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# **GAMES CONTRACTORS PLAY**

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*On Collusion and Corruption in Dutch Procurement*

**MASTER'S THESIS**

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# 1. INTRODUCTION

This master's thesis presents a thorough analysis of the Dutch construction cartel, using results from modern auction theory. It is known, through many documents that have surfaced and various testimonies, that hundreds of firms in the Dutch construction industry have colluded for at least 10 years by making price agreements and maintaining a system of side transfers<sup>1</sup>. The central focus of this study is threefold. First, I aim to answer whether the Dutch construction cartel has harmed social welfare. Second, I examine the validity of some arguments in favor of the cartel. Third, I explore some potential effects of corruption. The remainder of this introduction discusses these points in more detail and sketches the outline of my study.

## 1.1 Collusion: An Auction-Theoretic Approach

Based on so-called shadow accounts, a parliamentary inquiry committee has concluded that the greater part of colluding construction firms are active in the Ground Water & Road (GWR) sector. An important characteristic of the GWR sector is that the government is by far the biggest client of GWR firms: 60% of the total revenue comes from the (lower) government (*De bouw uit de schaduw*, p. 56). Furthermore, these firms have primarily consulted with each other on how to act at the procurement stage. In these preliminary talks, the firms agreed on the prices they would offer the buyer and possibly on side payments that the designated winner had to pay to the losing firms (*De bouw uit de schaduw*, p. 50). These two stylized facts, the central role of the government as a buyer and the predominance of collusion at the procurement stage, are the reasons why I restrict attention to the procurement mechanism that the government uses.

As the Dutch government is forced by law to contract out projects by means of a first-price sealed-bid procurement auction (FPPA)<sup>2</sup>, I will analyze what the scope for collusion is in the context of this particular auction format. In a FPPA, a number of firms is asked by a potential buyer to simultaneously submit a tender for some good. Given that the lowest price is below the reserve price of the buyer, the firm that submits the lowest price wins the

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<sup>1</sup> The interested reader is referred to *De bouw uit de schaduw* (2002), the report of the parliamentary inquiry committee that has investigated the Dutch construction cartel.

<sup>2</sup> Uniform Aanbestedingsreglement (UAR) 1986.

procurement auction and receives its bid from the buyer. The winning firm then delivers the good. A thorough analysis of the scope for collusion in the FPPA can answer whether the construction cartel has harmed the Dutch government by increasing prices and has lowered social welfare by selecting inefficient firms<sup>1</sup> to be the designated winner. If one finds that the contractors have done the latter, then one can conclude that social welfare is harmed, since the higher cartel price is just a transfer between firms and government.

In addition, taking an auction-theoretic approach allows me to assess the consequences of a calculation cost compensation scheme. Under such a scheme, the winner of the FPPA (partially) reimburses the other participants. It has been argued by executives of construction firms, in an effort to justify their cartel, that the sole purpose of the cartel was to do exactly this. According to these executives, this is a reasonable goal, given the substantial costs that bidding may entail (*De bouw uit de schaduw*, p 96).

A puzzling question that still fascinates many observers is why the construction industry, and not another industry, is affected by collusion. Moreover, collusion seems to be a persistent phenomenon, as collusion has taken place for decades and there is some evidence that the cartel is still in operation, after the construction firms have been fined. A simple explanation might be that the Dutch construction industry has a unique combination of several characteristics that causes collusion. However, this implies that construction industries in similar countries are equally vulnerable to collusion. Since this is not, or at least seems to be, the case, one needs to find other explanations. In chapter 6, I argue that corruption<sup>2</sup> explains why precisely the Dutch construction industry is so vulnerable to collusion. I will show in a simple game-theoretic model that if the procurement agency is corrupted, collusion and competition are both stable equilibria.

## 1.2 Scientific and Social Relevance

To my knowledge, this thesis is the first to present a more or less complete theoretical analysis of the Dutch construction cartel. An exception is Van Damme (2002). He shows in a first-price sealed-bid auction with uniformly distributed costs that social welfare decreases if

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<sup>1</sup> I define an inefficient firm to be a firm with a cost level higher than the lowest cost level in the industry.

<sup>2</sup> Bardhan (1997) provides a general economic definition of corruption: “the use of public office for private gains, where an official (the agent) entrusted with carrying out a task by the public (the principal), engages in some sort of malfeasance for private enrichment which is difficult to monitor by the public.”

firms are compensated for their calculation costs by the government procurement agency. Though the main focus of this thesis is on the Dutch construction cartel, most findings straightforwardly apply to other markets that feature FPPA's. In fact, an alternative title for this thesis might be "On collusion and corruption in first-price sealed-bid auctions".

As long as my assumptions are realistic, I can examine whether the Dutch construction firms did raise the cost of infrastructure projects, and if they lowered social welfare. Moreover, I shed some light on the possible role of corruption in procurement and explain the incidence of collusion.

### **1.3 Outline**

In chapter 2, I present a brief description of the Dutch construction industry and the Dutch construction cartel. This may be helpful for readers who are unfamiliar with this case, but can easily be skipped otherwise. Chapter 3 analyzes, as a benchmark, the familiar independent private values (IPV) first-price sealed-bid auction, under the assumption that firms do not collude. This assumption of noncooperatively acting firms is lifted in section 4. There, I examine two collusion mechanisms that have been proposed in the literature and subsequently compare them with the collusion mechanism that the Dutch builders have actually applied. This allows me to answer, from a theoretical point of view, to what extent the Dutch construction cartel has lowered social welfare. Chapter 5 analyzes the effects of calculation costs and examines whether, as some construction firms argue, society benefits from a calculation costs compensation mechanism. Finding support to this view may have profound policy implications. The issue of corruption in procurement is taken up in chapter 6. In that chapter, I show how corruption increases prices, when it may be hard to combat, and that it may explain the incidence of collusion. Chapter 7 concludes.

## 2. THE DUTCH CONSTRUCTION CARTEL

This chapter offers a description of the Dutch construction cartel<sup>1</sup>. The main significance of this chapter lies in the fact that it provides a justification of the models that are to be discussed in subsequent chapters. In particular, I show which firms have colluded and how they did it. Section 2.1 gives a brief account of the construction industry. The historic background and workings of the cartel is discussed in section 2.2. Some preliminary reasons why collusion flourished in the construction industry are explored in section 2.3. Section 2.4 makes some remarks on a number of supposedly benefits of the cartel.

### 2.1 A Brief Overview of the Industry

In 2000, roughly 20,000 construction firms provided employment for about 280,000 workers and had net sales of €44 billion, about 6% of GDP<sup>2</sup>. One commonly makes a distinction between Civilian & Utility (C&U) construction and Ground, Water and Road (GWR) construction, with annual sales in 2000 of €33 billion and €11 billion, respectively. Besides the obvious difference in the goods that both sectors produce, there are many other differences between the two sectors.

As figure 1a shows, the most important clients of firms in the C&U construction in 2000 were other (non-construction) firms. The role of the government as a client in this market is limited to a meager 9%.

Figure 1a – Clients C&U Construction in 2000

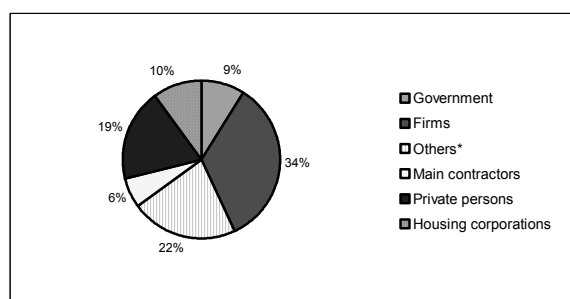
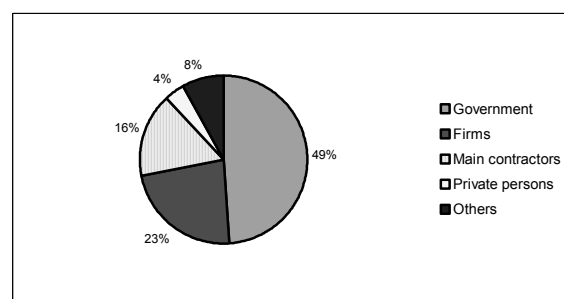


Figure 1b – Clients GWR Construction in 2000



<sup>1</sup> This chapter draws heavily on *De bouw uit de schaduw* (2002) and CapAnalysis (2002).

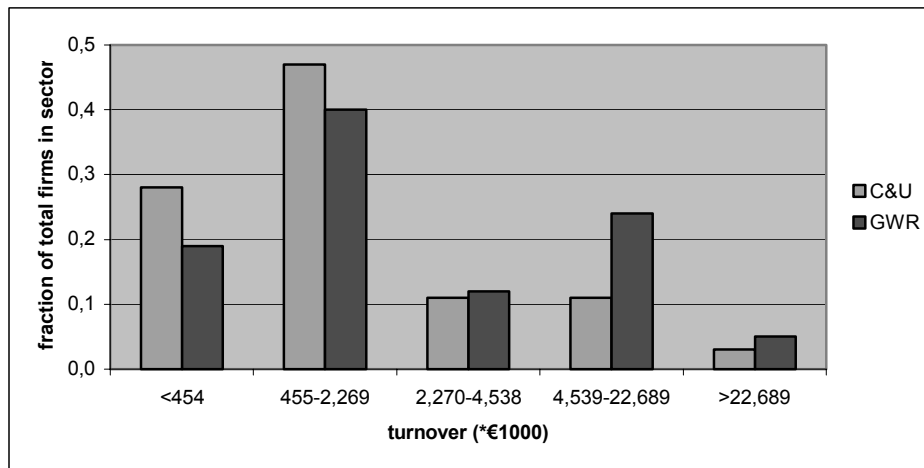
<sup>2</sup> CBS Statistisch Jaarboek 2002

The relatively low share in demand of the government in the C&U construction sector is in a marked contrast with the significant demand that the government exerts on the GWR construction sector. As one can see in figure 1b, almost half of the production in the GWR sector in 2000 was commissioned by the government.

The different composition of demand is not without consequence. Since all Dutch government agencies are obliged to publicly tender all orders worth more than €5,3 million<sup>1</sup>, public tenders are likely to be more common in the GWR sector. This conjecture is confirmed by the data. CapAnalysis (2002) finds that 25% of all contracts in the C&U sector were publicly procured, versus 58% in the GWR sector.

Another difference between C&U and GWR sector is that firms in the latter sector tend to be larger, as measured by annual turnover. Figure 2 gives a frequency distribution of firms by type and size in 2000.

Figure 2 – Construction Firms by Type and Turnover in 2000



Source: CapAnalysis (2002)

About 30% of all GWR firms had annual sales of at least €4,5 million, compared with just 15% of all firms in the C&U sector. This finding can be explained by the obvious fact that C&U and GWR firms differ in their activities. Constructing a bridge or a tunnel is usually far more challenging than building a house, and requires therefore more specialized and expensive capital goods.

<sup>1</sup> Richtlijn 93/37, June 14, 1993. PB L 199, August 9, 1993.

Figure 2 shows that the number of firms with an annual turnover of more than €22 million is large. In the C&U and GWR sector, there are about 500, respectively 130 of such firms. It seems hard to reconcile this with the charges of collusion, as basic industrial organization theory<sup>1</sup> suggests that the higher the number of firms in a cartel is, the lower are the per firm profits that stem from collusion, and the higher are the per firm profits that can be obtained by cheating on the cartel agreement. However, according to several illegal documents that have surfaced, the construction cartel counted at least hundreds of firms (*De bouw uit de schaduw*, p.263) or even all large construction firms (*De bouw uit de schaduw*, p. 266).

The number of firms with more than 500 employees has been fairly stable between 1995 and 2000, with a minimum of 16 in 1997 to 25 in 2000, according to CapAnalysis (2002). This suggests that prospective profits are either low in this segment, or that entry costs are substantial. Section 2.3 argues that the latter applies to the upper segment of the construction industry.

## 2.2 A History of Collusion

Collusion, or, more euphemistically, coordinated competition, and the Dutch construction industry went hand in hand for at least several decades (*De bouw uit de schaduw*, p. 269). Usually, the builders proceeded as follows. Prior to the day that the procurement agency asks a number of firms to submit a bid, the construction cartel arranges an informal meeting where they decide on which firm will offer the lowest bid, what this, and other bids, should be and on compensation of the other firms by the designated winner, see e.g. Priemus (2002).

To give an example, suppose that the government procurement agency has invited three firms,  $A$ ,  $B$  and  $C$ , to submit a tender for a project. It is commonly known that  $p$  is the highest price that will be accepted. This price may reflect either the gross social value of the project or the reserve price set by the procurement agency. Each firm has a privately known cost of producing the project:  $a$ ,  $b$  and  $c$ , respectively. In the preliminary talks, each firm announces what it will charge the government, if there would not have been a cartel. Suppose that firm  $A$  announces the lowest price (equal to  $p^a < p$ ). This means that firm  $A$ 's profit in the absence of the cartel is  $\pi^{nc} = p^a - a$ . The firms agree that firm  $A$  submits a price  $p$  and the other two firms charge a price higher than  $p$ . If firm  $B$  and  $C$  charge  $p - p^a + p^b$  and  $p - p^a + p^c$ , respectively, both

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<sup>1</sup> Tirole (1988, pp. 247-248).

firms will certainly lose the procurement auction, and the distribution of submitted bids appears to be competitive. Clearly, if the three firms stick to the agreement, then firm  $A$  makes a (gross) profit of  $\pi^c = p - a$ . This profit is clearly higher than firm  $A$ 's profit would have been in the absence of the cartel. The extra profit,  $\pi^c - \pi^{nc} = p - p^a$ , is shared equally among all three firms.

It may be tempting to conclude from the above example that this collusion mechanism raises the price of the project and maximizes the expected cartel profits. Though this intuition is correct, it cannot be deduced from the above analysis. This is proven formally, under the assumption of IPV, in chapter 4. Furthermore, it is shown there that this arrangement is an efficient mechanism<sup>1</sup>. That is, the firm with the lowest cost will deliver the project.

This collusive practice passed down from father to son<sup>2</sup>; it was simply the way that firms did business. It seems that the longer this form of collusion lasted, the more it was perceived, by all parties concerned, to be simply an inherent feature of the construction market.

In 1987, the construction firms, in close cooperation with the Dutch authorities, formalized the traditional rules, by the establishment of the *Vereniging van Samenwerkende Prijsregelende Organisaties* (SPO), or *Union of Cooperating Price Regulating Organizations*. From then on, firms that wanted to bid for a contract were obliged to inform the SPO. The SPO then arranged the preliminary talks in which the firms made collusive agreements. Collusive behavior was, from 1987 onwards, not only common practice; it was required by law as well. A prime example of *Nederland Kartelparadijs*, or *Netherlands Cartel Paradise*.

This came, at least officially, to an end in 1992, when the European Commission decided that the collusive practices, as laid down in the SPO regulations, are in conflict with European competition law<sup>3</sup>. The reaction of the conspiring contractors to this legal constraint was to stick to the tradition: the cartel went underground. It seems that the construction firms have been quite successful in maintaining the status quo. The cartel operated at least until November 9, 2001, the day that Mr. Bos, a former employee of a large construction firm, became a “national hero” by revealing that virtually all big firms made illegal price agreements, held preliminary talks and shared profits by means of side payments.

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<sup>1</sup> Throughout this thesis, and following conventional auction theory, I take a mechanism to be a well-defined allocation device that consists of an allocation rule and a payment rule. An efficient mechanism is a mechanism that always assigns the project to the firm with the lowest costs.

<sup>2</sup> *De bouw uit de schaduw*, p. 95.

<sup>3</sup> European Commission, *Beschikking 92/204/EEG*, Pb EG 7, April 1992, L92/1.

Anecdotal evidence, as in e.g. *De bouw uit de schaduw* (2002), suggests that illegal collusive behavior by construction firms from 1992 until 2001 took primarily place in the upper segment of the GWR sector, but occurred to a lesser extent in other segments as well. But why was precisely the GWR sector so vulnerable to collusion? And how could the cartel survive, when it was clearly illegal? Some tentative explanations to these questions are given the next section.

### **2.3 Why Was the Cartel Stable?**

There are several factors that may have fostered collusion. Roughly, these factors can be distinguished into two classes: a weak government and high entry costs.

After 1992, the government failed to provide new procurement regulations. Before, it was largely unclear to most public servants what the relevant procurement rules were. This, combined with the fact that most public officials were accustomed to conspiring contractors, has contributed to the continued existence of the cartel. The lack of legal clarity lasted until at least 2001. In this year, the government published a new set of rules on procurement procedures<sup>1</sup>.

Another way in which officials implicitly supported collusion, was by allowing firms to form joint ventures or to subcontract. In a joint venture, all participating firms cooperate in a newly established firm. With subcontracting, a winning firm pays other firms to undertake part of the project. This way, construction firms have been able to collude. Instead of submitting various competing bids, firms submitted just one (high) bid and allocated the spoils of collusion via the joint venture or subcontracting. A study by the NMa (the Dutch competition authority) of the 100 largest public projects suggests that this behavior is more the rule rather the exception in contracting. In principle, the forming of a combination is forbidden, except in a limited number of cases. In practice, however, authorities frequently neglected these rules.

A cartel cannot survive if the expected costs of maintaining a cartel are too high. For sure, most authorities, in particular the NMa, fell short in monitoring. As collusion was illegal since 1992, it seems obvious, with the benefit of hindsight, that authorities should have been keen to detect these irregularities. Yet, as noted above, all parties concerned passively

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<sup>1</sup> Uniform Aanbestedingsreglement 2001, *Staatscourant*, June 15 2001, no. 113.

accepted collusion to be part of the tradition. Administrators who dealt with construction firms were reluctant to commission the NMa to investigate the construction industry, despite several clues. Some officials have declared that they preferred a friendly long-term relation with construction firms to a relation filled with suspicious hostilities. Others were afraid that they did not have a legal case against the construction firms. The few indications that reached the NMa simply did not receive enough attention.

In a nutshell, a weak and naive government helped the construction cartel to continue their illegal businesses. This explains why especially the GWR sector was exposed to collusive contractors, as the government is by far the biggest client in this market.

The second class of reasons why the cartel was stable consists of factors that increased the newcomers' entry costs. A cartel is more likely to survive if it can deter entry successfully. A simple way of deterring entry is by making it costly. There are at least two natural reasons why entry on the (upper segment of the) construction market entails considerably high costs, which are, to some extent, sunk. First, most projects require investment in expensive equipment and skilled personnel. Second, construction is usually done on location and this increases the transportation costs. For this reason, construction firms enjoy some degree of local market power.

There is evidence<sup>1</sup> that several firms in the construction cartel have attempted to make entry even costlier, by vertical collusion. For instance, in the road construction industry, a necessary, and highly expensive input factor is a so-called asphalt grinder. Any newcomer that lacks this machine could, in theory, rent it from an incumbent firm. However, all firms in the cartel had agreed not to lend it to a non-cartel member, or only at an excessive cost. This clearly raises entry costs, potentially to a prohibitive level, and therefore hinders competition.

## **2.4 Alleged Benefits of the Cartel**

In the parliamentary inquiry that followed Mr. Bos' testimony, a few managers of construction companies argued that the construction cartel is (socially) desirable. In this

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<sup>1</sup> "Bouwwereld was een gesloten circuit", *NRC Handelsblad*, August 22, 2002.

section, some of these potential benefits are discussed. A formal analysis of the most convincing benefit, however, is postponed to chapter 5.

In a number of cases, the analysis of the firms is clearly devoid of any basic economic insights. For example, several managers insisted that, by frequently communicating on the bids, that prices are stabilized and that this is beneficial for both the client and the firm. Even if prices in the construction market can be stable, which is highly unlikely due to the heterogeneous character of most projects, it is not up to the firms to decide if this is desirable. All large construction firms are owned by shareholders, who can easily allocate the risk that stems from unstable prices themselves. The same reasoning applies to the argument that market sharing helps firms to reduce the risk that is associated with the discontinuous nature of the construction market.

According to some construction managers, the main *raison d'être* of the cartel is to allow firms to discuss the expected cost of a project. By comparing cost-estimates (signals), firms are prevented to submit a bid that is based on an unrealistically low signal, and thereby avoid the "winner's curse". Though it is not clear-cut whether society benefits from this, it seems hard, if not impossible, to design an incentive compatible and individually rational mechanism that induces firms to reveal their signals, without relying on side payments or collusion. This is easily seen in the pure common value case, in which the cost of each firm depends solely on all cost-estimates. Suppose that, due to some mechanism, all cost-estimates are fully known before firms make their (competitive) bid. Then, the winning price must be equal to the cost. Hence, without side payments and collusion, profits are zero if the firms share their cost-estimates, whilst without this mechanism, each firm would have made an (expected) positive profit.

Before a firm is ready to submit a bid in a procurement auction, it usually has invested ample resources in calculating its cost of producing the project. These calculation costs can be seen as the entry cost in the market for the project. Once more than two firms have plunked down these costs, they are like a sitting duck for the client. By incessantly renegotiating, a client can drive the price down to the second lowest marginal cost level. Peddling will surely lead to losses for all losers, and it might as well for the winner of the auction. Thus, construction firms argued that the winning firm should reimburse all other firms their calculation cost, as was common practice in the cartel. This view is challenged by the fact that current procurement law severely limits the scope for peddling by government agencies. Another reason why compensating calculation costs is a bad idea, is that it gives firms the

opportunity to allocate the supra-normal profits of collusion. A formal analysis of calculation costs awaits in chapter 5.

To summarize, the Dutch construction cartel has a strong historical foundation. For decades, contractors frequently met to make price agreements. The continued existence of the cartel, until at least 2001, may have been fostered by the fact that Dutch public officials have generally pursued a poor competition policy and the high entry costs that have deterred newcomers to enter the construction industry. Except for the "compensating calculation cost argument" all other arguments in favor of the Dutch cartel are false.

So far, I have not examined how the Dutch contractors actually colluded, and what the possible effects are for prices and efficiency, relative to the situation in which contractors compete noncooperatively. This is done in the next two chapters.

### **3. BIDDING FOR CONTRACTS**

This chapter presents a standard model of a FPPA that one frequently encounters in the literature on auctions. It is particularly useful as a workhorse for analysing collusion, as I will do in later chapters. As I have argued above, the Dutch construction cartel has primarily colluded during the procurement stage. The model that I discuss in this chapter is a formalization of the procurement mechanism that the government usually employs to contract out projects. Section 3.1 discusses some key assumptions of the model and makes a few remarks on the literature of (procurement) auctions. A formal analysis of the model is given in section 3.2. In section 3.3 I give an interpretation and discuss the main properties of the model.

#### **3.1 General Context**

In Dutch public tenders, the specifications that the good or project must satisfy are clearly spelled out. Furthermore, since 1993, (local) government is obliged to contract out all projects, and grant the order to the lowest bidder. The government is allowed to deviate from this only in a restricted number of cases, for example when there are serious doubts that the winning firm is able to meet all specified quality requirements or when the officials suspects firms to have colluded. Yet, if the public officials actually wish to do so, the burden of proof rests with them, and is usually prohibitively heavy. Consequently, contracts are almost automatically awarded to the lowest bidder. This in effect rules out the possibility of competition in quality. It therefore seems justified to model the Dutch procurement procedure as a FPPA. The difference between an auction and a procurement auction is that in the former the winning bidder pays an amount to the seller, whilst in the latter the winner seller receives an amount from the buyer (in this case the procurement agency).

Throughout this thesis, and following conventional auction theory, three important assumptions are maintained. First, each firm knows its own cost, but perceives the cost of all other firms to be independently drawn from a known probability distribution function (pdf). This assumption, known as the IPV assumption, is clearly a drastic deviation from real-world

observations, since firms differ in sizes, and costs are (to some degree) interdependent. Nevertheless, it allows economists to analyze auctions in a clean fashion. Besides, independently drawn costs are not inconsistent with a cost level that has some common elements. If, for example, production of a given project entails an investment with a cost that is common to all firms, plus a firm-specific cost, the IPV assumption still applies. Second, all firms are supposed to be risk-neutral. Third, the government procurement agency acts passively. That is, it simply executes the auction, and buys the good if the winning bid is below its maximum willingness to pay. In principle, the procurement agency could do better by setting a maximum price, see e.g. Krishna (2002). However, this may not be viable because of commitment problems or a lack of technical sophistication.

Vickrey (1961) was the first to derive equilibrium bidding strategies in a first-price sealed-bid auction with IPV. The insight that the first-price sealed-bid auction is analogous to a procurement auction is due to Holt (1980) and the model that I develop below closely follows his analysis. Myerson (1981) and Riley and Samuelson (1981) have analyzed the problem of optimal mechanism design. They find, inter alia, that a risk-neutral auctioneer maximizes profits by setting a reserve price for each bidder. This result is susceptible to at least two major objections. First, in order to determine the optimal reserve price, the auctioneer needs detailed knowledge of the pdf of each bidder. Second, a reserve price may not be fully credible, since by refusing to sell, the auctioneer foregoes some profits. See Milgrom (1987) for a discussion of this problem.

### **3.2 The Model**

Suppose the government contracts a single indivisible project or good from  $N \geq 1$  firms. The gross social value of this project is  $S > 0$ . Each firm is asked by the government to submit a tender, and the firm that submits the lowest price wins the procurement auction. The government pays the winning firm its offer,  $p^w$ . Each firm submits non-cooperatively a bid that maximizes expected profits. If a firm loses the auction, it has zero profits. If it wins, its profits are  $p^w$  minus the costs of producing the good. Before the auction, each firm privately learns its efficiency in producing the good. For each firm, efficiency is independently drawn from a pdf  $f(e)$ . The cumulative distribution function (cdf) of  $f(e)$  is given by  $F(e): [0, S] \rightarrow [0, 1]$ , which is continuous at all points in the domain and monotonically increasing.

Costs are defined to be  $S-e$ , so a firm with efficiency  $S$  has zero costs, and a firm with zero efficiency has a cost  $S$ .

The timing of the game is as follows. First, each firm privately learns its efficiency and, hence, its cost. Then, all firms submit a bid. The firm with the lowest price wins, and the government pays this firm the submitted price. All other firms receive nothing. The next proposition gives the optimal equilibrium strategies.

**Proposition 1.** *In the symmetric Bayesian Nash equilibrium, all firms bid according to*

$$p(e) = S - e + \int_0^e \frac{G(x)}{G(e)} dx$$

where  $G(x) \equiv F(x)^{N-1}$

**Proof.** This is based on the proof of proposition 2.2 in Krishna (2002). Assume that the equilibrium bid strategy is  $p(e)$ , and that this strategy is monotonically decreasing in  $e$ . This assumption is just an innocuous working hypothesis, and it will later be shown that  $p(e)$  satisfies these assumptions. Because  $p(e)$  is monotonically decreasing, the probability that a firm wins the auction is equal to the probability that the firm has the highest efficiency. The expected profit of a firm  $i$  with efficiency  $e_i$ , but bids as if it has efficiency  $z$ , while all other firms are using the equilibrium strategy is

$$E(\pi_i) = G(z)(p(z) - S + e_i) \tag{3.1}$$

$G(z)$  is the cdf of the highest order statistic  $Y_1^{(N-1)}$  of  $e$  out of  $N-1$  firms. In this case, it is the probability that the highest efficiency of all other  $N-1$  firms is lower than  $z$ . The profit of firm  $i$  in case it wins is the price it receives, minus the cost. To maximize the expected profits, take the first-order derivative with respect to  $z$ , and set it equal to zero

$$\frac{\partial E(\pi)}{\partial z} = g(z)(p(z) - S + e_i) + G(z) \frac{\partial p}{\partial z} = 0 \tag{3.2}$$

In a symmetric equilibrium,  $z=e_i$ , using this and rewriting yields

$$(G(e)p(e_i))' = g(e_i)(S - e_i) \quad (3.3)$$

Equation (3.3) can be solved by integrating both sides

$$G(e_i)p(e_i) - G(0)p(0) = \int_0^{e_i} g(x)(S - x)dx \quad (3.4)$$

Since  $G(0)=0$ , by virtue of the definitions of  $F(e)$  and  $G(e)$ , and using integration by parts to rewrite the RHS of (3.4), yields the desired solution

$$p(e) = S - e_i + G(e_i)^{-1} \int_0^{e_i} G(x)dx \quad (3.5)$$

Now, the working hypothesis can be verified, namely that  $p(e)$  is monotonically decreasing in  $e$ . The derivative of (3.5) is

$$\frac{\partial p(e)}{\partial e} = -1 - \frac{g(e)}{G(e)^2} \int_0^e G(x)dx + 1 < 0 \quad (3.6)$$

This is strictly lower than zero, because  $\frac{g(e)}{G(e)^2} \int_0^e G(x)dx$  is positive everywhere.

It remains to be shown that, given that all other bidders follow the equilibrium strategy, it is indeed optimal for firm  $i$  to bid according to his true type. This can be easily proven by using the concept of pseudo-concavity. If the expected profit of firm  $i$ , which is bidding as if its efficiency is  $z$ , while it is in fact  $e$ , is increasing for  $z < e$ , and decreasing for  $z > e$ , the optimum value for  $z$  is  $e$ , and optimality of the equilibrium strategy is proven. The expected profit of firm  $i$ , with efficiency  $e$  and bids as if its efficiency is  $z$  is

$$E(\pi_i) = G(z)(e - z + G(z)^{-1} \int_0^z G(x)dx) \quad (3.7)$$

The first-order derivative of (3.7) with respect to  $z$  is

$$\frac{\partial E(\pi_i)}{\partial z} = g(z)(e - z) \quad (3.8)$$

This is positive for  $z < e$ , and negative for  $z > e$ . Therefore, firm  $i$  maximizes the expected profits by setting  $z$  equal to  $e$ . ■

### 3.3 Interpretation and Discussion

In the FPPA, each firm that considers to lower its price offer strikes a balance between two effects. On the one hand, a lower price implies that the firm wins with a higher probability, given that the bids of all other firms remain the same. On the other hand, a lower bid means that the firm has a lower profit in the case it actually wins the auction. The optimal bid strategy, as recorded in Proposition 1, achieves this for a risk-neutral firm.

Four properties of the equilibrium are worth mentioning. First, efficiency is guaranteed, since bid strategies are monotone decreasing in costs and the buyer does not set a reserve price. This property is not without importance for a government procurement agency that aims to maximize social welfare. Second, all firms shade their bid. That is, each firm tenders a bid that is strictly higher than its cost. This is easily seen by noting that  $G(e)^{-1} \int_0^e G(x) dx$  is strictly positive for all  $e > 0$ . The third property is that firms prefer less competition to more. By (3.1), the expected profits  $E[\pi_i(e_i)]$ , of a firm with costs  $S - e_i$  are

$$E[\pi_i(e_i)] = G(e_i)(p(e_i) - S + e_i) \quad (3.9)$$

Inserting the optimal bid strategy in (3.9) and rewriting gives

$$E[\pi_i(e_i)] = \int_0^{e_i} F(x)^{N-1} dx \quad (3.10)$$

To obtain the effect of an increase in the number of firms on the expected single firm profits, take the first-order derivative of (3.10) with respect to  $N$

$$\frac{\partial E\pi_i(e_i)}{\partial N} = \int_0^{e_i} \ln(F(x))F(x)^{N-1} dx < 0 \quad (3.11)$$

This is strictly decreasing in  $N$ , because  $F(x) > 0$  and  $\ln F(x) < 0$ , for all  $0 < x < e_i$ . Finally, the *ex ante* expected payment of the government to the industry is equal to the expectation of the second lowest cost. To see this, note that the optimal bid can be rewritten as

$$p(e) = \frac{1}{G(e)} \int_0^e g(x)(S-x) dx \quad (3.12)$$

The expected payment of the government to a single firm is simply the probability that a firm with efficiency  $e$  wins, times the bid of this firm

$$m(e) = G(e)p(e) = \int_0^e g(x)(S-x) dx \quad (3.13)$$

Of course, *ex ante*, the cost levels are unknown, so the *ex ante* expected payment is obtained by integrating (3.13) over  $e$

$$E[m(e)] = \int_0^S \left( \int_0^e g(x)(S-x) dx \right) f(e) de \quad (3.14)$$

Interchanging the order of integration gives

$$E[m(e)] = \int_0^S \left( \int_x^S f(e) de \right) g(x)(S-x) dx = \int_0^S (1-F(x))g(x)(S-x) dx \quad (3.15)$$

Since all firms are *ex ante* symmetric, the total *ex ante* expected payment  $P$  is found by simply multiplying (3.15) by the number of firms

$$P = N \int_0^S (1 - F(x))g(x)(S - x)dx \quad (3.16)$$

It is straightforward to show that the density  $f_2^{(N)}$  of the second-highest order statistic  $Y_2^{(N)}$  is

$$f_2^{(N)} = N(1 - F(x))g(x) \quad (3.17)$$

Substituting (3.17) into (3.16) yields, as claimed,

$$P = \int_0^S (S - x)f_2^{(N)} dx = E[2^{\text{nd}} \text{ lowest cost}] \quad (3.18)$$

This is good news for the government, because the price it has to pay is independent of his maximum willingness to pay, and is equal to the second-lowest cost in the industry; almost as low as possible.

Thus, the FPPA has several desirable properties that may explain its popularity in procurement. Most important, the FPPA is an efficient mechanism and the expected price is equal to the expected second-lowest cost. It should be noted that these two properties are not unique to the FPPA. In fact, the results extend to every procurement auction format that grants the order to the firm with the lowest offer and gives nothing to firms with the highest possible costs. See Krishna (2002) for a formal demonstration of this in the context of auctions. An additional property, that does not extend to all other procurement auction formats, is the fact that the FPPA is very simple to implement.

In deriving the above results, it was assumed above that all firms noncooperatively submit a price offer. This assumption is relaxed in the next chapter, where several collusive mechanisms are examined and compared with the results from this chapter.

## 4. COLLUSION IN THE ONE-SHOT GAME

In the previous chapter, I have shown how the FPPA works, given that firms act noncooperatively. The following chapter assumes that firms have the option to cooperate and examines how firms can coordinate their bids in a FPPA in a static context. Clearly, collusion usually takes place in a dynamic setting, so this suggests that one-shot games are not relevant for this analysis. However, it will be demonstrated that the collusive arrangements that the Dutch construction cartel has used are viable in a static setting as well. Section 4.1 briefly reviews the literature of collusion in auctions. In section 4.2, I show that “optimal” collusion is generally impossible. This theoretical result puts a limit on the profits that a cartel can obtain. The two collusion mechanisms that the Dutch construction cartel have employed are bid rotation schemes and preauction knockouts. Under bid rotation, all firms agree to post exactly the same maximum price  $S$  (or, if applicable, the reserve price), under the assumption that the buyer randomly chooses a winner. When a cartel employs a preauction knockout, it conducts an auction prior to the real procurement auction. In this preauction knockout, a bid is the amount that a bidder will equally share among all other firms (including the winner), given that it wins. The winning firm (i.e. the firm with the highest bid) is given the right to be the sole contender in the actual procurement auction. Bid rotation schemes and preauction knockouts are discussed in section 4.3 and 4.4, respectively. As I mentioned in chapter 2, the Dutch construction cartel also assigned bids to the losing firms. In the simple collusion mechanisms that are discussed in sections 4.3 and 4.4, this is rather unnecessary and merely increases the burden of communication. However, I show in section 4.5 that the threat of cartel prosecution provides a rationale for this.

### 4.1 Notes on the Literature

The first formal analysis of collusion in auctions is Robinson (1985). He shows that first-price sealed-bid auctions are usually less susceptible to collusion than English or second-price sealed-bid auctions<sup>1</sup>. This can be most easily seen in the case of the second-price sealed-bid

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<sup>1</sup> In a second-price sealed-bid auction, all bidders simultaneously and noncooperatively submit a bid. The bidder that made the highest offer wins and pays the second-highest bid. In an English auction, each bidder can overbid the previous bid, until there is only one bidder left and he or she pays his bid.

auction. Consider the following collusive agreement: the designated winner submits a very high bid, and all other bidders bid zero. Since each bidder cannot gain anything by deviating from this agreement, the agreement constitutes an equilibrium in weakly dominant strategies. Graham and Marshall (1987) analyze collusion in a second-price auction. They suggest that a bidding ring can use a preauction knockout to achieve both efficiency and maximize cartel profits. Their suggestion, that a preauction knockout efficiently maximizes cartel profits, is proven by Mailath and Zemsky (1991). McAfee and McMillan (1992) show the same in the context of a first-price auction and derive the optimal collusion mechanism if side payments are impossible. Their results will be discussed in more detail in sections 4.2., 4.3 and 4.4. If an auction is infinitely repeated, the static collusion mechanisms that are to be discussed in sections 4.3 and 4.4 can be self-enforcing as long as players do not discount future profits too heavily. See for instance Stigler (1964), Friedman (1970) or Abreu (1984).

Aoyagi (2003) proposes a dynamic, i.e. history-dependent, mechanism that does not rely on side payments. The mechanism yields higher profits to the bidders than simple bid rotation, by means of an ingenious construction that indirectly uses side payments. Skrzypacz and Hopenhayn (2004) present a collusion mechanism that relies on explicit communication and outperforms a simple bid rotating mechanism.

Sometimes, the auctioneer does not announce what the winning price is, but only reveals who the winner is. In that case, standard bid rotation seems to be unfeasible, because it cannot be observed whether the winner has deviated or not. Yet, Blume and Heidhues (2002) show that, for sufficiently low discount factors, the simple bid rotation mechanism is still a Nash equilibrium.

## **4.2 An Impossibility Theorem**

In this section, I demonstrate that “optimal” collusion, which is defined to be a collusive agreement that maximizes cartel profits and restricts inefficient firms to earn zero profits, implies that expected cartel profits are equal to the expected profits if firms would not have cooperated. This result not only puts an upper bound on the scope of collusion; it also shows why a one-shot collusion mechanism must either allow inefficient firms to enter the industry, or assign the project randomly to each cartel member. That is, the impossibility theorem in this section nicely demonstrates why conspiring firms must choose between bid rotation and the preauction knockout mechanism.

Firms that consider to form a cartel (or bidding ring) face at least three problems. First, these firms must agree on some mechanism that determines how they will share the supra-normal profits of collusion. Second, this mechanism must be self-enforcing. Legal enforcement is not possible, as collusive agreements are usually forbidden. McAfee and McMillan (1992) suggest an "organized crime" solution to this problem: the mechanism may be self-enforcing if a cheating firm is (physically) punished by the other cartel members. Third, a successful cartel attracts new firms and this may drive profits to zero. In the worst-case-scenario, the cartel may even attract firms with a cost level so high that these firms would not have made a profit in the absence of a cartel. These firms, called "schleppers"<sup>1</sup>, can be excluded from the cartel by imposing that firms with cost equal to  $S$  receive nothing.

Given that the objective of the conspiring firms is to maximize firm profits, the spoils of collusion are maximized if the collusion mechanism selects the firm with the lowest cost to be the designated winner. Let an "optimal" collusion mechanism be an efficient mechanism that maximizes firm profits, subject to the condition that firms with  $e = 0$  receive zero. The timing is as follows. First, firms privately learn their cost. Then, they decide on a collusion mechanism. Third, firms report their efficiency to the mechanism and, finally, the mechanism is implemented. The next proposition was first formulated by McAfee and McMillan (1992).

**Proposition 2.** *An "optimal" collusion mechanism in an IPV FPPA implies that all firms receive noncooperative payments.*

**Proof.** The proof is basically a revenue equivalence argument. Because the mechanism is restricted to be efficient, a bidder with cost  $S-e$  wins with probability  $G(e)$ . Suppose that this bidder reports  $z$  instead of  $e$  to the mechanism. Then, its expected profits are

$$\pi(z, e) = m^{oc}(z) - G(z)(S - e) \tag{4.1}$$

where  $m^{oc}(z)$  is the expected payment a firm receives if it reports  $z$ . Maximization of (4.1) with respect to  $z$  gives

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<sup>1</sup> In Dutch: aanbestedingstoeristen.

$$\frac{\partial}{\partial z} \pi(z, e) = \frac{\partial}{\partial z} m^{oc}(z) - g(z)(S - e) = 0 \quad (4.2)$$

In equilibrium  $z=e$ , so

$$\frac{\partial}{\partial z} m^{oc}(e) = g(e)(S - e) \quad (4.3)$$

This can be solved by integrating over  $e$  to yield an expression for expected payments under an “optimal” collusion mechanism

$$m^{oc}(e) = \int_0^S g(e)(S - e)de \quad (4.4)$$

Note that the “anti-schlepper” condition ( $m^{oc}(z) = 0$ ) is imposed in deriving (4.4). ■

Strictly speaking, proposition 2 does not imply that “optimal” collusion is impossible, since firms are indifferent between “optimal” collusion and noncooperative bidding. However, even the slightest probability of cartel detection, combined with a positive fine, ensures that all firms prefer to bid noncooperatively to “optimal” collusion. Furthermore, proposition 2 means that if firms consider to form a cartel, they have either to drop the efficiency condition or the anti-schlepper condition. In the next section, I consider bid rotation, which is an inefficient collusion mechanism.

### 4.3 Bid Rotation

Many real-world cartels, including the Dutch construction cartel<sup>1</sup>, have used bid rotation as a collusion device, see for example Mund (1960), Scherer (1970) or Green (1985). In light of the previous section, it may be tempting to believe that firms are indifferent between bid rotation and noncooperative bidding. The next proposition, which is due to McAfee and McMillan (1992), claims that this is not true: firms prefer bid rotation to noncooperative bidding.

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<sup>1</sup> *De bouw uit de schaduw*, p. 264.

**Proposition 3.** *Ex ante expected firm profits are higher under a bid rotation scheme than under noncooperative bidding, independent of the distribution function  $F(e)$ .*

**Proof.** The proof is by induction. Note first that the expected profits of a single firm if all firms bid noncooperatively are given by (3.10). The *ex ante* expected profits  $\Pi^{nc}$  are obtained by integrating this expression

$$\Pi^{nc} = \int_0^S E[\pi(e)]f(e)de = \int_0^S \left( \int_0^e G(x)dx \right) f(e)de \quad (4.5)$$

$$= \int_0^S \left( \int_x^S f(e)de \right) G(x)dx = \int_0^S (1 - F(x))G(x)dx \quad (4.6)$$

Under bid rotation, all firms have the same probability of winning  $1/N$ . If all firms bid  $S$ , then the profit of a firm in case of winning is simply  $e$  ( $S$  minus the costs  $S-e$ ). The *ex ante* expected profits  $\Pi^{br}$  are given by

$$\Pi^{br} = \frac{1}{N} \int_0^S ef(e)de \quad (4.7)$$

If all firms prefer bid rotation, then

$$\frac{1}{N} \int_0^S ef(e)de > \int_0^S (1 - F(x))G(x)dx \quad (4.8)$$

or

$$\int_0^S (ef(e) - N(1 - F(e))F(e)^{N-1})de > 0 \quad (4.9)$$

Suppose that condition (4.9) holds for  $N=n$ , then it will also hold for  $N=n+1$ , since

$$\int_0^S (ef(e) - n(1 - F(e))F(e)^{n-1})de > \int_0^S (ef(e) - (n+1)(1 - F(e))F(e)^n)de \quad (4.10)$$

Rearranging (4.10) gives

$$\frac{n}{n+1} \int_0^S (1 - F(e))(F(e)^{n-1} - F(e)^n)de > 0, \quad \forall e \in (0, S) \quad (4.11)$$

The proof is complete if the LHS of (4.11) is nonnegative for  $N=1$ . For  $N=1$ , (4.11) simplifies to

$$\int_0^S (ef(e) - (1 - F(e)))de \geq 0 \quad (4.12)$$

Integration by parts gives

$$S - \int_0^S F(e)de - S + \int_0^S F(e)de = 0 \quad (4.13)$$

Hence, if  $N=1$ , all firms are, for obvious reasons, indifferent between competition and collusion. If  $N>1$ , collusion is strictly preferred. ■

From the perspective of the cartel, bid rotation has two important advantages. First, communication between firms is reduced to a minimum level. The only problem for firms is to find out what the maximum willingness to pay of the procurement agency is. Second, there is no need for side transfers. This diminishes the probability of detection, because a system of side transfers usually requires detailed accounts that can be used as evidence by the competition authority. Moreover, without side transfers, schleppers have no incentive to enter the market. A bid rotating system has a major drawback as well. Because the probability that a firm wins is independent of its cost level, bid rotation is likely to yield an inefficient outcome. In the next section the first-price preauction knockout will be discussed. This collusion mechanism does achieve efficiency, but is unable to keep schleppers back from earning positive profits.

#### 4.4 The First-Price Preauction Knockout

In this section, I discuss the first-price preauction knockout and show that it is equivalent to the mechanism that the Dutch contractors have used. The first-price preauction knockout is a mechanism that allows conspirators to collude efficiently by using side transfers. The next proposition, due to McAfee and McMillan (1992), establishes the optimal bid strategy for each firm in this first-price auction.

**Proposition 4.** *In the first-price preauction knockout, all firms bid according to*

$$p(e) = e - \int_0^e \left( \frac{G(x)}{G(e)} \right)^\alpha dx$$

where  $\alpha \equiv N/(N-1)$

**Proof.** The proof proceeds in the same fashion as the proof of proposition 1. Consider a firm  $i$  with efficiency  $e$  that submits a bid which corresponds to an efficiency level of  $z$ , when all other firms use the equilibrium strategy  $p$ . Its payoff structure is then

$$\begin{aligned} \pi_i &= (1/N)p(Y_1) && \text{if } z < Y_1 \\ \pi_i &= e - p(z) + (1/N)p(z) && \text{if } z > Y_1 \end{aligned} \tag{4.14}$$

With probability  $1-G(z)$  the firm loses the knockout and receives side payments from the winning firm. If a firm wins, with probability  $G(z)$ , it charges and receives  $S$  from the procurement agency. Its costs of producing are  $S-e$ , plus the side payments it makes to the other conspirators. The expected profit of this firm can be written as

$$E[\pi_i] = (1 - G(z)) \frac{1}{N} E[p(Y_1) | Y_1 > z] + G(z)(e - p(z) + \frac{1}{N} p(z)) \tag{4.15}$$

Notice that  $E[p(Y_1) | Y_1 > z]$  can be written as

$$\frac{1}{1-G(z)} \int_z^s p(x)g(x)dx \quad (4.16)$$

Substituting (4.16) into (4.15) and simplifying gives

$$E[\pi_i] = \frac{1}{N} \int_z^s p(x)g(x)dx + G(z)(e - p(z)) + \frac{1}{N} p(z) \quad (4.17)$$

To maximize the expected firm profits, one needs to take first-order derivative of (4.17) and set it to zero. Imposing the equilibrium condition  $z=e$  and rewriting gives

$$\frac{N-1}{N} p'(e)G(e) + p(e)g(e) - g(e)e = 0 \quad (4.18)$$

Contrary to the differential equation in (3.3), this nasty expression cannot be solved by straightforward integration. Nevertheless, (4.18) can be solved by means of a simple trick. Let  $H(\bullet) \equiv G(\bullet)^\alpha$ . Making the appropriate substitutions yields

$$\frac{1}{\alpha} p' H(e)^{1/\alpha} + \frac{1}{\alpha} p(e) H(e)^{(1-\alpha)/\alpha} h(e) - \frac{1}{\alpha} H(e)^{(1-\alpha)/\alpha} h(e)e = 0 \quad (4.19)$$

Dividing by  $\frac{1}{\alpha} H(e)^{(1-\alpha)/\alpha}$  allows one to write (4.19) in a more convenient form

$$p'(e)H(e) + p(e)h(e) = h(e)e \quad (4.20)$$

The solution of this expression can be found by integrating both sides

$$p(e) = e - \int_0^e \frac{H(x)}{H(e)} dx \quad (4.21)$$

Substituting  $G(\bullet)^\alpha$  for  $H(\bullet)$  into (4.21) completes the proof. ■

Besides an efficient way of allocating the spoils from collusion, the above mechanism may be handy in other situations as well, such as inheritances or divorces, as shown by Cramton et al.

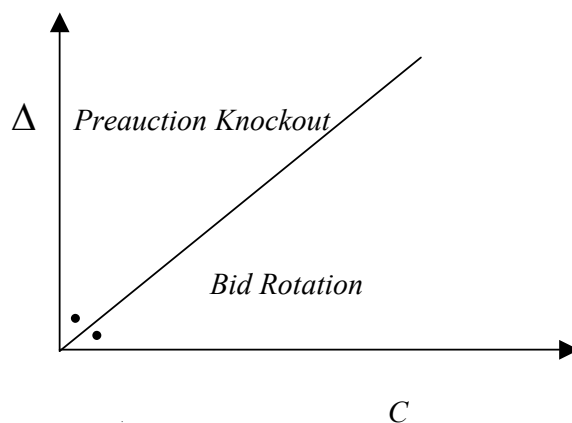
(1987). For example, in a divorce, two parties that own a indivisible property, such as a house, can allocate this by using the above mechanism. In a collusion context, the indivisible common “property” is simply the monopoly profit.

Note that this form of collusion is strategically equivalent to the collusive arrangement that was discussed in the example in chapter 2. In the terminology of that example, a firm  $i$  that reports  $p^i$  is implicitly announcing the maximum amount that it is willing to share among all cartel members, which is  $p-p^i$ .

It is easy to see that, with this form of collusion, expected profits that accrue to the cartel are equal to  $E[Y_1^{(N)}]$ . Under a system of bid rotation, expected cartel profits are  $E[e]$ , which is clearly lower. A preauction knockout mechanism achieves higher profits, because it is able to select the most efficient firm, whereas bid rotation typically does not. Unfortunately, these higher profits come at a cost. The Achilles' heel of the first-price preauction knockout is the use of side transfers. These side transfers usually require intensive communication between the conspirators. This communication can be used as evidence by the competition authority, as in the Dutch construction cartel, where Mr. Bos' main evidence were excerpts from a secret record, in which firms kept track of the illegal payments they made to each other. Another potential problem that side transfers bring along is that it may induce entry by new firms. However, as argued in section 2.3, entry costs in the (upper segment of the) Dutch construction market seems to be such that entry is effectively blocked.

The optimal choice between bid rotation and the first-price preauction knockout can be conveniently summarized in the figure below, with the difference  $\Delta \equiv E[Y_1^{(N)}] - E[e]$  on the vertical axis, and the expected cost of communication  $C$  on the horizontal axis.

Figure 3 – Optimal Choice of Collusive Agreement



In a one-shot market in which goods are procured by means of a FPPA, firms that consider to form a cartel can choose between a bid rotation scheme and a preauction knockout. What the optimal collusion mechanism is depends ultimately on the size of the difference between  $E[Y_1^{(N)}]$  and  $E[e]$  and on how risky communication between firms is.

As I argued above, the collusion mechanism that the Dutch construction cartel used is equivalent to the preauction knockout. Nonetheless, the mechanism of the Dutch builders is a bit more complicated. In secret preliminary talks, the preauction knockout, the cartel did not only decide on which firm would be the designated winner and side payments. It assigned to each losing firm a price that it should submit in the FPPA as well, with the goal of mimicking “competitive” prices. At first sight, this seems unnecessary: if all losing firms submit the same (high) price, the cartel obtains the same profits, with less communication. However, submitting equal bids will quickly raise the suspicion of the competition authorities, because the probability that all firms have the same costs is zero. Thus, by prescribing to each firm a different tender, the cartel can lower the expected costs of competition prosecution. This path to conspiracy was suggested by, *inter alia*, Cook (1963) and Comanor and Schankerman (1976) and formally analyzed by LaCasse (1995). Her model is the topic of the next section.

#### **4.5 The Threat of Prosecution**

In the last section, I showed the workings of the first-price preauction knockout. Under this collusion mechanism, there is no need to assign to each losing firm a different price offer, as the firms in the Dutch construction cartel consistently did. LaCasse (1995) finds that bidders can collude in an IPV first-price sealed-bid auction when they face an eager competition authority by mimicking competitive behavior. The striking result of this model is that it shows how and why bidding rings mimic competitive behavior, just as the Dutch construction cartel did.

The timing in her model is as follows. First, all bidders jointly decide whether to form a bidding ring and rig their bids at the auction, or to bid noncooperatively. Second, each bidder privately learns his valuation  $v$ . This is assumed to be either 0 or 1 (with probability  $\beta > 0$  and

$1-\beta$ , respectively). In the third stage, each bidder submits a bid. If the bidders at stage one have formed a cartel, this bid is assigned by a collusion mechanism. Else, each bidder with a positive valuation noncooperatively submits a bid. In both cases, the object is sold to the highest bidder at the highest (random) price  $x$ , given that this bid is positive. After observing all the bids, the competition authority decides whether to start an investigation. The cost of this inquiry is  $c > 0$ . This cost may, besides real expenditures, represent the opportunity cost of directing attention towards this cartel. LaCasse (1995) conveniently assumes that this investigation perfectly ascertains whether the buyers have cooperated. If the buyers have conspired and it is detected, the buyers lose their profits, and the competition authority receives  $\lambda > c$ . The total payoffs of the buyers and the competition authority, conditional on that the buyers have plotted, are depicted in table 1a. Table 1b shows the payoff of both parties if the buyers noncooperatively submit a bid. If at least one buyer has a valuation of 1, the object is sold, and the competition authorities have the option to investigate. This corresponds to the second row:  $v=1$ . Likewise,  $v=0$  in the lower row corresponds to the outcome in which all buyers have a valuation of 0. In this case, none of the buyers submits a bid, and the competition authorities have nothing to investigate.

Table 1a – Payoff if buyers cooperate

	investigate	does not investigate
$v = 1$	$(0, \lambda - c)$	$(1 - x, 0)$
$v = 0$	$(0, 0)$	$(0, 0)$

Table 1b – Payoff if buyers compete

	investigate	does not investigate
$v = 1$	$(1 - x, -c)$	$(1 - x, 0)$
$v = 0$	$(0, 0)$	$(0, 0)$

LaCasse (1995) shows that this game has a unique symmetric equilibrium, in which buyers not only randomize between collusion and competition, but also (given that they collude) make side payments to each other, and randomize their bids using a simple collusion mechanism. The competition authority is indifferent between investigating and not investigating. Though the derivation of the equilibrium strategies are quite involving, the result that, in equilibrium, both the competition authority and buyers are indifferent between their actions is easily seen. Suppose the competition authority is confident that the buyers have formed a cartel, that is, the probability of collusion is 1. Then, the competition authority finds itself in table 1a, and the optimal reaction is clearly to put all weight on [investigate]. Given that the competition authority investigates with certainty, the buyers can simply increase expected profits by abandoning the bidding ring and bidding noncooperatively. If competition prevails, it is pointless for the competition authority to choose [investigate].

However, an competition authority that never investigates is like a sitting duck for the buyers, because it allows them to collude and obtain higher profits than under competition. This reasoning implies that the competition authority can be sure that a bidding ring has formed, and the situation is just as at the start of this argument. So, there cannot be an equilibrium in pure strategies in this game. Hence, in equilibrium, the buyers and the competition authority adopt a mixed strategy.

Buyers do not only randomize over collusion and competition, they submit a random bid as well, independent of whether they collude or not. To see this, suppose first that the buyers act noncooperatively. Then, a bidder with valuation 0 clearly bids 0. If the highest bid is  $x$ , a bidder with valuation 1 makes a sure profit by bidding  $x+\varepsilon$ , with  $\varepsilon$  positive and close to zero. Other players can overbid until  $x=1$ , when no player makes a profit. Bidding 1, even with positive probability, however, cannot be part of an equilibrium. Each bidder with a valuation of 1 makes an expected profit of  $\beta^{N-1}$  if he bids 0, since with probability  $\beta^{N-1}$ , he is the only bidder with a positive valuation. If a bidder bids  $y$ , ( $0 \leq y < 1$ ) with positive probability, another bidder can simply grab extra profits by bidding  $y+\varepsilon$ . This implies that all bidders randomize their bids using some cdf  $H(b)$ . As is well known, in a mixed strategy equilibrium, a player is indifferent between all possible actions. Therefore, if a bidder considers to bid  $b$ , the following condition must hold in equilibrium

$$\beta^{N-1} = [1 - (1 - \beta)(1 - H(b))]^{N-1} (1 - b) \quad (4.22)$$

Equation (4.22) states that the guaranteed expected profits a bidder can obtain by bidding 0, on the LHS, should equal the profits a bidder obtains by bidding  $b > 0$ , on the RHS. The term between square brackets is the probability that  $b$  beats one other bidder. Solving (4.22) for the equilibrium bid strategy  $H(b)$  yields

$$H(b) = \frac{\beta}{1 - \beta} \left( (1 - b)^{\frac{1}{N-1}} - 1 \right) \quad (4.23)$$

As can be routinely verified,  $H(b)$  is defined on the interval  $[0, 1 - \beta^{1/(N-1)}]$  and monotonically increasing. This equilibrium implies that if the buyers act noncooperatively, the probability that two or more buyers submit the same bid is zero. Hence, if the bidders conspire in a bidding ring, they cannot use a bid rotating mechanism, since this will immediately draw the

attention of the competition authority. An analogous argument shows that a mechanism in which the bidding ring submits a particular bid with positive probability is not viable as well. Therefore, the bidding ring must draw its bids from a cdf as well.

The optimal collusion mechanism randomly picks one bidder with a valuation of 1 to be the designated winner. This player is assigned the winning bid  $x$ , which is drawn from some cdf  $I(x)$  and makes side-payment to all other players with a valuation of 1.  $I(x)$  assigns more probability to lower bids than  $H(x)$ , to make the gross profit of collusion higher than the profit of competition. The losing players with a positive valuation are assigned a bid that is drawn from the cdf  $H(b \mid b < x)$ . All players with a zero valuation do not bid and receive nothing. Note that, since all losing bids are drawn from  $H(b \mid b < x)$ , the competition authority can restrict attention to the winning bid, because all losing bids are compatible with competitive behavior.

A disturbing aspect of LaCasse's (1995) model is the assumption that, in the first stage, all players collectively choose whether to form a bidding ring or not. It would be more realistic if players could individually decide on this. The assumption that an investigation always reveals the truth is a potential problem, as it is not *ex ante* clear how an imperfect investigation changes equilibrium behavior.

## 5. THE EFFECTS OF CALCULATION COSTS

In this section, I discuss the effects of calculation (or, equivalently, entry, information processing or bid preparation) costs. All results derived so far rest on the assumption that participation in the FPPA is costless. Yet, bidding in a real-world auction can be quite expensive. Submitting a price does, evidently, hardly incur any costs, but before a firm can actually bid, it has to make serious efforts to understand the project that is demanded. This is especially true in complex large-scale projects, like the construction of subway-systems or bridges. For instance, Dutch contractor Heijmans claims it invested five million euro before it could make a bid in the Amsterdam North-South subway project<sup>1</sup>. Therefore, it seems reasonable to add the assumption that each firm that joins the auction incurs a calculation cost or, equivalently, an entry cost.

Section 5.1 starts with some notes on the literature. In Section 5.2, I analyze the strategic effects of calculation costs in a simple FPPA model without the IPV assumption. This simplification allows me to derive closed-form solutions and it will be shown that the conclusions of this simple model extend to the IPV case. As discussed in section 2.4, some firms have put forward that the (at first sight) harmless objective of the Dutch construction cartel is to repay losing firms their sunk calculation costs. Therefore, as promised, section 5.3 examines what may happen (in the simple FPPA model) if firms compensate each other. In section 5.4, I return to the IPV assumption and reexamine the effects of calculation costs.

### 5.1 Notes on the Literature

Smith (1982, 1984), Engelbrecht-Wiggans (1987, 1991) and McAfee and McMillan (1987) analyze (costly) entry in auctions. In their models, each potential bidder first decides on entry, and then learns his valuation and the number of actual bidders. This set-up becomes interesting only when the number of potential bidders  $N$  is such that if all bidders enter the auction, each bidder obtains an expected loss. The above authors restrict attention to asymmetric equilibria in pure strategies. This seems quite unnatural, given that all bidders are *ex ante* symmetric. Levin and Smith (1994) reestablish symmetry by introducing mixed entry

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<sup>1</sup> 'Rijk houdt bouw in wurggreep', *NRC Handelsblad*, July 19, 2002

strategies. They find that an increase in the number of potential bidders reduces social welfare. I will discuss their results in section 5.4. Samuelson (1985) considers an auction in which bidders pay an entry cost after they learned their valuation. He finds that bidders with a low valuation do not participate in the auction and has the same effect as a reserve price.

Several studies of entry into auctions usually abandon the IPV assumption and restrict the analysis to the pure common value case. In this context, Dasgupta and Stiglitz (1988) find that, in a model of sequential and costly entry, potential competition is completely ineffective. Lang and Rosenthal (1991), Sharkey and Sibley (1993) and Elberfeld and Wolfstetter (1999) find, analogous to Levin and Smith (1994), that if bidders simultaneously decide on entry, an increase in potential competition decreases the expected revenue for the seller.

## 5.2 The Contractor's Game

The following model is based on Elberfeld and Wolfstetter's (1999) analysis. Though Elberfeld and Wolfstetter (1999) actually model simultaneous entry in a Bertrand market, their study can straightforwardly be applied to examine a pure common values auction with entry. They find, inter alia, that in a FPPA the probability of competitive prices decreases in the number of potential competitors, if firms incur an entry cost. This result suggests that a buyer may find it optimal to limit the number of potential competitors. The remainder of this section discusses the assumptions in Elberfeld and Wolfstetter's (1999) framework, derives the unique symmetric equilibrium strategies and demonstrates the adverse effects of an increase in potential competition.

As before,  $N \geq 2$  firms simultaneously consider to bid for a project. If a firm decides to enter the FPPA and submit a bid, it incurs a cost  $C > 0$ . These costs are assumed to be sunk. After entry, all active firms first learn the number of competitors  $n \leq N$ , and then submit a bid. This timing of events captures an important aspect of real-world procurements, namely that the number of actual competitors is unknown when firms incur calculation costs, but is known at the bidding stage. It is common knowledge that each firm has a normalized cost of 0 of producing the project. Though this assumption is a drastic departure from the IPV framework, it simplifies the analysis and allows to focus on the strategic effects of entry costs. The maximum willingness to pay of the government procurement agency is equal to the gross social value of the project  $S > C$ .

The model is solved by backward induction. In the second stage, when  $n$  is known, an active firm can safely charge  $S$  if it is a monopolist. In that case, a firm makes a profit of  $S-C$ . If the number of active firms is more than one, the bidding process amounts to standard Bertrand competition and the winning bid is 0. All active firms then make a loss of  $C$ . A firm that contemplates entry in the first stage would clearly never do so if another firm enters for sure. Therefore, there exist exactly  $N$  asymmetric Nash equilibria in pure strategies in which one firm pays the calculation cost and all other firms stay out.

Since all firms are *ex ante* identical, it makes sense to restrict attention to symmetric equilibria. As can be straightforwardly verified, there are no symmetric equilibria in pure strategies. Hence, the symmetric equilibrium must involve mixed strategies. If all other firms incur the calculation cost with probability  $q$ , a firm that enters is a monopolist with probability  $(1-q)^{1/(N-1)}$ . Its expected profits of entry are therefore  $(1-q)^{1/(N-1)}S-C$ . In equilibrium, all firms are indifferent between entry and staying out. The profit of staying out is 0, so  $(1-q)^{1/(N-1)}S = C$ . This can be solved for the equilibrium value of  $q$

$$q = 1 - \left(\frac{C}{S}\right)^{\frac{1}{N-1}} \quad (5.1)$$

If the market breaks down, no firm enters, sale does not take place and the buyer's surplus is zero. Given that just one firm enters, the buyer's surplus is zero as well, because a monopolist will charge the maximum willingness to pay  $S$ . In the event that two or more firms enter, they will, by virtue of grim price competition, charge zero and the buyer's surplus is  $S$ . Hence, the expected buyer's surplus is  $S$  times the probability that  $n \geq 2$ . Notice that expected buyer's surplus equals expected overall welfare, because the expected profit of firms is zero in equilibrium.

The probability that two or more firms participate in the procurement auction is simply one minus the probability that less than two firms enter. With probability  $(1-q)^N$  no firm enters and with probability  $Nq(1-q)^{N-1}$  just one firm submits a bid. So the probability that the procurement auction is competitive is  $1 - (1-q)^N - Nq(1-q)^{N-1}$ . Substituting (5.1) into this expression and rewriting gives

$$\Pr(\text{comp}) = 1 - t^{\frac{N}{N-1}} - Nt + Nt^{\frac{N}{N-1}}, \quad (5.2)$$

where  $t=C/S$ . The effect of an increase in potential competition  $N$  is now given by

$$\frac{\partial \Pr(comp)}{\partial N} = -\ln(t)t^{\frac{N}{N-1}}\left(\frac{1}{N-1}\right) + t\left(t^{\frac{1}{N-1}} - 1\right) < 0 \quad (5.3)$$

The negative sign of this derivative follows by noting that  $\ln(t)$  can be written as  $-(N-1)\ln(t)^{\frac{1}{N-1}}$  and this is strictly larger than  $(N-1)(1-t^{\frac{1}{N-1}})$  since  $\ln(x) < x-1$ . Hence, the probability that the buyer can obtain the good at the competitive price is maximized if  $N$  is two. This result is in marked contrast with the common belief that more competition is always better for the consumer. It follows immediately that a procurement agency should invite exactly two firms to submit a bid, given that it is commonly known that firms face equal marginal cost levels and bid preparation is costly.

### 5.3 Compensating Calculation Costs

In this section, I extend the model of the above section to examine the effect on prices, entry strategies and welfare if all potential competitors have agreed that the winning firm will compensate each losing active firm. Furthermore, I show that such a calculation cost compensation scheme is, at least in the pure common values case, undesirable, since it lowers social welfare.

Consider the same framework as in the above section, but with a minor modification: each firm has committed itself, in the event of winning, to reimburse all losing firms their calculation cost. For the sake of simplicity, assume that  $NC < S$  holds. This assumption says that the relative size of compensation costs and the number of firms are small, as compared to gross social value. In this case, there is a symmetric equilibrium in pure strategies, in which each firm pays the compensation cost and submits a bid  $NC$ . To see this, suppose that  $2 \leq n \leq N$  have entered the FPPA. Then, a firm wins for sure if it submits a bid below  $nC$ . However, this yields a negative profit, because the winning firm is obliged to compensate all losing firms. So, if the winning bid is too low, the winner regrets. If a firm submits a bid higher than  $nC$ , it loses the procurement auction and profits are exactly zero. The minimum price at which a firm is indifferent between winning and losing is given by  $p - nC = 0$ , or  $p = nC$ . As the profits of participation are always zero and  $NC < S$ , each firm chooses to join in the auction and bids  $NC$ .

Net social welfare  $SW$  under the scheme as examined above is simply gross social welfare  $S$  minus the price  $NC$ , or  $S-NC$ . In order to judge the desirability of a compensation scheme, one needs to compare this with net social welfare  $SW'$  as in the original Elberfeld and Wolfstetter (1999) model. Net social welfare in their model can be seen to be

$$SW' = \sum_{n=2}^N \binom{N}{n} q^n (1-q)^{N-n} S \quad (5.4)$$

A compensation scheme lowers net social welfare if  $SW' > SW$ . By substituting (5.2) into (5.4), this inequality can be written as

$$1 - \left(\frac{C}{S}\right)^{\frac{N}{N-1}} - \frac{NC}{S} + N \left(\frac{C}{S}\right)^{\frac{N}{N-1}} > 1 - \frac{NC}{S} \quad (5.5)$$

or

$$\left(\frac{C}{S}\right)^{\frac{N}{N-1}} (N-1) > 0 \quad (5.6)$$

Since the above inequality holds, a compensation scheme lowers net social welfare, and the last argument in favor of the cartel is shown to be inaccurate. This can be intuitively seen by noting that a compensation scheme causes all potential firms to enter the procurement auction for sure and charge a price strictly higher than zero. Without a compensation scheme, firms enter at random and charge a price of zero, given that at least two firms have entered. In both cases, firms break even, at least in expected terms.

Given that firms are indifferent between compensating or not compensating, and net social welfare is harmed, an important question is why firms, such as the Dutch contractors, would ever prefer to use such an agreement. A cynical answer is that a calculation cost compensation agreement compensates anything but calculation costs. As observed in section 4.4, firms can efficiently collude by conducting a preauction knockout, which involves side payments. By dubbing these side payments “a compensation for calculation costs”, the bidding ring may divert the attention of the competition authorities and collude efficiently.

## 5.4 A More General Model of Calculation Costs

I have shown in the above section that, in the pure common values case, it is generally undesirable that losing firms are compensated by the winning firm. In this section, I show that this result extends to the IPV case. This section draws heavily on Levin and Smith (1994).

Let  $E[\pi | n]$  denote the *ex ante* expected profit of entry for a single firm, given that  $n$  firms enter. Because the expected *ex ante* firm profits in the FPPA are decreasing in the number of firms, there exists a unique integer  $n^*$  such that  $E[\pi | n^*] \geq 0 > E[\pi | n^* + 1]$ . If  $N$  is small, i.e.  $E[\pi | N] > 0$ , all firms will enter for sure and the model with calculation costs does not yield new insights, relative to the standard FPPA model that was studied in chapter 3. Therefore, following Levin and Smith (1994), let  $N > n^*$ .

The timing is as follows. First, all  $N$  firms simultaneously decide whether they enter the procurement auction. Each of the  $n$  firms that decides to enter, incurs a calculation cost  $C > 0$ . All other firms receive a profit of zero. After the entry stage, each active firm privately learns its efficiency  $e$ . As before, this efficiency is drawn from the cdf  $F(e)$ . Finally, all active bidders noncooperatively submit a bid. The firm that submitted the lowest bid receives its bid from the government procurement agency and delivers the project. All other firms receive nothing.

This two-stage game can be solved by backward induction. In the bidding stage, the number of firms is common knowledge, and  $C$  is a sunk cost. This constitutes the same game as in chapter 3, so it therefore has the same Bayesian-Nash equilibrium. The entry game is a bit more difficult to solve. By the same logic as in section 5.2 this game has a symmetric equilibrium in mixed strategies. In a symmetric mixed strategy equilibrium, each firm enters the auction with the same probability. Suppose that  $N-1$  firms enter the procurement stage with probability  $q \in (0,1)$ . This is an equilibrium if the *ex ante* expected profit of entry of a potential firm is zero:

$$(1-q)^{N-1} \int_0^S e f(e) de + \sum_{n=2}^N \left[ \binom{N-1}{n-1} q^{n-1} (1-q)^{N-n} E \left[ \frac{Y_1^{(n)} - Y_2^{(n)}}{n} \right] \right] - C = 0 \quad (5.7)$$

The first part in the above expression are the *ex ante* expected profits that accrue to the potential firm if it enters and all other  $N-1$  firms stay out. The second part denotes the *ex ante* expected profits that a potential firm obtains if it enters and it faces at least one competitor.

The *ex ante* expected profits when exactly  $n$  firm enter are  $E\left[\frac{Y_1^{(n)} - Y_2^{(n)}}{n}\right]$ , since in a FPPA

the *ex ante* expected payment of the government is  $S - E[Y_2^{(n)}]$ , see equation (3.18), the *ex ante*

expected cost of a firm in the event of winning is  $S - E[Y_1^{(n)}]$  and the *ex ante* probability that a

firm wins is  $1/n$ . If (5.7) holds then, in the symmetric equilibrium, each firm is willing to enter with probability  $q$ . Note that the value of  $q$  is implicitly defined by (5.7). Levin and Smith

(1994) show that, if  $N > n^*$ ,  $\frac{\partial q}{\partial C} < 0$ . This has a fairly intuitive interpretation. If the calculation

cost increases, the net profit of joining the auction, for given  $q$ , decreases. Since this profit must equal zero,  $q$  should decrease in order to shift more probability mass to profitable events.

Total expected industry profits  $\Pi$  are given by

$$\Pi = Nq(1-q)^{N-1} \int_0^S ef(e)de + \sum_{n=2}^N \left[ \binom{N}{n} q^n (1-q)^{N-n} E[Y_1^{(n)} - Y_2^{(n)}] \right] - NqC \quad (5.8)$$

The revenue of the government procurement agency is the gross social welfare of the project

$S$ , minus the *ex ante* expected costs. The *ex ante* expected costs if  $n$  firms enter is given by

(3.18). So the expected revenue is

$$\sum_{n=2}^N \left[ \binom{N}{n} q^n (1-q)^{N-n} E[Y_2^{(n)}] \right] \quad (5.9)$$

Net social welfare  $SW$  of the FPPA with calculation costs is found by summing (5.8) and (5.9)

$$SW = Nq(1-q)^{N-1} \int_0^S ef(e)de + \sum_{n=2}^N \left[ \binom{N}{n} q^n (1-q)^{N-n} E[Y_1^{(n)}] \right] - NqC \quad (5.10)$$

In equilibrium, the expected industry profits equal zero, so net social welfare is equal to the revenue of the procurement agency.

As observed in section 5.3, a direct effect of a compensation scheme is that it increases the probability that a firm enters the procurement auction by decreasing the cost of losing, and holding constant the profit of winning. Levin and Smith (1994) establish formally, in the IPV case, that the competitive mixed entry strategy,  $q$ , are optimal, both from the perspective of the procurement agency and from society's. This implies that a compensation cost scheme lowers social welfare, relative to a FPPA without such a scheme.

## **6. CORRUPTION AND THE INCIDENCE OF CARTELS**

In chapter 4 and 5, I have shown, among other things, how the Dutch construction cartel functioned and how it harmed government by increasing prices. An important topic that is thus far left unexplained is the question of incidence. That is, why were the Dutch contractors able to collude, but not their colleagues in Belgium or Denmark? In this section, I discuss a characteristic of the Dutch construction industry that may explain this: corruption. The analysis in this chapter is inherently more tentative than in the preceding chapters, since the information on the form of corruption in the Dutch construction industry is virtually absent. I therefore restrict attention to two possible cases of corruption.

After some notes on the economic literature of corruption in section 6.1, I discuss a simple model in which the winning firm bribes the procurement auctioneer in section 6.2. In section 6.3, I develop a simple model in which an entire cartel bribes the procurement auctioneer in order to obtain collusive profits.

### **6.1 Notes on the Literature**

Corruption has long been ignored by academic economists and was left to historians and sociologists. Until the late 70s, the debate on corruption was divided between moralists, who maintain that corruption is necessarily detrimental to economic development, and reformists, who hold the view that corruption may help the economy to yield efficient outcomes. A prominent advocate of this last view is Huntington (1968):

“In terms of economic growth, the only thing worse than a society with a rigid, over-centralized, dishonest bureaucracy is one with rigid, over-centralized, honest bureaucracy.”

The first economic study of corruption is Rose-Ackermann (1978). Building on the seminal analysis of crime and punishment by Becker (1968), she argues, *inter alia*, that corruption is less likely if public officials are given competing jurisdictions. Following the controversy between moralists and reformists, early economic studies of corruption have often been concerned with efficiency. Beck and Maher (1986) and Lien (1986, 1987 and 1990) apply

modern auction theory to establish that competitive bidding and bribery yield the same allocation, thereby supporting the reformists' view. This strand of analysis, however, ignores several negative aspects of corruption, such as moral costs or avoidance costs.

Another drawback of the narrow focus on efficiency, is that such models are usually unable to explain why the level of corruption varies strongly across industries or countries. A number of economists have tried to answer this question. For instance, Lui (1986) presents a simple OLG model, in which officials can be bribed. Lui (1986) assumes that the probability that corruption is detected is decreasing in the number of corrupt officials. He finds that this model has two stable equilibria; one without corruption, and the other with corruption. Similar models have been proposed by Cadot (1987), Andvig and Moene (1990), Tirole (1996) and Ehrlich and Lui (1999). The assumption that drives the multiple equilibria result in these models is the assumption that the net expected benefit of corruption to a single public official increases in the total number of corrupt public officials.

## **6.2 Corruption, Or: A Convex Pricing Rule**

In this section, I discuss a very simple model of corruption in a FPPA, which is due to Wolfstetter (2003). It shows how corruption, in a standard procurement environment, still yields an efficient allocation, supporting the reformists' point of view. At the same time, corruption increases the price that the government has to pay, supporting the moralists' point of view.

The basic framework of this model is the same as in chapter 3 and will therefore not be explained or discussed. The government has delegated the task of acquiring a project to a procurement auctioneer and it is commonly known by all firms that, after the FPPA is conducted, the public official informs the firm that has submitted the lowest price of the second-lowest price, in return for a bribe. With this information, the winning firms can safely increase its bid and, hence, its profits. The extra profits are shared between the official and the firm.

Let  $p^1$  and  $p^2$  be the lowest price and the second-lowest price, respectively. Knowledge of the realization of  $p^2$  allows the winning firm to obtain extra profits of at most  $\pi = p^2 - p^1$ . The official and the winning firm bargain over this extra profit, and it is assumed that the solution

of this bargaining problem is given by generalized Nash bargaining<sup>1</sup>. In this case, the bargaining outcome is found by maximizing  $\pi_a^\alpha(\pi-\pi_a)^{1-\alpha}$  with respect to  $\pi_a$ , where  $\pi_a$ ,  $\pi \geq \pi_a \geq 0$ , is the share of the extra profit that accrues to the auctioneer, and  $\alpha$ ,  $1 \geq \alpha \geq 0$ , is the bargaining power of the procurement official. It can be easily verified that the extra profits for the winning firm are given by  $(1-\alpha)\pi$ .

Thus, a firm with efficiency  $e$ , but bids as if its efficiency is  $z$ , when all firms use the equilibrium monotone decreasing bid strategy  $p(\bullet)$  has a payoff of

$$\pi = E[p(Y_1) - \alpha(p(Y_1) - p(z)) - S + e] \quad \text{with probability } G(z)$$

$$\pi = 0 \quad \text{with probability } 1-G(z)$$

The expected profit in case the firm wins can be written as  $E[\alpha p(z) + (1-\alpha)p(Y_1)]$  and it can be seen that this is a convex combination of the two lowest bids. Furthermore, note that  $E[p(Y_1) | z > Y_1]$  can be written as  $\frac{1}{G(z)} \int_0^z p(x) dG(x)$ . Hence, the expected profit can be written as

$$E[\pi] = (\alpha p(z) - S + e)(G(z) + (1-\alpha) \int_0^z p(x) dG(x)) \quad (6.1)$$

Maximizing (6.1) with respect to  $z$  gives the first-order condition

$$g(z)(\alpha p(z) - S + e) + G(z)(\alpha p'(z)) + (1-\alpha)p'(z)g(z) = 0 \quad (6.2)$$

In equilibrium,  $z=e$ . Using this, and rewriting gives the differential equation

$$\alpha p'(e)G(e) + p(e)g(e) = g(e)(S - e) \quad (6.3)$$

This equation can be solved by subsequently applying the transformation  $G(\bullet) = H(\bullet)^\alpha$ , rearranging and integrating both sides of (6.3)

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<sup>1</sup> Though the interpretation of the generalized Nash bargaining solution is pretty unclear, at least to me, it can be given a strategic justification. Binmore (1987) shows that Rubinstein's (1982) alternating-offer bargaining model converges to the generalized Nash bargaining solution.

$$\alpha p'(e)H(e)^\alpha + \alpha h(e)p(e)H(e)^{\alpha-1} = \alpha h(e)H(e)^{\alpha-1}(S - e) \quad (6.4)$$

$$(p(e)H(e))' = h(e)(S - e) \quad (6.5)$$

$$p(e) = S - e + \int_0^e \frac{H(x)}{H(e)} dx \quad (6.6)$$

Substituting  $G(\bullet)$  back in (6.6) yields the equilibrium bid strategy if the procurement auctioneer can be bribed by the winning firm in the IPV FPPA

$$p(e) = S - e + \int_0^e \left( \frac{G(x)}{G(e)} \right)^{1/\alpha} dx \quad (6.7)$$

Notice that if  $\alpha=1$  (i.e. the official has all the bargaining power), firms bid just as in the standard FPPA, while if  $\alpha$  goes to 0, firms simply submit their cost level, just as in the Vickrey procurement auction. Since  $p(\bullet)$  is monotone decreasing in the level of efficiency, corruption does, at least in this model, not affect the final allocation. As noted above, the introduction of corruption in the standard FPPA model increases the expected price that the government pays. This can be seen by first noting that revenue equivalence applies, because the assignment is still granted to the most efficient firm and the payoff to all other firms is zero. As the profit for the procurement auctioneer is positive, the expected price for the government is necessarily higher.

The above model suffers from a number shortcomings. First, it ignores a number of interesting and realistic difficulties, such as moral costs of corruption or the probability that the act of corruption may be detected. Second, the type of corruption as studied here is sub-optimal. In some cases, it may be optimal for the procurement auctioneer to inform a different firm of the other bids. This possibility has been studied in detail by Lengwiler and Wolfstetter (2002). They find, inter alia, that the resulting allocation may be inefficient. Third, and most important to this study, the above model is unable to explain the incidence of collusion. In the next section, I therefore study a different model that deals more satisfactorily with this issue.

### 6.3 Multiple Equilibria in a Bribing Game

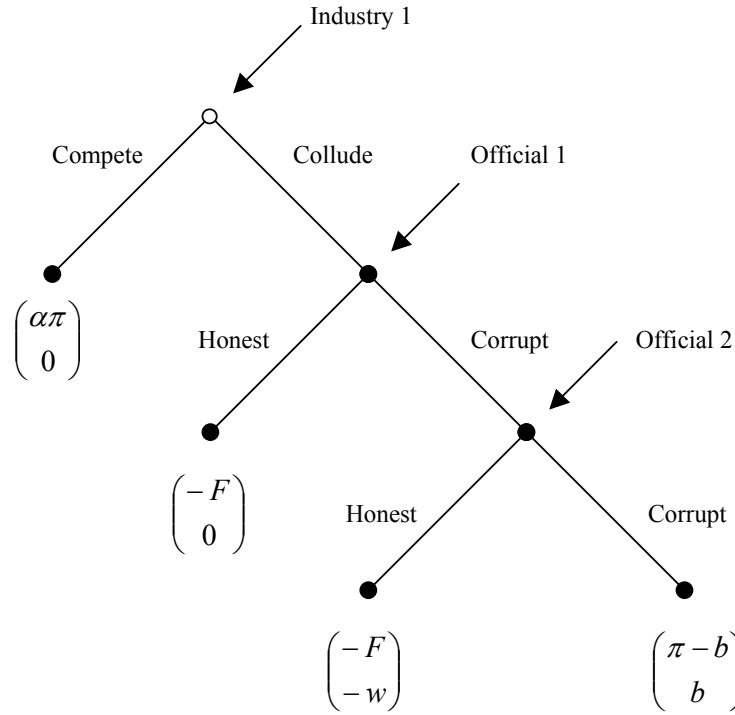
From 1992 to at least 2003, public officials in Amsterdam allowed six construction firms (the Stora-cartel) to divide orders among themselves, in exchange for bribes<sup>1</sup>. This form of corruption clearly differs from the one that was discussed in the above section. Instead of one firm bribing one official, there are now several firms bribing several officials. In this section, I explore some implications of this form of corruption. Using a simple game-theoretic model, I show that, under some mild assumptions, corruption is a self-sustaining equilibrium. Furthermore, I show that honesty, i.e. officials never accept bribes, is another self-sustaining equilibrium. The model that I discuss here is a drastic simplification of the analysis of Andvig and Moene (1990), but it still contains enough richness to allow for a nice interpretation.

The story goes as follows. Suppose that in two identical industries, firms can either collude, and make a gross profit of  $\pi$ , where  $\pi > 0$ , or they can compete, and make a profit of  $\alpha\pi$ , where  $0 < \alpha < 1/2$ . Each industry is inspected by one bureaucrat, who perfectly ascertains whether the firms have colluded or not. If an industry has competed, the game ends and the bureaucrat receives his wage, which is normalized to zero. If, on the other hand, the industry has colluded, the firms pay a fine  $F$ ,  $F > 0$  if the bureaucrat is honest and the game ends. If the bureaucrat is corrupt, which he is somehow able to signal, the bureaucrat and the cartel bargain over a bribe  $b$ ,  $b \geq 0$ . The bureaucrat receives this bribe in exchange for not reporting the cartel. I assume that this bargaining problem is solved by the Nash bargaining solution. After the bribing stage, both bureaucrats inspect each other. If an honest official catches a corrupt official, the latter is fired, and loses the bribe, plus some loss in income  $w$ ,  $w > 0$ . If a corrupt official finds that his colleague received a bribe as well, both agree not to report each other and keep the bribe. As Andvig and Moene (1990) argue, this may correspond to some tit-for-tat strategy: “If you don’t report me, I don’t report you”. If two honest officials meet each other, nothing happens and both receive zero. The extensive form representation of the above story, for one industry and one official, is depicted in figure 4.

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<sup>1</sup> See e.g. “Amsterdam houdt kartel in stand”, *NRC Handelsblad*, April 19, 2003, or “Onderzoek corruptie in Amsterdam”, *NRC Handelsblad*, July 7, 2003.

Figure 4 – Extensive form of the bribing game



The counterpart of the above game is found by interchanging labels 1 and 2. To solve this game, note first that this game is essentially a two-stage game, because after stage two, where both officials simultaneously choose whether to be corrupt, the game practically ends. As the decision between corruption and honesty is a simultaneous-move game, industry 1 and official 1 need to form an expectation of the action of official 2. Let  $y, y \in [0,1]$  be the value that both official 1 and industry 1 assign to the probability that official 2 chooses [Corrupt]. Then, for a given bribe  $b$ , the expected profits that accrue to industry 1 at the bribing stage are  $E[\pi^i(b)] = y(\pi - b) - (1 - y)F$ . The expected profit of being corrupt for official 1 is  $E[\pi^o(b)] = yb - (1 - y)w$ . The Nash bargaining solution is the unique  $b$  that solves

$$\max_b E[\pi^i(b)] * E[\pi^o(b)] \tag{6.8}$$

It is straightforward to establish that

$$b = \frac{1}{2}(\pi - \frac{F}{y} + F + \frac{w}{y} - w) \tag{6.9}$$

Substituting (6.9) into  $E[\pi^i(b)]$  and  $E[\pi^o(b)]$  gives

$$E[\pi^i] = \frac{1}{2}(\pi y^2 + Fy + Fy^2 - \omega y + \omega y^2) - F \quad (6.10)$$

$$E[\pi^o] = \frac{1}{2}(\pi y - F + Fy - \omega + \omega y) \quad (6.11)$$

Official 1 is indifferent between being honest and corrupt if  $E[\pi^o]=0$ . This holds if and only if  $y=(F+\omega)/(\pi+F+\omega)$ . Since (6.11) is increasing in  $y$ , official 1 will choose [corrupt] with probability 1 if  $y$  is above  $(F+\omega)/(\pi+F+\omega)$ . Because the officials are identical, it makes sense to focus on symmetric equilibrium strategies. This game has exactly two symmetric Nash equilibria in pure strategies. In the first equilibrium, firms in both industries choose [collude], and both officials choose [corrupt]. The profits of collusion  $\pi$  are split evenly between the cartel and the official. In the other equilibrium, firms in both industries choose [compete], and both officials choose [honest].

Hence, if players in this model expect others to be corrupt (honest), they will act corrupt (honest) themselves. The driving force behind this multiple equilibrium result is that corruption is a strategic complement, i.e. players perceive the individual expected profit of corruption to be an increasing function of the aggregate level of corruption. The above model suggests that an industry that is infected by corruption and collusion is not fundamentally different than other industries, but is simply caught in one of two symmetric equilibria in pure strategies. What is left unexplained by this game-theoretic analysis, is how players form their expectations. If one simply assumes that players have static expectations of how others behave, the resulting equilibrium is history-dependent. Corruption today causes corruption tomorrow.

## 7. CONCLUSION

In the introduction of this master's thesis, I asked how and to what extent the Dutch construction cartel has harmed the Dutch government. I have tackled this question by examining modern insights from the literature on auctions and collusion. This theoretical approach is vindicated by the two facts. First, it has been found that construction firms mainly disadvantaged the government. Second, the Dutch government primarily uses a first-price auction to procure contracts.

This procurement mechanism, the FPPA, is carefully analyzed in the context of independent private values in chapter 3. In this chapter, it is shown that the FPPA is an efficient mechanism and that the expected price is equal to the expected second-lowest cost among all participating firms. These results are derived under the assumption that firms do not cooperate and serve more as a benchmark than as an actual description of Dutch procurement.

According to the parliamentary inquiry committee that has investigated the Dutch construction cartel, construction firms have used two distinct mechanisms to collude: bid rotation and preauction knockouts. Bid rotation has the advantage that it does not require inter-firm communication and it gives zero or negative profits to firms with high costs. Without this last property, inefficient firms may enter the industry and erode the cartel profits. A drawback of bid rotation is that it is generally inefficient: the winning firm does not necessarily have the lowest cost. Thereby, the cartel misses some additional profits. It seems that if the cartel could somehow restrict this bid rotation mechanism to be efficient, the cartel is able to grab highest possible profits. Yet, as shown in section 6.2, this "optimal" mechanism is not likely to be chosen by the cartel, since it yields noncooperative payoffs. The other collusion mechanism, the preauction knockout, is somewhat more complicated than the bid rotation mechanism as it calls for more contact between the participating firms. The major benefit of the preauction knockout is that it is efficient: the cartel obtains monopoly profits.

The Dutch contractors have used preauction knockouts more frequently than bid rotations. This indicates that the (perceived) costs of illegal communication in the Dutch construction industry have been relatively low. These costs may have been low because the Dutch contractors have colluded for many decades. In that way, the conspiring firms may

have institutionalized collusion: standardized rules promoted cooperation and repeated interactions lowered the incentive to deviate from these standardized rules.

In chapter 5, I considered the effects of calculation costs on the bidding process. Under some circumstances, these costs add a potentially social wasteful coordination problem to the standard model. The inclusion of calculation costs also serves to address the welfare optimality of calculation cost compensation schemes. Many executives of construction firms maintained that they did not lower social welfare as the single objective of the cartel was to repay each losing firm its compensation costs. This argument is shown to rest on false grounds. Given that compensation costs are high, i.e. they affect the entry strategies of potential competitors, the social welfare maximizing outcome is equal to the competitive outcome.

In chapter 6, I analyzed two simple models of corruption and procurement. The first model demonstrates that corruption in a FPPA does not significantly alter the results: the expected payoffs of the participating firms are the same. The only effect of corruption is that the expected price increases. This may have adverse welfare consequences if the government is benevolent and does not have access to lump-sum tax financing. In the second model, it is shown that if corruption is a strategic complement, both collusion and competition are stable equilibria. This result may explain why similar industries are not similarly affected by collusion.

Hopefully, this master's thesis has convincingly demonstrated the usefulness of formal auction theory to analyze the Dutch construction cartel. Instead of paying attention to a whole range of factors, with the risk of getting stuck in vagueness, I have chosen to drastically restrict the analysis to simple auction mechanisms. This way, I have formally shown what "everybody already knew": the Dutch contractors did raise prices, to the detriment of the taxpayers.

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