Essays on risk management in procurement auctions

Inaugural-Dissertation
zur Erlangung des akademischen Grades eines Doktors
der Wirtschafts- und Sozialwissenschaften
(Dr.rer.pol.)
der Friedrich-Alexander-Universität Erlangen-Nürnberg

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22. November 2005
For my parents and Nina
Abstract

Governments as well as private firms face the risk that a contractor goes bankrupt before the completion of the work. In such an environment the possibility to declare bankruptcy makes bidders in a procurement auction bid more aggressively. Among other results we show that revenue equivalence breaks down and that in contrast to the standard auction theory, multi-sourcing, rationing, and other means to soften competition may fare better than a standard auction. We also discuss commonly used methods of how to avoid ruinous bidding and demonstrate that these might fare quite badly. Also, in contrast to the existing literature, cost-plus contracts might be no longer inefficient. In a second step, we extend our analysis to international trade theory and show that the practice of supporting domestic firms with price preferences against international competition leads to the opposite result as intended, namely more bankrupt domestic firms. The last part of this thesis deals with the investigation whether the introduction of compulsory surety bonds mitigates the problem of risky bidding. Since the issuers of the bond are specialized in screening the potential contractors they can evaluate contractors’ risks. Hence, they charge a risk-adjusted premium as a compensation for issuing the required surety bond. Our result is that if the bond is priced fairly, full insurance or even overinsurance is optimal. If the surety is priced unfairly, full insurance might be optimal.1

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1JEL-Classification: D44, D45, D82, F13, G33, H57, L51; keywords: auctions, revenue equivalence, bankruptcy, insurance economics, international discrimination, price preferences, protection, risk management, small and medium enterprises, surety bonds.
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Acknowledgements

First and foremost, I would like to thank my supervisor Achim Wambach for his encouragement and advice. He read and commented all chapters and gave me numerous suggestions to improve this thesis.

Furthermore, I would like to thank Ester Hauk and Juanjo Ganuza who worked with me on an article for the Handbook of Procurement. I benefitted from many comments of Alexander Rasch and Jesko Herre. Alexander was an excellent discussant for scientific and non-scientific topics at the last stages of this project. I am grateful to Paul Frijters who took care of my progress while I worked at the RSSS/ANU in Canberra in 2004. Being a visiting researcher at this School was financed by the German Academic Exchange Service (DAAD) under grant D/04/30600. I would also like to thank Kai-Ingo Voigt for being the second-reviewer (Koreferent) of this thesis.

Several other colleagues deserve my gratitude. The members of the chair of economic theory who were part of the ”Brühgruppe”: Kristina Kilian, Alexander Rasch, Rüdiger Reißaus, Michael Sonnenholzner, and especially Jesko Herre: thanks for all the discussions. A special thank also goes to David Haugh, my office-mate at the RSSS in Canberra, for business cycles, barbie, bush-walking, and breakfast tea. All other colleagues at the RSSS deserve my gratitude as well. Thanks to Ursula Briceno for administrative help as well as the student researchers of the chair (from 2002 to 2005) for their support.

Finally, I would like to thank my parents and my fiance Nina for listening to strange theories, giving me advice and their support to finish this project.
Chapter 1

Introduction

Public and private procurement is plagued with bankruptcy and contract non-fulfillment. In the United States more than 80,000 contractors went bankrupt between 1990 and 1997, leaving unfinished private and public construction projects with liabilities exceeding $US 21 billion.\textsuperscript{1} The direct costs of bankruptcy (e.g., administrative costs or lawyers) vary between 7.5% and 20% of the liquidation proceeds, indirect costs (e.g., delays and other losses) are estimated to be even higher.\textsuperscript{2} The bankruptcy of a contractor may arise when the payment (and therefore his winning bid) lies below the cost realization of the project which is uncertain from an ex-ante point of view. But why are firms willing to bid below the possible cost realizations of the project? Why do they risk bankruptcy with this aggressive behavior? The insights from standard auction theory cannot help to explain this phenomenon.\textsuperscript{3}

Going beyond standard auction theory, there are three main answers to these questions: (i) The winning firm underestimates the cost and bids too optimistically which, per se, can only be explained by irrationality. As we assume that all participants are rational we do not discuss this aspect in this thesis. (ii) The winning firm expects to renegotiate the contract later on when it is very costly for the agency to replace the firm. This renegotiation process generates both cost overruns for the

\textsuperscript{1}Dun and Bradstreet Business Failure record, cited from Calveras et al. (2004).
\textsuperscript{2}See White (1989).
\textsuperscript{3}An excellent textbook for auction theory is Krishna (2002). More demanding from a technical point of view is Milgrom (2004).
agency and rents for the winner that are discounted into the bid.\textsuperscript{4} We ignore renegotiation in the thesis for two reasons. First, renegotiation would make the analysis more complex as the initial bid may be regarded as cheap talk. Second, credibility is one of the most important features of an auction. If renegotiation is possible, the credibility of the agency would suffer which in turn would destroy all the virtues of an auction.\textsuperscript{5} (iii) Aggressive bidding can also be explained by limited liability as these bids might be from firms in a bad financial situation struggling for survival. If things go badly, the firm simply shuts down. Hence, the firm’s possible losses are bounded while her possible gains are not. This affects the firm’s bidding behavior and leads to more aggressive bids which can lie below possible cost realizations. This leads to a positive probability of bankruptcy. The focus of this thesis is on exactly this effect: limited liability makes firms bid more aggressively, leading to a positive probability of bankruptcy of the winning firm, and leaving the procuring agency with the risk of non-fulfillment. Standard auction theory can not explain this bidding behavior as it is assumed that firms have unlimited liability. As the limited-liability effect extends the standard analysis it (i) explains why firms follow such an aggressive bidding behavior and it (ii) alters the results of standard auction theory such as the revenue-equivalence theorem. We discuss how the standard procurement mechanisms fare under limited liability and how one has to deal with this problem.\textsuperscript{6} Each chapter of this thesis deals with this problem in its own way as each represents a paper on its own.

In the second chapter, we give an overview of the topic and present the results of this thesis in a non-technical way. This chapter can be regarded as an extended introduction. It outlines the ideas of this thesis and gives recommendations on how

\textsuperscript{4}More than 60\% of the failures in the US construction industry are due to cost overruns that are not covered by the contracted payment and the financial assets of the contractor (Arditi et al., 2000). 77\% of the largest public work projects in Spain led to cost overruns, with an average cost overrun of 22\% (Ganuza, 1997). The average cost overrun in a sample of US defence programs was more than 220\% of the budget (Peck and Scherer, 1962). Theoretical models of cost overruns include Lewis (1986), Arvan and Leite (1990), Ganuza (2003), and Bajari and Tadelis (2001).

\textsuperscript{5}We discuss the effect of cost-plus contracts in section 3.5 which has features of renegotiation.

\textsuperscript{6}An auction or mechanism is standard if the rules are such that the bidder with the lowest bid wins.
to deal with risky bids by giving rules of thumb. This chapter will be published in the Handbook of Procurement and it is joint work with Esther Hauk, Juanjo Ganuza, and Achim Wambach. The last two authors wrote most of the section on third-party guarantees.

The third chapter is the basic setup where we derive the effect of limited liability on the bidding behavior in a partial equilibrium model. We investigate how well the standard auctions fare in such an environment and analyze and compare common ways of dealing with bankruptcy. We discuss extensions like reserve prices and entry fees, asymmetries and common costs. Furthermore, we extend the basic model to a more complex information structure by adding an additional moral-hazard problem. The last section of this chapter is a transfer of our insights into the field of industrial organization. The first three sections of this chapter are joint work with Achim Wambach; especially the setup of the basic model, the proof of proposition 3, and the idea to introduce means to weaken competition. These three sections and the next chapter also benefited from comments of Esther Hauk, seminar participants at the CESifo area conference on Industrial Organization in Munich (2004), at the theory seminar in Berlin (2004), at the WRIEC conference in Salt Lake City (2005), at the seminars at the RSSS and the ANU in Canberra (2004), and from members of the auction group of CONSIP in Rome (2004). Achim Wambach also suggested further extensions of the basic setup which led to the next two chapters.

The fourth chapter is an extension of the basic model into the field of international trade. It is well known that governments subsidize domestic firms to protect them from international competition. This chapter deals with the question if governmental subsidies also protect domestic firms with limited liability.

The fifth chapter is a comment on a paper about surety bonds (Calveras et al., 2004) which are an institutional way of mitigating the problem of aggressive bidding. As Calveras et al. (2004) focus on only one aspect of surety bonds, namely the costs of the bond, we discuss surety bonds from an insurance point of view. We investigate how surety bonds fare if the insurance premium is priced fairly or unfairly. This
chapter benefitted from comments of Esther Hauk.

In the concluding remarks, we discuss the limitations of our analysis, stress the most important results of this thesis and give some policy implications.
Chapter 2

A practical guide to manage risky bids (ALTs)

2.1 Introduction

The logic that limited liability leads to more aggressive bidding and bankrupt firms (which leads to the non-fulfillment of the project) is as follows: as the cost of a project is uncertain by the time the firms enter the procurement process, the firms face the risk that the realization of the cost is higher or lower than calculated. Due to the possibility of declaring bankruptcy, the losses of a winning firm are limited in case of high costs. However, if the project is going well, the firm participates fully. Limited liability therefore changes the attitude towards the risk. In most economic activities firms dislike risk. But in procurement with limited liability good news (low-cost realizations) are always good news while bad news (high-cost realizations) may not matter so much. Thus, firms become risk-loving and bid more aggressively which leads to the case that the winning bid as well as the expected payment will be below possible cost realizations. If the payment does no cover the cost, firms go

\footnote{This may be caused by the uncertainty of the project in general, errors in the calculation or potential financial need to cover losses of other projects that are still in process.}
bust which in turn leads to the non-fulfillment of the contract.\textsuperscript{2}

**Remark 1** The limited-liability effect: limited liability leads to more aggressive bidding than under unlimited liability as the firm’s losses are limited but the profits are not.

We now illustrate the phenomenon and consequences of limited liability in the simple setting of a second-price sealed-bid (SPSB) auction.\textsuperscript{3}

**Example 1** An agency uses an SPSB-auction to procure a project with 50% probability of being low cost 2 or high cost 4. There are many identical potential firms. If there is no limited-liability problem because firms have deep pockets (big budgets) so that they can fully accommodate losses without risking bankruptcy, then each firm will bid the expected cost of 3. In case of low costs, the firm makes a positive profit of 1, in case of high costs, the firm makes losses of 1 and the expected profit will be zero. If, on the contrary, firms have no budget and therefore cannot incur any losses at all, a payment of 3 will lead to bankruptcy with 50% probability. The expected profit of the firms will be positive: with a 50% probability costs will be low and firms make a profit of 1 while in the case of high costs they declare bankruptcy and make no losses at all. Competition among firms will drive the bids down to 2 and firms will make zero profits even if costs are low. Notice that this price reduction is not good news for the agency as additional costs will follow the bankruptcy: if the realized costs are high, the agency will have to search for a new firm to whom she will have to pay 4 to be able to complete the project (in addition to the higher payment, the

\textsuperscript{2}A famous example for such a behavior in the context of a selling auction was the sale of the C-block spectrum licences in 1996 by the US-Federal Communications Commission (FCC). Winners were allowed to delay their payment at a below-market borrowing rate. The revenue was $10.2 billion, much more than anticipated. However, soon after the auction many buyers did not make their payments and declared bankruptcy. Following the bankruptcy of the most aggressive firm NextWave, the company’s obligations were reduced from $4.74 billion to $1.02 billion. However, this ruling was overturned by an appeal court. In 2004, the case was finally settled, with NextWave receiving approximately 1/6 of the contracted spectrum for $504 million.

\textsuperscript{3}In the SPSB-auction the firm with the lowest bid wins the auction at a payment equal to the second-lowest bid. In this auction it is a weakly dominant strategy for firms to bid the opportunity cost of building the project.
agency suffers direct and indirect bankruptcy costs which also include transaction costs of renegotiation or re-auctioning the contract). Hence, in expected terms the costs for the agency are always higher under limited liability than under unlimited liability.

Example 1 is very simple; especially since all firms have the same cost structure. In general firms are heterogeneous. Besides rent reduction, one of the main advantages of using an auction for procurement projects is that an auction helps the agency to select the most efficient firm for the project. We add a modification to the first example to illustrate that limited liability may destroy this virtue.

**Example 2** Imagine the same situation as in example 1 with the following modification. All firms have a budget of 1 except for one firm which has a different cost structure: low cost of 2 but a high cost of 6. If there is no problem with limited liability, this inefficient firm will never win the auction as her expected cost and therefore her bid are above the others’. This changes with limited liability: the efficient firms will bid the expected cost of 3: in case of high costs they can compensate the losses of 1 with their budget of 1. The inefficient firm will also bid 3: with low costs she makes a profit of 1, with high costs her losses are limited to her budget, namely -1. Since all firms bid the same the inefficient firm has some possibility of getting the contract. In this case limited liability destroys the screening capability of the auction while allowing for the possibility of bankruptcy at the same time.

**Remark 2** If firms have similar budgets but different costs, limited liability may destroy the capability of the auction to select the most efficient bidder.

In example 2 an inefficient firm with a risk of bankruptcy has the same probability of winning as an efficient firm without a risk of bankruptcy. If we consider a situation in which firms differ in budgets, the situation could be much worse: the auction may not only fail in selecting the best firm; in fact, we show that it may select the worst firm, namely the firm with the highest probability of bankruptcy.⁴

Example 3 Consider our example 1 with the following modification: all firms have a budget of 1 but one firm that has a budget of 0. As explained before, firms with a budget of 1 will bid 3 and will never go bankrupt. However, the firm with the budget of 0 will bid more aggressively since she has less to lose in case of a high-cost realization. In fact, she will bid 2: with a 50% probability cost will be low and the firm makes a profit of 1 (as all the others bid 3, the payment will be 3); with a 50% probability costs will be high and the firm declares bankruptcy losing her budget of 0.

Remark 3 If firms have different budgets but similar costs, the firm with the lowest budget and consequently the highest risk of bankruptcy will also be the firm most likely to win the auction.

Example 3 describes a situation which is very common in procurement: on the one hand, there are a number of healthy firms (those bidding 3 in the example) that could always finish the project and bid around expected cost. On the other hand, there are some potentially insolvent firms that would win the auction by bidding clearly below a possible cost realization. These low bids are referred to as abnormally low tenders (ALTs).\(^5\)

2.2 Managing risky bids

A natural remedy for many economic problems is to increase competition. However, for ALTs and other situations where risk taking under limited liability matters, the motto "the more competition, the better" does not work. As more competition will reduce the payment this will naturally increase the probability of bankruptcy. Since the costs of bankruptcy are potentially very large, this reduction in price is bad news for the agency. Furthermore, in a situation in which firms have different

\(^5\)The intuition why less solvent firms bid more aggressively than more solvent firms is similar to a phenomenon in the corporate finance literature where limited liability causes shareholders of risk-neutral firms in financial distress to choose riskier projects. This phenomenon is called the gambling for resurrection strategy.
budgets (financial strengths) and the auction adversely selects the least solvent firm, the fiercer the competition, the more likely it is that the winning firm is a firm in a very bad financial situation. Consequently, competition might even aggravate the problem of ALTs. On the other hand, if firms differ in efficiency, competition is the main instrument to select the more efficient firms over the less efficient ones. Thus, there is a fundamental trade-off. There are basically three strategies for reducing the problem of ALTs: (i) Weakening competition to increase the procurement payment, (ii) designing the procurement process such that the probability of winning is higher for more solvent firms than it is for less solvent ones, and (iii) reducing the impact of bankrupt firms. In the following we discuss remedies based on these strategies for dealing with ALTs.

Choosing the right auction format

Since firms behave like risk lovers under limited liability the standard auction formats are no longer revenue-equivalent: they will deliver different payments and therefore different probabilities of bankruptcy and project non-fulfillment. To illustrate this we compare the bidding behavior in the English (which is strategically equivalent to the SPSB-auction) and the Dutch auction (which is strategically equivalent to the first-price sealed-bid (FPSB) auction). In both auctions the bidding behavior will be driven by the opportunity cost of undertaking the project. This cost includes the expected cost of finishing the project in case it is finished and the expected loss of budget in case of bankruptcy. It is important to notice that this opportunity cost will be optimistic for potentially insolvent firms since it is lower than the expected cost of the project in the absence of bankruptcy. However, the auctions differ in the way the payment is set. The English auction stops at a price when the second lowest bidder exits. Therefore, from an ex-ante point of view, the

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6 The English auction starts with a very high price which is lowered gradually until there is only one firm left willing to accept the price. The remaining firm is awarded the contract at the exit-price of the last firm that dropped out. In the Dutch auction the price is steadily increased and the first firm to accept the called price obtains the contract at this price.
payment is uncertain conditional on winning. In the Dutch auction the payment is the bid of the winning bidder; therefore, the payment is certain conditional on winning. As the limited-liability effect makes firms risk-loving, less risk means less utility and therefore the Dutch auction will generate less competition. Thus, firms will bid more aggressively in the English auction and as the bids are lower, the expected payment is lower as well. For this reason, the probability of non-fulfillment in an English auction is in general at least as high or even higher than in a Dutch auction. This insight can be generalized beyond the comparison of the English and the Dutch auctions. Procurement processes which lead to high uncertainty on the bidders’ side makes them behave more aggressively which increases the bankruptcy risk.

\begin{center}
\textbf{RULE 1} Avoid procurement processes which increase the uncertainty for the contractors.
\end{center}

However, in a procurement process there are other factors that can influence the choice of the auction format. For example, if there are common-value components in the cost structure, the winner’s curse problem arises and the English auction tends to outperform the Dutch auction. But more importantly, the ranking of the firms is again the same in the two formats. In other words, the winning firm will always be the firm with the lowest opportunity cost which could be the one with the lowest budget and the highest probability of bankruptcy. Hence, standard auction formats fail to select the healthy firms.

\section*{The truncated English auction}

We can adapt standard auction formats to specifically deal with the problem of ALTs. One possibility is to use a truncated English auction which works as follows: the procurement process will have two stages. In the first stage the procurement

\footnote{For more details see Board (2005), Parlane (2003), and section 3.2.}
payment will be determined. This is done via an English auction which is carried out until \( m \) (\( m > 1 \)) firms are left. The auction stops when the firm with the \( m + 1 \) lowest offer exits. Consequently, the procurement payment will be higher than in a standard English auction. In the second stage the final firm will be chosen. As further price competition in the second stage would increase the probability of non-fulfillment, the agency should—without negotiating any further—check the offers of the prequalified \( m \) firms in more detail (e.g., screening or due diligence) and award the contract to the most appropriate firm. In this case the agency has to invest screening costs only for a small number of firms and not for all. A rather simple selection procedure (with the same consequences on the payment) would be a lottery between the remaining firms. A lottery is a special form of rationing where at the given price the demand for contracts (the \( m \) firms) exceeds the supply (the single contract to be awarded).\(^8\) While a lottery is often referred to as a fair allocation process it can also mitigate the problem of ALTs. Following the logic from above, an English auction with rationing leads to a higher price and a lower probability of non-fulfillment than the standard English auction.

**Example 4** Five firms with zero budget and different costs enter an English auction for one input factor. Each firm has either high or low costs for the good as shown in the table below:

<table>
<thead>
<tr>
<th>Firm</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>low</td>
<td>2.5</td>
<td>2.8</td>
<td>3.1</td>
<td>3.4</td>
<td>3.7</td>
</tr>
<tr>
<td>high</td>
<td>3.0</td>
<td>3.3</td>
<td>3.6</td>
<td>3.9</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Each cost realization has a 50% probability. Each firm is willing to remain in the auction until the lower realization of the cost is reached. In the standard English auction firm A wins at the payment 2.8. As the realization of firm A’s cost can be 2.5 or 3.0 the probability that she goes bankrupt is 50%. Consider now a truncated English auction with \( m = 2 \). The auction stops as soon as the third lowest firm exits.

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\(^8\)Lottery as a rationing device is a common method in an environment with excess demand—for instance, equity IPOs and Central Bank Tenders. See Gresik (2001) or Gilbert and Klemperer (2000).
the auction. In this case, firms A and B will enter the second round and the payment will be 3.1. If the allocation procedure is a lottery, the probability that A wins is 50%. A’s probability of bankruptcy is 0 as the payment is always higher than the realization of the cost. B also wins with a probability of 50% and has a bankruptcy probability of 50% (cost is higher than the payment). Thus, the truncated English auction yields a lower probability of non-fulfillment (25% vs. 50%) at higher prices (3.1 vs. 2.8) than the standard English auction.

A drawback of this method is that the second round could be regarded as arbitrary. The mechanism loses transparency which is a major advantage of auctions. Moreover, while this mechanism reduces the probability of winning for less solvent firms, it does not give priority to more solvent firms.

**Multi-sourcing**

Risk diversification means that an agency ”should not put all eggs into one basket”. Using the same principle, the agency can reduce the risk of non-fulfillment by sourcing the contract to more than one firm. As an example, automobile manufacturers often use more than one supplier for their components. When multi-sourcing (also called share auctions or split-award contracts) is used, a contract will be split up into $m$ sources ($m > 1$) and $m$ firms will win a share of the contract. The advantage of multi-sourcing in terms of risk is the flexibility that a solvent firm can finish the lot of a bankrupt firm. The disadvantage is that the price is generally higher than with single-sourcing. For example, if the agency procures two equal shares, the two winners of the contract have to beat the third best firm. There is no competition among the winning two.\(^9\)

There are several issues to be addressed by multi-sourcing. One is to determine whether the environment is such that multi-sourcing is indeed risk reducing. In this context we discuss capacity constraints and the correlation between risks. The other issue refers to the degree of competition and the trade-off between price and risk.\(^9\)

\(^9\)For this and more results on the competition in multi-share auctions see Wambach (2002).
We give guidelines for the sharing rule, i.e. how many shares with what size should be contracted.

The major advantage of multi-sourcing from a risk management point of view is the flexibility to let a solvent firm finish a bankrupt firm's part. So, as a first step one needs to investigate if such a switch between firms is possible. Switching might be impossible (or very costly) due to capacity constraints on the side of the firms. If each of the two firms gets an order of 50% of the total volume, but they both can provide only say up to a maximum of 70% each, then the risk-reduction effect of multi-sourcing due to switching firms is very much reduced. Another problem occurs if the risks of the firms are correlated. For example, the risk of bankruptcy of firms in one country is to some degree correlated as these firms face the same political risks, the same business cycle, perhaps the same risk of suffering from an earthquake, etc. Thus, if one firm goes bankrupt, it is quite likely that the other goes bankrupt as well. As a consequence, if an intra-group correlation of risk is given (e.g., firms from the same country), the agency should source by means of different criteria (e.g., to firms from different countries).

Once the decision to do multi-sourcing is made, the agency has to decide upon the number and the size of the shares. In the example given (50/50), the expected payment is the third lowest bid. But the agency can do better than this, i.e. the agency can award the contract at a lower price with a similar probability of non-fulfillment. If the agency procure two unequal shares, say 70/30, the expected price of the whole contract will be lower. With the 50/50 sharing rule, the firms compete to be among the two lowest. With the 70/30 sharing rule, the firms not only compete to be among the two lowest but also to get the larger share. The (theoretically) best case of multi-sourcing therefore would be to award according to the following rule: the winner gets 100% of the share and all others get 0% of the share and if the first goes bankrupt, the second lowest can finish the whole project and so on. In that case, the price will be the lowest possible price as all firms compete as toughly as possible for the 100% share. Also the probability of
non-fulfillment is minimized as there are many potential firms who can step in to finish the project if necessary.\textsuperscript{10} This extreme case shows the trade off a sponsor faces: If switching costs are low, it pays for the sponsor to make the split between the shares larger to foster competition.

**Entry fees**

The agency can also introduce additional features in the procurement process such as entry fees. Entry fees were used, for instance, in most European UMTS spectrum license auctions.\textsuperscript{11} To see how entry fees work in a framework with limited liability consider the following: with respect to cost efficiency, firms with high costs and a expected profit lower than the entry fee do not enter the auction. Firms with low costs and a higher expected profit do enter. Thus, the more inefficient firms are excluded and due to less competition the payment is higher on average (ceteris paribus) which reduces the probability of non-fulfillment. But entry fees will also affect the bidding behavior: bidders with low wealth will not enter the auction if the fee is higher than the budget. However, the others that enter have to pay the fee and become poorer. This will lead to more aggressive bidding as they have less to lose and a higher probability of non-fulfillment. Thus, the effect of entry fees on the probability of non-fulfillment is ambiguous. As entry fees are paid in advance they are similar to the instruments we will discuss in the next section, namely letters of credit and surety bonds.

**Third-party guarantees: letters of credit versus surety bonds**

Another possibility to deal with the risk of bankruptcy and contract non-fulfillment is to require guarantees from the firms. These guarantees are meant to compensate the agency in case of default and are only provided by the winning firm. However,

\textsuperscript{10}Surely this extreme case is not easy to implement but it is done occasionally.

\textsuperscript{11}Taken literally, entry fees are monetary fees that firms have to pay for the right to participate in the auction. However, entry fees can also be interpreted as any cost of preparation for the bidding process. Examples are the construction of a prototype, investment in qualification for the contract or internal costs for the calculation of the project’s cost.
all potential firms know before the procurement auction which type of guarantee is required by the agency and negotiate the potential fee for the required guarantee before the actual bidding takes place. Only the winning firm actually pays the fee and deposits the guarantee once awarded the project. During construction the winner learns the true costs of the project. She either finishes the project on her own (if costs are not too high) or the sponsor is compensated according to the guarantee.

The most common forms of guarantees used in practice are cash guarantees or letters of credits and surety bonds. The exact nature of a letter of credit and of a surety bond varies in different countries. To facilitate the discussion we will therefore define what we mean by each type of guarantee. We will use the definitions that make these two instruments for dealing with ALTs as distinct as possible.\footnote{To learn more about letters of credit and surety bonds see Calveras et al. (2004). The functioning of surety bonds in practice (mainly in the US) is described in Donohue and Thomas (1996) or at the surety information office (http://www.sio.org). The European and in particular the Spanish regulation how to deal with ALTs is discussed in Calveras et al. (2002).}

**Definition 1** A letter of credit (typically issued by a bank) is a cash guarantee to the owner. The letter of credit is secured by pledging sufficient assets from the firm. If the letter is rightfully called upon by the owner before its expiring date, the owner receives the amount specified in the letter as a cash payment. The fee the firm has to pay to obtain a letter of credit depends on the size of the letter but is identical for all firms.

**Definition 2** A surety bond (typically issued by a surety company) is a guarantee that the firm will perform the obligation stated in the bond. Surety bonds are secured by the financial strength (assets) of the surety company. No assets of the firm are pledged. In case of default, the issuer of the bond (the surety company) has two options: it can either take up the contract (complete the project) or pay the amount specified in the bond to the sponsor. The fee the firm has to pay to obtain the surety bond is firm-dependent.

According to these definitions issuing a letter of credit is a riskless activity for the bank. The task of the bank is to pledge sufficient assets from the firm and to
check, should the letter be called upon, that this call is correct. Issuing a surety bond is risky: the surety company compromises its own assets and therefore has incentives to screen the firm, i.e. it will try to learn about the efficiency of the firm and his financial strength. The advantage of the surety firm over the sponsor for doing this screening comes not only from specialization but also from the possibility to use soft information to assess the firm’s quality. To issue the bond the surety company will request a fee from the firm which is determined individually for each firm and depends on the firm’s risk of bankruptcy. The higher the risk, the higher the likelihood that the surety might have to intervene and hence the higher the fees.\footnote{As we said before there exist intermediate instruments like letters of credits in which banks do not require collateral and behave more like surety companies. In that case a letter of credit would be close to the surety bond and will achieve a similar result.}

How do these different guarantees affect the firm’s bidding behavior? Letters of credit pledge firms assets and thereby exclude firms with a lower budget than the one required by the letter from the bidding process. But at the same time letters of credit diminish the financial strength of the remaining firms: fewer assets are available for completing the project.\footnote{This arguments requires that at least some of the pledged assets cannot be used in production. Typically, these assets are liquid and remain deposited in the bank.} By reducing their financial liquidity letters of credit can convert good firms into potentially insolvent firms with some risk of bankruptcy. Moreover, if the required letter of credit is of a fixed size, among those firms who can afford the letter of credit, the lowest bid will still be from the firm with the lowest budget and therefore the highest risk of bankruptcy. To see this point, we assume that all firms are equally efficient. The sponsor requires a letter of credit of size $L$. We also assume that pledged assets cannot be used in production. In this case, all firms with assets less than $L$ will be excluded from the auction while each remaining firm’s accessible assets will be reduced by $L$ and each firm will bid more aggressively according to these accessible assets. Since the firm with the fewest assets has the least to lose, its bid will be the lowest.

On the contrary, a surety bond lowers the risk of bankruptcy by making the
surety company co-responsible for the completion of the contract. The surety company influences firm’s bidding behavior by conditioning the fees required for the bond on their financial situation. A worse financial situation implies a higher opportunity cost for issuing the bond and therefore a higher fee. Since the fees are passed to the sponsor, all bids will be higher. But, due to higher fees the bids of less solvent firms are increased by more than of more solvent firms. This partially counterbalances the effect that less solvent firms bid more aggressively since they have less to lose. Logically, firms with a worse financial status (lower budget) have to pay a higher fee, since it is riskier for the surety to issue the bond. Therefore, firms with lower budgets have to raise their bid to recover the fees and get some profits. This reduces the probability of ALTs. This implies that the probability of bankruptcy is reduced and sometimes even completely eliminated. Moreover, some potentially insolvent firms are converted into solvent firms from the sponsor’s point of view. The surety will finish the project if the firm gets into financial difficulties whenever the bond is larger than the missing budget for finishing the project.

While surety bonds mitigate and sometimes even eliminate the problem of abnormally low tenders, letters of credit tend to worsen it. Therefore,

| Rule 2 | Default insurance/surety bonds (which involve risk taking, screening, and individual fees): YES; default deposits/letters of credit (which involve no risk taking and the same fee for all): NO |

If firms are free to choose the guarantee themselves, it is unlikely that they choose the socially efficient one, since they have no incentives to internalize the externalities inflicted on the administration by their choice. In countries where surety bonds are not well developed, the fee for a surety could be very high and a construction firm might prefer to present a letter of credit since it has lower costs and consequently permits a more aggressive bid. The sponsor should therefore not just require any

\footnote{This strong claim is done according with the above definition of letters of credit and surety bonds.}
kind of guarantee from firms but a surety bond. However, since the price of the bond is passed onto the sponsor, the question arises how sureties set the price and how it depends on the organization of the market for surety bonds. Moreover, the argument in favor of surety bonds assumes that surety companies actually fulfill their obligations should the firm default. This requires some regulation on who can act as a surety and the organization of the surety’s collateral.

**RULE 3** Only use surety bonds if the regulatory setting guarantees that surety companies have sufficient financial strengths to fulfill their obligations.

What should this regulatory setting look like? It will be very similar to the regulation of banking and other financial institutions. Competition is a desirable goal but protecting the rights of the less informed party (customers of the bank or the sponsor in our setting) is a MUST. Hence, the regulatory framework has to guarantee that surety bonds are riskless for the sponsor. This discussion leads us to a more general question why regulating sureties is better than regulating bidders directly.

It is easier to regulate sureties than bidders for several reasons: (i) there are fewer sureties than bidders. (ii) The financial strength of a surety is easier to observe: the accounting of the surety captures most of the relevant information while in the case of the bidder the complexity of the technology and pre-existing commitments is also relevant. Hence, screening the bidders requires to rely on soft information and it is difficult to characterize efficient regulatory rules. Finally, given the complementarity of the surety business with the financial business in general there should be regulatory synergies.

To illustrate the previous discussion we will briefly describe the organization of the market for surety bonds in the US where surety bonds are commonly used and are legally required for all Federal construction contracts over $100,000 (Miller act).

In the US the Treasury approves a list of corporate sureties. For each corporate surety the Treasury determines its financial strength and sets an underwriting limit, also called bonding limit. This limit states the maximum amount of money that can
be compromised in surety bonds by the company and thereby guarantees the firm’s financial soundness. However, only few firms will be able to issue large bonds, hence competitiveness of the surety market decreases with the size of the bond. Three measures are taken to mitigate this problem: (i) co-bonding is allowed, i.e. for very large projects smaller bonds are issued by several surety companies. (ii) A corporate surety company can compete for a too large bond since it can exceed its bonding limit by contracting surety bonds from other surety companies that ensure the too large bond it has issued. (iii) Competition is increased by allowing individuals and non-approved companies to act as a surety. In order to do so, they need to pledge certain assets (cash, readily marketable assets or irrevocable letters of credit) in the amount of the bond. This last measure has the drawback that individuals might lack the necessary experience to screen firms and might therefore assess firm’s bankruptcy risk badly. Screening should be left to specialized firms whose experience allows to reduce screening costs and improve the efficiency of screening tools.

Bonding limits or cash guarantees are necessary to avoid default by the surety but they necessarily reduce the competitiveness for large surety bonds to some extent and thereby increase its price. This leads to the question on the optimal size of the bond. This question is important even if there was perfect competition for every bond size. We assume that there is some opportunity cost for issuing the bond. This implies that even the completely solvent firm will have to pay some fee for receiving the bond. Therefore, it is costly for the sponsor to increase the size of the bond.\(^{16}\) On the other hand, a higher bond improves the solvency level of the winning firm in two ways: (i) if the bond is very large, the surety will always prefer to finish the project than paying the bond. (ii) the potentially insolvent firm have to pay a higher fee to receive the surety bond. The larger the bond, the larger this fee: hence the larger the probability that the winning firm will be a solvent firm.

The optimal size of the bond for the sponsor is a trade-off between increasing the

\(^{16}\)This opportunity cost of the surety bond lies between zero and the riskless interest rate. This two extreme scenarios have been analyzed by Engel et al. (2005c) and Calveras et al. (2004) respectively.
price and increasing the expected solvency of the winning firm. From this trade-off we can conclude that the optimal size of the bond will depend on the riskiness of the project: it increases with the underlying uncertainty and the costs of bankruptcy and decreases with the solvency level of the industry - since firms are financially stronger.

**RULE 4** Increase the size of the surety bond with the riskiness of the project where riskiness is captured by the underlying uncertainty and the sponsor’s costs of bankruptcy.

In general it might be difficult to get a precise estimate of the underlying uncertainty of a project and consequently it could be difficult to set the size of the optimal surety bond. However, a broad classification of projects according to their uncertainty should be possible. For example, the sponsor should require lower bonds for projects that have been undertaken in a similar way many times before and a larger bond for innovative projects where there is little historical experience. This broad classification will improve the existing regulatory mechanism for fixing the size of the surety bond. For example, the US system requires a bond equally to the price of the project. This system has its weakness because it links the size of the bond to the expected costs of the project which can be easily improved. Think for example of two projects: one is very costly but basically riskless and one has a lot of uncertainty but it is considerably cheaper. The US system puts a higher surety bond on the first project, while the optimal system would require the opposite: the second project is riskier and therefore the bond for the second project should be higher.

### 2.3 How not to deal with ALTs

In this section we discuss some commonly used procurement rules to prevent ALTs that can have unintended negative consequences. We first discuss attempts to identify ALTs and exclude them from the auction. We then turn to the average-bid
method and to explicitly supporting weaker firms.

Mechanisms to identify ALTs

The working group on ALTs in the European Union suggested a statistical method for identifying ALTs. It consists of a statistical analysis of former bids offered for similar projects. The idea is to infer from past projects with similar characteristics what an ALT is in the present contest. We do not recommend this mechanism mainly due to two drawbacks: (i) What was efficient or possible in the past need not be efficient today. Also many public projects are highly idiosyncratic and therefore it will be difficult to find projects that serve as a reference point. More subtle is the second drawback: (ii) If such a rule leads to different treatments of bids submitted, firms will presumably bid differently which in turn changes what should be considered an ALT. Take, for instance, a method that is used in many countries\textsuperscript{17} which defines a tender as abnormally low if it lies a certain percentage below the average of all bids or below the second lowest bid. Such tenders are either automatically excluded or checked in detail before exclusion.\textsuperscript{18} However, the mechanism fails to be successful since it has strategic effects on the bidding behavior. Anticipating exclusion, firms will bid higher. It is also not guaranteed that a financially healthy firm is chosen. Indeed, less solvent firms will not be excluded from bidding in the auction. The intuition is the following: less solvent firms can always reproduce the bids of financially healthy firms (since their minimum bid is higher) and hence become indistinguishable from the financially healthy firm. While the probability of non-fulfillment is reduced due to a higher payment, the auction does not exclude firms with the higher probability of bankruptcy from the auction. This insight is discussed in more detail in the next section.

\textsuperscript{17}E.g., Italy, Belgium, France, Portugal, Romania, and Spain.
\textsuperscript{18}Usually, the firm is automatically excluded but has the opportunity to justify its bid and be readmitted if the justification is satisfactory. In practice readmission is very rare.
Average-bid method

Excluding abnormally low bids from the auction is similar to the average-bid method where the average bidder wins the auction. Such a method or similar methods were used in Italy, Peru, and Taiwan. Alternatively, one might think of taking the second lowest bid to be the winning bid as the appropriate procurement rule (as reported to us being used in Switzerland). Again firms’ bidding behavior will be affected by this change in rules. In a procurement environment with a rule that specifies that the second lowest bid (or the average bid) wins the contest, no one will want to deliver a low bid. As this is anticipated every firm will raise its bid even further which might lead to very high bids. Bankruptcy might be eliminated but at a very high price.¹⁹

The line of argumentation for the average-bid method works in a similar way. Suppose every firm bids the same high price, then everyone makes the average bid, and everyone has the same chance of winning the contract. And if one wins, one will make a decent profit as the price is quite high. Offering any other bid implies moving away from the average; thus, the firm will lose the contest for sure. Bidding this price therefore is an equilibrium. As everyone tries to be just average this will take the competition out of the contest. These attempts to deal with ALTs lead to undesirable result as it pays not to be among the lowest firms. In general these designs will result in lower (or zero) bankruptcy rates but at very high prices.

**RULE 5** Do not design your procurement such that it pays not to be among the first.

¹⁹The following story about cycling nicely illustrates how. In the quarter final of the individual pursuit World Championships in Milan in 1955, the Dutch sprinter Jan Derksen had to compete with the Italian Antonio Maspes. After the first round, Maspes was in first position and Derksen had the advantage of the windbreak in which he needs about 20% less energy. With the disadvantage of being first, Maspes stopped and tried to force Derksen to the first place but the latter also stopped. After 32 minutes and 20 seconds without moving the officials stopped the race. After it was started again, Maspes won the race. As it turned out, the desire to be second and not first made the cyclists move very slowly.
One issue which complicates this analysis even further is the possibility of fake bids. In some cases, the agency does not control who offers a bid and how many bids someone offers. If the rule is such that the average bid wins, it may pay for a firm to offer one extremely high bid to raise the average and then a second bid close to the expected average. Fake bidding, also known as shill bids, is very hard to analyze theoretically. However, as the strategic behavior in an auction with shill bidding is very complicated to determine it does not seem to be a good advice to design the procurement process such that shill bids might become attractive.

**Subsidizing weaker firms**

The agency might have some information about what firm might be a weak firm (e.g., the local firm, a small or medium-sized enterprise, etc.) which has less financial means. Supposing that the agency wants to keep the weaker firm in the contest, either for political reasons or to foster competition, one might argue that in order to lower the risk of bankruptcy of the weaker firm, it is useful to subsidize it. This subsidy can be a price preference, a bonus or a discount. Such a scheme is used, for instance, in some countries which favor firms by giving them discounts (e.g., the Buy American Act in the US public procurement gives domestic firms a discount of 6% and small domestic firms a discount of 12%). This rule is, at first glance, risk reducing—subsidizing a weak firm will make it go bankrupt less often. However, a closer look at the consequences shows that a subsidy has three effects on the outcome, two of which might increase the risk for the agency. The positive effect is that as the subsidy is paid in case of winning to the weak firm, the supported firm has to cover less costs. Thus, the supported firm goes bankrupt less often. The two negative effects are as follows. First, as the subsidized firm can bid lower than she could without the subsidy there is more competition in the contest and prices are generally lower.\(^{20}\) Following the logic of section 2.2 (means to weaken competition reduce the risk), using a subsidy which fosters competition will increase the risk of

\(^{20}\)This is the argument brought forward by McAfee and McMillan (1989) to justify the use of the Buy American Act as it leads to lower prices.
bankruptcy. Thus, this effect is good in terms of lower prices but it is does not improve the outcome from a risk perspective. Second, as the subsidy makes the weak firm more aggressive, it can be the case that a weak firm only wins because of the discount. Then, a less efficient and less solvent firm wins over a more efficient and more solvent firm which is again bad news for the agency. As the two negative effects can offset the positive effect, subsidizing weaker bidders does not help reduce the risk of bankruptcy.\(^{21}\) As subsidizing weaker bidders makes them bid even more aggressively this increases the risk of bankruptcy.

RULE 6 In the presence of limited liability do not subsidize weaker competitors.

2.4 Conclusion

In this chapter we have explained why low bids can be bad news for the agency. Potentially insolvent firms protected by limited liability bid very aggressively for a project with uncertain costs since they have little to lose in case of bankruptcy. If the costs turn out to be low, they make profits; however, if the costs turn out to be high, their losses are limited since they close down the firm. This aggressive bidding behavior, known as the problem of ALTs, leads to a high risk of bankruptcy and contract non-fulfillment and destroys the screening capability of auctions to select the most adequate firm. Moreover, strong competition can even worsen the outcome. On the other hand, some competition might still be necessary to select a more efficient firm and to keep prices under control.

The potential remedies for this problem try to reduce the risk of bankruptcy by increasing the procurement payment and by designing the procurement mechanism such that the more solvent firm is selected. They also try to reduce the impact of bankruptcy for the agency. Increasing the payment is an easy task: measures like minimum bids or an auction format which weakens competition (as the truncated

\(^{21}\)See chapter 4 for more details.
English auction) might be appropriate. Designing the mechanism to select the right firms is more difficult. While a standard auction is likely to select the firm with the lowest budget most of the remedies (entry fees, truncated English auction) eliminate this bias in favor of the less solvent firm but do not select a healthy firm for sure. The cost of the agency in case of bankruptcy might be reduced by letters of credits or multi-sourcing. But these instruments also have drawbacks. Multi-sourcing is not always possible and in case of capacity constraints or correlation between firms might not be risk reducing. Letters of credits tend to worsen the financial situation of competing firms and might convert some good firms into potentially insolvent firm.

While there does not exist any perfect remedy for ALTs, a surety bond seems to be a fairly good remedy: screening is delegated to the private sector (some surety company) that is made co-responsible in case of bankruptcy. The surety company will base the surety fee on the financial status of the firm and might even deny the bond to less solvent firms. The fees for the bond are higher for less solvent firms whose bids are therefore increased considerably. Hence, the bias of the auction towards less solvent firms is reduced. Moreover, if the firm runs into financial difficulties, this does not necessarily imply non-fulfillment for the agency because the surety company might finish the project. Otherwise, the costs of bankruptcy are reduced by the size of the surety bond. Surety bonds thus combine the three potential ways to reduce the problem of abnormally low tenders.
Chapter 3

A simple model of limited liability

3.1 Introduction

Procurement auctions are an important mechanism in the public and private sector to buy goods and services. But many projects—especially in the construction industry—are delayed or more expensive because of the bankruptcy of contractors. For example, more than 80,000 contractors went bankrupt in the United States in the period between 1990 and 1997, leaving unfinished private and public construction projects with liabilities exceeding US$ 21 billion.\(^1\) The direct costs of bankruptcy (e.g., lawyers) make up 7-20\% of the liquidation proceeds and the indirect costs (e.g., delays) are estimated to be even higher.\(^2\) Bankruptcy arises if the payment and therefore the firm’s bid lies below the realization of the cost of the project. The reason why firms bid so low can simply be an overoptimistic or wrong calculation or, as we show, the right to file for bankruptcy (due to limited liability).\(^3\) As the firm can declare bankruptcy to avoid losses if the project is going bad and makes

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\(^1\)Dun and Bradstreet Business Failure record, cited from Calveras et al. (2004).

\(^2\)For details see White (1989). The recovery rate in the high-income OECD states is 72\% (Worldbank, 2004).

\(^3\)If it is very costly to replace the winning contractor, the procuring agency can renegotiate the contract at additional cost (cost overrun). Anticipating renegotiation, firms in turn will bid more aggressively. The magnitude of cost overruns varies, from an average of 22\% for the largest Spanish public works projects (Ganuza, 1997) to more than 220\% in a sample of US-defence contracts (Peck and Scherer, 1962). Cost overruns are analyzed in Lewis (1986), Arvan and Leite (1990), Ganuza (2003), and Bajari and Tadelis (2001).
profits otherwise, it pays to bid more aggressively. Thus, a very low bid might not be good news for the agency as it implies a higher risk of bankruptcy. This problem is also mentioned in a recent report of the European Commission’s Enterprise section (1999) which accentuates that "clients often underestimate ... the risks of abnormally low tenders (ALTs), especially the possibilities of bankruptcy and failure of enterprises...". In this chapter we define ALTs as bids that lead to a positive probability of bankruptcy of the winning firm. Although contract non-fulfillment seems to be an important factor in practice, most theoretical models ignore the fact that firms have limited liability and face the risk of bankruptcy before the completion of the project. We therefore take explicit consideration of the possibility of bankruptcy and analyze the bidding behavior in different procurement mechanisms in an environment with cost uncertainty. By comparing standard auction formats and common modifications of standard auctions, we show that means to weaken competition might lead to better results than the standard auctions. We also show that frequently used ways of dealing explicitly with the problem of ALTs lead to undesirable results if they are such that it pays not to be among the lowest bidders. Extending the analysis, we investigate reserve prices and entry fees. Furthermore, we show that cost-plus contracts might be preferred. Finally, we discuss how the standard auctions fare under asymmetries and common costs and give an example of how limited liability may offset the effect of risk aversion.

In the model we use, firms (bidders) have ex-ante uncertainty about their cost. The reason for this can be the uncertainty about the cost of the project in general, errors in the calculation or financial need, either caused by preceding projects or by projects still in process.\footnote{Arditi et al. (2000) investigate the factors associated with company failures in the US construction industry. Human issues like lack of knowledge explains 7.5% of company failures, budgetary issues like heavy operating losses and insufficient profit explain 60.2% of the failures.} After the auction, the winning bidder sees the realization of the cost which can be high or low. If the payment is higher than the realized cost, the winning bidder makes a profit; if not, he declares bankruptcy. In our framework, bidders have no budget as our focus is on the effect that different efficiency
levels have on the bidding behavior under limited liability. Hence, one could say that we investigate the bidding behavior of firms that are close to ruin. If bidders differ also in budgets, a second effect would arise, namely that the bidding behavior differs also with respect to the size of the budget (see example 3). The option to declare bankruptcy makes the bidding more aggressive as it reduces the losses if costs are high.\textsuperscript{5} Hence, prices turn out to be lower than under unlimited liability. As bidders' losses are limited but their profits are not, the utility function becomes convex and this makes bidders behave like risk-lovers. By comparing the standard auctions, we obtain that the allocations in a first-price sealed-bid and a second-price sealed-bid auction are still efficient. Furthermore, we show that—for the case of a sufficiently large number of bidders—the expected payment in both auction formats is the same but as the distributions of the payments differ, the probability of non-fulfillment differs too. Thus, the revenue-equivalence theorem breaks down in spite of identical expected payments. Going beyond the standard auctions, we show that multi-sourcing, rationing, lotteries, and other means to soften competition lead to better results for the procurement agency. Furthermore, while entry fees lower the probability of non-fulfillment (ceteris paribus) reserve prices lead to an increase. This result is also in contrast to the standard auction literature where these two features have equivalent consequences.

However, explicit ways of dealing with ALTs like average-bid methods and other mechanisms where it pays off for bidders not to be the lowest bidder lead to undesirable results. For instance, the Public Works Directive of the European Union lays the rules on how European governments have to procure. While governments are generally obliged to buy from the lowest tender\textsuperscript{6} explicit consideration of the problem of ALTs is also given: "§4: If, for a given contract, tenders appear to be

\textsuperscript{5}One could argue that if bidders have private information about the quality then only the lowest quality is offered. This would be in line with Manelli and Vincent (1995) who show that take-it-or-leave-it offers fare better than auctions in respect to quality. The effect that auctions favor the lowest bid (and the corresponding low quality) is reinforced by limited liability.

\textsuperscript{6}Article 30 PWD (Public Works Directive 93/37/EEC (1993)) of the European Union says "1. The criteria on which the contracting authorities shall base the award of contracts shall be: (a) ... the lowest price only;...".
abnormally low in relation to the works, the contracting authority shall, before it may reject those tenders, request ... details of the constituent elements of the tender which it considers relevant and shall verify those constituent elements taking account of the explanations received.” As a result, in order to deal with the problem of ALTs and the non-fulfillment of contracts some countries have explicitly defined what will be taken as an ALT and should be rejected. Bids are called abnormally low if they are a certain percentage below the average bid or sometimes abnormally below the second lowest bid. But if such rules lead to different treatments of submitted bids, bidders will anticipate the exclusion and will bid higher which in turn changes what should be considered an ALT. Other countries have adapted their procurement design, especially their allocation rules. As an example, Taiwan is reported to have used a design where the bid closest to the average bid wins the contest. As everyone wants to be average, no one will place a low bid. We show in our analysis below that several of these reported ways of tackling the problem of ALTs and bankruptcy lead to undesired consequences as these rules will not only affect the allocation but will also have strategic effects on the bidding behavior.

Related literature

There are just a few papers which analytically discuss the relation between limited liability and auctions. Zheng (2001) shows in the context of a common-value selling auction that if bidders are budget constrained, the value of the object auctioned is uncertain, and the payment can be postponed, it may be the case that the most budget constrained bidder is the bidder most likely to win the auction. The reason is that if a bidder declares bankruptcy, he will loose his entire budget. As these costs of bankruptcy are smaller the smaller the budget, the bidder with the lowest budget might well be the bidder with the highest interest in winning the object and

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7 About 10-20% in Belgium, France, Italy, Portugal, Romania, Spain, and Greece.
8 A different way of avoiding ruinous competition was used in the Netherlands where a pre-procurement with all firms and with the disclosure of all bids took place, allowing firms to withdraw their bid if it was obviously a too optimistic calculation (Lupp, 1993).
therefore the bidder with the most aggressive bid.

The paper closest to this chapter is that of Parlane (2003). In her article, individual cost uncertainty is modelled as a general distribution with a continuous distribution density on a bounded support. She shows that the expected procurement price is higher in an FPSB-auction than in any other efficient mechanism where only the winner pays. The intuition for this result is straightforward: as the possibility of bankruptcy leads to a convex utility function, bidders behave as if they were risk-loving. Only in an FPSB-auction the winning price (conditional on winning) is certain. Any other mechanism leads to uncertainty in the winning price which makes bidders bid more aggressively.

Board (2005) uses a mechanism design approach in a similar framework as Parlane (2003), although he considers a selling rather than a procurement auction. He argues that limited liability makes the bidding more aggressive by cutting off the downside loss. Board shows that the expected selling price is higher under limited liability than under unlimited liability. He also shows that the FPSB-auction leads to the lowest expected selling price of all standard winner-pays auctions and he outlines conditions under which the FPSB-auction will lead to the lowest probability of non-fulfillment. Furthermore, he investigates wealth effects and shows that the bids decrease in wealth, an effect which was also shown by Waehrer (1995).

To our knowledge, we are the first to discuss the effects of different procurement mechanisms beyond the standard auctions in a framework with limited liability.

In an experimental paper, Roelofs (2002) investigates a common-value auction with default. In his framework, default gives the winner an opportunity to avoid the winner’s curse, i.e. limited liability works as an insurance against the winner’s curse. The experiment shows that the possibility of default leads indeed to more aggressive bidding.

Calveras et al. (2004) analyze the use of surety bonds and letters of credits and discuss to what extend these instruments can help to eliminate the problem of ALTs. They show that, if a surety company is specialized in screening applicants, surety
bonds can indeed be useful instruments to mitigate the problem of ALTs.

In a different context without limited liability, Bulow and Klemperer (2002) show that rationing and/or multi-sourcing can be revenue enhancing. Their result was derived in a framework with common values and asymmetric bidders. As multiple shares reduce the impact of the winner’s curse, it leads to less cautious bidding and hence to a higher revenue than a single source. Limited liability gives an alternative explanation why these mechanisms might be preferred to a standard auction.

The chapter is structured as follows: in section 3.2 the model is described and the results for the SPSB- and FPSB-auction are derived. In section 3.3 we discuss reported ways of dealing with ALTs. Then, we analyze other alternative procurement methods including reserve prices and entry fees in section 3.4. In the following section 3.5, we discuss if cost-sharing or cost-plus contracts might reduce the impact of limited liability. The last sections deal with asymmetries and common costs (section 3.6) and a discussion of industrial organization related topics (section 3.7). Section 3.8 concludes.

3.2 The standard auctions under limited liability

A risk-neutral procurement agency has one tender contract to offer. There are \( n \) potential risk-neutral bidders (indexed by \( i \)) with costs of either \( c_i \) or \( c_i + \Delta \) (with a probability of \( \rho \) and of \((1 - \rho)\) respectively (with \( 0 < \rho < 1 \)). The cost term \( c = c_i \) is distributed on the support \([c, \overline{c}]\) and is identical for all bidders. We denote \( F(c) \) as the distribution and \( f(c) = F'(c) \) as the density of the cost term.\(^9\) It is assumed that \( \Delta \) is smaller than the differences in cost levels \((0 < \Delta < (\overline{c} - \underline{c}))\).

The order of events is as follows: (1) The agency announces the auction rules and defines the specifications of the project. While bidders know their individual cost term \( c \) at this stage, they do not know if they have to incur the additional cost of \( \Delta \) later on. (2) Bidders bid in the auction. A winner is declared according to the auction rules who receives a payment \( p \). Losing bidders have a payoff of zero. If

\(^9\)The realization of the cost is bounded on the support \([\underline{c}, \overline{c} + \Delta]\).
the bidder with the lowest cost term wins, we call this allocation efficient. (3) The
winner observes his realized cost and either makes a profit if the payment is higher
than the realized cost, or he decides to declare bankruptcy otherwise. To avoid
multiplicity of equilibria later on, we assume that, if a bidder goes bankrupt, he has
to bear small costs of bankruptcy $\epsilon$. Thus, if a bidder with cost term $c$ wins the
contract at payment $p$ (or the price from the agency’s point of view), his expected
payoff is given by

$$
\pi = \begin{cases} 
(p - c) - (1 - \rho)\Delta & \text{if } p \geq c + \Delta \\
\rho(p - c) - (1 - \rho)\epsilon & \text{if } c \leq p < c + \Delta \\
-\epsilon & \text{if } p < c.
\end{cases}
$$

(3.1)

The expected utility of the procuring agency is given by

$$
u(p, \phi) = (1 - \phi)(v - p) - \phi B
$$

(3.2)

where $v$ is the valuation for a project successfully implemented and $B$ are the costs
the agency has to bear in case of non-fulfillment. $\phi$ is the probability that the
winning bidder goes bankrupt. As we show next, this probability depends on the
procurement mechanism used.

**Second-price sealed-bid auction**

In an SBSB-auction, the contract is awarded to the bidder with the lowest bid and
the payment is the second lowest bid.

---

10 It is important that the agency has to stick to the rules set in (1) and there is neither renegotiation nor resale.

11 This costs can also be interpreted as the loss of a budget of size $\epsilon$.

12 We use a very simple form of the agency’s bankruptcy costs, namely additional costs like delays, other accountable costs or costs of re-auctioning. One could ask what happened to the money paid (e.g., half-finished project left with some value to the agency) but this is not part of our analysis. For an analysis of different recovery rates of half-finished projects see Board (2005).

13 If the cost realization is observable and verifiable, the optimal mechanism would be to give the winning firm $\Delta$ in case of high costs. But as the real costs are not verifiable, this rule would lead to a different bidding behavior and non-truthful reports about the real costs.
Proposition 1 In an SPSB-auction, in the limes of $\epsilon \to 0$, it is a weakly dominant strategy for each bidder to bid his cost term:

$$\beta_{SPSB}(c) = c$$

Proof The proof is straightforward and follows textbook analysis. The small costs of bankruptcy $\epsilon$ are assumed such that no bidder has an incentive to bid less than $c$. Assume that bidder $i$ bids $b_i = c_i$ and the lowest competing bid is $b^{(2)} = \min_{i \neq j} b_j$. Bidder $i$ wins if $b_i < b^{(2)}$ and does not win if $b_i > b^{(2)}$ which gives him zero payoff.\(^{14}\)

The expected payoff if he wins is $\rho E[b^{(2)} - c_i] + (1 - \rho) E[(b^{(2)} - c_i - \Delta \mid b^{(2)} > c_i + \Delta)] - E[(\epsilon \mid b^{(2)} < c_i + \Delta)]$ which is larger than zero for $\epsilon$ small enough. Suppose now that he deviates from bidding $b_i = c_i$ and bids $z_i > c_i$. If $b^{(2)} < c_i < z_i$, he still gets zero payoff; if $c_i < z_i < b^{(2)}$, he still gets the same payoff as bidding $c_i$; and if $c_i < b^{(2)} < z_i$, he losses whereas a bid of $c_i$ would have won yielding a positive expected payoff. Now consider he bids $z_i < c_i$. If $b^{(2)} < z_i < c_i$, he still gets zero payoff; if $z_i < c_i < b^{(2)}$, he still gets the same payoff as bidding $c_i$; and if $z_i < b^{(2)} < c_i$ he wins and always goes bankrupt yielding a payoff of $-\epsilon$. Thus, deviating from bidding $b(c_i) = c_i$ never increases his payoff but sometimes decreases it.\(^{15,16}\)

Thus, in an SPSB-auction, the bidder with the lowest cost term wins the contract, i.e. the sourcing is efficient. In the SPSB-auction the winner receives the second lowest bid as the payment which is the expectation of the second lowest order statistic. This is given in the following equation, with $f_i(c)$ as the density of the $i$th lowest

---

\(^{14}\)Because $f(c)$ is continuous we neglect ties.

\(^{15}\)We assumed that bidder $i$ knows the lowest competing bid. But the proof does not change if the lowest competing bid is random with some density function $f(\cdot)$. The proof is a standard Bayesian argument (e.g., see Matthews, 1995), working with expected profits. Note that the bidding strategy, the expected price, and the probabilities of bankruptcy would be same in an English auction.

\(^{16}\)The proof above must be slightly modified if the agency never pays more than $\tau$ or the reservation price is $r \leq \tau$. In this case the bidder with cost term $\tau$ receives his bid as the payment and this would give him always a payoff of $-\epsilon$ if he wins (which is with probability zero). So bidding anything above $\tau$ is an optimal bid for this bidder. But since he never wins, his expected payoff is zero and so we let him bid $\tau + \epsilon$. 

order statistic and \( c^{(i,n)} \) as the \( i \)th (lowest) order statistic out of \( n \) draws:

\[
E[p_{SPSB}(c)] = E[c^{(2,n)}] = \int_{\xi}^{\bar{\xi}} c f_2(c) dc
\]

\[
= \int_{\xi}^{\bar{\xi}} n c(n - 1) F(c)(1 - F(c))^{(n-2)} f(c) dc. \tag{3.4}
\]

From the contracting agency’s point of view, the probability that the contract will not be finished is equal to \((1 - \rho)\) times the probability that the second lowest cost term (payment) is less than \( \Delta \) away from the lowest cost term. Formally, the latter term is the probability that \( c^{(2,n)} - c^{(1,n)} < \Delta \):

\[
Prob[c^{(2,n)} - c^{(1,n)} < \Delta] = \int_{\xi}^{\bar{\xi}} f_1(c) \int_{c}^{c+\Delta} f_2(z \mid z \geq c) dz dc
\]

\[
= \int_{\xi}^{\bar{\xi}} \int_{c}^{c+\Delta} n(n - 1) f(c) f(z)(1 - F(z))^{(n-2)} dz dc \tag{3.5}
\]

with \( f_2(z \mid z \geq c) \) being the density of the second lowest order statistic conditional on \( c \) being the lowest order statistic.\(^{17}\) Thus, the probability of non-fulfillment is given by

\[
\phi_{SPSB} = (1 - \rho) \int_{\xi}^{\bar{\xi}} \int_{c}^{c+\Delta} n(n - 1) f(c) f(z)(1 - F(z))^{(n-2)} dz dc. \tag{3.6}
\]

The expected utility for the agency is

\[
E[u(p, \phi)] = (1 - \phi_{SPSB})(v - E[p_{SPSB}]) - \phi_{SPSB}B. \tag{3.7}
\]

**First-price sealed-bid auction**

In an FPSB-auction, the bidder with the lowest bid wins the contract and receives his respective bid as the payment. Here multiplicity of equilibria is not a problem, therefore we set \( \epsilon = 0 \). Furthermore, we distinguish between two cases: \( n \) small

\(^{17}\)For the uniform distribution equation (3.5) is \((1 - [1 - F(\xi + \Delta)]^n)\) which is smaller than 1.
and \( n \) large. This can be relevant for the agency as with many bidders \((n \text{ large})\) the equilibrium is such that the competition is tough and all bidders will bid aggressively (below \( c + \Delta \)). With only a few bidders \((n \text{ small})\), the incentives are such that more efficient bidders do not have to bid aggressively as this would lead to a lower expected payoff.\(^{18}\)

**Proposition 2** In an FPSB-auction, for
\[
\hat{n} \geq \max\{\hat{n}; 1 + \frac{1}{\Delta}\rho f(c)\},
\] an equilibrium exists where a bidder with cost term \( c \) will bid the expectation of the lowest cost term of the \((n - 1)\) competing bidders, conditional on his cost term being the lowest:

\[
\beta_{FPSB}(c) = E[c^{(1,n-1)} | c^{(1,n-1)} \geq c]
\]  

(3.8)

with \( \hat{n} \) being the smallest \( n \) that satisfies
\[
\int_c^\infty \frac{(1-F(z))^{(n-1)}}{(1-F(c))^{(n-1)}} dz < \Delta.
\] For the uniform distribution \( \hat{n} = \frac{1}{\Delta f(c)} \).

The bidding function for the uniform distribution is given in Figure 3.1.

---

\(^{18}\)Note that the bidding strategy, the expected price, and the probabilities of bankruptcy would be the same in a Dutch auction.
Proof Suppose all bidders \((j \neq i)\) follow the bidding strategy \(\beta_{FPSB}\) given in proposition 2. We argue that in this case, it is optimal for bidder \(i\) to follow \(\beta_{FPSB}\) as well. First, we show that under the assumption that a bidder with cost term \(c\) bids less than \(c + \Delta\), it is indeed optimal for him to bid according to the equilibrium strategy. In a second step, we derive conditions under which bidding more than \(c + \Delta\) is not optimal if everyone follows this bidding strategy.

In equilibrium a bidder with cost term \(c\) chooses a bid \(b(c)\) which corresponds to a \(\hat{c}\) with \(\beta(\hat{c}) = b(c)\). Formally, such a bidder maximizes the following expression with respect to \(\hat{c}\):

\[
\pi(\hat{c}, c) = \rho(\beta(\hat{c}) - c)(1 - F(\hat{c})^{(n-1)})
\]

where \((1 - F(\hat{c}))^{(n-1)}\) is the probability that all other bidders have cost terms higher than \(\hat{c}\). For an easier notation we denote \((1 - G(c)) = (1 - F(c))^{(n-1)}\). The derivative of equation (3.9) with respect to \(\hat{c}\) gives the following first-order condition:

\[
\beta'(\hat{c})(1 - G(c)) + (\beta(\hat{c}) - c)(-g(\hat{c})) = 0
\]

where \(-g(c) = d(1 - G(c))/dc\). In a symmetric equilibrium \(c = \hat{c}\), so (3.10) can be rewritten as

\[
\frac{d}{dc}(1 - G(c))\beta(c) = -cg(c).
\]

Integrating both sides yields

\[
\beta_{FPSB}(c) = \frac{1}{1 - G(c)} \int_c^\tau z g(z) dz = E[c^{(1,n-1)}|c^{(1,n-1)} \geq c]
\]

(3.12)

with the integration constant \(C = 0\) for \(\beta(\tau) = \tau\). Integration by parts gives

\[
\beta_{FPSB}(c) = c + \int_c^\tau \frac{1 - G(z)}{1 - G(c)} dz = c + \int_c^\tau \frac{(1 - F(z))^{(n-1)}}{(1 - F(c))^{(n-1)}} dz.
\]

(3.13)

For \(\beta_{FPSB}\) to be smaller than \(c + \Delta\), we need \(\int_c^\tau \frac{(1 - F(z))^{(n-1)}}{(1 - F(c))^{(n-1)}} dz < \Delta\) as a minimum requirement.
In a second step, we show that if everyone else behaves according to this strategy, it is indeed not optimal to bid more than $c + \Delta$. Assuming that a bidder bids such that he never goes bankrupt yields the following profit function

$$\pi(\hat{c}, c) = (\beta(\hat{c}) - c + \Delta(\rho - 1))(1 - F(\hat{c}))(n-1).$$

(3.14)

Maximizing this expression with respect to $\hat{c}$ and—in a symmetric equilibrium—setting $\hat{c} = c$ yields

$$\beta(c) = \frac{\beta'(c)(1 - F(c))}{(n-1)f(c)} + c - \Delta \rho + \Delta.$$

(3.15)

This solution for the optimal bid $\beta(c)$ is smaller than $c + \Delta$ whenever

$$\rho \geq \frac{\beta'(c)(1 - F(c))}{(n-1)f(c)\Delta}.$$  

(3.16)

Using the fact that $(1 - F(c)) \leq 1$ and $\beta'(c) \leq 1$ we have the sufficient condition

$$n \geq 1 + \frac{1}{\Delta \rho f(c)}.$$  

(3.17)

This also implies that the probability of having high costs must be sufficiently small as otherwise bidding below the high-cost level would not be profit-maximizing.

The interpretation of the $n$ large case is the following: the competition in the auction (a large number of bidders or a high $\rho$) must be sufficiently large in order to force all bidders to bid below the threshold of $c + \Delta$. Raising the bid above the threshold would lower the expected payoff of the bidder because the gain in payment is smaller than the loss in the probability of winning.

In the FPSB-auction for $n$ large, the expected price for the procurement agency is

$$E[p_{FPSB}] = \int_{\xi} \int_{c=0}^{\infty} nc(n-1)F(c)(1 - F(c))^{(n-2)}f(c)dc.$$  

(3.18)
Thus, under the condition that the winning bidder does not go bankrupt, the expected price in the FPSB-auction for \( n \) large is the same as in the SPSB-auction.

As \( \beta_{FPSB} \) is increasing and continuous in equilibrium the bidder with the lowest cost term submits the lowest bid and wins the auction. Thus, also an FPSB-auction for \( n \) large is efficient. Under the condition of \( n \) large, each bidder bids more than \( c \) but less than \( c + \Delta \). From the point of view of the contracting agency, the probability of not being served is therefore given by the probability that the cost realization is \( c + \Delta \) which is

\[
\phi_{FPSB} = 1 - \rho. \tag{3.19}
\]

Thus, the probability of non-fulfillment in an FPSB-auction which—in contrast to the SPSB-auction—does not depend on the distribution of the payment is higher than the probability of non-fulfillment in an SPSB-auction.\(^\text{19}\)

The expected utility of the procurement agency in the FPSB-auction is

\[
E[u(p, \phi)] = \rho(v - E[p_{FPSB}]) - (1 - \rho)B. \tag{3.20}
\]

Therefore, we can give a new reason why revenue equivalence breaks down: given that the expected price is the same and that the distributions of the payments differ, the probability of non-fulfillment and the utility of the agency differs in the two formats.\(^\text{20}\) Combining the previous results, the expected utility for the procurement

\(^{19}\)Parlane (2003) derives the result that the expected payment in the FPSB-auction is higher than in the SPSB-auction. Upon this result, she speculates that the probability of non-fulfillment is smaller in the FPSB-auction. However, this is not true in general as in our framework the probabilities are reversed. Board (2005) shows that if the general cost distribution function is convex, the probability of non-fulfillment is higher in the SPSB-auction. However, in our framework the realization of the cost distribution \( H(\cdot) \) is concave in the relevant region, so the probability of non-fulfillment is lower in the SPSB-auction. Conditional on winning with cost term \( c \) the probability of non-fulfillment in the FPSB-auction is \( H(p_{FPSB}) \) while it is \( \int H(p_{SPSB})f(p_{SPSB})dp_{SPSB} \) in the SPSB-auction. Due to Jensen’s Inequality if \( H(\cdot) \) is concave, the probability of non-fulfillment is smaller in the SPSB-auction.

\(^{20}\)As the expected payment is the same in both auction formats and the probabilities of bankruptcy differ, payoff equivalence for the bidders is no longer valid. A standard result in the auction literature is that risk-loving behavior leads to different expected payments in different auction formats. In our case, we have found a different channel why payoff equivalence breaks down, although expected payments are identical. Here the payoff equivalence theorem is no longer valid because of the shift to risk-loving behavior but due to the differences in the payment distri-
agency is higher in the SPSB-auction.

If the number of bidders is small \( (n \text{ small}) \), this is no longer the case. If \( n \) is small, the more efficient bidders can abstain from the aggressive bidding. We show that the equilibrium bidding function will be monotone increasing and that bidders with cost terms below a critical \( c^* \) will bid above the threshold \( c + \Delta \) and bidders with cost terms higher than \( c^* \) will bid below the threshold. The intuition behind this result is the following: while bidders with high cost terms still have an incentive tobid below \( c + \Delta \) to win more often bidders with low cost terms can abstain from bidding aggressively: shading their bid below \( c + \Delta \) would raise the probability of winning slightly but it would reduce the profit if he wins substantially. Therefore, bidders with low cost terms will bid above \( c + \Delta \).\(^{21}\)

**Proposition 3** In an FPSB-auction, for \( n < \hat{n} \), an equilibrium with the following properties exists: there exists a \( c^* \) with \( \underline{c} < c^* < \overline{c} \), the bidding function is monotone increasing, and bidders with costs \( c \leq c^* \) will bid above \( c + \Delta \) and bidders with costs \( c > c^* \) will bid below \( c + \Delta \).

For \( c \leq c^* \):

\[
\beta(c) = c + \Delta + \int_c^{\overline{c}} \frac{1 - G(z)}{1 - G(c)} dz - \int_c^{c^*} \frac{1 - G(z)}{1 - G(c^*)} dz \tag{3.21}
\]

For \( c > c^* \):

\[
\beta(c) = c + \int_c^{\overline{c}} \frac{1 - G(z)}{1 - G(c)} dz \tag{3.22}
\]

\(^{21}\)One could argue that bidders to the left of \( c^* \) are still risk-neutral and bidders to the right become risk-loving. The result that bidders with low cost terms may not run into bankruptcy, while bidders with high cost terms may do so, was also shown by Parlane (2003).
Figure 3.2 sketches the bidding function for the uniform distribution.

\[ \beta(c) = c + \int_c^{c^*} \frac{1-G(z)}{1-g(c)} dz \]

**Figure 3.2:** Bidding strategy in an FPSB-auction for \( n \) small

**Proof** We have already derived the result that bidders which bid below the threshold will bid according to the equilibrium bidding function of proposition 2. Hence, for \( c > c^* \): \( \beta(c) = c + \int_c^{c^*} \frac{1-G(z)}{1-g(c)} dz \). We also showed that maximizing the profit of a bidder that never goes bankrupt (equation (3.14)) leads to the following differential equation (in a symmetric equilibrium):

\[ \beta'(c)(1 - G(c)) - \beta(c)g(c) = -cg(c) - (1 - \rho)\Delta g(c) \]

(3.23)

where \( -g(c) = d(1 - G(c))/dc \). The last equation can be rewritten as

\[ \frac{d}{dc} (1 - G(c))\beta(c) = -cg(c) - (1 - \rho)\Delta g(c). \]

(3.24)

Integrating both sides yields

\[ \beta(c) = \frac{1}{1 - G(c)} \int_c^{\bar{c}} zg(z)dz + (1 - \rho)\Delta + C \]

(3.25)
with the integration constant $C$. Integration by parts gives

$$
\beta(c) = c + \int_c^{\tau} \frac{1 - G(z)}{1 - G(c)} dz + (1 - \rho)\Delta + C. \tag{3.26}
$$

As the bid of the bidder with costs of $c^*$ has to satisfy $\beta(c^*) = c^* + \Delta$, $C$ is $\rho\Delta - \int_{c^*}^{\tau} \frac{1 - G(z)}{1 - G(c^*)} dz$.

Hence, compared to the case when $n$ is large, the FPSB-auction for $n$ small leads to a higher expected price and to a lower probability of non-fulfillment. This result is driven by the fact that there is less competition not only due to a smaller number of firms but also due to less aggressive bidding by the more efficient bidders. As a general result, prices in the FPSB-auction are at least the same (as we have shown for $n$ large) or higher as in the SPSB-auction.\footnote{For this result in a more general framework see Board (2005).}

### 3.3 Alternative procurement mechanisms

In this section we analyze different procurement mechanisms. As mentioned in the introduction of this chapter, governments as well as private firms have used different ways of dealing with ALTs. First, we investigate some of the mechanisms proposed and then we turn to other ways of allocating contracts. Our aim is to find an understanding of the interaction of the different parameters and to give some implications for the choice of the right mechanism. Since all alternative methods allocate the contract at prices higher than a standard auction the probability of non-fulfillment is lower per se. But the decision which of these mechanisms to use is faced by a trade-off between low prices (if bankruptcy costs are low) and a low probability of non-fulfillment (if bankruptcy costs are high). We shed some light on the question which mechanism addresses this trade-off best.
CHAPTER 3. A SIMPLE MODEL OF LIMITED LIABILITY

Average-bid method

In Taiwan an auction format was used where the winner was the bidder with the bid closest to the average. In Italy, a similar auction was employed where the bidder was the winner whose bid was closest to but less than the average bid. Similar to that rule is a method in Peru where all bids 10% above and below the average are eliminated. The contract goes to the bidder whose bid is closest (from below) to the new average. Note that these allocation rules are no longer standard auction as the bidder with the lowest bid does not win. To illustrate the effects of mechanisms that allocate the contract such that it pays not to be among the lowest bidders, we consider a sealed-bid auction where the bid closest to the average bid wins. If there is more than one winning bid, there will be a lottery among the winners. Then, it holds:

Lemma 1 For any price $P > \bar{c}$, it is an equilibrium if every bidder bids $P$.

Proof The proof is straightforward. Suppose everyone bids $P$, then everyone makes the average bid. Thus, everyone has the same chance of winning the contract and will make a positive expected profit if one wins. Offering any other bid implies moving away from the average. Thus, the deviating bidder will lose the contest for sure. Therefore, bidding $b(c) = P \forall c$ is an equilibrium.

As everyone tries to be just average this will take the competition out of the contest. Thus, although the average-bid method was intended to exclude all ALTs, the change in the bidding behavior leads to very high prices. The logic behind the result for average bidding extends to other mechanisms as well. We were told that in some regions of Switzerland, an auction design was used where the winning bid was not the lowest bid but the second lowest bid. Although this design was probably chosen

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25See appendix A.1 for more details.
26Ioannou and Leu (1993) argue that the average-bid method may be preferred over low-bid methods (e.g., FPSB-auction) as it does not give priority to risky bids and awards the contract to average prices. However, they do not derive a Nash-Equilibrium for their bidding strategy.
to avoid the abnormally low(est) bid the result stated above also holds here. The rule has strategic effects on the bidding behavior and as everyone tries to become second and not first prices might turn out to be very high again.\textsuperscript{27}

**Truncated English auction (rationing)**

Rationing is a common method in an environment with excess demand where bidders get only a proportion of their requested demand.\textsuperscript{28} In a common-value environment, Bulow and Klemperer (2002) show that rationing can increase revenues in selling auctions. If bidders are asymmetric, the second source gives the disadvantaged bidders a higher incentive to participate (especially in a sealed-bid auction). We show that a second source might also mitigate the problem of ALTs.

Consider the following truncated English auction. Do an English auction until \( m \) bidders are left (with \( m \leq n \)). Consider \( m = 2 \) as the extreme case. This implies that the winner is one of the two bidders with the lowest cost terms. As the auction stops at \( c^{(3,n)} \) the price is \( p_{TE} = E[c^{(3,n)}] \) which is higher than in the standard English auction. A rather simple method to choose between the \( m \) remaining bidders is a lottery where everyone obtains the contract with probability \( \frac{1}{m} \).\textsuperscript{29} The probability of non-fulfillment is given by

\[
\phi_{TE} = \left( \frac{1}{2} \text{Prob}[c^{(3,n)} - c^{(1,n)} < \Delta] + \frac{1}{2} \text{Prob}[c^{(3,n)} - c^{(2,n)} < \Delta] \right)(1 - \rho) \tag{3.27}
\]

which is lower than in an SPSB-auction.\textsuperscript{30}

\textsuperscript{27}An issue which complicates this analysis is the possibility of shill or fake bidding. In some cases, the agency does not control who offers a bid and how many bids someone offers. If the rule is such that the average bid wins, it may pay off for a bidder to offer one extremely high bid to raise the average and a second bid close to the expected average.

\textsuperscript{28}For instance, in equity IPOs and Central Bank Tenders. See Gresik (2001) or Gilbert and Klemperer (2000).

\textsuperscript{29}For an analysis of \( 1/m \) auctions in a framework with common values see Harstad and Bordley (1996).

\textsuperscript{30}The same can be done with a screening process instead of the lottery. As further price competition in the second round would increase the probability of non-fulfillment, the agency should check the offers of the prequalified bidders in more detail (e.g., through screening or due diligence) and award the contract to the most qualified bidder. In this case the agency has to invest screening costs only for a small number of bidders and learns more about the pre-qualified bidders.
Lotteries

The use of lotteries where the agency sets a price and awards the contract randomly was quite common in the 1980s, especially in the US where the allocation of spectrum licences was done via lotteries until 1994.\textsuperscript{31} Consider the following: the government sources at the payment \( p_L = \bar{c} + \Delta \) and holds a lottery between all bidders. This will lead to zero bankruptcy at a very high price. Note that this lottery is the same as the truncated English auction with \( m = n \). The allocation of a lottery is very inefficient but depending on how high the costs of bankruptcy are, the truncated English auction or even a lottery might fare better than any standard auction.

Multi-sourcing

Risk diversification means that an agency "should not put all eggs into one basket". Using the same principle, the agency can reduce the risk of non-fulfillment by sourcing the contract to more than one contractor. Multi-sourcing (also called share auctions or split award contracts) is used when a contract is split up in \( m \) parts and \( m \) firms win a certain share of the contract. As an example, many automobile manufacturers use more than one supplier for their components.\textsuperscript{32} The advantage of multi-sourcing is the flexibility to switch between projects, i.e. a solvent contractor can finish the lot of a bankrupt contractor.

Assume that the agency uses an SPSB-auction and that the agency can split the contract, i.e. she can allocate the contract to two or more contractors. If the agency procures two equal shares, the contract goes to the two firms with the lowest bids and the payment is the third lowest bid. In this scenario, bidding the cost term \( c \) is again a dominant strategy. Therefore, the expected price will be \( p_M,50/50 = E[c^{(3,n)}] \). Since we assume that one contractor can finish the part of the other, the probability of non-fulfillment is the probability that both contractors go bankrupt: \( \phi_M = (1 - \rho)^2 \text{Prob}[c^{(3,n)} - c^{(1,n)} < \Delta] \) which is lower than in the single-source

\textsuperscript{31}Milgrom (2004), pp. 3, 79.
\textsuperscript{32}See Perry and Sakovics (2003); for defence contracts of the U.S. government and PC-CPU’s see Anton and Yao (1989).
CHAPTER 3. A SIMPLE MODEL OF LIMITED LIABILITY

SPSB-auction.\textsuperscript{33}

Multi-sourcing may be the best choice for the procuring agency for two reasons. First, as in the case of lotteries and rationing, multi-sourcing increases the expected payment as bidders bid less aggressively. An increase in payment reduces the probability of non-fulfillment. But by choosing an unequal size of the shares, the price with multi-sourcing is lower than in the case of lotteries or rationing. Second, multi-sourcing may allow the procurement agency to switch to a solvent contractor in case one of the contractors goes bankrupt.\textsuperscript{34} Thus, if the agency can use multi-sourcing (firms are not capacity constrained) and if the costs of switching between contractors are small, multi-sourcing leads to a lower price and a lower probability of non-fulfillment than other means to weaken competition. The disadvantage is that the price is in general higher than with single-sourcing.

Comparison between the procurement methods

For the purpose of illustration, we compare three different mechanisms for the uniform distribution from the agency’s point of view. As mentioned above, the lottery between \( n \) bidders (rationing between \( n \) bidders) and the average-bid method lead to zero probability of non-fulfillment but as the latter can lead to higher prices we only investigate the lottery \( (p_R = \overline{c} + \Delta) \). The utility of the agency in this case is \( u_R = v - (\overline{c} + \Delta) \).

The second mechanism is the multi-source SPSB-auction with two equal shares which leads to a price of \( E[p_M] = \frac{3\overline{c} + nc - 2c}{n+1} \) and \( u_M = (v - E[p_M])(1 - \phi_M) - B\phi_M \).

The third mechanism is the single-source SPSB-auction with a price of \( E[p_{SPSB}] = \frac{2\overline{c} + nc - c}{n+1} \) and \( u_{SPSB} = (v - E[p_{SPSB}])(1 - \phi_{SPSB}) - B\phi_{SPSB} \).

Agencies with high costs of bankruptcy (\( v \) and \( B \) large) prefer a mechanism that

\textsuperscript{33}For a discussion of different share sizes and the limits of multi-sourcing see section 2.2.

\textsuperscript{34}Gilbert and Klemperer (2000) show that multi-sourcing may also be preferred to single-sourcing in an environment that has different future states of demand and requires investment by the bidders. If there are costs of entering an auction, a commitment that allows profits (which is the case with multi-sourcing) can be desirable because it gives high-cost bidders an incentive to participate which increases incentives for innovation.
induces less bankruptcy, i.e. a mechanism that weakens competition. This may be the goal of a welfare-maximizing agency (e.g., the government). On the other hand, agencies with low costs of bankruptcy can use the competition in the auction to lower the price. This is more likely to be the goal of a revenue-maximizer (e.g., firms in the private sector). Thus, the trade-off for the agency is to pay informational rents on the one hand (high price but a low probability of non-fulfillment) and opportunity cost on the other hand (high probability of non-fulfillment but a low price).

Figure 3.3: Comparison of the the SPSB, multi-sourcing, and the lottery for $n = 8$, $\rho = 0.5$, $c \in [0, 1]$, and $B=0.5$.

In figure 3.3 the different mechanisms are compared. The lottery (light grey) is only preferred if the uncertainty and/or $v$ is very high. The competition of a single-source SPSB-auction (black) is desired if the agency has a low valuation and/or the magnitude of the uncertainty is very low. In any other case, multi-sourcing is the preferred mechanism.\(^{35}\) But note that switching projects in the case that one winner goes bankruptcy is costless in our multi-sourcing framework. If switching is costly, the preference for multi-sourcing would be weaker.

\(^{35}\)Multi-sourcing fares even better compared to the SPSB-auction if the agency uses unequal shares. See Engel et al. (2006) for a discussion of this result.
3.4 Reserve prices and entry fees

Here we investigate additional instruments apart from differences in the allocation or payment rules, namely reserve prices and entry fees. Both were used, for instance, in most European UMTS spectrum license auctions.\textsuperscript{36} Using a reserve price $r$ or an entry fee $k$ in a standard procurement auction can lower the expected price for the agency by excluding bidders with high cost terms. However, there is also an efficiency loss due to the possibility of not awarding a contract. The standard result in the literature with unlimited liability is that if the agency sets the reserve price (or the entry fee) optimally, the effect of a lower expected price outweighs the efficiency loss. Also, the introduction of an optimal reserve price or an optimal entry fee leads to the same outcome because the allocation is identical and the payoff for the marginal bidder is the same.\textsuperscript{37}

In a framework with limited liability, this equivalence no longer holds as the bidding strategy will be affected in different ways. Because entry fees are paid in advance, we have to assume that bidders have a certain budget $\epsilon$. The bidding strategy in the SPSB-auction with limited liability and a reserve price $r$ is straightforward.\textsuperscript{38} If $\epsilon \geq \Delta$, the participants bid as if under unlimited liability. I.e. they bid the expectation of the cost $(c + (1 - \rho)\Delta)$ because this strategy will leave each bidder indifferent between winning or not. Bidders with expected costs above the reserve price will not enter the auction. In this scenario, no participating bidder will go bankrupt. The analysis for the entry fee is different. Assume that the agency requests an entry fee $k$ ($\epsilon - k < \Delta \leq \epsilon$) which bidders have to pay in advance. For simplicity, let’s assume the extreme case $k = \epsilon$. Then, the participating bidders have not enough assets to cover a high-cost realization and the dominant strategy is to bid the cost term $c$ as the entry fee affects the decision to enter the auction but not the bidding strategy, i.e. the entry fee is sunk. Hence, the entry fee leads to a

\textsuperscript{36}Entry fees can also be interpreted as costs of preparation for the bidding process.

\textsuperscript{37}See Matthews (1995) or Krishna (2002), p. 27.

\textsuperscript{38}We only analyze the SPSB-auction as it is technically less demanding and it enables us to show the effects of reserve prices and entry fees.
negative wealth effect (turns solvent bidders into potentially insolvent bidders) and makes bidders bid more aggressively. Which in turn leads to a positive probability of bankruptcy for each bidder.\textsuperscript{39} Therefore, if bidders have some but not unlimited wealth, the reserve price fares better than the entry fee as it does not turn solvent bidders into potentially insolvent bidders. But as we show next, there is no general ranking possible.

Assume the case that $\epsilon < \Delta$ and the agency sets a reserve price $r$. Then, as the weakly dominant strategy has to leave the bidder indifferent between winning and losing at this payment he bids $c + \frac{1 - \rho}{\rho} \epsilon$. Therefore, all bidders with cost terms such that $c + \frac{1 - \rho}{\rho} \epsilon > r$ will never participate as they would always make a loss.

The analysis for the entry fee is the same as above, i.e. the bid will be $c$ as $\kappa$ is sunk. Assume that $\kappa$ and $r$ are such that the marginal bidders that decide to participate are the same under both instruments. I.e. the reserve price and the entry fee will lead to the same set of bidders and to the same allocation. Then, both instruments will have different expected payments and are no longer equivalent. As a simple example, assume the following extreme case: reserve price or entry fee are chosen such that only one bidder enters the auction. Then, the reserve price or the maximal willingness to pay (in case of an entry fee) will determine the payment. As the maximal willingness to pay ($\bar{c} + \Delta$) is by definition higher than the reserve price, the payment is higher with an entry fee. Therefore, the expected probability of bankruptcy with an entry fee is $E[Prob[\bar{c} + \Delta - c < \Delta]] = 0$ which is smaller than the expected probability of bankruptcy with a reserve price, $E[Prob[r + \epsilon - c < \Delta]] \geq 0$.

If there is strictly more than one bidder willing to place a bid, the two formats yield the same result as the winner receives the bid of the second lowest participating bidder as the payment. Thus, even if the reserve price and the entry fee lead to the same set of bidders, an auction with an entry fee leads to a higher price and a lower probability of non-fulfillment than an auction with a reserve price.

Hence, we can distinguish three different cases: if bidders have unlimited liability,
both instruments are equivalent. If the budget is such that an entry fee triggers limited liability, the reserve price fares better as it does not have a negative effect on the bidding behavior. If bidders are close to ruin, i.e., they already have small budgets, the entry fee fares better as it puts less pressure on the payment.

### 3.5 Moral Hazard and cost-sharing contracts

In the previous sections, we discussed an adverse-selection problem which is caused by the information advantage of the bidder before the auction. In this section we discuss a more complex information structure, i.e., we add an additional moral-hazard problem. In contrast to the adverse-selection problem, the moral-hazard problem arises after the auction. For instance, if the costs turn out to be higher than the payment (cost overrun), should the bidder declare bankruptcy or should he spend some additional effort to reduce the costs and avoid bankruptcy? In general, cost reductions is good for the agency as the procurement price is lower. But as spending some effort is costly for the bidder, the agency has to give the bidder the right incentives to do so.

Contract theory with adverse selection and moral hazard would suggest that the agency should screen the agents by offering a menu of contracts in such situations. This is done fixed-price (FP) contracts, cost-plus (C+) contracts, and cost-sharing (CS) contracts. With a CS/C+ contract the resulting payment to the winning bidder is the auction price plus a fraction of the cost overrun. The higher the sharing rule, the less of the cost overrun the contractor has to cover himself. On the other side, when the sharing rule is high, less incentives to spend efforts in cost reduction are given. For instance, the C+ contract would always pay the observed costs plus a margin. This contract leads to no investment into cost reduction.\footnote{One could argue that a C+ contract is a renegotiation with all the bargaining power on one side.} The other extreme of a C+ contract is an FP contract where no cost sharing is possible as in the previous sections. Thus, two opposing effects are here at work: the competition
effect of the adverse-selection problem and the incentive effect of the moral-hazard problem. The question is which contract balances these effects optimally for the agency. As a C+ contract gives no incentives in cost reduction, it is—in terms of minimizing expected procurement costs—usually dominated by the other contracts.

A second reason for cost sharing—despite cost minimization—is given in our framework with limited liability. The cost reduction effort may reduce or even eliminate the probability of non-fulfillment. For instance, as the C+ contract will never lead to bankruptcy, it can indeed be optimal. This could be an explanation for using C+ contracts for projects that are of major importance and face high cost uncertainty, such as defence or other public projects. If the agency wants to make sure that the project is completed, regardless of how expensive it will be, a C+ contract may be preferred. The setting of the optimal sharing rule is complex as there is a trade-off between giving cost-reduction incentives, stimulating competition, and avoiding bankruptcy costs. We will investigate these effects for the FPSB and the SPSB-auction. However, the focus of this section is not to derive the optimal sharing rule but to identify properties of the sharing rule to avoid or to reduce bankruptcies.

Related literature

The first work on the trade-off between stimulating competition and giving incentives to reduce costs was McAfee and McMillan (1986). They derive—for the FPSB-auction—that if bidders are risk-averse, the optimal (linear) contract which minimizes procurement costs has to trade off cost-reduction incentives, competition stimulation, and risk sharing. Upon these effects McAfee and McMillan (1986) show that the optimal linear contract is never a C+ contract, it may be an FP contract but it is usually a CS contract. Even if bidders are risk-neutral, the optimal contract is never a C+ contract.

If bidders are risk-averse, an additional risk sharing effect which works in the same direction as the competition effect would be present.

Especially weapon acquisition programs are a prominent example.
Laffont and Tirole (1987) analyze the SPSB-auction (dominant-strategy auction) with an additional incentive problem and show that an auction that uses information about the first and the second lowest bids implements the optimal allocation. They also show that the winner faces a linear incentive contract.

Cox et al. (1996) test incentive contracts in a laboratory experiment and find that CS contracts lead to lower expected procurement costs in comparison to FP contracts. But CS contracts are also less efficient.

Bajari and Tadelis (2001) investigate a situation where changes in the initial design are possible after the contract is awarded. These project adaptations are an important reason for cost overruns. Bajari and Tadelis (2001) show that the agency faces a trade-off between giving incentives to reduce costs before the auction and spending renegotiation costs (transaction costs) for the adaptation later on. If the project is not complex as adaptations are not very likely, an FP contract with a high level of design completeness is preferred. If the project is complex as adjustments are very likely, C+ contracts with a low level of design completeness fare better.

**Cost-sharing and cost-plus contracts**

The model we present in this section is an extension of the basic model and of McAfee and McMillan (1986).\(^{43}\) The cost term of a bidder is \(c\) and each bidder faces an additional uncertainty of \(\tilde{\Delta}\) which is either 0 or \(\Delta\) with a probability of \(\rho\) or \((1 - \rho)\), respectively.\(^{44}\) After the auction the winning bidder can decide to spend some effort \(e(\xi)\) in cost reduction which means that the observable cost \(c^o\) consist of the following components:

\[
c^o = c + \tilde{\Delta} - \xi
\]

\(^{43}\)An important aspect of McAfee and McMillan (1986) is risk aversion on the bidders’ side. If risk aversion is present, an additional risk-sharing effect would affect the results. But as we assume that the effect of risk aversion is small in a framework with limited liability (see section 3.7 and since we are only interested if cost-sharing can reduce the risk of bankruptcy, we will ignore risk aversion.

\(^{44}\)\(c\) is independently and identically distributed according to the distribution \(F(c)\) and the density \(f(c)\). All bidders are symmetric.
with $\xi$ being the cost reduction caused by effort $e(\xi)$. As a C+ contract provides no incentives to reduce the cost we assume that no effort is spent in this case. The realized cost $c^o$ is observable for everyone, the realizations of $c$, $\tilde{\Delta}$, and $\xi$ are only observed by the respective bidder. Hence, the agency cannot control if the winning bidder spends some effort in cost reduction or not.

We assume that for giving cost-reduction incentives the contract is such that the payment $P$ has the following linear form:

$$P = p + \alpha(c^o - p) + \gamma = (1 - \alpha)p + \alpha c^o + \gamma$$

which is the price $p$ determined in the auction plus a mark-up $\gamma$ and a fraction $\alpha$ of the cost overrun, with $\alpha \in [0, 1]$. If $\alpha = 0$, $P$ is an FP contract like the standard auctions in the previous sections. If $\alpha = 1$, $P$ is a C+ contract. If $0 < \alpha < 1$, then a bidder’s cost overrun is not entirely covered by the agency but shared between the agency and the bidder. Note that the mark-up $\gamma$ is inconsequential as any increase in $\gamma$ would induce an equal decrease of the bid. Hence, as McAfee and McMillan (1986), we ignore $\gamma$ in our analysis.

As the optimal $\alpha$ determines the trade-off described above, the parameter the risk-neutral agency has to control is $\alpha$. The agency wants to maximize the following expression:

$$U_A(P, \alpha) = (1 - \phi(\alpha))(v - P) - \phi(\alpha)B$$

with $B$ as the costs of bankruptcy. The order of events is as follows: (1) The agency announces the auction format and the sharing rule $\alpha$. (2) The bidders bid, the disclosure of the bids takes place, and the auction price is determined. (3) Bidders decide to spend effort in cost reduction. In case of a low cost realization, the winning bidder always makes a profit. In case of a high cost realization, the winning bidder has to decide either to declare bankruptcy or to spend enough effort to prevent bankruptcy. We solve the game by backward induction with the agency acting as a

\footnote{Following McAfee and McMillan (1986), we assume that zero effort leads to zero cost reduction ($e(0) = 0$) and that effort costs increase ($e''(\cdot) > 0$) at an increasing rate ($e'''(\cdot) > 0$).}
Stackelberg leader setting the optimal $\alpha$. First, the agency determines the optimal $\alpha$ which maximizes her utility, then the winning bidder’s decision to spend some effort is taken, and finally the bidding functions are determined.

The critical question is: will bidders decide to declare bankruptcy or not? This depends on the cost realization $c + \tilde{\Delta}$, the cost-sharing parameter $\alpha$, the cost-reduction effort $e(\xi)$ (measured in monetary units), the resulting $\xi$, and the bid which determines the price $p$. Therefore, we have to investigate the bids conditional on the decision to declare bankruptcy. If the parameters are such that a bidder with a high cost realization never goes bankrupt, the expected utility conditional on winning is as under unlimited liability:

$$E[U_{UL}(c)] = (1 - \alpha)(p - (c + (1 - \rho)\Delta)) + k + \epsilon.$$  \hspace{1cm} (3.31)

where $k = (1 - \alpha)\xi - e(\xi)$ and $\epsilon$ is a small budget of the bidder. If the parameters are such that bankruptcy cannot always be prevented, the expected utility of a bidder with cost term $c$ conditional on winning is:

$$E[U_{LL}(c)] = (1 - \rho)[\max\{0; (1 - \alpha)(p - (c + \Delta)) + k + \epsilon\}] + \rho[(1 - \alpha)(p - c) + k + \epsilon].$$  \hspace{1cm} (3.32)

To derive the bidding behavior, we have to distinguish three cases: (i) In case of a high cost realization, a bidder always goes bankrupt, regardless of $\epsilon$, $\alpha$, and $\xi$. This means that, as the high cost realization can never be covered, bidders will maximize $E[U_{LL}]$ and spend efforts only when costs are low. (ii) The optimal $\alpha$ is such that bankruptcy can always be prevented and bidders behave as under unlimited liability. (iii) Only some bidders can avoid bankruptcy (maximize $E[U_{UL}]$) while others cannot (maximize $E[U_{LL}]$). This situation is similar to the FPSB-auction for $n$ small in section 3.2.

Ad (i): In this case the risk of non-fulfillment for the agency remains the same; she can only set $\alpha$ such that the expected payment is reduced if costs are low.\footnote{The case that the winning bidder always declares bankruptcy if costs are high, can only be derived for the FPSB-auction as in the SPSB-auction this decision depends on the lowest competing...}
Assuming that a bidder bids such that he goes bankrupt and he will not invest in cost reduction whenever costs are high yields the expected utility (for $\epsilon \to 0$) given in equation (3.33). In an FPSB-auction a bidder with cost term $c$ chooses a bid $b(c)$ which corresponds to a $\hat{c}$ with $\beta(\hat{c}) = b(c)$. Formally, such a bidder maximizes the following expression with respect to $\hat{c}$:

$$
\rho[(1 - a)(\beta(\hat{c}) - c) + k](1 - F(\hat{c}))^{(n-1)}.
$$

which leads to

$$
\beta_{FPSB}(c) = c + \int_{c}^{\bar{c}} \frac{(1 - F(z))^{(n-1)}}{(1 - F(c))^{(n-1)}} dz - \xi + \frac{e(\xi)}{1 - \alpha} = p_{FPSB}.
$$

The agency can now determine the optimal $\alpha$ according to equation (3.30).\(^\text{47}\)

Ad (ii): the parameters are such that a cost overrun will never lead to bankruptcy; hence, bidders bid as under unlimited liability. In an SPSB-auction a bidder bids such that he is indifferent between winning and not winning at this bid $\beta_{SPSB}$:

$$
E[U_{SPSB}(c)] = (1 - \alpha)(\beta_{SPSB}(c) - c - (1 - \rho)\Delta) + k + \epsilon = \epsilon.
$$

This leads to a bid of

$$
\beta_{SPSB}(c) = c + (1 - \rho)\Delta - \xi + \frac{e(\xi)}{1 - \alpha}.
$$

The expected auction price $E[p]$ is the second lowest bid $\beta_{SPSB}^{(2)}(c)$ which yields the following expected payment for a bidder with cost term $c = c^{(1)}$:

$$
E[p_{SPSB}(c)] = E[c^{(2)}] + (1 - \rho)\Delta - \xi + \frac{e(\xi)}{1 - a}
$$

bid (=payment) which is random. As the payment is random, it can always be the case that a bidder receives a payment high enough to prevent bankruptcy with positive probability.

\(^{47}\)See McAfee and McMillan (1986) for the setting of the optimal $\alpha$.
In an FPSB-auction a bidder with cost term $c$ chooses a bid $b(c)$ which corresponds to a $\hat{c}$ with $\beta(\hat{c}) = b(c)$. Formally, such a bidder maximizes the following expression with respect to $\hat{c}$:

$$(1 - \alpha)(\beta_{FPSB}(\hat{c}) - c - (1 - \rho)\Delta + k)(1 - F(\hat{c}))^{(n-1)} + \epsilon$$  \hspace{1cm} (3.38)

which leads to

$$\beta_{FPSB}(c) = c + (1 - \rho)\Delta + \int_{c}^{\pi} \frac{(1 - F(z))^{(n-1)}}{(1 - F(c))^{(n-1)}} dz - \xi + \frac{e(\xi)}{(1 - \alpha)} = p_{FPSB}(c).$$  \hspace{1cm} (3.39)

Hence, the expected price in both formats is the same. The necessary condition for this result to hold is that if costs are high, the winning bidder never goes bankrupt:

$$(1 - \alpha)(p - (c + \Delta)) + k + \epsilon \geq 0$$  \hspace{1cm} (3.40)

which yields

$$(1 - \alpha) \left( \int_{c}^{\pi} \frac{(1 - F(z))^{(n-1)}}{(1 - F(c))^{(n-1)}} dz - \rho\Delta \right) + \epsilon \geq 0.$$  \hspace{1cm} (3.41)

This inequality holds whenever:

$$\alpha \leq \frac{\rho\Delta - \int_{c}^{\pi} \frac{(1 - F(z))^{(n-1)}}{(1 - F(c))^{(n-1)}} dz - \epsilon}{\rho\Delta - \int_{c}^{\pi} \frac{(1 - F(z))^{(n-1)}}{(1 - F(c))^{(n-1)}} dz}.$$  \hspace{1cm} (3.42)

First, if $\epsilon \to 0$, this implies that $\alpha = 1$ (the optimal contract is a C+ contract) and this leads to no bankruptcy for all $c$. But no incentives to reduce costs are given; hence, the price for the project is quite high.\(^{48}\)

Second, if $\epsilon$ is significantly different from zero ($\epsilon > 0$), the bankruptcy-preventing $\alpha$ is smaller than 1 and decreases in the size of the budget. If the budget is such that $\epsilon \geq \rho\Delta$, $\alpha = 0$ is sufficient to prevent bankruptcy which is a trivial result. If the budget is such that $0 < \epsilon < \rho\Delta$, the agency has to assume the worst case: the

\(^{48}\)It can also be that the profit margin $\int_{c}^{\pi} \frac{(1 - F(z))^{(n-1)}}{(1 - F(c))^{(n-1)}} dz$ $\forall c$ always has to be higher than the maximal loss $\rho\Delta$. In this case no one will declare bankruptcy by definition.
bidder with cost term \( \sigma \) wins. Then, she can set \( \alpha \) such that

\[
\alpha = \frac{\rho \Delta - \epsilon}{\rho \Delta}.
\]  

(3.43)

This will prevent the bankruptcy of the bidder with cost term \( \sigma \). In this case not even the bidder with the highest risk goes bankrupt which leads to the conclusion that the agency can avoid bankruptcy if she has knowledge about the uncertainty of the project.

Ad (iii): As case (i), this case is only relevant for the FPSB-auction. Some bidders will go bankrupt if costs are high, others will not. This corresponds to the case of a small number of bidders in the standard FPSB-auction (proposition 3).

Assume that there is a \( c^* \) where bidders with higher cost terms never spend efforts and go bankrupt if costs are high. And bidders with cost terms below \( c^* \) spend the optimal effort and never go bankrupt. Can the agency set \( 0 < \alpha < 1 \) such that bidders spend some effort to prevent bankruptcy? I.e., compared to proposition 3, can the agency push the critical bidder \( c^* \) further to the right? The derivation is analogously to proposition 3 and bidders with cost terms \( c \leq c^* \) will bid according to (for \( \epsilon \rightarrow 0 \)):
distribution, CS and even C+ contracts can reduce the risk of non-fulfillment if the
bidders do not have enough financial means to cover a high cost realization.

3.6 Asymmetries and common costs

In this section we depart from the assumption that bidders are symmetric and have
independent private costs. We discuss how asymmetries and cost interdependence
will affect the outcome. This is of relevance as bidders are often asymmetric in the
sense that one has a better cost structure or is an incumbent with more information
about the market (less uncertainty). Also, there are situations where bidders’ costs
are interdependent which means that ex-post, bidders have the same cost realization
but ex-ante this realization is unknown to each bidder. It is interesting to see how
limited liability will affect the bidding behavior in such environments.

Asymmetries

It is a well known result in auction theory that if asymmetric bidders compete in
an FPSB-auction, the weakness of a disadvantaged bidder leads to more aggressive
bidding. This is bad news for the agency if bidders have limited liability, as more
competition increases the risk of non-fulfillment. The logic behind this result is
the following: assume that two bidders with different cost functions compete in
an FPSB-auction. Maskin and Riley (2000a) show that in this case, an increasing
equilibrium bidding function exists under certain conditions. If a strong bidder’s
(indexed by S) cost term distribution dominates the weak bidder’s (indexed by W)
in the sense of reverse hazard rate dominance (which implies first order stochastic
dominance), the bidders’ bids are distributed the same way. The stronger bidder’s
bid distribution will be lower than the weaker bidder’s. Knowing this, the weaker
bidder will bid more aggressively, i.e. a weaker bidder will bid less than a stronger
bidder for each cost realization. Maskin and Riley (2000b) show that $\beta_W(c) < \beta_S(c)$
$\forall c$ is indeed an equilibrium. Combining the last two results, we see that the stronger
bidder has a lower equilibrium bid distribution but his bidding strategy is such that he bids more than the weaker bidder for each cost term.\footnote{A good discussion of this topic is given in Milgrom (2004), pp. 149-155.} Hence, the stronger bidder can, even if he has a lower cost term, sometimes lose the auction as the weaker bidder bids more aggressively. The results for the SPSB-auction are not affected by asymmetries, it is still a weakly dominant strategy to bid the cost term and—in contrast to the FPSB-auction—this format is efficient in the sense that the bidder with the lowest cost term always wins.

Transferred into our framework, this would mean that the agency should not use the FPSB-auction as it does not allocate the contract to the most efficient bidder and it increases competition which in turn leads to a higher non-fulfillment rate. The result that the SBSP-auction might be preferred to the FPSB-auction is in contrast to most of the empiric and theoretic results where the FPSB-auction—without limited liability—is preferred as it gives the right bias towards the weak bidder.

**Common costs**

A crucial point of our analysis so far is the independent private cost assumption. *Private* means that each bidder’s costs depend only on his own type and *independent* means that there is no statistical dependence between the types. The other extreme are pure common costs where all bidders have the same ex-post cost realization but different ex-ante signals about the true realization.\footnote{In many situations the costs of the bidders are interdependent, i.e. bidders have common or almost common costs (e.g., the market price of a spectrum or a drilling licence).} For instance, the cost to finish a project is identical for the bidders but their estimates (signals) differ, i.e. their information is of different quality.

To give an example how cost interdependence will affect the outcome in our framework, we follow the analysis of Bulow and Klemperer (2002) and investigate the almost common cost case for 3 symmetric (or asymmetric) bidders in a single-unit
(or multi-unit) English auction. In a common-cost environment, the winner is the bidder with the most optimistic signal. Conditional on winning without updating the belief about the true costs, this signal would be too low on average and the winning bidder will lose money on average. To avoid this winner's curse, bidders will use any information to update their beliefs about the true cost realization of the project and bid more cautiously. For example, in the English auction an exit of a bidder means that the beliefs of the remaining bidders about the true cost realization are lower. This is bad news as these might be too optimistic. Hence, the remaining bidders bid more cautiously. Does this affect the outcome in our framework? Note first that the possibility to declare bankruptcy can be regarded as an insurance against the winner’s curse. However, also bidders with limited liability will take account of the winner’s curse—although maybe not as much as without limited liability—as they have no interest in lowering their survival rate too far.

Assume that bidders’ costs have a common-cost part (e.g., market factors like exchange rates) and a private-cost part (e.g., efficiency levels) and the error term $\Delta$ is part of the private costs. Also with common costs bidders ignore the error term, i.e. bid below possible cost realizations. If bidders are symmetric, then bidders bid cautiously in respect to their common cost signal to avoid the winner’s curse. If the agency procures two units, the expected payment will be higher than with one unit as there is less competition and the probability of bankruptcy is reduced.

But this is no longer true for the asymmetric case. If a bidder has a very large private cost advantage (e.g., a better production technology), the other bidders have to bid very cautiously. Because if a disadvantaged bidder wins against the advantaged bidder, then his signal about the common costs must have been very optimistic. Thus, the advantaged bidder almost always wins. If bidders are restricted to bid only for one unit, selling two units reduces the winner’s curse for the second unit as only bidders 2 and 3 compete for this unit. And as bidders 2 and 3 bid more

\[^{51}\text{The results of Bulow and Klemperer (2002) and of the example in appendix A.2 hold if hazard rates are increasing.}\]

\[^{52}\text{See appendix A.2 for an example of this bidding strategy.}\]
aggressively due to a reduction of the winner’s curse, bidder 1 is now not much more likely than bidder 2 or 3 to be the winner of the auction. Therefore, bidder 1 will also have to bid lower (to win the first unit) and the expected payment will decrease. As procuring two units instead of one leads to a reduction of the winner’s curse and more aggressive bidding, reducing the winners curse might lead to an increase in risk.

### 3.7 A transfer to industrial organization

The analysis of auctions is an analysis of price competition under incomplete information. It is related to the analysis of price competition in industrial organization. In the following, we want to transfer the insights of our analysis into the field of industrial organization.

#### Mergers and entry

A standard result in industrial organization is that a merger between two competitors increases market power and reduces competition which in turn leads to higher prices and lower welfare\(^{53}\). Hence, it is important to regulate mergers, especially mergers between firms of the same industry (horizontal mergers). We give an example: assume that market demand is \(1 - Q\) and \(n\) identical firms with linear costs \(cq\) compete in quantities (Cournot competition). Then, the equilibrium market price is \(p = c + \frac{(1-c)}{(n+1)}\). A merger between two firms (reducing \(n\) to \(n-1\)) leads to an increase in price which in turn leads to lower welfare.\(^{54}\) As a consequence, the merger should be prohibited if there are no welfare-increasing effects of the merger\(^{55}\) offsetting this negative effect. Risk reduction might be such a welfare-increasing effect. As a merger leads to higher prices due to less competition it also reduces the risk of non-fulfillment according to the analysis in section 3.3. This means that

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\(^{54}\)This effect can also be transferred to a situation in which firms compete in prices, e.g. when products are differentiated.

\(^{55}\)In the traditional analysis the reduction of fixed costs, for instance.
the merger is increasing welfare if this risk reduction effect outweighs the increase in prices. Therefore, regulators should not only investigate the relevant market and the market power of the newly created firm but also be aware of the uncertainty and the solvency of the industry.\textsuperscript{56}

**Price competition under cost uncertainty and risk aversion**

An important result in industrial organization is the Bertrand paradox which states that two risk-neutral firms are sufficient to restore perfect competition: if two firms with identical marginal costs $c$ compete in prices, it is a Nash-Equilibrium that both firms set price equal to marginal cost ($p = c$) and share the market. An important assumption that drives this result is the discontinuity in market share: if two firms charge the same price, they share the market. But if one firm undercuts the other firm slightly, it will serve the whole market. This leads to a race to the bottom, erodes all profits, and welfare is maximized.\textsuperscript{57} Taking cost uncertainty into account does not change this result if the uncertainty is common knowledge: risk-neutral firms now charge the expected cost ($p = E[c]$) and the expected profit will again be zero. There are several ways out of the Bertrand paradox, i.e. there are situations in which firms set prices above expected cost and make positive profits. One of these is when a rival’s costs are unknown; another is risk aversion.\textsuperscript{58} We discuss how limited liability can eliminate the effect of risk aversion and prices will turn out to be very low again. The intuition is the following: Suppose two risk-neutral firms which have either high or low costs compete in prices and charge a price above the equilibrium price $p^* = E[c]$. Undercutting the competitor slightly would increase the market share from $1/2$ to $1$. The profit is now twice as large in the good state of nature (low costs) but such is the loss in the bad state (high costs). Risk-neutral firms give

\textsuperscript{56}The same logic can be applied to the question of barriers of entry where low barriers of entry might actually result in more aggressive bidding and more bankruptcies as they create more competition.

\textsuperscript{57}See Tirole (1988), pp. 209-211.

\textsuperscript{58}See Spulber (1995) for the first, Wambach (1999) for the second environment and an overview of the literature.
equal weight to profits and losses. As long as \( p > E[c] \), the overall expected profit increases when undercutting until the minimum possible price \( p^* = E[c] \) is reached. If firms are risk-averse, the weight of losses and profits is no longer equal. As risk-averse firms value their losses higher than their profits they have less incentives to undercut the competitors price because serving the whole market is too risky if the costs turn out to be high. Hence, the equilibrium Bertrand price will be above the minimum possible price. With limited liability the incentives to undercut are restored as a second discontinuity is introduced. If things go bad, the firm simply shuts down and loses only its budget. Hence, firms have higher incentives to undercut as they can avoid serving the whole market with a high-cost realization by declaring bankruptcy. Compared to the case with unlimited liability, limited liability will change the previous results (depending on the size of the budget). The minimum possible price and the Bertrand price will be below expected costs and—for a small budget—may be even zero. An example for this is given in appendix A.3.

### 3.8 Conclusion

In this chapter the risks of procurement are analyzed in an environment where firms can go bankrupt. When firms have uncertainty about the cost realization and limited liability, their bidding behavior is affected and they will bid more aggressively. It is shown that the revenue-equivalence principle breaks down even if the expected payments are the same. The reason is that if bankruptcy occurs, the distribution of payments becomes relevant. As a general result, the more competition the mechanism produces, the lower the expected payment and the higher the probability that the project will not be finished. But although competition is bad in terms of risk, it is good to select the more efficient firms. Therefore, when choosing a mechanism, the procurement agency faces a trade-off between the price and the risk of non-fulfillment. Mechanisms like rationing and multi-sourcing in particular handle the

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59 See Wambach (1999).
trade-off quite well while others like the average-bid method, lead to undesirable results as prices turn out to be very high. We also showed that reserve prices and entry fees are no longer equivalent and that C+ contracts can be efficient from a risk point of view.

Extensions of this analysis allow for asymmetries between bidders and common costs of the bidders. As the possibility of bankruptcy makes it desirable to have rather less competition than more, we gave examples that in these cases, the standard insights from the literature no longer hold. E.g., as the winner’s curse leads to less aggressive bidding this might be preferred by the procuring agency. Thus, the agency might use a sealed-bid rather than an open auction. She can also prefer single-sourcing to multi-sourcing if bidders are asymmetric, as in this case multi-sourcing reduces the winner’s curse.

The insights of auction theory with limited liability are also transferred into the field of industrial organization. Here we discuss how limited liability can offset the effect of risk aversion in a price setting industry. Furthermore, we stress that horizontal mergers might be welfare increasing, even if (or better because) they reduce competition.
Chapter 4

An extension to international trade theory

4.1 Introduction

Discriminatory public procurement in favor of domestic firms is common practice in many countries.\(^1\) The way local governments discriminate can either be explicit through price-preference rules (subsidies) or set-asides (quotas) or implicit through hidden discrimination like ex-post bailouts, nontransparent tenders or legal requirements that make it hard for foreign firms to participate. Both kinds of discrimination in public procurement are in conflict with the fair-trade rules of the GATT/WTO. But attempts to deal with the problem (e.g., the Government Procurement Agreement) have not fully succeeded as discrimination still takes place. There are many reasons why governments might want to favor domestic firms. Some of them have political motivations (e.g., supporting small firms, considerations of national security, the power of interest groups) and some are motivated by the idea of maximizing domestic welfare (e.g., shifting profits from foreign to domestic firms, increasing competition to minimize procurement costs, increasing the returns of learning effects).

The focus of this paper is on the concern of a government to protect domestic firms

\(^1\)For an analysis of this home bias see Trionfetti (2000).
from ruinous competition with foreign firms. The weaker the domestic firms are in respect to efficiency or financial means, the higher is the risk that these firms go bankrupt if competition is tough. Hence, one might argue that weak domestic firms need financial support or should be favored by the government. This is a widespread argument in developing countries, but also in industrialized nations discrimination takes place in favor of potentially weak firms, like small and medium-sized enterprises (SMEs), minority owned firms (e.g., in the FCC-auctions) or industries that suffer from structural weakness. A common method of discrimination is to use a price preference. For instance, the Buy American Act in the US offers a 6% preference to all domestic firms in public procurement. The preference increases up to 12% if firms are small or medium-sized or from a region with high unemployment. As a price preference is given to a domestic firm in case of winning, it makes the domestic firm more competitive and it wins more often. Hence, on average the expected profit of a domestic firm is higher. This effect—a profit-shifting argument as in Branco (1994)—protects supported domestic firms from international competition.

However, this argument does not hold if firms have limited liability. This is important insofar as the weak firms which are protected suffer very often from insufficient financial means or capital market restrictions (e.g., SMEs). It is therefore not unlikely that the protected firms have limited liability, i.e. go bankrupt if the project is going bad. As derived in several papers, firms with limited liability will bid more aggressively as they can close their business if things turn out badly but participate fully if things go well. The weaker the firm (the less it has to lose), the more aggressive the bid and therefore the higher the risk of bankruptcy. If competition gets tougher, the incentives for the weak firms to bid aggressively are even higher. As a price preference increases competition, it makes the weak firms bid even more aggressively which in turn leads to more bankruptcies of these firms.

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2E.g., if a domestic industry is infant in the sense that the foreign firms are mature and the domestic firms experience learning effects over time, subsidies can attain the social optimum (Bardhan, 1971). However, Melitz (2005) comes to the conclusion that when favoring infant-industry firms, quotas should be preferred to tariffs and subsidies.

3 For an overview of domestic price preferences, see Carrier (1997).

This strategic effect on the bidding behavior (risk-shifting effect) can actually offset the profit-shifting effect.\footnote{This analysis can also be transferred to the literature of export subsidies à la Brander and Spencer (1985) where subsidizing a domestic firm with limited liability which competes with a foreign firm for a third market can lead to more bankruptcies.}

**Related literature**

As mentioned in the introduction, one motivation to use price preferences in public procurement is to maximize domestic welfare. There are two effects of price preferences with regard to welfare that are discussed in the literature: first, if domestic firms have cost disadvantages, discrimination in favor of domestic firms stimulates competition which in turn reduces procurement costs. McAfee and McMillan (1989) show that a price preference for high-cost domestic firms puts more pressure on low-cost foreign firms and leads to lower expected prices.\footnote{However, the simulations of McAfee and McMillan (1989) show that the maximal reduction in procurement price is very small.} If the disadvantaged domestic firms have a sufficiently high probability of winning, the profits of the domestic firms are also higher on average. But note that in this case, the agency distorts the allocation and generates a sub-optimal level of efficiency as the less efficient domestic firms win more often.

Second, in the absence of cost disadvantages, discrimination in favor of domestic firms increases welfare if the government prefers domestic profits to foreign profits (Branco, 1994; Vagstad, 1995). The intuition behind this is straightforward: with a price preference the domestic firms win more often and the agency shifts profits from foreign to domestic firms. However, favoritism increases procurement costs which can create welfare distortions if e.g., there is a deadweight loss of money raised by the government.

A combination of both effects described above is analyzed in Naegelen and Mougeot (1998) who show that a property of the optimal mechanism is that discrimination should occur in favor of the domestic firm and in favor of the disadvantaged firm.
In the next section, we introduce price preferences into an auction framework with firms that have limited liability. The aim is to find if a price preference is suited as a protection device for domestic firms. In a first step, we derive the basic results in a framework with limited-liability but without a price preference. In a second step, we investigate how a price preference will affect these results.

### 4.2 A model of national discrimination and limited liability

We adopt a simplified version of the model in chapter 3 where an agency (e.g., the government or a public entity) procures one project via a second-price sealed-bid (SPSB) auction. A welfare-maximizing agency cares about the social value $v$ of a successful implementation and the expected price $E[p]$ of the project.\(^7\) In addition in a framework with limited liability, the agency also cares about the probability of non-fulfillment $\phi$ (i.e. the project is abandoned or the agency suffers from higher costs of procurement due to re-auctioning the contract), the domestic firms’ survival rate $(1 - \phi_d)$ and the welfare losses $B$ due to a bankrupt domestic firm\(^8\) (e.g., litigation costs or social costs such as unemployment). Hence, the utility of the agency is

$$u = (1 - \phi)(v - p) - \phi_d B. \quad (4.1)$$

There are two potential firms, one foreign (indexed by $f$) and one domestic (indexed by $d$) firm.\(^9\) We assume that both firms are risk-neutral and have limited liability.\(^10\) The cost realization of firm $j$ is either $c_j$ or $c_j + \Delta$ with a probability of $\rho$ or $(1 - \rho)$ (with $0 < \rho < 1$). This means that firm $j$ knows its individual cost term $c_j$ at the stage of the auction and that it can suffer additional cost of $\Delta$ during

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\(^7\)We use this simplified welfare function to keep the analysis tractable.

\(^8\)We normalize the welfare loss if a foreign firms go bankrupt to zero.

\(^9\)A price preference has an effect on the outcome only if the two lowest bids come from a foreign and a domestic firm. Thus, the assumption of 2 firms only is without loss of generality.

\(^10\)The main result of this paper is still valid if the foreign firm’s liability is unlimited or if the foreign firm has cost advantages.
the completion of the project. The cost term for the project \( c = c_j \) is distributed on the support \([c; \bar{c}]\), identical for both firms. \( F(c) \) denotes the distribution and \( f(c) = F'(c) \) denotes the density of the cost term.\(^{11}\) Our analysis is based on the following assumption regarding the properties of the cost term distribution:

**Assumption 1**

\[
\frac{df(\cdot)}{dc} \geq 0 \text{ and } \frac{df(\cdot)}{dc}(1 - F(\cdot)) - f(\cdot)^2 \leq 0
\]

This assumption is sufficient for our result to hold. The first part of the assumption means that \( f(\cdot) \) is weakly monotone increasing in the cost term. The second part means that \( f(\cdot)(1 - F(\cdot)) \) is weakly decreasing in the cost term. Both properties hold for the uniform distribution, for instance. Each firm has a small budget of \( \epsilon \). If a firm wins the contract and receives a payment which lies below the realized cost and its budget, it declares bankruptcy as its profit would be negative otherwise. Notice that as bidders lose only a small budget of \( \epsilon \), it is almost cost-free to declare bankruptcy.\(^{12}\)

The order of events is as follows: (1) The agency announces the specification of the project and the auction rules (SPSB-auction). (2) The firms bid. The firm with the lowest bid wins the contract and receives the second lowest bid as the payment. The losing firm has a payoff of zero. (3) The winner observes its realized cost \((c \text{ or } c + \Delta)\) and makes a profit if the payment is higher than the cost or decides to declare bankruptcy otherwise. Thus, if a firm with cost term \( c \) wins the contract at payment \( p \), its expected profit is given by

\[
\pi = \begin{cases} 
(p - c) - (1 - \rho)\Delta & \text{if } p \geq c + \Delta \\
\rho(p - c) - (1 - \rho)\epsilon & \text{if } c \leq p < c + \Delta \\
-\epsilon & \text{if } p < c
\end{cases}
\]

\(^{11}\)The realization of the cost is bounded on the support \([c; \bar{c} + \Delta]\). It is assumed that \( \Delta \) is smaller than the differences in cost levels \((0 < \Delta < (\bar{c} - c))\).\(^{12}\)To see how the bidding is affected if firms have significant wealth they can lose, see Board (2005).
The derivation of the bidding strategy in the SPSB-auction follows textbook analysis and is given in the appendix. The optimal bidding strategy is to bid such that a payment equal to the bid makes a firm indifferent between winning and not winning the contract. In our framework with limited liability, it is a weakly dominant strategy for firm $j$ to bid the cost term $c_j$ if $\epsilon \to 0$.\footnote{A derivation of the bidding strategy is given in the appendix.} Bidding less would always result in losses of $\epsilon$. By bidding more, firms would forego profits if the costs are low (if it is not going well, firms will simply declare bankruptcy). Therefore, the winner will be the firm with the lowest cost term which is the lowest order statistic $c^{(1)}$. This implies that the sourcing is efficient. As the expected payment is determined by the second lowest bid, it is given by the following equation:

$$E[p] = E[c^{(2)}] = \int c f_2(c) dc$$  \hspace{1cm} (4.3)

with $f_2(c)$ being the density of the second lowest order statistic $c^{(2)}$.

The probability that the project will not be finished is $(1 - \rho)$ times the probability that the second lowest cost term (payment) is less than $\Delta$ away from the lowest cost term. Formally, the latter term is the probability that $c^{(2)} - c^{(1)} < \Delta$. Let $f_1(c)$ be the density of the lowest order statistic and let $f_2(z | z \geq c)$ be the density of the second lowest order statistic conditional on $c$ being the lowest order statistic. Then,

$$Prob[c^{(2)} - c^{(1)} < \Delta] = \int f_1(c) \int_c^{c+\Delta} f_2(z | z \geq c) dz dc.$$  \hspace{1cm} (4.4)

The probability of non-fulfillment is given by

$$\phi = (1 - \rho)Prob[c^{(2)} - c^{(1)} < \Delta].$$  \hspace{1cm} (4.5)
Price preferences

Assume now that the agency wants to reduce $\phi_d$ by giving the domestic firm a price preference of $\kappa$ if it wins.\(^{14}\) Compared to the standard setting, the order of events changes as follows: in stage (1): the agency additionally announces the size of the price preference. In stage (2): if the domestic firm wins, it will receive the bid of the foreign firm plus $\kappa$ as the payment. As the domestic firm receives the price preference conditional on winning, it is like a cost reduction in case of winning. The bidding strategy in an SPSB-auction is to bid such that a bidder is indifferent between winning and not winning; hence, the domestic firm will bid $c_d - \kappa$.\(^{15}\) Note that the bidding strategy of the foreign firm is not affected by the price preference.

Figure 4.1 shows the different effects of a price preference on the expected payment (line 1), on the probability of bankruptcy of a domestic firm $\phi_d$ (line 2) and on the probability of non-fulfillment $\phi$ (line 3).

\[\begin{array}{|c|c|c|}
\hline
\text{case 1} & \text{case 2} & \text{case 3} \\
\hline
\text{change in } p & \kappa & +\gamma < \kappa & +\kappa \\
\text{change in } \phi_d & = & > & < \\
\text{change in } \phi & > & = & < \\
\hline
\end{array}\]

\[\begin{array}{cccc}
c_f & c_d - \kappa & c_f & c_f \\
\end{array}\]

**Figure 4.1:** Effects of a price preference

For the illustration of the different effects, assume that the cost term of the domestic firm is $c_d$ and the cost term of the foreign firm is either $c_{f1}$, $c_{f2}$ or $c_{f3}$. Then, a price preference will lead to the following cases: (1) No change in allocation but a change in the expected payment for the foreign firm. This is the case in

\(^{14}\)For technical reasons, we assume that $\kappa < \Delta$. Note that this does not imply that the our results will change (or be the opposite) if $\kappa > \Delta$.

\(^{15}\)The derivation of the bidding strategy is analogously to proposition 1.
which the foreign firm would have won with or without the price preference. Now
the foreign firm gets a lower payment which increases its risk of bankruptcy. (2) A
change in the allocation and a change in the expected payment. This is the case if
the domestic firm only wins because of the price preference. Then, there is a shift
of bankruptcy risk from the foreign firm to the domestic firm. This shift in risk
is the negative effect $\phi_d^-$ of a price preference (negative risk-shifting effect). If the
agency introduces the price preference to protect the domestic firm (lower $\phi_d$), she
is not interested in such a shift in risk. (3) No change in allocation but a change in
the expected payment for the domestic firm. This is the case in which the domestic
firm would have won with or without the price preference. Now the probability
of bankruptcy of the domestic firm decreases due to a higher payment. This is the
positive effect $\phi_d^+$ of a price preference on the probability of bankruptcy of a domestic
firm (positive risk-shifting effect). It remains to show which effect is larger.

The positive risk-shifting effect is illustrated in figure 4.2. If $c_f \in [c_d + \Delta - \kappa, c_d + \Delta]$, the domestic firm no longer goes bankrupt if costs are high while it would have
gone bankrupt without the price preference.

\[ \phi_d^+ = (1 - \rho) \int_{c_d}^{c_d + \Delta} f_1(c_d) \int_{c_d + \Delta - \kappa}^{c_d + \Delta} f(z | z \geq c_d) dz dc_d + (1 - \rho) \int_{c_d}^{c_d + \Delta + \kappa} f_1(c_d) \int_{c_d + \Delta - \kappa}^{c_d + \Delta + \kappa} f(z | z \geq c_d) dz dc_d \]  

(4.6)
with \( f_1(c_d) \) being the distribution of the domestic firm’s cost term conditional on being the lowest cost term (as the domestic firm would have won with or without the price preference). The density of the foreign cost term conditional on the domestic cost term being the lowest cost term is \( f(z \mid z \geq c_d) \). The range of the inner integral is the reduction in the probability of bankruptcy compared to the situation without any price preference. A domestic firm with high costs \((c_d \in [\bar{c} - \Delta, \bar{c} - \Delta + \kappa])\) only partly benefits from the price preference, thus in the second term the inner integral integrates to \( \bar{c} \). For a domestic firm with costs close to \( \bar{c} \) \((c_d \in [\bar{c} - \Delta + \kappa, \bar{c}])\), even the price preference cannot prevent bankruptcy (as \( \kappa \) is smaller than \( \Delta \)).

The negative risk-shifting effect occurs if the domestic firm only wins because of the price preference, i.e. if \( c_d - \kappa < c_f < c_d \). As the payment \( c_f \) and the price preference \( \kappa \) never suffice to cover a high-cost realization \((c_f + \kappa < c_d + \Delta)\) the probability of bankruptcy is given by the probability of a high-cost realization \((1 - \rho)\). The risk-shifting effect is therefore \((1 - \rho)\) times the probability that the domestic firm only wins because of the price preference. This is illustrated in figure 4.3.

![Negative risk-shifting effect](image)

**Figure 4.3:** Negative risk-shifting effect

Formally, the negative risk-shifting effect is given in the following equation:

\[
\phi_d^-= (1 - \rho) \int_{\bar{c} + \kappa}^{\bar{c}} f_2(c_d) \int_{c_d - \kappa}^{c_d} f(z \mid z \leq c_d) dz dc_d \\
+ (1 - \rho) \int_{\bar{c}}^{\bar{c} + \kappa} f_2(c_d) dc_d 
\]

\[(4.7)\]
with \( f_2(c_d) \) being the distribution of the domestic firm’s cost term conditional on being the highest cost term (as the domestic firm only wins because of the preference). \( f(z \mid z \leq c_d) \) is the density of the foreign cost term conditional on the domestic cost term being the highest cost term. The range of the inner integral of the first term gives the probability of winning if the domestic firm only wins due to the price preference. As domestic firms with costs \( c_d \in [c, c + \kappa] \) always win, the second term is the probability that \( c_f < c_d \).

**Proposition 4** If an agency supports a firm with limited liability with a price preference \( \kappa \) with \( \kappa < \Delta \), it will increase the probability of bankruptcy of this firm.

**Proof** To see whether the overall effect on the probability of bankruptcy is negative or positive, we have to calculate the difference between \( \phi^+_{d,M} \) and \( \phi^-_{d,M} \). For simplicity’s sake, we drop the subscripts of \( c_d \). We distinguish two cases: (i) The main effect which is the difference between the first terms of \( \phi^+_{d} \) and \( \phi^-_{d} \). (ii) The border effect which is the difference between the second terms of \( \phi^+_{d} \) and \( \phi^-_{d} \).

Ad (i) main effect (M): Using that \( f_1(c) = 2 f(c)(1 - F(c)) \), \( f(z \mid z \geq c) = \frac{f(z)}{1 - F(c)} \) and after a transformation of variables \( (x = c + \Delta \) and replacing \( x \) with \( c \) in a second step), we can write the first term of equation (4.6) as

\[
\frac{\phi^+_{d,M}}{1 - \rho} = \int_{c-\kappa}^{c+\Delta} \int_{c+\Delta-\kappa}^{c+\Delta} 2 f(c)(1 - F(c)) f(z) \frac{dz}{1 - F(c)} dc \\
= \int_{c+\Delta}^{c} 2 f(c - \Delta) \int_{c-\kappa}^{c} f(z) dz dc.
\] (4.8)

Using that \( f_2(c) = 2 f(c) F(c) \) and \( f(z \mid z \leq c) = \frac{f(z)}{F(c)} \), the first term of equation (4.7) can be rewritten as

\[
\frac{\phi^-_{d,M}}{1 - \rho} = \int_{c+\kappa}^{c} \int_{c-\kappa}^{c} 2 f(c) F(c) f(z) \frac{dz}{F(c)} dc = \int_{c+\kappa}^{c} \int_{c-\kappa}^{c} 2 f(c) f(z) dz dc \\
= \int_{c+\kappa}^{c} 2 f(c) \int_{c-\kappa}^{c} f(z) dz dc + \int_{c+\Delta}^{c} 2 f(c) \int_{c-\kappa}^{c} f(z) dz dc.
\] (4.9)
Subtracting equation (4.9) from equation (4.8) gives the main effect:

\[
\frac{\phi^{+}_{d,M} - \phi^{-}_{d,M}}{1 - \rho} = \int_{\xi + \Delta}^{\xi} 2[f(c - \Delta) - f(c)] \int_{c-\kappa}^{c} f(z)dzdc - \int_{\xi + \kappa}^{\xi + \Delta} 2f(c) \int_{c-\kappa}^{c} f(z)dzdc.
\]

(4.10)

If \(f(\cdot)\) is weakly monotone increasing in \(c\) (first part of assumption 1), the first term of equation (4.10) is negative. Hence overall, the main effect is negative.

Ad (ii) border effect (B): to complete the proof, we show that the second term of \(\phi^{+}_{d} - \phi^{-}_{d}\) is smaller than zero as well. Note that this effect is of minor importance as it is only relevant for a small area. Using transformation of variables for the first integral of equation (4.11) \((x = c + \Delta - \kappa)\) and replacing \(x\) with \(c\) in a second step), the border effect can be rewritten as

\[
\frac{\phi^{+}_{d,B} - \phi^{-}_{d,B}}{1 - \rho} = \int_{\xi - \Delta}^{\xi - \Delta + \kappa} 2f(c)(1 - F(c)) \int_{c + \Delta - \kappa}^{\xi} f(z)dzdc - \int_{\xi}^{\xi + \kappa} 2f(c)(1 - F(c))dc
\]

(4.11)

Due to assumption 1, \(f(c - \Delta + \kappa) \leq f(c)\) and as \(f(\cdot)(1 - F(c))\) is weakly monotone decreasing in the cost term, the border effect is always negative. Hence, the overall effect is negative.

As given in proposition 4, the probability of bankruptcy is higher with a price preference than without due to the more aggressive bidding strategy caused by the price preference.

### 4.3 Conclusion

This chapter describes the risk of using a price preference in an environment where domestic firms have limited liability. Due to the limited-liability effect, domestic firms bid below possible cost realizations and have a positive probability of
bankruptcy. If domestic firms receive a price preference, they will bid even more aggressively and the probability that a domestic firm goes bankrupt increases. If a government wants to avoid bankruptcies of domestic firms, price preferences may not be the adequate tool of protection.

Protecting weak domestic industries is better done with quotas or set-asides as (i) these reduce competition which reduces the limited-liability effect\(^{16}\) and as (ii) these will have no strategic effect on the bidding behavior of domestic firms in an SPSB-auction. The drawback of such a scheme would be to accept higher procurement costs. Further research is left to be done in order to derive the optimal protection scheme.

\(^{16}\)Similar to the analysis of multi-sourcing in section 3.3
Chapter 5

An insurance against ALTs:
surety bonds

5.1 Introduction

In a recent paper Calveras, Ganuza, and Hauk (CGH, 2004) investigate the problem of abnormally low tenders (ALTs) and discuss the regulatory practice of surety bonds. During a procurement process, a low winning tender can be bad news for the agency if the project leads to financial distress of the winning contractor who can go bankrupt before finishing the project. This problem arises if the agency has no information on the solvency of the potential contractors. Surety bonds, issued by surety companies which are specialized in screening the contractors, are used to deal with this problem. If the contractor is in financial difficulties, the surety company guarantees the agency either to finish the project or to abandon the project and pay the surety bond to the agency. CGH show that surety bonds mitigate the problem of ALTs and that the size of the surety bond is optimally chosen such that in some situations the project is neither finished by the contractor nor by the surety company. They also show that the US practice of requiring a bond the size of which is equal to the actual payment may lead to inefficient overinsurance. CGH arrive at their results by assuming that if a surety bond of size $L$ is required from the contractor,
the issuing surety company has to freeze $L$ and has opportunity cost of $r_0L$ which would be the return of a risk-free investment. We modify this assumption for three reasons: first, the insurance literature has always focused on the benchmark of fair insurance where under full information an efficient outcome is obtained. Thus, it is interesting in its own right to analyze fairly priced surety bonds and the resulting outcome. Second, even if insurance is priced unfairly, in the case in which the contractor never goes bankrupt (i.e. possesses enough financial assets himself), the surety company knows that the contractor’s assets (and therefore the project) are not at risk and should not charge a risk premium. Third, even if a surety bond has to be frozen to cover the potential losses, it can be invested (at least in a risk-free asset). It turns out that the optimal fairly priced surety bond is such that finishing the project is always preferred. Furthermore, in contrast to the insurance literature, overinsurance in the sense that the surety bond required is higher than the money at risk can be efficient. Interestingly, even if insurance is priced unfairly, full insurance might be optimal. The chapter is structured as follows: first, we derive the bidding strategy and the size of the optimal surety bond for fair insurance premia. Second, we derive properties of the bidding strategy and the optimal size of the surety bond for unfair premia.

### 5.2 Fairly priced surety bonds

In their model CGH assume that a risk-neutral agency wants to undertake a project with value $V$ and procures it via a second-price sealed-bid auction. $N$ risk-neutral contractors bid for the contract but face uncertainty about the realization of the cost. Ex ante, the cost $C$ is either $c - k_G$ with a probability of $(1 - q)$ or $c + k_B$ with a probability of $q$ where $(1 - q)(-k_G) + qk_B = 0$. All contractors (indexed by $i$) have the identical, commonly known cost structure but differ in financial assets $A_i$. $A_i$ is private information, i.e. the agency can neither identify nor quantify the contractors’ assets. Due to limited liability, the winning contractor can declare bankruptcy if his costs are higher than the sum of the payment $P_i$ and the assets
 CHAPTER 5. AN INSURANCE AGAINST ALTS: SURETY BONDS

$A_i$. In this case the contractor loses all his assets (to the agency) but avoids higher losses. This bankruptcy option makes contractors behave like risk lovers which leads to the result that overall (i) contractors bid more aggressively (ALTs) and (ii) contractors which are in a bad financial situation win more often (high bankruptcy rate).\textsuperscript{1} To mitigate this problem, regulatory policies such as surety bonds are used in states like Canada, Japan, and the USA. If a surety bond of size $L$ is required by the agency, each potential contractor has to have a bond of size $L$ guaranteed by a surety company. Because of the guarantee, the contractor (limited to $A_i$) and the issuing surety company (limited to $L$) are liable. CGH assume that the surety company which is specialized in dealing with the financials of contractors, can—in contrast to the agency—perfectly screen the contractors, i.e. learn about $A_i$. Once the surety company has learned about $A_i$, she will charge contractor $i$ a risk-adjusted fee $R_i(A_i)$. The fee $R_i(A_i)$ compensates the surety company for the guarantee, in case of the contractor’s bankruptcy, either to finish the project or to pay $L$ to the agency. In both cases, the contractor loses all his assets. It is assumed that the market for surety bonds is perfectly competitive. So, surety companies make zero profits. It is also assumed that the outside option for the surety companies is to invest $L$ at the risk free interest rate $r_0$. While CGH assume that a surety company does not accrue interest at the risk free interest rate if she issues the bond, we criticize and relax this assumption. To do so is not unrealistic because (i) deposits usually accrue interest and (ii) the bond is not at risk until the contractor is in financial difficulties which is the case at the end of the project.\textsuperscript{2}

The investment at the risk free interest rate makes the timing of the cash flows important. Therefore, we use a two-period model to compare the cash flows at the end of the project. In the first period ($t = 0$), the agency announces the auction, the specifications of the project as well as the required size $L$ of the surety bond. The

\textsuperscript{1}Zheng (2001) shows that if contractors are budget-constrained, the most budget-constrained contractor is the contractor most likely to win the auction.

\textsuperscript{2}One might argue that the agency indeed has costs for freezing the deposits. In CGH these costs are proportional to the size of the bond $L$. We also allow for costs of screening in a second step in section 5.3. However, these costs are either fixed or proportional to the money at risk but not proportional to $L$. 
surety bond is required in $t = 1$, so the discounted surety that a surety company has to guarantee in $t = 0$ is $L \frac{1}{(1+r_0)}$. In $t = 0$ the surety companies screen the contractors, learn about the value of their financial assets $A_i \frac{1}{(1+r_0)}$, and charge the discounted fee $R_i \frac{A_i}{(1+r_0)}$. Once the potential contractors have the guarantee, they enter the auction and bid according to their bidding functions. Following the rules of the second-price sealed-bid auction, the lowest bid wins and the winning contractor receives the second lowest bid as the payment. Since we compare all cash flows at the end of the project, we define the bids $P^*_i(A_i)$ and the payment $P_i$ in $t = 1$. The discounted payment the winning contractor receives is $P_i \frac{1}{(1+r_0)}$. Note that $P_i$ is uncertain before and during the auction. Once a contractor wins, he pays the fee $R_i \frac{A_i}{(1+r_0)}$ to the surety company in $t = 0$ and starts the project.

In the last period ($t = 1$), the contractor sees his realized cost and the project is finished either by the contractor, the surety company or the agency. The bankruptcy decisions and the payoffs in $t = 1$ are as follows: if the winning contractor has enough assets in order to never go bankrupt he will always finish the project. In this case the guarantee of the surety company is not needed and the utility of the agency is $U = V - P_i$. If the costs are high and the winning contractor’s assets are not sufficient to finish the project, the winning contractor loses all his assets and the surety company has two options. First, if $A_i$ is large enough so that the difference between the cost and the sum of the payment and the remaining assets is smaller than the bond $(L - (c+k_B - P_i - (A_i-R_i(A_i)))) \geq 0)$, the surety company finishes the project. In this case the utility of the agency is again $U = V - P_i$. Second, if $A_i$ is not large enough so that the difference between the cost and the sum of the payment and the remaining assets is larger than the bond $(L - (c+k_B - P_i - (A_i-R_i(A_i)))) < 0)$, the surety company pays the bond to the agency. In this case the agency obtains $L$ and the remaining assets of the contractor, so the utility of the agency is given by $U = V - c - k_B + (A_i - R_i(A_i)) + L - C_B$. $C_B$ are additional bankruptcy costs of the agency if she finishes the project herself. An overview of the timing of the cash flows is displayed in table 1.
Next, we sketch the bidding strategies and present our results. The surety companies make zero profit, as the market is perfectly competitive. Thus, a surety company has to be indifferent between issuing the bond and investing into the risk-free asset:

\[ E[\Pi_S(\text{issue}, R_i(A_i), L)] = L. \] (5.1)

For the bidding in \( t = 0 \), each contractor will take the fee \( \frac{R_i(A_i)}{1+r_0} \) and the remaining assets \( \frac{A_i - R_i(A_i)}{1+r_0} \) into account and bid according to his equilibrium bidding function \( P_i^*(A_i) \). It is well known that if the procurement mechanism is a second-price sealed-bid auction, the equilibrium bid is such that in the case of winning with this payment, the contractor is indifferent between winning and not winning the contract. Therefore,

\[ \Pi_C(\text{win}, P_i = P_i^*(A_i), R_i(A_i), L) = A_i. \] (5.2)

As mentioned, there are three different cases one has to consider: (i) The winning contractor has enough assets to never go bankrupt (contractors of group (i)). In this case \( L \) is never at risk. Consequently, the surety company does not need to charge a risk premium \( (R_i(A_i) = 0) \). This result differs from CGH because here the contractor does not have to pay any fee, whereas in CGH even the wealthy contractors of group (i) have to pay \( r_0 L \). According to equation (5.2) the equilibrium bid must satisfy

\[
(1-q)(P_i^*(A_i) - c + k_G + A_i) + q(P_i^*(A_i) - c + k_B + A_i) = A_i
\]

which leads to a bid of \( P_i^*(A_i) = c \) for contractors with \( A_i \geq k_B \).
(ii) The second case occurs when the surety company will help the contractor finish the project in case of high costs (contractor of group (ii)). Therefore, the optimal fee is defined by $R_i(A_i) + (1 - q)L + q(L - (c + k_B - E[P_i] - A_i + R_i(A_i))) = L$.\(^3\) $E[P_i]$ is the expected payment and depends on the bids made by the other contractors. The last equation leads to a fee of $R_i(A_i) = \frac{q(c + k_B - E[P_i] - A_i)}{(1 - q)}$. According to equation (5.2), a contractor bids $P^*_i(A_i)$ such that $(1 - q)(P^*_i(A_i) - c + k_G + A_i - R_i(A_i)) = A_i$ which leads to $(1 - q)P^*_i(A_i) + qE[P_i] = c$. Given the payment rule of the second-price sealed-bid auction the bid must be $P^*_i(A_i) = c$ if $A_i \geq k_B - (1 - q)L$.

(iii) The third case is relevant when the contractor goes bankrupt and the surety company does not finish the project and pays $L$ to the agency (contractor of group (iii)). Then, the surety company sets $R_i(A_i) + (1 - q)L = L$, leading to $R_i(A_i) = qL$. The contractors bid such that $(1 - q)(P^*_i(A_i) - c + k_G + A_i - R_i(A_i)) = A_i$ which gives $P^*_i(A_i) = c - k_G + qL + \frac{A_i}{(1 - q)}$ if $A_i < k_B - (1 - q)L$. Note that $P_i(A_i) < c$.

With these modifications Lemma 4 of CGH now reads

**Lemma 4***

For $L < \frac{k_B}{(1 - q)}$:

$$P^*_i(A_i, L) = \begin{cases} c - k_G + qL + \frac{A_i}{(1 - q)} & \text{if } 0 \leq A_i < k_B - (1 - q)L \\ c & \text{if } A_i \geq k_B - (1 - q)L. \end{cases} \quad (5.3)$$

For $L \geq \frac{k_B}{(1 - q)}$:

$$P^*_i(A_i, L) = c. \quad (5.4)$$

\(^3\)If this condition holds, the surety company is indifferent between issuing the bond (left-hand side) and not issuing the bond (right-hand side). The left-hand side always yields the fee, the bond (if the costs are low), and the amount the surety company has to pay, if the costs are high and if she wants to help the contractor.

\(^4\)If a contractor of this group wins, there are two possible payments. First, the payment is determined by a contractor of group (i) with $P^*_i(A_i) = c$. Second, the payment is determined by a contractor of the same group. With $P^*_i(A_i) = c$, we have $E[P_i] = c$. As the next paragraph shows, a contractor of group (iii) will always bid less.
The optimal size of the surety bond

The next step is to determine the optimal size of the surety bond that maximizes the utility of the agency. Assume first that \( L < \frac{k_B}{(1-q)} \). Equation (5.5) represents the expected utility of the agency. With \( f_i \) being the distribution of the \( i \)th lowest assets and \( A_2 \) being the second lowest asset.

\[
V - \int_{k_B - (1-q)L}^{\infty} cf_1(A) dA
- (1 - q) \int_{k_B - (1-q)L}^{k_B - (1-q)L} \left[ \int_{A}^{k_B - (1-q)L} \left( c + \frac{qA_2}{(1-q)} - k_G + qL \right) dA_2 \right] f_1(A) dA
- (1 - q) \int_{0}^{k_B - (1-q)L} \left[ \int_{k_B - (1-q)L}^{\infty} cf_2(A_2) dA_2 \right] f_1(A) dA
- q \int_{0}^{k_B - (1-q)L} (c + k_B - (1-q)L - A + C_B) f_1(A) dA.
\]

Equation (5.5) can be rewritten as:

The first integral describes the case that the winning contractor has \( A \) large enough to assure completion of the project either by himself or by the surety firm. In this case the contractor receives \( c \) as the payment (group (i) and (ii)). For the second and third integrals, the project is only finished if the costs are low. The second integral represents the case where a contractor of group (iii) wins and receives a bid of a contractor of the same group as the payment. The third integral is the case in which a contractor of group (iii) wins and receives \( c \) as the payment. The last integral represents the case when the costs are high and neither the winning contractor nor the surety company finishes the project.
\[
V - c - q \int_0^{k_B - (1-q)L} (k_B - (1-q)L - A + C_B) f_1(A) dA \\
- (1-q) \int_0^{k_B - (1-q)L} \left[ \int_A^{k_B - (1-q)L} \left( \frac{qA_2}{1-q} - k_G + qL \right) dA_2 \right] f_1(A) dA.
\]  \hspace{1cm} (5.6)

In the case of \( L \geq \frac{k_B}{1-q} \) the surety bond is such that the project will always be finished (only group (i) and (ii) contractors). In this case the utility of the agency is:

\[
V - c.
\]  \hspace{1cm} (5.7)

The optimal size of the surety bond is determined by optimizing (5.6) and (5.7) with respect to \( L \).

**Proposition 5** The optimal size of the surety bond that maximizes the agency’s utility is \( L^* \geq \frac{k_B}{1-q} \).

**Proof** Note that the integrand of the first integral in equation (5.6) is positive because \( A < k_B - (1-q)L \). For the same reason the integrand of the second integral is positive as well. As both integrals are subtracted from \( V \), equation (5.6) is maximized if the range of each integral becomes zero. This is the case if \( L^* = \frac{k_B}{(1-q)} \) (or larger as then equation (5.7)) holds. \( \blacksquare \)

From Lemma 4\# we know that for \( L \geq \frac{k_B}{(1-q)} \) the surety company will always complete the project for any \( A_i \) which yields a utility of \( V - c \) for the agency. This result is contrary to CGH where the non-completion of the project can be an optimum. However, in line with the insurance literature, we obtain that fair insurance pricing leads to an efficient outcome in the sense that the surety company always finishes the project. Interestingly, this can be obtained with overinsurance in the sense that the required surety bond \( L \) might be larger than the money at risk. However, overinsurance on the side of the agency translates into full insurance on the side of
the surety company as this implies that the surety company will always finish the project. The interpretation of this result carries over to the US practice of surety bonds where the agency requires a bond which is equal to the actual payment, i.e. \( L = P \). In this case CGH come to the conclusion that inefficient overinsurance may be present. Our result is that, even if overinsurance is present, overinsurance is efficient as long as the surety bond is priced fairly.

CGH observe that the problem of the US practice is that the size of the surety bond is linked to the expected cost and not to the underlying uncertainty. In the next section, we argue that this reasoning might be correct but must not always be correct for unfairly priced insurance.

### 5.3 Surety bonds with a risk loading

Having established that for fair premia full insurance (and even overinsurance) can be optimal, let us now consider the case where the surety company faces costs of screening and risk costs which might be a reason for unfair insurance premia. As it is common in the insurance literature, we assume that the unfair part of the premium consists of a fixed fee \( \mu \) and a premium loading \( \lambda \) which is proportional to the fair premium (and not to \( L \) as in CGH). The fee contractor \( i \) has to pay is \( R_i(A_i) = \mu + (1 + \lambda) R_i^f(A_i) \) where \( R_i^f(A_i) \) is the fair premium derived in the previous section. We proceed as follows: in a first step, we derive the bidding strategies of the contractors before in a second step the optimal size of the bond is determined.

**Lemma 1** If \( L < \frac{c\mu}{(1-q)} \), the bidding function will be non-monotonic. \( \Box \)

**Proof** Following steps (i)-(iii) from above, the bids of the contractors are as follows: in case (i) the contractor never goes bankrupt. Therefore, the surety company will only charge the fixed premium \( R_i(A_i) = \mu \) and the bid will be \( P_i^*(A_i) = c + \mu \) if \( A_i \geq k_B \).

In case (iii) the surety company pays \( L \) to the agency if the costs are high, i.e. she will not help the contractor finish the project. Therefore, the surety company will
charge a premium of $R_i(A_i) = qL(1 + \lambda) + \mu$ because she wants to be compensated for paying $L$ to the agency in case the costs are high which occurs with probability $q$. The bids of the contractors of group (iii) have to satisfy $(1 - q)(P^*_i(A_i) - c + k_G + A_i - R_i(A_i)) = A_i$ which gives $P^*_i(A_i) = c + \mu - k_G + \frac{qA_i}{(1 - q)} + qL(1 + \lambda)$. A property of this bidding function is that it is increasing in $A_i$. Therefore, the highest bid of group (iii) is placed by the contractor with the highest $A_i$.

In case (ii) the surety company helps the contractor complete the project and charges a premium of $R_i(A_i) = \mu + q(1 + \lambda)(c + k_B - E[P_1] - A_i + R_i(A_i))$. Here the premium compensates the surety company for the case that the costs are higher than the expected payment and the remaining assets (but lower than $L$). \(^5\) This leads to a fee of $R_i(A_i) = \frac{\mu + q(1 + \lambda)(c + k_B - E[P_1] - A_i)}{(1 - q) \lambda}$ which depends on the bidding function $P^*_i(A_i)$ and on the expected payment $E[P_1]$ if a contractor wins with $P^*_i(A_i)$. A property of this bidding function is that the bid is decreasing in $A_i$ as $E[P_1]$ is increasing in $P^*_i(A_i)$. Therefore, the highest bid of group (ii) is placed by the contractor with the lowest $A_i$ of this group.

In the next step, we turn to the question of which contractors belong to group (ii) and group (iii). Therefore, we have to identify the marginal contractor with the lowest $A_i = \hat{A}_i$ whom the surety company is willing to help, i.e. the contractor with the lowest assets who still belongs to group (ii). First, assume that the highest bid of group (ii) is always higher than the highest bid of group (ii). If the contractor with the highest bid of group (ii) wins, the payment must be the same as his bid for it is the maximum possible bid. In this case $P^*_i(\hat{A}_i) = E[P_1]$ and thus the bid is $P^*_i(\hat{A}_i) = c + \mu + \frac{q\lambda(k_B - A_i)}{(1 - q)}$. Hence, the marginal contractor the surety company helps finish the project is the contractor with $\hat{A}_i = k_B - (1 - q)L$. Second, we have to show that the surety company does not want to finish the project and prefers paying the bond to the agency for contractors with $A_i < k_B - (1 - q)L$, namely

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^5$E[P_1]$ is again the expected payment in equilibrium if a contractor with assets $A_i$ wins, i.e. the expectation of the second lowest bid under the assumption that $P^*_i(A_i)$ is the lowest bid.
$L - (c + k_B - P - (A_i - R_i(A_i))) < 0$. Substituting the fee and the maximum possible payment (since this is the best case for the surety company if a contractor of group (iii) wins), the surety company indeed does not help contractors with $A_i < k_B - (1 - q)L$ finish the project. Note that our assumption that the maximum possible bid is placed by a contractor of group (ii) holds for $\hat{A}_i = k_B - (1 - q)L$, because the bids of all contractors with assets below $\hat{A}_i$ (group (iii)) lie below the maximum possible bid and the contractor with $\hat{A}_i$ also bids more than $c + \mu$.

The resulting bidding function is sketched in figure 5.1 where the solid line sketches the real bidding function and the dashed line is an approximation of the real bidding function for $E[P_i] = P^*_i(A_i)$ which yields $P^*_i(A_i) = c + \mu + \frac{q\lambda(k_B - A_i)}{(1 - q)}$. Note that the real bidding function has to be below the approximation because each winning contractor receives some kind of average payment and not his bid which would be the minimum possible payment.

![Figure 5.1: Bidding function for unfair premia; $\lambda > 0$: solid line; CGH: dotted line](image)

If we compare our result with CGH, we can distinguish two cases. First, if the premium loading is zero ($\lambda = 0$), the distribution of the bidding function is similar to CGH which is the dotted line in figure 5.1. In both cases, the bidding function
is increasing in $A_i$ until it reaches its maximum $(c + r_0L$ in CGH and $c + \mu$ in our framework) at $A_i = k_B - (1 - q)L$ and is flat afterwards. However, the consequences differ as the surety company charges a fixed fee of $r_0L$ in CGH and of $\mu$ in our model which is independent of $L$. Therefore, we can derive the optimal $L$ which is not possible in CGH. As $\mu$ is fixed, the optimal $L^*$ is as in proposition 5: $L^* \geq \frac{k_B}{(1+q)}$, or if $\mu$ is very large, $L^* = 0$. Second, if the premium loading is $\lambda > 0$, our result is different from CGH. In their paper the bidding function is increasing in $A_i$ until it reaches its maximum and is flat afterwards. As sketched in figure 5.1, in our model the bidding function is first increasing in $A_i$ until it reaches its maximum $(c + \mu + q\lambda L)$ at $A_i = k_B - (1 - q)L$, then decreasing in $A_i$ to $c + \mu$ at $A_i = k_B$ and flat afterwards. Hence, if the costs of bankruptcy are very high and if the agency wants to set the probability of non-fulfillment to be zero, we suggest that also in this case, the agency should require a large surety bond, $L \geq \frac{k_B}{(1-q)}$. Then, $L$ is such that the winning contractor or the surety company always finish the project which is true for $L \geq \frac{k_B}{(1-q)}$. We summarize our results in the following proposition:

**Proposition 6** If $\lambda = 0$, full insurance is optimal. If $\lambda > 0$, full insurance might be optimal if $B$ is sufficiently large.

### 5.4 Conclusion

Industries with uncertainty about future costs are plagued by ALTs and bankruptcy. In some countries compulsory surety bonds are used to deal with this problem which is analyzed in CGH. CGH come to the result that surety bonds indeed mitigate the problem of ALTs. But by linking the cost of the surety bond proportionally to its size, CGH can not derive the optimal size of the surety bond in general. It might be the case that the project has to be finished by the agency or even be abandoned. CGH also show that linking the size of the bond to the actual payment might lead to inefficient overinsurance.

We relax CGH’s assumption and assume in a first step that the surety bonds are
priced fairly which is the common benchmark case in the insurance literature. Then, full insurance or even overinsurance is optimal, i.e. the project is always finished by either the contractor or the surety company. In a second step, we introduce a risk loading (unfair premia) and show that also in this case, full insurance might be optimal. Which is interesting to note as this is not a standard result in the insurance literature where unfair premia always lead to partial insurance.

CGH come to the conclusion that the regulatory practice of requiring surety bonds seems to be an appropriate way of dealing with ALTs. We come to the same conclusion, although we alter their underlying assumptions and work with a different pricing scheme. However, although the practice of surety bonds seems to be adequate and quite successful in theory, it is only used in some countries. This raises the question why surety bonds have not evolved in private markets but have to be imposed and regulated by the government. It could be the case that regulation is necessary to prevent market breakdown due to an adverse-selection problem (à la Akerlof’s Lemon model). If this is indeed the case is left to further research.
Chapter 6

Concluding remarks

This chapter provides a few concluding remarks on the topics presented in this thesis. The basic model on limited liability gives a new reason why revenue equivalence breaks down, namely due to different payment distributions. Furthermore, we are the first to propose means to weaken competition as a solution to the ALT problem and discuss how not to deal with ALTs. Multi-sourcing—when possible—might be the best method for the agency in terms of risk and price. We also show that C+ contracts can be optimal in terms of risk minimization. However, different situations lead to different results, so there is no general ranking of methods possible. One could criticize that the setup of the basic model is not complex enough. But the simple model enables us to compare the different methods which is important for an understanding of the relevant parameters. However, it would be interesting to analyze C+ contracts in a more complex framework with risk aversion and to derive the optimal sharing rule.

Our analysis of price preferences is the first work in this field that comes to the conclusion that price preferences may have negative consequences on domestic welfare. The change in the bidding behavior due to limited liability leads to more bankruptcies of weak domestic firms. As weak domestic firms are regarded as the main beneficiaries of a price preference this result suggests that favoritism does not always work the way it was planned. As favoritism is an ongoing phenomenon it
would be interesting to derive the best favoritism scheme.

The investigation of surety bonds suggests that the problem of ALTs might be eliminated by regulation. We extend the analysis of the (small) existing literature and show that a surety bond insures the agency against the risk of contract non-fulfillment if the surety bond is priced fairly. Only if the surety bond is priced unfairly, lower sureties might be preferred. This result indicates that surety bonds—when the market is regulated—may indeed be a good method of dealing with ALTs. However, it remains to be shown how surety bonds fare in an unregulated market.

The goal of this thesis was to highlight the risks of procurement and to derive remedies of dealing with the problem of ALTs. There is no such thing as the optimal mechanism because nearly every single situation needs a different treatment. However, being aware of the problem, identifying the relevant factors, and proposing remedies of dealing with this problem is a first step into the right direction.
Appendix A

Mathematical appendix

A.1 Proof of Lemma 1

The equilibrium of the average-bid method is derived by iterated elimination of dominated strategies. Let the average cost for any distribution be $E[c]$, neglecting the error term $\Delta$ in order to keep the proof easy. First, any bid $b(c_i)$ will be $c_i$ or higher as no one will bid below his cost term. The average bid will be $E[c]$ or higher.

To win the contract, bidders will bid as close to the average as possible. The bidders with cost terms below $E[c]$ can raise their bids close to the average, while the ones with cost above the average cannot reduce it as no one bids below the cost term. This raises the average, leading to more adjustments, until the average bid reaches $\overline{c}$ or any higher price as the high-cost bidders can adjust their bids as well. In the end, all bidders will submit the same high bid and the winner is drawn randomly.

If the agency’s maximal willingness to pay is $\overline{c}$, this is also highest possible bid.

Assume that the equilibrium bid is $P^* = \overline{c}$. We have to check if this is indeed an equilibrium, i.e. no one will shade his bid below $P^* = \overline{c}$. If a bidder with a cost term below $\overline{c}$ deviates by bidding $\overline{c} - \epsilon$, the new average price will be $E'[P] = \frac{nc - \epsilon}{n}$.

The deviating bidder wins the contract if his bid is the bid closest to the average;\(^1\)

\(^1\)If the difference between the average and the bid is the same as for the other bidders, we let him win the contract because his bid is lower.
hence, the following inequality has to hold for a profitable deviation:

\[ \left| \frac{n\bar{c}}{n} - \epsilon \right| \leq \left| \bar{c} - \frac{n\bar{c}}{n} - \epsilon \right|. \] (A.1)

The left-hand side measures the difference between the new average and the bid of the deviating bidder, the right-hand side measures the difference between the bids of the non-deviating bidders and the new average. Deviating is profitable only if \( n \leq 2 \). Thus, for \( n > 2 \), the average-bid method will lead to the price of \( P^* = \bar{c} \) (or higher if there is no maximal willingness to pay) and the winner will be drawn randomly which is inefficient. This bidding behavior is caused by the allocation rule. As the average bid wins low cost bidders will raise their bid, and once a high price is reached no one has an incentive to deviate as the deviation has not enough impact on the average price. If we add \( \Delta \) and let the maximal willingness to pay be \( \bar{c} + \Delta \), the equilibrium price will be \( P^* = \bar{c} + \Delta \) and the bankruptcy probability is zero (\( \phi = 0 \)).

**A.2 Example for the common-cost case**

Let \( c_i \) be the ex-ante signal for bidder \( i \) and \( \bar{c} \) be the highest possible signal. The expected cost \( C_i \) for each bidder has a common-cost part and an expected private-cost part (\( c_i \alpha_i \)), so bidders have almost common costs.

\[
\begin{align*}
E[C_1] &= c_1(1 + \alpha_1) + c_2 + c_3 + (1 - \rho)\Delta \\
E[C_2] &= c_1 + c_2(1 + \alpha_2) + c_3 + (1 - \rho)\Delta \\
E[C_3] &= c_1 + c_2 + c_3(1 + \alpha_3) + (1 - \rho)\Delta
\end{align*}
\] (A.2)

with the true common cost \( C = \sum_{i=1}^{n} c_i \). We consider two different cases with \( \alpha > 0 \), the symmetric (\( \alpha_1 = \alpha_2 = \alpha_3 = \alpha \)) and the asymmetric bidder case (\( \alpha_1 < \alpha_2 = \alpha_3 = \alpha \)). There are either one or two units for sale and bidders’ demand is one; hence, it
is restricted to bid only for one unit.² Like in the private-cost case, bidders ignore $\Delta_1$ in the English auction because if the costs are higher than the payment, bidders will declare bankruptcy. If bidders are symmetric, the bidder with the highest signal $c^{(3)}$ quits at the price $3c^{(3)}$ where he is indifferent about winning or losing if both opponents exit at that price. The next lowest bidder $c^{(2)}$ exits when the price is $p = c^{(3)} + 2c^{(2)}$ which is also the payment. Thus, the expected payment to the winner with costs $c$ will be $E[p] \approx E[C] + E[c^{(2)} - c \mid c \leq c^{(2)}]$.³ If there are two units for sale, the bidder with the highest signal will quit when he is indifferent between winning or being the marginal bidder (tie with $c^{(2)} = c^{(3)}$). This is when the second highest bidder has the same signal and the expectation of the remaining signal is lower. Thus, the price at which he quits is $p = c^{(3)} + c^{(3)} + E[c \mid c \leq c^{(3)}]$ and the expected payment to the winner with costs $c$ will be $E[p] \approx E[C] + E[c^{(3)} - c \mid c \leq c^{(3)}]$. Hence, if bidders are symmetric, multiple units (multi-sourcing) raises the price and therefore lowers the probability of non-fulfillment for each unit as in the private-cost case.

More interesting is the asymmetric case. If we follow Bulow and Klemperer (2002) and assume that $\alpha_1$ is such that $c + \alpha_1 < c^{(2)} + \alpha < c^{(3)} + \alpha$, i.e. bidder 1 has a huge advantage, then bidder 3 exits at $c^{(3)} + c^{(3)} + \bar{c}$ and bidder 2 exits at $c^{(2)} + c^{(3)} + \bar{c}$. The intuition behind this result is that bidder 1 is so strong that bidders 2 and 3 face enormous winner’s curses if bidder 1 exists. So, they have to assume the best possible case $c_1 = \bar{c}$ whenever bidder 1 bids. Thus, they exit at $c^{(2)} + c^{(3)} + \bar{c}$, bidder 1 (almost) always wins, and the expected payment for this bidder will be $E[p] \approx E[C] + E[\bar{c} - c]$. While selling two units in the symmetric case leads to a higher payment and reduces the probability of non-fulfillment, this is no longer true in the asymmetric case. Selling two units reduces the winner’s curse for the second unit as only bidders 2 and 3 (which are symmetric) compete for this unit. And with increasing hazard rates, bidder 1 is not much more likely than bidder 2 or 3 to win the English auction for two units. Therefore, bidders 2 and 3 will bid more

²Selling two equal shares instead of two units is the same analysis.
³For $\alpha$ small but larger than zero.
aggressively and bidder 1 will also have to bid lower in order to win the first unit. The expected payment will be $E[p] \approx E[C] + E[c^{(3)} - c | c \leq c^{(3)}]$ which is less than with single-sourcing. Therefore, as rules that reduce the winner’s curse will lead to more aggressive bidding, multiple sources might increase the risk of non-fulfillment.

### A.3 Example for the effect of limited liability under risk aversion

We extend the example from Wambach (1999) to illustrate the effect of limited liability under risk aversion. Consider a market with $n$ identical firms with the following utility function:

$$U(v) = \ln(1 + \epsilon + v) \quad (A.3)$$

with $v$ being profit and $\epsilon$ being the budget which the contractor will lose in case of bankruptcy. The overall demand is 1 and costs are either 0 or $\Delta$, with a probability of 1/2 each. The minimum possible price in a setting with risk-neutral firms and unlimited liability would be $1/2\Delta$. Wambach (1999) shows in a setting with risk-averse firms and unlimited liability that the minimum possible price (for $\epsilon = 0$ and $\Delta = 1$) is $p_{min,UL} = 1/2(1 - 2n + \sqrt{4n^2 + 1})$ which is above $E[c]$. Wambach (1999) also shows that the Bertrand price $p_{B,UL}$ is above $E[c]$ and $p_{min,UL}$. Hence, risk aversion is an environment in which the Bertrand Paradox does not hold. It is very intuitive that as limited liability limits the losses in case of high costs, it will reduce the effect of risk aversion.

To derive the effect of limited liability on the price setting, we show that limited liability increases price competition. At the minimum possible price, firms share the market (demand = 1/n) and have the same utility as the outside option $ln(1 + \epsilon)$:

$$1/2ln(1 + \epsilon + \frac{1}{n}p) + 1/2ln(\max\{1; 1 + \epsilon + \frac{1}{n}(p - \Delta)\}) = \ln(1 + \epsilon). \quad (A.4)$$

The left term represents the utility if costs are low and the term in the middle is
the utility in case of high costs. If the latter case occurs, the firm has to decide either to declare bankruptcy and lose its budget \((u_{c=\Delta} = \ln 1)\) or to suffer high costs \((u_{c=\Delta} = \ln(1 + \epsilon + \frac{1}{n}(p - \Delta)))\). Assume that the budget is small \((\epsilon \to 0)\) and that the minimum price is \(p^*_{\text{min,LL}} > \Delta\). We show that this can not be an equilibrium.

First, if \(p_i > p_j > \Delta\) or \(p_i = p_j > \Delta\), firm \(i\) would have an incentive to undercut firm \(j\) slightly. Hence, price competition will drive the price down until \(p_i = p_j = \Delta\). \(p_i = p_j = \Delta\) is also not an equilibrium because one firm has an incentive to bid slightly below \(\Delta\) and go bankrupt in case of high costs. This gives the firm an expected utility of \(1/2\ln(1 + \epsilon + p) + 1/2\ln 1\) which is more than the utility when sharing the market at \(p = \Delta\) \((1/2\ln(1 + \epsilon + \frac{p}{n}) + 1/2\ln(1 + \epsilon))\). Hence, the minimum possible price has to be below \(\Delta\) and price competition will drive the price down to 0. We show that \(p^*_{\text{min,LL}} = 0\) is indeed an equilibrium. First, if \(p_i > p_j > 0\) or \(p_i = p_j > 0\), firm \(i\) would have an incentive to undercut firm \(j\). Second, if \(p_i > p_j = 0\) firm \(j\) has an incentive to raise its price slightly below \(p_i\). Hence, the equilibrium is where both firms charge \(p_{\text{min,LL}} = 0\) and the minimum possible price under limited liability is below \(p_{\text{min,UL}}\).

In a next step, we show that also the Bertrand price is affected by limited liability.

The Bertrand price is the highest sustainable price at which a firm is (at least) indifferent between undercutting and not undercutting the other firm. Hence, the following has to hold:

\[
\frac{1}{2}\ln(1 + \epsilon + \frac{1}{n}p) + \frac{1}{2}\ln(\max\{1; 1 + \epsilon + \frac{1}{n}(p - \Delta)\}) \\
\geq \frac{1}{2}\ln(1 + \epsilon + p) + \frac{1}{2}\ln(\max\{1; 1 + \epsilon + (p - \Delta)\}).
\]

(A.5)

Having established that bids will be below \(p^* < \Delta\), we have to derive the price for which each firm is indifferent between sharing the market if costs are low and serving the whole market if costs are low. From

\[
\frac{1}{2}\ln(1 + \epsilon + \frac{1}{n}p) + \frac{1}{2}\ln(1) \geq \frac{1}{2}\ln(1 + \epsilon + p) + \frac{1}{2}\ln(1)
\]

(A.6)
follows that this price is $p = 0$. Hence, also the Bertrand price is affected by limited liability.
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Deutschsprachige Zusammenfassung


In vielen Situationen wird Wettbewerb - und damit auch Auktionen - als bestmögliche Lösung gesehen, sowohl das effizienteste Unternehmen zu finden als auch um einen Marktpreis zu generieren. Jedoch können Auktionen in Situationen, die zu riskanten Strategien führen, aus zuvor genannten Gründen kontraproduktiv sein. Dies liegt daran, dass mehr Wettbewerb den Preisdruck erhöht und zu einem noch aggressiveren Bietverhalten führt, was zwangsläufig in ALTs und einem höheren Ausfallrisiko resultiert. Andererseits ist Wettbewerb immer noch das effektivste


Ferner werden in dieser Arbeit Methoden besprochen, die versuchen, die Kosten des fundamentalen Zielkonflikts zu minimieren. Um den Wettbewerb abzuschwächen, können die Standard-Auktionen modifiziert werden. Eine Möglichkeit ist die abgeschnittene Englische Auktion, die folgendermaßen funktioniert: Die Vergabe verläuft in zwei Stufen. Zuerst wird eine Englische Auktion durchgeführt, bis nur noch $m$ Anbieter im Wettbewerb sind. Da die Auktion endet, wenn der $(m + 1)$'te Anbieter ausscheidet, ist der Preis höher als in einer reinen Englischen Auktion. In der zweiten Stufe wird der Gewinner mittels einer Lotterie, einer Qualitätsprüfung oder eines anderen, nicht auf den Preis konditionierenden Verfahrens ausgewählt. Da der erwartete Preis und damit auch die Zahlung an den Auftragnehmer höher


Zusätzliche Details in der Vergabemethode wie Teilnahmeentgelte können dazu führen, dass das Problem noch relevanter wird, da Teilnahmeentgelte die Auftragnehmer ärmer machen. Dies impliziert, dass diese noch weniger zu verlieren haben und noch aggressiver bieten. Auf der anderen Seite könnten Teilnahmeentgelte besser abschneiden als Mindestgebote, sofern die beteiligten Bieter nur noch sehr wenig zu verlieren haben. Dann ist nicht mehr entscheidend, ob die Bieter aggressiver bieten, sondern wie die Zahlung bestimmt wird. Da bei Mindestgeboten automatisch eine hohe Zahlung an den Gewinner der Auktion ausgeschlossen wird, dies bei Teil-
nahmeentgelten aber nicht der Fall ist, können in dieser Situation letztere bevorzugt werden.


Auch staatliche Maßnahmen, wie die Subventionierung kleiner und mittlerer Unternehmen, können zu einer Erhöhung des Ausfallrisikos führen. Angenommen der Auftraggeber (Staat) kennt die Wettbewerbssituation kleinerer Unternehmen und entschließt sich, diese zu subventionieren, um deren Konkurswahrscheinlichkeit zu minimieren. Ein Grund für ein solches Motiv ist zum Beispiel der Erhalt von Arbeitsplätzen. Derartige Verfahren werden zum Beispiel in den USA angewandt: So gibt der Buy American Act heimischen Firmen einen Bonus von 6%. Dieser Bonus erhöht sich auf 12%, wenn die Unternehmen kleiner oder mittlerer Größe sind. Der positive Effekt einer solchen Subvention ist, dass die Kosten eines heimischen Unternehmens, welches den Auftrag erhält, tatsächlich verringert werden. Diese Regel hat aber über ihren positiven Effekt hinaus auch die Eigenschaft, dass die subventionierten Unternehmen aggressiver bieten werden, was wiederum zu niedrigeren Preisen und einem höheren Ausfallrisiko für den Auftraggeber führt. Ferner kann der Fall eintreten, dass ein heimisches Unternehmen nur aufgrund der Subvention gegen ein Angebot eines überlegenen ausländischen Unternehmens gewinnt. Dann erhält ein weniger effizientes und weniger solventes Unternehmen den Auftrag, was ebenfalls im Hinblick auf das Ausfallrisiko nicht im Interesse des Auftraggebers sein kann.

Eine bessere Möglichkeit für den Staat, die Ausfallrisiken zu minimieren, ist
die staatliche Verpflichtung zu projektbezogenen, besicherten Anleihen. So muss beispielsweise in den USA jeder potentielle Auftragnehmer eine solche Anleihe vorweisen, wenn das Projektvolumen über 100.000 US-Dollar liegt. Die Umsetzung dieser Vorweispflicht geschieht über so genannte surety bonds, die von einem auf dieses Geschäft spezialisierten, staatlich geprüften Emittenten ausgegeben werden. Der Vorteil dieses Intermediärs ist nicht nur sein Know-how über die Risiken der Auftragnehmer, sondern auch, dass er über die Anleihe am Ausfallrisiko beteiligt wird. Um mögliche Ausfälle einzelner Anleihen zu kompensieren, wird er von jedem Auftragnehmer einen risikoadjustierten Zins für die Herausgabe einer Anleihe verlangen. Surety bonds führen - wenn sie zu einem fairen Preis angeboten werden - theoretisch immer zu einer Fertigstellung des Projekts. Wenn sie unfair bepreist sind, führen sie dazu, dass zwar nicht immer, aber zumindest in vielen Fällen das Projekt fertig gestellt werden kann. Ein Nachteil dieser Methode ist der höhere Preis, den der Auftraggeber für die Minimierung des Ausfallrisikos zahlen muss. Dennoch eignen sich surety bonds sehr gut als Mittel gegen ALTs.

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Nürnberg, den 22. November 2005