Competition or collusion? Screening the Finnish road maintenance market

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Abstract: This study focuses on quantitative tools of economic analysis aimed at detecting collusion based on market data. Screening is a term covering many different methods with varying levels of complexity and ambition. Behavioural screening consists of methods using different strategies of which all concern analysing the pricing or bidding of firms.

In the empirical part, a behavioural screening approach is used to examine whether firms on the Finnish road maintenance market can be argued to be competitive or collusive. For this purpose, methods developed by Porter and Zona (1993; 1999) as well as Bajari and Ye (2003) are used on data concerning tenders from years 2009 to 2017. The tests used to separate between competitive and collusive behaviour are based on assumptions that hold for sealed-bid auction markets such as the present market. To be able to conduct the tests, a model that depicts the bidding of the firms is constructed. This model controls for firm's own distance to the contract area, measured as the shortest distance from its branch locations. It also controls for firm's capacity utilization rate at the moment of the tender and its familiarity of the local market based on earlier contracts. In addition to these variables that reflect the firm's own competitiveness, three variables that control for competitive pressure are derived based on values of rivalling firms.

Collusiveness is studied both through the conditional independence of firms' bids after all public information has been controlled for and the exchangeability of firms' bid function coefficients. Based on these tests, no explicit evidence of collusion is found.

Keywords: Competition, collusion, screening, cartels, bidding markets, quantitative methods, microeconomic modelling, road maintenance in Finland

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Konkurrens eller kollusion? Screening av den finska marknaden för vägunderhåll

Sammandrag: Denna studie fokuserar på kvantitativa metoder av ekonomisk analys med syfte att avslöja kollusion på basis av marknadsdata. Screening är ett begrepp som täcker många olika metoder av varierande komplexitet och ambition. Screening av beteende består av metoder med olika strategier varav alla handlar om att analysera data gällande företagens prissättning eller budgivning.

I den empiriska delen används screening av beteende för att undersöka om företag på den finska marknaden för vägunderhåll kan påstås konkurrera eller samarbeta med varandra. För detta syfte tillämpas metoder som har utvecklats av Porter och Zona (1993; 1999) samt Bajari och Ye (2003) på data gällande anbud från åren 2009 till 2017. Testen som används för att skilja mellan konkurrens och samarbete baserar sig på antaganden som kan göras för en marknad med slutna budprocesser, som utnyttjas på den studerade marknaden. För att kunna utföra testerna konstrueras en modell för att simulera företagens budgivning. Modellen kontrollerar för företagets avstånd till kontraktsområdet, mätt som det kortaste avståndet från dess fasta lokaler. I tillägg kontrollerar modellen för företagets kapacitets utnyttjandegrad vid tidpunkten av anbudet samt, för dess kännedom av den lokala marknaden som baserat på tidigare kontrakt. Förutom dessa variabler, som reflekterar företagets egna konkurrenskraft, härleds tre variabler som kontrollerar för konkurrenstryck baserat på värdena för de konkurrerande företagen.

Samarbete på marknaden studeras både genom ett krav på självständighet av företagens bud efter att all offentlig information har kontrollerats för samt genom utbytbarheten av företagens budgivningsfunktions koefficienter. Baserat på testen hittas inte tydliga bevis på samarbete mellan företagen.

Nyckelord: Konkurrens, kollusion, screening, karteller, anbudsmarknader, kvantitativa metoder, mikroekonomisk modellering, vägunderhåll i Finland

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1 INTRODUCTION

The aim of this thesis is to study whether behaviour of Finnish road maintenance firms can be argued to be competitive or collusive based on a quantitative approach using data from tenders held between years 2009 and 2017. As these tenders concern solely public procurement, the information concerning participants and submitted bids are all public information that can be requested from the Finnish Transport Infrastructure Agency (FTIA). However, the data used in this study has not been received directly from the FTIA but instead from the Finnish Competition and Consumer Authority (FCCA).

The FCCA gathered the data to assess the impact of a proposed merger between YIT and Lemminkäinen. It used the data mainly to examine how the winning bid is affected by the number of bidders. YIT and Lemminkäinen were the second and third largest operators on the road maintenance market at the time of the merger investigation. The phase II merger was cleared unconditionally on the 26th of January 2018. The FCCA motivated its decision partly by stating that, based on its analysis, the decrease in suppliers does not have an impact on the competitive situation of the road maintenance market. (Kilpailu- ja kuluttajavirasto 2018)

In addition to competition authorities using economic analysis to support investigations related to merger control, economic analysis can be used to detect cartels from market data. Using quantitative tools in combination with economic reasoning to investigate a market based on data is commonly denoted as screening (Harrington 2006; Laitenberger & Hüschelrath 2011; Sjöblom 2015). This study provides an overview of the different screening methods that are usually grouped into structural and behavioural ones but can be grouped even further (Harrington 2006). In the empirical part of this study, the road maintenance market is investigated using a behavioural screen that separates between competitive and collusive behaviour. The two tests that are used for this purpose are based on assumptions that hold for sealed-bid auction markets such as the road maintenance market, where bids are submitted simultaneously without communication. (Bajari & Ye 2003)

This study is the first one to screen the Finnish road maintenance market for collusion. Subsequently, by using the methods developed by Porter and Zona (1993; 1999) as well as Bajari and Ye (2003) on a new market, the usability of these methods is better understood for future studies. This study contributes to existing literature also by testing

how rivalling firms' familiarity with the local market affects bidding through competitive pressure.

This study is built to give the reader an introduction to the area of competition control in Finland before the analysis. The study begins with an overview of the present market. Following this, the legislative framework of competition and the responsible authorities for competition control in Finland are presented. Subsequently, methods used in cartel detection are discussed. These methods can be grouped into reactive and proactive ones, of which the latter better describes the methods of this study. From cartel detection, the study continues with an overview of the literature concerning behavioural screening methods and it ends the theoretical part.

The empirical part starts by presenting the data briefly and the model more in detail. The core model consists of six variables that are used to control for factors relating to the bidding firm's own competitiveness as well as competitive pressure caused by other firms. In addition to the core variables, fixed effects of all tenders and of the main firms are controlled for in the full model. After presenting the model and its boundary conditions, the analysis is conducted. The analysis consists of three sections of which the first part is used to consider the fit of the model on the data. The first actual test for collusion is the second part of the analysis, where a conditional independence test is run on the residuals of the model. The second test for collusion is in the third part of the analysis, where the exchangeability of the main firms' coefficients is studied. The study ends with a discussion before conclusions.

2 BACKGROUND

2.1 Public tendering of road maintenance jobs in Finland

Public road maintenance means preserving the safety and usability of roads. Over fifty per cent of the road maintenance related costs are caused by winter care. This includes ploughing, gritting and salting roads in the winter. Road maintenance consists among other things of keeping road environments tidy, making sure lane markings and traffic signs are in suitable condition, as well as fixing road damages caused by weather conditions. Nevertheless, road maintenance should not be confused with road reparation projects that are tendered separately. (Partanen 2018)

The maintenance of public roads in Finland is divided into 79 contract areas (Väylävirasto 2019a). ELY Centres are responsible for the administration of road maintenance contracts on their territories (Elinkeino- liikenne- ja ympäristökeskus 2018). They distribute the contracts in co-operation with the Finnish Transport Infrastructure Agency to private actors through tenders. Following the tendering processes, contract areas are then managed for five years by winners of the tenders, before being tendered again. (Väylävirasto 2019b) In earlier years, some contracts have even covered seven-year periods (Kilpailu- ja kuluttajavirasto 2018). The contracts are renewed gradually: in 2019 seventeen of the 79 contracts were tendered for the period covering 2020 to 2024 (Hussi 2019). For a map over contract areas and their distribution between firms in 2019, see Appendix 1.

The maintenance of public roads in Finland was completely state managed up until 1998 when the administrative and executing departments of the road maintenance office were separated from each other. This was a necessary step in the process of opening the market for competition, as the distribution of contracts could not be handled by the same body competing over them. During the following seven years the road maintenance market was gradually opened for competition, until becoming a fully competitive market as of the beginning of 2005. In 2008 the former executing department was incorporated, and its name was changed from Tieliikelaitos to Destia. It continued for a while as a state-owned company until 2014 when all its shares were sold to private investors. (Destia 2018)

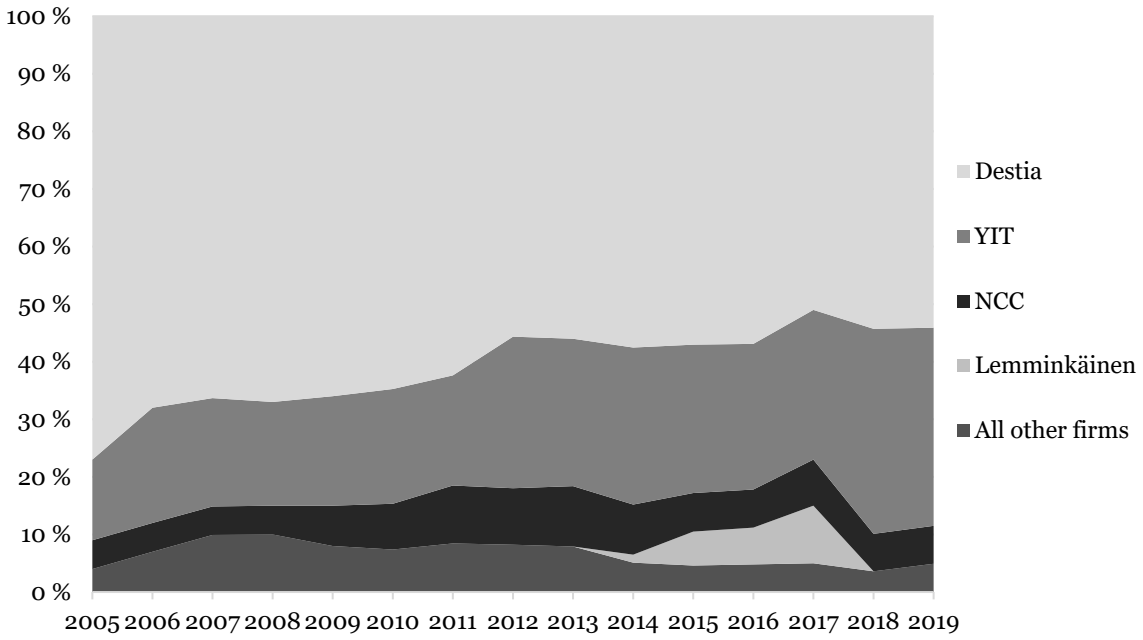


Figure 1 Market shares of the Finnish road maintenance market, based on Hussi (2019)

The market share development during years of full competition is described in Figure 1. In 2018 the market can still be called fairly concentrated. The former state monopoly still holds a remarkable share of the contracts, but its majority has been quite steadily decreasing. During the years of full competition, Destia has lost twenty per cent of the whole market to its rivals. Most of the market share has been grabbed by the second largest player YIT which has held its second position ever since it won its first contracts back in 1998 (YIT 2018a). From 2015 to 2017 the market had four major players, but this number was reduced to three as Lemminkäinen was merged into YIT on the 1st of February 2018 (YIT 2018b). The third noteworthy actor in the road maintenance market is NCC. The remaining contract holders have varied through the years. During the tender free season ranging from October 2019 to October 2020 contracts are held by only two other firms, these being Savon Kuljetus and Kuljetus- ja Vihertyö Tapio Pahkakangas (Hussi 2019).

One important reason for the seemingly concentrated situation on the market is that the tendered contracts are considerably large. Moreover, one of the mandatory requirements for candidates is their yearly revenue from three previous years being at least 1.5, 2 or 3 times higher than the annual cost estimate of the contract, depending on its level of difficulty. Contracts can be evaluated as either normal, demanding or very demanding. (Kohonen 2016) During the tender season of 2019, the lowest annual cost estimate of a

normal contract was eight million euros (Hussi 2019). A candidate was therefore required to have had at least twelve million euros in yearly revenues from 2015 to 2017 to qualify for the tender. However, even the participation of smaller firms is encouraged by allowing bids submitted by consortiums meeting the given requirements (Kohonen 2016). In addition to this, road maintenance work opportunities are available to smaller firms through subcontracting which is widely used on the market (Partanen 2018).

In 2019 most road maintenance tenders are open procedures, meaning that any firm can submit an offer (Levola 2018). However, before 2016 the main rule was a restricted procedure where firms first asked for permission to participate and only if it was granted did they submit a bid (Kilpailu- ja kuluttajavirasto 2018). Both types can be considered to be first-price sealed bid auctions in nature, as firms submit their bids privately unaware of their competition. In addition to the open procedures, some of the tenders are executed as offer based negotiated procedures. In these, all firms may bid but only a few are then selected to a negotiation phase. The final terms of the contract and the winner is then determined based on these negotiations. (Levola 2018) Because the negotiations are conducted privately with each of the candidates and the exact contents of the competing offers are not revealed (Kilpailu- ja kuluttajavirasto 2018), these procedures cannot be considered to be English auctions in nature, but arguably more of that descent than the open procedures. The portion of the offer based negotiated procedures was roughly 3.4 per cent of the tenders included in the data (Kilpailu- ja kuluttajavirasto 2018).

In the open procedures after an invitation to tender has been published, firms bid by submitting the required standardized documents before a given deadline. A candidate is to submit to separate envelopes: one with the qualitative details of the offer and a second one with all pricing information concerning the offer. The contracting entity reviews all received offers by opening the first mentioned envelopes. In this phase, the quality of all offers is assessed. Offers not meeting the minimum quality requirements are disqualified, when this happens the second envelopes are not even opened. For all offers that pass the quality assessment, pricing envelopes are opened and regardless of the ranking of the first phase, the offer with the lowest price wins. (Kohonen 2016)

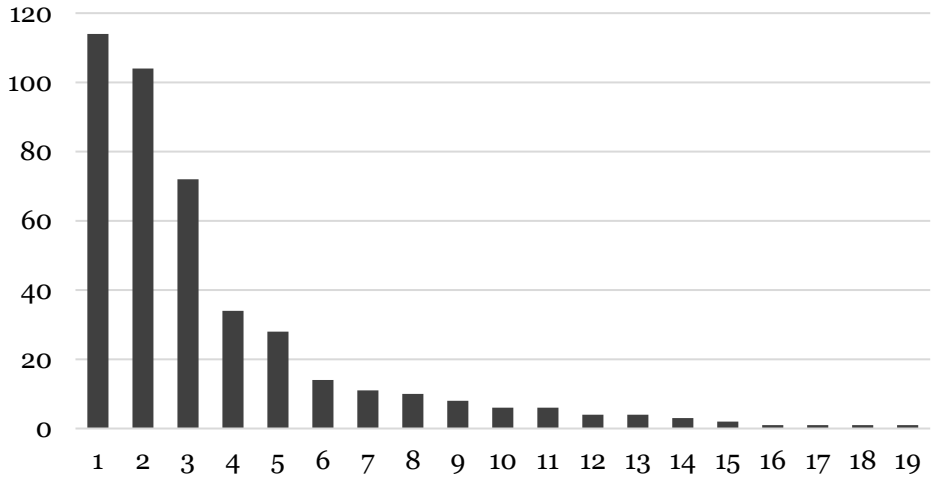


Figure 2 Firms ranked according to their bidding activity

The bidding activity of all firms that have bid at least once during the observation period is demonstrated in Figure 2. In later chapters firms will no longer be referred to by name, but instead identity numbers based on this ranking.

2.2 Competition control in Finland

2.2.1 The legal framework

Restrictions on competition enables competitors to refrain from competing against each other, allowing them to earn supra-normal profits. In economics, this is often referred to as a collusion. Collusive behaviour is hurtful for the total welfare of the economy, because it produces inefficiencies that can materialize in the form of higher prices and increased public expenditure. (Krishna 1989)

Economic theory commonly divides collusions into explicit and tacit ones. In tacit collusions firms can refrain from competing without the need to explicitly communicate this to each other (Ivaldi et al. 2003). A tacit collusion can be facilitated for example with the help of low-price guarantees as they remove the benefit of undercutting (Sargent 1992). A collusion that restricts competition and is based on an agreement is denoted in economics as being explicit, in other words a cartel.

Cartels are illegal in Finland according to both national and EU law which are implemented alongside each other. As section 5 of the Competition Act has been harmonized with Article 101(1) of the Treaty on the Functioning of the European Union

(TFEU), these two sections are almost identical to each other. The applicability of Art. 101(1) TFEU in Finland is as broad as the power of the European Commission to investigate potential competition restrictions on Finnish territory (Oinonen 2016). In order to EU competition law to be applicable, the restriction needs to affect trade between member states and have as its object or effect the prevention, restriction or distortion of competition in the internal market. When Art. 101(1) TFEU is applicable, both laws can be applied simultaneously on the infringement but in infringements that are completely domestic in nature, only the Competition Act may be applicable.

Section 5 of the Competition Act states as follows:

> *(1) All agreements between undertakings, decisions by associations of undertakings, and concerted practices by undertakings which have as their object the significant prevention, restriction or distortion of competition or which result in a significant prevention, restriction or distortion of competition shall be prohibited.*
>
> *(2) In particular, agreements, decisions, or practices which:*
>
> *1) directly or indirectly fix purchase or selling prices or any other trading conditions;*
>
> *2) limit or control production, markets, technical development, or investment;*
>
> *3) share markets or sources of supply;*
>
> *4) apply dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage; or*
>
> *5) make the conclusion of a contract subject to acceptance by the other party of supplementary obligations which, by their nature or according to commercial usage, have no connection with the subject of such a contract shall be prohibited.*

The first paragraph of the section prohibits all forms of agreements between competing firms that significantly damage competition. The second paragraph contains a list of possible violations, but it is not exhaustive as also conduct not mentioned on the list can be considered a violation of the first paragraph. The importance of the second paragraph is that it contains the *per se* violations of the section – agreements that are in most cases harmful and therefore assumed to be anti-competitive (Jones 2010). The per se violations are therefore assumed to have as their *object* the prevention, restriction or distortion of competition and are thus always illegal with only a few exceptions. The exceptions to the rule meet all four requirements put forth in section 6 of the Competition

Act. Mainly, they do not restrict competition more than necessary, create efficiencies and a reasonable part of the created surplus is shared with the customers.

Restrictions not included in the list of section 5(2) of the Competition Act are forbidden as well, if they result in the significant damaging of competition. In the case of a restriction by *effect* (Jones 2010), the competition authority must be able to prove both the existence of the agreement, decision or concerted practice and its harmful effect on competition. The proving of a per se violation can be regarded somewhat simpler, as in this case proving only the existence of the agreement is enough and no further consideration of its effects is needed. The division into restrictions by object or effect is important as the need to prove the anti-competitive effects of the agreement through economic analysis raises the competition authority's burden of proof considerably. (Whish 2012)

In Finland, the FCCA is therefore sometimes forced to use economic analysis in order to justify a penalty payment proposal to the Market Court. This is not an easy task as the standard of proof in competition cases is relatively high and results of economic analysis tend to be easily challenged by altering the underlying assumptions (Röller 2005). This has also been stated by the Supreme Administrative Court in its decision concerning the asphalt cartel. The court noted that the type of economic analysis used by both the FCCA and the firms responding to its accusations always includes "numerous elements of uncertainty" *[own translation]* (Korkein hallinto-oikeus 2009, paragraph 1095). The strength of economic analysis as evidence can therefore be said with certainty to be lower than that of hard evidence, in the form of written communication, as these analyses tend to leave more leeway for different interpretations.

The easiest way for a competition authority to prove an illegal restriction on competition can therefore be said to be through hard evidence on per se violations. It is also worth noting that even in the case of a violation by effect, hard evidence on the action that induces the effect is needed. There can be said to be two main ways a competition authority can get access to hard evidence; through dawn-raids and leniency programs.

2.2.2 Competition authorities

The FCCA is the party mainly responsible for the enforcement of the competition legislation in Finland. The FCCA's objective concerning the enforcement of competition can be found in section 2 of the Act on the FCCA. A more detailed description of its tasks and the limits of its powers are to be found in the Finnish Competition Act (948/2011).

In addition to the national competition authority, competition enforcement in Finland can sometimes also be conducted by the European Commission. Although the European Commission has been granted broad rights to act in order to secure the implementation of EU competition policy, its competence to act in Finland is limited to the scope of Art. 101 and 102 TFEU (Oinonen 2016). The European Commission's right to take measures concerning a competition infringement requires that the infringement may affect trade between EU member states and has as its object or effect the prevention, restriction or distortion of competition in the internal market.

One of the FCCA's main objectives is to investigate restrictive practices that can be considered harmful to economic competition in Finland. Whenever it finds a practice to be harmful enough for competition, it can order to terminate the restraint on competition and when applicable oblige the undertaking to deliver the product. This is stated in section 9 of the Competition Act. The FCCA does however not have the power to impose fines on undertakings for breaking the law. This judicial power is held by the Market Court which decisions can be appealed to the Supreme Administrative Court. The latter acts as the highest instance in competition cases concerning the right application of the Competition Act. The FCCA's responsibility is nevertheless to make penalty payment proposals to the Market Court whenever an undertaking's illegal conduct cannot be deemed to be minor or the imposition of the penalty payment is otherwise justified in order to safeguard competition. This is stated in section 12 of the Competition Act. The FCCA can therefore be seen to act as the prosecutor in competition related matters. Although not being able to discipline firms independently, the FCCA's role in the imposition of fines should not be understated, as the courts themselves are also unable to fine undertakings without a proposal.

2.3 Methods of cartel detection

2.3.1 Introduction to methods

The different ways to detect cartels are often divided into reactive and proactive methods (International Competition Network 2010; OECD 2013; Abrantes-Metz 2013). In reactive methods the competition authority reacts to information it receives from others. Reactive methods include complaints, leniency applications and other sorts of information received from external sources. Only after the initial contact does the competition authority obtain awareness of the issue and can therefore start its own investigation. On the other hand, in proactive methods the competition authority makes use of information it has generated itself. This means that the initiation of an

investigation is less dependent on external events. Proactive methods include screening of markets, tracking of individuals and following news and internet sources. (International Competition Network 2010) Investigations conducted proactively, without them stemming from external contact, are commonly denoted as *ex officio* investigations (OECD 2013; Friederiszick & Maier-Rigaud 2008).

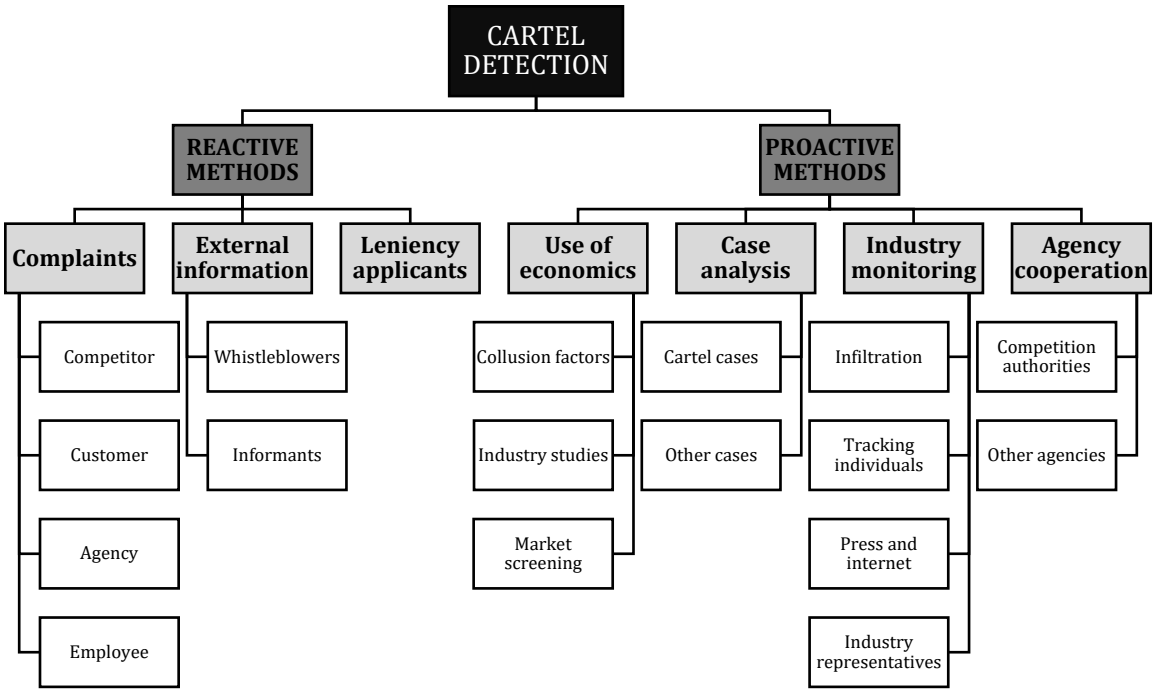


Figure 3 Methods to detect cartels, based on Hüschelrath (2010)

One way to illustrate the different cartel detection methods, is demonstrated in Figure 3. It is often argued that a proper combination of both reactive and proactive tools yields the best results in cartel detection. The methods should therefore be seen as complementary goods, rather than substitutes to each other (OECD 2013; International Competition Network 2010). In recent years leniency policies have become an increasingly important tool for the revelation and successful prosecution of cartels. At some point, over ninety per cent of the fines imposed in competition cases in the U.S. could be traced to investigations initiated from leniency applications (Werden et al. 2011). There have however been critical voices saying that competition authorities should beware of relying too heavily on leniency programs. It is often argued that these programs work best when firms experience being exposed by proactive investigations as a credible threat (Hammond 2010; Harrington & Chang 2015).

2.3.2 Leniency programs

A well-designed leniency program can be regarded the most important tool for revealing and punishing cartels. Leniency programs destabilise cartels by promising the first one to report full immunity from fines. Leniency policies are often thought to mitigate cartels in two ways: by incentivizing the revelation of cartels in the short-run and deterring the formation of new cartels in the long-run (Brenner 2009; Chen & Rey 2013). In order to either of these mechanisms to work the punishment for being caught must be substantial enough to make colluding overall a worse alternative than competition. The power of leniency programs can also be improved by the imprisonment of persons responsible for the illegal conduct. Although the personal liability of executives might arguably deter the formation of cartels more efficiently than fines payed by firms (Wils 2005), cartels are not criminalized in Finland or EU.

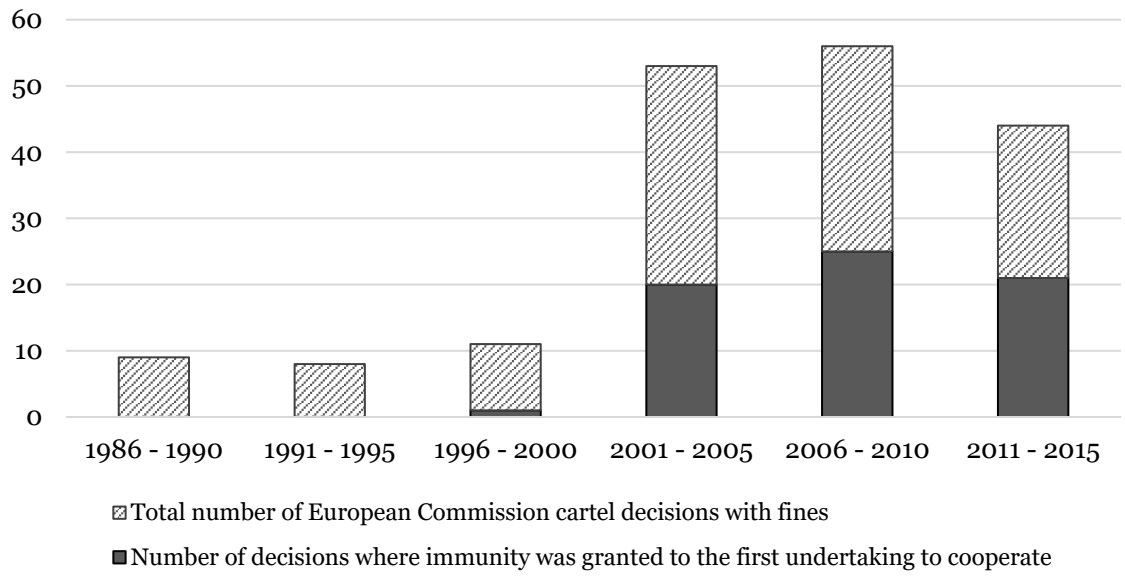


Figure 4 Cartels fined by the European Commission 1986-2015, based on (Wils 2016)

The first leniency program that was put into force was the U.S. Corporate Leniency Program in 1978 (Hammond 2010). The first leniency program in the EU came into force when the European Commission issued its first Leniency Notice in 1996. The leniency program currently in use in the EU is based on the Leniency Notice issued in 2006. Based on Figure 4, it seems clear that the leniency program has had some effect on the number of cartel investigations conducted at the European level. It has however been questioned how much of the increased number in fined cartels can be explained by the increased cross-border activity that is a natural consequence of the integration measures taken

during the last decades (Brenner 2009). It is worth noting that the European Commission's proceedings tend to be lengthy and there may therefore be a time lag of at least a couple of years from the leniency application being received to the fines being imposed (Wils 2016).

The Finnish leniency program was first adopted in the Finnish Competition Act in 2004 (Eduskunta 2004). The program is now embodied in sections 14 to 17 of the Competition Act. These sections form a body that largely resemble the 2006 Leniency Notice issued by the European Commission. According to section 14 of the Competition Act, full immunity is granted to the first firm to reveal a secret restraint on competition. According to section 15 of the Competition Act, smaller reductions ranging from zero to fifty per cent can be granted to other participants of the same cartel, if new significant information about the cartel that helps the FCCA establish the entire extent or nature of the restraint is submitted. Section 16 of the Competition Act concerns conditions for receiving full immunity or reductions in fines. Finally, section 17 of the Competition Act explains how immunity or a reduction should be applied for. More detailed information about the leniency program has been published by the FCCA in the form of guidelines (Kilpailu- ja kuluttajavirasto 2011).

Although leniency programs can well be argued to be the most successful weapon the competition authorities have against cartels, there is still a clear need for the use and development of alternative methods. As already mentioned, many authors have noted that the efficiency of leniency programs stems from a real threat of being exposed by other types of investigations (Hammond 2010; Harrington & Chang 2015). However, it should be remembered that because of the secrecy of cartels, empirical studies struggle to prove this point, despite of the intuition. Abrantes-Metz and Bajari (2009) have also noted that it is possible that leniency programs are biased towards uncovering only cartels that are close to their breaking point. This would suggest a significant need to the further development of other tools to detect cartels, as it implies that the most stable conspiracies are never caught by leniency programs.

Fortunately, there seems to be no easy way for colluding firms to create this stability, as any agreement involving a competition restriction that is in contrast with Art. 101(1) TFEU is automatically void according to Art. 101(2). The same principle is stated in Section 8 of the Finnish Competition Act. This means that a party to an illegal agreement cannot seek compensation from a breach of contract, in the form of a deviation, from official tribunals or through arbitration. Firms forming a cartel may therefore be tempted

to form their own ways of dispensing justice. Gambetta and Reuter (1995) note that mafias tend to be able to solve the problem of instability by posing a real threat of violence, that deters deviations effectively.

2.3.3 Screening

The objective of this chapter is to briefly discuss the role of screening in cartel detection. Screening in this area of interest is commonly divided into structural and behavioural approaches (Abrantes-Metz 2013; Doane et al. 2015; Harrington 2006). The empirical part of this thesis uses the behavioural approach. A more detailed review of the literature concerning behavioural screening can therefore be found in Chapter 3.

Screening is a proactive method that competition authorities can use to detect cartels (International Competition Network 2010). This umbrella term can be used to denote very different kinds of activities, the unifying factor in this context being the attempt of identifying illegal conduct. One way of dividing the literature and methodology concerning screening, is into a structural and a behavioural approach (Harrington 2006). These two approaches can be regarded fundamentally different in many ways and could be simplified as the macro and micro levels of screening.

The structural approach means screening on a macro level. It can be regarded as a rough way of narrowing down candidate markets to the ones where the possibility of an operating cartel is deemed to be the highest. This is performed by observing the structural characteristics of different markets (OECD 2013; Harrington 2008; Hüschelrath 2010). Criterions to look for in practice may be for example market share stability, increased concentration and lack of market entry (OECD 2018). This approach has also been denoted as the top-down approach (Laitenberger & Hüschelrath 2011).

Structural screening can be regarded as a rough methodology. Because of different market dynamics, competitive markets can take so many different forms that it seems unlikely that collusions could credibly be detected using general market characteristics. Nonetheless, the obvious reason for competition authorities to use structural screening to some extent is their scarce resources: Conducting resource-intensive investigations on all different product and geographic markets is simply not possible, as it is too expensive and time consuming. Although its imperfections, structural screening can therefore be used as a tool to reduce the number of markets to a conceivable subset.

Unlike the structural approach, behavioural screening focuses on identifying illegal conduct on a specific market (Harrington 2006), this approach can therefore be denoted as being screening on a micro level. By concentrating on only one market at a time, behavioural screening could easily be thought to have more modest requirements on data than the structural approach, but it is on the contrary. In order to conduct structural screening, even cross-sectional aggregate data from an industry may suffice. In contrast, when conducting behavioural screening, panel data with firm specific information from different points in time is usually needed. This is intuitive because although a lot can be said about market structure based on a moment in time, behaviour is, by definition, interaction and development. Therefore, it cannot be studied based on static information.

One trait of the behavioural approach over the structural approach is that even though neither methodology can give a definite answer on whether a market is competitive or not, the answer of the behavioural approach is more satisfying in terms of causality. Although, the aggregate level changes in a market caused by a cartel may become visible and caught eventually by structural screening, no market operates in a vacuum and these changes can therefore mostly be argued to result from something else. The strength of behavioural screening is that, it is not only able to observe the market outcome, but it can also present a description of the potential violations that led there.

This chapter presented briefly how different screening methods can be useful tools for competition authorities in cartel detection. However, it must be mentioned that especially behavioural screening can equally well be used by defendants, as a way of defending themselves against an alleged competition law infringement (Abrantes-Metz & Bajari 2009). As it relates to the aim of this thesis, a more in-depth review of the literature concerning behavioural screening will be given in Chapter 3.

3 THEORETICAL FOUNDATIONS

3.1 Literature review

The objective of this chapter is to give a good overview of the available behavioural screening methods that can be used to conduct a more thorough quantitative investigation of a market. More precisely, the focus is to discuss methods that are closely related or otherwise good alternatives to the chosen methodology of this thesis.

The different tools that can be labelled under behavioural screening form a somewhat heterogenic group with different levels of complexity. The options available can be seen to depend to an extent on what data can be collected concerning the market in question. However, there seems to be one crucial element that is needed to use any behavioural screen, and it is information on decision making. This information means, in essence, either pricing or output decisions, depending on the relevant market structure.

Information on decision making is a common element in all behavioural screens, because how firms behave can be thought to equal the decisions they make. Considering for example a firm producing and selling a generic product, there is a lot of information that can be gathered concerning its operating environment, but these elements are mostly exogenous and outside the control of the firm. Such elements may include, among other things, raw material costs and demand fluctuations. Even though this sort of information can be useful for an analysis, only information on what the firm decides may reveal if it is working independently or colluding with its rivals.

A large part of the literature concerning behavioural screening is based on bidding markets. One obvious reason for this is that these markets tend to be well endowed with pricing data (Abrantes-Metz et al. 2012). This can also be thought to be the consequence of a high number of revealed bid-rigging cartels compared to price-fixing cartels: Froeb et al. (1993) reports that between years 1988 and 1993, criminal cases concerning bid-rigging were over two twice as common, as those involving price-fixing.

Harrington (2008) has grouped behavioural screens to detect bid-rigging into four distinct groups based on the approach they take on identifying a collusion. This same systematization will be used in the literature review of this chapter, although, these kinds of categorizations are always to some degree artificial. Following this, even though some studies may be easily allocated to one category, the borders are not always clear and some of the categories overlap each other more than others.

Harrington (2008) categorizes the different types of behavioural screens to detect collusion as follows: The first group tries to identify a structural break in firm behaviour. The second group compares the behaviour of suspected firms to a competitive benchmark. The third group fits at least one competitive and one collusive model on the data to see which one of the models explains the behaviour of firms better. Finally, the fourth group studies whether firms' behaviour is consistent with competition. (Harrington 2008)

3.1.1 Investigating a structural break in firm behaviour

The first category studies whether there is a seemingly unexplained structural break in the behaviour of all firms or a subgroup of firms on a market. These sudden changes in collective behaviour can in some cases be more or less convincingly argued to be the result of either the formation or the collapse of a cartel. As colluding firms usually try to be rather subtle when increasing the price (Feinstein et al. 1985), a structural break can be thought to be more often caused by a collapse.

If considering a sealed-bid auction market, any type of coordinated behaviour should be regarded suspicious because no communication is allowed between competing firms. The coordination might however just become obvious as a result of a structural break. Based on theory and past evidence one should however especially look for changes in average bids, the relationship between costs and bids and the variance of bids (Harrington 2008).

An example of a structural break in firm behaviour is presented in a study by Froeb et al. (1993) concerning the sale of frozen seafood to a public authority in Philadelphia. The bid rigging involved determining winners and complementary bids for weekly held auctions. The authors are able to identify a significant drop in the price of frozen perch that is explained by one of the participants withdrawing from the conspiracy after an investigation was started. Even though the conspiracy involved also other types of seafood, frozen perch was chosen by the authors because best cost data was available for this product. The structural break was identified by comparing the winning bids of frozen perch with contemporaneous and lagged prices of fresh perch. The price of fresh perch remained relatively stable when there was a sharp drop in the winning bids caused by the cartel collapsing. (Froeb et al. 1993)

In addition to simply looking for a price drop, the structural break approach can be executed in other ways. Cartels tend to not only lift the market price or the average

winning bid, its presence can be reflected to sealed-bid auctions also through a lower variance, caused by candidates knowing the winning bid beforehand: Using the same data as Froeb et al. (1993), Abrantes-Metz et al. (2006) show that as the mean price of frozen perch fell by sixteen per cent, the standard deviation increased by over 250 per cent. This remarkable increase in discrepancy seems to be explained by firms making their decisions in great uncertainty, following a period of close coordination.

3.1.2 Comparing behaviour to a competitive benchmark

The second category of behavioural screening compares the behaviour of firms that are suspected of colluding to some competitive benchmark. The competitive benchmark can be similar firms operating in another distinct geographical market, other firms in the same market that are assumed to be competing or data of the suspected firms from another time period when the firms are assumed to be competing (Harrington 2008). This category seems to be the most broadly defined by Harrington (2008). This leads to the category overlapping with both the first and the fourth category. When the chosen competitive benchmark is another time period with the suspected firms, the setup is almost identical with the structural break approach. Moreover, if the chosen benchmark is competing firms on the same market, the approach bears a close resemblance with the consistency with competition approach. It therefore seems that this category is best motivated when the suspected firms are compared to firms operating in another geographical market.

An example of a screen comparing suspected firms to a competitive benchmark is a study by Hüschelrath et al. (2013). The authors use the difference-in-differences approach to estimate the price overcharge of a cartel in the German cement industry. The competitive benchmark is a group of firms operating on four different geographical markets, namely Spain, France, the United Kingdom and Poland. The difference-in-differences approach compares the price development in the target market to that in the group of control markets. The other geographical markets have mainly the same objective as the price of fresh perch on the market of Froeb et al. (1993): to control for cost development but also other types of industrial development. As other control variables the authors include quarterly control variables for seasonal effects and the log of energy price which is argued as being an important driver of cement prices. The price overcharge is estimated of the cartel is estimated to be 26.5 per cent. (Hüschelrath et al. 2013)

3.1.3 Choosing between a competitive and collusive model

The third category of behavioural screens consists of a set of at least two models: a competitive and a collusive model which are both applied on the data to see which one is the better fit. However, fitting two models on the data is only the minimum, nothing stops from fitting more competitive and collusive models to find the one that best explains what is happening on the market (Baldwin et al. 1997). Related to this point, the biggest shortcoming of this type of screens is that if one does not know which forms competition and collusion might take, all fitted models might be misspecified. It then comes up to chance which model happens to fit the data best, and this might lead to the false conclusion. (Doane et al. 2015)

An example of a screen comparing the fits of competitive and collusive models is a study by Baldwin et al. (1997) concerning oral ascending timber auctions. The authors criticise the empirical auction literature for the wide use of models that are based on unrealistic assumptions, namely on the sale of one single object to one of several noncooperative bidders. The main focus of the paper is therefore to introduce a new multi-unit approach by comparing its results against the single-unit model. The authors fit a total of five different models on the market: a collusive and a competitive single-unit model, a competitive multi-unit model and two different nesting models combining collusion with the multi-unit model. Because the winning bids are best explained by the multi-unit models allowing for collusive behaviour, the authors conclude there being evidence of collusion. (Baldwin et al. 1997)

3.1.4 Studying consistency with competition

The analysis developed by Bajari and Ye (2003) is an example of behavioural screening inspecting whether suspected firms act in consistence with either competitive assumptions or other competitive firms. In addition to presenting this paper and its results, two other influential papers in this area will be presented: The two papers by Porter and Zona, published in 1993 and 1999, have had an important impact on this area of economic analysis. The three papers will be presented in their order of publication, as they can be seen forming a chain of development in which the newer papers build on the methods first presented in the older ones.

3.1.4.1 Porter and Zona (1993)

The study by Porter and Zona (1993) is based on procurement auction data from the highway construction industry of Long Island. The authors identify a candidate cartel of

five firms based on their reputation of having participated in bid-rigging schemes concerning individual contracts. The authors then compare the bidding behaviour of this group of firms during the whole observation period with the bidding behaviour of another group, consisting of all other firms on the market that are assumed to be competing. The hypothesis of the authors is that the two groups might behave significantly different from each other if the supposedly colluding firms engage in shadow bidding. Moreover, this difference is emphasized if the designated winner is picked on other grounds than the firm having the lowest costs to take on the contract. (Porter & Zona 1993)

The comparison of the two groups is conducted by designing a model explaining the log of a bid by firm *i* on contract *t* with the observable cost variables of firm *i* for contract *t,* in addition to variables controlling for auction specific fixed effects. The cost variables concern the current capacity utilization rate, the overall capacity and a location dummy variable. The capacity related variables are obtained by first computing a backlog that equals the accumulated value of won contracts, assuming that contracts are completed within three months. The overall capacity of firm *i* is then the maximum backlog during the whole observation period. Furthermore, the capacity utilization rate is the overall capacity subtracted with the current backlog. The location dummy variable controls for transportation costs, as it equals one if the firm has its headquarters on Long Island. (Porter & Zona 1993)

The outputs of the model from the two different groups of firms are compared in two different ways, to see if they are significantly different. In the first test, the estimated coefficients of the two groups are compared. The authors conclude based on the coefficients both that the model seems to fit the data of the competitive firms well and that the bids of the collusive firms are indeed significantly different from the competitive group. In the second test, the coefficients are not only estimated separately for the two groups of firms, they are estimated separately even for low- and high-ranking bids within the groups. This breakdown is aimed specifically at revealing shadow bidding, as the designated winning bids can be assumed to be the only bids that are formulated in a competitive manner before being scaled up. After testing the coefficient stability across ranks for both groups of firms, the authors conclude that although the competitive group's bids are generated in the same way across ranks, the bids of the colluding group are formulated differently depending on the rank. (Porter & Zona 1993)

3.1.4.2 Porter and Zona (1999)

Another example of the competitive benchmark approach which also demonstrates the overlap between this and the fourth category is a study by Porter and Zona (1999) concerning procurement auctions of school milk. The authors compare the behaviour of a group of firms charged with collusion to a group of competitive firms. The analysis is twofold: first the likelihood of firm *i* participating in an auction concerning district *t* is tested using several probit models and secondly, the bid level is estimated. (Porter & Zona 1999)

The first part of the analysis is based on the idea that a competitive firm acting independently will only submit a bid if the expected profit exceeds the costs of preparing the bid and the incremental costs of supplying the district. The probit models that are used to estimate this probability are based on both firm *i's* absolute and relative advantages in serving district *t*. The model controls for distance, being closest or second closest to the district, the size of the district, special terms of the contract and whether the bidder has access to a processing plant. Based on the first test, the authors conclude that the collusive firms choose participation in auctions in a significantly different way from the control group. (Porter & Zona 1999)

The second test assumes that a firm's bid should be on a level that maximizes its expected profit, this level is found at the optimal combination of profit margin and winning probability. Porter and Zona (1999) recognize that there are two types of variables that determine the optimal level: variables contributing to the underlying costs of the bid and variables describing the competitive environment. The second test is run using the same control variables as in the first test but also controlling for bidder and district fixed effects. Of the bidding function variables distance controls for costs and the dummy variables of being closest or second closest to the district control for competitive advantages. The main finding of the second test is that although the non-colluding firms' bids increase in relation to distance, the colluding firms' behaviour differs from the control group significantly. This is explained by the colluding firms keeping prices artificially high on their local market as their competing against non-collusive firms on markets further away. (Porter & Zona 1999)

After comparing the participation and bidding functions' coefficients of the collusive and competitive firms, the authors consider the relationship between private and public information and how these should be reflected in the bidding function. When public

information is correctly incorporated into the bidding function, the residuals of different firms should become independent from each other. The assumption of independent behaviour of competing firms is used at both stages of the analysis to see whether the colluding firms act in a parallel fashion. (Porter & Zona 1999)

At the first stage three different scenarios are possible of which one is the competitive outcome and the other two concern two different forms of collusive strategies. Firms are assumed to be competing, in other words, not coordinating their actions when there is no significant correlation between residuals. Then again both a significant positive and negative correlation is a collusive marker, the first signalling complementary bidding and the latter territorial allocation. Reviewing the residuals, reveal significant positive correlations between almost all firms suggesting the collusion used complementary bidding. The result is also supported by the testimonies of the firms. (Porter & Zona 1999)

Unlike the participation test, the second test concerning the bidding only really has two alternative scenarios of which one is competitive bidding and the second the only available collusive strategy. Also here residuals of competitive firms can be assumed to be independent from each other after public information is controlled for. However, only significant positive correlation can suggest the use of complementary bidding to give the impression of competition. In this case both firms may bid over the model's estimated level. The reason why a negative correlation is excluded as a collusive strategy is because it can only be achieved if one of the firms bids lower than the model would estimate. (Porter & Zona 1999)

3.1.4.3 Bajari and Ye (2003)

The study by Bajari and Ye (2003) concerns the seal coating market in Minnesota, North Dakota and South Dakota. Seal coating is a method for prolonging the life of a road by adding oil and gravel on the surface of it. The mixture adds a new layer on the surface and the soaked oil slows down the development of cracks to the core of the road. This paper can be seen as building on the earlier work of Porter and Zona (1993; 1999). (Bajari & Ye 2003)

Unlike Porter and Zona (1999), Bajari and Ye (2003) do not consider whether a competitive firm should enter an auction. Therefore, the first step of the analysis is constructing a bidding function, incorporating all observable information that affects the level of bids. As in both earlier papers, some of the core variables control for costs and

others for the observed competitive pressure. In addition to distance and capacity related variables, Bajari and Ye (2003) argue that the familiarity with local regulators and material suppliers partly determine the inherent costs associated to a contract. In addition to the bidding function, both firm and contract specific effects are controlled for. (Bajari & Ye 2003)

The second step of the analysis is conducting the conditional independence test first introduced by Porter and Zona (1999). The authors report only the results of firm pairs that met each other at least four times during the observation period. This is argued both in terms of credibility based on sample size but also the intuition that forming a collusion is most worthwhile for firms that meet each other constantly. The latter argument can be criticized on the basis that some cartels operate by dividing the market. Of the 23 tested pairs, four reject the null hypothesis of no correlation at a five per cent significance level. (Bajari & Ye 2003)

In the third part of the analysis, Bajari and Ye (2003) introduce the exchangeability test. For this test it is assumed that the observable information that is controlled for always affects the level of a firm's bid in the same way and this process is unaffected by who the firm bids against at an auction. The way of testing this is by comparing an unconstrained model with firm specific coefficients to constrained models where a firm pair's individual coefficients interact with each other while everything else is kept constant. For the same number of tested pairs, this test is only rejected in the case of one pair. (Bajari & Ye 2003)

3.1.5 Concluding remarks of the literature review

The different behavioural screens are now compared to each other to conclude the literature review. One remarkable difference between the two first groups and the two latter ones following the division by Harrison (2008) is that the two first ones are usually softer on the data requirements. In connection to this, the statistical techniques employed seem to be more easily understood. These are some obvious strengths as an efficient screen does not only return few false positives and negatives, a certain kind of lightness in implementation is also desirable (Imhof et al. 2018).

Concerning the data requirements, it must however be stated that the paper by Porter and Zona (1993) is proof of how much can be done with seemingly little data. Having only data from procurement auctions with participants and accompanying bids, the authors computed proxies of the capacities and utilization rates. This process in combination with the gathering of the distances can however still be regarded heavy

compared to many other analyses where cost data is either ready-to-use as in Froeb et al. (1993) or not needed at all as in Abrantes-Metz et al. (2006). These were the studies that both concerned the sale of frozen perch.

Because of their heavy implementation, the screens of the third and fourth group might only overpower the simpler ones in really tough cases. One flaw of some behavioural screens using aggregate data is that they are unable to detect partial collusion, meaning that collusion is detected only if it has enough market coverage (Imhof et al. 2018). Other screens, such as Porter and Zona (1993), are able to verify partial collusion but require that the collusive group is known beforehand with some accuracy. Therefore, it seems that the methods developed by Porter and Zona (1999) as well as Bajari and Ye (2003) are the most advanced, as they may be able to even reveal the collusive firms if the underlying model is correctly specified.

4 METHODOLOGY

4.1 The data

The data obtained from the FCCA for the use of this study, includes all tenders concerning the Finnish road maintenance market from years 2010-2017 and the first round of 2018. The total number of contracts included in the data is 116. However, because the model used in this thesis cannot measure competitive pressure without at least one rivalling bid, two tenders only receiving one bid are omitted. The data can be regarded comprehensive with over 30 different variables describing different features of the contracts. Variables describing bids include their prices and quality scores.

Variable	Mean	Std. Dev	Min.	Max.
Winning bid	11 744 719	4 706 313	3 551 446	30 485 904
Mark-up (mark-down): (winning bid – estimate)/est.	-0.0332	0.1432	-0.3566	0.4300
Normalized winning bids: winning bid/estimate	0.9668	0.1432	0.6434	1.4300
Money on the table: 2nd bid – winning bid	772 116	870 319	209	5 876 903
Norm. money on the table: (2nd bid – winning bid)/est.	0.0635	0.0585	0.00002	0.3358
Number of bidders	4.1580	1.3356	1	7
All bids normalized: bid/estimate	1.0541	0.2100	0.6434	2.5535

Table 1 Summary statistics of the bidding data

The mark-up or mark-down of the contracts compared to the engineer's cost estimate implies that the competitive situation on the market is good: The average winning bid was three per cent under the engineer's cost estimate of the contract. However, these estimates seem to be sometimes overconservative, as at least one winning bid undercut the engineer's cost estimate with more than 35 per cent. The current contractor was replaced in roughly two out of five tenders, meaning that contracts were won in most cases by the incumbents. This result can be thought to reflect especially the strong status of Firm 1 which still possesses the clearly highest market share.

The data is further described by two simple screens. In the variance screen, each tender's bid variance is divided with the associated bid average (Imhof et al. 2018). These values are then visualized together in a scatter plot, where each dot presents the result of one tender. The dots are arranged chronologically because systematically smaller values may

reveal a collusive period, as was earlier discussed in relation with the study by Abrantes-Metz et al. (2006) concerning frozen fish auctions. The results of this screen are presented in Figure 5. In the present market, no clear signs of collusion under our observation period can be reported. It seems however that the as the number of bidders varies between one and seven the emergence of extreme values is more likely than with bidding data having more bidders on average. The two contracts receiving only one bid can not be included in this analysis either.

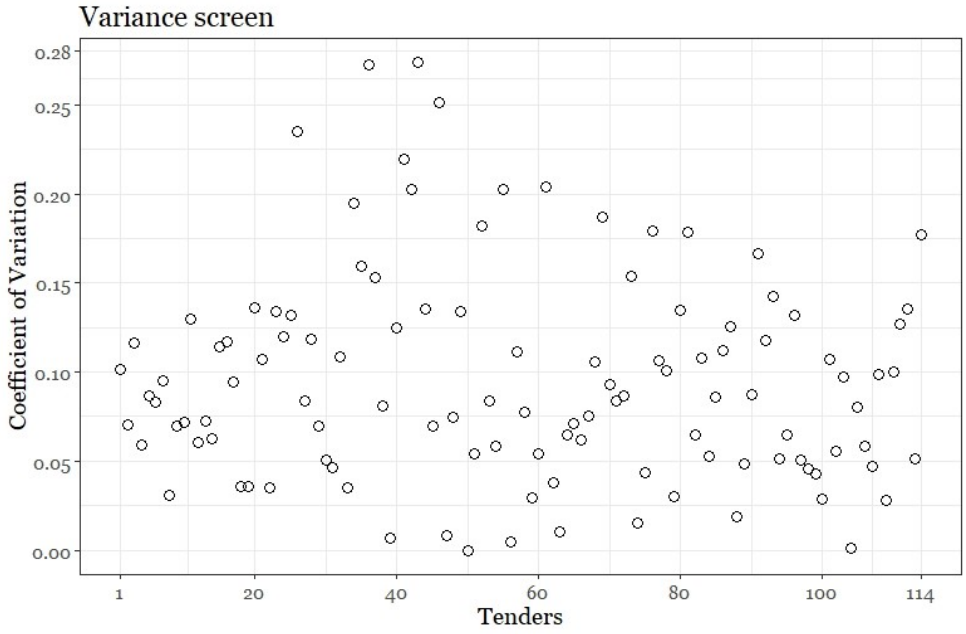


Figure 5 Results of the variance screen

A second screen used to describe the data is called the relative distance screen. The motivation of this screen is that it may detect a collusion where the level of shadow bidding is exaggerated. Shadow bidding is the practise of pre-determined losing firms submitting complementary bids to give an impression of competition. In the relative distance screen the distance between the best and the second best bid is compared to the variance of the losing bids. The calculated ratios are then again visualized in a scatter plot in chronological order where each dot represents one tender. The coefficient being frequently over one may mark a collusive period, as this signals that firms could be using shadow bidding combined with a bid rotation scheme. (Imhof et al. 2018)

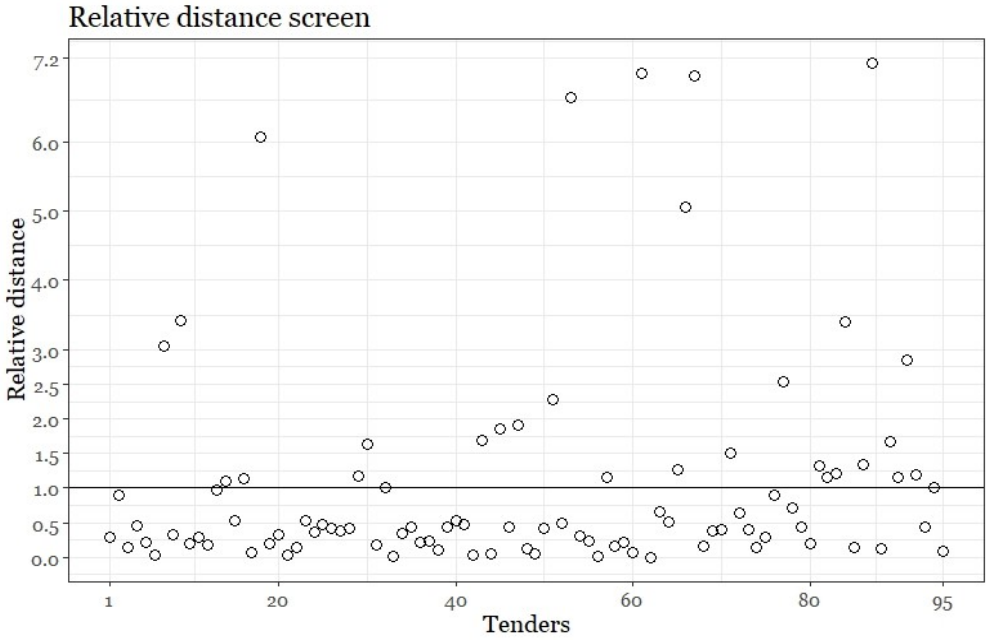


Figure 6 Results of the relative distance screen

The results of this screen for the present market are presented in Figure 6. As the ratio is usually under one, no clear signs of shadow bidding can be found. The distance between the best and the second-best bid is in most tenders less than the average distance of the losing bids. The low number of bidders is reflected in this figure too, as the emergence of extreme values.

4.2 Model overview

The objective of this thesis is to use screens developed by Porter and Zona (1999) and Bajari and Ye (2003) to screen the Finnish road maintenance market for collusion. Before conducting the tests, it is necessary to construct a core model that captures the bidding process of firm *i* in tender *t*. The model used in this thesis is based on the model used by Bajari and Ye (2003). In addition to the core elements describing the bidding function, fixed effects of the largest firms and all contracts are controlled for.

The core model is illustrated below:

$$\frac{\mathrm{BID}_{i,t}}{\mathrm{EST}_t} = \alpha + \beta_1 \mathrm{LDIST}_{i,t} + \beta_2 \mathrm{CAP}_{i,t} + \beta_3 \mathrm{FAM}_{i,t} + \beta_4 \mathrm{LMDIST}_{i,t} + \beta_5 \mathrm{MAXP}_{i,t} + \beta_6 \mathrm{MAXF}_{i,t} + \varepsilon_{i,t}$$

The dependent variable is the normalized bid, meaning firm *i's* bid in tender *t* divided by the associated engineer's cost estimate. In addition to a constant and an error term, the right-hand side contains six dependent variables which are now presented briefly: $\mathrm{LDIST}_{i,t}$ denotes the log-transformed distance of firm *i* to the contract area of tender *t*. $\mathrm{CAP}_{i,t}$ denotes the capacity utilization rate of firm *i* at the time of tender *t*. $\mathrm{FAM}_{i,t}$ denotes firm *i's* familiarity with the local submarket of tender *t*. $\mathrm{LMDIST}_{i,t}$ denotes the minimum log-transformed distance of firm *i's* rivals to the contract area of tender *t*. $\mathrm{MAXP}_{i,t}$ denotes the minimum utilization rate of firm *i's* rivals at the time of tender *t*. $\mathrm{MAXF}_{i,t}$ denotes the maximum familiarity of firm *i's* rivals concerning the local submarket of tender *t*.

The approach of using firm-specific information to measure both efficiency of firm *i* but also its perceived competitive pressure was already used by Porter and Zona (1993). In addition to Bajari and Ye (2003), distance and capacity related variables were used for these purposes also by Porter and Zona (1993; 1999). However, the control variable concerning firm *i's* familiarity with the local submarket was introduced by Bajari and Ye (2003). As a small extension of this thesis even rivalling firms' familiarity of the local submarket is included in the model as an additional control variable of the competitive pressure. In what follows, the different elements of the core model will be presented and discussed more in detail.

4.2.1 The dependent variable

The dependent variable is firm *i*'s bid in contract *t,* divided with the engineer's cost estimate of the same contract. Normalizing the bids by dividing them with the associated engineer's cost estimates evens out different sized contracts and enables comparing them as different outcomes of the dependent variable. As reference, the winning bids of different contracts range from 3.6 million to 30.5 million euros.

After the division, the dependent variable becomes a ratio where winning values range between 0.64 and 1.43. These values are to be interpreted as meaning that the lowest winning bid is 36 per cent under and the highest winning bid 43 per cent over the engineer's cost estimate of the associated contract.

Both the bids and the engineer's cost estimates are already included in the data acquired from the FCCA. The final form of the dependent variable is acquired by dividing all bids with their corresponding engineer's cost estimates.

4.2.2 Variables based on distance

Distance to the contract is incorporated in the bidding function because as a measure of transportation costs it directly determines some of the firm specific costs of managing the contract. $\text{LDIST}_{i,t}$ is the log-transformed distance between firm *i*'s premises and the location of contract *t*. Correspondingly, $\text{LMDIST}_{i,t}$ is the log-transformed distance between the location of contract *t* and the closest located competitor. The distance variables are log transformed to make them normally distributed (Lütkepohl & Xu 2012).

The data needed for the distance variables was not already included in the data, so the information needed for these variables needed to be gathered before being log transformed. The distance variables should measure the shortest distance from firm *i*'s and the closest located competing firm's premises to the contract area. The contract areas are considerably large geographical areas. As the objective of a contract holder is to maintain the quality of all predefined roads all over the area, the locations of the contract areas have been simplified to be the central points of each contract area. The coordinates of these points were acquired using Google Maps. A list of the coordinates of all contract areas is presented in Appendix 2.

To compute the distance variables also information on firm premises is needed. As the geographical market is rather large compared to many other studies, a comprehensive approach of collecting the addresses of all firm premises was chosen in contrast to some other studies such as Porter and Zona (1993) where the location of headquarters was deemed enough. The addresses of all branches were gathered using a search engine by Fonecta that is available at www.finder.fi. After acquiring the addresses, they were converted to coordinates using Google Maps. A list of coordinates for all different branches of firms included in the data is to be found in Appendix 3.

Having the needed coordinates, the distance variable concerning firm *i's* own distance to contract *t* is computed by selecting the shortest distance from all different branches and log transforming it. After doing this for all firms, the second distance variable measuring the competitive pressure from rivalling firms is gotten by selecting the shortest log transformed distance to contract *t* by all other firms except for firm *i*.

4.2.3 Variables based on capacity

Capacity in the form of a utilization rate is incorporated in the bidding function because as all firms have some level of fixed costs relating to the market, idle capacity is assumed

to be costly. This should be reflected in the bidding behaviour of firms especially towards the end of the tender season, as firms that have leftover capacity may start bidding more aggressively. $\mathrm{CAP}_{i,t}$ measures the capacity utilization rate of firm i at the moment it is bidding for contract t. Similarly, as with the distance variables, $\mathrm{MAXP}_{i,t}$ measures the best value of all firm i's rivals which is in this case the lowest capital utilization rate at the time of the tender.

The capacity utilization rate will be measured in the same way as it was measured by Bajari and Ye (2003): Comparing the number of contracts won by firm i during the tender season before contract t with the total of its won contracts during the whole season. A necessary condition for this approach is that the tenders are held in multiple rounds. Distributing all contracts in one round each year, would remove almost completely the explanatory power of capacity utilization rate as part of the bidding function. However, in this case capacity could still be incorporated in the model at least in the form of an overall capacity, as was done by Porter and Zona (1993). Fortunately, the contracts in this market are handed over in multiple rounds each tender season. The number of tenders and rounds held each year during the observation period is reported in the table below:

Season	N of tenders	N of rounds
2010	12	3
2011	13	3
2012	15	3
2013	12	3
2014	17	6
2015	12	4
2016	12	4
2017	19	5
2018*	4	1
Sum	116	32
Average	*12.89*	*3.56*

Table 2 Number of tenders and rounds held in each tender season

The data contains only the tenders of the first round held in 2018. Of the whole seasons, it can be noted that while both the number of tenders and rounds are subject to some variation, the number of rounds has slightly increased since the start of the observations period.

Although the capacity variables were not initially in the data, all the information needed for their computation was. This information concerns the winners and their associated winning bids. The capital utilization rate of firm i is computed comparing the sum of its winning bids during the season so far with the total its winning bids for the whole season. Although it would be easier to treat all contracts equally, the size of the winning bid better reflects the influence different sized contracts have on the capacity of the firm. Because of the nature of this variable, it is a ratio that is always between zero and one. After all values of $\mathrm{CAP}_{i,t}$ have been computed, $\mathrm{MAXP}_{i,t}$ is computed by picking the lowest value of this variable from all firm i*'s* rivalling firms that also participate in tender t.

4.2.4 Variables based on familiarity of the local market

Familiarity with the local market is incorporated in the bidding function because knowing local subcontractors and material suppliers might lower a firm's costs relating to a specific market. When Bajari and Ye (2003) this variable they motivated it by the fragmented nature of their market consisting of three states in the United States of America.

Variables $\mathrm{FAM}_{i,t}$ and $\mathrm{MAXF}_{i,t}$ reflect firm i's own and its rivals' familiarity with local the local market. For this variable, the Finnish market is divided into local submarkets using the prevailing regional division of the fifteen ELY-centres (Elinkeino- liikenne- ja ympäristökeskus 2016). The division into local submarkets is illustrated in Figure 7.

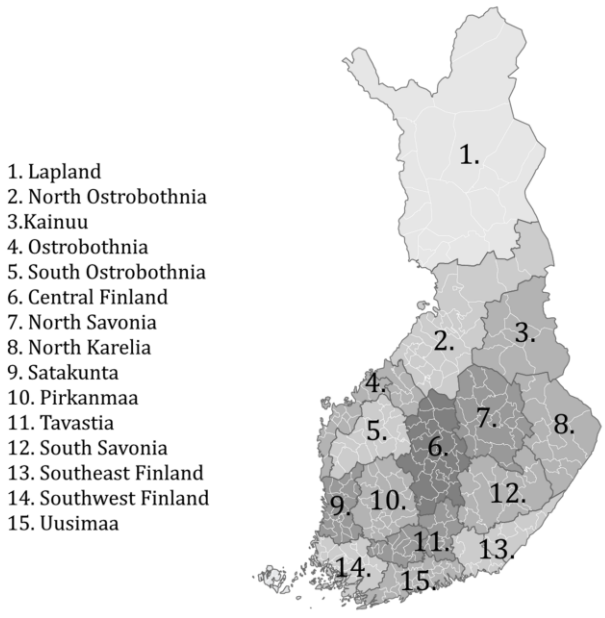


Figure 7 Map over local submarkets, based on Elinkeino- liikenne- ja ympäristökeskus (2015)

All contracts are allocated to only one of the fifteen submarkets. The firm i specific $\mathrm{FAM}_{i,t}$ values for different submarkets are computed based on how many times firm i has participated in a tender in the given submarket compared to its total participation in the overall market. The values range between zero and one, where the first means complete absence from the market and the latter exclusive presence on the market. After computing the values of $\mathrm{FAM}_{i,t}$ for all firms, the values of $\mathrm{MAXF}_{i,t}$ are gotten by taking the highest familiarity of the associated local market of all rivalling firms also bidding for the contract.

The variables that control for familiarity can be derived in at least two different ways from data concerning regional bidding activity of firms. The products of these two approaches can be denoted as the *progressive* and the *rigid* alternatives to measure familiarity. The rigid alternative will be used in this thesis. Both methods will nevertheless be presented shortly and compared against each other.

The tenders have a known chronological order. Even though tenders happen simultaneously if they are competed for in the same round, the total of 32 rounds provides enough separation to account for the order in which firms participate in tenders held in different areas. In the same way that familiarity can be thought to increase only upon participation, a progressive variable would base familiarity only on past tenders and evolve during the observation period as new tenders are held.

The second alternative, that is chosen in this thesis, is somewhat simplified. Instead of allowing for the abovementioned progressivity, each firm receives a rigid set of fifteen regional values which sum up to one. These rigid values therefore incorporate familiarity from all tenders during the observation period at once meaning that all activity is equally accounted for already at the very first tenders.

Although this simplification can easily be criticized, it can also be considered justified because this way even the first observations can be preserved and used in the analysis. Moreover, because the progressive method fails to account for the impact of historical tenders held before the observation period, the values produced by the method will be affected by the starting point and produce misleading values especially for firms that participate in all areas virtually as much. The submarkets that are tendered more often in the beginning of the observation period will therefore first get too high values at the expense of other submarkets before the levels eventually even out. As the market already exists before the observation period and continues to exist after it, it seems reasonable

to assume that ratios based on all observed contracts reflect well the areal preferences of the firms.

Firm	1	2	3	4	5
Central Finland	0.0789	0.0769	0.1111	0.0294	0.1429
Kainuu	0.0526	0.0577	0.0556	0	0
Lapland	0.114	0.1058	0.1389	0.0882	0
North Karelia	0.0526	0.0288	0.0833	0.0294	0.1429
North Ostrobothnia	0.0877	0.0962	0.0833	0.0588	0
North Savonia	0.0702	0.0577	0.0694	0.0588	0.2857
Ostrobothnia	0.0526	0.0577	0	0.0882	0
Pirkanmaa	0.0877	0.0962	0.0972	0.1471	0
Satakunta	0.0702	0.0673	0.0556	0.1471	0.0357
South Ostrobothnia	0.0526	0.0577	0.0139	0.0882	0.0357
South Savonia	0.0614	0.0673	0.0556	0.0294	0.25
Southeast Finland	0.0351	0.0385	0.0556	0.0294	0.0714
Southwest Finland	0.0526	0.0577	0.0278	0.0882	0
Tavastia	0.0351	0.0385	0.0417	0.0294	0
Uusimaa	0.0965	0.0962	0.1111	0.0882	0.0357

Table 3 Territorial participation of the five most active firms

Table 3 presents the values for the $\mathrm{FAM}_{i,t}$ variable for the five most active firms. This table reveals two problems with the descriptiveness of the variable. Firstly, especially the values of active firms are affected by the number of contracts distributed in different areas which varies to some extent. Lapland is the largest area, so it is only natural that the highest number of contracts was awarded in this area. This is however also directly reflected in the $\mathrm{FAM}_{i,t}$ variable, as the three most active firms all have their highest concentration in this area. The uneven allocation of contracts to different submarkets mitigates the variable's explanatory effect as a firm can participate in all tenders concerning some submarket but still receive a lower value there than somewhere else with a lower participation rate, because the total number of contracts distributed in the first mentioned submarket is low compared to the other.

Another weakness of the variable is that it overemphasizes the effect on small local operators and clearly underestimates the localness of large operators with many local branches. To elaborate, Firm 1 can have a branch at the heart of Tavastia and know the market better than a firm mostly active in another industry and bidding only once during the whole observation period. If the variable was to perfectly reflect the reality, Firm 1 should be handed a high number and the other firm a somewhat low number. Instead, whereas the hypothetical small firm's familiarity of the market would be a maximum one,

Firm 1 receives 0.0351 because it participates in tenders all over Finland and only a tiny bit of them concern Tavastia.

4.3 The boundary conditions of the model

4.3.1 Model misspecification

The first boundary condition of the model concerns mainly the conditional independence test. For this test the model is fitted on the data and the dependency of residuals from different firms are compared over same tenders. The intuition is that if all observable information that affects how firms behave is controlled for, the residuals of different firms should be uncorrelated. This is founded on the idea of residuals representing private information, wherefore they can only be correlated if firms are communicating with each other. (Porter & Zona 1993; Bajari & Ye 2003)

For the conditional independence test to be able to separate between competitive and collusive behaviour, it is important that all public information affecting how firms bid is included in the model because otherwise the model is misspecified. Results from a conditional independence test based on a misspecified model are unreliable, as the null hypothesis of competition may be rejected because of something else than collusion (Bajari & Ye 2003). Thus, competitive firms that base their decisions on a common body of public information may appear to be sharing private information.

If an important cost element that creates asymmetries between firms is not included in the model, the problem of misspecification can affect the results of the whole market. If on the other hand, for example all branch locations are not considered when computing the distance related variables, the results may be unreliable for only some firms and some geographical areas.

4.3.2 Failure to catch a sophisticated cartel

The first boundary condition of the model was that it must be correctly specified in order for it to produce reliable results. The second boundary condition applies to even correctly specified models, but it may be more theoretical in nature than the threat of omitted variable bias. According to this boundary condition, a sophisticated cartel including all inspected firms could operate a cartel on the market with all firms appearing competitive. This is accomplished by carefully constructing competitive bids and scaling them up would violate neither the assumption of conditional independence nor exchangeability that the tests for collusion are based on. This type of a cartel would be

sophisticated in the sense that often when firms agree on winners beforehand, designated losers do not construct their bids carefully enough and this negligence can be used to reveal the collusion. (Bajari & Ye 2003)

The risk of the scaling up going unnoticed is somewhat reduced by the engineer's cost estimate. If all bids are constantly substantially higher than the estimated costs of the contracts, this will likely raise other sorts of suspicions even if the cartel would be able to circumvent this type of analysis. Nevertheless, the engineer's cost estimates only have a mitigating effect if they are carefully prepared based on real costs faced by contractors. If these estimates are in turn based on previous bids, the subtle enough scaling up could go unnoticed. This was exemplified in a case in the road building industry where the engineer's cost estimates depended too heavily on the results of previously held tenders and became therefore over time inflated by shadow bids placed close to the winning bids (Feinstein et al. 1985).

Another point that can be thought to reduce the risk of a cartel not being detected is competition inside the cartel. If the cartel is designed so that firms submit competitive bids to the ringleader and all bids are then scaled up equally by for example 40 per cent, firms may start to consider the scaling up already when constructing their competitive bid. Assuming that all other cartel members leave a competitive bid that is then scaled up, a firm might be tempted to cut its competitive bid by 20 per cent. A deviation will make the firm win more contracts and still have an extra 20 per cent margin because of the illegal co-operation. However, an obvious solution for the cartel to counteract this problem would be to have an independent body first prepare all competitive bids and then scale them up.

5 THE ANALYSIS

The analysis of this study can be divided into three separate sections. Firstly, the fit of the model is tested on the data by estimating a set of common coefficients of $\text{LDIST}_{i,t}$, $\text{CAP}_{i,t}$ $\text{LMDIST}_{i,t}$, $\text{MAXP}_{i,t}$, $\text{FAM}_{i,t}$ and $\text{MFAM}_{i,t}$ for all firms when fixed effects of the main firms and of all contracts are controlled for. Secondly, the conditional independence of residuals produced by the model are compared between firms over the same tenders. Thirdly, firm-specific coefficients are estimated and compared over firms to see if elements of the bid function are affected depending on who the firm meets in a tender. Firm-specific bid function coefficients are estimated in both the second and third part of the analysis, and these are the tests for collusion. In the second part the assumption of conditional independence of bids is tested, whereas the third part tests exchangeability of bids. (Bajari & Ye 2003)

5.1 Testing the model parameters

At this phase of the analysis a model without firm-specific coefficients is fitted on the data to see how well the normalized bid is explained by the variables included in the model. For simplicity, a total of six bids from consortiums are excluded from the analysis as defining their locations and capacities is too troublesome. Two observations concerning tenders that only received one bid are also excluded from the analysis as defining the $\text{LMDIST}_{i,t}$, $\text{MAXP}_{i,t}$ and $\text{MFAM}_{i,t}$ variables for these observations is not meaningful. These tenders were won by Firm 1 and Firm 2 and concerned Raasepori in 2011 and Hämeenlinna in 2013, respectively. Following these reductions, the total number of observations is at 422.

The dependent variable is bid divided by the engineer's cost estimate of the contract and the model is tested both including and excluding the $\text{MFAM}_{i,t}$ variable. In addition to the five or six bidding function variables, 114 contract dummy variables and eleven firm dummy variables for the main firms are included in the model. The objective of the 125 dummy variables is to control for contract-specific and firm-specific fixed effects. The remaining eight firms are assumed to be sufficiently equal in terms of productivity and are therefore pooled together (Bajari & Ye 2003).

The results of the regression are presented below. The variable $\text{MFAM}_{i,t}$ is in italic because all other values are from a model where it is excluded. However, the impact on other variables from adding $\text{MFAM}_{i,t}$ to the model is so insignificant, that the values do not change much depending on which model is used. In addition to the control variables

that model firm *i's* bidding function, the values for the firm specific fixed effects are reported in the table.

	Estimate	Std. Error	t-value	p-value	
Intercept	1.572	0.288	5.457	**0.0 %**	***
LDIST	-0.053	0.024	-2.190	**2.9 %**	*
LMDIST	-0.062	0.036	-1.712	8.8 %	.
CAP	-0.046	0.027	-1.743	8.2 %	.
MAXP	-0.175	0.142	-1.234	21.8 %	
FAM	-0.008	0.090	0.086	93.2 %	
**MFAM*	*-0.005*	*0.071*	*-0.077*	*93.9 %*	
Firm 1	-0.102	0.057	-1.796	7.4 %	.
Firm 2	-0.041	0.057	0.723	47.0 %	
Firm 3	0.053	0.056	0.945	34.6 %	
Firm 4	-0.039	0.059	0.658	51.1 %	
Firm 5	-0.054	0.051	-1.044	29.7 %	
Firm 6	0.179	0.060	2.978	**0.3 %**	**
Firm 7	-0.028	0.059	0.464	64.3 %	
Firm 8	0.056	0.060	0.927	35.5 %	
Firm 9	0.126	0.064	1.977	**4.9 %**	*
Firm 10	-0.083	0.072	-1.150	25.1 %	
Firm 11	-0.037	0.065	0.562	57.5 %	

Table 4 The results of the regression

Studying the coefficients of the bidding function, it is noticeable that only $\text{LDIST}_{i,t}$ is significant at a 95 per cent level. Nonetheless, $\text{LMDIST}_{i,t}$ and $\text{CAP}_{i,t}$ are not far from being significant too. Focusing next on the sign of the estimated $\text{LDIST}_{i,t}$ coefficient, one can see that it is opposite of what one would expect: firm *i's* bid is decreasing in its distance to contract *t*. Combined with the high significance, this is to be interpreted that there is a high probability that firms submit low bids if the contract is far away and high bids if it is close to their premises. The estimated coefficient of $\text{LMDIST}_{i,t}$ is negative too, contrary to what one would expect, as increasing distance of competing firms could be thought to ease the competitive pressure resulting in a higher bid. In this case, firms seem to bid higher when a rivalling firm is close to the contract area and lower when all rivalling firms are further away.

The estimated coefficient of $\text{CAP}_{i,t}$, which denotes capacity utilization rate, is also opposite from how one would expect varying capacity levels influencing the level of bids. This variable is zero when firm i has all its capacity still unused when the tender is held. It approaches one, meaning full capacity usage, when the firm has won tenders held earlier in the same season. If firms are assumed to bid more aggressively when they have more free capacity, the relationship between $\text{CAP}_{i,t}$ and firm *i's* bid should be positive instead of negative. Although being far from significant, the sign of the estimated coefficient of $\text{MAXP}_{i,t}$ is also negative, meaning that the effect of the lowest capacity utilization of a rivalling firm is also opposite of what one would expect. This result suggests that firms bid lower when their rivalling firms are running out of capacity and higher when these firms have most of their capacity unused.

The two variables controlling for firm *i's* own and its rivals' familiarity of the local market are far from significant. Nonetheless, it can be noted that the negative signs of the estimated coefficients of $\text{FAM}_{i,t}$ and $\text{MFAM}_{i,t}$ are in accordance with what could be expected based on intuition. Higher familiarity of the local market decreases the bid of firm i. A high familiarity of a rivalling firm can be thought to have the same lowering effect on the level of firm *i's* bid. However, as the standard errors of $\text{FAM}_{i,t}$ and $\text{MFAM}_{i,t}$ are larger than the estimated coefficients, these variables might as well have opposite signs.

The simultaneous significance of including the three clearly insignificant variables $\text{MAXP}_{i,t}$, $\text{FAM}_{i,t}$ and $\text{MFAM}_{i,t}$ in the model can be tested with a partial F-test that compares the full model to a nested model where the three variables have been omitted. The null hypothesis of this test is that these models are as good at explaining the dependent variable, whereas if the null hypothesis is rejected the full model is significantly better. (Hocking 1976)

The results of the F-test are $F(2.292) = 0.0066$ and a p-value of 0.993. As this p-value is extremely high, it can be concluded that including $\text{MAXP}_{i,t}$, $\text{FAM}_{i,t}$ and $\text{MFAM}_{i,t}$ to the model adds nothing to it. Therefore, the variables should be dropped, and the nested model used instead. This F-test can also be done omitting all six bid function variables. Put in a different way, the full model can be compared to a nested model with only the variables controlling for the fixed effects. This F-test produces the following results: $F(5.292) = 1.47$, $p = 0.196$. Although this p-value is much lower it is still far from being significant. This suggests that all the variables of interest should be abandoned as the

model is described well enough by the contract and firm dummy variables. Contrary to this, the adjusted R-squared supports the full model by giving it a slightly higher value even when $\mathrm{MFAM}_{i,t}$ is included: 0.6477 compared to 0.6449 of the nested model.

The values of the firm-specific fixed effect variables are reported in the same table above. Most of the firms' estimated coefficients are far from significant and should therefore not be given too much thought. All that can be said is that the bidding of these firms seem to not differ significantly from the bidding of the pooled group of eight non-main firms. The estimated coefficients of two firms are significantly positive. This means that taking account of distances, capacities, familiarity and contract specific effects Firm 6 and Firm 9 have bid on average clearly higher than the control group of non-main firms. Based on the firm-specific estimated coefficients it seems that the largest player is also the most efficient, as Firm 1 is the only firm that has bid lower than the control group with a ten per cent significance.

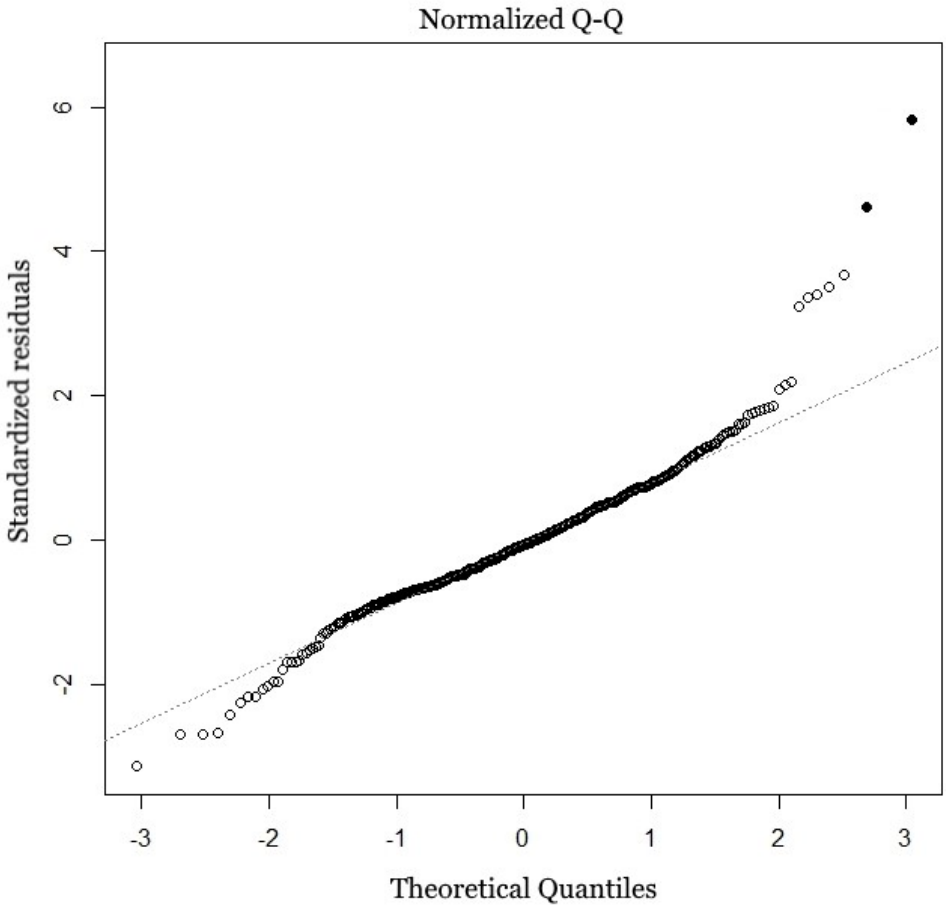


Figure 8 Quantile-quantile plot of the standardized residuals

If the residuals from the model without $\mathrm{MFAM}_{i,t}$ are normalized by dividing them with their standard deviations and plotted in a quantile-quantile figure, possible outliers can be easily detected visually (Roth 2006). This plot shows that most of the 422 observations seem to be nicely normally distributed but in the upper right corner there are at least two somewhat clear outliers that have been marked with black dots. The impact of these outliers might not be substantial on the bid function variables as the number of observations is reasonably high. The effect of an outlier on a firm specific dummy variable might on the other hand be significant as the impact is not mitigated by as many other observations.

The outlier furthest away represents a bid by Firm 6 for a contract concerning Pudasjärvi-Taivalkoski in 2013. This bid exceeds the engineer's cost estimate with over 150 per cent for whatever reason. The other outlier represents a bid by Firm 3 for a contract concerning Kiuruvesi in 2012. This bid in turn exceeds the engineer's cost estimate with over 80 per cent.

Removing the two outliers from the regression does not change the results significantly. The bids of Firm 6 are still significantly higher than those of the control group even after removing its highest bid. This could point towards a chosen strategy instead of a one-time mistake. Interestingly, removing only these two outliers from the data, turns the sign of the $\mathrm{FAM}_{i,t}$ variable from negative to positive and makes $\mathrm{CAP}_{i,t}$ statistically significant at a 95 per cent level.

To conclude the first part of the analysis, the results are overall unexpected. The bidding function variables that best explained the behaviour of firms in the data, all have an opposite sign of what one could expect based on intuition. Regardless of the unexpected relationships, three of the six bidding function variables seems to explain the bidding of firms fairly well, considering that the model includes 125 variables controlling for fixed effects. The results of this part of the analysis were only presented in this chapter shortly. Possible explanations and how these results relate to earlier literature, will be discussed later in Chapter 6.

5.2 Testing conditional independence

The first test that aims to separate between competitive and collusive behaviour is called the conditional independence test. This test is based on the idea that there are two types of information firms can base their bidding decisions on: public and private information. Moreover, the public information can concern something that creates asymmetries

between firms and are considered by all firms when they decide on the level of their bid. However, a competitive firm should never base its bidding decisions on any other private information than its own. Because of the observable nature of public information data on these elements can be gathered and incorporated in the model. When information is controlled for, its effect on bidding is removed. Subsequently, if all public information is included in the model, the residuals should concern only private information and because of this, residuals of competitive firms should not be correlated. The null hypothesis of competitiveness can therefore be written as follows:

$$H_0 : \rho_{ij} = 0$$

The null hypothesis is rejected if two firms' bids are still strongly correlated after controlling for all public information. This suggests that these firms share private information with each other and therefore behave collusively. As mentioned before in connection with the boundary restrictions of the model, for this test to succeed it is important that the model is correctly specified. If all public information is not controlled for, the results become unreliable, as the correlation can be caused by something else than collusion.

During the observation period, nineteen firms have participated in the organized tenders, meaning a total of 171 pairwise relationships. To increase the reliability of this test, a pairwise relationship will only be considered if the firms have bid against each other at least five times during the observation period. This directly excludes eight firms from the sample as they have bid overall less than five times. The remaining eleven firms form 55 different pairwise relationships.

Of the remaining firms, the top three firms have encountered all other firms at least five times. Because Firm 4 has entered the market during the observation period, it has not encountered any of the other firms at least five times. Other pairwise relationships that are considered are between Firm 5 and Firm 8, Firm 7 and Firm 8, Firm 7 and Firm 9, as well as, Firm 8 and Firm 9. Thus, the total number of analysed pairwise relationships is 31.

For the conditional independence test the same model that was tested earlier is allowed to be more flexible, meaning that individual coefficients are estimated for the eleven firms under scrutiny. This way the fixed effects of these main firms are better controlled for and distance and capacity are allowed to affect differently on their bidding. As an

exception, familiarity is only estimated once and is therefore a common value used for all firms. This was done by Bajari and Ye (2003) because there was not enough firm-specific variation for the estimation of individual coefficients and the same applies in the present market, as estimated coefficients for the familiarity related variables are so clearly insignificant.

The individual coefficients for the eleven main firms and common coefficients for the least active firms are pooled together into one regression. This is done by expanding the model of the first test by interacting the eleven firms' dummy variables with the distance and capacity related variables. After this the tenders in which firms have encountered each other are identified pairwise. For all inspected pairs, both firms' residuals from the specific tenders are collected, and a Pearson correlation is calculated which F-statistic is based on the subset of encounters. The null hypothesis is rejected if the p-value is less than 0.05. The results of the conditional independence test are reported in Table 5:

Firm	1	2	3	4	5	6	7	8	9	10	11
1		-0.077	**-0.350**	-0.338	0.172	**-0.660**	**-0.653**	**0.837**	-0.178	0.575	0.213
2	**102**		**-0.400**	-0.304	-0.363	**-0.606**	-0.288	0.060	0.240	0.618	0.230
3	**71**	**66**		-0.284	-0.430	-0.624	-0.212	**-0.849**	**-0.713**	-0.873	-0.600
4	**33**	**29**	**18**								
5	**28**	**24**	**21**	*3*				0.354			
6	**14**	**13**	**8**	*4*	*2*						
7	**11**	**10**	**11**	*0*	*4*	*0*		-0.183	-0.088		
8	**10**	**9**	**10**	*0*	**8**	*0*	**5**		-0.398		
9	**8**	**6**	**8**	*0*	*3*	*0*	**6**	**5**			
10	**6**	**6**	**5**	*0*	*1*	*0*	*2*	*2*	*1*		
11	**6**	**6**	**5**	*2*	*1*	*0*	*0*	*0*	*0*	*0*	

Table 5 Results of the conditional independence test

The left part of the table reports the number of encounters between firms. For example, Firm 2 and Firm 3 have encountered each other 66 times during the observation period. Here the values of the pairs that have encountered each other at least five times are bolded. The right part of the table contains the results for the pairs whose residuals were

compared. Correlation coefficients of all relevant relationships are reported, but only the ones written in bold are significant at a 95 per cent level.

The null hypothesis of conditional independence is rejected in eight of the 31 inspected relationships. This means that there is a strong correlation between some of the firms' bids that goes unexplained by the model. Of the eight significant correlations seven is negative in nature. The negative relationship suggests that firms are probably not colluding with each other because one party in the relationship needs to bid lower than the model would estimate the firm to bid during the encounters. This suggests that knowing about the other firm participating does not have a softening effect on competition. It therefore seems that the negative correlations cannot be attributed to collusive behaviour and are better explained by omitted variable bias or an overall bad fit of the model on the data.

The only potentially collusive relationship is therefore between Firm 1 and Firm 8, as this pair is the only one whose bids correlate significantly positively after the effect of public information has been controlled for. A more detailed review of this relationship is given to evaluate whether this correlation can be argued to be caused by collusion. Firm 1 and Firm 8 have met each other a total of ten times during the observation period. Of these encounters Firm 1 has bid five and Firm 8 six times over the model's estimate. These firms bidding roughly as many times under as above the estimated bids, does not support a theory of collusive bidding, as firms would only benefit from collusion by coordinating high bids. The correlation is caused by positive and negative residuals emerging in same tenders. Of the ten tenders, these firms' residuals have the same sign on seven occasions. However, of these seven encounters both firms have bid four times under and only three times over the model's estimate. This too suggests that the correlation could be better explained by something else than collusion.

5.3 Testing exchangeability

The second test for collusion, assumes that the way bids are formed based on values of $\text{LDIST}_{i,t}$, $\text{LMDIST}_{i,t}$, $\text{CAP}_{i,t}$ and $\text{MAXP}_{i,t}$ should not differ considerably between firms. It is also a test to see if meeting a specific firm makes some firm bid unnaturally, suggesting that bids in these tenders are based on something else than the listed parameters. Because of the sealed-bid auction form of tenders in the present market, the firms should not know beforehand who they will encounter in the tender when submitting their bid. A firm alternating its bidding behaviour when meeting some specific firm hints therefore

directly at collusive behaviour. However, a firm constantly incorporating the values of $\mathrm{LDIST}_{i,t}$, $\mathrm{LMDIST}_{i,t}$, $\mathrm{CAP}_{i,t}$ and $\mathrm{MAXP}_{i,t}$ differently to its bids than other firms, can produce a lot of significantly different relationships without suggesting that the firm is collusive. Constantly diverging behaviour from others can be better explained for example by a measurement error in the form of a forgotten branch location. (Bajari & Ye 2003)

As in the conditional independence test, exchangeability is tested on a pairwise basis. The test is run on the same pairs, meaning that the firms must have encountered each other at least five times during the observation period. The pooled model from the conditional independence test is used as a benchmark and denoted as the *unrestricted* model. As in the previous test, this model has individual coefficients for the eleven main firms for $\mathrm{LDIST}_{i,t}$, $\mathrm{LMDIST}_{i,t}$, $\mathrm{CAP}_{i,t}$ and $\mathrm{MAXP}_{i,t}$ variables. (Bajari & Ye 2003)

For the exchangeability test, constrained models for every investigated firm pair is created. A constrained model is created by combining the inspected firms' $\mathrm{LDIST}_{i,t}$, $\mathrm{LMDIST}_{i,t}$, $\mathrm{CAP}_{i,t}$ and $\mathrm{MAXP}_{i,t}$ interaction variables, keeping everything else constant. The exchangeability of $\mathrm{FAM}_{i,t}$ and $\mathrm{MFAM}_{i,t}$ is not studied as the firm-specific variation of these variables is deemed insufficient. The constrained models are sequentially compared against the unrestricted model, to see if these models significantly differ based on a F-test. (Bajari & Ye 2003) The null hypothesis of the test can be written as follows:

$$H_0\colon \beta_{ik} = \beta_{jk} \text{ for all } i, j, i \neq j, \text{and for all } k = 1, 2, 3, 4.$$

For the null hypothesis to hold, different values of the four bid function parameters should not enter the bids of firm *i* and *j* in significantly different ways (Bajari & Ye 2003). The results of the exchangeability test are presented in Table 6.

Firm pair	F-Statistic	p-value	Firm pair	F-Statistic	p-value	Firm pair	F-Statistic	p-value
(1, 2)	1.035	0.4069	(2, 4)	1.4591	0.1822	(3, 6)	1.3257	0.2535
(1, 3)	2.1441	**0.0396**	(2, 5)	0.7890	0.5971	(3, 7)	0.3915	0.8842
(1, 4)	1.3266	0.2378	(2, 6)	2.0227	0.0758	(3, 8)	0.2288	0.9498
(1, 5)	0.8076	0.5816	(2, 7)	0.7432	0.6153	(3, 9)	0.3410	0.8877
(1, 6)	2.1600	0.0589	(2, 8)	0.6033	0.6974	(3, 10)	0.3275	0.8962
(1, 7)	0.8665	0.5200	(2, 9)	0.8289	0.5301	(3, 11)	0.8703	0.5015
(1, 8)	0.8144	0.5403	(2, 10)	0.7532	0.5844	(5, 8)	0.2692	0.9297
(1, 9)	1.0145	0.4095	(2, 11)	1.2313	0.2947	(7, 8)	0.3353	0.8913
(1, 10)	0.9901	0.4242	(3, 4)	0.3426	0.9337	(7, 9)	0.5221	0.7595
(1, 11)	1.4359	0.2117	(3, 5)	0.6429	0.7202	(8, 9)	0.2531	0.9076
(2, 3)	2.1098	**0.0429**						

Table 6 Results of the exchangeability test

The null hypothesis is rejected in two of the inspected relationships. Values of $\text{LDIST}_{i,t}$, $\text{LMDIST}_{i,t}$, $\text{CAP}_{i,t}$ and $\text{MAXP}_{i,t}$ affect significantly differently the bidding of Firm 1 and Firm 3 as well as Firm 2 and Firm 3 with p-values under 0.05. The relationship between Firm 1 and Firm 2 is far from significant with a p-value of over 0.40. It seems that while values of the listed variables enter the bids of Firm 1 and Firm 2 almost symmetrically, these values enter the bids of Firm 3 somehow differently. Without giving an answer to this question, it can be noted that based on the results from the first part of the analysis, Firm 3 also seems to bid higher on average than Firm 1 and Firm 2. Also, Firm 6 has almost significant relationships with Firm 1 and Firm 2. However, the relationship between Firm 3 and Firm 6 is quite far from significant.

6 DISCUSSION

6.1 The model parameters

The analysis began with an inspection of the model parameters. At that stage distance and capacity related variables were still estimated only on a general level, on the contrary to the later parts of the analysis. The aim of this phase was to review the coefficients of the model and the significance of the variables of interest. The results were surprising in two ways: Firstly, the sign of most coefficients was opposite of the expected based on economic intuition. Secondly, despite the sign some variables had reasonably high degrees of significance.

Although not being a test to detect collusion per se, the first part of the analysis has an important role in the analysis: It is to ensure that the model is a good fit on the data. The results of this part inform of possible shortcomings in the model that can either be fixed using a different approach or that just need to be borne in mind when interpreting the results of the later phases. (Doane et al. 2015)

The variable $\mathrm{LDIST}_{i,t}$ was the only bidding function variable that was significant at a 95 per cent level. According to intuition and backed by earlier studies, distance can be thought to have a raising effect on bidding through added transportation costs (Porter & Zona 1993; Pesendorfer 2000; Bajari & Ye 2003). However, the relationship turned out to be opposite in the analysis of this thesis, as the sign of the estimated coefficient implies distance having a significant lowering effect on bids. Although the main rule seems to be that bids increase in distance, the opposite is not completely precedented in earlier research, as exemplified by Porter and Zona (1999) in the school milk market. There it resulted from the collusive firms fixing prices in the home market and competing against competitive producers further away. (Porter & Zona 1999)

Even on the market of Porter and Zona (1999), the bids were increasing in distance for the firms that had not been found to have participated in the illegal conduct. The situation seems to therefore be somewhat different in this thesis, as the negative relationship would not be significant if it would not be a generally occurring phenomenon. In what follows, some other possible explanations will be discussed.

Part of the reason for the seemingly erroneous behaviour of the $\mathrm{LDIST}_{i,t}$ variable can be ascribed to a measurement error related to information concerning the used locations of the firms. Although the observations range from tenders held between years 2009 and

2017, the branch locations were only considered in the way they were reported in 2019. This simplification can be thought to cause a measurement error, at least to some degree. It seems, however, exaggerated to think that the branch locations would have changed so completely in just ten years that results would be significantly biased in the opposite direction. It seems more likely that the result of this simplification is somewhat negligible but also random. Only a systematic error would yield opposite estimates of the real coefficients. A random measurement error produces instead noise that increases the standard error and reduces the likelihood of a variable being statistically significant (Hutcheon et al. 2010). As the $\text{LDIST}_{i,t}$ variable was significant, the reason seems to stem elsewhere.

Another reason for the negative relationship between distance and the level of bids could be the wide-spread use of subcontracting. However, the problem with this theory is that while subcontracting may indeed decrease costs of managing contracts far away, this should not turn the relationship upside down. A more natural consequence of subcontracting would be an equalization, whereby distance would not affect costs and therefore not determine the level of firms' bids. This anticipated consequence of subcontracting should reduce the explanatory power of distance and possibly even make it statistically insignificant.

The best theory for the significantly counterintuitive $\text{LDIST}_{i,t}$ variable could be as follows: Despite the contract-specific fixed effects being controlled for, the cost estimates of the contracts in northern Finland seem to be more inflated than the cost estimates in other parts of the country. As contracts in this area are often tendered and the distances for all firms to these areas are large, the product of these effects is realized in a significantly negative $\text{LDIST}_{i,t}$ variable even if some of the inflation were removed by the contract-specific dummy variables. The same explanation applies to the $\text{LMDIST}_{i,t}$ variable, as this is essentially a derivative of the $\text{LDIST}_{i,t}$ variable.

The estimated signs the $\text{CAP}_{i,t}$ and $\text{MAXP}_{i,t}$ variables were also opposite of what would be expected based on intuition. A negative relationship of the capacity utilization rate and the level of bids suggests that firms bid higher when they have zero contracts than when they are running out of capacity. This conflicts with the intuition of fixed costs incentivizing firms to ensure their first contracts with lower bids before raising the level. However, earlier research has not been undivided regarding this question. While Bajari and Ye (2003) reports a positive relationship between the capacity utilization rate and

the bid level, Porter and Zona (1993) found the relationship to be weakly positive for a group of firms suspected of forming a cartel and weakly negative for the control group of firms assumed to be competitive. Although not self-evident from the results, even Porter and Zona (1993) argued the relationship between capacity utilization and the bid level to be partly positive: with increasing capacity utilization bids first decrease over a small range before increasing. An opposite relationship of the one observed in the present market seems to thus be backed by both intuition and earlier research. Furthermore, the estimated coefficient of $\mathrm{CAP}_{i,t}$ had a relatively low p-value of 0.082.

The relationship seems to be too strong to be explained by the convex relationship presented by Porter and Zona (1993). A better explanation in this case could be the capacity indicator being fundamentally flawed. The problem is that although many firms participate, only a few win, meaning that most firms lose all of the tenders they participate in. Firms that never win contracts can be assumed to not only submit high bids but also always have a minimum capacity utilization rate. Also the opposite is true, as more efficient firms that win contracts both submit lower bids on average and have more variation towards the upper end of the $\mathrm{CAP}_{i,t}$ variable.

Interestingly, the same capacity utilization rate indicator that worked well on the market of Bajari and Ye (2003), fails in the present market. This seems to be explained by the very different market structures. The seal coating market of Bajari and Ye (2003) is more fragmented as the largest firm's market share is 21.1 per cent and the three largest firms have together 39.1 per cent of the market. In the present market, Firm 1 has a market share of 53.5 per cent and the three largest firms together have 89.1 per cent of the market. Moreover, Firm 1 and Firm 2 cover together as much of the present market as the twelve largest firms on the seal coating market (Bajari & Ye 2003).

Although not offering any further explanation to the estimated negative coefficients of the capacity related variables, it is worth discussing what the effects of increased use of subcontracting could be. Subcontracting essentially frees firms from capacity restrictions or at least blurs the upper limit to some degree. As with the distance related variables subcontracting should not be expected to turn the relationship upside down, but only decrease the explanatory power of the capacity utilization rate, making its estimated coefficient less significant.

As a suggestion for future research, there is a way how the $\mathrm{CAP}_{i,t}$ and $\mathrm{MAXP}_{i,t}$ variables could be improved in a similar situation. In this thesis, the capacity of all firms is at zero

at the beginning of the tender season. The capacity level of a firm then increases towards one as the rounds go by and the firm wins contracts. In this method the capacity of a firm is always benchmarked to the total value of the contracts it wins that season. Thus, depending on how well a firm succeeds in different seasons, its total capacity may vary substantially between seasons. In reality firms can be thought to have a less fluctuating, somewhat stable level of capacity. The capacity indicator could therefore reflect reality better if the utilization rate was calculated on a moving five-year basis, the motivation being that the same contracts are tendered at this interval. In connection with this, the total capacity should not vary between seasons, but instead be based on the moment during the whole observation period when the five-year backlog is maximized.

Lastly, some thoughts concerning the estimation of the $\mathrm{FAM}_{i,t}$ and $\mathrm{MFAM}_{i,t}$ variables. Beforehand it seemed that these variables could have a more significant role in the analysis compared to Bajari and Ye (2003). This preconception was triggered by uncertainty regarding the extent and effects that increased use of subcontracting would have on the distance and capacity related variables. However, the results proved this concern false in two ways: distance and capacity related variables had explanatory power and the familiarity related variables did not.

There are at least two conclusions that can be drawn from the near-zero estimated coefficients of the familiarity related variables. Firstly, it raises the question of misspecification which has been discussed earlier. In short, the way the $\mathrm{FAM}_{i,t}$ variable is computed is not descriptive, as its values depend too much on the total number of contracts in an area compared to others and the overall participation of firm i in other tenders. This variable clearly over emphasizes the local expertise of firms only visiting the market compared to large operators participating in almost all tenders. Even on a firm level, the division into home and foreign markets is biased by the number of tenders that are included in the different submarkets.

A second conclusion concerning the near-zero coefficients of the familiarity variables is do these variables really add any value to the model in this setting. In the application of Bajari and Ye (2003) the seal coating market was divided into three distinct areas, with their own local regulators. Because the borders of these areas actually had some real function, the variable was able to explain the bidding of firms at least weakly. The market division in this study is harder to justify because as there are no administrative barriers, the division becomes artificial and lacks purpose. Moreover, the residual purpose in the

form of familiarity with local subcontractors and material suppliers is already controlled by the $\text{LDIST}_{i,t}$ variable.

As a suggestion for future research, although not guaranteed to be able to save this variable, the chosen number of submarkets should be lower in relation to the number of tenders. It would be desirable if the division could be based on some distinctive feature that really affects how the firms participate in tenders held in different areas. But as such a decisive separator seems to be missing from the present market, the second-best thing would be to make the total numbers of tenders in different areas as same as possible. This would already mitigate a large part of the biases created by the way in which the $\text{FAM}_{i,t}$ variable is computed in this study. Moreover, the descriptiveness of the variable could further be improved by the introduction of different steps of total familiarity that depend on the overall participation on the market: The most active firms' familiarity components from different submarkets would still sum up to one but less active firms total could be reduced to for example 0.5.

6.2 The conditional independence test

After inspecting the model parameters, the second part of the analysis was the first actual test for collusion. In that section, the conditional independence of residuals from firms that had encountered each other at least five times during the observation period was inspected. This requirement was met by a total of 31 firm pairs.

The rationale of testing conditional independence is that once controlling for all public information concerning bids, the residuals of the bids of different firms in the same tenders should be uncorrelated. This follows from the idea that the remaining unexplained part of bids consists of private information. Therefore, in the null hypothesis of competition where firms are not assumed to be sharing private information with each other their bids should be conditionally independent. Rejecting the null hypothesis by finding significant correlation can be interpreted reflecting collusive behaviour where competitors share private information with each other.

The null hypothesis was rejected eight times, seven of the significant relationships being negative and one being positive in nature. Despite the considerable amount of significant correlations these results can be thought to be better explained by something else than collusion because the only feasible collusive strategy would be for firms to coordinate high bids. Assuming the model being correctly specified, collusive coordination would be flagged both firms bidding higher than estimated during their encounters. Because of

this, seven of the eight significant relationships can be regarded being caused by something else other than collusion, as a negative correlation implies one firm bidding lower and the other higher than estimated.

The only potentially collusive relationship was therefore between Firm 1 and Firm 8. However, a more detailed review of the composition behind this correlation revealed that neither these firms bid constantly high. Even though the firms bid roughly as many times lower as higher than estimated by the model, the positive correlation was caused by these firms' residuals having 70 per cent of the time the same sign.

Based on these results and their interpretation two conclusions for this test can be drawn. Firstly, there is no explicit evidence of collusion and secondly, the model may be misspecified. Both conclusions are based on the high number of significant negative correlations. The analysis of Porter and Zona (1999) demonstrates well the implications the two types of correlation can have in some circumstances and in others not. Although the two types of correlations signal two types of collusive strategies when testing whether the participation of a specific competitor affects the likelihood of firm *i's* participation, there is only one feasible collusive strategy when both firms participate – bidding high.

6.3 The exchangeability test

The second test for collusion turned the attention from residuals to exchangeability of the coefficients of $\text{LDIST}_{i,t}$, $\text{LMDIST}_{i,t}$, $\text{CAP}_{i,t}$ and $\text{MAXP}_{i,t}$. After inspecting the model parameters and conducting the conditional independence test it seems that the model is not an excellent fit on the data. Fortunately, the model behaving otherwise than expected is not necessarily problematic as firms can nevertheless be assumed to behave consistently.

Although comparing firms' coefficients to each other at a pairwise basis, a firm can in principle behave significantly differently than other firms as long as it is consistent in doing so. A firm changing how it incorporates the values of the listed variables to its bids when encountering another specific firm, can indicate collusive behaviour simply because the firm should not know beforehand which other firms are participating in the tenders.

The null hypothesis was rejected in two of the inspected 31 relationships, both instances involving Firm 3 together with either Firm 1 or Firm 2. As the p-value of the test between Firm 1 and Firm 2 was far from significant, this should be interpreted as the values of

$\mathrm{LDIST}_{i,t}$, $\mathrm{LMDIST}_{i,t}$, $\mathrm{CAP}_{i,t}$ and $\mathrm{MAXP}_{i,t}$ entering significantly differently the bidding of Firm 3. The thought of Firm 3's bids being less based on costs than its two rivals can be thought to be supported by its fixed effect coefficient which was positive although it being larger in size than the group of firms used as a benchmark.

From the point of view of collusion, the results of the exchangeability test seem to leave more questions unanswered than the first test. These results are not as easily interpreted as the results of conditional independence test. To separate between competitive and collusive behaviour one should look for inconsistent behaviour. It is questionable if the behaviour of Firm 3 is constantly different from that of other firms: all its six other inspected relationships are far from significant.

As was earlier noted, also Firm 6 was close to significance in its relationships with Firm 1 and Firm 2. Although the interpretation not being clear-cut, these results might be best explained by Firm 3's and Firm 6's bids being at times so high that they are not explained anymore by the underlying cost parameters. After all, these same firms had the two obvious outliers of the data visualized by the quantile-quantile plot in Chapter 5.1. Therefore, the conclusion of this test is that no explicit evidence of collusion is found.

7 SUMMARY AND CONCLUSION

The aim of this study was to screen the Finnish road maintenance market for collusion using a behavioural screening approach. The chosen method for this purpose were tests developed by Porter and Zona (1993; 1999) as well as Bajari and Ye (2003). Before being able to conduct the tests, the bidding of firms in the market needed to be modelled. The constructed model estimated the normalized bids of firms based on their distance to the contract area, their capacity utilization rate at the moment of the tender and their familiarity of the local market. Even three variables controlling for competitive pressure that were derived from the information of rivalling firms were included in the model as well as control variables for fixed effects of all contracts and all main firms.

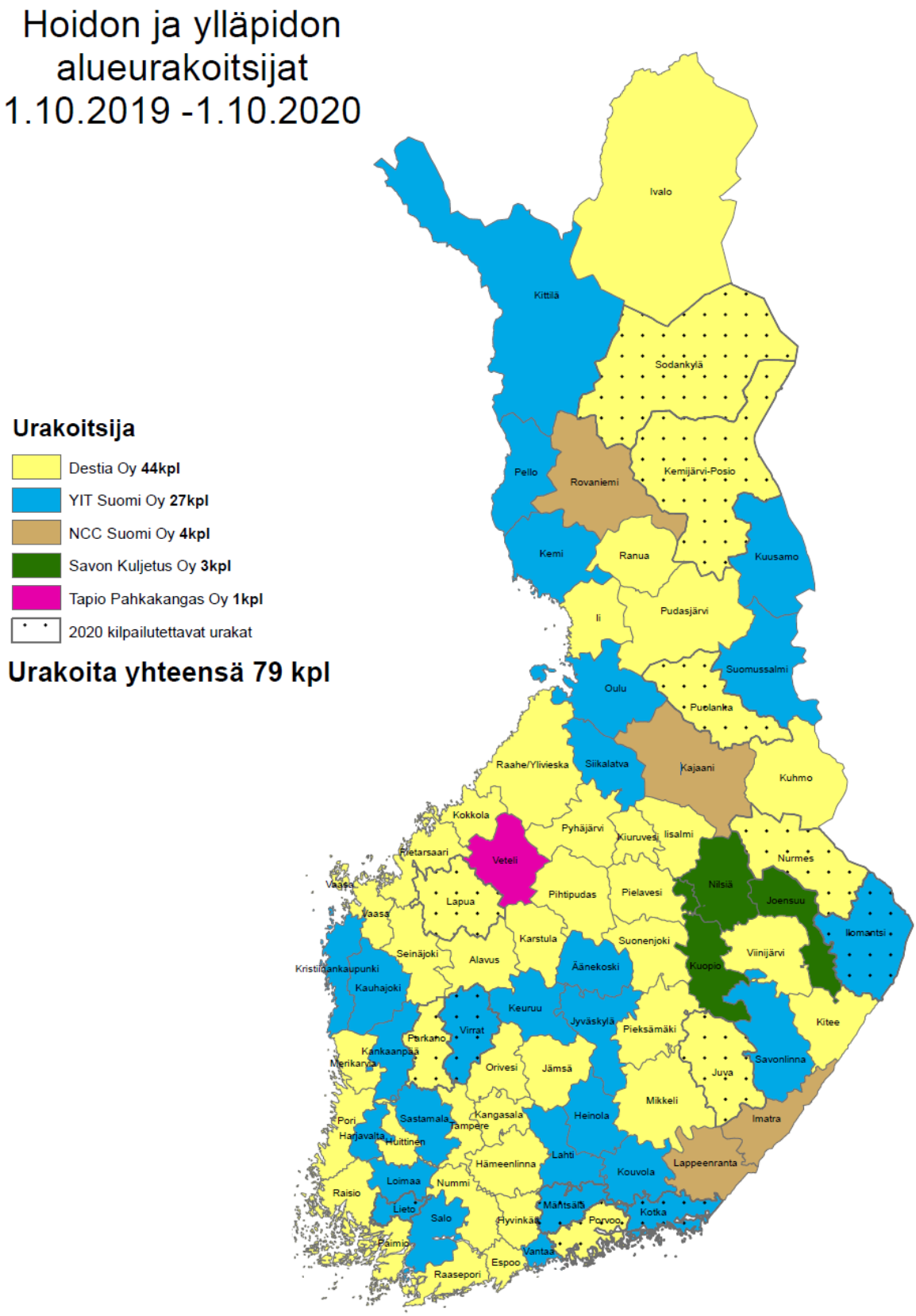
Fitting the model on the data revealed almost exclusively unprecedented relationships, but nevertheless $\mathrm{LDIST}_{i,t}$, $\mathrm{LMDIST}_{i,t}$ and $\mathrm{CAP}_{i,t}$ seemed to explain the bidding of firms fairly well, even though all these variables signs were opposite of expected. Many different explanations for the counterintuitive relationships were presented and discussed. The bidding firm's own distance having a decreasing effect on its normalized bid was argued to be mainly caused by the long distances of all firms to contract areas in Lapland, combined with relatively higher engineer's cost estimates for these remote contracts. The capacity utilization rate did also have a negative relationship with the normalized bid. Although this could be explained by a convex relationship (Porter & Zona 1993), a better explanation could be that the way the capacity utilization rate was measured fits badly the very oligopolistic nature of the market with few winners.

The first test for collusion used the residuals produced by the model to test the conditional independence of bids from firms that have met each other at least five times during the observation period. The null hypothesis of competition was in a sense rejected for eight pairs, but not truly. Because none of these correlations implied firms coordinating their bids over the estimated bids by the model, although significant, they were not supported by a theory of collusion. The high number of significant correlations between different firms' residuals, suggests that the model might be misspecified. This misspecification might not be as much caused by an omitted variable bias, as at least one of the existing variables being badly formulated.

The second test for collusion tested the exchangeability of firms' coefficients of $\mathrm{LDIST}_{i,t}$, $\mathrm{LMDIST}_{i,t}$, $\mathrm{CAP}_{i,t}$ and $\mathrm{MAXP}_{i,t}$. In this test, the behavioural inconsistency caused by meeting some other firm is used as a collusive marker, as firms operating in a sealed-bid

market should not know beforehand what other firms are participating in the tenders. Two relationships involving Firm 3 with Firm 1 or Firm 2 rejected the null hypothesis, meaning that values of the listed variables enter significantly differently the bids of Firm 3 compared to Firm 1 and Firm 2. Another firm which relationships with the same two firms were almost significant at a 95 per cent level was Firm 6. Even though the interpretation is not completely clear, the overall high nature of Firm 3's and Firm 6's bids is assumed to explain the differences in behaviours compared to Firm 1 and Firm 2. Overall, based on the results of the tests, it can be concluded that no explicit evidence of collusive behaviour in the Finnish road maintenance market is found.

APPENDIX 1 MAP OVER THE ROAD MAINTENANCE CONTRACT AREAS



Source: Väylävirasto (2019c)

APPENDIX 2 COORDINATES OF THE CONTRACT AREAS

Contract area	Longitude	Latitude	Contract area	Longitude	Latitude
Alavus	23.73957	62.71240	Myrskylä	25.85367	60.66972
Espoo	24.57348	60.17825	Mäntsälä	25.28360	60.66385
Harjavalta	22.07549	61.10243	Nilsiä	28.08648	63.20381
Heinola	26.04575	61.21021	Nummi	28.08648	63.20381
Huittinen	22.54962	61.14689	Nurmes	29.46366	63.53699
Hyvinkää	24.83609	60.56804	Orivesi	24.35740	61.67743
Ii	25.38292	65.31249	Oulu	25.46507	65.01208
Iisalmi	27.18264	63.56942	Paimio	22.69794	60.32702
Ilomantsi	31.04936	62.77346	Parkano	23.02549	62.01178
Imatra	29.01197	61.31727	Pello	24.03226	66.65045
Ivalo	27.53970	68.65764	Pieksämäki	27.15515	62.18784
Joensuu	29.76357	62.60101	Pielavesi	26.75567	63.23245
Juva	28.07061	61.76537	Pietarsaari	22.64159	63.45502
Jyväskylä	25.74725	62.24260	Pihtipudas	25.50409	63.34600
Jämsä	25.18020	61.86198	Pori	21.67134	61.20127
Kajaani	27.72784	64.22217	Porvoo	25.66527	60.39319
Kangasala	24.31461	61.38523	Pudasjärvi-Taivalkoski	25.66527	60.39319
Kankaanpää	22.37515	61.81265	Puolanka	27.67520	64.86747
Karstula	24.64702	62.95015	Pyhäjärvi	25.83303	63.81713
Kauhajoki	22.16019	62.20458	Raahe-Ylivieska	25.83303	63.81713
Kemi	24.56574	65.73556	Raasepori	21.78443	60.67929
Kemijärvi-Posio	24.56574	65.73556	Raisio	26.51589	65.92950
Keuruu	24.70785	62.25598	Ranua	25.72939	66.50394
Kitee	30.13800	62.09843	Rovaniemi	23.52624	60.37742
Kittilä	24.55248	67.96501	Salo	22.91849	61.33760
Kiuruvesi	26.58804	63.56357	Sastamala	23.96186	60.38029
Kokkola	23.12503	63.84150	Savonlinna	22.86149	62.68471
Kotka	27.06128	60.57450	Seinäjoki	25.86682	64.26846
Kouvola	26.70416	60.86788	Siikalatva	26.58897	67.41599
Kristiinankaupunki	21.36859	62.44698	Sodankylä	29.01052	64.93295
Kuhmo	29.52028	64.12874	Suomussalmi	27.12212	62.62609
Kuopio	27.67817	62.89796	Suonenjoki	23.67303	61.40335
Kuusamo	29.18866	65.96458	Tampere	21.61645	63.09508
Lahti	25.66120	60.98267	Vaasa	25.03776	60.29335
Lappeenranta	28.04693	60.95396	Vantaa	23.78642	63.47993
Lapua	22.97516	63.16322	Veteli	29.14330	62.33139
Lieto	22.59309	60.51704	Viinijärvi	23.73719	62.24603
Loimaa	22.47698	60.83757	Virrat	24.53213	64.07136
Merikarvia	21.50042	61.85829	Äänekoski	25.72788	62.60146
Mikkeli	27.27214	61.68872			

APPENDIX 3 COORDINATES OF THE FIRMS

ID	Longitude	Latitude	ID	Longitude	Latitude	ID	Longitude	Latitude
Firm 1	23.89775	61.16784	Firm 2	25.66261	60.98714	Firm 4	22.90078	62.78323
Firm 1	24.66940	60.22121	Firm 2	28.18925	61.05425	Firm 4	23.66262	61.51795
Firm 1	24.98092	60.18960	Firm 2	25.46061	65.02799	Firm 4	22.31552	60.44766
Firm 1	27.17384	60.60054	Firm 2	21.79814	61.48624	Firm 4	24.99787	60.34123
Firm 1	27.19946	63.58100	Firm 2	25.72830	66.50311	Firm 4	24.98868	60.33975
Firm 1	28.79387	61.17067	Firm 2	22.90078	62.78323	Firm 4	21.66820	63.11046
Firm 1	27.53254	68.61269	Firm 2	23.75777	61.50069	Firm 4	24.03269	61.25651
Firm 1	29.80674	62.58890	Firm 2	22.31891	60.43886	Firm 4	24.95265	60.28878
Firm 1	25.75121	62.24473	Firm 2	22.25225	60.45096	Firm 5	29.80601	62.62661
Firm 1	25.80850	62.22234	Firm 2	21.62436	63.09989	Firm 5	27.69857	62.91393
Firm 1	26.69643	60.86767	Firm 2	24.91573	60.32549	Firm 5	27.32017	61.70798
Firm 1	27.62960	62.89041	Firm 2	23.78248	62.24701	Firm 5	26.76024	63.23506
Firm 1	29.17259	65.98058	Firm 3	24.89979	60.20358	Firm 5	28.83331	61.87767
Firm 1	25.59430	60.97068	Firm 3	24.85159	60.63665	Firm 5	27.25466	61.69301
Firm 1	28.19471	61.04394	Firm 3	26.82349	60.70124	Firm 5	27.82444	62.32937
Firm 1	27.31411	61.70709	Firm 3	29.77307	62.61315	Firm 6	25.54343	65.04561
Firm 1	25.54732	65.04374	Firm 3	25.75548	62.24000	Firm 6	25.10685	60.30145
Firm 1	25.50635	65.01976	Firm 3	27.67306	62.89642	Firm 6	23.99545	61.48987
Firm 1	23.62880	61.45258	Firm 3	25.66160	60.98170	Firm 7	29.20594	66.09596
Firm 1	21.82797	61.44766	Firm 3	25.46693	65.00610	Firm 8	29.84741	61.91033
Firm 1	25.65430	64.50412	Firm 3	25.45639	65.05923	Firm 9	24.90123	60.20770
Firm 1	25.69255	66.49682	Firm 3	23.77537	61.49515	Firm 9	25.81540	62.28572
Firm 1	23.77212	61.48881	Firm 3	22.27935	60.45964	Firm 9	22.17710	62.42702
Firm 1	22.23371	60.44179	Firm 4	24.40657	61.01581	Firm 10	25.43538	64.94621
Firm 1	25.02114	60.34524	Firm 4	29.75141	62.56950	Firm 11	23.08609	61.11778
Firm 1	21.70188	63.07074	Firm 4	25.74559	62.22550	Firm 12	25.64651	62.09931
Firm 1	25.03204	60.29131	Firm 4	25.06528	60.49894	Firm 12	25.81550	62.28864
Firm 1	24.51503	64.07513	Firm 4	27.73117	64.22771	Firm 12	25.26030	62.70457
Firm 2	24.61004	60.18780	Firm 4	24.57400	65.74056	Firm 12	25.84600	63.09442
Firm 2	27.16127	60.54380	Firm 4	23.11739	63.83526	Firm 13	24.68130	60.16012
Firm 2	24.94827	60.22175	Firm 4	26.90688	60.49396	Firm 13	22.68720	60.45620
Firm 2	24.85345	60.62558	Firm 4	26.68450	60.85171	Firm 13	21.83730	61.44925
Firm 2	24.48420	60.99094	Firm 4	27.71157	62.89766	Firm 13	28.06740	63.20387
Firm 2	27.20724	63.57492	Firm 4	29.18065	65.96664	Firm 13	25.73580	62.23200
Firm 2	28.81299	61.19714	Firm 4	25.72400	60.96698	Firm 13	22.89870	62.77415
Firm 2	29.77003	62.59582	Firm 4	28.22144	61.04772	Firm 14	24.96245	63.93020
Firm 2	25.74559	62.22550	Firm 4	24.21530	60.29538	Firm 15	23.34579	63.40288
Firm 2	22.20206	62.43246	Firm 4	27.25420	61.67985	Firm 16	25.56825	64.95817
Firm 2	23.11739	63.83526	Firm 4	21.71048	63.11807	Firm 17	25.61628	66.58809
Firm 2	26.70260	60.86689	Firm 4	25.43850	65.06145	Firm 18	21.78987	62.19596
Firm 2	25.48444	60.31657	Firm 4	24.48660	64.68753	Firm 19	29.10341	63.55428
Firm 2	27.71157	62.89766	Firm 4	23.10833	60.38000			

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