

# PROCUREMENT AND ACCIDENTS: BIDDING FOR JUDGMENT PROOFNESS, AND THE LIABILITY CURSE.

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## ABSTRACT

In this paper we analyze a procurement setting in which the sponsor intends to allocate a project that involves some risk of external harm. The firm who is awarded the project may reduce the probability of accidents, and an ex-post regulatory regime, such as Tort Law, provides incentives to invest in care. The effectiveness of these incentives is undermined by the limited liability of the winning firm/injurer: the potential liability / monetary sanction cannot exceed its current wealth. The paper shows that the “judgment proof” problem leads to the less solvent firms to bid more aggressively in the auction so that competitive mechanism adversely selects undercapitalized firms. The paper also presents the “liability curse” in competitive procurement settings that tougher ex post regulations (such as increases in the liability standard) lead to worse allocations, so that both less capitalized and less efficient firms merge their chances of getting the project. The use of policies such as minimum asset requirements and surety bonds to alleviate the problem is also explored.

**KEYWORDS:** Procurement, limited liability, bankruptcy, Accidents, Liability Standards.

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## 1 INTRODUCTION

There are many public projects and procurement contracts concerning activities involving relevant risk of harm that are allocated competitively among potential contractors. Examples of such projects in various countries include hospitals, airports, large public works, prisons, mineral and oil concessions, security in public spaces and property, defense activities and programs, to name the most important categories. In all these cases, once the project is awarded, the contractor enters a stage in which the project may result in harm to third parties (customers, bystanders, the environment, etc..) and governed by the standard legal liability framework. On the latter setting we have a large literature devoted to the study of the incentives of the injurer (in our case, the project-winning firm) to take care and reduce the probability of accident to third parties. The increasing popularity of PPP schemes<sup>1</sup> to allocate and operate public services, where operational risk is fully transferred to the contractor, seems to increase the real-world relevance of such settings of competitive allocation of projects that may generate external losses.<sup>2</sup>

However, as far as we know, there are no previous theoretical contributions analyzing the interaction between the procurement process, and the accidents that the awarded contractor may induce and may lead to liability for harm caused. We believe this is an important problem, since the procurement process will determine the features of the winning firm, who then becomes the potential injurer. And these features in turn will affect the outcome of the accident and liability stage. In particular, we know that the probability of accident will be linked to the level of assets of the contractor (winning firm) due to the so-called “Judgment Proof” problem. Less capitalized firms pay lower damages in case of accident, and thus invest less in care. For this reason, they obtain larger net profits from operating the project, which in turn influences their bidding at the procurement stage and the selection of the contractor.

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<sup>1</sup>See, Burger and Hawkesworth (2011).

<sup>2</sup>In fact, PPP projects are defined as those to provide a public service or output, where private parties are responsible not just for their initial financing of the project, but also for the provision and operation vis-à-vis third parties.

In a standard procurement process participating firms are likely to differ both in their costs of undertaking the project and in their level of assets. The selection procedure will determine the winning firm, and consequently the final assets of the potential injurer. Competitive auction mechanisms allocate the project to the firms with the larger willingness to pay (willingness to accept a lower price, in the case of procurement). This leads to select the most efficient firm in a standard setting. However, in the case of risky projects, the undercapitalized firms have a competitive advantage due to the “Judgment Proof”, effect over the payment of damages or monetary sanctions. Then, liability rules or equivalent ex-post regulations will influence not only the incentives of the winning firm to exert care in undertaking the project and managing it after completion, but also the incentives of firms to bid. Through this channel, liability rules affect the outcome of procurement processes.

In this paper we analyze a procurement setting, in which a project involving risk of external harm has to be allocated among firms that differ in their cost and in their asset level. The winning firm is protected by limited liability and its incentives to exert care depend on the liability rule and on its assets. In this framework, we obtain three fundamental results: i) Competitive mechanisms adversely select undercapitalized firms for undertaking risky projects. ii) The liability curse: tougher liability ex post standards lead to worse allocations: since the winning firm is likely to be both less solvent and less efficient as a result. iii) Minimum asset requirements as pre-qualification checks in the procurement process, and liability rules governing the activity of the contractor can be used to improve the allocation.

The recent wave of EU Directives in this field has also essentially overlooked the connection between procurement and external harm. Directive 2014/23/EU, on the award of concession contracts, Directive 2014/24/EU on public procurement, and Directive 2014/25/EU on procurement in the water, energy, transport and postal services sector, simply refer to economic and financial standing of bidders as admissible criteria for selection but pays no attention to the interaction between the bidding phase and the project operation phase. Even when dealing with behavior

after the award of the project (e.g. performance of concessions in Directive 2014/23/EU), European rules fail to identify the link of the award mechanism and ex post operation and, eventually, liability.

Only recently, in a few European countries, performance based bonuses and penalties correlated with quality and safety have been introduced. For instance, in Finland, Hungary, Norway, Portugal, Spain and the UK, for PPP roads and highways positive incentives linked to road safety outcomes and indicators have been put in place.<sup>3</sup> However, even when such incentives have been introduced, the role of ex post standards and liability and their effects on procurement mechanisms seems not to have been considered.

This implies that selection processes to undertake projects (public works and public services among them) and the substantive rules regulating the completion and management of the project, are more closely intertwined than is commonly perceived. Both instruments need to be considered jointly if one desires to select the more efficient firms to carry out the projects, and also to provide incentives for adequately investing in avoidance of external costs (or obtaining quality) in the execution of the project. When one looks at the best practices and guidance in the area of public procurement that organizations such as the World Bank, the WTO and the OECD promote and champion, one observes little trace of such a broader perception of this type of challenge in making correct decisions in the area of public procurement.

This paper is related to two different branches of the literature. There is a rich literature studying procurement settings with cost uncertainty and limited liability [Waehrer (1995), Zheng (2001), Calveras et al (2004), Engel and Wambach (2006), Board (2007) Chillemi and Mezzetti (2010), Burguet et al (2012)]. The main results from these contributions may be briefly summarized as follows: i) In the presence of cost uncertainty, limited liability introduces the possibility of default in procurement. ii) Limited liability cuts off the potential downside losses of the winning bidder making bidders bid more aggressively. iii) This effect is stronger for financially weaker

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<sup>3</sup>Rangel, Vassallo and Arebas (2011).

bidders, and thus they are selected with higher probability by competitive mechanisms. In this paper we obtain a similar result in a tort-procurement setting that adds to the adverse selection problem a moral hazard dimension plus ex-post risk regulation.

The paper is also related to the literature on how judgement proofness affects the functioning of liability rules for activities that may produce external harm: Summers (1983); Shavell (1986); Dari-Mattiacci and De Geest (2002); Micelli and Segerson (2003); Ganuza and Gomez (2008, 2011); Wickelgren (2011). These papers, among others, have pointed out that: i) When injurers are insolvent, first-best behavior in terms of accident prevention cannot generally be attained through liability rules. ii) Negligence-like rules are superior to strict liability, at least when one does not consider settlement, and even with settlement, when the level of insolvency is large. iii) Tougher liability standards may worsen the problem, specially when levels of assets are endogenous for firms. iv) Liability standards and other policy instruments, such as minimum asset requirements, are complements. We add an adverse selection dimension to this moral hazard problem with ex post regulation. Thus, we extend the previous literature to a richer setting in which the potential injurer is selected through a competitive process that, in turn, is affected by the outcome of the accident and liability element.

To our knowledge, this is the first paper to jointly consider these two dimensions of procurement of risky projects, and thus the first to identify the liability curse in public procurement.

The paper is organized as follows: Section 2 presents the basic features of the model. Section 3 characterizes the equilibrium in both the liability and the bidding stages. Section 4 shows the effect of increasing liability standards on the outcome of the procurement process and the liability curse. Section 5 discusses the extensions related to the performance of less competitive mechanisms, surety bonds and minimum assets requirements. Section 6 briefly concludes.

## 2 MODEL

We analyze a procurement setting in which a risk neutral sponsor procures an indivisible project or contract for which he is willing to pay  $V$ . We assume  $V$  large enough so as to make the possibility of not contracting unattractive for the sponsor.  $N$  firms compete for the indivisible contract. Firms differ both in their cost for undertaking the project and in their initial financial status. Let  $c_i \geq 0$  and  $l_i \geq 0$  denote, respectively, the cost of undertaking the project and the value of the assets of potential contractor  $i = 1, 2, \dots, N$ . Both  $c_i$  and  $l_i$  are contractor  $i$ 's private information. The contract is awarded using a second price auction.<sup>4</sup>

The contract with the sponsor requires the winning firm to undertake an activity that involves the risk of causing accidents affecting third parties (users of the services provided by the project, the environment, etc.). The contractor may make an effort (that for simplicity we assume to be non monetary) for reducing the likelihood of the accident. Let  $x$  be the contractor's monetary equivalent of the precautionary effort and  $p(x)$  be the probability of an accident resulting in external harm,  $D$ , where  $p(x)$  is decreasing and convex in  $x$ .

In case of an accident, liability of the winning firm is determined by a legal rule taking the form of a negligence rule which specifies that if an accident materializes the contractor (injurer) is liable and has to pay a monetary sum to the victim if her precautionary effort is lower than a pre-specified and legally required level  $\bar{x}$ .<sup>5</sup> We assume that this standard is weakly lower than the first best care level,  $\bar{x} \leq x^* = \arg \min\{(1 - p(x))D + x\}$ .<sup>6</sup> Contractors have limited liability, i.e. the losses to contractor  $i$  from payments to victims cannot be larger than the firm's total wealth, which at that point is  $P - c_i + l_i$ . Therefore, if awarded the project, the contractor  $i$  will close down and discontinue the project if there is an accident, she is found liable, and the net profits

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<sup>4</sup>As we will focus on the dominant strategy equilibrium of the second price auction, we do not need to specify how firms' types  $(c_i, l_i)$  are distributed.

<sup>5</sup>In most legal systems, this is the way in which legal liability operates most commonly: meeting the legal standard or falling short of the standard is the key determinant of legal liability.

<sup>6</sup>It is clear from the analysis that it cannot be optimal for the sponsor to set a standard larger than the socially efficient level of care. We make this assumption to simplify the presentation and to avoid dealing with uninteresting cases that would remain out of the equilibrium path.

from undertaking the project, the sum  $(P - c_i)$  and its initial wealth  $l_i$ , are lower than the social harm  $D$ .<sup>7</sup>

We now summarize the timing of the model:

1. Nature chooses the cost  $c_i$  and the financial value  $l_i$  of each firm.
2. The sponsor announces the procurement process (that we assume takes the form of a second price auction). Firms submit their bids.
3. The project is awarded to the firm with the lowest bid at a price equal to the second lowest bid. Ties are decided using a lottery. Denote the auction price by  $P$ , and the cost and the assets of the winning firm by  $c$  and  $l$ . The winning firm starts undertaking the project and chooses the level of care,  $x$ . The accident takes place or not, according to the probability  $p(x)$ . If there is an accident and the contractor is liable, *i.e.*  $x < \bar{x}$ , the contractor goes on and completes the project if  $P - c + l - D > 0$ . Otherwise,  $P - c + l - D \leq 0$ , the firm declares bankruptcy and exits.

We want to analyze how this standard procurement setting that we take as given works. In order to do so, we do not need to specify the sponsor's preferences but it is likely that the sponsor's objective function will be decreasing in the procurement price, the expected accident costs (or unpaid liabilities), and bankruptcy probability. In the next subsection we show that a simple auction mechanism, as the standard second price auction, does not optimally balance these goals.

### 3 CHARACTERIZATION OF THE EQUILIBRIUM

We solve the model by backwards induction. We start with the accident stage.

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<sup>7</sup>We assume that legal liability imposes all social harm as a damages payment or monetary fine to the firm causing harm, something that is at least a widely accepted aspiration by legal systems. Our setting would easily allow for infracompensatory or supracompensatory (punitive) levels of damages payments.

### 3.1 Accident Stage

In this stage, the winning bidder, the contractor, faces an effective penalty in case of being found liable of  $z = \min\{P - c + l, D\}$ . A potentially liable injurer chooses a level of care  $x_L(z)$  which minimizes her expected total cost,

$$x_L(z) \in \arg \min p(x)z + x,$$

where  $z$  is the effective penalty (assumed to be monetary) faced by the liable injurer whenever the accident occurs. Let  $\gamma(z)$  be the expected private cost of being liable,

$$\gamma(z) = p(x_L(z))z + x_L(z).$$

Intuitively,  $x_L(z)$  and  $\gamma(z)$  are increasing functions. For further results is useful some additional characterization of  $\gamma(z)$ , in particular,  $\gamma(0) = 0$ ,  $\gamma(z) < D$ ,  $\gamma(z)' = p(x_L(z)) < 1$  (since  $\frac{\partial \gamma}{\partial x_L} \frac{\partial x_L}{\partial z} = 0$  by the envelope theorem) and  $\gamma(z)'' \leq 0$ .<sup>8</sup>

Under a negligence rule, the judgment-proof injurer compares its private expected cost of being liable  $\gamma(z)$  with the cost of satisfying the negligence standard  $\bar{x}$ . As a result, the equilibrium level of care will be

$$x_E(\bar{x}, l) = \begin{cases} \bar{x} & \text{if } \bar{x} < \gamma(z) \\ x_L(z) & \text{otherwise.} \end{cases}$$

given that the exerted effort (probability of accident) is increasing (decreasing) in  $l$ . Therefore, the net expected profits of the contractor are

$$\pi_N(P, c, l, \bar{x}) = P - c - \min\{\bar{x}, \gamma(z)\}$$

**LEMMA 1** *The net expected profits are increasing in  $P$ , and decreasing in  $c, l$  and  $\bar{x}$ .*

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<sup>8</sup>We assume that legal liability imposes all social harm as a damages payment or monetary fine to the firm causing harm, something that is at least a widely accepted aspiration by legal system.

### 3.2 Bidding Stage

Firm  $i$  wins the second price auction if and only if  $P_i^* = \min\{P_1^*, \dots, P_i^*, \dots, P_N^*\}$ , and will be paid  $P = \min\{P_1^*, \dots, P_{i-1}^*, P_{i+1}^*, \dots, P_N^*\}$ . Under the second price auction the procurement process is similar to Bertrand competition among heterogeneous firms. Hence, the equilibrium bid of each firm  $i$  is the minimum price  $P_i^*$  for which firm  $i$  is willing to accept the project, defined by:

$$E\{\pi_N(P_i^*, c, l, \bar{x})\} = 0, \quad (1)$$

In other words, the equilibrium bid of  $i$  is the price for which her net expected profits are zero, in case firm  $i$  wins the project.

If firm satisfies the liability standard (which means she is not liable), the price that makes the net expected profits zero is  $P_i^* = c_i + \bar{x}$ . Equivalently, if we take the markup between the contract price and the cost as the relevant variable, the equilibrium margin in such case is equal to the cost of satisfying the legal standard:  $g_{NL}^* = P_i^* - c_i = \bar{x}$ . If the firm is liable, the price that makes the net expected profits equal to zero is given by the expression  $P_i^* = c_i + \gamma(P_i^* - c_i + l_i)$  or, in terms of the price-cost markup,  $g_L^*(l_i) = P_i^* - c_i$ ,  $g_L^*(l_i) = \gamma(g_L^*(l_i) + l_i)$ . Notice that  $g_L^*(l_i)$  is uniquely defined, since  $\gamma(g + l_i)$  is increasing, has a slope lower than one, and  $\gamma(0 + l_i) \geq 0$ . Moreover,  $g_L^*(l_i)$  is increasing in  $l_i$  and  $g_L^*(0) = 0$ .<sup>9</sup>

Given that the equilibrium bid is the minimum price for which the net expected profits are zero, the firm chooses the minimum markup between the two. Then, the equilibrium bid is  $P_i^* = c_i + g(\bar{x}, l)$ , where  $g(\bar{x}, l) = \min\{g_{NL}^* = \bar{x}, g_L^*(l_i)\}$ . Notice that the decision to be liable or not (choosing  $g_{NL}^*$  or  $g_L^*$ ) depends on the level of wealth of the firm. There is a cut-off level  $l^*$ , such that  $g_L^*(l^*) = g_{NL}^* = \bar{x}$ , where  $l^*(\bar{x})$  is increasing on  $\bar{x}$ . Thus, the equilibrium bidding markup is

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<sup>9</sup>Notice that  $f(x, l_i) = \gamma(x + l_i) - x$ , then  $f(x^*, l_i) = 0$  has a unique solution, since  $f(0, l_i) > 0$ ,  $f'(0, l_i) < 0$  and  $f(D, l_i) < 0$ .

$$g(\bar{x}, l) = \begin{cases} \bar{x} & \text{if } l > l^*(\bar{x}) \\ g_L^*(l_i) & \text{otherwise.} \end{cases}$$

Proposition 1 summarizes the characterization of the bidding equilibrium, provides direct comparative statics, and a useful feature of the equilibrium markup function  $g(\bar{x}, l)$ .

**PROPOSITION 1** *The equilibrium bid in a second price auction is  $P_i^* = c_i + g(\bar{x}, l_i)$ , which is increasing in  $c_i, \bar{x}$ , and  $l_i$ , and  $g(\bar{x}, l_i)$  is supermodular (and consequently  $P_i^*$  is supermodular in  $(\bar{x}, l_i)$ ).*

The intuition of the proposition is as follows: the equilibrium bid is such that the expected profits of the bidder are equal to zero. Then, the price (bid) has to compensate the private cost of undertaking the project,  $c_i$ , and the liability cost,  $g(\bar{x}, l_i)$ . The liability costs are larger, the larger is the legal standard, and the larger is the asset level of the bidder. We can also illustrate Proposition 1 with the following algebraic example.

### 3.3 Example

Consider that  $p(x) = 1 - \sqrt{x}$ ,  $l \in [0, 1]$  and  $D = 1$ .

The contractor chooses a level of care  $x_L(z)$  which minimizes her expected total cost given the expected penalty  $z$ ,

$$x_L^*(z) \in \arg \min (1 - \sqrt{x})z + x. \rightarrow x_L^*(z) = \frac{z^2}{4}$$

Given  $x_L(z)$ , the expected total cost of being liable is

$$\gamma(z) = p(x_L(z))z + x_L(z) = z - \frac{z^2}{4}.$$

The equilibrium markup, in case of being liable, is given by  $g_L^*(l_i) = \gamma(g_L^*(l_i) + l_i)$ . Then

$$\begin{aligned} g_L^*(l_i) &= \gamma(g_L^*(l_i) + l_i) = g_L^*(l_i) + l_i - \frac{(g_L^*(l_i) + l_i)^2}{4} \\ g_L^*(l_i) &= -l + \sqrt{4l} \end{aligned}$$

Where  $g_L^*(l_i)$  is increasing,  $\frac{\partial g_L^*}{\partial l} = -1 + \frac{1}{\sqrt{l}} \geq 0$ .

The equilibrium bid is  $P_i^* = c_i + g(\bar{x}, l_i)$ , where  $g(\bar{x}, l) = \min\{\bar{x}, -l + \sqrt{4l}\}$ . Finally,

$$\bar{x} = g(\bar{x}, l^*) \implies \bar{x} = \sqrt{4l^*} - l^* \implies l^* = (1 - \sqrt{1 - \bar{x}})^2$$

Then

$$P^* = \begin{cases} c_i + \bar{x} & \text{if } l \geq l^* = (1 - \sqrt{1 - \bar{x}})^2 \\ c_i - l + \sqrt{4l} & \text{otherwise.} \end{cases}$$

[FIGURE 1 AROUND HERE]

Let  $i = (c_i^*, l_i^*)$  be the winner of the auction, such that  $P_i^* = \min\{P_1^*, \dots, P_i^*, \dots, P_N^*\}$ .

### 3.4 The Adverse Selection Effect

Therefore, for a given level of private cost in delivering the project, the lower is  $l$ , the larger is the probability of winning. This leads to the following corollary, which is the main implication from Proposition 1

**COROLLARY 1** *The second price auction mechanism adversely selects undercapitalized firms for undertaking the project.*

Would this result change with alternative competitive procurement mechanisms?. Burguet et al (2012) use a mechanism design approach for analyzing a procurement setting with cost uncertainty and where, like in the present paper, firms have private information regarding their wealth and are protected by limited liability. They show that, in such settings, financially weaker contractors are selected with higher probability in any incentive compatible mechanism. In our setting, the opportunity cost of undertaking the project is decreasing in the wealth of the injurer and then, we conjecture that any “monotone” auction (including first price, all pay, etc..) would adversely select undercapitalized contractors. Finally, it is easy to see that increasing competition in the procurement process does not improve matters. Consider the case in which the cost of

undertaking the project is constant. Then, the winner,  $l_i^*$ , will be the firm with the lowest level of assets,  $l_i^* = \min\{l_1, \dots, l_i, \dots, l_N\}$ . Increasing the number of bidders will lead to an even lower  $l_i^*$ .

#### 4 THE LIABILITY CURSE

The previous analysis has an important implication for the design of optimal liability rules (or ex post regulation) for firms in undertaking projects in procurement settings. We have to take into account that the liability system influences the probability of accidents in two ways: i) by shaping the incentives of the winning firm to exert care; and ii) by affecting the incentives of firms to bid and, in this way, determining the outcome of the procurement process.

The effects of liability rules on the outcome of the procurement process are counterintuitive, as shown in the following proposition.

**PROPOSITION 2** *Let  $(\bar{l}, \bar{c})$  be the type of the winner under the standard  $\bar{x}$ . Under a higher liability standard  $\bar{x}'$  the winner  $(\bar{l}', \bar{c}')$  will be both less solvent and less efficient than under a less exacting legal rule, i.e.,  $\bar{l}' \leq \bar{l}$  and  $\bar{c}' \geq \bar{c}$ .*

The next figure shows the bidding equilibrium for a given  $c$  when the negligence standard increases from  $\bar{x}$  to  $\bar{x}'$  and which, may help to understand the intuition of Proposition 2

[FIGURE 2 AROUND HERE]

If we increase the standard from  $\bar{x}$  to  $\bar{x}'$ , then the firms with levels of assets in the interval  $[l^*, l^{*'}]$  that would have met the standard  $\bar{x}$ , would now fail to meet the higher standard  $\bar{x}'$ . Therefore, these firms would bid more aggressively than firms with assets larger than  $l^{*'}$ , which in turn would increase the probability of winning of the firms that are more aggressive bidders as a result of the tougher legal standard. If the winning firm under standard  $\bar{x}$ , is a firm with assets lower than  $l^{*'}$ , this latter firm would remain the winner under  $\bar{x}'$ . This informal argument shows that the winning firm would have lower assets than under a weaker legal standard. The

second part of the proposition is less intuitive at first blush: the winning firm is not only less solvent, but is also less efficient (has larger costs) in undertaking the project. This is because if one firm wins the contest under  $\bar{x}'$ , but loses under  $\bar{x}$ , this necessarily means that it has higher costs than the winner under the lower standard  $\bar{x}$  because otherwise it would also have won under  $\bar{x}$ , given that by the first affect, it has less assets than the winner under  $\bar{x}$ . In sum, a higher ex post standard has the effect of inducing the selection of both a less solvent and a less efficient winner. We may call this effect the liability curse in procurement. Thus, ignoring the link between the procurement phase and the operation phase may actually hurt social welfare along the two dimensions on which potential contractors diverge: asset levels and efficiency in executing and operating the project.

We can provide a further characterization of the effect of liability standards over the allocation of the project. Let  $(c_E, l_E)$  be the type of the most efficient firm (in term of production cost, i.e.  $c_E = \min\{c_1, \dots, c_i, \dots, c_N\}$ ), of an arbitrary set of firms

$$S = \{(c_1, l_1); (c_2, l_2); \dots (c_N, l_N)\}$$

**PROPOSITION 3** *i) There exists a liability standard  $\bar{x}_{\max}(S) \in (0, \infty)$ , such that for all liability standards lower than  $\bar{x}_{\max}(S)$ , the winning firm with probability one is the most efficient firm  $(c_E, l_E)$ .*

Notice that  $(c_E, l_E)$  is the best feasible allocation, since the type  $(c_E, l_E)$  beats any other firm with a higher level of wealth, and it could be beaten only by firms with lower levels of wealth that are by definition less efficient, and consequently result in worse allocations. Then, Proposition 3 states that the best feasible allocation can be obtained as long as the standard is low enough, since higher standards may provide an advantage to less efficient firms with lower levels of assets. A finite cut-off does not necessarily exist, for example, if the most efficient firm is also the firm with the lowest level of assets, and then  $\bar{x}_{\max}(S) = \infty$ , since the type  $(c_E, l_E)$  beats all other firms for any standard. If  $\bar{x}_{\max}(S) < \infty$ , the most efficient firm would satisfy the standard  $\bar{x}_{\max}(S)$  and

then, setting this standard maximizes care, conditioning on having the best feasible allocation,  $(c_E, l_E)$ .<sup>10</sup>

Proposition 2 and Proposition 3 have a direct but interesting Corollary for the law and economics literature.

**COROLLARY 2** *Strict liability ( $\bar{x} = \infty$ ) leads to worse allocations than Negligence.*

In a nutshell, Proposition 2 and Proposition 3 suggest that there are additional costs of increasing liability standards. These result are very much in line with the main insight of Ganuza and Gomez (2008), showing that in a standard accident setting higher  $\bar{x}$  does not lead to a higher choice of care (lower probability of accidents). In fact, we may reproduce the result of Ganuza and Gomez (2008) in our present procurement setting.

**COROLLARY 3** *Care exerted by the winning bidder may be lower under a higher standard.*

This corollary is a combination of Ganuza and Gomez (2008), that shows that for a fixed  $l$  care may be decreasing in the standard, and Proposition 2, that shows that  $l$  would decrease with the standard.

We can illustrate Corollary 3 (and also Proposition 2) with the following example in which the equilibrium exerted care decreases when the sponsor increases the standard. In particular, consider the parametric example of section 3.3,  $p(x) = 1 - \sqrt{x}$ ,  $D = 1$ , and two bidders with types  $(l, c)$  equal to  $(1, 0)_1$  and  $(0, \frac{1}{9} + \varepsilon)_2$ .  $(c_E, l_E) = (1, 0)_1$  and  $\bar{x}_{\max}(\{(1, 0)_1; (0, \frac{1}{9} + \varepsilon)_2\}) = \frac{1}{9}$ . The next table summarizes the outcome of the procurement process in this example for  $\bar{x} = \frac{1}{9}$  and  $\bar{x}' = \frac{1}{9} + 2\varepsilon$ .

$\bar{x}$	$(l, c)^*$	$x^*(\bar{x})$
$\frac{1}{9}$	$(1, 0)_1$	$\frac{1}{9}$
$\frac{1}{9} + 2\varepsilon$	$(0, \frac{1}{9} + \varepsilon)_2$	$\frac{\varepsilon^2}{4}$

<sup>10</sup>The intuition of this result is as follows. The equilibrium bid  $P_i^*(c_i, \bar{x}, l_i)$  is weakly increasing in  $\bar{x}$ . In particular if the firm plans to satisfy the standard, the slope is one, and if it does not plan to comply it, the slope is 0. Then, if the winner of the auction changes by increasing the standard, this necessarily implies that the former winner was satisfying the former standard, since otherwise its bid would not change, and the bid of the other firm cannot decrease.

If the standard  $\bar{x}$  is  $\frac{1}{9}$ , the bids are  $b_1 = \frac{1}{9}$  and  $b_2 = \frac{1}{9} + \varepsilon$ , the winner will be bidder 1,  $(l, c)^* = (1, 0)_1$  and the exerted care equal to the standard  $\frac{1}{9}$ . If the standard  $\bar{x}'$  increases to  $\frac{1}{9} + 2\varepsilon$ , the bids would be  $b_1 = \frac{1}{9} + 2\varepsilon$  and  $b_2 = \frac{1}{9} + \varepsilon$ , the winner will be bidder 2,  $(l, c)^* = (0, \frac{1}{9} + \varepsilon)_2$ , and the exerted care would be  $x_L^*(z) = \frac{z^2}{4}$ , in our case,  $z = P - c = \varepsilon$ , then  $x_L^*(P - c) = \frac{\varepsilon^2}{4}$ . As this simple example shows, increasing the standard may lead to a worse allocation, leading to the selection of a winning firm with higher costs and lower assets, and to lower exerted care in equilibrium.

## 5 EXPLORING SOLUTIONS

Therefore, the main conclusion of our model is that auctions adversely select less solvent firms for undertaking risky projects. Given the previous results of the literature (Burguet et al (2012)), the design of an optimal mechanism is likely to be very challenging (incentive compatibility leads to adverse selection) and not very illuminating (the optimal mechanism is likely to be non generic and depend on the details of the setting).<sup>11</sup> Instead, we want to explore solutions analyzed in the procurement literature precisely to deal with the problem of insolvency of bidders. In particular, we want to analyze: i) if less competitive mechanisms (fixed price, beauty contests, the so-called competitive dialogues, etc..) may outperform auctions in this setting, specially when the potential cost from the accident is very large. ii) To study the role of minimum asset requirements and surety bonds in this setting.

### 5.1 Limiting Competition: Generic Contests

As discussed above, competition does not help to solve the problem in our setting. In fact, a less competitive mechanism may perform better than auctions. Consider the following alternative

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<sup>11</sup>For example, we have stated that if  $\bar{x}_{\max}(S) < \infty$ , setting this cut-off as standard and using a second price auction maximizes care conditioning on having the best feasible allocation,  $(c_E, l_E)$ . However,  $\bar{x}_{\max}(S)$ , may be very low if the assets of the most efficient firm are very low. Depending on the preferences of the sponsor, in such situations, it may be better to increase actual care exercised by the winning firm by setting a higher standard with a high posted price (which increases liabilities) and allocated the project using a lottery.

and less competitive mechanism that we denote as a “generic contest” . This mechanism works as the second price auction, but bids are evaluated according to the following scoring rule

$$S_i = \alpha\theta_i - (1 - \alpha)P_i$$

where  $\theta_i$  is an independent draw of an arbitrary distribution, related to exogenous features of the firms (and unrelated to firms’ types  $(c_i, l_i)$ ) or just a lottery. The firm with the highest score  $S_i$  wins, and the price is set equal to the highest price such that the winning firm would have obtained the highest score. Notice that with  $\alpha = 0$ , the mechanism coincides with the second price auction. Moreover, under this scoring rule the bidding equilibrium coincides with the one characterized by Proposition 1 for the second price auction. This is because the equilibrium bid of each firm  $i$  is the minimum price  $P_i^*$  for which firm  $i$  is willing to accept the project, and the mechanism coincides with the second price auction over the price/bid dimension.

We can show that this generic contest may outperform the second price auction with two examples. If all firms have the same cost, the allocation of the second price auction is the opposite to the optimal one. In this setting,  $\alpha = 1$  (pure lottery) generates larger welfare than running a second price auction. Consider also our parametric example,  $p(x) = 1 - \sqrt{x}$ ,  $D = 1$ ,  $\bar{x} = 1$ , and two bidders with types  $(l, c)$  equal to  $(1, 2)_1$  and  $(0, 2)_2$ . The equilibrium bid is  $P_i^* = c_i + \min\{\bar{x}, -l + \sqrt{4l}\}$  independently of  $\alpha$ .

$(l, c)$	$P_i^*$	$S_i^*$
$(1, 2)_1$	3	$\alpha I_1 - (1 - \alpha)3$
$(0, 2)_2$	2	$\alpha I_2 - (1 - \alpha)2$

With a second price auction ( $\alpha = 0$ ), the winner will be bidder 2 and the price will be equal to 3. If we set  $\alpha = 0.5$ , and  $\theta_1$  and  $\theta_2$  distributed uniformly between  $[0, 4]$ . Under this parametrization, firm 2 wins the generic contest only with probability 0.75 and the expected price is 3.785.<sup>12</sup> Therefore, the generic contest with  $\alpha = 0.5$  is less competitive than the second

<sup>12</sup>For a better intuition of how the generic contest works, consider that  $\theta_1 = 3$  and  $\theta_2 = 1$ . Then  $S_1 = .53 - .53 = 0$ ;  $S_2 = .51 - .52 = -.5$ . The firm 1 wins and the procurement price is set in such a way that the scoring would be identical to the one achieved by firm 2,  $S_1^* = .53 - .5p^* = -.5 \implies p^* = \frac{2}{5} = .4$ .

price auction, since it leads to a higher price, but also to better capitalized winning firms, and consequently, less accidents and bankruptcies.

## 5.2 Auction with Surety Bonds

If the sponsor can screen firms according to its financial situation (and eliminating, for example the bottom tail of less solvent firms) the problem is alleviated. However, the model is still valid (it is just applied to a more favorable distributions of assets) and our results hold. In practice, even if the sponsor does not have information regarding the firms' financial situations or if the sponsor cannot prevent (for legal constraints) the participation of some firms, there are several mechanisms that may perform well in terms of doing the screening and preventing bankrupt bidders. One mechanism that is extensively used in procurement is the surety bond. A surety bond is a guarantee in which the surety company (a bank, for example) guarantees that the firm will perform and pay its obligations to the amount stated in the bond. In our setting, the surety may commit to pay the surety bond, if there is an accident, the firm is found negligent and it defaults because it is not able to pay the full amount of money specified in the surety bond (for simplicity, we limit the liability to the bond).

The surety evaluates the firm and agrees a contract with the potential bidder that typically involve a surety premium (the price of the surety bond, usually a percentage/interest rate of the size of the surety bond), and possibly a restriction over the bid. The surety bond conditions depend on the surety's evaluation of the financial status and the relative cost efficiency of the firm.

In the following, we introduce surety bonds in our framework. Consider that the sponsor requires a surety bond of size  $L$  from the winning firm. Each firm will have to resort to a surety company to apply for the bond. Surety companies screen firms and learn their types  $(l_i, c_i)$  and they can choose a different contract for each firm, the contract specifying a  $r_i$  and a minimum bid,  $P_i^*$  (less capitalized firms may want to increase their bids in order to increase their assets, reduce

their risk and interest rate). We assume that surety companies are perfectly competitive, hence they make zero profits. If the surety bond of size  $L$  is granted, sureties have to freeze sufficient funds of their own to back it up, alternatively the surety company could invest  $L$  in a riskless asset at interest rate  $r_0$ . Then,  $r_0$  is also the competitive price of a riskless surety bond.

Consider that the sponsor asks for a security bond equal to  $L^* = \gamma^{-1}(x^*)$ , the level of assets that generates an expected liability cost equal to the first level of care  $x^*$  and sets a standard equal to  $\bar{x} = x^*$ . Firms with level of assets higher than  $L^*$  are riskless for sureties. In case of accidents, they have enough assets to pay  $L^*$  (in addition, they will not be liable since they will satisfied the standard, then they pay  $r_0$  for the bond and bid  $P_i = c_i + r_0L^* + \bar{x}$ . If firms do not have enough assets  $l_c < L^*$ , they have two options. They can increase their wealth by increasing their bids. For example, if they increase their bid  $(L^* - l_c)$ , they become riskless and their equilibrium bids are in this case  $P_i = c_i + (L^* - l_c) + r_0L^* + \bar{x}$ . It is clear that in this case, the higher the wealth of the firm, the lower its bid. Alternatively, they can pay a higher interest rate to the surety company, and they can bid  $P_i = c_i + rL^* + \gamma(l_c)$ . As we assume that surety companies are perfectly competitive  $rL^* = r_0L^* + p(x_L(l_c))(L^* - l_c)$ . Then, the bid of liable firm are  $P_i = c_i + r_0L^* + p(x_L(l_c))(L^* - l_c) + \gamma(l_c)$ . Using the definition of  $\gamma(l_c)$ , we can rewrite this bid as  $P_i = c_i + r_0L^* + p(x_L(l_c))L^* - x_L(l_c)$ . By definition,  $p(x_L(l_c))L^* - x_L(l_c) > p(x_L(L^*))L^* - x_L(L^*) = \gamma(L^*) = \bar{x}$ . Moreover, as  $p(x)L^* - x$  is convex (decreasing in  $x$  for  $x < x_L(L^*)$ ), and  $x_L(l_c)$  is increasing in  $l_c$ , the bid is decreasing in  $l_c$ . In summary, surety bonds alleviate the problem since we show that  $P_i$  is decreasing in  $l$ , for  $l$  lower than  $L^*$ . Firms with lower level of assets have lower probability of winning, since they have either to pay more for the surety bonds or to increase their bids.

## 6 CONCLUSIONS

Our analysis explains why competitive mechanisms are likely to select undercapitalized firms for undertaking risky projects. On top of that, enhanced competition in the process does not

help, and tougher regulation (more stringent negligence standards) directed to contractors will be counterproductive. The liability curse illustrates how toughening ex post standards leads to worse allocations both in terms of efficiency in undertaking the project, and in the probability of accidents that may result in harm. We have also shown how asset requirements may improve-but not solve-matters, and how optimal surety bonds could be designed to alleviate the problem. However, these may not be feasible or too costly in various settings. The fundamental results we have identified thus, may be more prevalent in reality than one may predict.

Our theoretical results we believe have relevant policy implications. In particular, it is likely that in procurement environments in which the social cost of harm by contractors is large, non purely competitive mechanisms (contests, fixed price, negotiated procedures, competitive dialogues...) may outperform competitive ones. We believe that the accident stage must be given its due importance, and this may lead to reconsider the most desirable mechanism for risky projects.

When one looks at initiatives in the area of public procurement by organizations such as the World Bank, or the WTO, who often emphasize international competitive bidding (ICB), one may wonder if the proposals advocated are always desirable. The same may apply to harmonizing rules on procurement, such as the recent wave of EU procurement Directives. As we have shown, despite their attractive properties for other reasons, they may lead to the unattractive results described above, specially if competitive bidding is combined with tough legal or regulatory standards in the execution of the project, and inadequate or insufficient pre-screening of potential bidders. It is true that such initiatives also refer to pre-qualification controls, but the combined role of such ex-ante checks, competitive bidding, and substantive standards in executing projects does not seem to be properly understood by the institutions sponsoring legal policy in this area.

## A APPENDIX

PROOF OF LEMMA 1:

Differentiating the net profit function with respect to  $P$ , we obtain:

$$\frac{\partial \pi_N}{\partial P} = \begin{cases} 1 & \text{if } \bar{x} < \gamma(z) \\ 1 - p(x_L(z)) & \text{otherwise.} \end{cases}$$

Notice that due to the envelope theorem, we can disregard the effect of  $P$  over  $x_L$ . By the same token

$$\frac{\partial \pi_N}{\partial c} = \begin{cases} -1 & \text{if } \bar{x} < \gamma(z) \\ -1 + p(x_L(z)) & \text{otherwise.} \end{cases}$$

$$\frac{\partial \pi_N}{\partial l} = \begin{cases} 0 & \text{if } \bar{x} < \gamma(z) \\ -p(x_L(z)) & \text{otherwise.} \end{cases}$$

$$\frac{\partial \pi_N}{\partial \bar{x}} = \begin{cases} -1 & \text{if } \bar{x} < \gamma(z) \\ 0 & \text{otherwise.} \end{cases}$$

■

#### PROOF OF PROPOSITION 1.

Immediate from the arguments in the main text. We have only to show that  $g(\bar{x}, l)$  is a supermodular function, i.e, if  $\bar{x}' > \bar{x}$  then  $g(\bar{x}, l) - g(\bar{x}', l)$  is weakly increasing in  $l$ . Consider  $\bar{x}' > \bar{x}$ ,

$$g(\bar{x}', l) - g(\bar{x}, l) = \begin{cases} \bar{x}' - \bar{x} & \text{if } l \geq l^*(\bar{x}'). \\ g_L(l) - \bar{x} & \text{if } l^*(\bar{x}') \geq l \geq l^*(\bar{x}) \\ 0 & \text{if } l < l^*(\bar{x}) \end{cases}$$

Notice that as  $g_L(l)$  is increasing in  $l$ , and  $g_L(l^*(\bar{x}')) = \bar{x}'$ , then  $g(\bar{x}', l) - g(\bar{x}, l)$  is increasing in  $l$ . This implies that  $g(\bar{x}, l)$  is a supermodular function. ■

#### PROOF OF PROPOSITION 2:

Firstly, consider contrary to the Proposition that the winner under  $\bar{x}'$  is more solvent than the winner under  $\bar{x}$ ,  $\bar{l}' > \bar{l}$ . Given that  $P^*$  is increasing in  $c$  and increasing in  $l$ ,  $\bar{l}' > \bar{l}$  and  $P(\bar{l}', \bar{c}', \bar{x}') < P(\bar{l}, \bar{c}, \bar{x}')$ , implies that  $\bar{c}' < \bar{c}$ . Given that  $(\bar{l}', \bar{c}')$  is the winning bid under  $\bar{x}'$ , and  $(\bar{l}, \bar{c})$  under  $\bar{x}$ . Then, the next two conditions have to be satisfied.

$$P(\bar{l}', \bar{c}', \bar{x}') = \bar{c}' + g(\bar{l}', \bar{x}') \leq \bar{c} + g(\bar{l}, \bar{x}') = P(\bar{l}, \bar{c}, \bar{x}')$$

$$P(\bar{l}', \bar{c}', \bar{x}) = \bar{c}' + g(\bar{l}', \bar{x}) > \bar{c} + g(\bar{l}, \bar{x}) = P(\bar{l}, \bar{c}, \bar{x})$$

This is equivalent to

$$\begin{aligned} g(\bar{l}', \bar{x}') - g(\bar{l}, \bar{x}') &\leq \bar{c} - \bar{c}' \\ g(\bar{l}', \bar{x}) - g(\bar{l}, \bar{x}) &> \bar{c} - \bar{c}' \end{aligned}$$

These two conditions imply that

$$g(\bar{l}', \bar{x}) - g(\bar{l}, \bar{x}) > g(\bar{l}', \bar{x}') - g(\bar{l}, \bar{x}')$$

or equivalently

$$g(\bar{l}, \bar{x}') - g(\bar{l}, \bar{x}) > g(\bar{l}', \bar{x}') - g(\bar{l}', \bar{x})$$

and this leads to a contradiction with Lemma 1, since  $g(l, \bar{x})$  is supermodular, which implies that

$$g(\bar{l}, \bar{x}') - g(\bar{l}, \bar{x}) \leq g(\bar{l}', \bar{x}') - g(\bar{l}', \bar{x}).$$

Finally, consider, contrary to the Proposition, that the winner under  $\bar{x}'$  is more efficient than the winner under  $\bar{x}$ ,  $\bar{c}' < \bar{c}$ . The case in which the winner under  $\bar{x}'$  is also more solvent, is discussed above. But, if the winner under  $\bar{x}'$  is more efficient and less solvent, she should have won also under  $\bar{x}$ , since her bid is lower than the bid of  $(\bar{l}, \bar{c})$  for any legal standards. ■

PROOF OF COROLLARY 3:

See the explanation of the Corollary in the main text. ■

PROOF OF PROPOSITION 3:  $P(c, l, \bar{x})$  is increasing in  $c$  and  $l$ . If  $\bar{x} = 0$ ,  $P(c, l, 0)$  does not depend on  $l$  and  $(c_E, l_E)$  wins. If  $(c', l')$  (with  $c' > c_E$ , and  $l' < l_E$ ) beats  $(c_E, l_E)$  for  $\bar{x}$ , then  $(c', l')$  also beats  $(c_E, l_E)$  for  $\bar{x}' \geq \bar{x}$ . This is because,  $P(c, l, \bar{x})$  is supermodular in  $(l, \bar{x})$ . Supermodularity implies the single crossing property. Then, if

$$P(c_E, l_E, \bar{x}) - P(c', l', \bar{x}) > 0 \rightarrow P(c_E, l_E, \bar{x}') - P(c', l', \bar{x}') > 0$$

. ■

## B ABSTRACT MECHANISMS

We assume that the cost is common for all bidders,  $c_i = c$ . Now, we consider abstract direct mechanisms  $(\sigma, P)$ , where  $P : [l, \bar{l}]^N \rightarrow R^N$ , and  $\sigma : [l, \bar{l}]^N \rightarrow \Delta^N$ . We interpret  $\sigma_i(l)$  as the probability that firm  $i$  is assigned the project when  $l$  is the vector of assets, and  $P_i(l)$  as the price of the contract if the vector of types is  $l$  and firm  $i$  is assigned the project.

We will be focus on mechanisms where the payments are independent of types other than that of the winner. Thus, let us define  $\Psi_i(l_i) = E_{A_{-i}} \sigma_i(A)$ .  $\Psi_i(A_i)$  is the expected probability that bidder  $i$  obtains the contract when conditioning on its information,  $l_i$ . Incentive compatibility implies a crucial monotonicity property of trading mechanisms.

**LEMMA 2** *In any IC mechanism  $\Psi_i(l_i)$  is monotonically decreasing and  $P(l_i)$  monotonically increasing.*

**PROOF OF LEMMA 2:**

Consider that  $l'_i > l_i$ . Then by incentive compatibility

$$\Psi(l_i) \Pi_i(P(l_i), l_i) \geq \Psi(l'_i) \Pi_i(P(l'_i), l_i) \quad (2)$$

$$\Psi(l'_i) \Pi_i(P(l'_i), l'_i) \geq \Psi(l_i) \Pi_i(P(l_i), l'_i) \quad (3)$$

Combining these two equations we get

$$\Psi(l_i) [\Pi_i(P(l_i), l_i) - \Pi_i(P(l_i), l'_i)] \geq \Psi(l'_i) [\Pi_i(P(l'_i), l_i) - \Pi_i(P(l'_i), l'_i)] \quad (4)$$

Remember that  $\Pi(P, c, l, \bar{x}) = P - c - \min\{\bar{x}, \gamma(z)\}$ , where  $z = \min\{P + l - c, D\}$ . Note that  $\Pi_i(P, l_i)$  is decreasing in  $l_i$  and increasing (non-decreasing) in  $P$ , which implies that  $\Pi_i(P, l_i) > \Pi_i(P, l'_i)$ .

We want to show that,  $\Pi_i(P, l_i) - \Pi_i(P, l'_i)$  is weakly decreasing in  $P$ . Let define  $\bar{l} = \gamma^{-1}(\bar{x})$  and assume that  $\bar{l} \leq D$ .<sup>13</sup> Firstly, if  $l'_i > l_i > \bar{l}$ , then  $\Pi_i(P, l_i) - \Pi_i(P, l'_i) = 0$  since both types will not be liable. If  $l'_i > \bar{l} > l_i$ , then

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<sup>13</sup>This condition is satisfied for example if  $\bar{x} < x^*$ .

$$\begin{aligned} & \Pi_i(P, l_i) - \Pi_i(P, l'_i) = \\ & = \begin{cases} \bar{x} - \gamma(P + l_i - c) & \text{if } 0 \leq P < \bar{l} - l_i + c, \\ 0 & \text{if } P \geq \bar{l} - l_i + c \end{cases} \end{aligned}$$

Which is decreasing since  $\gamma(P + l_i - c)$  is increasing in  $P$ . Finally, we have to consider  $\bar{l} > l'_i > l_i$ ,

$$\begin{aligned} & \Pi_i(P, l_i) - \Pi_i(P, l'_i) = \\ & = \begin{cases} \gamma(P + l'_i - c) - \gamma(P + l_i - c) & \text{if } P < l^* - l'_i + c, \\ \bar{x} - \gamma(P + l_i - c) & \text{if } \bar{l} - l_i + c \leq P < \bar{l} - l_i + c, \\ 0 & \text{if } P \geq \bar{l} - l_i + c \end{cases} \end{aligned}$$

We concentrated in  $\gamma(P + l'_i - c) - \gamma(P + l_i - c)$ , in that case,

$$\frac{d[\Pi_i(P, l_i) - \Pi_i(P, l'_i)]}{dP} = \gamma'(P + l'_i - c) - \gamma'(P + l_i - c) < 0$$

This is because,  $\gamma'' < 0$  and  $P + l'_i - c > P + l_i - c$ . Then, we have shown that  $\Pi_i(P, l_i) - \Pi_i(P, l'_i)$  is weakly decreasing in  $P$ . Now, assume for contradiction that  $P(l'_i) < P(l_i)$  which since  $\Pi_i(P, l_i) - \Pi_i(P, l'_i)$  is decreasing in  $P$  implies that

$$[\Pi_i(P(l_i), l_i) - \Pi_i(P(l_i), l'_i)] \leq [\Pi_i(P(l'_i), l_i) - \Pi_i(P(l'_i), l'_i)] \quad (5)$$

Given (5) the inequality(4) can only be satisfied if  $\Psi(l'_i) \leq \Psi(l_i)$ . But  $P(l'_i) < P(l_i)$  and  $\Psi(l'_i) \leq \Psi(l_i)$  violates the incentive compatibility constraint of type  $l'_i$  (equation 3). Hence  $P(l'_i) > P(l_i)$ . But then  $\Psi(l'_i) \leq \Psi(l_i)$ . Otherwise the incentive compatibility constraint of type  $l_i$  would be violated (equation 2). ■

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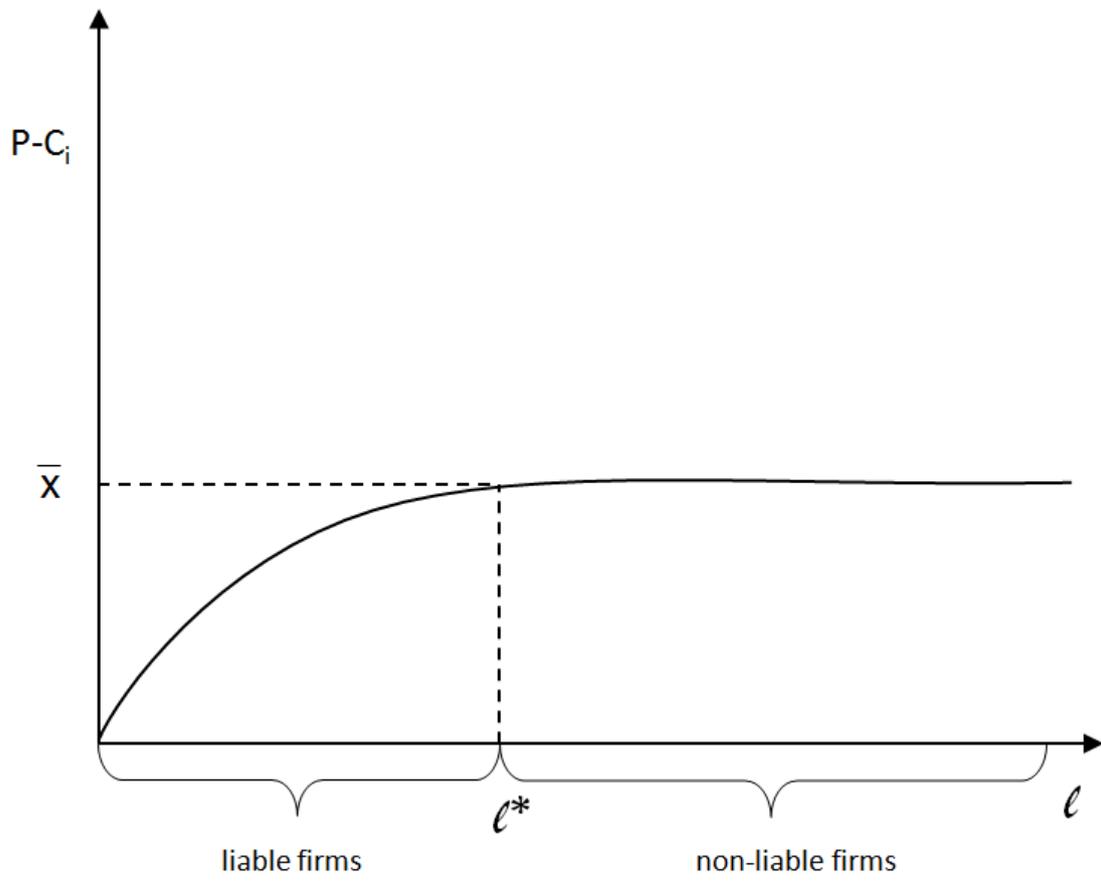


Figure 1

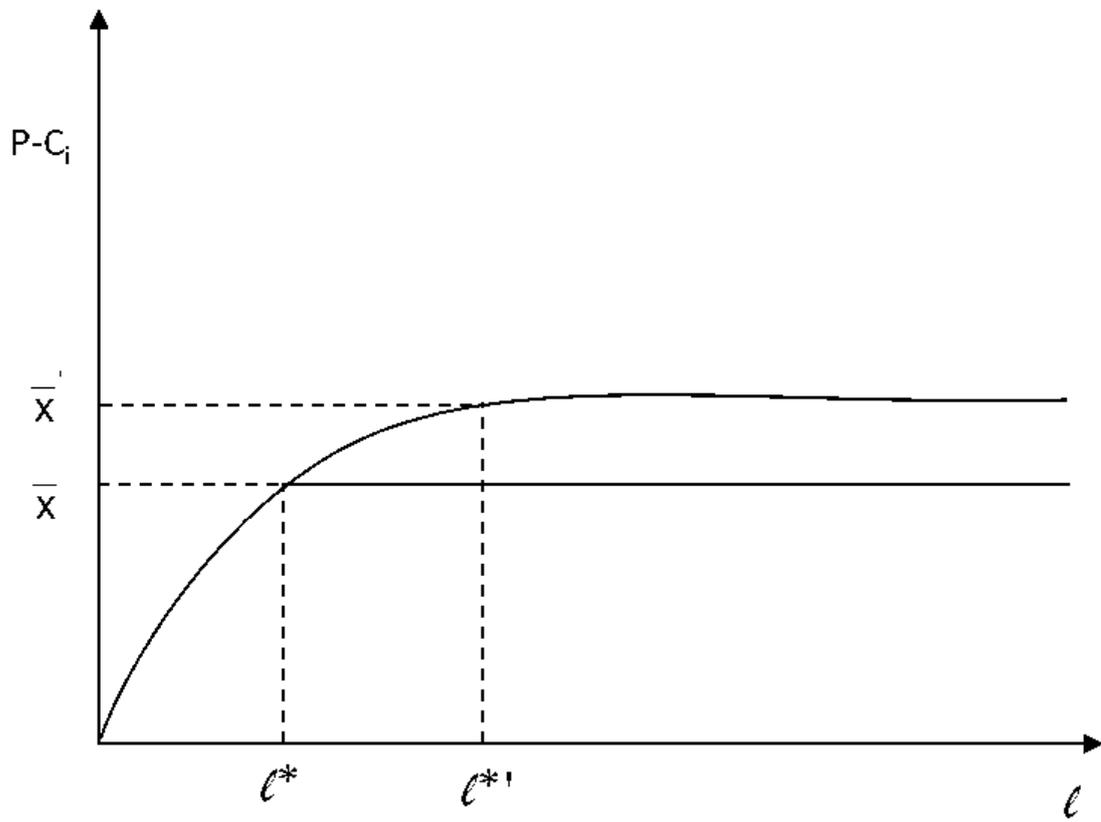


Figure 2