	(0.00123)	(0.00411)
post1950×Treated	0.00850***	0.0279***
	(0.000472)	(0.00203)
Number of firms	-5.86e-07***	1.75e-06
	(1.87e-07)	(2.52e-06)
Industry organisation	-0.00529**	-0.0114
	(0.00235)	(0.0104)
GDP	0.0263***	-0.123***
	(0.000920)	(0.00350)
Sanctions		-0.00241
		(0.00696)
Coordination mechanism		0.00573
		(0.00828)
Price clause		0.0152*
		(0.00820)
Quota clause		0.0121
		(0.00892)
Market division clause		0.00366
		(0.00554)
Constant	-0.248***	2.161***
	(0.00942)	(0.0365)
Observations	4,185	2,835
Number of industries	279	189

Note: Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Note that the number of observations in the regression for cartel survival is lower due to missing values for the additional control variables. However, if we exclude these control variables, thus running the two regressions on the same observations, we obtain the same results as in this table.

6.3 Robustness tests

ML estimation

We estimate our hidden Markov model parameters on a number of alternative specifications to ensure that our results are robust to modelling choices. Our robustness tests show similar averages for both transition probabilities, and similar trends over time, as shown in *Table 5* and *Figure 7*.

Table 5: Estimates for cartel formation and survival from robustness tests

	Main model	Time polynomial	1946-1982	Law spline	Excluding cartels starting before 1947
Formation	3.5%	2.8%	3.6%	3.2%	2.7%
Survival	80.8%	75.4%	83.8%	81.0%	83.6%

Note: Mean estimates of the parameters across all industries and years.

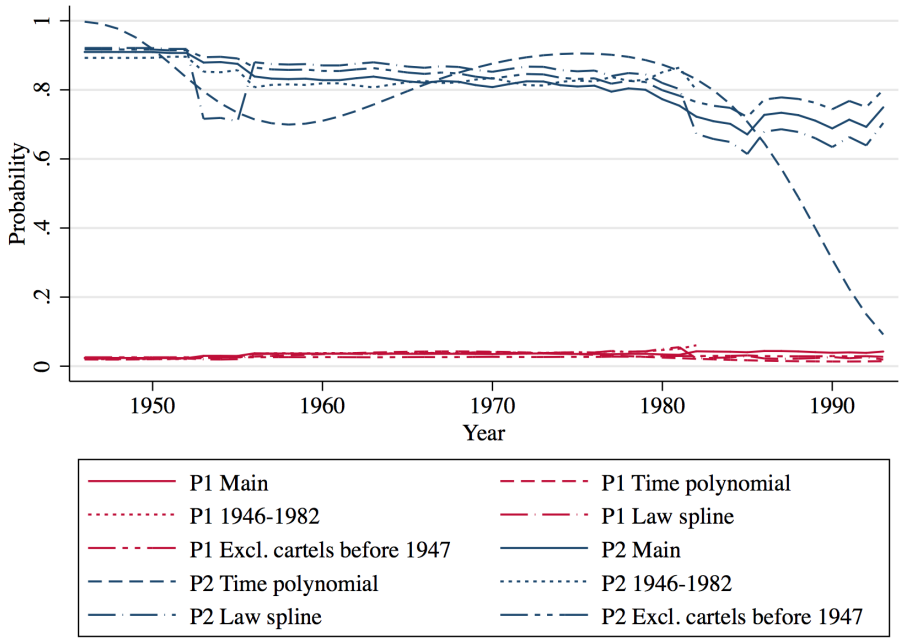
Test 1, Time polynomials: To ensure that our results are not driven by our choice of explanatory variables, we follow Hyytinen, Steen and Toivanen (2018) and estimate our model on a fourth order polynomial of time. The average probabilities are similar to our main model and broadly follow the same trend.

Test 2, 1946-1982: In 1982, Sweden tightened its competition policy, and the cartel authorities got more power to intervene in cartels found to be harmful. This would have put significant pressure on existing cartels as well as firms considering to form a cartel. Therefore, cartels might have started to behave differently after the new law, and the behaviour of cartels after 1982 could have distortive effects on our results from the main model that studies the whole period. When we exclude the observations for years after 1982, our results do not change significantly.

Test 3, Law spline: Following Hyytinen, Steen and Toivanen (2018), we allow the effect of the competition law changes to be nonlinear. We therefore replace the law index with dummies for the three legislative changes in 1953, 1956 and 1982, respectively. Our results are consistent with our main specification.

Test 4, Excluding cartels starting before 1947: A few of the cartels in the register were born before 1947. In our main analysis the data on these cartels is included, but we only study their activity from 1946 and onwards. For instance, one cartel started in 1926. While there might have been other cartels starting this year and terminating before 1947, the cartel that appears in the data managed to survive long enough to be captured by the register. One could suspect this cartel to be systematically different from the shorter cartels, which would bias our results. In order to make sure that including these cartels does not affect our result, we estimate the parameters with the maximum likelihood estimation excluding these cartels, which reproduces our results.

Figure 7: Robustness tests for cartel formation and survival



Note: Estimates for cartel formation and survival based on the robustness tests. We display averages across all industries.

Difference-in-difference

We also test the robustness of our difference-in-difference estimates. We estimate a model with fixed effects for industries and a model with both industry fixed effects and time fixed effects. Both specifications generate results that are consistent with those of the our main difference-in-difference model. For cartel survival, both specifications generate results that are marginally higher, while for cartel survival the effects are marginally lower (see *Appendix I*).

In order to further test the assumption of parallel trends before the intervention, we allow for lags and leads in the treatment. We include three lags and three leads on the treatment year. The coefficients on the leads of the treatment should be zero if the parallel trends assumption holds, while the lags may reflect "phasing in" effects if the treatment takes time to affect cartel stability (Angrist and Pischke, 2009). The results of this estimation are also shown in *Appendix J*. Confirming the parallel trends assumption, all of the lead or lag coefficients are close to zero. These results also allows us to discard the possibility of an anticipation effect that could have appeared if firms had changed their collusive behaviour before 1950 to prepare for the effects of trade liberalisation.

7 Discussion

Our analysis on cartel stability shows that the probability of forming a cartel is low and stable over time, with an average value of 3.5 percent across the industries and the period we study. The probability of cartel survival, on the other hand, is high during the whole period, with an average of 80.8 percent. This implies that once a cartel was formed, there was a high probability that the industry would remain cartelised. The trend of cartel survival is decreasing over time. Legislative changes seem to have had an impact. When competition laws were tightened in the 1950s and the 1980s there was a decrease in cartel survival rates. In the 1980s and early 1990s, cartel survival was also notably more volatile. The changes in the probability of cartel survival in the 1980s and 1990s are likely to be an effect of the macroeconomic turbulence Sweden experienced at this point. Sweden had been growing steadily for almost a whole century, and was hit by its worst economic crisis in 50 years in the 1990s (Hassler, 2015). High interest rates and decreasing demand would both have contributed to the decreasing and volatile rates of cartel survival at the time, as predicted by the literature (see e.g. Bó, 2007 and Green and Porter, 1984).

Our parameter estimate of the probability of cartel survival is similar to the those found in previous studies. Hyytinen, Steen and Toivanen (2018) find an average survival probability of 88 percent, and Harrington and Wei (2017) and Ellison (1994) find similarly high probabilities (albeit for illegal cartels). It is hard to contrast our estimated probability of forming a cartel to the literature, since it has not previously been estimated for the whole economy. Compared to Hyytinen, Steen and Toivanen (2018), who find an average formation probability of 23 percent for the manufacturing industry, our estimate is low. This is likely due to the fact that cartels are more prevalent in the manufacturing sector, as shown by several studies (see e.g. Hellwig and Hüschelrath, 2017; Connor and Helmers, 2006).

Turning to our analysis on the effects of trade liberalisation on cartel stability, we find that the probabilities of cartel formation and cartel survival are both generally higher in the industries that were affected by the GATT until the 1980s, when cartel survival decreased and became more volatile across the whole economy. This is in line with predictions in the literature that expect cartels to be more common in commodified industries. Our results find that lowering tariffs across a wide number of industries has a moderate effect on the probability of cartels surviving, and a negligent effect on the probability of cartels forming. Industries that experienced a decrease in trade barriers experienced an increase in the probability of cartel survival that was 2.8 percentage points higher than the increase in the excluded industries. This implies that cartels are more likely to survive when trade barriers are low, while the ability of cartels to form is unaffected by trade liberalisation.

Our finding that trade liberalisation increases cartel survival can be explained by our theoretical model, as discussed in *Section 4.2*. Trade liberalisation affects cartel survival by both increasing competition on domestic markets, and increasing the incentives to collude for cartels operating on several markets, based on multimarket contact. Our findings indicate that the second effect dominates. A closer look at the actual tariff cuts taking place in 1950 could provide insights into why the multimarket effect seems to dominate for cartel survival. Already before joining the GATT, Sweden had relatively low tariffs. Hence, Swedish markets were already quite exposed to international competition before 1950 (Karlsson, 2004). For a country experiencing a larger decrease in import tariffs, the first effect might be more prominent. On the other hand, by joining the GATT, Sweden's trade barriers to foreign markets decreased significantly. Many other economies had large tariffs on Swedish exports before 1950, which were lowered significantly when Sweden joined the GATT. This decrease in trade barriers gave Swedish firms much greater access to foreign markets and increased opportunities for collusion across multiple markets. Multimarket collusion is thought to be more stable since deviations are retaliated on all markets (Bernheim and Whinston, 1990).

The fact that we find no economically significant impact of trade liberalisation on cartel formation can also be explained by our theoretical framework in *Section 4.1*. Trade liberalisation both makes it harder to form cartels since the transaction cost to reach an agreement increase, and at the same time increases the incentives to form a cartel as a protective means. Our results suggest that these two effects cancel each other out.

In this paper, we provide insights into the effect of a large shock to trade liberalisation on cartel stability. Given the way in which we construct our treated and control group, we capture the average effect of trade liberalisation in the industries that were subject to the GATT. Hence, we include industries where actual tariff cuts did not take place. This implies that trade liberalisation likely has a greater effect than our results show. Due to data limitations we cannot estimate the quantitative impact of a tariff cut on cartel stability in a particular industry. There is a discrepancy between our data on cartel activity and the data on tariff cuts. Tariff reductions were made on specific product descriptions (e.g. footballs), while the data on cartel activity is at the industry level (e.g. sports goods industry). To estimate the quantitative marginal impact of tariff cuts, we would either need more detailed data on the products that the cartels colluded on or industry-level estimates of tariff reductions. We therefore leave this for future research.

We use a dataset on legal cartels to overcome the bias that data on detected cartels contain. This, however, implies that one should be careful about making inferences about cartel stability today based on our findings. Cartels are most likely less common today, since they face the risk of detection and prosecution by competition authorities. It is difficult to say with certainty whether cartel survival today would increase with trade liberalisation, given different legislative environments. However, we find this plausible, since the effect that increases cartel survival, the multimarket contact, should affect legal and illegal cartels in the same way.

8 Conclusion

In this paper, we provide the first analysis of the development of cartel stability in Sweden and empirically estimate how it is affected by trade liberalisation. Our results show that while there is a low probability that new cartels form in industries without any existing cartels, once cartels are formed they tend to endure. We also show that the probability of cartel survival is positively affected by a shock to trade liberalisation, implying that cartels become more stable when integration with international markets increases.

Our findings highlight two key implications for policy. First, our analysis emphasises the importance of competition law, as our results indicate that cartels tend to be long-lived, and would persist if not prosecuted by competition authorities. Our results also show that trade liberalisation cannot be used as a substitute for competition policy. Trade liberalisation and integration in international trading systems are often motivated by increased competition on the domestic markets, which is expected to generate more productivity increases and higher innovation. However, as our results show, this effect might be counteracted by the increased stability of cartels. In order to realise the benefits of trade liberalisation, it is important that it is complemented by effective competition policy.

As we conclude that cartels are persistent, once formed, one would like to know how harmful they were to the economy. Future research is needed on the welfare implications of cartels and their impact on prices, productivity and innovation. The extent to which trade liberalisation still has a pro-competitive effect, despite increasing incentives to collude, should also be explored.

9 References

Altman, R. (2007). Mixed hidden Markov models: an extension of the hidden Markov model to the longitudinal data setting, *Journal of American Statistical Association*, 102 (477): 201-10.

Angrist, J. and Pischke,J. (2009). *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton and Oxford. Princeton University Press. Bain, J. (1959). *Industrial Organization*. New York:John Wiley and Sons.

Berg, P. (2012). *Cartel Damages and Cost Asymmetries* (Doctoral dissertation). Copenhagen Business School.

Bernheim, B., and Whinston, M. (1990). Multimarket Contact and Collusive Behavior. *The RAND Journal of Economics*, 21(1), 1-26.

Bigoni, M., Fridolfsson, S, Le Coq, C., Spagnolo, G. (2015) Trust, Leniency and Deterrence, *The Journal of Law, Economics, and Organization*, 31(4).

Bó, P. (2007). Tacit Collusion under Interest Rate Fluctuations, *The RAND Journal of Economics*, vol. 38(2), pp. 533–540.

Bond, E., and Syropoulos, C. (2005). Trade costs and multimarket collusion, *The RAND Journal of Economics*, 39(4): 1080-1104.

Bradburd, R., and Over, M. (1982).Organizational Costs, 'Sticky Equilibria,' and Critical Levels of Concentration. *Review of Economics and Statistics*, 64(1): 50-58.

Connor, J. and Bolotova, Y. (2006). Cartel Overcharges: Survey and Meta-Analysis, *International Journal of Industrial Organization*, 24.

Connor, J., and Helmers, G. (2006).Statistics on modern private international cartels, 1990-2005. *No 06-11, Working Papers*, Purdue University, College of Agriculture, Department of Agricultural Economics.

Connor, J. and Zimmerman, J. (2005). Determinants of Cartel Duration: A Cross-Sectional Study of Modern Private International Cartels.

Davidson, C. (1984). Cartel stability and tariff policy. *Journal of International Economics* 17(3–4): 219-237.

Dick, A. (1996). When are cartels stable contracts?, *The Journal of Law Economics*, 39(1): p. 241-283.

Edvinsson, R. (2005). *Growth, Accumulation, Crisis: With New Macroeconomic Data for Sweden 1800-2000* (Doctoral dissertation).

Ellison, G. (1994). Theories of Cartel Stability and the Joint Executive Committee. *The RAND Journal of Economics*, 25(1), 37-57.

Fung, K. (1992). Economic Integration as Competitive Discipline. *International Economic Review*, 33(4):837-847

Fölster, S. and Peltzman, S. (1997). The Social Costs of Regulation and Lack of Competition in Sweden: A Summary. In Freeman, R., Topel, R., and Swedenborg, B. (Eds.) *The Welfare State in Transition: Reforming the Swedish Model*.University of Chicago Press.

Gaisford, J., and Kerr, W. (2008). *Handbook on International Trade Policy*, Edward Elgar Publishing.

Green, E., Porter, R. (1984). Noncooperative Collusion under Imperfect Price Information. *Econometrica*, 52(1), 87-100.

Harrington, J. and Chen, J. (2006). Cartel pricing dynamics with cost variability and endogenous buyer detection, *International Journal of Industrial Organization*, 24(6): 1185-1212.

Harrington, J., and Wei, Y. (2017). When can we expect a corporate leniency program to result in fewer cartels? *Journal of Law and Economics*, 58(2): 417-49.

Hassler, J. (2015). Experiences from the Swedish Crisis in the 1990s – An Opportunity for a Complete Makeover. *Intereconomics*, 50:5.

Haucap, J., Heimeshoff, U., and Schultz, L. (2010). Legal and illegal Cartels in Germany between 1958 and 2004, *Heinrich-Heine-Universität Düsseldorf, Department of Economics, Düsseldorf Institute for Competition Economics (DICE)*, Discussion paper.

Hellwig, M. and Hüschelrath, K. (2017). When do Firms Leave Cartels?, Determinants and the Impact on Cartel Survival, *ZEW Center for European Economic Research*, Discussion Paper 17-002.

Hyytinen, A., Steen, F., and Toivanen, O. (2018). Cartels uncovered, *American Economic Journal: Microeconomics*, 10(4): 190-222.

Karlsson, B. (2004).Neutrality and free trade: Sweden and trade liberalisation, 1948–1958. *Scandinavian Economic History Review*, 52(2-3): 39-61.

Konkurrensverket. (2004). Kartellregistret Kartellregistrets historia, 1946-1993, *Konkurrensverket.*

Le Coq, C., and Marvão, C. (2019). Post-Mortem of Legal Cartels: The case of Sweden. SITE Working Paper

Lee, L., and Porter, R. (1984). Switching Regression Models with Imperfect Sample Separation Information–With an Application on Cartel Stability. *Econometrica*, 52(2), 391-418.

Levenstein, M. and Suslow, V. (2006). What determines cartel success?, *Journal of Economic Literature*, Vol XLIV, pp 43-95.

Levenstein, M. and Suslow, V. (2011). Breaking Up Is Hard to Do: Determinants of Cartel Duration, *Journal of Law and Economics*, 54(2): p.455 - 492.

Lommerud, K. and Sørgard, L. (2001). Trade Liberalization and Cartel Stability. *Review of International Economics*, 9: 343-355

Motta, M. (2004). *Competition policy: theory and practice*, Cambridge, Cambridge University Press.

Porter, R. (1983). A Study of Cartel Stability: The Joint Executive Committee, 1880-1886. *The Bell Journal of Economics*, 14(2), 301-314.

Petit, L. (2017). *Legal Cartels: A formula for durable cartels: which cartel characteristics help them grow older?* (Doctoral dissertation). Erasmus University Rotterdam.

Rauch, J. (1999).Networks Versus Markets in International Trade. *Journal of International Economics* 48(1):7-35.

Rotemberg, J. and Saloner, G. (1986).Tariffs vs Quotas with Implicit Collusion *The Canadian Journal of Economics*, 22(2):237-244.

Sandberg, P. (2016). Cartel registers around the world. In Fellman, S. and Sheenan, M. (Eds.) *Regulating competition: Cartel registers in the twentieth-century world*(113-32). New York: Routledge.

Schröder, P. (2007). Cartel Stability and Economic Integration. *Review of International Economics*, 15: 313-320.

Stigler, G. (1964). A theory of oligopoly, *Journal of Political Economy* 72(1): 44-61.

Strumpf, E., Harper, S., and Kaufman, J. (2017). Fixed Effects and Difference-in-Differences, in Oakes, M. and Kaufman, J., (Eds) Methods in Social Epidemiology, Jossey-Bass.

Suslow, V. (2005). Cartel contract duration: empirical evidence from the inter-war international cartels, *Industrial and Corporate Change*, 14(5): p.705-744.

Sveriges Riksbank (2014). House Prices, Stock Returns, National Accounts, and the Riksbank Balance Sheet, 1620–2012. Edvinsson, R., Jacobson T., and Waldenström, D. (Eds). Stockholm: Ekerlids Förlag.

Tirole, J. (1988). *The theory of industrial organisation*, Cambridge, MIT Press.

Trustlagstiftningskommittén. (1921). *Trustlagstiftningskommittéens betänkande: Förslag till lag om vissa åtgärder beträffande monopolistiska företag och sammanslutningar*, Almqvist & Wiksells boktryckeri, Uppsala.

Legal sources:

Proposition 1950:5 Angående Sveriges anslutning till allmänna tull- och handelsavtalet (GATT), m.m., Stockholm.

Statens Offentilga Utredningar (SOU) 1940:35, Organiserad samverkan inom svenskt näringsliv. Betänkande angivet av 1936 års näringsorganisationssakkunniga, Stockholm.

Statens Offentilga Utredningar (SOU) 1945:42, Framställningar och utlåtanden från kommissionen för ekonomisk efterkrigsplanering V: Betänkande angående övervakning av konkurrensegränande företeelser inom näringslivet, Stockholm.

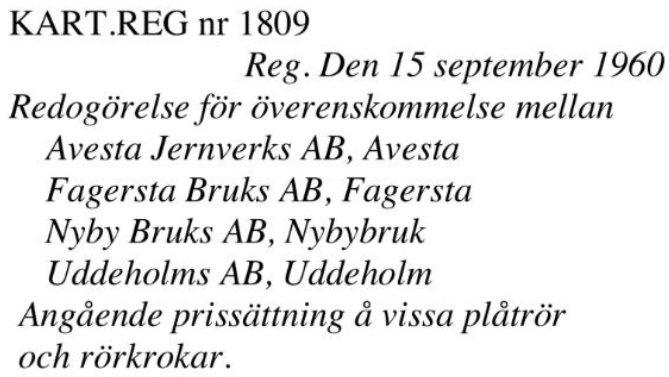
Statens Offentilga Utredningar (SOU) 1951:27, Konkurrensbegränsning. Nyetableringssakkunnigas betänkande med förslag till lag om skydd mot samhällsskadlig konkurrensbegränsning, Stockholm.

Statens Offentilga Utredningar (SOU) 1951:28, Konkurrensbegränsning. Nyetableringssakkunnigas betänkande med förslag till lag om skydd mot samhällsskadlig konkurrensbegränsning, Stockholm.

Appendices

A Sample contract

Figure 8: Cartel contract sample


KART.REG nr 1809

Reg. Den 15 september 1960

Redogörelse för överenskommelse mellan
Avesta Jernverks AB, Avesta
Fagersta Bruks AB, Fagersta
Nyby Bruks AB, Nybybruk
Uddeholms AB, Uddeholm
Angående prissättning å vissa plåtrör
och rörkrokar.

Note: An example of a contract from the Swedish cartel register (Konkurrensverket, 2004).

B Observed transitions

Table 6: Observed transitions

$t-1/t$	Cartel (C)	No cartel (N)	Unknown (U)	Total
Cartel (C)	1,963	62	1,048	3,073
	63.88%	2.02%	34.10%	100.00%
No cartel (N)	78	40	61	179
	43.58%	22.35%	34.08%	100.00%
Unknown (U)	928	73	22,913	23,914
	3.88%	0.31%	95.81%	100.00%
Total	2,969	175	24,022	27,166
	10.93%	0.64%	88.43%	100.00%

Note: The number of transitions from one state to another, as well as the probability of each transition, based on the Swedish cartel register (Le Coq and Marvão dataset). The total number of observations is 578 less than the number of observations in the data as transitions are not calculated for the first year.

C Matrix form of the likelihood function

The likelihood function of the hidden Markov model can be written in terms of the transition and observation probabilities:

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

$$L(\Theta; o) = \prod_{i=1}^{N} \left(\begin{vmatrix} d_{i1}^{s_z}(s_o) \\ d_{i1}^{s_z}(s_o) \end{vmatrix}' \left(\prod_{t=2}^{T_i} \begin{vmatrix} d_{it}^{s_z}(s_o) & d_{it}^{s_z}(s_o) \\ d_{it}^{s_z}(s_o) & d_{it}^{s_z}(s_o) \end{vmatrix} \right) \begin{vmatrix} 1 \\ 1 \end{vmatrix} \right)$$

$$L(\Theta; o) = \prod_{i=1}^{N} \left(\begin{vmatrix} \alpha_i^N b_{i1}^N(s_o) \\ \alpha_i^C b_{i1}^C(s_o) \end{vmatrix}' \left(\prod_{t=2}^{T_i} \begin{vmatrix} a_{it}^{NN} b_{it}^N(s_o) & a_{it}^{NC} b_{it}^C(s_o) \\ a_{it}^{CN} b_{it}^N(s_o) & a_{it}^{CC} b_{it}^C(s_o) \end{vmatrix} \right) \begin{vmatrix} 1 \\ 1 \end{vmatrix} \right)$$

$$L(\Theta; o) = \prod_{i=1}^{N} \left(\begin{vmatrix} Prob(Z_{it} = N) Prob(O_{it} = s_o | Z_{it} = N) \\ Prob(Z_{it} = C) Prob(O_{it} = s_o | Z_{it} = C) \end{vmatrix}' \left(\prod_{t=2}^{T_i} \begin{vmatrix} (1 - P1_{it}) \mu_{it}^N & P1_{it} \mu_{it}^C \\ (1 - P1_{it}) \mu_{it}^N & P2_{it} \mu_{it}^C \end{vmatrix} \right) \begin{vmatrix} 1 \\ 1 \end{vmatrix} \right)$$

D Construction of the explanatory and control variables

Table 7: Explanatory variables for the Maximum Likelihood estimation

Explanatory variable	**Description**
Product homogeneity	We construct a dummy for product homogeneity based on Rauch (1999) classification. We use the liberal classification and, following the literature, we classify goods traded on an organised exchange (w) and reference priced goods (r) as homogenous.
Interest rate	We use the short-term interest rate provided by Sveriges Riksbank.
Gross value added	Data on gross value added comes from Edvinsson (2005). We use a Hodrick-Prescott filter to detrend gross value added, decomposing it into a long-run growth trend and cyclical deviations from this trend.
Competition law index	Since competition law changed over the period we study, we include an index for competition law. The period 1946-1953 is indexed by 0, the period 1953-1956 is indexed by 1, the period 1956-1983 is indexed 2, and the period 1983-1993 is indexed 3.

Table 8: Control variables for the difference-in-difference estimation

Control variable	**Description**
Number of firms	We use the maximum number of firms that were registered over the period that the cartel was registered.
Industry organisation	We have a dummy variable equal to 1 if there is an industry organisation in the industry that the cartel pertains to.
Sanctions (dummy)	We construct a dummy variable that is equal to 1 if there is at least one type of explicit sanction mentioned in the cartel contract. These sanctions can be expulsion from the cartel, suspension, fees that have fixed values, minimum or maximum values, or that are counted per unit, or a combination of these.
Coordinating mechanism (dummy)	If the cartel contract specifies that there are regular meetings, voting mechanisms, or an explicit hierarchy of firms, this dummy equals 1.
Type of agreement (dummies)	The type of activity that is colluded on is represented by dummies corresponding to each type. If a cartel has some price agreement clause, the dummy for price type is 1. A cartel is allowed to collude on more than one aspect. The different types are: price agreements, quotas, and market division.
GDP fluctuations	The variable GDP fluctuations is the yearly percentage change in GDP, in fixed prices.

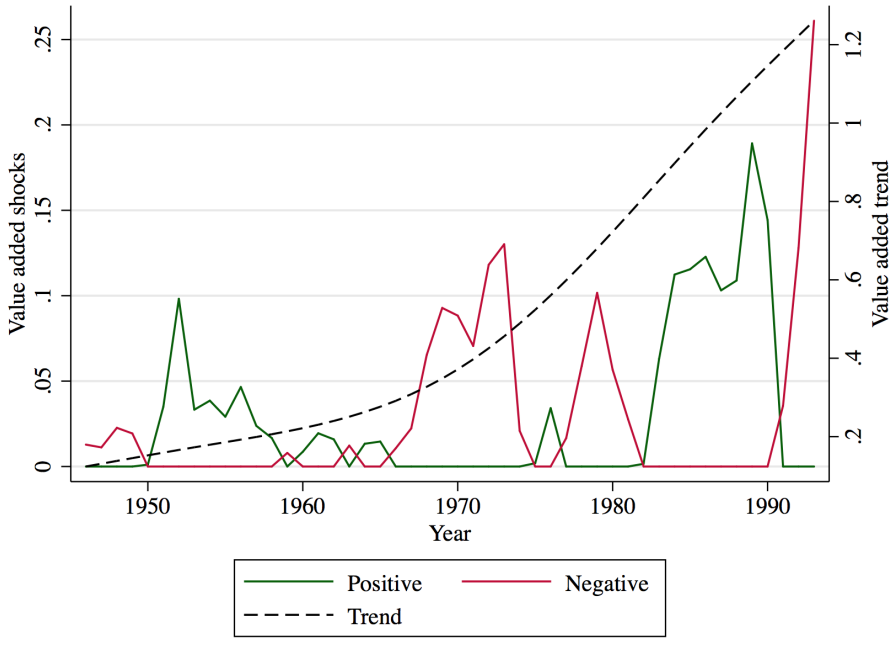
E Descriptive statistics for the hidden Markov model estimation

Table 9: Descriptive statistics for the explanatory variables

Variable	Observations	Mean	Std. Dev.	Min	Max
Cartel formation and survival					
Product homogeneity	27,744	0.82	0.38	0	1
Interest rates	27,744	6.61	3.36	2.5	14.49
Law Index	27,744	1.90	0.94	0	3
Value added trend	27,744	1.01	0.16	0.00	1.26
Observation probabilities					
Law Index	27,744	1.90	0.94	0	3
Birth Count	27,744	2.85	9.64	0	136
Death (stock)	27,744	1240.46	713.02	0	2431
Death (flow)	27,744	50.65	47.78	0	295
Birth (stock)	27,744	1238.04	718.00	0	2431
Birth (flow)	27,744	50.65	52.82	0	179

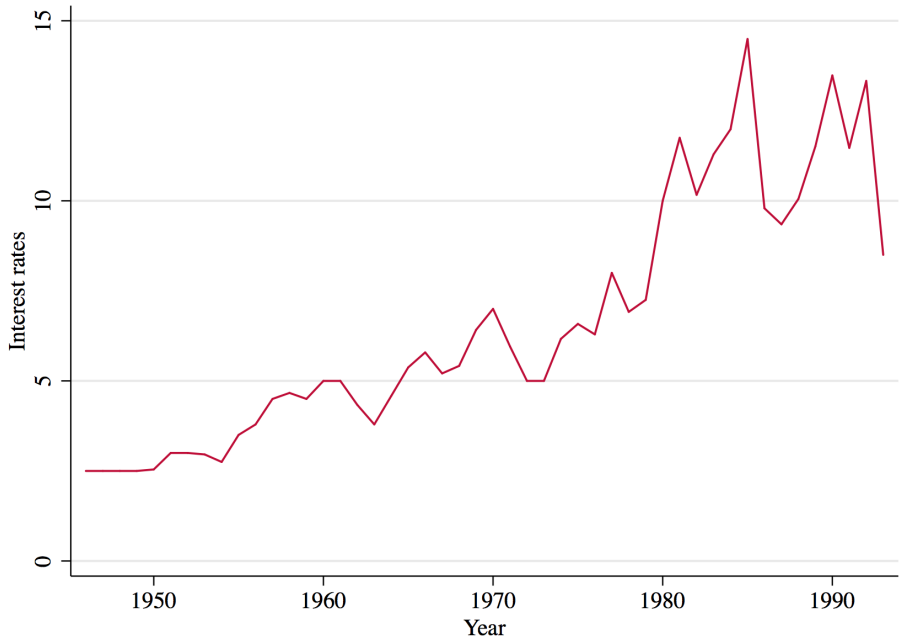
Note: Descriptive statistics of the data used for the explanatory variables in the maximum likelihood estimation of the hidden Markov model.

Figure 9: Gross value added



Note: Average gross value added across industries. Gross value added is detrended using a Hodrick-Prescott (HP) filter, resulting in the trend and cyclical components. The cyclical component if further divided into positive and negative developments. Authors' rendering of data from Edvinsson (2005).

Figure 10: Interest rates



Note: Development of interest rates 1946-1993. Authors' rendering of data from Sveriges Riksbank (2014).

F Descriptive statistics for the difference-in-difference estimation

We present descriptive statistics for all data used in our difference-in-difference analysis:

Table 10: Descriptive statistics of dependent and control variables

Variable	Observations	Mean	Std. Dev.	Min	Max
Dependent variables					
Cartel formation ($P1_{it}$)	27,744	0.03	0.02	0.00	0.28
Cartel survival ($P2_{it}$)	27,744	0.82	0.098	0.00	1.00
Control variables					
Price clause	13,392	0.61	0.36	0	1
Quota clause	13,392	0.42	0.38	0	1
Market division clause	13,344	0.66	0.47	0	1
Sanctions	9,072	0.41	0.39	0	1
Coordinating mechanisms	13,392	0.68	0.34	0	1
Industry organisation	13,392	0.34	0.37	0	1
ln(GDP)	27,744	12.24	1.29	10.07	14.31
Max. number of firms	13,392	165.05	1058.23	2	15306

Note: Descriptive statistics of the data used for the difference-in-difference regressions. Note that once we map cartels to industry levels, we first take the average of all control variables for all cartels in an industry. In this table we present the averages across all industries. The number of observations for some control variables is lower due to missing data in the Swedish cartel register. It is worth mentioning that the average number of firms is significantly higher than the median (10 firms).

G Parameter estimates for observation probabilities

Table 11: Parameter estimates for observation probabilities

VARIABLES	μ_{it}^N	μ_{it}^C	$\alpha_i^{s_z}$
Product homogeneity			-0.347**
			(0.151)
Law index	-0.038	-0.482***	
	(0.029)	(0.041)	
Birth count	-0.033**	0.049***	
	(0.015)	(0.006)	
Death (stock)	0.000		
	(0.000)		
Death (stock^2)	-0.000		
	(0.000)		
Death (flow)	0.001**		
	(0.001)		
Birth (stock)		-0.000	
		(0.000)	
Birth (stock^2)		0.000	
		(0.000)	
Birth (flow)		0.003***	
		(0.001)	
Constant	-2.515***	0.866***	-0.557***
	(0.107)	(0.111)	(0.134)
Observations	27,744	27,744	27,744
Likelihood	-6990.5405		

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

H Parameter estimates for treated and control groups

Table 12: Parameter estimates for transition probabilities for the treated group

VARIABLES	Formation ($P1_{it}$)	Survival ($P2_{it}$)
Product homogeneity	0.403***	-0.226**
	(0.090)	(0.113)
Interest rates	-0.017	-0.042*
	(0.017)	(0.023)
Law index	0.134**	-0.105
	(0.059)	(0.075)
Value added (trend)	6.262	-559.523***
	(11.739)	(36.788)
Value added (trend^2)	-27.522	1,501.809***
	(33.552)	(56.327)
Value added (trend^3)	20.520	-957.827***
	(22.577)	(47.725)
Value added (positive shock)	20.901*	-2,328.800***
	(11.060)	(412.709)
Value added (negative shock)	-1.956	-19.920
	(14.945)	(176.071)
Constant	-1.955***	42.845***
	(0.591)	(5.453)
Observations	13,200	13,200
Likelihood	-4158.1949	

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 13: Parameter estimates for observation probabilities for the treated group

VARIABLES	μ_{it}^N	μ_{it}^C	$\alpha_i^{s_z}$
Product homogeneity			-0.254
			(0.215)
Law index	-0.062	-0.409***	
	(0.040)	(0.048)	
Birth count	-0.060**	0.051***	
	(0.024)	(0.006)	
Death (stock)	0.000		
	(0.000)		
Death (stock^2)	-0.000		
	(0.000)		
Death (flow)	0.001		
	(0.001)		
Birth (stock)		-0.000	
		(0.000)	
Birth (stock^2)		0.000	
		(0.000)	
Birth (flow)		0.002***	
		(0.001)	
Constant	-2.349***	0.708***	-0.331*
	(0.149)	(0.130)	(0.194)
Observations	13,200	13,200	13,200
Likelihood	-4158.1949		

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 14: Parameter estimates for transition probabilities for the control group

VARIABLES	Formation ($P1_{it}$)	Survival ($P2_{it}$)
Product homogeneity	-0.076	-0.352***
	(0.094)	(0.124)
Interest rates	-0.021	0.009
	(0.018)	(0.030)
Law index	0.102*	-0.270***
	(0.060)	(0.099)
Value added (trend)	1.559	0.360
	(2.886)	(4.918)
Value added (trend^2)	-3.794	0.641
	(6.270)	(10.534)
Value added (trend^3)	2.384	-1.020
	(3.780)	(6.241)
Value added (pos)	-2.740*	-3.773
	(1.508)	(2.524)
Value added (neg)	-3.760	3.456
	(3.654)	(5.784)
Constant	-2.002***	1.680***
	(0.244)	(0.384)
Observations	14,544	14,544
Likelihood	-2745.951	

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 15: Parameter estimates for observation probabilities for the control group

VARIABLES	μ_{it}^N	μ_{it}^C	$\alpha_i^{s_z}$
Product homogeneity			-0.538**
			(0.215)
Law index	-0.007	-0.550***	
	(0.043)	(0.076)	
Birth count	-0.014	0.010***	
	(0.016)	(0.002)	
Death (stock)	0.000		
	(0.000)		
Death (stock^2)	-0.000		
	(0.000)		
Death (flow)	0.002***		
	(0.001)		
Birth (stock)		-0.000	
		(0.000)	
Birth (stock^2)		0.000	
		(0.000)	
Birth (flow)		0.004***	
		(0.001)	
Constant	-2.677***	1.224***	-0.729***
	(0.156)	(0.217)	(0.185)
Observations	14,544	14,544	14,544
Likelihood	-2745.951		

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

I Difference-in-difference with fixed effects

We run two difference-in-difference models with the following specifications for both cartel formation, $P1it$ and for cartel survival, $P2_{it}$:

Industry fixed effects:

$$Pj_{it} = \beta_0 + \beta_1 treated + \beta_2 post1950 + \beta_3 treated \times post1950 + \beta_4 controls + a_i + \varepsilon_{it} \quad (13)$$

Industry and year fixed effects:

$$Pj_{it} = \beta_0 + \beta_1 treated + \beta_2 post1950 + \beta_3 treated \times post1950 + \beta_4 controls + \beta_{5-19} T_{2-15} + a_i + \varepsilon_{it} \quad (14)$$

Table 16: Difference-in-difference with industry fixed effects

VARIABLES	Formation ($P1_{it}$)	Survival ($P2_{it}$)
post1950	-0.0118***	0.0382***
	(0.000431)	(0.00166)
post 1950×Treated	0.00766***	0.0291***
	(0.000342)	(0.00327)
GDP	0.0215***	-0.136***
	(0.000582)	(0.00266)
Constant	-0.196***	2.296***
	(0.00602)	(0.0279)
Observations	8,670	8,670
R-squared	0.633	0.635
Number of industries	578	578

Note: Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 17: Difference-in-difference with industry and year fixed effects

VARIABLES	Formation ($P1_{it}$)	Survival ($P2_{it}$)
post1950×Treated	0.00766***	0.0291***
	(0.000343)	(0.00327)
T_2	1.27e-05	-6.80e-06*
	(8.36e-06)	(4.09e-06)
T_3	2.56e-05	6.50e-07
	(1.93e-05)	(1.16e-05)
T_4	1.83e-05	8.28e-06
	(1.15e-05)	(1.11e-05)
T_5	-0.00365***	-0.0140***
	(0.000221)	(0.00167)
T_6	-0.00403***	-0.0169***
	(0.000212)	(0.000956)
T_7	-0.00407***	-0.0170***
	(0.000212)	(0.000963)
T_8	0.00323***	-0.0507***
	(7.26e-05)	(0.00101)
T_9	0.00349***	-0.0506***
	(7.17e-05)	(0.000984)
T_{10}	0.00260***	-0.0526***
	(7.35e-05)	(0.001000)
T_{11}	0.0111***	-0.0977***
	(0.000195)	(0.00162)
T_{12}	0.0101***	-0.1000***
	(0.000185)	(0.00154)
T_{13}	0.00983***	-0.100***
	(0.000175)	(0.00153)
T_{14}	0.0101***	-0.0997***
	(0.000178)	(0.00154)
T_{15}	0.00939***	-0.101***
	(0.000169)	(0.00150)
Constant	0.0234***	0.910***
	(0.000126)	(0.00115)
Observations	8,670	8,670
R-squared	0.752	0.722
Number of industries	578	578

Note: Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

J Difference-in-difference with lags and leads

We also run the difference-in-difference model with lags and leads to further test for the parallel trends assumption and detect any phasing in effect:

$$Pj_{it} = \beta_0 + \beta_1 treated + \beta_2 post1950 + \beta_3 treated \times post1950 + \beta_4 controls$$

$$+ \sum_{k=-3}^{3} \beta_k post1950 \times treated(t = 1950 + k) + \varepsilon_{it} \tag{15}$$

Table 18: Difference-in-difference estimation with lags and leads

VARIABLES	Formation ($P1_{it}$)	Survival ($P2_{it}$)
post1950	-0.00880***	0.0495***
	(0.000398)	(0.00184)
Treated	0.0203***	-0.0306***
	(0.00125)	(0.00378)
lead (1)	-0.000664***	0.00507***
	(5.17e-05)	(0.000145)
lead (2)	-0.00174***	0.0146***
	(6.08e-05)	(0.000419)
lead (3)	-0.00170***	0.0142***
	(5.29e-05)	(0.000406)
post1950×Treated	0.00522***	-0.0206***
	(0.000301)	(0.00127)
lag (1)	-0.00405***	0.0273***
	(0.000254)	(0.000872)
lag (2)	-0.00159***	0.0124***
	(0.000132)	(0.000354)
lag (3)	0.0138***	-0.00148
	(0.000453)	(0.00118)
Number of firms	-5.86e-07***	1.75e-06
	(1.87e-07)	(2.52e-06)
Industry organisation	-0.00529**	-0.0114
	(0.00235)	(0.0104)
GDP	0.0180***	-0.147***
	(0.000565)	(0.00422)
Sanctions		-0.00241
		(0.00697)
Coordinating mechanism		0.00573
		(0.00828)
Price clause		0.0152*
		(0.00821)
Quota clause		0.0121
		(0.00893)
Market division clause		0.00366
		(0.00555)
Constant	-0.164***	2.405***
	(0.00577)	(0.0427)
Observations	4,185	2,835
Number of industries	279	189

Note: Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.