Chapter 7

Collusion in multidimensional auctions

7.1 Introduction

Public procurement outlays constitute a large fraction of GDP in Western countries. Dimitri, Piga and Spagnolo (2006) report that the value of public procurement in EU countries is about 16% of GDP and 20% in the United States. Given the massive amounts of public money involved in procurement it is important that these funds are spend efficiently. Unfortunately, collusion seems to be a significant problem in public procurement. Collusion tends to inflate prices and may yield inefficient allocations. Understanding how collusion in procurement takes place and how governments can respond to it is therefore an important research goal.

Since public procurement is typically conducted by means of auctions, the study of collusion in procurement can learn much from the theory of collusion in auctions. As seen in chapter 6, the models in this literature focus on auctions in which the auctioneer only cares about the price of the good. In procurement, the government also cares about the quality of the good. This implies that the government often faces a trade-off when awarding the contract to a firm. Should the low quality, low price firm win the procurement auction, or should the government select the high quality, high price firm? In practice, contracts are typically awarded to either the firm that submits the lowest price or the firm that submits the economically

\[\text{\footnotesize Albano, Buccirossi, Spagnolo and Zanza (2006) provide several examples of recent cases of collusion in public procurement.}\]
most advantageous offer. In the former case, the selected firm should meet certain quality criteria. In the latter case, the government adopts a scoring rule, that weighs the price and quality of the offer to order the firms’ proposals.

This chapter extends the results of McAfee and McMillan (1992) to a two-dimensional setting. The analysis builds on Che’s (1993) framework of two-dimensional auctions. In Che (1993), a buyer has quasilinear preferences over the price and the quality of the good she buys. Firms have a convex cost of producing quality and are privately informed about their relative efficiency of producing quality. The findings of McAfee and McMillan straightforwardly carry over. This exercise helps to understand one of the key results in the theory of collusion in auctions. In this sense, the analysis below can be seen as a technical appendix to chapter 6.

That interpretation would, however, under-appreciate the added value of a two-dimensional focus over McAfee and McMillan’s one-dimensional focus. In particular, the literature on collusion in one-dimensional auctions suggests that the government can use an aggressive reserve price policy. This policy is suboptimal in a two-dimensional setting. When the government commits to a low reserve price, firms can still collude and set quality inefficiently. This chapter proposes an alternative auction format, the reservation utility auction. In this auction, the government requires firms to offer at least the reservation utility. A reservation utility policy places a restriction on the admissible price quality combinations and is therefore the natural extension of a reserve price policy to a two-dimensional auction format. This reservation utility auction yields the government a strictly higher payoff than an auction with just a reserve price. The reason is that a reservation utility auction allows firms to choose their quality level in an *ex post* efficient manner.

The remainder of this chapter is as follows. The model is presented in section 7.2. The non-cooperative equilibrium is characterized in section 7.3. Section 7.4 shows how the optimal collusive mechanisms follow from standard mechanism design. To study collusion, the analysis follows McAfee and McMillan (1992) by assuming that firms design and commit to a collusive mechanism before they learn their types. Anti-collusive strategies are studied in section 7.5. Concluding remarks are in section 7.6.

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2 For a good overview of actual procurement practices, see Carpineti, Piga and Zanza (2006).

3 An aggressive reserve price increases the government’s payoff and simultaneously may help to deter collusion. McAfee and McMillan (1992) first demonstrated the efficacy of a reserve price in a one-dimensional auction in the presence of a cartel. See Thomas (2005) for an extensive numerical exposition of this result. Kovacic et al. (2006) recommend practitioners to use a low reserve price policy to deter collusion.
7.2 The model

7.2.1 Overview

The set-up closely follows Che (1993). There are two types of players: the government and \( n \geq 2 \) firms. The government wishes to obtain an indivisible unit of a good or service. The government is unable to produce this good itself, so it has to buy the good from a firm. An alternative assumption with the same implication might be that the cost of producing for the government is higher than the cost for the least efficient firm. The government employs a sealed bid auction mechanism. This means that all firms simultaneously submit their offer, consisting of a price \( p \) and a quality level \( q \). The government selects the firm that submits the best offer at the auction.

7.2.2 Government

When the government obtains the good from firm \( i \), it receives a utility level

\[
U(p_i, q_i) = V(q_i) - p_i, \tag{7.1}
\]

where \( q_i \) is the quality supplied by firm \( i \) and \( p_i \) is the price paid from the government to firm \( i \). The function \( V(\cdot) \) evaluates the quality of the good and satisfies \( V'(\cdot) > 0, V''(\cdot) \leq 0, \lim_{q_i \to 0} V'(\cdot) = \infty, \) and \( \lim_{q_i \to \infty} V'(\cdot) = 0 \). After the auction, it observes the price and quality offers of all firms and awards the contract to the firm offering the highest utility, given that it is non-negative.

7.2.3 Firms

When firm \( i \) is selected by the government to supply the good or service, its profit is

\[
\pi_i(p_i, q_i) = p_i - c(q_i, \theta_i), \tag{7.2}
\]

where \( c(q_i, \theta_i) \) is the firm’s cost of supplying the good with quality level \( q_i \). The cost function is increasing in the firm-specific cost parameter \( \theta_i \). Each firm is privately informed about its own cost parameter. The government and the \( n - 1 \) other firms perceive \( \theta_i \) as being drawn from a continuous distribution function \( F(\theta) : [\theta, \bar{\theta}] \to [0, 1] \). Suppressing the firm subscript and arguments, it is assumed that \( c_q > 0, c_\theta > 0, c_{qq} \geq 0, c_{\theta\theta} \geq 0, \) and \( c_{q\theta} > 0 \) holds for every firm. Furthermore, the social surplus
resulting from a sale between the least efficient firm and the government is at most
zero. Technically, \( \max_q \{ V(q) - c(q, \theta) \} = 0 \). This condition is just a normalization. The
government is exactly indifferent between provision of the good by the least
efficient firm and its best outside option (which could be foregoing the product or
producing it in-house).

Before firms learn the realization of their cost parameter, they may form a cartel
by committing to a collusive mechanism. Since firms are assumed to be endowed
with commitment power, firms are unable to cheat on the cartel agreement once
they have committed themselves to it. Using the terminology introduced by McA-
fee and McMillan (1992), the analysis below considers both weak and strong cartels.
A weak cartel is unable to make transfers between firms whereas a strong cartel is.
All firms need to commit to the mechanism. If one or more firms reject it, firms act
non-cooperatively at the procurement auction.

7.2.4 Timing

The timing of moves is as follows. First, the firms may commit to a collusive mecha-
nism. It is without loss of generality to assume that the firms commit to a mecha-
nism, because bidding non-cooperatively is a mechanism as well. Then, each firm
privately learns its cost parameter and reveals its private information to the mecha-
nism. The mechanism subsequently recommends a particular action to every firm
and every firm adheres to this recommended action. Finally, the government sim-
ply awards the contract to the firm offering the best offer. Quality is assumed to be
contractible, so the government knows the realization of quality at the contracting
stage.

7.3 The non-cooperative equilibrium

This section derives the non-cooperative equilibrium bid strategies. Given the ex
ante symmetry of firms, it is natural to focus on a symmetric equilibrium in which
all firms use the same bid functions \( \{ p(\theta_i), q(\theta_i) \} \) to determine their optimal price
and quality offer as a function of the privately known cost parameter. This situation
was first studied by Che (1993) and all results in this section can be found there.

As a first step in finding the equilibrium, lemma 7.1 states that one can restrict
attention to deterministic quality offers. An intuition behind this separability con-
dition is that firms first choose quality such that the size of the pie (the sum of
firm profit and government utility) is maximized, and then select a price to offer a division of the pie.

**Lemma 7.1** (Che, 1993). In any non-cooperative equilibrium, each firm $i$ offers a quality level $q^*(\theta_i)$, where

$$q^*(\theta_i) = \arg\max_q \{ V(q) - c(q, \theta_i) \}.$$  

**Proof.** Consider a firm deciding between two offers with the same probability of winning. These offers, $(q, p)$ and $(q^*(\theta_i), p')$, are such that $V(q^*(\theta_i)) - p' = V(q) - p$. Clearly, both offers imply the same probability of winning, because the government is indifferent between them. The profit of the firm, conditional on winning with an offer $(q^*(\theta_i), p')$, is

$$\pi(p', q^*(\theta_i)) = p' - c(q^*(\theta_i), \theta_i) = V(q^*(\theta_i)) - V(q) + p - c(q^*(\theta_i), \theta_i) = V(q^*(\theta_i)) - c(q^*(\theta_i), \theta_i) - V(q) + c(q, \theta_i) + p - c(q, \theta_i) \geq p - c(q, \theta_i),$$

where the inequality follows because $q^*(\theta_i)$ maximizes $V(q, \theta_i) - c(q, \theta_i)$.  

Lemma 7.1 greatly simplifies the analysis. Instead of solving a two-dimensional problem, one now only needs to consider the one-dimensional problem of characterizing the price function $p(\theta_i)$. Assuming that $V(q) - p(\theta_i)$ is decreasing in the cost parameter $\theta_i$, the equilibrium probability that a firm wins the procurement auction is monotonically decreasing in $\theta_i$. Below, this assumption is shown to hold. So, the expected profit of a firm $i$ that has a cost parameter $\theta_i$, but charges a price as if $\theta_i = x$, is

$$E[\pi_i] = Pr\left( x < \min_{j \neq i} \{ \theta_j \} \right) (p(x) - c(q^*(x), \theta_i)) = H(x)(p(x) - c(q^*(x), \theta_i)), \tag{7.3}$$

where $H(x) \equiv (1 - F(x))^{n-1}$ denotes the probability that a firm with cost parameter $x$ wins the procurement auction. If $p(\theta)$ is part of a symmetric non-cooperative equilibrium, firm $i$ maximizes (7.3) by setting $x = \theta_i$. Using standard techniques from the auction theory literature, consult e.g. Krishna (2002) for a good overview, one can solve for the equilibrium price function. The next proposition gives the optimal price and quality offered by each firm in the non-cooperative equilibrium.
Proposition 7.1 (Che, 1993). In the unique symmetric equilibrium in pure strategies, each firm $i$ with cost parameter $\theta_i$ offers

$$p(\theta_i) = c(q^*(\theta_i), \theta_i) + \int_{\theta_i}^{\bar{\theta}} \frac{H(t)}{H(\theta_i)} c_0(q^*(t), t) dt,$$

$$q(\theta_i) = q^*(\theta_i).$$

Proof. A firm with cost parameter $\theta_i$ maximizes (7.3) with respect to $x$. The first-order condition, evaluated at $x = \theta_i$, is

$$\frac{\partial}{\partial \theta_i} (H(\theta_i) p(\theta_i)) - \frac{\partial}{\partial \theta_i} (H(\theta_i) c(q^*(\theta_i), \theta_i)) + H(\theta_i) c_0(q^*(\theta_i), \theta_i) = 0.$$

Integrating over the interval $[\theta_i, \bar{\theta}]$ and noting that $H(\bar{\theta}) = 0$ gives the solution for $p(\theta_i)$. Observe that the probability of winning is indeed decreasing in $\theta_i$ because

$$\frac{\partial}{\partial \theta_i} (V(q^*(\theta_i)) - p(\theta_i)) = V_q q_\theta - c_q q_\theta - c_\theta + c_\theta$$

$$+ \frac{h(\theta_i)}{H(\theta_i)^2} \int_{\theta_i}^{\bar{\theta}} H(t) c_0(q(t), t) dt$$

$$= \frac{h(\theta_i)}{H(\theta_i)^2} \int_{\theta_i}^{\bar{\theta}} H(t) c_0(q(t), t) dt < 0,$$

where the inequality follows because $V_q = c_q$ from lemma 7.1, $h(\theta_i) < 0$ by definition, and $c_\theta > 0$ by assumption.

In the non-cooperative equilibrium, the expected profit of a firm $i$ with cost parameter $\theta_i$ is $\int_{\theta_i}^{\bar{\theta}} H(t) c_0(q^*(\theta_i), \theta_i) dt$. Before the firm learns its cost parameter, the ex ante expected profit is

$$E[\pi^N_i] = \int_{\theta_i}^{\bar{\theta}} \int_{x}^{\bar{x}} H(t) c_0(q^*(t), t) dt f(x) dx$$

$$= \int_{\theta_i}^{\bar{\theta}} \int_{\theta_i}^{t} H(t) c_0(q^*(t), t) f(x) dx dt$$

$$= \int_{\theta_i}^{\bar{\theta}} F(t) H(t) c_0(q^*(t), t) dt. \quad (7.4)$$

where the third equation follows from changing the order of integration. Clearly, when firms are colluding, they require an ex ante expected profit at least as large as (7.4).
7.4 Optimal collusive mechanisms

From now on, assume that firms may form a cartel. Before the firms learn their cost parameter, they design a collusive mechanism that maximizes joint expected profits.

7.4.1 Some mechanism design

The problem for the firms of how to collude is not straightforward. First, firms are privately informed about their own cost parameter and therefore must somehow select a firm that ultimately wins the procurement auction. A second and closely related problem is that all losing firms must be compensated. If their expected collusive profits are lower than the non-cooperative profits the firms will reject the proposed mechanism. Third, the firms may not be able to make transfers. A firm that just won the procurement auction and donates large sums of money to losing firms may raise the suspicion of the authorities.

Stated in the language of mechanism design theory, the first problem means that the mechanism should be incentive compatible. The second problem implies that the mechanism should satisfy the individual rationality constraint. If the third problem is applicable, one needs to impose the restriction that the mechanism does not stipulate transfers between firms.

The revelation principle (Myerson, 1979) implies that one can focus on incentive compatible direct mechanisms. In a direct mechanism, it is optimal for every firm to truthfully reveal its private information to the mechanism. Let \( \theta_{-i} \equiv \{\theta_1, \theta_2, \ldots, \theta_{i-1}, \theta_{i+1}, \ldots, \theta_n\} \). Then, if \( n - 1 \) firms report that their cost parameters are \( \theta_{-i} \) and firm \( i \) reports \( \theta_i = x_i \), the mechanism selects firm \( i \) to be the designated winner with probability \( a_i(x_i, \theta_{-i}) \). The winning firm is required to deliver the good with quality \( q_i(x, \theta_{-i}) \). Conditional on all reports, firm \( i \) receives an expected transfer of \( b_i(x_i, \theta_{-i}) \) from the mechanism. Then,

\[
\text{Lemma 7.2. A mechanism described by } \{a_i(\theta_i, \theta_{-i}), b_i(\theta_i, \theta_{-i}), q_i(x, \theta_{-i})\} \text{ is incentive compatible if and only if}
\]

\[
\frac{dE[\pi_i(\theta_i)]}{d\theta_i} = -a_i(\theta_i, \theta_{-i})c_\theta(q_i(\theta_i), \theta_i)
\]

and

\[
a_i'(\theta_i, \theta_{-i}) \leq 0.
\]
Proof. The proof of this result is standard in the mechanism design literature, but is included for the sake of completeness. Consider firm $i$ with cost efficiency $\theta_i$, but announces to the mechanism that its type is $x$. Given that all other firms truthfully submit their information to the mechanism, firm $i$ maximizes its expected profit

$$E[\pi_i(x, \theta_i)] = b_i(x, \theta_{-i}) - a_i(x, \theta_{-i})c(q_i(x), \theta_i)$$

with respect to $x$. In an incentive compatible mechanism, it is optimal for the firm to announce $x = \theta_i$. Therefore, the necessary condition for the firm’s maximization problem is

$$\frac{\partial \pi_i(x, \theta_i)}{\partial x} \bigg|_{x=\theta_i} = b_i'(\theta_i, \theta_{-i}) - a_i'(\theta_i, \theta_{-i})c(q_i(\theta_i), \theta_i)$$

$$- a_i(\theta_i, \theta_{-i})c_q(q_i(\theta_i), \theta_i)q_i'(\theta_i) = 0. \quad (7.5)$$

Given that the mechanism is incentive compatible, the firm optimally chooses $x = \theta_i$ and the expected profit of firm $i$ can be written as

$$E[\pi_i(\theta_i)] = b_i(\theta_i, \theta_{-i}) - a_i(\theta_i, \theta_{-i})c(q_i(\theta_i), \theta_i).$$

Totally differentiating the above expression gives

$$\frac{dE[\pi_i(\theta_i)]}{d\theta_i} = b_i'(\theta_i, \theta_{-i}) - a_i'(\theta_i, \theta_{-i})c(q_i(\theta_i), \theta_i)$$

$$- a_i(\theta_i, \theta_{-i})(c_0(q_i(\theta_i), \theta_i) + c_q(q_i(\theta_i), \theta_i)q_i'(\theta_i)). \quad (7.6)$$

Subtracting (7.5) from (7.6) gives the necessary condition

$$\frac{dE[\pi_i(\theta_i)]}{d\theta_i} = - a_i(\theta_i, \theta_{-i})c_q(q_i(\theta_i), \theta_i).$$

Now, in order to obtain the sufficient condition for incentive compatibility, observe that the sufficient condition for the firm’s maximization problem is, evaluated in $x = \theta_i$,

$$b_i''(\theta_i, \theta_{-i}) - a_i''(\theta_i, \theta_{-i})c(q_i(\theta_i), \theta_i) - 2a_i'(\theta_i, \theta_{-i})c_q(q_i(\theta_i), \theta_i)q_i'(\theta_i)$$

$$- a_i(\theta_i, \theta_{-i}) \frac{\partial}{\partial x}(c_q(q_i(\theta_i), \theta_i)q_i'(\theta_i)) \leq 0. \quad (7.7)$$
Differentiating the necessary condition for profit maximization (7.5) with respect to $\theta_i$ gives

$$b''_i(\theta_i, \theta_{-i}) - a''_i(\theta_i, \theta_{-i}) c(q_i(\theta_i), \theta_i) - 2a'_i(\theta_i, \theta_{-i}) c_q(q_i(\theta_i), \theta_i) q'_i(\theta_i)$$

$$- a_i(\theta_i, \theta_{-i}) \frac{\partial}{\partial x} (c_q(q_i(\theta_i), \theta_i) q'_i(\theta_i)) - a'_i(\theta_i, \theta_{-i}) c_\theta(q_i(\theta_i), \theta_i) = 0. \quad (7.8)$$

Relying once again on the same trick as before allows one to obtain a convenient sufficient condition for incentive compatibility. Subtracting equation (7.8) from (7.7) shows that the sufficient condition can be written as

$$a'_i(\theta_i, \theta_{-i}) c_\theta(q_i(\theta_i), \theta_i) \leq 0.$$

However, by assumption, $c_\theta(q_i(\theta_i), \theta_i)$ is strictly positive. So, the sufficient condition for incentive compatibility reduces to

$$a'_i(\theta_i, \theta_{-i}) \leq 0.$$

Hence, incentive compatibility requires that the expected profit of every firm in the mechanism is decreasing in its cost parameter. Moreover, the mechanism should be (weakly) efficient. Observe that the non-cooperative outcome can be replicated via an incentive compatible mechanism in which each firm truthfully announces its cost parameter, and the mechanism submits for every a bid $\{p(\theta), q^*(\theta)\}$ to the procurement official. However, the interesting question is whether the firms can construct an alternative mechanism that attains profits above the non-cooperative level. McAfee and McMillan (1992) show that the optimal collusive mechanism depends on the ability of firms to make side transfers. Weak cartels may be unable to attain profits above the non-cooperative level. In a strong cartel, i.e. when cartel members are allowed to make transfers, firms are able to obtain the full surplus. The next two sections extends these results to two-dimensional auctions.

### 7.4.2 Weak cartels

By definition, members of a weak cartel cannot make explicit monetary transfers to each other.\(^4\) This implies that $b_i(\theta) = 0$ for all $\theta$. As a result, the only instruments

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\(^4\) Implicit transfers may be possible if the government regularly conducts procurement auctions. In that case, the cartel members may e.g. temporarily exclude a previous winner from future auctions.
left to the designer of the mechanism are the allocation functions $a_i(\theta)$ and quality function $q_i(\theta)$.

Absent asymmetric information, cartel profits would be maximized if the collusive mechanism is efficient. This requires $a_i' < 0$. Then, the firm with the most advanced technology is selected to be the winner of the auction and this firm fully extracts the social surplus by supplying a quality $q^*$. If a weak cartel uses an efficient mechanism, the *ex ante* expected profit of firm $i$ is

$$E[\pi_i] = \int_\theta^\theta \pi_i(t)f(t)dt$$

$$= \pi_i(t)F(t)|_\theta^\theta - \int_\theta^\theta \frac{d}{dt} \pi_i(t)F(t)dt.$$ 

The second equation follows from integration by parts. Clearly, in the above expression $\pi(\theta) = 0$ and $F(\theta) = 0$. From lemma 7.2, any incentive compatible mechanism satisfies $\frac{dE[\pi_i]}{d\theta} = -a_i c_\theta$, where the arguments are omitted. Furthermore, efficiency implies that $a_i(\theta) = H(\theta_i)$. Using these observations expected profits can be rewritten as

$$E[\pi_i] = \int_\theta^\theta F(t)H(t)c_\theta(q^*(t),t)dt. \quad (7.9)$$

But this equals the non-cooperative profit level, as given by equation (7.4). As a result,

**Lemma 7.3.** *In any efficient weak collusive mechanism, firms attain non-cooperative profits.*

This ‘impossibility theorem’ mirrors a related finding by McAfee and McMillan (1992). They show that, in the context of one-shot first-price auctions, the dual condition of efficiency and zero profits for cartel members with a valuation below the reserve price implies that the cartel cannot improve on the non-cooperative outcome. The intuition for this result is straightforward. The celebrated Revenue Equivalence Principle (REP) from auction theory states that if values are independently and identically distributed and bidders are risk neutral,

“[...] any symmetric and increasing equilibrium of any standard auction, such that the expected payment of a bidder with value zero is zero, yields the same expected revenue to the seller.” (Krishna, 2002).

This increases the expected profit of all other firms and therefore constitutes a dynamic transfer. See for instance Skrzypacz and Hopenhayn (2004) for a model along these lines.
The procurement auction in this chapter can be interpreted, after some changes of variables, as a standard first-price auction and is therefore subject to the logic of the REP as well. Given that the firms are risk neutral, and their cost parameters are identically and independently distributed, any efficient mechanism implies that each firm earns its informational rent, plus some constant. Because the least efficient firm does not have an informational rent, and necessarily earns zero profits, the REP implies that the cartel’s profits under the mechanism equal the non-cooperative profits.

Hence, a weak cartel cannot expect to extract the full social surplus. In some cases, however, a weak cartel might be able to attain supra-non-cooperative profits. By lemma 7.3 this requires the firms to sacrifice efficiency. An example of an inefficient mechanism is bid rotation, which is a collusive agreement under which the cartel members agree to be randomly allocated to be the designated winner of the procurement auction, may improve on the non-cooperative outcome if the technological environment satisfies certain properties. More specifically, let \( K(x) \equiv \frac{F(x)}{f(x)}c_\theta(q(x), x) \). Then,

**Proposition 7.2.** In a weak cartel, the expected weak collusive profits \( E[\pi_{WC}] \) are maximized by non-cooperative bidding if \( K'(x) \leq 0 \). Bid rotation is optimal if \( K'(x) \geq 0 \).

**Proof.** The ex ante expected profit of firm \( i \) is

\[
E[\pi_{WC}^i] = \int_\theta^\bar{\theta} \pi_i(t)f(t)dt \\
= \pi_i(t)F(t)\bigg|_{\theta}^{\bar{\theta}} - \int_\theta^\bar{\theta} \frac{d\pi_i(t)}{dt}F(t)dt \\
= \pi(\theta)F(\theta) - \pi(\bar{\theta})F(\bar{\theta}) - \int_\theta^\bar{\theta} \frac{d\pi_i(t)}{dt}F(t)dt \\
= \int_\theta^\bar{\theta} a_i(t, \theta_{-i})c_\theta(q_i(t), t)F(t)dt.
\]

Use integration by parts to go to the second equation, and insert the necessary condition for incentive compatibility to arrive at the third line. Industry profits can now be written as

\[
E \left[ \sum_{i=1}^n \pi_{WC}^i \right] = E \left[ \sum_{i=1}^n \frac{F(t)}{f(t)}a_i(t, \theta_{-i})c_\theta(q_i(t), t) \right].
\]

If \( K(\cdot) \) is monotonically decreasing, the industry profits are maximized by giving the largest weight to the most efficient firm. This is achieved by choosing \( a_i' < 0 \).
From lemma 7.3, this implies non-cooperative profits.

Now, suppose that $K(\cdot)$ is monotonically increasing. To save on notation, let $\mu_i(x)$ denote $E_{-i}[a_i(x, \theta_{-i})]$, which is firm $i$’s expectation that it will be the designated winner, conditional on its announcement $x$ to the mechanism. By deriving an upper bound on the industry profits, one can show that the cartel can achieve this upper bound by using a bid rotation device. The industry’s profits are

$$E \left[ \sum_{i=1}^{n} \pi_{i}^{WC} \right] = \sum_{i=1}^{n} \int_{\theta}^{\bar{\theta}} \frac{F(t)}{f(t)} c_\theta(q_i(t), t) \mu_i(t) f(t) dt$$

$$\leq \sum_{i=1}^{n} \left( \int_{\theta}^{\bar{\theta}} \frac{F(t)}{f(t)} c_\theta(q_i(t), t) f(t) dt \cdot \int_{\theta}^{\bar{\theta}} \mu_i(t) f(t) dt \right)$$

$$= \sum_{i=1}^{n} \int_{\theta}^{\bar{\theta}} \mu_i(t) f(t) dt \cdot \int_{\theta}^{\bar{\theta}} \frac{F(t)}{f(t)} c_\theta(q_i(t), t) f(t) dt$$

$$\leq \int_{\theta}^{\bar{\theta}} F(t) d_\theta(c(q_i(t), t)) dt.$$ 

The first inequality follows from a generalization of Chebyshev’s inequality. The interested reader is referred to Sun (1996) for details. The second inequality stems from the fact that $E[\sum a_i(x, \theta_{-i})] \leq 1$. The cartel can easily obtain this bound on profits. Under a bid rotation arrangement, every firm is the designated winner with probability $1/n$. This implies that the cost parameter of the winner is drawn from the cdf $F(\theta)$. At the procurement auction, it is in the designated winner’s interest to maximize its profits $p - c(q, \theta_i)$ with respect to price and quality, subject to the constraint $V(q) - p \geq 0$. Clearly, it is optimal for the firm to supply $q^*(\theta_i)$ and charge $p = V(q^*(\theta_i))$. The industry profit therefore equals

$$E \left[ \sum_{i=1}^{n} \pi_{i} \right] = \int_{\theta}^{\bar{\theta}} (V(q^*(t)) - c(q^*(t), t)) f(t) dt$$

$$= \int_{\theta}^{\bar{\theta}} F(t) \left( \frac{d}{dt} c(q^*(t), t) - \frac{d}{dt} V(q^*(t)) \right) dt.$$ 

From the necessary condition for profit maximization, one knows that $\frac{d}{d\theta} V(q^*) = \frac{d}{d\theta} c(q^*, \theta).$ This allows one to rewrite total profits as

$$E \left[ \sum_{i=1}^{n} \pi_{i}^{WC} \right] = \int_{\theta}^{\bar{\theta}} F(t) c_\theta(q^*(t), t) dt.$$ 

Thus, bid rotation achieves the upper bound. 

As one can see, the above proof closely follows McAfee and McMillan’s (1992)
proof of their theorem 1. The proof for the two-dimensional case is stated here because it remains to show that quality is chosen optimally. Furthermore, a crucial step requires a generalization of Chebychev’s inequality, a detail that McAfee and McMillan did not mention in their proof.

Again, there is an interesting parallel with the work of McAfee and McMillan (1992). In a standard auctions context, they show that if \( \frac{1 - F(x)}{f(x)} \) is increasing, it is optimal for a weak cartel to bid in a non-cooperative fashion. If, on the other hand, \( \frac{1 - F(x)}{f(x)} \) is decreasing, bid rotation is optimal. Their finding is extended to procurement auctions. In a two-dimensional auction, bid-rotation is optimal if \( F(x) \) increases sufficiently fast. For example, if \( V(q) = \sqrt{q} \) and \( c(q, \theta) = q\theta \), then bid rotation is optimal if the \( \theta \)'s are distributed according to the uniform distribution. On the other hand, non-cooperative play is optimal when the cost parameters are random draws from the Pareto distribution. Complementing McAfee and McMillan (1992), the above analysis shows that not only the mere distribution of types is relevant for the choice of the optimal collusive mechanism, but also the shape of the cost function. In particular, bid rotation is optimal if the cost function is sufficiently convex.

### 7.4.3 Strong cartels

There are many examples of bidding rings which were able to compensate losing firms. McAfee and McMillan (1992) establish that a strong cartel can extract the full \textit{ex post} social surplus by organizing a preauction knockout (PAKT). This is an auction before the actual auction, where the firms bid for the right to be the only contender. The revenue from this auction is split evenly between the cartel members. This result carries over to the two-dimensional procurement auction.

From an \textit{ex post} perspective, the spoils from collusion are maximized by awarding the right to be the single bidder to the most efficient firm. This firm supplies a socially optimal (and hence efficient) level of quality and charges \( p = V(q^*(\theta)) \). If such a mechanism exists, the \textit{ex ante} expected cartel profits amount to

\[
E \left[ \sum_{i=1}^{n} \pi_i^{SC} \right] = \int_{\theta}^{\bar{\theta}} \pi(t) nF(t)(1 - F(t))^{n-1} dt
\]

\[
= \int_{\theta}^{\bar{\theta}} (V(q^*(t)) - c(q^*(t), t)) nF(t)(1 - F(t))^{n-1} dt, \tag{7.10}
\]

where \( nF(t)(1 - F(t))^{n-1} \) is the probability density function of the first-order statistic. Consider a PAKT where firms non-cooperatively and simultaneously submit a
sealed bid \( T_i \). The highest bidder \( i \) pays every other firm \( T_i \) and all other firms commit to stay away from the actual procurement auction (or to submit phony bids). It is straightforward to show the following.

**Proposition 7.3.** The symmetric equilibrium bid function at the PAKT is

\[
T(\theta) = \int_{\theta}^{\overline{\theta}} \frac{(1 - F(t))^{n-1}}{(1 - F(\theta))^n} (V(q^*(t), t) - c(q^*(t), t)) f(t) dt.
\]

The winning firm submits an uncontested bid at the procurement auction that extracts the full social surplus and pays every losing bidder \( T(\theta) \). This mechanism is efficient, achieves budget balance, and maximizes cartel profits.

**Proof.** To derive the equilibrium bid function, suppose that in the PAKT, \( n - 1 \) firms truthfully submit their bid using \( T(\theta) \) and \( T'(\theta) < 0 \). Firm \( i \) submits a bid as if its cost parameter is \( x \). Then, the expected profit of firm \( i \) is

\[
H(x)(V(q^*(\theta)) - c(q^*(\theta), \theta_i) - (n - 1)T(x)) - \int_{\theta}^{x} T(y) h(y) dy.
\]

The first-order condition, evaluated in \( x = \theta_i \), implies that

\[
\frac{h(\theta)}{H(\theta)} T'(\theta_i) + \frac{n}{n - 1} T(\theta) = \frac{V(q^*(\theta)) - c(q^*(\theta), \theta_i)}{n - 1}.
\]

This is a linear first-order differential equation with variable coefficients. Using \( e^{\left(\int_{\theta}^{\overline{\theta}} \frac{n}{n - 1} \frac{h(t)}{H(t)} dt\right)} \) as the integrating factor and noting that \( T(\overline{\theta}) = 0 \), the solution can be shown to be

\[
T(\theta) = \int_{\theta}^{\overline{\theta}} \frac{(1 - F(t))^{n-1}}{(1 - F(\theta))^n} (V(q^*(t), t) - c(q^*(t), t)) f(t) dt.
\]

To prove the other claims in the proposition, note that \( T'(\theta) < 0 \). Hence, efficient firms submit higher bids than inefficient firms and therefore the most efficient firm in the cartel is the designated winner of the procurement auction. Budget balance is trivially achieved because the scheme divides the full social surplus between all cartel members. Cartel profits are maximized as the most efficient firm is selected, this firm extracts the full social surplus, and transfers a fraction of this surplus to every other cartel member. \( \blacksquare \)

The PAKT allows firms to obtain the maximum possible profits, as given by equation (7.10), because it is efficient and the government receives zero utility. As
mentioned above, McAfee and McMillan (1992) find a similar result for a one-dimensional first-price auction. The fact that a PAKT also enables firms to maximize profits for a two-dimensional procurement auction, suggests that a PAKT is an optimal collusive mechanism for more general environments.

Given that a PAKT is optimal in quite general environments, it should not come as a surprise that many real-world cartels have relied on agreements that are similar to a PAKT. Even without knowledge of the rather intricate details of mechanism design, many cartels have figured out how to optimally collude. For example, the cast-iron-pipe cartel (1894–1898), which is the first cartel convicted under the Sherman Act\(^5\), used a mechanism similar to a PAKT, see Orr and MacAvoy (1965). There are strong indications that the Dutch construction cartel operated under a PAKT as well. The interested reader is referred to the report of the parliamentary inquiry commission for an extensive description of this cartel (The Vos Committee, 2002).

### 7.5 Coping with collusion

The collusive mechanisms studied in this chapter have important implications for the government. Both a weak cartel and a strong cartel leave the government with zero utility. A weak cartel has the additional drawback that it is inefficient. Since government projects are typically financed by means of distortionary taxation, decreasing the impact of collusion should be a top priority.

There are several ways to do this. An emerging strand of literature, initiated by Motta and Polo (2003), focuses on the use of optimal fines and leniency programs to destabilize cartels. By punishing cartel members and awarding fine reductions to firms who self-report, a cartel may break down. A leniency policy is a general method to destabilize cartels and is applicable in many other markets besides auctions.

Another approach, which is more specific to auctions, is suggested by McAfee and McMillan (1992). They propose that the auctioneer can actively meddle with the collusive mechanism. If the auctioneer suspects that firms have formed a bidding ring, for instance, he could commit to bargain with a single firm. This instantly breaks down the cartel (as there is just one firm active) and leaves the auctioneer with a positive surplus.\(^6\) Another way in which the government can interfere with the collusive mechanism is by being vague about the government’s valuation for

---

\(^5\) Addyston Pipe and Steel Co. v. United States, 85 F. 271,(1898).

\(^6\) See the following chapter for a comparison of negotiations and auctions in the presence of a cartel.
quality. That is, the government does not resolve any uncertainty among the firms about $V(q)$. This might make it harder for the firms to find the optimal collusive price and creates a need for communication between firms. Given that communication between firms can be intercepted by the anti-trust authority, this strategy makes collusion more costly to the firms.

The third approach, and the one pursued below, consists of changing the auction rules. More specifically, the government may announce (and commit to) a reservation utility, which means that only bids that yield the government at least a minimum utility level are eligible. The first-score auction is a special case of the reservation utility auction, as it requires firms to submit bids that leave the government with at least zero utility. Even if firms coordinate their bids, the reservation utility auction guarantees at least a positive expected utility. The section below derives the optimal reservation utility auction. This auction maximizes the government’s surplus, given the presence of a bidding ring.

### 7.5.1 The reservation utility auction

Suppose that the government commits to a reservation utility $\bar{U} \geq 0$ and the firms collude by organizing a PAKT. Then, the cartel’s designated winner clearly chooses to leave the government with the lowest possible utility, which is $\bar{U}$. The profit of the selected firm is, after substituting for the price, $\pi = V(q) - c(q, \theta) - \bar{U}$. As $\bar{U}$ is constant, the selected firm offers the quality level $q^*(\theta)$ that maximizes social surplus, given $\theta$.

If $\bar{U} > 0$, some relatively inefficient firms are excluded. In particular, all firms with type above $\hat{\theta}$ are unable to supply the minimum utility level, where $\hat{\theta}$ is implicitly (and uniquely) defined by $V(q^*(\hat{\theta})) - c(q^*(\hat{\theta}), \hat{\theta}) = \bar{U}$. The problem for the government is to choose $\bar{U}$ such that

$$E[U] = \Pr(\theta < \hat{\theta}) \bar{U} = (1 - (1 - F(\hat{\theta}))^n) \bar{U} = (1 - (1 - F(\hat{\theta}))^n)(V(q^*(\hat{\theta})) - c(q^*(\hat{\theta}), \hat{\theta}))$$

(7.11)

is maximized. To go from the first to the second line, note that the distribution of $\theta$ is the distribution of the lowest-order statistic since the firms use a PAKT. To arrive at the third equation, substitute $\bar{U}$ for $V(q^*(\hat{\theta})) - c(q^*(\hat{\theta}), \hat{\theta})$. So, the government can indirectly find the optimal $\bar{U}$ by choosing $\hat{\theta}$ optimally. The first-order condition
is

\[
\frac{1 - (1 - F(\theta))^n}{nf(\hat{\theta})(1 - F(\hat{\theta}))^{n-1}} = \frac{V(q^*(\hat{\theta})) - c(q^*(\hat{\theta}), \theta)}{c_\theta(q^*(\hat{\theta}), \theta)}.
\] (7.12)

Then,

**Proposition 7.4.** Suppose firms collude by using a PAKT. Then, the optimal reservation utility \( \overline{U} \) is unique if \( F(\cdot) \) is log-concave.

**Proof.** Clearly, \( \overline{U} \) is unique if \( \hat{\theta} \) is unique. There is a unique solution of (7.12) if \( F(\theta) \) is log-concave. To see this, observe that the right-hand side of (7.12) is positive for \( \theta \) (because social surplus is positive for the most efficient type) and is strictly decreasing in \( \theta \) (because social surplus strictly decreases as the firm becomes less efficient). The left-hand side is zero for \( \theta \), one for \( \hat{\theta} \) and increases monotonically if \( F(\theta) \) is log-concave.

Log-concavity implies \( f(x)^2 - F(x)f'(x) \geq 0 \). Many ‘named’ probability distributions satisfy this property, including the uniform, the exponential, and the normal distribution. See Bagnoli and Bergstrom (2005) for an extensive discussion of log-concavity. Interestingly, log-concavity also implies that the mechanism design problem is regular.

It is straightforward to show that proposition 7.4 can be extended to the case where firms collude by using a bid-rotation mechanism. In that case, the efficiency parameter of the selected firm is drawn from \( F(\theta) \), conditional on \( \theta < \hat{\theta} \).

### 7.5.2 Minimum quality, maximum price

Despite its theoretical appeal, few government agencies seem to use the reservation utility auction. Presumably, an important obstacle that hinders its actual implementation is that in reality the way in which quality is valued is asymmetrically (and often imperfectly) known by the government and very costly to communicate to the firms. Moreover, it may be very hard to describe \( \overline{U} \) in a contract such that a court can enforce it.

To circumvent these problems, government agencies typically revert to simpler procurement auction formats. For instance, a government agency could award the contract to the firm that offers the highest utility, but require that the price does not exceed a maximum price \( P \) and entails at least a minimum quality level \( Q \). To save some space, call an auction format with these rules a \( PQ \) auction.
It is easy to see that in the first-score auction, $P$ is set at $\infty$ and $Q$ is zero. Suppose the government uses a $PQ$ auction with a finite maximum price $P$ and positive quality level $Q$. Then, if the firms collude by using a PAKT, the selected firm offers the good at the maximum price with the lowest possible quality level. This implies that the $PQ$ auction, in contrast to the reservation utility auction, yields productive inefficiency: the firm’s quality decision does not maximize social surplus. Just as under the reservation utility auction, however, some inefficient firms are excluded. All firms with efficiency parameter $\theta$ above $\tilde{\theta}$, where $\tilde{\theta}$ is implicitly defined by $P - c(Q, \tilde{\theta}) = 0$, are unwilling to provide the good.

To maximize its expected utility under this auction format, the government chooses $P$ and $Q$ to maximize

$$E[U] = \Pr(\theta < \tilde{\theta})(V(Q) - P).$$  \hspace{1cm} (7.13)

It is not difficult to demonstrate that an optimal reservation utility auction yields a higher expected utility level than a $PQ$ auction where $P$ and $Q$ are optimally chosen. Suppose that both auction formats require the same utility from the firm with type $\theta$ that is selected by the cartel. Then, $\overline{U} = V(q^*(\theta)) - c(q^*(\theta), \theta) = V(Q) - P$. Assuming that $\theta > \hat{\theta}$ and $\theta > \tilde{\theta}$, the profit for the designated winner under the reservation utility auction is

$$\pi(\theta) = p - c(q^*(\theta), \theta)$$
$$= V(q^*(\theta)) - c(q^*(\theta), \theta) - \overline{U}$$
$$> V(Q) - P,$$

where the inequality follows from the definition of $q^*(\theta)$. Thus, keeping $\overline{U}$ constant, the profit of a firm under the reservation utility auction is higher than the profit under the $PQ$ auction. This implies that $\hat{\theta}$ (the shut-down type in the reservation utility auction), is smaller than $\tilde{\theta}$ (the shut-down type in the $PQ$ auction). This means that the expected utility for the government is necessarily higher under the reservation utility auction because the probability that a firm is unable to supply is lower. The next proposition summarizes this finding.

**Proposition 7.5.** Suppose firms collude by sending a single firm to the procurement auction. Then, the reservation utility auction yields a higher expected utility to the government than the $PQ$ auction.

Therefore, the reservation utility auction is superior to the $PQ$ auction in terms
of the expected utility they garner when firms collude. This results holds both when the firms use a PAKT and when they use a bid-rotation mechanism.

7.5.3 Deterring collusion

The reservation utility auction helps the government to lower the costs of collusion. It may even allow the government to deter collusion altogether, as the analysis in this section shows.

Equation (7.12) characterizes the unique optimal reservation utility $\bar{U}$ if firms collude. Call this solution $\bar{U}^K$. It should be clear that in this case the optimal reservation utility (call it $\bar{U}^N$) differs from $\bar{U}^K$. This is because a cartel member offers a price and quality such that the government just obtains $\bar{U}^K$. A non-cooperative firm cannot afford to do this. It is subject to competition from other firms and therefore offers a higher utility than $\bar{U}^N$. As can be shown using standard tricks, a non-cooperative firm offers a quality level $q^*(\theta)$ and charges a price

$$\hat{p}(\theta) = c(q^*(\theta), \theta) + \int_\theta^{\hat{\theta}} \frac{H(t)}{H(\theta)} c_\theta(q^*(\theta), \theta) dt.$$  \hspace{1cm} (7.14)

The government’s expected utility under non-cooperative bidding is

$$E[U] = n \int_\theta^{\hat{\theta}} [V(q^*(\theta)) - \hat{p}(\theta)] (1 - F(\theta))^{n-1} f(\theta) d\theta.$$  \hspace{1cm} (7.15)

The optimal reservation utility level under non-cooperative behavior is characterized by

$$\frac{F(\hat{\theta})}{f(\hat{\theta})} = \frac{V(q^*(\hat{\theta}), \hat{\theta}) - c(q^*(\hat{\theta}), \hat{\theta})}{c_\theta(q^*(\hat{\theta}), \hat{\theta})}.$$  \hspace{1cm} (7.16)

Again, the optimal $\hat{\theta}$, and therefore the optimal $\bar{U}^N$, is uniquely defined if $F(\theta)$ is log-concave.

The government’s response, $\bar{U}$, is affected by the firms’ decision to cartelize. The government commits to $\bar{U}^N$ if firms do not collude, and to $\bar{U}^K$ if they collude by using a PAKT. Clearly, changes in $\bar{U}$ affect firms’ expected profits. It may even be possible that the firms’ expected profits under collusion are lower than under competition, once the government commits to the optimal reservation utility level.

To show this formally, consider the following timing of events. First, firms decide whether they form a bidding ring. If one or more firms decide not to join
the ring, all firms act non-cooperatively at the procurement auction. Second, the government observes the cartel decision of the firms (but cannot notify the anti-trust authorities) and commits to a reservation utility. Third, the cartel members or the non-cooperative firms submit bids and the contract is awarded according to the rules of the reservation utility auction.

The assumptions about the timing of events seems to be fairly realistic. In practice, the government agency designs a procurement process, given the expected behavior of firms. Firms form a cartel only if the expected benefits outweigh the expected costs. See Thomas (2005) for a study of optimal reserve prices in the presence of collusion in first-price one-dimensional auctions that employs the same assumptions about timing.

It is impossible to compare profits for the general case. Therefore, consider the following parametric assumptions: $V(q) = q$, $c(q, \theta) = \theta q$ and $\theta$ is drawn from $U(0, 1)$.

<table>
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<th>$n$</th>
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<th>$100 \times E[\pi^K]$</th>
<th>$n$</th>
<th>$100 \times E[\pi^N]$</th>
<th>$100 \times E[\pi^K]$</th>
</tr>
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<td>10</td>
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</tr>
<tr>
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<td>0.616</td>
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</tr>
<tr>
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</tr>
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<td>1.137</td>
<td>14</td>
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</tr>
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</table>

Table 7.1. Profits under Competition and Collusion

Table 7.1 shows the expected profits per firm, both under non-cooperative and collusive behavior. For $n \geq 8$, firms expect higher profits if they can commit to non-cooperative behavior. Hence, collusion lowers firms’ profits if their number is relatively small and the government optimally responds to the presence of a cartel.

Consistent with McAfee and McMillan (1992) and Thomas (2005), these results suggest that the government has the tools to mitigate the effects of collusion or to even deter it. However, the optimal tool differs in a two-dimensional setting. Instead of a reserve price, the government should commit to a reservation utility. In practice, this could be implemented by using a scoring rule auction, and requiring that the winning offer attains at least a minimum score. See Dini, Pacini and Valletti (2006) for a discussion of scoring rules. In practice, scoring rules are used to rank multidimensional bids. The message of this chapter is that scoring rules can be an
anti-collusive device.

## 7.6 Concluding remarks

Ample anecdotal, legal, and empirical evidence shows that firms collude in public procurement. To study collusion in procurement, Che’s (1993) model of multidimensional auctions is extended McAfee and McMillan’s (1992) results on collusion. Interestingly, in contrast to the optimal mechanism (from the cartel’s perspective), collusion does not distort the quality decision of the firms, but does reduce the government’s expected utility to zero.

To lower the costs of collusion, or even to deter it, the government can try to commit to a reservation utility auction. It is shown that this auction format enables the government to capture a large fraction of the social surplus, even in the presence of collusion. Using simple arguments, it is demonstrated that the reservation utility auction is a better instrument to mitigate the costs of collusion than the commonly used (and advocated) auction with a reserve price and a minimum quality level. Finally, using a parametric example, the anti-collusive effect of the reservation utility auction is demonstrated. This suggests that procurement agencies could profitably procure goods or services by using an auction with a scoring rule, combined with a minimum score requirement.
Chapter 8

Auctions vs. negotiations with asymmetric or colluding buyers

8.1 Introduction

When an owner of a valuable asset decides to sell his property he may conduct an auction to maximize his expected profits, but there are alternative mechanisms. In practice, a seller (or, in a procurement context, a buyer) often reverts to negotiations with a single buyer. The use of negotiations is puzzling, as Bulow and Klemperer (1996) (BK henceforth) have shown that auctions tend to yield more revenue than negotiations. More precisely, they demonstrate that an English auction without a reserve price and \( n + 1 \) buyers generates more revenue than the optimal mechanism (assuming the seller has superior bargaining skills) with \( n \) buyers. This suggests that revenue-maximizing sellers should direct attention at expanding the set of buyers instead of designing ‘clever’ negotiation procedures.

The aim of this chapter is to understand why some sellers still prefer negotiations over auctions. To do so, the analysis of BK is adjusted in three directions. First, the seller is allowed to have better information than buyers, in the sense that a seller knows the value of each buyer whereas the buyers only know their own value and perceive the value of each other buyer as being randomly drawn from some probability distribution. Then, with a superiorly informed seller, BK’s reve-

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1 Examples include public procurement officials or boards of directors involved in the takeover of their company. See Significant B.V. (2005) for an overview of the practice of public procurement in the Netherlands. They report that procurement agencies are reluctant to comply with European procurement guidelines, which stipulate that large projects should be publicly tendered. Boone and Mulherin (2007) study the market for corporate takeovers. They find that about 50% of corporate acquisitions are accomplished through auctions and the other half through negotiations.
nue ranking is shown to be reversed. Second, buyers are often asymmetric. In a European Union-wide public procurement process, as an example, the costs of a domestic firm are likely to be drawn from a very different distribution than the costs of a foreign firm. Third, the buyers are assumed to coordinate their behavior in a bidding ring. Asymmetry and collusion turn out to have similar effects. BK’s revenue ranking remains intact if the buyers are not too asymmetric or the cartel is not too large.

This chapter continues with a quick review of BK’s result in section 8.2.1. BK assume that the seller is uninformed about the realization of the values of the buyers. In section 8.2.2 the effect of an informed buyer in considered. The “auction vs. negotiation” result is reconsidered for asymmetric buyers and colluding buyers in section 8.3 and 8.4, respectively. Section 8.5 offers some final remarks.

8.2 The symmetric benchmark

8.2.1 An uninformed seller

A seller owns an indivisible object and may sell it to one of \( n \geq 1 \) symmetric buyers. The seller’s value for the object is normalized to zero, and the buyers’ values are drawn independently from a common cumulative distribution function \( F \) with support \([0, v]\).\(^2\) Buyers privately observe their value and are uninformed about the realization of the other values. \( F \) is continuously differentiable and has a positive density on its entire support. Additionally, the virtual valuation \( \phi(u) \equiv u - \frac{1 - F(u)}{f(u)} \) increases in \( u \). This assumption guarantees that the seller’s mechanism design problem is regular. In the present context, regularity implies that it is optimal to set a reserve price and allocate the object to the highest bidder. Each buyer is privately informed about its value before the auction or mechanism takes place. The seller and the buyers are risk-neutral and aim to maximize expected payoffs.

From the theory of mechanism design, it is well-known that the seller can extract at most

\[
\Pi_N = E[\max\{\phi_1, \phi_2, \ldots, \phi_n, 0\}]
\]

(8.1)

from the buyers. The subscript \( N \) refers to negotiations and \( \phi_i \) is the virtual valuation of buyer \( i \). See Myerson (1981) for the seminal contribution to mechanism

\(^2\)This chapter restricts attention to the private values framework. BK study auctions and negotiations in a more general interdependent values setting.
design and Krishna (2002) for a recent introduction. This places an upper bound on the revenue the seller may expect from negotiations. In fact, the seller is likely to obtain much less revenue from negotiations. This is because the seller is unlikely to hold all bargaining power, as mechanism design theory presupposes. Furthermore, he may not be able to commit to actions that are dominated ex post.

The seller may also allocate the object by means of an absolute English auction. This is an auction without a reserve price in which the price continuously increases until all but one bidder have dropped out. By the assumption that buyers are symmetric and that virtual valuations are increasing, the revenue of the auction can be written as

$$\Pi_{EA} = E[\max\{\phi_1, \phi_2, \ldots, \phi_n\}], \quad (8.2)$$

where the subscript $EA$ refers to English auction. This is clearly, and by definition, lower than the revenue from the optimal mechanism. However, BK show that with just one additional buyer, the revenue of the absolute English auction is strictly larger than the revenue of negotiating with the former set of buyers.

**Proposition 8.1** (Bulow and Klemperer, 1996). *An absolute English auction with $n+1$ buyers yields more expected revenue than any negotiation with $n$ buyers.*

**Proof.** The proof follows Krishna (2002). It is obvious that the auction dominates the optimal mechanism if $\max\{\phi_1, \ldots, \phi_n\} > 0$. Therefore, suppose that $\max\{\phi_1, \ldots, \phi_n\} < 0$. Then,

$$E[\max\{\phi_1, \ldots, \phi_n, \phi_{n+1}\} | \max\{\phi_1, \ldots, \phi_n\} < 0]$$

$$> \max\{E[\phi_1 | \phi_1 < 0], \ldots, E[\phi_n | \phi_n < 0], E[\phi_{n+1}]\}$$

$$= \max\{E[\phi_1 | \phi_1 < 0], \ldots, E[\phi_n | \phi_n < 0], 0\}$$

$$= 0$$

$$= E[\max\{\phi_1, \ldots, \phi_n, 0\} | \max\{\phi_1, \ldots, \phi_n\} < 0].$$

The inequality follows from Jensen’s inequality and the fact that “max” is a convex function.\(^3\)

Hence, the auction is also superior if $\max\{\phi_1, \ldots, \phi_n\} < 0$ and the result follows.

\(^3\)To see this, note first that a function $f(x) = f(x_1, x_2, \ldots, x_n)$ is convex if $\lambda f(x) + (1-\lambda)f(y) \geq f(\lambda x + (1-\lambda)y)$ for all $x$ and $y$ in the domain of $f$ and all $\lambda$ in $(0, 1)$. Suppose without loss of generality that $x_1 \geq x_2 \geq \ldots \geq x_n$. Then, $\max\{x\}$ is convex if $\lambda x_1 + (1-\lambda)\max\{y\} \geq \max\{\lambda x + (1-\lambda)y\}$. By assumption, $\lambda x_1 + (1-\lambda)\max\{y\} \geq \max\{\lambda x + (1-\lambda)y\}$ and a sufficient condition for convexity is therefore $\lambda x_1 + (1-\lambda)\max\{y\} \geq \lambda x_1 + (1-\lambda)\max\{y\}$. This weak inequality is exactly met.
The common interpretation of proposition 8.1 is that competition is more valuable than negotiations. A revenue-maximizing seller is better off by spending resources to enlarge the number of buyers, than to find the optimal mechanism.

Krishna’s (2002) proof of proposition 8.1 is used here mainly because of its elegance. However, it may be instructive to discuss an alternative proof. In a recent contribution, Kirkegaard (2006) offers an intuitive interpretation of BK’s result. Consider the revenue of the optimal mechanism, \( \Pi_N \), with \( n \) buyers. With \( n + 1 \) buyers, the seller can easily obtain the same revenue by applying the optimal mechanism to the first \( n \) buyers, and give the object for free to the \((n + 1)\)th buyer if the object was not allocated under the optimal mechanism. This mechanism always allocates the object to a buyer. However, the seller can do even better by conducting an absolute English auction. This is because the absolute English auction is the optimal mechanism to allocate an object, subject to the condition that the object must be allocated.

### 8.2.2 An informed seller

BK assume that the revenue of negotiations is bounded by the expected revenue of the optimal mechanism. This assumption implicitly supposes that the seller is equally informed about the value of any given buyer as each other buyer. In many important settings, this common prior assumption seems to be justifiable. For instance, buyers and sellers on the market of collectible items frequently interact, regularly change positions (a buyer today could be a seller tomorrow), and have similar sophisticated information about the value of items.

In other settings, however, it may be more realistic to assume that the seller has better information about the values than the buyers. This might apply to the housing market or the market for second-hand cars. In these markets, sellers trade frequently with inexperienced buyers. The large number of trades enables sellers to predict the values of potential buyers. For instance, the value of a potential buyer of a car might be correlated with observable characteristics, like the size of the buyer’s family, the buyer’s current car, or whether the buyer owns a dog. Other potential buyers are less capable of estimating a buyer’s value because they lack the seller’s experience.

The simplest way to incorporate the idea that the seller has superior information, is to suppose that the seller knows the buyers’ values. The buyers still consider
the value of any given buyer as an independent draw from $F$. By making a take-it-or-leave-it offer to the buyer with the highest value, the seller can extract the entire surplus. The (expected) revenue is simply the (expected) highest value. Call this mechanism *perfect negotiations*.

The obvious question is whether BK’s revenue ranking extends to perfect negotiations. The answer is no.

**Lemma 8.1.** *Perfect negotiations with $n$ buyers generate more revenue than an absolute English auction with $n+1$ buyers.*

**Proof.** Perfect negotiations are superior to auctions for any realization of the values. Let $x$ be the highest value among $n$ buyers, and $y$ the highest value among $n+1$ buyers. The revenue of perfect negotiations is $x$. First, notice that for $y > x$ the auction yields a revenue of $x$. This is because the winner of the auction, which is the additional buyer, pays the second-highest bid, $x$. For $x > y$, the winner is among the first $n$ buyers and pays less than $x$. Hence, the revenue of the auction is bounded by $x$, and strictly lower with positive probability.

This result turns BK’s revenue ranking around. An informed seller would never find it optimal to invite an additional buyer and let an English auction determine the price.

One could conjecture that lemma 8.1 follows from the fact that in an English auction buyers have a dominant strategy to bid their own value. This implies, as the proof demonstrates, that the revenue of the auction is bounded by the revenue of negotiations for any realization of the values. Alternative auction formats may not have this property. However, a simple application of the Revenue Equivalence Principle shows that lemma 8.1 extends to a comparison of perfect negotiations and any standard auction format.\footnote{Krishna (2002) defines a standard auction as an auction whose rules dictate that the buyer who bids the highest amount is awarded the object.} \footnote{In the discussion of their main result, BK anticipate this result. However, they do not derive it formally and do not discuss its implications.}

**Proposition 8.2.** *Perfect negotiations with $n$ buyers generate more revenue than any symmetric and increasing equilibrium of any absolute standard auction with $n+1$ buyers.*

Proposition 8.2 generalizes lemma 8.1. Given that the seller has perfect information, he prefers negotiations with $n$ buyers over a simple auction with $n+1$ buyers. Under the assumption that the seller is uninformed, BK obtain the exact opposite
result. BK derive an upper bound on the value of mechanism design, whereas proposition 8.2 provides an upper bound on the value of competition. This helps to understand not only the limitations of BK’s result, but also institutional characteristics of particular markets. For instance, proposition 8.2 may explain why houses and second-hand cars are predominantly sold via negotiations, and government bonds and art via auctions.

Admittedly, proposition 8.2 applies only to environments where buyers have private values. An open question is how this result can be generalized to buyers with interdependent values.

8.3 Asymmetric buyers

Introducing an informational asymmetry between the seller and buyers upturns BK’s result. Ex ante asymmetry may also arise between buyers. In many important settings, such as public procurement or corporate takeovers, asymmetry appears to play a crucial role. The first firm to enter a procurement process, for instance, is likely to have a lower cost of providing the good than the second firm. This section discusses the effects of asymmetry between buyers on BK’s revenue ranking.

To keep the analysis tractable, restrict the number of buyers to two and assume that values of the buyers are drawn from the power function distribution with support \([0, 1]\). The value of the first buyer is drawn from \(x^\alpha\) and the second buyer’s value is drawn from \(y^\beta\). The exponent of the distribution functions indicates the strength of a buyer. Buyer 1 is called strong if \(\alpha > \beta\) and weak otherwise. Suppose that \(\alpha \geq 1\). This restriction ensures that the mechanism design problem is regular.

As before, the revenue of the optimal mechanism is \(E[\max\{\phi_1, 0\}]\). This can be written as

\[
\Pi_N = \Pr \left( x - \frac{1 - x^\alpha}{\alpha x^{\alpha-1}} > 0 \right) E \left[ x - \frac{1 - x^\alpha}{\alpha x^{\alpha-1}} \middle| x > \frac{1 - x^\alpha}{\alpha x^{\alpha-1}} \right] \\
= \frac{\alpha}{\alpha + 1} E \left[ x - \frac{1 - x^\alpha}{\alpha x^{\alpha-1}} \middle| x > \left( \frac{1}{1 + \alpha} \right)^{1/\alpha} \right] \\
= \alpha (\alpha + 1)^{\frac{\alpha+1}{\alpha}}. \tag{8.3}
\]

Suppose the seller has the opportunity to invite another potential buyer and conduct an absolute English auction. Let \(F\) and \(G\) be the cumulative distribution func-

\[^6\text{Clearly, there exists an ex post asymmetry between buyers in the private values model since buyers do not know each others’ values.}\]
tions of the values of the first and second buyer. Then, expected revenue can be written as

$$\Pi_{EA} = \int_0^v (1 - F(u))ug(u)du + \int_0^v (1 - G(u))uf(u)du.$$  

For the power function distribution, this simplifies to

$$\Pi_{EA} = \frac{\alpha \beta (2 + \alpha + \beta)}{(1 + \beta)(1 + \alpha + \beta)}. \quad (8.4)$$

Suppose $\alpha = 1$. Then, the auction is revenue superior if and only if $\beta > -\frac{3}{2} + \frac{1}{2}\sqrt{17} \approx 0.562$. Hence, BK’s result holds if the additional buyer is not too weak. This insight applies more generally. The English auction is revenue superior if and only if

$$\beta (2 + \alpha + \beta) - (1 + \alpha)^{-1/\alpha} > 0. \quad (8.5)$$

It is not hard to show the following.

**Proposition 8.3.** There exists a unique $\beta$ such that for any finite $\alpha$, the absolute English auction with two buyers yields more expected revenue than any negotiation with one buyer.

**Proof.** For $\beta = 0$, a non-serious additional buyer, the optimal mechanism yields a higher revenue than the auction. As $\beta$ increases, the expected revenue of the auction increases monotonically. In the limit, as $\beta$ becomes arbitrarily large, the auction dominates negotiations because the price paid by the winner of the auction is the value of the first buyer. As a result, there is a unique $\beta$ for which the auction and negotiations yield the same revenue. 

The seller prefers the English auction over any negotiation if the second buyer is sufficiently strong. This extends BK’s revenue ranking to asymmetric buyers and uncovers an important restriction of the validity of BK’s analysis. In the concluding remarks, BK argue that “a firm that refused to negotiate with a potential buyer, and instead put itself up for auction, should be presumed to have exercised reasonable business judgment.”. The result of proposition 8.3 substantially weakens this assertion.

One could object, however, that proposition 8.3 states the obvious. BK’s result is valid for symmetric buyers and, by continuity, remains valid if the additional buyer is not too weak. It may be more important to understand *how* weak the additional buyer is allowed to be.
To address this critique, notice first that the explicit solution for \( \Pi_N \) and \( \Pi_{EA} \) can be used to check whether the additional buyer is strong enough for any \( \alpha \) and \( \beta \). Second, \( \bar{\beta}(\alpha) \), which is the lowest \( \beta \) for which (8.5) holds, is strictly lower than \( \alpha \). This is because (8.5) holds for \( \alpha = \beta \) and, by continuity, also if \( \beta \) is slightly lower. Third, it is easy to show that \( \frac{\partial}{\partial \alpha} \bar{\beta}(\alpha) < 1 \). This implies that, as the first buyer becomes stronger, the additional buyer needs to be relatively less strong.

### 8.4 Colluding buyers

Buyers may cooperate and form a cartel of buyers, also known as a bidding ring. The presence of bidding rings has been documented in various industries and, according to some observers, bidding rings almost always plague auctions. Even if firms are ex ante symmetric, the formation of an incomplete bidding ring creates asymmetries between ring-members and outsiders. This section studies the effect of a bidding ring on the value of competition.

Suppose the initial \( n \geq 1 \) buyers have formed a bidding ring, of the type described in Graham and Marshall (1987). Then, the bidding ring sends the buyer with the highest value to the negotiations. This implies that the seller faces a buyer whose value is drawn from \( F(u^n) \). For tractability, assume that individual buyers draw their value from the uniform distribution on the unit interval. Then, by relabeling (8.3), the revenue of the optimal mechanism can be written as

\[
\Pi_N = n(n + 1)^{n+1}. \tag{8.6}
\]

Instead of inviting one additional buyer, as BK assume, suppose that the seller may invite \( k \) additional buyers and run an absolute English auction. Assume that the new buyers do not join the ring or collude themselves. (Otherwise, the auction yields zero revenue to the seller.) To derive the revenue of the English auction, note that if the cartel’s nominee wins the auction, he expects to pay the maximum value among the non-colluding buyers. This implies that, for a general common distribution function \( F \), the expected payment of the nominee when his value is \( x \) is

\[
M(x) = \int_0^x udF(u)^k. \tag{8.7}
\]
The \textit{ex ante} expected payment, i.e. before the nominee learns his value, is simply

$$E[M] = \int_{0}^{\nu} u(1 - F(u)^{n})dF(u)^{k}. \quad (8.8)$$

Given that the nominee’s value is \(x\), the representative new buyer’s value is \(y_{i}\), and \(y_{i} > x\), buyer \(i\) expects to pay

$$m_{i}(x, y_{i}) = \Pr(x > \max\{y_{-i}\})x$$

$$+ \Pr(x < \max\{y_{-i}\} < y_{i})E[\max\{y_{-i}\} < y_{i}]$$

$$= F(x)^{k-1}x + \int_{x}^{y_{i}} u dF(u)^{k-1}. \quad (8.9)$$

By integrating over \(x\) and \(y\) one obtains the new buyer’s \textit{ex ante} expected payment

$$E[m] = \int_{0}^{\nu} (1 - F(u))F(u)^{k-1}udF(u)^{n} + \int_{0}^{\nu} (1 - F(u))F(u)^{n}udF(u)^{k-1}. \quad (8.9)$$

The revenue of the English auction is simply \(E[M] + kE[m]\). For the uniform distribution, this becomes

$$\Pi_{EA} = \frac{k(n + k^2 + 2kn + n^2 - 1)}{(k + 1)(n + k)(n + k + 1)}. \quad (8.10)$$

Does the presence of collusion destroy BK’s revenue ranking? To answer this question, consider first a bidding ring of two buyers \(n = 2\). In that case, as is straightforward to verify by comparing \(\Pi_{N}\) and \(\Pi_{EA}\), just one additional buyer is sufficient to ensure that the auction yields more revenue. So, even if a seller faces an all-inclusive cartel in negotiations, inviting just one extra buyer and hold an auction instead more than offsets the loss in bargaining power.

Just as with asymmetric non-cooperative buyers, the English auction generates more revenue if the number of additional (non-cooperative) buyers is sufficiently large.

**Proposition 8.4.** There is a unique number of buyers \(k\) such that for every bidding ring with \(n\) buyers the absolute English auction with \(n + k\) members raises more revenue than any negotiation with the bidding ring.

**Proof.** For \(k = 0\), the English auction yields zero revenue, and is therefore dominated by negotiations. As \(k\) goes to infinity, the revenue of the English auction converges to 1, which is strictly above \(\Pi_{N}\). Finally, since the revenue of the English auction with \(n + k\) buyers increases in \(k\), there is a unique \(k\) such that \(\Pi_{N} = \Pi_{EA}\).
Similar to the case of asymmetric buyers, collusion among buyers does not imply that additional buyers are less valuable than the optimal mechanism. Negotiations with a small bidding ring are less profitable to the seller than an English auction with a relatively large group of outsiders. To understand how large the number of outsiders should be, consider the ratio $\bar{k}(n)/n$, where $\bar{k}(n)$ is the (unique) solution of $\Pi_N(k) = \Pi_{EA}(k)$. It is straightforward to show that $\bar{k}(1)/1$ is $2/3$. Moreover, $\bar{k}(n)/n$ decreases in $n$. Hence, for any bidding ring, the number of outsiders is at most $2/3$ of the number of cartel members.

Two caveats. When a bidding ring exists, foregoing the ability to negotiate may be very costly, irrespective of the number of additional buyers. First, the new buyers may collectively join the ring, extracting all surplus from the seller. Second, switching from negotiations to an auction may actually induce collusion, because, as Robinson (1985) noted, collusion in an English auction is one-shot stable.

### 8.5 Concluding remarks

This chapter complements BK’s upper bound on the value of mechanism design with an upper bound on the value of competition. This new upper bound helps to explain why in many environments sellers prefer negotiations over auctions. In particular, a seller who possesses better information about the value of a buyer than any other buyer is better off by relying on negotiations to maximize revenue.

There are more reasons why a seller may prefer negotiations over auctions. Large asymmetries between buyers tilts the scale in favor of negotiations, as do bidding rings. The underlying reason why BK’s revenue ranking of auctions and negotiations fails in these two cases is the same. In negotiations, the seller is able to extract (through a take-it-or-leave-it-offer) the buyer’s or ring’s large expected value. In a simple auction without a reserve price he is unable to exploit his knowledge of one buyer’s or ring’s large willingness-to-pay.

In view of the general theme of this thesis, collusion, this chapter’s main insight is that in the presence of a cartel a seller may respond by changing the selling format. This is more drastic than the policy recommendations in chapters 6 and 7, which concluded that an auctioneer may adapt the auction rules in response to collusion. The analysis in this chapter advises to abandon the auction altogether in certain special cases.
Chapter 9

Conclusion

9.1 Summary

Many countries, including Germany, the United Kingdom and the United States, have adopted antitrust (or competition) laws that prohibit firms to enter into agreements that are potentially harmful to society at large. Acts that are considered to be illegal include horizontal mergers that create a monopoly and price agreements. Although such laws have been in place for many years (the U.S. Sherman Act dates from 1890) and are uncontroversial among most economists and policymakers,\(^1\) there are still many open questions. The essays in this thesis apply game-theoretic tools to formulate and answer some of these questions.

A central tenet of the Chicago School is that a cartel bears the fruit of its own destruction, because supra-competitive profits attracts new firms. As this reasoning seems plausible, the open question here is why we still observe cartels. How long does it take for entry to destabilize a cartel? More generally, which factors determine the durability of a cartel? Chapter 2 presents a model to address this issue. It is shown that collusion is viable, even when cartel members face the threat of entry. The model allows for a closed-form expression of the expected lifetime of a cartel. Key determinants that affect a cartel’s stability are the number of cartel members and the cost of deterring entry.

\(^1\) Robert Bork (1978) is one of the few outspoken critics of antitrust laws. He contends that the American antitrust policy slows down innovation and protects small businesses instead of consumers.
One of the main activities of antitrust authorities is to detect and punish collusive behavior. Given the illegal nature of price conspiracies, firms try to keep their agreements private by negotiating in the proverbial “smoke-filled rooms”. The only information that may give away the presence of a cartel is therefore public information such as prices. A high price might indicate the presence of a cartel, but is also consistent with a high-cost industry. An antitrust authority has an \textit{ex post} incentive to investigate the former industry but not the latter. Chapter 3 studies this game between firms and an antitrust authority. The analysis reveals that, when an antitrust authority is unable to commit, firms will collude with some probability. The government can decrease the incidence of collusion by instructing the antitrust authority to maximize consumer welfare instead of social welfare.

Chapter 4 considers semicollusion. When firms engage in semicollusion, they coordinate on some strategic variables, such as the range of products, prices or service provision, but act non-cooperative on others. Even though this form of collusion seems to be ubiquitous, the vast majority of the literature on collusion restricts attention to full collusion. An important open question is how semicollusion differs from full collusion. Does competition on the quality dimension wash away the collusive profits obtained by coordination of prices? Are consumers better off under semicollusion than under full collusion? The analysis in the chapter implies that semicollusion is still profitable for firms, as compared to non-cooperative behavior, but the optimal price depends on the firms’ ability to compete through service provision. In particular, when providing service is relatively costly, the cartel chooses to set a high price, knowing that firms will be restricted in competing the collusive profits away. On the other hand, when providing service is relatively easy the cartel chooses to set a low price, as compared to the non-cooperative price, to moderate the degree of competition through service provision. In general, consumers prefer non-cooperative behavior over semicollusion, and semicollusion over full collusion.

Chapter 5 revisits a classic topic of industrial organization: resale price maintenance. The classic Chicago position on vertical restraints such as resale price maintenance is that they are voluntarily agreed to by upstream and downstream firms, and necessarily enhance efficiency. The prevailing view, however, holds that resale price maintenance is pro-collusive and should therefore be banned. Chapter 5 studies a simple model of a manufacturer and two downstream retailers. Under the assumption that the manufacturer and retailers aim to maximize profits, it is shown that resale price maintenance may have an anti-collusive effect. The reason
is that by imposing a price floor, the manufacturer makes it impossible for retailers
to form a cartel as a high price floor makes it attractive for retailers to deviate from a
cartel agreement. This suggests another pro-efficiency interpretation of resale price
maintenance.

An important question concerns the interplay between market characteristics
and the scope for collusion. It is well-known that certain properties of markets
may hinder or foster collusion between firms. For instance, it is easier to collu-
de for firms when consumers order their goods regularly and frequently. There is,
however, little systematic knowledge on this relation. Chapter 6 fills this gap by
reviewing the existing literature on the ties between collusion and market character-
istics for a market that becomes increasingly important: auctions. The bottom line
of this chapter is that auctioneers may prevent collusion by twisting and tweaking
the auction rules. In response to a cartel, an auctioneer has various tools at his dis-
posal, such as adjusting the auction format, imposing a reserve price, or limiting
the bidders discretion in submitting a bid. The task of deterring cartels, therefore,
does not rest solely on the shoulders of antitrust authorities.

The discussion on collusion in auctions continues in chapters 7 and 8. Chapter
7 studies collusion in a multidimensional auction, in which a firm’s bid consists of
a price and a quality index. The analysis consists of two parts. First, the chapter
presents a derivation of the optimal collusive scheme when firms can and cannot
make transfers to each other. This exercise helps to understand how cartels work in
actual multidimensional auctions. Moreover, the analysis is instrumental in the se-
cond part of the chapter, where a number of anti-collusive strategies are discussed.
The main insight is that, in order to lower the costs of collusion, auctioneers should
not merely announce a minimum quality level and a maximum price, but try to
construct a scoring method that ranks price and quality pairs and announce a mi-
nimum score below which bids are not eligible. This method is more efficient in the
sense that it results in the socially optimal quality level and yields the auctioneer a
higher surplus.

Although auctions are a popular method in procurement, an even more fre-
quently used method is to negotiate. This seems puzzling, as auctions are easy
to conduct and tend to deliver the buyer better terms of trade than negotiations.
Chapter 8 analytically compares the two mechanisms, and find that in some cases
negotiations do outperform auctions. Most importantly, a seller is better off nego-
tiating when he is certain that a relatively large bidding ring exists.

\footnote{See Motta (2004), chapter 4 for a discussion of these factors.}
9.2 Avenues for further research

Hopefully, the essays in this thesis provide convincing evidence that collusive behavior forms a rich source of interesting research. There are many ways in which the above models can be extended or modified to yield new insights or applications. This section discusses a few.

The first essay offered a theory of entry deterrence and finite cartel duration. That model is still highly stylized. For instance, entrants are passive bystanders. In practice, entrants do not wait patiently for the incumbents to fail but actively lobby the government as well. A promising extension would therefore be to explicitly model the lobbying process by adding a ‘political economy’ component in which incumbents, entrants and politicians have a strategic role. Another challenging question is to formulate an econometric model and estimate the expected duration of cartels.

The essay on antitrust enforcement, chapter 3, studied a model in which firms may have two types; low costs or high costs. An obvious extension is to analyze the ‘continuous-type’ version of the model, in which the costs of firms is drawn from a continuous interval. A related adjustment is to drop the assumption of common costs and consider the case where firms’ costs are correlated.

Chapter 4 considered semicollusion. The analysis in that chapter simply assumed semicollusive behavior. It would be interesting to understand why firms adopt this type of collusion instead of full collusion. An answer presumably relies on imposing costs of observing a firm’s strategic decisions and assuming that those costs differ across strategic variables. It is arguably easier to observe a competitor’s price than its level of service.

The analysis in chapter 5 suggests that it is worthwhile to examine the effect of vertical restraints other than a price floor on the ability to collude. Empirical research is also welcome. Despite the controversial nature of the topic, and the existence of a large theoretical literature, there are few empirical studies of the economic effects of vertical restraints. An empirical study may also provide insights about the empirical relevance of the various theoretical explanations of vertical restraints, including the one proposed in this thesis.

Chapter 6 reviewed the literature on collusion in auctions. The most urgent challenges in this field are empirical: how to detect collusion and how to estimate the welfare costs of collusion? An answer to these questions can probably only be given in the context of a case study, where the researcher has access to detailed (cost) data. An open theoretical issue is to explain the often used practice of orga-
nizing a knockout after the actual auction. This method is inefficient and does not seem to maximize a cartel’s revenue.

The most promising approach for new research related to chapters 7 and 8 seems to be empirical. There is little empirical research on multi-dimensional auctions. By estimating bid functions for these auctions, economists can potentially estimate the welfare gains or losses of alternative auction formats. Explaining the choice of a mechanism seems to be a highly relevant research topic as well. Insights from such a study could improve auction theory. Understanding the determinants of the choice of a mechanism may also guide public policy. When is it sensible to instruct government agencies to use a particular procurement mechanism? Rich and reliable data are often scarce and an alternative method to study collusive behavior in auctions are experiments.

Of course, there are many other issues left to be explored in antitrust economics. For instance, the profession is now starting to integrate insights from the endogenous growth literature into industrial organization models. In models of endogenous growth (the seminal reference is probably Aghion and Howitt, 1992), firms invest in R&D to become the market leader and render the previous market leader’s product obsolete. An important characteristic of endogenous growth models is that firms do not compete ‘on’ the market, but rather ‘for’ the market. Segal and Whinston (2007) investigate some implications of this form of competition for antitrust policy. As this literature is still to be developed, there are many interesting open questions. What is, to name just an example, the scope for collusion when firms are involved in a perpetual R&D race? What is the relevance of merger policy in such an environment?

There exists a large body of knowledge on political economics. The majority of articles in that field, however, restricts attention to macroeconomic issues such as monetary policy, income distribution or economic growth, see for instance the textbooks by Drazen (2000) and Persson and Tabellini (2000). Antitrust policy often has a significant political dimension. Governments sometimes encourage a merger of large national firms to create a ‘national champion’. And a supra-national or federal antitrust authority, such as the European Commission, may encounter strong local political opposition when it decides to impose a huge fine for price fixing. This political dimension of antitrust is usually ignored in the literature. An exception to this claim are papers by Röller and his co-authors (see Neven and Röller, 2005 or Röller and Waverman, 2001). There are many interesting problems in ‘political industrial organization’. How should we view the interaction between politicians
and the antitrust authority? In the spirit of the central banking literature, are politically independent antitrust authorities better capable of deterring collusion than dependent ones?

9.3 Policy recommendations

Every essay in this chapter is a theoretical exercise. Yet, one can distill several insights that are relevant for policymakers. Perhaps the most general lesson that can be drawn is that there are many ways to combat cartels. Investigating industries and imposing a fine if a cartel is found is not the only strategy. There are other, more creative, solutions. This section discusses the policy implications in more detail.

The analysis in chapter 2 suggests that the antitrust authority should take the expected duration of a cartel into account when deciding to investigate an industry. The model suggests that industries with a well-organized trade union are more likely to accommodate a long-lived cartel, as are industries which are protected from vigorous competition by an import barrier. Investigation is costly, and should therefore be targeted toward the (potential) cartel with the largest negative impact. A second implication is that policymakers can attempt to decrease the durability of cartels. For instance, the government can lower the import tariffs to induce entry of foreign firms. The strategy of decreasing the durability of cartels can be seen as an indirect way to combat cartels, as compared to the traditional strategy of fining cartels.

The lesson of chapter 3 is that policymakers should carefully rethink the objectives of the antitrust authority. Does the antitrust authority have the right incentives to effectively deter collusion? Related to this issue is the question of how the antitrust authority can be held accountable. In contrast to central banking, where the performance of the central bank can be measured according to an inflation target, there is no obvious, measurable, target in antitrust.

The results in chapter 4 warn antitrust authorities not to take quality, service, or other non-price strategic variables as given when setting a fine for a cartel. Assuming that non-price strategic variables are unchanged under collusion tends to yield biased estimates of the welfare costs of collusion.

The immediate policy implication of chapter 5 is that the current European ban on resale price maintenance should be lifted. The arguments in favor of resale price maintenance, which may be summarized under the header of pro-efficiency, are more compelling than the traditional view that resale price maintenance fosters col-
The simple model in this chapter demonstrates that resale price maintenance may actually be anti-collusive, which undermines the pro-collusive argument against this vertical restraint.

The U.S. Supreme Court decided in *Leegin* to abolish the illegal treatment of resale price maintenance, and now favors a rule of reason standard.\(^3\) This seems to be an attractive option for the European Union as well. With a rule of reason, the European Union effectively adopts a ‘wait-and-see’ strategy. When the pro-collusive view turns out to be correct, the Union can still refuse upstream firms to use this restraint.

The articles surveyed in chapter 6 clarify the role of the auctioneer in preventing collusion. By responding to signals for collusive behavior, an auctioneer can adjust the design of the auction to prevent the emergence of a cartel or at least mitigate the negative revenue effects. Thus, collusion can be deterred *ex ante* at the market design stage, instead of *ex post*, by prosecuting an existing cartel.

The most important implication of chapter 7 is that an auctioneer in a multidimensional setting should construct a scoring index to rank multidimensional bids and announce a minimum score below which bids are not eligible. Of course, the construction of such an index can be a difficult exercise, and in some cases prohibitively costly.

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Bibliography


Che, Y.-K., & Kim, J. (2006). Robustly collusion-proof implementation. *Econometri-


Froeb, L. (1988). *Auctions and antitrust.* (Unpublished, Department of Justice, Antitrust Division)


Industrial Organization, 10, 633-641.


Samenvatting

Kort overzicht

Dit proefschrift gaat over de economische theorie van kartels. Er is sprake van een kartel wanneer een aantal bedrijven, expliciet of stilzwijgend, afspreekt om de prijs te verhogen of de kwaliteit te verminderen. In Nederland en veel andere landen is dit verboden, omdat consumenten door dergelijke afspraken meer betalen voor een inferieur produkt. In ieder hoofdstuk probeer ik één of meer aspecten van de dynamiek van kartels beter te begrijpen door een speltheoretisch model op te stellen. Aan de hand van zo’n model kunnen vervolgens methoden worden afgeleid die bijdragen aan het uiteenvallen van kartels of zelfs de vorming ervan voorkomen.

Kartels


Een voorbeeld. Stel dat op een lokale markt voor paarden vier potentiële koopers zijn; Arnold, Bas, Corine en Daniel. Elke koper heeft interesse in slechts één paard en de bedragen die ze daar maximaal voor willen betalen zijn, respectievelijk, € 10.000, € 8.000, € 5.000 en € 2.000. Op dezelfde markt zijn ook twee paardenfokkers actief. De totale kosten voor het leveren van een paard bedragen, inclusief een redelijke marge voor de aanbieder, € 2.000. In het geval dat de paardenfokkers geen kartel vormen, zullen de kopers het paard kopen bij de aanbieder met de laagste prijs. Dit zal uiteindelijk leiden tot een prijs van € 2.000. Voor Arnold betekent
dit een surplus van € 8.000, want € 10.000 - € 2.000 is € 8.000. Het totale surplus van de kopers (het consumentensurplus) is € 15.000. Figuur 1a vat de situatie samen. Het consumentensurplus is weergegeven als het grijze oppervlak. De winst van de paardenfokkers is precies nul en daarmee is het maatschappelijke surplus (het surplus van consumenten plus de winst van bedrijven) ook € 15.000.

Stel nu dat de fokkers een prijsafsprak maken. Het is voor hen optimaal om € 8.000 per paard te vragen. Andere prijzen leveren minder winst op, zoals eenvoudig is na te rekenen. De winst van de fokkers wordt dan € 12.000, omdat de verkoop aan Arnold en Bas tweemaal € 8.000 oplevert minus de kosten van tweemaal € 2.000. Het consumentensurplus daalt naar € 2.000, zoals is te zien in figuur 1b. Het lagere consumentensurplus hoeft nog geen rechtvaardiging van overheidsinterventies te zijn. De consumenten zijn weliswaar slechter af, maar de fokkers hebben een hogere winst. En waarom zou de overheid het belang van de fokkers minder zwaar laten wegen dan dat van de paardenkopers?

De reden is dat consumenten onevenredig hard getroffen worden door het kartel. Het verlies van de consumenten weegt niet op tegen de hogere winst. Vóór de oprichting van het kartel was het maatschappelijke surplus € 15.000. Als gevolg van de hogere prijs daalt het maatschappelijke surplus naar € 14.000. Sommige consumenten (in dit geval Corine en Daniel) zijn niet meer bereid te kopen en hun surplus gaat verloren.

Het voorkomen van dit welvaartsverlies is de voornaamste reden om prijzspraken te bestrijden. Een ander belangrijk argument is dat kartels innovatie en daarmee de economische groei vertragen. Als bedrijven onderling afspraken maken hoeven ze niet meer om de gunst van de consument te strijden door nieuwe of verbeterde produkten aan te bieden.
Bevindingen


Deel 1

Het ene kartel is het andere niet. Sommige kartels bestaan tientallen jaren, in andere houden bedrijven het niet langer dan twee jaar met elkaar uit. De negatieve maatschappelijke impact van een kartel is veel groter als het kartel langer bestaat. Het is daarom van belang om te begrijpen wat de determinanten zijn van de verwachte levensduur van een kartel. In hoofdstuk 2 introduceer ik een model om dit te analyseren. De essentie van het model is dat karteldeelnemers moeten investeren om toetreding te voorkomen. De verwachte levensduur van een kartel neemt af als het aantal karteldeelnemers of de investeringskosten toenemen.

Een belangrijke taak van mededingingstoezichthouders is om kartels te voorkomen. Hiervoor spoort de toezichthouder kartels op en deelt een boete uit als een overtreding wordt geconstateerd. Gezien de mogelijk hoge boetes is het niet verwonderlijk dat bedrijven prijsafspraken stil proberen te houden. In het uiterste geval is het enige waarop een toezichthouder zich kan baseren de hoogte van de prijzen. Een hoge prijs kan een indicatie zijn dat een kartel actief is, maar kan ook betekenen dat de kosten hoog liggen. Een toezichthouder zal alleen onderzoek uit willen voeren als er een kartel bestaat. In hoofdstuk 3 bestudeer ik het spel tussen de toezichthouder en bedrijven. Ik laat zien dat bedrijven altijd met positieve kans een kartel vormen. De kans dat dit gebeurt kan worden verkleind door de toezichthouder consumentenwelvaart te laten maximaliseren in plaats van totale welvaart.

In de bestaande literatuur wordt er normaliter van uitgegaan dat karteldeelnemers perfect samenspannen. De praktijk leert dat bedrijven soms prijsafspraken maken, maar tegelijkertijd met elkaar blijven concurreren door bijvoorbeeld meer kwaliteit te bieden. De vraag die ik in hoofdstuk 4 stel is in hoeverre een kartel waarin alleen prijsafspraken maken (een semikartel) verschilt van een kartel waar-
in ook afspraken over kwaliteit worden gemaakt (een volledig kartel). Hiervoor maak ik gebruik van een model waarin bedrijven zich van elkaar kunnen onderscheiden door een hogere kwaliteit aan te bieden of door toevallig beter te passen bij de persoonlijke voorkeuren van consument. Consumenten zijn niet alwetend en zullen erop uit moeten gaan om te zoeken naar een produkt dat goed bij hen past. Het model kan worden gezien als een wiskundige kijk op de zoektocht van een shopaholic naar dat ene perfecte paar schoenen. Net als bij een volledig kartel zijn consumenten slechter af bij een semikartel, hoewel het tweede type minder schadelijk is dan de eerste. Een verrassende uitkomst is dat de prijs bij een semikartel lager kan liggen dan zonder een kartel. Door een lage prijs af te spreken voorkomen de karteldeelnemers dat ze vervolgens een felle concurrentiestrijd om de consument beginnen.

In het vierde essay van dit proefschrift, hoofdstuk 5, bestudeer ik een klassiek onderwerp uit de literatuur: verticale prijsbinding. Dit is een voorwaarde waarbij een fabrikant of groothandelsonderneming een afnemer verplicht om het produkt niet onder een door de fabrikant of groothandelsonderneming vastgestelde prijs te verkopen. Het gebruik van deze voorwaarde stuit vaak op mededingingsrechtelijke bezwaren. Het argument dat hiervoor door de toezichthouder wordt gegeven is dat verticale prijsbinding leidt tot hogere prijzen. In een eenvoudig model laat ik zien dat verticale prijsbinding juist kan leiden tot lagere prijzen, doordat een fabrikant minimumprijzen zal gebruiken om een afnemerskartel te voorkomen.

**Deel 2**

In hoofdstuk 6 bestudeer ik hoe bedrijven prijsafspraken kunnen maken bij aanbestedingen of veilingen. Het belang van veilingen in de economie is enorm en neemt alleen maar toe. Aanbestedingen zijn helaas vaak zo opgezet dat kartelvorming in de hand wordt gewerkt. Ondernemingen weten, door ervaring of openbare informatie, meestal goed welke andere ondernemingen meedingen naar de opdracht. Daarnaast geeft de aanbestedende dienst vaak openheid over maximale toelaatbare prijs. Het enige wat kartelleden dan nog moeten doen is afspreken wie intekent op deze maximale toelaatbare prijs. Mocht een kartellid het niet eens zijn met deze afspraak en hoger bieden dan de uitverkorene winnaar, dan kunnen de overige kartelleden bij een veiling bij opbod alsnog hoger bieden dan het dwarse kartellid. Afwijken van de afspraak is dan niet winstgevend.

Aan de hand van bestaande literatuur laat ik zien hoe een veiling aangepast kan worden om de kans op een kartel te verkleinen of zelfs uit te sluiten. Dit kan
bijvoorbeeld door een reserveringsprijs in te stellen waarboven niet geboden mag worden.

De bestaande literatuur over kartels bij veilingen gaat uit van ééndimensionale competitie: het laagste bod wint. Bij aanbestedingen stelt de opdrachtgever meestal ook eisen aan de kwaliteit. Hoofdstuk 7 breidt daarom de analyse uit naar veilingen waarbij het bod een combinatie is van een prijs en een kwaliteitsaanbod. Ik laat zien hoe de inzichten uit de ‘ééndimensionale’ literatuur vertaald kunnen worden naar deze situatie. Om de schade van een kartel te beperken kan de opdrachtgever een *reservation utility auction* gebruiken. Dit is een veiling waarbij een bod de opdrachtgever tenminste een minimale prijs-kwaliteit verhouding moet garanderen. In de praktijk wordt vaak een maximumprijs en een minimumkwaliteit ingesteld. De *reservation utility auction* levert de opdrachtgever meer op dan een combinatie van een maximumprijs en een minimumkwaliteit.

Er bestaan natuurlijk meer methoden dan veilingen om een produkt te kopen of verkopen. Een veel gebruikte methode is om te onderhandelen. In hoofdstuk 8 vergelijk ik veilingen met onderhandelingen. Het blijkt dat onderhandelingen de verkoper meer opleveren dan een veiling als de kopers een kartel hebben gevormd.