

The Simple Economics of White Elephants*

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Abstract

This paper shows that the concession model discourages firms from acquiring information about the future profitability of a project. Uniformed contractors carry out good and bad projects because they are profitable in expected terms even though it would have been optimal to invest in screening them out according to their value. White elephants are identified as *avoidable* negative net present-value projects that are nevertheless undertaken. Institutional arrangements that limit the losses that firms can bear exacerbate this distortion. We characterize the optimal concession contract, which fosters the acquisition of information and achieves the first best by conditioning the duration of the concession to the realization of the demand and includes payments for not carrying out some projects.

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1 Introduction

On May 28, 1873 the New York Times published an article called “White Elephants” that starts with the following paragraph

When a Siamese despot takes a grudge against one of his poorer subjects, and determines on his ruin, he does not cut off the delinquent’s head and confiscate his property. On the contrary, he makes him a present – he sends him the handsomest and healthiest white elephant he can find. The luckless recipient knows at once that his fate is sealed. He knows that the beast will eat him out of house and home without the possibility, on his part, of resistance. He cannot sell or give away the fatal gift, for no one would accept it, and the attempt to get rid of it even would be direct treason and sacrilege. He sits down with Oriental resignation to submit to the inevitable, and the white elephant devours his substance.

As Bullen (2011) explains, this story is probably a myth as white elephants were considered a symbol of virtue and status in Siam and no king would consider them burdensome. Nevertheless, this story has taken root in the economics literature, popularized in papers such as Robinson and Torvik (2005), and it is now commonly used to identify facilities and infrastructures of little practical use or value. More precisely, white elephants are associated with projects with a negative social value.

The perception that these white elephants are common is widespread and each country has its favorite example: The Montréal-Mirabel International Airport was once the largest in the world in terms of surface;¹ the New South China Mall, the largest mall in the world, has sat mostly vacant; the Brisbane’s Clem Jones Tunnel had less than 50% of

¹Designed for 50 million passengers a year when it opened in 1975 it never handled more than 2.8 million. See Krauss, C. “End of Era Near in Montreal for White-Elephant Airport”, Oct 3, 2004.

the projected traffic even after tolls were slashed by half; the “Radial” Highways around Madrid suffered from an even superior demand overestimation.²

In this paper we discuss how these white elephants may come about in the construction of public infrastructure by private firms, which are compensated through concession contracts. We argue that standard procurement procedures do not provide incentives for firms to get informed about relevant characteristics of the demand (or the cost) and, as a result, contractors engage in insufficient screening of projects and end up building unnecessary infrastructures.

Concession contracts, typically between a government agency and a private consortium of firms (the concessionaire), involve the transfer of the construction and/or the operation of an asset from the former to the latter for a period of time. Toll highways are a classical example. Their construction is managed by a concessionaire that engages in a long-term contract with a government, designed to recover the large investment cost through user fees (i.e. toll revenues). This kind of schemes has been extended in recent years to all types of Public-Private Partnerships (PPPs).³ They are now common in the construction of roads, prisons, airports, hospitals, railway infrastructure, etc., where the government pays a fee according to their usage. As opposed to what occurs in public-work contracts where the government assumes all risk and manages the infrastructure directly, concession contracts are used to transfer the risk to the concessionaire.

The risk of such projects is high, since PPP concessions covering infrastructures are long-term contracts – to allow investors to recover the huge upfront investment –, and their profitability depends on variables (traffic, costs, etc.) that are difficult to forecast even for a short horizon. In the case of demand estimation, Bain and Polakovic (2005)

²According to Engel et al. (2015) first year traffic of the R-2, R-3, R-4 R-5, M-12, and AP-41 highways was between 56% and 82% lower than anticipated.

³See Engel et al. (2014) for an overview of the rise of the investment in infrastructures financed through PPPs. They report that in Europe they went from irrelevant in 1990 to close to a €30 billion industry in 2006. In low and middle-income countries PPP investment reached US\$160 billion in 2010.

report, using a sample of highway concession projects collected by Standard and Poors (S&P), that first-year traffic volumes averaged about 76% of their predicted values and the error had a standard deviation of 0.26. A similar error persisted in the years 2 to 5.⁴ The underperformance of the concessions is striking since one of its main advantages over a standard public-work contract is precisely the fact that a firm can better assess the demand since its own money is at stake.

Our paper provides an explanation for this result that arises from the interaction between the (asymmetric) consequences of the unpredictability of revenue (or costs⁵) and the incentives for firms to acquire information. Regarding the revenue risk, it is often the case that if traffic is lower than expected, concessionaires will force a renegotiation. Guasch (2004) analyzes concession contracts in Latin America and shows that over 30% of concession contracts are renegotiated. In the transportation sector this proportion reaches 54.7%. The results are similar in other concessions characterized by huge sunk investments, long concession horizons and demands risk such as water and sanitation, where renegotiation occurs in 74.4% of the cases. Importantly, Guasch (2004) also reports that most renegotiations favor the concessionaire by raising tariffs (62% of the cases) and/or through a decrease in the required investment. In other cases the duration of the concession is extended. These changes are in contrast with what occurs when revenues are higher than expected. In that case concessionaires typically cash the extra profits.

These asymmetries are controversial and, in many countries, they have had an impact in the public debate. In this paper we highlight another important distortion that these asymmetries might entail. The core idea of our work is that if the potential losses of

⁴Flyvbjerg et al. (2005) analyze 214 road projects in 14 countries – mainly free roads –, and although they find almost no overestimation bias, the forecasting errors are even larger than in the previous case (a standard deviation of 0.44). They also show that railway demand is systematically overestimated worldwide.

⁵Flyvbjerg et al. (2003) analyze a sample of 258 infrastructure projects across 20 countries and 5 continents, and found that 90% of these projects were subject to cost overruns.

the concessions are limited by a future renegotiation (while the firm appropriates the potential upside) the incentives to acquire information are reduced, negatively affecting project selection.

We propose a principal-agent model where the public sector (the principal) is the sponsor interested in carrying out a public-work project. This project has an unknown value that might be uncovered with the costly acquisition of information by the contractor (the agent). The principal designs a simple concession contract that assigns a proportion of the value of the project to the contractor, for example, through the collection of toll fees during a limited period of time. The agent decides on the acquisition of information and contingent on that whether to invest in the project or not. The goal of the principal is to foster the acquisition of information and to induce investment only when the value of the project is higher than its cost.

We characterize the optimal concession contract and we show that both objectives (undertaking only projects that generate positive surplus and inducing the acquisition of information when it is efficient to do so) cannot be attained at the same time. As a result some white elephants inevitably emerge in equilibrium. The intuition is as follows. Suppose first that the cost of acquiring information is small. Then, the first best can be attained by designing a concession contract that allocates the share of the revenue to the firm that, once informed, allows it to break even only when a project has a positive social value. Naturally, the incentives to acquire information decrease as the cost of this information increases. To prevent the firm from carrying out the project without information the concession contract must be distorted. In particular, the value of information rises if the share of the revenues that the firm appropriates is reduced and avoiding bad projects becomes more valuable. In this second-best world, some good projects are not undertaken. Furthermore, for a sufficiently high cost of information, the acquisition of information that occurs in the first best becomes too expensive, in terms

of incentives, to motivate in the second best. In that case the principal prefers not to induce the acquisition of information, leading to some bad projects (white elephants) to be undertaken in equilibrium. Our result is not specific to the case studied here and we show that similar implications arise when we extend the model to allow for competition.

It is important to notice that our definition of white elephants is restricted to those projects for which proper ex-ante information acquisition was optimal but it did not occur. This is in contrast with the way they are typically interpreted, where evaluation of projects like the ones mentioned earlier is carried out ex-post. The presence of uncertainty inevitably implies that for some projects the costs will never be recovered but this does not imply an upfront bad project selection. The question that our paper addresses is how those bad projects that ex-ante could have been efficiently screened out by investing in information end up being built, and how standard contracts could be adapted to provide the proper incentives and reduce their cost for the society.

In practice, as mentioned above, an important element of these concession contracts is the limit on the losses that the contractor can incur due to the renegotiation or the rescue of the infrastructure by the public sector. When we introduce this element in the model we show that the lower the losses that the firm might absorb, the more critical is the problem of providing incentives for the firm to acquire information. As a result, distortions increase when fewer losses can be absorbed leading to more white elephants. An important policy recommendation of our analysis is that governments should compensate bankrupt concessionaries according to the value of the concession and not the incurred cost. This value can be uncovered by auctioning the failed concession.⁶

All our analysis relies on two important assumptions. First, we take the institution of

⁶In some countries the limit on the losses takes an explicit legal form. For example, in Spain it is denoted as “Responsabilidad Patrimonial de la Administración”, for which an underwater concession is taken over by the state and the firm is compensated according to the cost incurred. In line with the policy recommendation of this paper, a recent change in the law has linked this compensation, instead, to the present value of the cash-flows of the concession at the time of the rescue.

concessions as given and we do not consider transferring ownership of the infrastructure to the firm. Clearly, this allocation of risk would achieve the first best, but it is rarely observed in practice for several reasons, including among others, legal constraints or financing advantages of the government compared to the firm. Second, we assume that the firm can acquire information beyond the knowledge of the principal. This assumption is very reasonable in the case of many PPPs in which the contractor might have an expertise in a particular infrastructure or a particular market. We claim, however, that this assumption is also appealing in a more general context even when the firm does not necessarily possess an advantage in the acquisition of information simply because the public sector typically discloses all the available information prior to the contract. There are many reasons why this occurs. There are legal obligations to disclose all relevant information for the project. Furthermore, the provision of information might entail efficiency gains by inducing a better match between the firm and the project and by reducing the winner's curse when the project is allocated through an auction. Thus, our private information acquisition process ought to be understood as the additional precision in the assessment of the value of the project that the firm might obtain by carrying out its own study.

Our paper is related to the literature that has studied the optimal concession contracts. The prevalence of the renegotiation highlights the importance of managing the risk of these long-term contracts. While the firm has control of most cost components, the demand is often exogenous to its actions. This might be due to many reasons such as the fact that the quality of infrastructures like highways can be specified as part of the contract. As a result, demand risk should be absorbed by the government. Transferring risk to the firm has little effect on performance but might induce contract renegotiation.

One way to achieve this goal is to adjust the duration of the concession to the evolution of the demand. Engel et al. (1997, 2001) proposed the Least Present Value of the Revenues

(LPVR) mechanism that has become the most influential way to exploit this idea. The mechanism consists on a flexible-term concession that awards the contract to the bidder that demands the lowest discounted total revenue for the project. The winner is then entitled to receive the revenues of the concession up to the point in which their discounted flow equals the present value revenue offered in the bid. At that point the concession expires.

The previous literature has usually ignored the optimal selection of projects which is the main focus of our work. Here we show that although in our model the revenues of the project are exogenous, a standard application of the LPVR mechanism is suboptimal because it does not provide incentives for firms to acquire information. Taking this effect into account requires some demand risk to be transferred to the contractor in order to provide incentives to get informed.⁷

However, our main theoretical result, the characterization of the optimal concession contract, relies on a powerful idea of the LPVR mechanism: the need to enrich the concession contract with the available information about the realized demand. We show that a concession contract with this feature, together with the possibility of paying for not undertaking a project, can attain the first best. As in the standard application, when the realization of the demand is sufficiently high (indicating that it is likely that information was acquired), the firm is compensated for the total cost. It also receives a compensation when the project is not carried out. If demand is low, however, the firm is penalized. Although it can be argued that a mechanism involving payments to the firm for not undertaking the project may not be politically feasible, we believe that our approach opens a new way to think about the provision of incentives in concession contracts when project selection matters. We also characterize the second best contract

⁷This is because the expected realization of the demand is different depending on whether the contractor is informed or not. In some sense, the demand is not completely exogenous to the actions taken by the contractor.

when such a compensation is not feasible and we show that the distortions that arise are similar to those that we described in the benchmark model.

The paper proceeds as follows. Section 2 and 3 discuss the basic model. Section 4 analyzes the effects of limits on the losses that firms can absorb and section 5 characterizes the optimal flexible-term concession contract. Section 6 discusses extensions of the model, including the effect of competition. Section 7 concludes. All proofs are relegated to a technical appendix.

2 The Model

A government considers the possibility of undertaking a project of a known cost of $c > 0$. Together with the construction cost the government must account for the opportunity cost of the project $d > 0$. This opportunity cost might be interpreted as the benefits of an alternative project that could be funded with the same resources or, in the case of a public work project, the alternative uses that resources devoted to it, for example land, may have had. The project is not carried out directly by the government but by a private firm, that we denote the *contractor*.⁸

The return of the project is uncertain. It produces a total value θ drawn from a distribution $G(\theta)$ in the interval $[0, 1]$ with density $g(\theta)$, assumed to be positive in all the support.

The value the project can be assessed before construction takes place if an amount $k \geq 0$ is invested in a study. We assume that if this cost is incurred the exact value of θ is revealed.⁹ Otherwise, the value is only revealed after investment takes place.

Throughout the paper we make the assumption that even without information it is

⁸The concession of an infrastructure distinguishes between the firm that builds it, the contractor, and the firm that manages it, the concessionaire. For the purpose of this paper this distinction is irrelevant, and we call the firm simply as the contractor.

⁹We choose this fully informative signal for tractability reasons. But we see no reason why if the value of the project were observed with noise the results would be qualitatively different.

in the interest of society in expected terms that the project is carried out. That is,

$$E(\theta) = \int_0^1 \theta g(\theta) d\theta > c + d. \quad (1)$$

Thus, the main effect of acquiring information is to reduce the proportion of projects that are undertaken by weeding out those that are known to have a low value. It is natural to assume that projects have an ex-ante positive social value since we are in a contractual stage. Beyond this assumption our results are distribution free.

In exchange for incurring in a construction cost c , the principal awards the contractor a compensation consisting of a proportion $\beta \in [0, 1]$ of the returns from the project. This is typically the case, for example, in infrastructures like toll highways. In that case, we can interpret θ as the total traffic generated and β as how many years the contractor will be able to collect tolls from it.¹⁰

Furthermore, we also assume that the investment in obtaining information can only be carried out by the contractor. An interpretation of this assumption is that the government has already collected information which has been made public and it is already embedded in the distribution $G(\theta)$. The firm can invest in obtaining a more accurate signal. Importantly, we will assume that whether the firm has incurred in the cost of information k or not is not contractible.

The government's objective function is to maximize social welfare. As we will see next, attaining this aim implies minimizing decision errors: reducing the possibility that projects with a low value θ are carried out while, at the same time, not passing over socially profitable investment possibilities. When several contracts lead to the same level of social welfare we will assume that the government chooses the one that minimizes firm profits.

¹⁰In this paper we abstract from other important dimensions, like the amount of the toll, which affects how much of the cost is recovered each period, and can be compensated with the duration of the concession. This is not a new trade-off and it has been studied in other context like in the case of patents, starting with classical works like Nordhaus (1969). Weyl and Tirole (2012) study how prices can also be used in order to screen private information in such a context.

Before we characterize the optimal contract we briefly discuss the first best. This allocation will become useful as a benchmark in the rest of the paper.

2.1 The First Best

If no information is acquired our previous assumption, in (1), implies that the expected value of a project of unknown return θ is higher than $c + d$ and it should be carried out. Thus, information should be acquired if it produces higher social welfare. The investment of an amount k uncovers the return of the project and it allows to select only those for which $\theta \geq \underline{\theta}$. Acquiring information will be efficient if

$$\max_{\underline{\theta}} \int_{\underline{\theta}}^1 [\theta - (c + d)] g(\theta) d\theta - k \geq \int_0^1 \theta g(\theta) d\theta - (c + d),$$

leading to an optimal threshold in the value of the project of $\underline{\theta}^s = c + d$. Hence, information should be acquired if

$$k \leq K^s \equiv - \int_0^{\underline{\theta}^s} [\theta - (c + d)] g(\theta) d\theta,$$

In other words, if $k \leq K^s$ information is gathered and bad projects are screened out. Instead, if $k > K^s$, it is socially optimal not to acquire information and all projects will be carried out.

3 The Optimal Contract

In order to illustrate our analysis it is useful to start by pointing out that if information could be acquired by the firm at no cost the first best could be easily implemented. We know that the contractor would always acquire information and it would only carry out those projects that produced a positive return, identified as $\beta\theta \geq c$. As a result, the first best in terms of project selection can only be attained by choosing $\beta^* = \frac{c}{c+d} < 1$. The intuition is straightforward. Since the firm does not internalize the opportunity cost of the investment, d , the duration of the concession must be reduced in order to eliminate the excessive incentives to invest.

When k increases the contractor's decision to get informed will depend on whether the losses avoided by using this information are greater than k or not. That is, the contractor will get informed if

$$\max_{\underline{\theta}} \int_{\underline{\theta}}^1 [\beta\theta - c] g(\theta) d\theta - k \geq \int_0^1 \beta\theta g(\theta) d\theta - c.$$

This problem yields a profit-maximizing threshold $\underline{\theta}^* = \frac{c}{\beta}$ under which the contractor will decide to get informed if

$$k \leq K(\beta) \equiv - \int_0^{\frac{c}{\beta}} [\beta\theta - c] g(\theta) d\theta.$$

Notice that the critical value $K(\beta)$ is decreasing in β ,

$$K'(\beta) = - \int_0^{\frac{c}{\beta}} \theta g(\theta) d\theta < 0.$$

The intuition for this negative relationship can be easily explained using Figure 1, which computes the returns for different values of θ . The dashed line corresponds to the social welfare generated. The dotted line computes private profits under a concession $\beta^* = \frac{c}{c+d}$. As discussed before, by construction, profits of an informed firm are positive in this case if and only if $\theta \geq \underline{\theta}^s$. Notice, however, that the value of information for the firm is lower than the value for society, since the gains from avoiding bad projects – low θ – are smaller.¹¹ As a result, when $k > K\left(\frac{c}{c+d}\right)$ a conflict arises. Providing incentives to invest in such a case requires lowering the profits when a bad project is undertaken, which implies $\beta < \frac{c}{c+d}$ as shown in the solid line of the figure. However, this decrease in profits discourages the firm, once informed, to carry out some profitable projects with $\theta \in [\underline{\theta}^s, \underline{\theta}^*]$. The next lemma summarizes this discussion.

Lemma 1. *For values of $k \in \left[K\left(\frac{c}{c+d}\right), K^s\right)$ the first best cannot be attained.*

¹¹The profits from undertaking projects with $\theta \geq \underline{\theta}^s$ are also smaller than the social welfare they generate. However, this difference does not affect the value of information since for those projects the profits with and without information are the same.

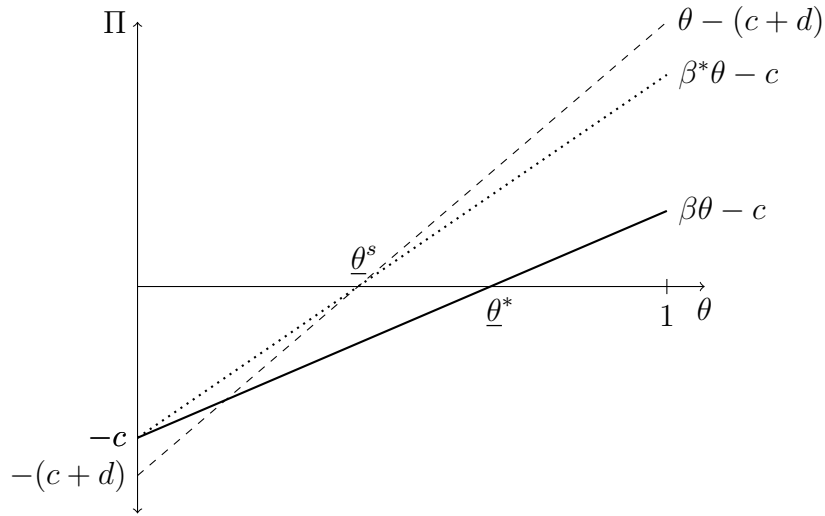


Figure 1: Losses and profits depending on θ .

This result implies that the first best allocation will be possible in two circumstances. First, when k is small the firm has incentives to get informed and, thus, β^* maximizes social welfare. Second, when k is sufficiently high so that gathering information is not socially optimal there is no incentive problem and it is enough that β allows the firm to break even in expected terms for the projects to be undertaken.

In the remaining situations, when the first best cannot be attained, the government trades off two types of distortions. On the one hand, it can give up providing incentives for the firm to learn and, thus, bad projects are carried out. On the other, it can distort β in order to provide incentives for the contractor to learn but, as a result, forestall some good projects.

These two distortions will give raise to standard Type-I and Type-II errors. Type-I errors arise because in order to entice the contractor to invest, the value of β must be distorted downwards. The lower the β the higher is $K(\beta)$. That is, the incentives to get informed increase since the losses the contractor suffers when θ is low and the project has been carried out due to the lack of information are higher. Of course, this distortion implies that a range of projects with a value of θ higher that $c + d$ will not be undertaken since β is too low. Thus, the optimal β is the highest value that provides incentives for

the contractor to get informed, $\tilde{\beta}(k) = K^{-1}(k)$. The cost of these Type-I errors for a given k is

$$E_I(k) = \int_{c+d}^{\frac{c}{\tilde{\beta}(k)}} (\theta - (c+d))g(\theta)d\theta.$$

Following the previous discussion, Type-I errors arise because projects with $\theta \in \left[c+d, \frac{c}{\tilde{\beta}(k)} \right]$ have a value greater than $c+d$ but will not be carried out if the firm gets informed. Of course, the size of this error is increasing in k , since the higher is this cost the higher will need to be the distortion in β to entice learning.

Type-II errors arise in those cases in which the sponsor decides not to provide incentives to learn the value of the project. Consequently all projects are carried out implying a social cost of

$$E_{II} = - \int_0^{c+d} (\theta - (c+d))g(\theta)d\theta = K^s,$$

that must be compared with the savings that society accrues when k is not incurred. The optimal contract is characterized by comparing Type-I and Type-II error costs.

Proposition 1. *The optimal contract corresponds to*

$$\beta^*(k) = \begin{cases} \frac{c}{c+d} & \text{if } k < K\left(\frac{c}{c+d}\right), \\ \tilde{\beta}(k) & \text{if } K\left(\frac{c}{c+d}\right) < k < \tilde{K}, \\ \frac{c}{E(\theta)} & \text{otherwise,} \end{cases}$$

where

$$E_I(\tilde{K}) + \tilde{K} = E_{II}.$$

Notice that since $E_{II} = K^s$, $\tilde{K} < K^s$. Figure 2 illustrates how the optimal value of β changes when k varies together with the lowest value of the project that will be implemented, $\underline{\theta}^*$. As Lemma 1 showed, the optimal contract corresponds to the first best when k is very low or very high, $k \leq K\left(\frac{c}{c+d}\right)$ or $k \geq K^s$. We have two regions in-between. When $K\left(\frac{c}{c+d}\right) < k < \tilde{K}$ the firm will invest because the lower Type-I error – the dotted area in Figure 1 – dominates. Instead, when $k \in \left[\tilde{K}, K^s \right]$ it is not optimal to provide incentives for the contractor to get informed. The Type-II error becomes less

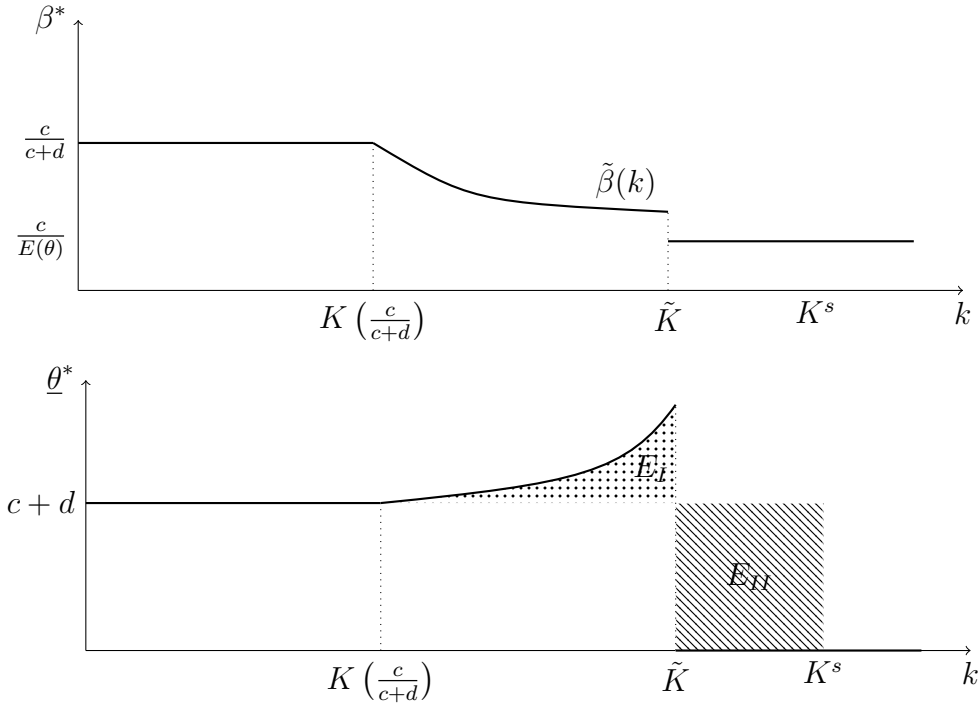


Figure 2: Second best as a function of k .

costly. The low value projects that are carried out in this region (when $\theta < c + d$) will be identified as white elephants, because the firm does not have incentives to acquire information although it is socially optimal to do so. These projects that should have been screened out are identified as the dashed area in Figure 2.

4 Limited Losses

In the basic model the contractor invests in the project c or $c + k$ depending on whether information is acquired or not. This investment sets a cap on the maximum losses that the firm might incur due to limited liability. In many cases, however, the government imposes additional limits on the losses that the contractor might bear. In countries like Spain the procurement of public projects has traditionally included an amount that the government will cover in case some unexpected costs arise or if the demand turns out to be lower than anticipated. More generally, the prospects of a costly and uncertain renegotiation process might motivate governments to subsidize underwater concessions.

We denote the maximum losses that the firm may incur as L and we restrict them to be between 0 and c .

The analysis in this case is very similar to the one we conducted in section 3. Because now the losses are capped by L , profits will be $-L$ for any realization $\theta < \frac{c-L}{\beta}$. As a result we obtain that information is acquired if

$$\max_{\underline{\theta}} \int_{\underline{\theta}}^1 [\beta\theta - c] g(\theta) d\theta - k \geq \int_{\frac{c-L}{\beta}}^1 [\beta\theta - c] g(\theta) d\theta - LG \left(\frac{c-L}{\beta} \right).$$

Notice that when the firm gets informed, losses will never be incurred and, as a result, L does not play a role. The previous expression yields a new threshold cost of information that provides incentives for the contractor to get informed and that, with some abuse of notation, we denote as $K(\beta, L)$. When $L = c$ we obtain the same threshold as in the baseline model, $K(\beta)$. At the other extreme, when $L = 0$, the threshold is equal to 0. In this last case, the contractor will never get informed because the value of information is precisely to eliminate those realizations of θ for which the firm makes losses and this is something that $L = 0$ already guarantees at no cost to the contractor.

The optimal contract can again be cast in terms of the comparison of Type-I and Type-II errors.

Proposition 2. *The optimal contract under limited losses corresponds to*

$$\beta^*(k, L) = \begin{cases} \frac{c}{c+d} & \text{if } k < K\left(\frac{c}{c+d}, L\right), \\ \tilde{\beta}(k, L) & \text{if } K\left(\frac{c}{c+d}, L\right) < k < \tilde{K}(L), \\ \frac{c}{E(\theta)} & \text{otherwise,} \end{cases}$$

where

$$E_I(\tilde{K}, L) + \tilde{K} = E_{II}. \quad (2)$$

The structure of the optimal contract bears many similarities with the one in the benchmark case. When k is low the first best can be implemented but, compared to the benchmark case, the threshold value is lower, since $K\left(\frac{c}{c+d}, L\right)$ increases with L .

For intermediate values of k , the principal prefers to induce learning by distorting β downwards. As in the benchmark case, for a given k , it is optimal to choose the highest value of β that guarantees that learning takes place, $\tilde{\beta}(K, L)$. In other words, $k = K(\tilde{\beta}, L)$. Because the only distortion is that some good projects are not carried out, only Type-I errors can arise and their cost can be computed as

$$E_I(k, L) = \int_{c+d}^{\frac{c}{\tilde{\beta}(k, L)}} (\theta - (c + d))g(\theta)d\theta,$$

which is decreasing in L .

For higher values of k it is not optimal for the sponsor to induce learning at all and, thus, only Type-II errors can arise. These errors are identical to the ones in the benchmark case and, in particular, they do not depend on L which, from a social point of view, is just a reallocation of surplus towards the firm.

The minimum value of k for which it is not optimal to induce learning corresponds to the one for which the cost of the Type-I error plus the cost of learning equates the cost of the Type-II error, as indicated in (2). Notice, though, that since E_I is decreasing in L we have that the critical value \tilde{K} is increasing in L . That is, when the contractor can absorb fewer losses the social value of fostering information acquisition is reduced and the threshold value for which it is optimal that the firm carries out all projects decreases. This effect implies that the white elephants are more likely when L is lower. Figure 3 also shows that β^* is decreasing in L .

All this discussion can be summarized in the following result.

Corollary 1. *When L increases,*

1. *Social welfare increases,*
2. *White elephants are less likely, and*
3. *Equilibrium decision errors are smaller.*

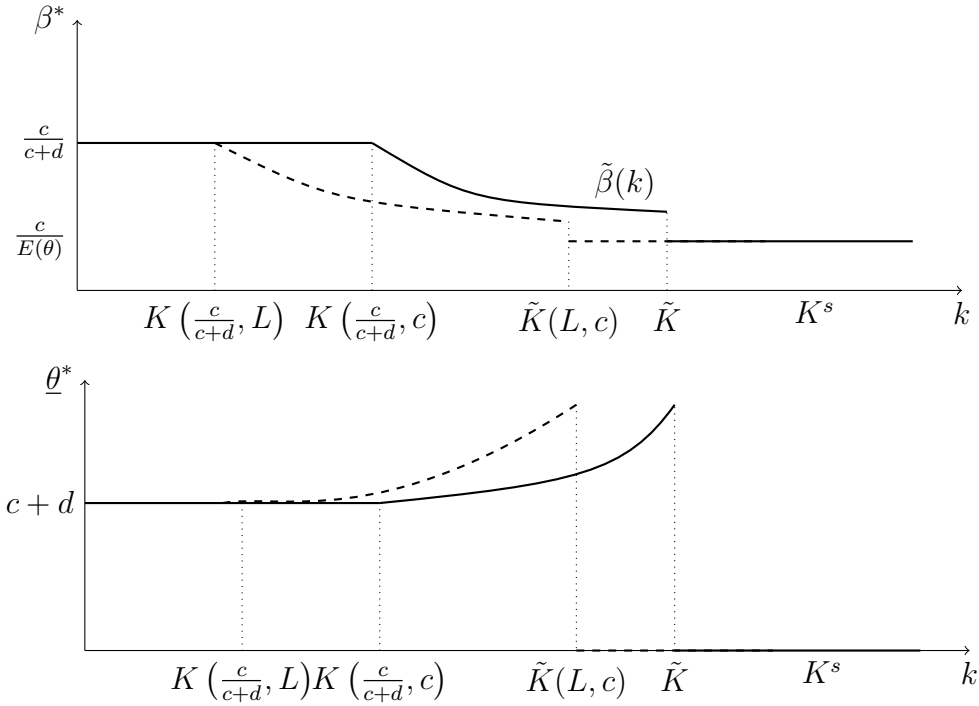


Figure 3: The effect of the limit in losses. The dashed line corresponds to $L < c$ whereas the solid line indicates the benchmark case $L = c$.

As it transpires from the previous analysis, institutional reforms aiming to increase L will raise social surplus. This occurs, for example, in the case of renegotiation of an underwater concession (a situation in which future revenues are not enough to repay the remaining debt). Our results indicate that if the contractor expects to receive more than the present value of the future cash-flows of the concession the ex-ante incentives to acquire information will be harmed. A commitment to prevent that could be acquired if the government specified that in case of bankruptcy the concession would be taken over and auctioned off again. The receipts from this auction would go to compensate the previous concessionaire.

From the previous discussion we can also conclude that enlarging the space of contracts that can be offered to the contractor by including a subsidy $T \geq 0$ will have a similar effect as limited liability. When it is optimal to carry out the project the firm receives the subsidy regardless of whether information has been acquired or not. Instead, if θ is low

the subsidy is paid only when the project is carried out anyway, decreasing the payoffs from acquiring information.

Proposition 3. *Suppose that the principal offers a concession with duration β together with a subsidy $T \geq 0$. Among all the contract combinations that lead to a threshold $\underline{\theta}$ above which the projects are carried out, the incentives to acquire information are maximized when $T = 0$.*

As we will see later, however, the previous result may change when the subsidy might be a function of θ . In that case, a higher subsidy can be associated to a higher traffic realization and, as a result, be used to provide incentives and compensate the costs of information acquisition.

5 Flexible-Term Concession Contracts

The optimal contract characterized in the previous sections assumed that k was not contractible but also that the contract offered, following standard practice in concessions, could not be a function of θ . In recent years, however, it has been pointed out that the distortions associated with the threat of renegotiation would be mitigated if the contract could depend on the realized return of the project. Engel et al. (2001) have convincingly argued that in infrastructures such as highways the duration of the concession should depend on the realized traffic. Highways that are busier than expected should be subject to a lower concession period, enough for the contractor to recover the investment costs. Highways that are less successful than expected should see the duration of the concession extended as much as necessary until the firm breaks even.

In our benchmark model this kind of contracts can be easily accommodated by assuming that $\beta(\theta)$. In particular, if $k = 0$ the Least Present Value of Revenues mechanism implements the first best by setting $\beta(\theta)\theta - c = 0$. This mechanism removes all risk from

the firm and guarantees that it obtains zero profits regardless of the realization of the demand. However, when $k > 0$ this standard flexible-term contract is inefficient in terms of providing incentives for firms to get informed. By shifting the risk from the firm to the government, the mechanism also decreases the incentives for the firm to become informed in the first place. In some sense, it operates as a demand-contingent loss limit and, thus, it suffers from problems similar to those discussed in previous sections.

This flexible-term contract, however, can be improved upon if rents are provided to compensate the cost of learning and these rents are doled out when the firm only undertakes high value projects. The next proposition shows that a flexible-term contract achieves the first best if it also introduces a payment for the firm not undertaking some projects.

Proposition 4. *A Flexible-Term Contract with payments when the project is not carried out can implement the first best for any value of k . This contract can be characterized as:*

- If $k \leq K^s$ and
 - the firm does not invest, it receives a payment $\rho_N(k)$,
 - the firm invests when
 - * $\theta \geq c + d$, then $\beta^*(\theta) = \frac{c + \rho_P(k)}{\theta}$,
 - * $\theta < c + d$, then $\beta^*(\theta) = 0$.

where

$$\rho_N(k) = \max \left\{ \frac{k}{G(c+d)} - c, 0 \right\},$$

$$\rho_P(k) = \rho_N(k) + \frac{k}{1 - G(c+d)}.$$

- If $k > K^s$ then $\beta^* = \frac{c}{E(\theta)}$.

When $k \leq K^s$ the previous contract consists of three different elements. In the spirit of other flexible-term contracts, $\beta^*(\theta)$ is such that when the project is socially valuable the firm obtains the same compensation regardless of θ . This compensation is higher than the cost c and equal to $\rho_P(k) \geq k$ which, in expected terms, covers the cost of information. When the project undertaken has a low value, however, the firm is awarded a concession with $\beta = 0$ as this is an indication that no information was acquired.

Rewarding the firm when θ is high might undermine the incentives for the firm to acquire information in the first place as it might anticipate in some cases positive profits from not acquiring information and undertaking the project anyway. For some parameter values the punishment that $\beta = 0$ implies when θ is small might make this an irrelevant concern. When this punishment is not enough to provide incentives to acquire information increasing $\beta(\theta)$ when the $\theta \geq \underline{\theta}^s$ does not help since this payment is always received. Thus, we need to introduce a third element in the contract which is a compensation $\rho_N(k)$, when the contractor decides not to carry out the project. This payment works because it increases the wedge in profits between undertaking low value projects and not doing so and, as a result, it provides additional incentives to become informed.¹²

Notice, though, that when the contractor is paid for not carrying out the project it will obtain positive rents. The reason is that in this case the firm could guarantee a profit of $\rho_N(k)$ by not acquiring information and never carrying out the project. Thus, the optimal contract must provide higher profits when the firm is informed and this is the reason why $\rho_P(k)$ is increasing in k and $\rho_P(k) > \rho_N(k)$. This last inequality also explains why subsidies are useful in this case, as opposed to what we concluded for the contracts studied in the benchmark model. In Proposition 3 we showed that subsidies were not optimal since they could not be associated to specific realizations of θ . Here

¹²In practice extreme punishments are unlikely to be implementable. For example, the government may learn about the realization of θ when the firm has already operated the project for some time and, therefore, this punishment might imply that the revenues can be reclaimed at no legal cost. When β has a lower limit the previous proposition suggests that $\rho_N(k)$ should increase.

$\rho_P(k)$ is only paid when $\theta \geq c + d$, making transfers weakly increasing in θ .

Finally, notice that when the firm carries out the project we are interpreting the payment $\rho_P(k)$ as an increase in $\beta(\theta)$, and we implicitly allow for $\beta^*(\theta) > 1$. This is without loss of generality since it is immediate that because we can condition on θ , any combination of a proportion of the project and subsidy that leads to the same profits $\beta\theta - T$ provides identical incentives.

Of course, a contract like the previous one might not be feasible in some contexts. For example, suppose that the capacity of a firm to carry out a project is unknown to the principal. A contract like the one described here might attract firms that are not qualified just because they expect to receive a positive payment $\rho_N(k)$ from not carrying out the project, without the need to invest in information. Similarly, a problem would also arise if the firm were the one proposing the project as it could come up with *phony concessions*, contracts that should never be undertaken, just to be compensated for that. Finally, another reason why such a contract might not be realistic is the fact that when the firm gets large rents this contract might entail a high social cost either for political reasons (because the firm is paid when the project is not carried out) or due to the distortionary taxation involved.

If the previous payments are not possible, depending on parameter values the government may still induce learning under a Flexible-Term concession for all $k \leq K^s$. In particular, notice that for any $\theta \geq c + d$ the contractor obtains an increase in profits of k when it is not informed. When $\theta < c + d$, however, it is still optimal for the government to impose the maximum penalty on the contractor which means that $\beta(\theta) = 0$. Comparing expected profits we obtain that the firm prefers to get informed if

$$k \leq cG(c + d). \tag{3}$$

Therefore, the first best will still be possible if $K^s \leq cG(c + d)$ which is consistent with the

result of the previous proposition that the first-best was implementable with $\rho_N(k) = 0$. Otherwise, inefficiencies along the same line as the ones discussed in the benchmark case will arise for $k \in (cG(c+d), K^s]$. The next proposition characterizes the contract that implements the second best.

Proposition 5. *The optimal Flexible-Term Contract when payments for not carrying out the project are not possible can be characterized as:*

- If $k \leq K^{ft}$ and

- $\theta \geq \underline{\theta}^{ft}$ then $\beta^*(\theta) = \frac{c+\rho_P(k)}{\theta}$;

- $\theta < \underline{\theta}^{ft}$ then $\beta^*(\theta) = 0$,

where $\underline{\theta}^{ft} = \max [c+d, G^{-1}(\frac{k}{c})]$ and $\rho_P(k) = \frac{k}{1-G(\underline{\theta}^{ft})}$.

- If $k > K^{ft}$ then $\beta^* = \frac{c}{E(\theta)}$.

The threshold value K^{ft} is defined as

$$K^{ft} = - \int_0^{\underline{\theta}^{ft}} [\theta - (c+d)] g(\theta) d\theta \leq K^s.$$

Notice that the contract we describe here is not unique and other combinations of $\beta(\theta)$ may lead to the same outcome. When the probability that the low realizations of θ arise and condition (3) is unlikely to hold distortions similar to those in the benchmark problem will arise here. Some projects, those with $\theta \in [\underline{\theta}^s, \underline{\theta}^{ft})$ will not be implemented in order to penalize the firm when no information is gathered. For this reason, the value of information will be lower in this case. As a result, for intermediate values of the cost of information, $k \in (K^{ft}, K^s]$, the firm will carry out the project uninformed, leading to white elephants.

Notice also that an important consequence of eliminating negative payments is that the firm will obtain a higher reward when θ is high, compared to the first best. The cost of information must be reimbursed through fewer states of the world.

6 Extensions of the Results

In this section we extend the discussion of the model in three directions. We start by analyzing the effects of considering the dead-weight loss associated with the market power necessary for the firm to recoup the investment during the concession period. We later study the case in which ex-ante, without information, it is not worthwhile to undertake the project. Finally, we show that competition generates similar distortions to the ones analyzed in the one firm case.

6.1 Distortions and Externalities

In the benchmark model we have interpreted β as the duration of the concession contract. That is, during a proportion β of the future, the firm could reap all the returns from the project.

This simple setup has two main limitations. First, market power typically generates a loss that neither the firm nor the society can appropriate. Second, a concession contract comprises many terms like the price and the duration, many combinations of which lead to the same β but have different welfare implications.

The demand model that would be consistent with our assumptions would be one in which $D(p) = 1$ if the price $p \leq \theta$ and $D(p) = 0$ otherwise. Obviously, in this case no distortion would arise and, contingent on production, surplus would always equal θ . Furthermore, any combination of a duration of the concession, denoted as γ , and price, p , such that γp is constant would be equivalent.

In more general contexts the two previous limitations might become relevant. We will not discuss here the trade-off between the price and the duration of the concession as this is an issue that has been studied at length in the literature, for example in the context of patent design.¹³ Instead, we focus on the effects of introducing static distortions.

¹³Two classical references of the conditions necessary for one dimension to be less distortionary than

Suppose that a price $p > 0$ leads to profits θ for the firm and a distortion δ while this concession is in place. Assume also that absent a concession (when $p = 0$) consumer surplus implies that θ generates a total surplus $s\theta$ with $s \geq 1$. Total welfare can, thus, be written as

$$W = \beta(1 - \delta)s\theta + (1 - \beta)s\theta = (1 - \beta\delta)s\theta \equiv \sigma\theta,$$

where, $(1 - \delta)s \geq 1$ implies $\sigma \geq 1$. As in the benchmark model, the firm would have *excessive* incentives to invest if $\sigma \leq \frac{c+d}{c}$ and, hence, $\beta^* \leq 1$ when $k = 0$. As a result, when $k > 0$ similar effect to the ones discussed in that case will emerge here.

6.2 Ex-ante Unprofitable Investments

A maintained assumption throughout the paper was that $E(\theta) \geq c + d$, meaning that without information the project had a net positive expected value. The acquisition of information was useful to screen out bad projects that without it would be undertaken.

It is reasonable to believe that the previous assumption captures the natural default case. The reason is that the project under consideration is likely to be the outcome of a wider selection process in which alternatives with lower expected value are screened out.

Nevertheless, we now discuss how the results change if $E(\theta) < c + d$. From a social standpoint, in this case the project should be undertaken if and only if information has been acquired and $\theta \geq c + d$. As a result, the acquisition of information is socially valuable if $k \leq K^s \equiv \int_{c+d}^1 [\theta - (c + d)] g(\theta) d\theta$.

As in the benchmark model, under a concession contract, choosing a $\beta^* = \frac{c}{c+d}$ implements the first best when k is small. For k sufficiently large there is no distortion either, since the project is never carried out. For intermediate values of k , as the case discussed in the main text, the firm lacks incentives to acquire information. As shown in Figure 1, when $\theta \geq \underline{\theta}^s$ the private returns when $\beta^* = \frac{c}{c+d}$ are smaller than the social returns. As a

the other are provided by Klemperer (1990) and Gilbert and Shapiro (1990).

result we have two situations. When k is relatively small, β must be distorted upwards as this increases the rents for the firm when it acquires information and carries out the project. Notice that this higher β leads to undertaking projects that are not socially efficient since $\underline{\theta}^* < \underline{\theta}^s$. When k is relatively large, the high β necessary implies that many bad projects would be carried out and it is socially preferable to not acquire information and not undertake any project.

One implication of this discussion is that the firm never incurs in losses in the equilibrium path. Either the project will not be undertaken or only those that have a private positive return will be carried out. Thus, limits on the losses or the anticipation of the renegotiation of the concession play no role have no effect on the incentives to acquire information.

Finally, the characterization of the flexible-term contract that attains the first best is simple. The function $\beta(\theta)$ must satisfy three conditions. When $\theta < \underline{\theta}^s$ then $\beta(\theta) = 0$ in order not to undertake inefficient projects. When $\theta \geq \underline{\theta}^s$ and $k \leq K^s$ it has to satisfy the condition

$$\int_{c+d}^1 [\beta(\theta)\theta - c] g(\theta) d\theta = k$$

so that the firm has incentives to acquire information. Finally, when $\theta \geq \underline{\theta}^s$, $\beta(\theta) \geq \frac{c}{\theta}$ so that undertaking good projects is profitable. Of course, the optimal contract is not uniquely defined. Also, notice that this contract is simpler than the one in the main text which required payments for not carrying out the project. There is an intuitive reason for that. The idea of flexible-term contracts is to reward the firm when the project is worthwhile. In the baseline model, this reward makes the ex-ante problem of acquiring information worse. In this case, however, rewarding the firm when θ is high provides more incentives to acquire information in order to undertake good projects.

6.3 Competition

Our benchmark model assumes that only one firm can carry out the project. However, most concessions are awarded competitively through an auction. To address this issue, in this section we discuss a simple model of competition that emphasizes an additional force that operates in the same direction and complements the results discussed in our benchmark framework.

Consider the case of two identical firms $i = 1, 2$ bidding to build the same project. The project is allocated according to a second-price auction. Each firm bids β_i . The firm that offers the lowest β wins the auction and the price, denoted as β^c , is set according to the losing bid. As in the previous sections this price can be interpreted as the proportion of the value of the project that it is allocated to the contractor, for example, through the combination of the toll level and the duration of a concession contract. Hence, the firm that commits to receive the lowest proportion of the value of the project wins.

In the benchmark model the principal sets β optimally. An important difference here is that β is now determined in equilibrium and not directly as part of the contract. However, as it is typically the case in the design of auctions, the principal can still affect the resulting β by setting a reserve price. In particular, we denote this price ceiling for which the bid will be accepted and the concession awarded to the winning firm as $\bar{\beta}$.

Similarly to what we assumed in the benchmark model here we suppose that firms decide to get informed or not before placing a bid and after knowing the reserve price in the auction. To keep things simple, we also assume that, although the result of this investment is private information, whether a firm gets informed or not is observable but not contractible before placing the bid.

The timing of the model is now as follows. In the first stage, the government sets the reserve price. Second, firms decide simultaneously whether to pay k to get informed or

not. Finally, firms decide simultaneously on β_i .

Solving the model by backward induction, we start by analyzing the bidding behavior of firms in the last stage as a function of their information investment decisions. As it is standard, we focus on the weakly dominant strategy equilibrium of the second-price auction. In our framework this means that firm i bids a value β_i such that this share of the value of the project allows it to break even given the available information. Of course, if this break-even β_i is higher than $\bar{\beta}$ firm i will not participate in the auction.

There are three cases to be analyzed. First, both firms get informed. Then, each firm learns the real θ and bids $\beta_i = \frac{c}{\theta}$. As a result, their profits are equal to $-k$. Second, none of the firms gets informed. In that case, firms will bid according to the expected value, $\beta_i = c/E(\theta)$ as long as $\bar{\beta} > c/E(\theta)$ and they will not participate otherwise. In either case, firms will make expected profits of 0. Finally, if one firm gets informed, say firm 1, firm 2 will not participate due to the *Winner's Curse*. As firm 1 knows the profitability of the project and bids a break-even $\beta_1 = c/\theta$, firm 2 faces two outcomes. Either it loses the auction and gets 0 or it wins and in that case, it loses money. Thus, it is a weakly dominant strategy not to participate and, consequently, the equilibrium price is given by the reserve price $\bar{\beta}$. In this case we can compute expected profits for firm 1 when it gets informed as

$$\pi^c(\bar{\beta}) = \int_{\frac{c}{\bar{\beta}}}^1 (\bar{\beta}\theta - c)g(\theta)d\theta - k.$$

With the previous payoffs, we can now move to the second stage of the game in which firms decide whether to get informed or not. In the next payoff matrix we represent the profits of both firms as a result of their investment decision.

		Firm 2	
		Investment	No Investment
Firm 1	Investment	$-k, -k$	$\pi^c(\bar{\beta}), 0$
	No Investment	$0, \pi^c(\bar{\beta})$	$0, 0$

Notice that if k is sufficiently large $\pi^c(\bar{\beta}) \leq 0$ and the only equilibrium corresponds to neither firm gets informed. Otherwise, if $\pi^c(\bar{\beta}) > 0$, the payoffs resemble those of a *Chicken Game*. As a result, this game has two asymmetric equilibria in pure strategies and one symmetric mixed-strategy equilibria. We will focus on the latter, in which firms randomize between getting informed (with probability α_i) and not doing so. This equilibrium can be easily characterized by equating the payoff of acquiring information with those that arise when the firm does not get informed, 0. In the symmetric equilibrium $\alpha_i = \alpha^*$ for $i = 1, 2$ and this probability is equal to

$$(1 - \alpha^*) \int_{\frac{c}{\bar{\beta}}}^1 (\bar{\beta}\theta - c)g(\theta)d\theta - k = 0. \quad (4)$$

In the first stage the principal sets the reserve price, $\bar{\beta}$, to maximize welfare. Notice that this reserve price only affects the probability that firms get informed. From equation (4), we can observe that increases in $\bar{\beta}$ raise α^* . This is an important difference with respect to our benchmark model. In that case, changes in β affected the rents that firms obtained when they decided not to get informed. Here these rents are always 0 by virtue of competition.

We can write down the maximization problem of the principal as

$$\begin{aligned} \max_{\bar{\beta}} \int_{\frac{c}{\bar{\beta}}}^1 (\theta - (c + d))g(\theta)d\theta + (1 - \alpha^*)^2 \int_0^{\frac{c}{\bar{\beta}}} (\theta - (c + d))g(\theta)d\theta - 2\alpha^*k, \\ \text{s.t. } (1 - \alpha^*) \int_{\frac{c}{\bar{\beta}}}^1 (\bar{\beta}\theta - c)g(\theta)d\theta - k = 0. \end{aligned}$$

The first term refers to the surplus of the projects that generate non-negative profits for a firm when it is informed. Those projects are always undertaken regardless of whether

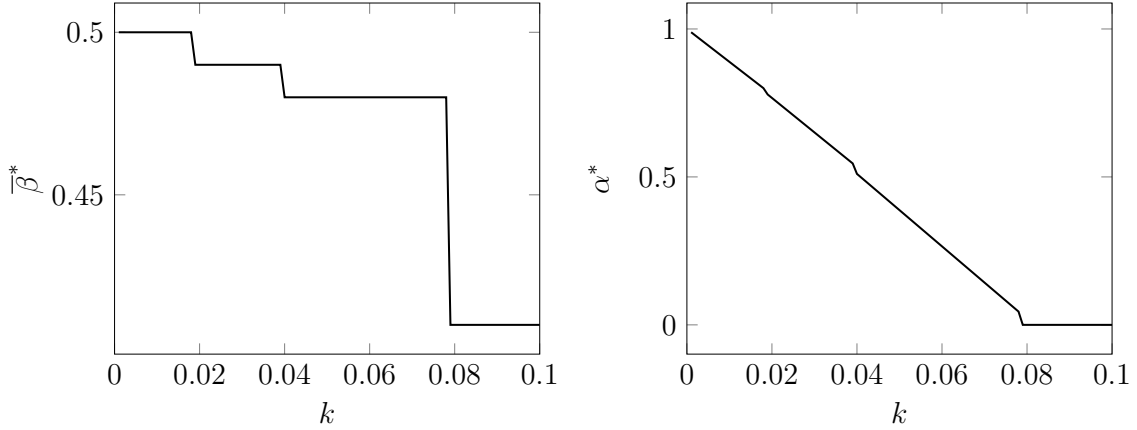


Figure 4: Optimal reservation price and probability that the each firm acquires information as a function of k . The remaining parameters are $c = d = 0.2$ and $\theta \sim U[0, 1]$.

any firm is informed or not. The second term refers to the projects that informed firms would not carry out given the reserve price. Those projects are undertaken when both firms are uninformed, which happens with probability $(1 - \alpha^*)^2$. The third term captures the total expected costs of firms getting informed.

This maximization has no explicit solution and for this reason we rely on the simulation in Figure 4 to convey the intuition for the results. When $k = 0$ firms always get informed and $\alpha^* = 1$. In that case, it is socially optimal to choose $\bar{\beta} = \frac{c}{c+d}$ as this guarantees that all efficient projects and only those are carried out.

In the benchmark model, when the costs of learning increase the principal must decrease $\bar{\beta}$ in order to provide incentives for firms to get informed. As noticed before, the reason for the negative relationship between k and $\bar{\beta}$ is different. Competition leads to excessive incentives for firms to get informed. This is the result of a standard externality: firms acquire information without taking into account that by doing so they reduce the value of the information that their competitor is also acquiring. As k becomes sufficiently large, it eventually becomes optimal to induce no learning. This is achieved through $\bar{\beta} \geq \frac{c}{E(\theta)}$. In that case, competition among firms will dissipate all the profits.

The benchmark model and the competition setup studied here constitute two extreme

cases in which increases in the cost of acquiring information lead to a decrease in the share of the project being assigned to the contractor, although for very different reasons. In a more general case, several heterogeneous firms might participate in the auction – for example, with different costs c_i –, leading to an intermediate level of competition. Our results for the extreme cases makes intuitive the prediction that both effects operating in the same direction would emerge in combination in this situation, although in a weaker version.

7 Concluding Remarks

This paper emphasizes the effects of considering the selection of projects in the characterization of the optimal concession contract. The renegotiation that has been a focus in the literature is often the reflection of an underlying poor project selection. The main insight of our analysis is that when this is the case it is optimal to transfer part of the demand risk to the contractor in order to foster the acquisition and better use of information. Institutional frameworks that limit the losses that the firm can absorb aggravate this incentive problem. Hence, an important lesson from our analysis is that in case of failure the firm and its debtors should only be compensated for the present value of the concession from that point on. The incentives to acquire information on the profitability of the project by the contractor will depend on the commitment power of the principal to such a policy.

Our model abstracts from several important aspects. In particular, our principal-agent model assumes that the project is given. Many times, however, the project is proposed by the firms that might carry it out. This introduces an additional reason why demand is endogenous to the firm's actions. Allowing for the project to be strategically offered requires the optimal mechanism to have a screening component. When this component is not considered additional distortions might arise. An illustration of that is

the *Castor Project*, the biggest investment in the natural gas system in Spain, consisting of a submarine gas storage facility by the east coast. This project, aimed to store up to 1.3 billion cubic meters of gas, was sponsored by a firm specialized in this kind of infrastructure. Amid the concerns about the risk of generating earthquakes due to the location of the storage facility close to a tectonic fault, the sponsor/concessionary was protected from this contingency by the contract in spite of its information advantage over the administration. The earthquakes materialized soon after the project started and the Spanish government was forced to suspend the works and compensate the firm.

Finally, although we introduce a simple model of competition and a procurement auction our approach makes several restrictive assumptions such as a second price mechanism or the fact that the acquisition of information is known to all firms. A more general approach to competition would require the optimal mechanism to not only generate incentives for firms to acquire information but also to aggregate it in a way that minimizes the winner's course.

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A Proofs

Proof of Lemma 1: From the text we know that the first best requires to acquire information if $k \leq K^s$ and in that case to carry out projects if $\theta \geq c + d$. As we have seen in the text the firm carries out these projects if $\beta = \frac{c}{c+d}$. Notice that

$$K\left(\frac{c}{c+d}\right) = \int_0^{c+d} \left[\frac{c\theta}{c+d} - c\right] g(\theta) d\theta = \frac{c}{c+d} \int_0^{c+d} [\theta - (c+d)] g(\theta) d\theta = \frac{c}{c+d} K^s.$$

Hence, the first best is achieved if $k \leq K\left(\frac{c}{c+d}\right)$ and $\beta = \frac{c}{c+d}$. When $k \in \left(K\left(\frac{c}{c+d}\right), K^s\right)$ an inefficiency arises since providing the incentives to do the right projects does not induce the firm to acquire information.

Finally, if $K > K^s$ it is not efficient to acquire information in the first place but the project should be carried out. This can be achieved with $\beta \geq \frac{c}{E(\theta)}$. \square

Proof of Proposition 1: The optimum when $k < K\left(\frac{c}{c+d}\right)$ or $k > K^s$ is immediate from the proof of Lemma 1. In the remaining region, when $k \in \left(K\left(\frac{c}{c+d}\right), K^s\right)$ the total surplus in the first best corresponds to

$$W^s(k) = \int_{c+d}^1 [\theta - (c+d)] g(\theta) d\theta - k.$$

As explained in the text, when we set $\beta = K^{-1}(k)$ the firm has incentives to acquire information. The welfare achieved in this case is

$$W^s(k) - E_I(k).$$

When no information is acquired all projects are carried out if $\beta = \frac{c}{E(\theta)}$ and welfare corresponds to

$$W^s(k) + E_{II} + k.$$

As a result, the firm should acquire information if and only if

$$E_I(k) \leq E_{II} - k$$

As $E_I(k)$ is increasing in k there will be a unique cutoff point \tilde{K} such that information is acquired if and only if $k \leq \tilde{K}$. \square

Proof of Proposition 2: Immediate from the proof of Proposition 1. \square

Proof of Proposition 3: Consider all combinations of β and T that lead to projects above a certain value $\underline{\theta}$ being carried out. That is, these contracts are such that

$$T(\beta, \underline{\theta}) = c - \beta \underline{\theta}.$$

Using standard calculations, the contractor has incentives to acquire information if

$$k \leq K(\beta, \underline{\theta}) = - \int_0^{\underline{\theta}} \beta [\theta - c + T(\beta, \underline{\theta})] g(\theta) d\theta = \int_0^{\underline{\theta}} \beta (\underline{\theta} - \theta) g(\theta) d\theta.$$

It is immediate that

$$\frac{\partial K}{\partial \beta} = \int_0^{\underline{\theta}} (\underline{\theta} - \theta) g(\theta) d\theta \geq 0.$$

Thus, the higher is β (and the lower is T) the more incentives to acquire information. \square

Proof of Proposition 4: In order to show that the contract is optimal we need to show that four conditions are satisfied:

$$\rho_P(k)(1 - G(c + d)) + \rho_N(k)G(c + d) - k \geq 0, \quad (\text{PC})$$

$$\rho_P(k) \geq \rho_N(k) \geq 0, \quad (\text{IC0})$$

$$\rho_P(k)(1 - G(c + d)) + \rho_N(k)G(c + d) - k \geq \rho_N(k), \quad (\text{IC1})$$

$$\rho_P(k)(1 - G(c + d)) + \rho_N(k)G(c + d) - k \geq \rho_P(k)(1 - G(c + d)) - cG(c + d). \quad (\text{IC2})$$

Equation (PC) is the participation constraint. Condition (IC0) guarantees that if the firm acquires information it carries out all projects if and only if $\theta \geq c + d$. Conditions (IC1) and (IC2) guarantee that the firm does not prefer to not acquire information and not carrying out all projects or carrying out all of them, respectively.

Condition (IC2) means that $\rho_N(k) \geq \frac{k}{G(c+d)} - c$. Notice also that the first part of condition (IC0) is satisfied if (IC1) holds. Thus, when $k \leq cG(c+d)$ we can implement the first best with $\rho_N(k) = 0$ since this also satisfies (PC) and (IC1) when $\rho_P(k) = \frac{k}{1-G(c+d)}$ and the firm receives no rents.

When $k \geq cG(c+d)$, $\rho_N(k) = \frac{k}{G(c+d)} - c \geq 0$ and from (IC1) we have that (PC) is not binding. In order to minimize rents we need (IC1) to hold with equality which implies

$$\rho_P(k) = \rho_N(k) + \frac{k}{1 - G(c + d)},$$

proving the result. \square

Proof of Proposition 5: From Proposition 4 we know that if $k \leq cG(c+d)$ the first best can be implemented with $\rho_N(k) = 0$. This means, following the proof of the previous

proposition, that the conditions that need to be guaranteed in the optimal contract with information acquisition are

$$\rho_P(k)(1 - G(\underline{\theta})) - k \geq 0, \quad (\text{PC})$$

$$\rho_P(k) \geq 0, \quad (\text{IC0})$$

$$\rho_P(k)(1 - G(\underline{\theta})) - k \geq \rho_P(k)(1 - G(\underline{\theta})) - cG(\underline{\theta}). \quad (\text{IC2})$$

Hence, for condition (IC2) to hold and minimize the distortions we need that $k = cG(\underline{\theta}^{ft})$. Furthermore, from (PC) rents are minimized if $\rho_P(k) = \frac{k}{1 - G(\underline{\theta}^{ft})}$.

The rest of the contract can be characterized as in the benchmark model. □