Government's Credit-Rating Concerns and the Evaluation of Public Projects*

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Abstract

Public projects typically generate both monetary revenue and social benefits that cannot be monetized. Anticipated revenues from government-owned projects increase the liklihood that the government will be able to repay its debt and thus improve its credit rating and lower the financing costs of the debt. This should give monetary revenue an added value relative to social benefits. However, informational problems – dynamic inconsistency and adverse selection – push the government to an excessive emphasis on social benefits, ignoring the external effect of monetary revenue on debtholders. Since the credit market anticipates this, the government's credit rating is adversely affected and it is thus unable to extract the full potential of the projects. Finally, we show that while privatization can sometimes alleviate these problems, there are cases in which the government would be better off if its hands were tied and it were not allowed to privatize.

Keywords: public projects, credit rating, social discount rate, privatization

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1 Introduction

Governments on all levels – national, state and local – turn to credit markets to finance a significant proportion of their activities. A government's cost of borrowing is determined by its credit rating, which reflects the credit market's confidence in its ability to repay its debt. This can vary considerably between governments. For example, the yield spread between Italian 10-year euro-denominated bonds (rated A+ by S&P) and the equivalent German bonds (rated AAA) has averaged about one percentage point over the last two years, and the yield spread between 18-year general-obligation bonds issued by the State of California (rated Baa1 by Moody's) and those issued by the State of Georgia (rated Aaa) is currently[1] 1.16%. The effect on a government's cost of borrowing is substantial. For example, in the case of Italy, with a debt-to-GDP ratio of over 100%, its lower credit rating is responsible for an additional annual borrowing cost of more than one percent of GDP.

The impact on the government's credit rating can be a major consideration in its decisions regarding investment in public projects. The additional debt taken on to finance a project negatively affects the credit rating. On the other hand, the addition of the project to the asset side of the government's balance sheet has a positive impact. Since these changes in the credit rating affect the cost of financing the government's debt, they should be included in the project's cost-benefit analysis. These considerations are important not only for large projects with a major impact on the government's credit rating, but also for projects that are small relative to the size of the entire government debt. While their impact on the credit rating is smaller, the associated change in the cost of financing the debt remains significant relative to their size.

While the effect of a project's financing cost on the credit rating is straightforward, understanding the effect of its benefits is more subtle and requires a closer look at the nature of public projects. Public projects typically generate both monetary revenue and social benefits that cannot be monetized. For example, a new highway will yield both toll income and social benefits in the form of driver surplus and reduced congestion on other roads. An oil field generates sales revenue, but also carries environmental risks (in this case, a negative social

[1] Sources: Yahoo! Finance, municipalbonds.com (September 2010).

benefit). In Section 2 we develop a model that explains how the level of government debt and the composition of its assets affect the probability of default and the interest it pays on its debt. Monetary revenue can be used to prevent default in cases of financial distress – in contrast to social benefits that cannot be converted back into money. We derive a valuation formula for public projects that takes into account their mix of monetary and social benefits and serves as the main tool of the subsequent analysis. According to the formula, monetary revenue has added value relative to social benefits, which can be decomposed into two components: the *option value* of avoiding the penalties associated with default, and the *credit market value* – the reduction in the cost of financing the government's debt due to the improved credit rating.

Crucially, this credit market value of the project depends on the credit market's expectations. Therefore, the information available to the market at the time the expectations are formed plays a central role. While credit-rating considerations imply that the government should place additional emphasis on a project's monetary benefits relative to its social benefits, we argue that there are two important informational barriers that tend to prevent such "credit market discipline" from materializing. When the government has private information regarding a prospective project's characteristics, its choice of projects is biased toward those with high social benefits and low monetary revenue. And in cases where the mix of monetary and social benefits is decided on only after the credit market has priced the government's debt, the government operates projects with an excessive emphasis on social benefits. Due to these informational problems, the government is unable to harness the full revenue-generating potential of its assets to improve its credit rating.

Section 3 looks at the first problem, i.e. private information regarding the project's characteristics. Consider, for example, a government that develops a new oil field. Future oil revenue raises the probability that it will be able to repay its debt. An accurate prediction of the field's future output, however, is only available to the government, who has conducted the geological survey. Since the credit market does not possess this information, the credit rating will only reflect the expectations, based on publicly available information. Moreover, whether the new field is economically viable cannot be inferred from the fact that the government found that developing the field is beneficial, since the credit market does not know the magnitude of non-monetary elements that influenced the decision, such as job creation, pressure from lobby groups, environmental risks, etc. Such private information gives rise to *adverse selection* in the government's decision whether or not to undertake a project. Relative to the complete information benchmark, the government's selection criterion is tilted in favor of social benefits. Since the uninformed credit market treats every project as one with an average income, the government is forced to forgo desirable income-intensive projects, whose positive effects on its credit worthiness are not fully appreciated. It also undertakes projects with ample social benefits but negative true net value, taking advantage of the market's inability to observe their below-average monetary income. However, since the credit market anticipates these choices, the revenue from projects undertaken in equilibrium is evaluated correctly on average and the overall effect on the government is, ex ante, negative.

In Section 4 we consider the second issue, i.e. the implementation decision in which the government chooses a project's mix of monetary revenue and social benefits. In the case of a toll road, for example, the main tradeoff between future operating profits and social benefits is determined by the toll level. A higher toll increases revenue at the expense of reduced driver surplus and increased congestion on alternative roads. During the construction stage, the government would like to assure the credit market of an eventual stream of significant toll revenue, but once the road is operational, the government, now free of credit rating considerations, has no reason to neglect social benefits and chooses a low toll. The credit market foresees this at the construction stage and downgrades the credit rating accordingly. The government thus faces a costly commitment problem, which takes the form of a *dynamically inconsistent* toll policy.

As a natural application of our analysis we consider, in Section 5, the issue of privatization. Privatization is commonly viewed as a tool for governments to capitalize the future monetary income of public enterprises. In the case of a new project, the private operator shares the setup cost in exchange for future revenue. For an existing enterprise, privatization generates immediate revenue that can be used for other purposes. We show, however, that in the absence of the informational limitations described in Sections 3 and 4 (and abstracting from differences in efficiency), privatization is exactly equivalent to the alternative of maintaining ownership and raising the same amount of capital by issuing additional government debt. That is, privatization simply lowers both sides of the government's future balance sheet (debt and revenue) by the same amount.

Privatization becomes non-neutral when these informational problems are present. It then emerges as a way to overcome the adverse consequences of the government's bias towards social benefits. The dynamic inconsistency problem is solved since privatization delegates away the government's discretion over the implementation decision. However, unless the actions of the profit-maximizing private operator can be sufficiently restrained by a contract, it will utterly disregard the social benefits and shift the implementation to the other extreme. Thus, the government's decision whether to privatize an asset involves a comparison between two regimes – private versus government control – under which the respective modes of implementation are shifted away from the desired outcome in opposite directions. The results of the comparison are, in general, ambiguous.

Privatization can also change the nature of the adverse selection problem. A private entity that bids for the project has the incentive to invest in verifying its revenue prospects. In this way, it differs from the holders of (non-dedicated) government debt who do not have sufficient incentive to perform a costly investigation of a specific project. While the fact that potential private operators acquire full information may suggest that the adverse selection problem should disappear, we show that such a result requires that operation by the government not be superior to that by private operators for any project. In the general case, projects heavily endowed with social benefits remain in government hands since the private operator's excessive focus on monetary revenue would be detrimental in this case. Revenue-rich projects are provided by the private sector, which is better at extracting revenue from projects. The inefficiency in project selection remains: the government has an incentive to privatize projects with above-average monetary revenue and thereby gain the increment over the uninformed credit market's perceived value. This, however, negatively affects the credit rating contribution of those projects that the government decides to undertake on its own. The credit market interprets the fact that the option to privatize was not exercised as a negative signal and infers that the project has a below-average monetary income. Thus, while the option to privatize projects must be beneficial to the government ex post, an ex ante evaluation of this option is complex. We show that there may be types of projects that the government would be better off by committing, ex ante, to never privatize.

The paper is related to the "social discount rate" literature (see, for example: Marglin (1963), Harberger (1968), Sjaastad and Wisecarver (1977)), which is concerned with the appropriate discount rate to be used by the government in its cost-benefit analysis of prospective public projects. Most of this literature focuses on an economy that is isolated from external credit markets, and therefore government borrowing crowds out private investment. Our framework differs from the main stem of this literature in that the government can borrow in global credit markets and is small relative to them (a notable exception is Edwards (1986); we explore the relationship with that paper in Section 2.4). The contribution of our paper to this literature is the focus on the composition of benefits from public projects and the conclusion that the government should apply different discount rates to monetary and social benefits. Moreover, we highlight the relevance of the credit markets' expectations and the effect of informational asymmetries between the government and the credit market.

2 Credit rating and the valuation of public projects

In this section, we develop a minimalistic model that captures the effect of a government's balance sheet on its credit rating. The model highlights the differential effect of monetary revenue and social benefits from a government's assets on its probability of default. This leads to a valuation formula for public projects that is the basis for our subsequent analysis.

The basic premise of the model is that the government discounts the future at a higher rate than the credit markets and therefore wishes to borrow. The first and main interpretation of the model is of an open economy that is small relative to the global credit market. The government mirrors a representative agent with a higher intertemporal substitution rate than the rest of the "world". Under this interpretation, the model can be applied to governments of subnational bodies such as municipalities and states, as well as national governments – as long as the country is not large enough to significantly affect global interest rates. A second interpretation of the model, which can also applied to large countries, is of a closed economy in which the government discounts the future at a higher rate than its citizens and displays a preference for supplying government goods over private consumption.[2]

[2] The heavier discounting by the government can be the result of, for example, the uncertainty as to whether it will remain in power in the second period (as in Bulow and Rogoff (1989a)). A preference for supplying public goods can be due to the positive effect on the probability of being re-elected, to direct rents extracted from running a large government (empire-building) and so on.

2.1 The basic model

There are two periods: In period 1, the government issues debt with face value d which it promises to pay back to debtholders in period 2. The period 1 revenue from issuing the debt (which depends on the credit market's assessment of the risk of default) is R. This revenue can be used for consumption or for investment in public projects that will yield benefits in period 2. Period 1 utility, apart from the revenue from issuing debt R and investment expenses I, is normalized to 0:

$$u_1 = R - I.$$

The period 2 return on the public projects consists of a monetary component X and social benefits Y. Period 2 utility is the sum of X and Y, plus a random income from other sources $s \geq 0$ (with cdf F and a continuous pdf f), less the amount $e \leq d$ of debt that the government decides to repay.[3] In the case of default (whether partial or total) on the debt, there is also a utility loss of $L > 1$ for every dollar of default $d - e$.[4] Thus,

$$u_2 = X + Y + s - e - L \cdot (d - e).$$

Once it observes s, the government decides on e, subject to a monetary feasibility constraint:

$$\max_{e \in [0,d]} u_2 \quad s.t. \quad X + s - e \geq 0. \tag{1}$$

Thus, while X and Y are equivalent in terms of consumption value, only X can also be used for debt repayment. For example, the government can use the revenue from an oil field (X) to supply goods or to repay debt. In contrast, a nature preserve generates utility to its citizens (Y) that cannot be monetized to repay debt in case of financial distress.

[3] For simplicity, we ignore the possibility of taxation and assume that s is exogenous. The effects of allowing taxation are discussed in Concluding Remark 6.2.

[4] Under the open-economy interpretation, the loss L can represent the costs of direct trade sanctions or of costly seizure of assets (see Bulow and Rogoff (1989a) for an in-depth discussion). L can also include the costs of damage to reputation, which diminishes the ability to borrow in the future. In the case of a closed economy, L can represent the costs to the government due to debtholders' unrest, which may affect their future voting or even result in physical damage to government property.

The interest rate on riskless debt is normalized to 0. The government discounts the future at a higher rate than does the credit market. Its intertemporal utility function is therefore:

$$U = u_1 + \delta u_2.$$

where u_1 and u_2 are the per-period utilities and $\delta \in (0,1)$ is the discount factor that applies to the time between the two periods. This time spans from the project's inception, through the point at which it becomes operational, and until a "representative" point in the operational phase (which is reduced in the model to a single point in time – period 2). Since this time span tends to be of a magnitude of several years, δ is considerably less than one.

2.2 The debt repayment decision

Since $L > 1$, the solution to the period 2 problem (1) is simply:

$$e^* (d, X, s) = \min \{d, X + s\}. \tag{2}$$

In other words, the government repays as much of its debt as it can and defaults (partially) only when it doesn't have enough funds to repay it all. This decision rule implies that the government defaults whenever the realized income s is less than $d - X$, which occurs with probability $F(d - X)$.[5] For convenience, we also denote $L^* (d, X, s) = L \cdot (d - e^* (d, X, s))$.

[5] There is a vast literature on sovereign debt, the risk of default and the mechanisms that enforce debt repayment by sovereign borrowers. One strand of the literature, beginning with the seminal paper by Eaton and Gersovitz (1981), considers the reputational effects of default on the creditor's future ability to borrow as a deterrent to repudiating debt. The validity of this explanation has been questioned by Bulow and Rogoff (1989b). Another strand of the literature (see, for example, Bulow and Rogoff (1989a)) considers direct sanctions that lenders can impose on creditor countries within their own borders (for example, trade sanctions or seizure of assets) or through international bodies.

A main premise in the entire literature is that it is the country's willingness, rather than its ability, to repay its debt that determines the decision to default. The aim here is to develop a simple model of credit rating, rather than a model that focuses solely on the default decision. Therefore, a simplified framework was chosen in which default on debt is solely the outcome of monetary constraints. While the model is a simplistic description of the government's default decision, it yields a very tractable formulation. The main results developed in the rest of the paper regarding the effects of credit rating on the valuation of public projects should also follow from a more elaborate model of default and credit rating.

2.3 Determination of the debt level

We now analyze the government's decision on the optimal debt level d, given its investment I and the anticipated returns on the investment X and Y. We assume that credit markets are risk-neutral. Since the interest rate on secure debt is normalized to 0, the period 1 revenue R from issuing debt with face value d is the expected payout:

$$R(d,X) = E_s\left[e^*(d,X,s)\right].$$

The government's debt-determination problem in period 1 is:

$$U(X,Y,I) = \max_d R(d,X) - I + \delta\left(X + Y + E_s\left[s - e^*(d,X,s) - L^*(d,X,s)\right]\right). \quad (3)$$

Substituting for $R(d,X)$ and taking the derivative with respect to d, we obtain the first-order condition:[6]

$$(1-\delta)\frac{\partial E_s[e^*]}{\partial d} = \delta\frac{\partial E_s[L^*]}{\partial d}.$$

Note that the marginal dollar of debt augments $e^*(X,s,d)$ by 1 if eventually there is no default – an event with probability $1-F(d-X)$ – and augments $L^*(X,s,d)$ by L in the case of default – an event with probability $F(d-X)$. Thus:

$$\frac{\partial E_s[e^*(X,s,d)]}{\partial d} = 1 - F(d-X)$$

and

$$\frac{\partial E_s[L^*(X,s,d)]}{\partial d} = L\cdot F(d-X).$$

Substituting these into the first-order condition yields:

$$(1-\delta)(1-F(d-X)) = \delta L\cdot F(d-X). \quad (4)$$

The first-order condition is interpreted as follows: as the government issues more debt, its credit rating deteriorates and the revenue from issuing an additional bond, $\partial R/\partial d = \partial E(e^*)/\partial d = 1-F$, decreases. At the margin, the probability of default F is so high that the gains from trade which result from increasing the debt by one more dollar (LHS) equal the discounted marginal loss in period 2 (RHS).

[6] The derivations below show that the second-order condition is clearly satisfied.

2.4 Evaluating the social and monetary benefits of projects

We now analyze the government's evaluation of the marginal project. Suppose that the government has already decided on a stock of projects with aggregate period 2 returns of X and Y (and has optimized the level of debt accordingly). It now contemplates undertaking one more project, which will add x units to X and y units to Y, where x and y are small relative to the stock of government debt d.[7] In view of the credit-rating considerations analyzed in the previous section, what is the period 1 value of the period 2 outcome (x, y)? That is, what should the "social discount rate" be?

Theorem 1 below presents a simple valuation formula that forms the foundation of our analysis in the following sections. Part 1 deals with the case where x is commonly known. It shows that the government should employ two distinct social discount rates: One, which equals the government discount rate δ, to social benefits, and another, which equals the credit market risk-free discount rate 1, to monetary benefits.[8] Part 2 deals with the case where the credit market's belief x^e to differ from the true value x.[9] In this case, the valuation formula includes a third term: the difference $x^e - x$ (which may be positive or negative) weighted by the probability of default, F.

[7] For simplicity of exposition, it is assumed here that the project outcomes, x and y, are deterministic. All our results would still follow if instead x and y were stochastic, as long as x is stochastically independent of s. In this case, x and y would be interpreted as the expectations of the respective variables.

[8] Note that even though the government has access to a perfectly elastic supply of credit, its discounting of social benefits (δ) is lower than the credit market's discount rate (1). This difference is possible because default is costly and the cost is increasing in the level of government debt that is not backed by future monetary revenues. Edwards (1986) also obtains a social discount rate for an open economy which is above the international credit market rate. The mechanism by which his model yields an increasing marginal cost of borrowing, however, is different from ours and is based on lenders and borrowers having a different perception of the default probability.

[9] More precisely, x^e denotes the belief itself in the case that it is single-valued and the expectations of the belief in the case that it puts weight on multiple values.

Theorem 1 *Consider a small project that yields monetary benefits x and social benefits y.*

1. *In the case that x is commonly known, the first-order approximation of the project's net present value to the government is:*

$$V(x, y) = x + \delta y. \tag{5}$$

2. *In the case that x is not commonly known, denote the expectations of the credit market's belief on x by x^e and assume that the belief is independent of s, the period 2 income. Then, the first-order approximation of the project's value is:*

$$V(x, y; x^e) = (1 - F) \cdot x + F \cdot x^e + \delta y, \tag{6}$$

or equivalently

$$V(x, y; x^e) = x + \delta y + F \cdot (x^e - x) \tag{7}$$

where F is the probability of default given the stocks of d and X.

Proof: Appendix.

While social benefits y only has *consumption value* (which equals δ per unit when discounted to period 1 terms), monetary benefits x have an additional value, which comes from two sources: its *option value* to repay debt and reduce direct default costs in cases of financial distress, and its *credit market value* – the increase in the price of the debt issued by the government due to the bondholders' understanding that the additional x will help to repay debt in case of default. Equation 5 states that the sum of the three components is 1 per unit. Equation 6, deals with the case where the credit market's belief x^e may differ from the true value x. It decomposes the total value of x to an *internal value* – the sum of the consumption and option value – which equals $1 - F$ and multiplies the true x, and the credit market value, which applies to the belief x^e, and equals F.[10]

The intuition behind the calculation of the internal and credit market values of x is as follows: The internal value of each unit of x is a weighted average of 1 (the value in the case

[10] There is also a third element that captures the benefit to the government from re-optimizing the level of debt d in response to the change in X. However, since the project is assumed to be small, this element is negligible by the envelope theorem.

that there is no default and the added x is used for consumption) and L (the value in the case of default in which the government uses the additional x to reduce the amount of the default). The respective probabilities of the two events are $1 - F$ and F (we can ignore the effect of x, which is relatively small, on the probability of default $F(d - X)$ since it is of second-order importance). Discounting the weighed average to reflect period 1 utility, the internal value of x thus becomes $\delta[(1 - F) \cdot 1 + F \cdot L]$ per unit. By the first-order condition for the level of debt (4), this is simply $1 - F$.

As for the credit market value, recall that it is equal to the increase in the revenue R to the government from issuing the (same) debt d, due to undertaking the project. The government's creditors expect that an additional x^e will be added to the debt repayment whenever the government defaults – an event with probability F. Thus, their expectations of the payout on the entire debt d, and hence also the revenue R, are augmented by $x^e \cdot F$. Hence, the credit market value of each unit of x^e is F.

Note that the internal value of x, i.e. $1 - F$, is already larger than δ, the value of y. Thus, even when the credit market does not observe x, the government values x more than it values y. When the credit market does observe x, the government adds the credit market value, F. (We sometimes refer to this additional weight as the effect of *credit market discipline* on the government's valuation of public projects.) The sum of these two values is simply 1.[11]

We now turn to exploring two key situations in which the credit market does not observe x before it prices the debt in period 1. Section 3 examines the case in which the government has private information on x. Section 4 deals with the case in which the government chooses x in period 2.

[11] That the complete-information value of a unit of x equals 1 can also be deduced directly: The government can increase its debt d by the same amount x, in which case, by (2), the payout e^* will also increase by x, independently of the income shock s. This leaves period 2 consumption unchanged and increases period 1 revenue R by x. Thus, because we assume that the government will always use any funds it has in period 2 to repay debt and because the interest rate on secure debt is zero, every additional dollar that the government has in period 2 – and which the market is aware of – is worth exactly one dollar in period 1 as well.

3 Project choice and adverse selection

In this section, we study the implications of informational asymmetry, whereby aspects of the project are privately known to the government but not to the credit market. For example, consider a discovery by Mexico of a new offshore oil field in its territorial waters in the gulf. The expected oil output (x) is known only to the Mexican government which is in possession of the geological survey. The development of the field also carries significant environmental risks, as exemplified in the recent oil spill from a BP well. The importance of these risks is embodied in the geological data, but also depends on the Mexican government's preferences (such as the importance attributed to environmental concerns and the sensitivity to pressure from the US which can also be affected in case of a spill). These environmental risks, as well as other externalities, such as job creation, determine y, which is thus also the government's private information. Assume that Mexico decides to invest in developing the oil field. Since x is unknown to the credit market, its re-evaluation of the government's credit rating can respond only to its expectation, based on publicly available information. Moreover, even the fact that the government decided that developing the field is beneficial is not enough to convince the market that x is large. Since the credit market does not know the magnitude of y, it will not be able to infer whether the project is expected to yield substantial monetary benefits (which must be the case if the environmental risks are very high) or meager revenue (which could be the case if the project creates many jobs).

We will show that the government's informational advantage over the credit market can lead to an adverse selection problem. Since the credit market responds similarly to all projects of the same type, the government's valuation and selection of projects is distorted. It undervalues projects rich in monetary income and overvalues projects poor in monetary income but rich in social benefits. Thus, the set of projects it undertakes is not optimal in light of the credit-market considerations.

Information structure and timeline

The government has the option to undertake a single project. The project has a setup cost of 1 in period 1. The period 2 pair of monetary and social benefits, (x, y), is drawn at the onset of period 1 from a finite set H with a prior distribution G. We refer to pairs (x, y) in H as "potential projects". (To be clear, one should interpret H not as a set of many projects, but rather as the set of possible realizations of the attributes of one specific project – for example, all the possible pairs of oil revenue x and environmental risks y for a specific oil field.)

The government *privately* learns which potential project was realized and decides whether or not to undertake it. The credit market only knows the distribution G but not which potential project was drawn from it.[12] Nonetheless, it observes the government's decision and takes it into consideration when it prices the government's debt. That is, it prices the government debt on the assumption that the project is an average one, conditional on the fact that the government decided to undertake it.[13] In period 2, the project bears fruit (x, y). Then, the period 2 income s is realized and the government's debt-repayment decision is made. We assume that the project is small relative to the government's stock of debt (for any (x, y) in H). Thus, the first-order approximations of a project's valuation (Theorem 1) can be applied.

3.1 The complete information benchmark

As a benchmark, we consider the case in which the realized project (x, y) is commonly known. The government undertakes the project as long as its value exceeds its cost of 1 or, by Theorem 1, whenever:

$$V(x, y) = x + \delta y \geq 1.$$

The set of projects that the government will undertake under complete information is given by:

$$GOV_{CI} = \{(x, y) : V(x, y) \geq 1\}.$$

[12] While small holders of the government's debt clearly do not have sufficient incentive to undertake an expensive investigation of the project's parameters, neither are there adequate incentives for credit rating agencies (who rate the entire debt) to go beyond a crude estimate of the government's assets and to perform an in-depth analysis of each project. For instance, a credit rating agency will estimate the future output of a new oil field according to historical precedents, rather than conduct its own geological survey.

[13] We ignore possible signaling of the project's characteristics through the re-adjustment of the level of debt. This could be made formal by introducing some noise into the debt decision (either by assuming a small amount of private information on the discount factor δ or in the market's observation of the debt d), but this is beyond the scope of the paper.

Figure 1 illustrates the set GOV_{CI}. The line dividing between this region and that of rejected projects (NON) has the slope $-1/\delta$.

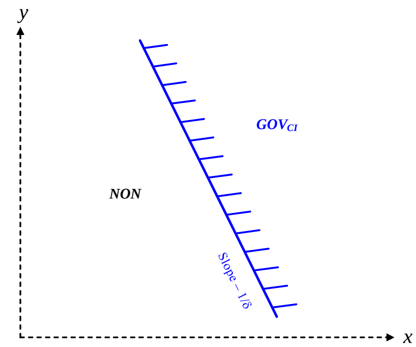

Figure 1: Projects undertaken by the government - the complete information benchmark

The government's ex ante utility is given by:

$$U_{CI} = \sum_{(x,y)\in GOV_{CI}} \left(V\left(x,y\right)-1\right) G\left(\left(x,y\right)\right).$$

3.2 Asymmetric information

Under asymmetric information, the credit market only knows the distribution of projects G, while the government knows the realization. Thus, when the government undertakes a project, the (risk-neutral) credit market – unaware of the true monetary outcome of the project – takes it to be that of an average project. More precisely, the price of government debt reflects the expected monetary revenue from the project over all projects that the government undertakes in equilibrium, denoted by x^e, rather than the true x of the specific project.

Denote the set of possible projects that the government undertakes in equilibrium by:

$$\begin{aligned} GOV &= \left\{(x,y) : V\left(x,y;x^e\right) \geq 1\right\} \\ \text{where } x^e &= E\left[x|(x,y)\in GOV\right] \end{aligned}$$

By Theorem 1, the government undertakes a project if:

$$x + \delta y + F\cdot\left(x^e - x\right) \geq 1.$$

This decision rule can be readily compared to its complete information counterpart (where $x^e = x$):

$$x + \delta y \geq 1.$$

Thus, relative to the benchmark, the government adds the amount $F \cdot (x^e - x)$ to the value of the project. This term is positive for a project whose monetary benefit x is below the average x^e and negative for projects with $x > x^e$. Consequently, the government undertakes more projects with low x and high y and fewer projects with high x and low y. Figure 2 illustrates the set of projects that the government would undertake. The boundary line is flatter than that for the complete information benchmark (a slope of $(1-F)/\delta$ vs. a slope of $1/\delta$). Thus, there are projects with negative net value under complete information that the government undertakes under asymmetric information (the region denoted by $*$) and projects with positive net value under complete information are rejected (the region denoted by $**$).

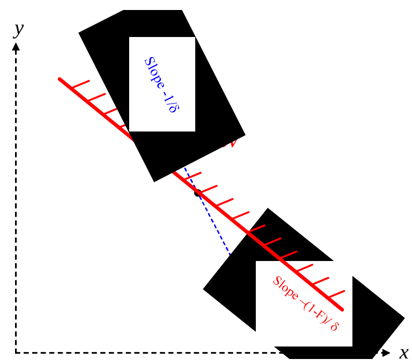

Figure 2: Projects undertaken by government - asymmetric information

While the government's decision rule is optimal ex post, given its knowledge of x, its ex ante utility under asymmetric information is below that under complete information. The credit market – whose expectations are rational – anticipates the government's choices and evaluates x^e correctly, as the expectations of x over the actual set GOV of projects that the government undertakes. Thus the government "pays" for fooling the credit market. Its ex ante utility is the sum of the complete information value of the projects this set, which differs from the set of all the projects with positive complete information value (GOV_{CI}).

Denoting the government's ex ante utility under asymmetric information by

$$U_{AI} = \sum_{(x,y)\in GOV} \left(V\left(x,y;x^e\right) - 1\right) G\left((x,y)\right),$$

we thus obtain:

Theorem 2 *If $GOV \neq GOV_{CI}$, then $U_{AI} < U_{CI}$.*

Proof. Appendix.

In order to illustrate the results of this section, we consider two simple examples. In both, a project is drawn from a distribution with two mass points with equal probabilities. In the first, both projects have positive net value (and thus would be undertaken under complete information), but under asymmetric information, the one with higher monetary revenue is inefficiently rejected (i.e., located in region $**$ in Figure 2). In the second example, only one project has positive net value, but under asymmetric information, the second project, which has negative value, is also undertaken – inefficiently (region $*$).

Example *The government's discount factor is* $\delta = 0.5$ *and the utility loss on each dollar of defaulted debt is* $L = 4$*, so that, by (4), the probability of default is* $F = 0.2$*. A project with setup cost* 1 *is drawn from a distribution with two points,* a *and* b*, each with equal prior probability.*

Case 1 $a = (0.7, 0.65)$*,* $b = (0.4, 1.25)$*. Under complete information,* $V(0.7, 0.65) = V(0.4, 1.25) = 1.025 > 1$ *and therefore both projects would be undertaken. Under asymmetric information, only* b *is undertaken in the unique equilibrium. To see why, observe that* b *must be undertaken in any equilibrium since* $V(0.4, 1.25; x^e) \geq V(0.4, 1.25)$ *for any* $0.7 \geq x^e \geq 0.4$*.*[14] *Next, observe that* a *will not be taken in any equilibrium. Since* b *is undertaken with certainty,* x^e *is at most* $0.5 \cdot 0.4 + 0.5 \cdot 0.7 = 0.55$*. But then* $V(0.7, 0.65; x^e) \leq V(0.7, 0.65; 0.55) = 1.025 + 0.2 \cdot (0.55 - 0.7) = 0.995 < 1$*.*

Case 2 $a = (0.7, 0.65)$*,* $b = (0.6, 0.79)$*. Under complete information,* $V(0.7, 0.65) = 1.025 > 1$ *and* $V(0.6, 0.79) = 0.995 < 1$ *and therefore only* a *will be undertaken. Under asymmetric information, the unique equilibrium is for both* a *and* b *to be undertaken. To see why, observe that* a *must be undertaken in any equilibrium since* $V(0.7, 0.65; x^e) \geq 1$ *for any* $0.7 \geq x^e \geq 0.6$*. Next, observe that* b *will also be undertaken: Since* a *is undertaken with certainty,* x^e *is at least* $0.5 \cdot 0.7 + 0.5 \cdot 0.6 = 0.65$*. But then* $V(0.6, 0.79; x^e) \geq V(0.6, 0.79; 0.65) = 0.995 + 0.2 \cdot (0.65 - 0.6) = 1.005 > 1$*.*

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[14] Formally, we assume that even out of equilibrium the belief x^e is some convex combination of the two possible values of x.

4 Project implementation and the government's commitment problem

We now turn to analyzing a second type of informational asymmetry between the government and the credit market whereby the government decides on a project's mix of monetary and social benefits after the credit market has priced its debt. Recall the toll road example, in which increasing the toll yields higher income at the expense of reduced driver surplus and higher congestion on alternative roads. Crucially, the decision on the mix of monetary and social benefits is often taken long after the investment in the project.

To model the tradeoff, we enrich the definition of a project in order to endogenize the choice of the monetary to social benefit mix (x, y). A project is now assumed to be a convex set of feasible pairs (x, y) with a smooth efficient frontier from which the implementation point (x, y) is chosen. The efficient frontier is represented by the function $y = h(x)$ which is decreasing, smooth and concave and defined over the interval $x \in [x_{\min}, x_{\max}]$. We assume again that the project is small relative to the total debt of the government, so that the valuation functions derived in Theorem 1 can be applied. In order to simplify the exposition, we abstract from the uncertainty studied in the previous section and assume that h is commonly known.

The timeline is as follows: In period 1, the decision to undertake the project is announced. The credit market takes the project into consideration when pricing the government's debt. Importantly, the market prices the debt based on its (rational) expectations regarding the implementation point (x, y). In period 2, the government chooses the mix (x, y). Then, s is realized and the debt-repayment decision is made.[15]

We will show that the informational asymmetry leads to a dynamic inconsistency problem: In period 2, the government ignores credit rating implications and chooses an implementation point that is skewed towards social benefits. Neglecting the monetary aspect, however, is costly to the government since the credit market anticipates it. We start our analysis with a benchmark case, in which the government does not face a commitment problem.

[15] In reality, the operating phase (period 2) can be quite long. In that case, s is slowly revealed over time and the implementation (e.g., the toll level) can change continuously over the operating period. Our reduced-form model, in which the implementation decision is made before s is realized, can be viewed as a lower bound on the timing of the implementation decision.

4.1 The full commitment benchmark

Assume that the government undertakes the project and commits to the implementation scheme $(x_c, y_c = h(x_c))$ before the credit market prices the debt. By Theorem 1, the government's maximization problem is:

$$\max_x V(x, h(x)) = \max_x x + \delta h(x)$$

The first-order condition for x yields:

$$h'(x_c) = -\frac{1}{\delta}.$$

The value of the project to the government is:

$$V(x_c, h(x_c)) = x_c + \delta h(x_c).$$

4.2 Government implementation absent commitment

Assume now that the government makes the implementation decision without commitment. The valuation formula (Theorem 1) can be rewritten as:

$$V(x, y; x^e) = F \cdot x^e + \delta \left[\frac{1-F}{\delta} \cdot x + y \right].$$

In period 1, the credit market prices the debt according to its expectation x^e of the revenue x that the government will choose in period 2. In period 2, the government takes x^e as given, and chooses x and $y = h(x)$ that maximize the expression in the square brackets:

$$\max_x \frac{1-F}{\delta} \cdot x + h(x).$$

Denoting the optimal solution by (x_{gov}, y_{gov}), the first-order condition is:

$$h'(x_{gov}) = -\frac{1-F}{\delta}. \tag{8}$$

Thus, instead of choosing the point (x_c, y_c) on the efficient frontier, where its slope $h'(x_c)$ is $\frac{1}{\delta}$, the government now has no "credit market discipline", i.e. it ignores the credit market value of x and chooses the point (x_{gov}, y_{gov}) where the slope is $\frac{1-F}{\delta}$. Figure 3 illustrates the relationship between the two points.

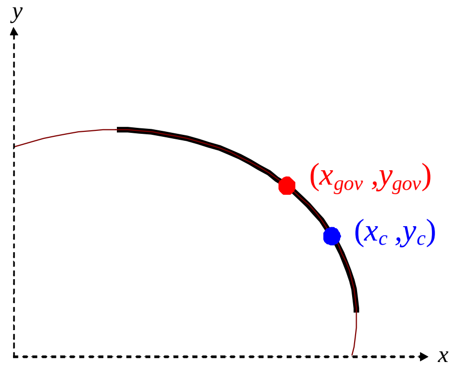

Figure 3: Government vs. commitment implementation

By rational expectations in the credit market, $x^e = x_{gov}$. We thus have:

$$V\left(x_{gov}, h\left(x_{gov}\right); x_{gov}\right) = V\left(x_{gov}, h\left(x_{gov}\right)\right) = x_{gov} + \delta h\left(x_{gov}\right).$$

By revealed preference, this is less than the full commitment outcome $V\left(x_c, h\left(x_c\right)\right) = \max_x V\left(x, h\left(x\right)\right)$.

The underlying intuition can be summarized as follows: The government ignores the externality imposed on its debtholders when it chooses the type of implementation and thus puts excessive weight on the social benefits y. However, debtholders foresee this and price the debt accordingly. In a rational expectations equilibrium, the government pays exactly for the negative externality. The government thus faces a *dynamic inconsistency* problem. It would like to promise its creditors that it will shift implementation in favor of the monetary component x, but such a promise would not be credible.

The above results are summarized in the following theorem:

Theorem 3

1. *The full commitment outcome is* (x_c, y_c)*, which is characterized by* $h'\left(x_c\right) = -\frac{1}{\delta}$.

2. *A government with no ability to commit chooses the implementation* (x_{gov}, y_{gov})*, which is characterized by* $h'\left(x_{gov}\right) = -\frac{1-F}{\delta}$*. Relative to* (x_c, y_c)*, this implementation is tilted towards higher social benefits and lower monetary benefits and yields lower ex ante value for the project, i.e.* $V\left(x_{gov}, y_{gov}\right) < V\left(x_c, y_c\right)$.

5 Privatization

On October 15, 2004, the City of Chicago opened bids to operate the Chicago Skyway, a 7.8 mile toll bridge and road located on the City's southeast side linking the Indiana Toll Road (ITR) to the Dan Ryan Expressway. The winning bidder, the Cintra-Macquarie consortium, agreed to make a $1.82 billion upfront payment (36 percent of Chicago's budget) in exchange for the right to operate and receive revenues for 99 years. Two years later, the State of Indiana signed a 75-year lease agreement for the ITR with the same company. In return the State received an upfront payment of $3.85 billion.[16]

In both cases, the privatization had a favorable impact on credit rating. On February 2006, Moody's upgraded the city of Chicago's overall bond rating from A1 to Aa3. In its report, Moody's cited one of the City's credit strengths as "the vital infusion of $1.82 billion from the lease of the Skyway."[17] The privatization also contributed to Standard & Poor's upgrade of Indiana's credit rating from "AA" to "AA+". Standard & Poor's noted that the $3.85 billion lease has contributed to the state's improved credit standing.[18]

Can our model shed light on the motivation for these privatizations? Can a reduction in debt using the proceeds from privatization explain the improvement in credit rating?

In a world without informational asymmetries, the answer would be no. Thus, assuming that the upfront payment from the highway privatizations equals the net present value of the future revenue stream and that all proceeds of privatization were used to reduce debt,[19] privatization leads to an equal reduction in both sides of the government balance sheet. However, in our model the probability F of default on the marginal dollar of debt is simply a function of the difference $d - X$ (since a government in financial distress uses all the future monetary revenue X from projects it owns to pay its debt d). Thus, an equal reduction in debt and revenue is neutral and does not affect its credit rating.

The previous sections, however, showed that informational asymmetries cause the govern-

[16] The account of these privatizations is based on Johnson, Luby and Kurbanov (2007).

[17] Associated Press, February 10, 2006.

[18] Standard & Poor's Credit Profile for Indiana, January 24, 2006.

[19] This is indeed the solution to the debt-determination condition (4).

ment to only partially internalize the credit market consequences of its decisions regarding public projects and that it is thus unable to extract the full value of its assets. Specifically, the results in Section 4 show that governments tend to operate public projects with an excessive emphasis on social benefits. This is well illustrated by the ITR example. Johnson et al. (2007) estimate the NPV of future cash flow from ITR – had it remained under state control – at \$1.92 billion, far below the \$3.85 billion lease. Not surprisingly, the high price paid for the lease did not come for free. Under the contract with the private operator, the tolls immediately jumped from \$4.65 to \$8 for passenger vehicles and from \$14.55 to \$32 for trucks, with a clause that allows for further increases of at least the change in nominal GDP per capita. Had the State of Indiana operated the ITR with the same fees, its revenues would have been much higher. However, in view of our results in Section 4, it could not commit to putting so much weight on monetary revenue. Such a policy would be dynamically inconsistent since social benefits such as driver surplus and reduced congestion on other roads would have always remained a priority under state control.

In this section we explore the effects of privatization. The model presented below combines both the implementation issue exemplified in the ITR case above and the selection issue discussed in Section 3 which is more relevant in the case of new projects.

In the context of implementation, we assume that under private operation there would be less emphasis on social benefits, thus raising the project's monetary revenue. By transferring the project to a private operator, the government avoids the credit market's predicament that the project will be operated with a bias toward social benefits. However, unless the actions of the profit-maximizing private operator can be sufficiently limited by a contract, it will utterly disregard the social benefits and reduce them further than is optimal, even taking into account the credit-rating perspective. The comparison between the two regimes is, in general, ambiguous.

In the context of project selection, we assume that a potential private owner who bids for a project will learn its parameters – in contrast to the credit market which is composed of small debtholders. While the fact that potential private operators acquire full information may suggest that the adverse selection problem should be solved, we show that the problem does not disappear. There are cases in which projects are privatized even though their implementation by the government is more efficient. Moreover, there are examples in which the government carries out projects with a negative net value and rejects projects with a positive net value, while in the regime without the option to privatize it takes the efficient action.[20]

5.1 The model

There is a finite set of potential projects H. A project $h \in H$ is a decreasing and concave function, representing the efficient frontier $y = h(x)$ of all feasible implementation points. (To focus on the credit rating dimension, we abstract from differences between the efficiency of the private operator and that of the government and assume that the frontier h is identical irrespective of who undertakes the project.) At the onset of period 1, one project in H is drawn according to a prior distribution G. The government privately learns its attributes and decides whether to undertake it on its own, to privatize it or to reject it.[21] The credit market observes this decision and takes it into consideration when it prices the government's debt. In

[20] There is a vast literature on privatization and its effects. Vickers and Yarrow (1988) discuss the main theoretical approaches and the experience with privatization programs in various countries. Megginson and Netter (2001) survey the empirical studies on privatization. Two papers that have a more direct bearing on our model are Hart, Shleifer and Vishny (1997) and Vickers and Yarrow (1991). Hart et al. demonstrates that privatization can affect the quality of the services provided. They argue that, under private control, managerial effort in both cost reduction and service improvement is greater than under public control. However, incentives for cost reduction under privatization can be too large and thus have an adverse effect on the quality of service provided. The tendency of private operators to focus on the monetary aspects of the service (in this case, cost reduction) and to ignore the benefits to the recipients is similar to what is postulated in our model. Vickers and Yarrow (1991) argue that the raising of revenue is unlikely to be an important rationale for privatization in developed countries. Selling bonds is likely to be a less costly way to raise revenue than selling equity due to the direct costs of issuing equity (writing a prospectus, advertising, underwriting, etc.) and the more accurate pricing of bonds. They argue, however, that the revenue motive may be relevant in less-developed countries provided that the commitment not to expropriate equityholders is more credible than the commitment not to expropriate bondholders. It may also be attractive to governments that are publicly committed to constraining their borrowing levels. The arguments presented here show that a revenue motive may be important even in the presence of a developed market for the country's debt.

[21] For purposes of exposition, the discussion relates to a new project. In the case of privatization of an existing asset with the option to shut down, the analysis is the same except that the setup cost is taken to be zero. Without this option, the government only has two options – retaining the project or privatizing it – but the analysis that follows leads to similar insights.

period 2, the project (unless rejected) is operated by the government or the private operator. Finally, the government's income shock s is realized and its debt-repayment decision is made.

In the case that the government decides, in period 1, to privatize a project, it invites potential private operators to bid for the right to finance and operate the project and to collect its future monetary benefits (bids can be negative, i.e., the private operator may demand a subsidy). We assume that potential bidders know which project h was drawn.[22] We also assume that there is competition among potential private operators and that they also have access to the zero-interest credit market.[23] The project's setup cost for a private operator is 1, which is the same as that for the government. In period 2, the private operator collects the monetary revenue while the government enjoys the social benefits.

We analyze the game backwards: for any potential project h, we find the period-2 implementation schemes under government and private operation, denoted $(x_{gov}(h), y_{gov}(h))$ and $(x_{po}(h), y_{po}(h))$, respectively (when no confusion arises we omit the (h)). We then revert to the project selection phase in period 1.

5.2 The value to the government of a privatized project

We begin by showing that the valuation formulas presented in Theorem 1 also apply to the case of privatized projects. Since potential private operators have access to the zero-interest credit market, the bids for the project equal its expected operating revenue, x_{po}, minus the setup cost of 1. In period 2, the government no longer receives monetary income from the project, but does enjoy the social benefit y_{po}. The period 1 value to the government from privatizing the project is thus $x_{po} - 1 + \delta y_{po}$, i.e., exactly $V(x_{po}, y_{po}) - 1$. If the government had operated the project on its own, the value would have been $V(x_{gov}, y_{gov}; x^e) - 1 = V(x_{gov}, y_{gov}) + F(x^e -$

[22]This assumption is justified by the idea that, unlike the small holders of the government's debt, potential bidders for a project do have sufficient incentive to invest resources in an expensive in-depth analysis of the project's attributes.

[23]That a private operator can finance the project at a riskless interest rate can be deduced from the following assumptions: 1. The private operator maximizes profits. 2. The credit market is aware that the private operator knows h with certainty. 3. Bids are publicly observed. For brevity, we state this as an additional assumption.

$x_{gov}) - 1$. This implies that if the implementations were identical (i.e., $(x_{po}, y_{po}) = (x_{gov}, y_{gov})$) and if the credit market were fully informed about which project was drawn (and thus $x^e = x_{gov}$), then the value of the project would be the same whether the government or the private sector finances the project. In other words, whether the government privatizes the project or issues more debt and retains ownership and the right to future monetary revenue, then its credit rating will remain unchanged. Any deviation from this neutrality must be due either to a difference in the modes of operation under the two regimes or to the credit market's lack of knowledge regarding the attributes of the project.

5.3 Implementation by the private operator

We distinguish between two possible situations: In the first, the private operator has full discretion to choose the period-2 mode of operation. In the second, the project's attributes are such that the government is able, in period 1, to sign a binding contract with the operator specifying how the project will be operated in period 2.

5.3.1 A private operator with full discretion

If the project is delegated to a private operator (PO) who is free to choose the implementation scheme, it will ignore y and choose the point that maximizes x:

$$(x_{po}, y_{po}) = (x_{\max}, h(x_{\max})).$$

The value of the privatized project to the government (before deducting the setup cost) is $V(x_{po}, y_{po})$, which is below the full commitment outcome $V(x_c, y_c)$. Recall (from Section 4) that under government operation, the value of the project is $V(x_{gov}, y_{gov})$, which is also below $V(x_c, y_c)$. The comparison of $V(x_{po}, y_{po})$ to $V(x_{gov}, y_{gov})$ is in general ambiguous. These two modes of implementation are shifted away from the commitment outcome in opposite directions, as illustrated in Figure 4.

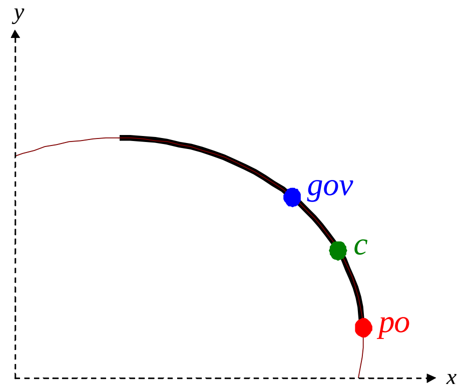

Figure 4: Government vs. Private Operator implementation

5.3.2 Contracting with the private operator

Assume now that the government and the PO can write a binding contract $(x, h(x) = y)$ that specifies the implementation scheme for the project. For example, the toll on a privatized road can be contracted rather than left to the private operator's discretion. In this case, the government chooses x to maximize $V(x, h(x))$. This is exactly the same maximization problem as in the benchmark case (Section 4.1). The optimal contract is thus the same as the full commitment outcome: $(x_{po}, y_{po}) = (x_c, h(x_c))$ and the value to the government is $V(x_c, h(x_c))$.

In this sense, one can view privatization as a commitment device: Whenever full contracting with the private operator is feasible, a project should be delegated to the private sector, thereby restoring the government's first-best outcome.

Remark 1 *An important insight is that the optimal ex ante contract will seem suboptimal when viewed from an ex post perspective. For example, the toll on an existing toll road (as contracted with the PO) might seem excessive when compared to that which generates the ex post optimum* (x_{gov}, y_{gov}). *However, arguments that criticize the "excessive" toll might fail to account for the ex ante considerations that put more weight on* x *as a result of credit market discipline. In the ITR case, for example, there is an ongoing public outcry regarding the diversions of traffic to already-congested state-owned routes as a result of the new aggressive toll rate regime. A balanced evaluation of whether this privatization has benefitted the people of Indiana must also take into account the savings due to the improved credit rating in the years since the privatization.*

The results of this section are summarized in the following theorem:

Theorem 4 *1. A private operator with full discretion chooses the implementation point $(x_{po}, y_{po}) = (x_{\max}, h(x_{\max}))$. Relative to (x_c, y_c), this implementation is tilted towards lower social benefits and higher monetary benefits and yields lower ex ante value for the project, i.e. $V(x_{po}, y_{po}) < V(x_c, y_c)$. If instead full contracting with the private operator is feasible, then the outcome is (x_c, y_c).*

2. $V(x_{po}, y_{po})$ can be lower or higher than $V(x_{gov}, y_{gov})$.

Remark 2 *The analysis of the privatization scenario in this section (with or without contracting) implicitly assumes that the government and the PO cannot renegotiate at the beginning of period 2. Renegotiation in this case implies that the government will pay the PO to choose (x_{gov}, y_{gov}) rather than the point it would have implemented otherwise (equivalently, the government could buy the project back from the PO). While there are gains to be made from such trade at this stage, the credit market would foresee the period 2 renegotiation and monetary transfer to the PO and would downgrade the government's credit rating in period 1 to reflect this, thus nullifying the gains from privatization.*

Note, however, that while in many other dynamic applications the possibility of renegotiation is inherent and difficult to overcome, it is less likely in the context of privatization. Here, various types of private information can be expected to break down the period-2 negotiations. For example, the government may have private information regarding its relative preference between x and y, reflecting factors such as the production functions for public and government goods and politicians' preferences (note that this information does not affect the period 1 negotiation if the PO does not expect to renegotiate). Another example would be if the PO accumulates private information on parameters such as consumer demand, operating costs, etc. during the construction and early stages of operation. Finally, even if renegotiation were to change the outcome of implementation under privatization to make it identical to that under government operation, privatization would still have a beneficial effect on the adverse selection problem (see Theorem 5 below).

5.4 The decision whether to privatize

We now revert to analyzing the project-selection issue in period 1. Observe that if the credit market had complete information on each project's parameters, the government would privatize a project h whenever $V(x_{po}(h), y_{po}(h)) > \max(V(x_{gov}(h), y_{gov}(h)), 1)$ and operate h on its own whenever $V(x_{gov}(h), y_{gov}(h)) > \max(V(x_{po}(h), y_{po}(h)), 1)$. Clearly, in that case the option to privatize can only be beneficial. Projects that are transferred to private operators generate higher values while those that remain under government ownership retain the same value. In addition, some projects that would have been rejected due to their negative value under government implementation may be profitably privatized.

Under incomplete information, this argument is no longer valid. The value of a project under government operation is no longer independent of the equilibrium privatization decision regarding other projects. In this case, the gross value of a self-operated project is $V(x_{gov}(h), y_{gov}(h); x^e)$ rather than $V(x_{gov}(h), y_{gov}(h))$, where x^e is the mean x of all projects operated by the government in equilibrium. More formally, the space of projects is thus partitioned into three subsets (some of which may be empty): projects undertaken by the government (GOV), privatized projects (PO) and rejected projects (NON), where:

$$\begin{aligned} GOV &= \{h \in H : V(x_{gov}(h), y_{gov}(h); x^e) \geq \max(V(x_{po}(h), y_{po}(h)), 1)\} \\ PO &= \{h \in H : V(x_{po}(h), y_{po}(h)) \geq \max(V(x_{gov}(h), y_{gov}(h); x^e), 1)\} \end{aligned}$$

where $x^e = E[x_{gov}(h) | h \in GOV]$.

We start our analysis with the special case in which the complete information value of any potential project under government ownership does not exceed that under private ownership. That is, for any $h \in H$, $V(x_{po}(h), y_{po}(h)) \geq V(x_{gov}(h), y_{gov}(h))$. This occurs if the distortion due to the government's dynamic inconsistency problem is more severe than that under private operation. One notable case is when full contracting with the private operator over the implementation of the project is feasible, thus making the PO's implementation fully efficient (see Section 5.3.2). Another interesting case, in which the condition holds with equality, is that in which each potential project has only one feasible implementation point, i.e., any $h \in H$ is a singleton (x_h, y_h). A concrete example is the oil field scenario discussed in Section 3, where even though there is substantial uncertainty regarding x and y, the only decision is whether to develop the field, while no significant tradeoff between the two is present in the implementation.

Consider again the set of all projects that the government would have undertaken under complete information. With the option to privatize, it is now defined as:

$$GOV_{CI} = \{h \in H : V(x_{gov}(h), y_{gov}(h)) \geq \max(V(x_{po}(h), y_{po}(h)), 1)\}.$$

Note that this set may be empty (which would be the case, for example, if implementation by a PO strictly dominates that by the government). If it is not empty, let $\underline{x}$ denote the minimal revenue for a government-operated project under complete information:

$$\underline{x} = \min\{x_{gov}(h) : h \in GOV_{CI}\}$$

The following theorem states that if implementation by a PO (weakly) dominates government implementation, then PO's will crowd out the government from undertaking projects. The intuition behind this can be seen using an unraveling argument: For the realizations of h that are most attractive from the credit market's perspective (those with above-average $x_{gov}(h)$), the government prefers to privatize the project – otherwise, the credit markets would take the project to be an average one. Understanding that, the credit market classifies projects that are not privatized as belonging to a set of inferior projects. Consequently, the government is induced to also privatize the "better" projects in the new and smaller set, and so on. The end result is that the government may only retain ownership of projects with minimal monetary revenue or perhaps none at all.

Theorem 5 *Assume that* $V(x_{po}(h), y_{po}(h)) \geq V(x_{gov}(h), y_{gov}(h))$ *for all* $h \in H$*. Then, the government does not undertake any project, except perhaps those with minimal revenue in* GOV_{CI}*, i.e.* $GOV \subset \{h \in H : h \in GOV_{CI}$ *and* $x_{gov}(h) = \underline{x}\}$.[24]

Proof. Appendix.

Note that if the set GOV is non-empty, then $x^e = \underline{x}$, which implies that the government obtains the complete information value $V(x_{gov}(h), y_{gov}(h))$ for every project h that it undertakes. Thus, if the government decides to undertake a project, it must be that the value under

[24] While our model assumes that the government and the PO face the same efficient frontier for each potential project and can differ only in their choice of implementation point, the theorem clearly extends to the case in which the efficient sets are different, as long as the PO still extracts a higher value from any potential project.

privatization $V(x_{po}(h), y_{po}(h))$ cannot strictly exceed $V(x_{gov}(h), y_{gov}(h))$. This argument proves the following (weaker) corollary:

Corollary 6 *If full contracting with the PO is feasible (so that $V(x_{po}(h), y_{po}(h)) > V(x_{gov}(h), y_{gov}(h))$, for all $h \in H$) then the set GOV is empty, i.e. the government does not undertake any projects.*

In the special case dealt with in Theorem 5, the project is implemented by whoever (either the government or a PO) extracts a higher value under complete information (unless that value is below the setup cost, in which case the project is rejected). Thus, there is no inefficiency due to the credit market's inferior information regarding the project's attributes.[25]

What is the ex ante benefit of adding the option to privatize projects? In this special case it is clearly positive. Not only does the value that the government extracts from the project increase with privatization, but the introduction of privatization also corrects the distortion in the selection of projects (undertaking projects with a negative value and rejecting positive-value ones), which exists when the government is the only candidate for undertaking projects (Section 3).

In general, however, the outcome need not be efficient. A project is sometimes implemented by the entity that generates a lower complete-information value. In addition, as in the case without privatization, the rejection criterion might be suboptimal. Remarkably, it might even be the case that the government would have been better off, ex ante, if the option to privatize projects did not exist at all. These potential inefficiencies are demonstrated in the following examples:

Examples in which the option to privatize is disadvantageous

It is clear that when presented with a specific project, the government can only benefit from having the option to privatize. Why does this not imply that privatization is necessarily beneficial ex ante? Because the value of a project undertaken by the government depends on the credit market's assessment regarding its monetary revenue. This assessment changes if the market knows that the government had the option to privatize the project but chose not to exercise it.

[25] This can formally be shown by a trivial extension of Theorem 2.

We present two examples that are constructed to highlight two separate effects. In the first, the same set of projects is undertaken with or without privatization. The source of inefficiency in this example is suboptimal implementation under privatization. In the second, the implementation of any project that is undertaken under both regimes is identical. However, projects with positive net value that are undertaken by the government in the absence of the privatization option are rejected when the option for privatization is added.

Each of the examples considers a different set of potential projects which are all transformations of the positive orthant of the unit circle. The transformation is defined by a pair of positive scalars α_x and α_y, which "stretch" the unit circle in the x and y directions, respectively. For brevity, we refer to the potential project defined by $\alpha = (\alpha_x, \alpha_y)$ as "project α" and to its efficient frontier as h_α. We thus have:

$$y = h_\alpha(x) = \alpha_y \sqrt{1 - \frac{x^2}{\alpha_x^2}} \quad \text{for } x \in [0, \alpha_x]$$

Figure 5 illustrates the Pareto frontier of the project for different values of $\alpha = (\alpha_x, \alpha_y)$:

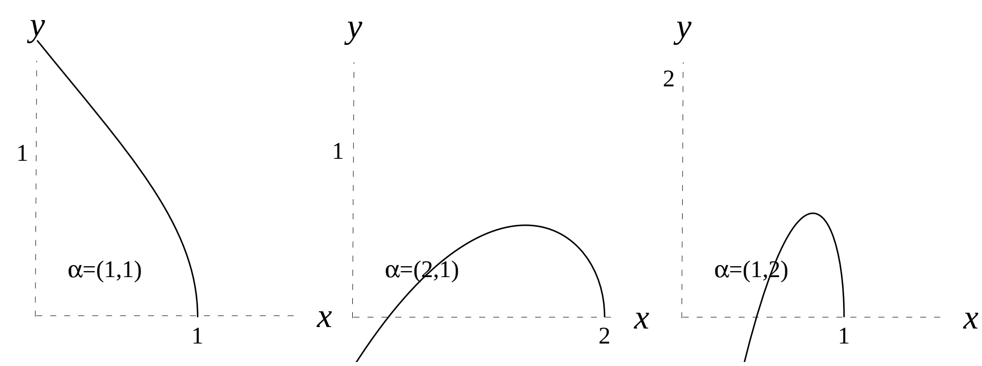

Figure 5: Examples of potential projects

The project's setup cost is 1 and the government's discount factor is $\delta = 1/3$. The other parameters of the model are chosen so that the probability of default is $F = 1/3$. Calculations show that the government's implementation is:

$$x_{gov}(\alpha) = \frac{2\alpha_x^2}{\sqrt{4\alpha_x^2 + \alpha_y^2}}; \quad y_{gov}(\alpha) = \frac{\alpha_y^2}{\sqrt{4\alpha_x^2 + \alpha_y^2}}.$$

Under PO control, we have:

$$x_{po}(\alpha) = \alpha_x; \quad y_{po}(\alpha) = 0.$$

In Example 1 below, there are two potential projects. Under complete information, both have a higher value under government implementation than under private operation. (Note that this is the opposite case to that analyzed in Theorem 5.) Under incomplete information, the projects are misvalued by the credit market; nonetheless, the sum of misvaluations must be null and the maximal ex ante value is obtained if both are kept under government control. However, this is not an equilibrium if privatization were allowed since in that case the government would prefer to privatize the project with the higher monetary benefit in order to prevent it from being undervalued.

Example 1 *There are two potential projects,* $(1,1)$ *and* $(1.21,1)$*, each assigned equal prior probability.*

The values of the projects under complete information exceed the setup cost of 1 *and are higher under government operation:*

$$\begin{aligned} V\left(x_{gov}\left(1,1\right),y_{gov}\left(1,1\right)\right) &= 1.043 > V\left(x_{po}\left(1,1\right),y_{po}\left(1,1\right)\right) = 1 \\ V\left(x_{gov}\left(1.21,1\right),y_{gov}\left(1.21,1\right)\right) &= 1.245 > V\left(x_{po}\left(1.21,1\right),y_{po}\left(1.21,1\right)\right) = 1.21 \end{aligned}$$

Thus, if the option to privatize does not exist, both projects are undertaken by the government.

If, however, the option to privatize does exist, this is no longer an equilibrium. To see this, assume the opposite. We would then have $x^e = \left[x_{gov}\left(1,1\right) + x_{gov}\left(1.21,1\right)\right]/2$*, implying that* $V\left(x_{gov}\left(1.21,1\right),y_{gov}\left(1.21,1\right);x^e\right) = 1.208$*. However this is slightly less than* $V\left(x_{po}\left(1.21,1\right),y_{po}\left(1.21,1\right)\right) = 1.21$*. The government would thus prefer to transfer the project into the hands of a PO – a contradiction.*

Therefore, in the (unique) equilibrium, the project $(1,1)$ *is undertaken by the government and the project* $(1.21,1)$ *is delegated to a PO. The ex ante expected value to the government under such an equilibrium is* $\frac{1.043+1.21}{2}$*, which is lower than in the case when privatization is not allowed, i.e.* $\frac{1.043+1.245}{2}$*.*

In Example 2, there are three potential projects. In the absence of privatization, all of them are undertaken by the government. With the option of privatization, the one with very high monetary benefits is transferred into private hands, even though its implementation under government and PO ownership is identical. As in the previous example, the motive for privatization is to avoid undervaluation. However, in this case there is a "market failure" with regard to the remaining projects: adverse selection leads to the rejection of one of them, even though it has a positive complete-information net value under government ownership. Essentially, as long as the first project was part of the pool of government projects, it "subsidized" the others and prevented market failure.

Example 2 *There are three potential projects,* $(0,3)$*,* $(3,0)$ *and* $(7/8,2)$*, each of which is assigned equal probability.*

The first two projects are degenerate, i.e. each has a unique implementation point, $(0,3)$ *and* $(3,0)$*, respectively. Their values, if undertaken, are therefore independent of the regime and equal to* 1 *and* 3*, respectively. The complete-information value of the third project is higher than its cost of* 1 *only under government operation:*

$$V\left(x_{gov}\left(7/8,2\right),y_{gov}\left(7/8,2\right)\right)=1.078>V\left(x_{po}\left(7/8,2\right),y_{po}\left(7/8,2\right)\right)=7/8.$$

If the option to privatize does not exist, the three projects are undertaken by the government. (Since, in this case, $x^e=1.192$*, the projects* $(0,3)$ *and* $(7/8,2)$ *are valued above their complete information valuations and the value of the project* $(3,0)$*, which "subsidizes" the others, is still well above its cost.)*

If the government has the option to privatize, then the project $(3,0)$ *is privatized so as not to suffer from undervaluation by the credit market since* $V\left(3,0;x^e=1.192\right)<V\left(3,0\right)$*. However, in that case, the project* $(7/8,2)$*, which has a positive net value, must be rejected. To see this, assume that there is an equilibrium in which the government undertakes both remaining projects* $(0,3)$ *and* $(7/8,2)$*. Then,* $x^e=0.288$*, and thus* $V\left(x_{gov}\left(7/8,2\right),y_{gov}\left(7/8,2\right);x^e\right)=0.982$*. Since this is less than the project's cost of* 1*, the government would prefer to reject it* $(7/8,2)$ *– a contradiction.*

Note that in the absence of privatization, the cross-subsidy between the projects prevented a market failure from arising. The cream-skimming effect, by which the highest-revenue project is privatized and thus no longer subsidizes the others, leads to market failure.

In conclusion, there are types of projects for which the option to privatize is beneficial for the government. In particular, privatization is unambiguously beneficial if, at the implementation stage, the value of the project under private operation weakly exceeds that under government operation (whether because there are no degrees of freedom in the implementation or because full contracting with the private operator is possible or because the distortion due to the government's dynamic inconsistency problem is more severe than that due to the private operator's exclusive focus on revenue for all possible realizations of the project). However, for types of projects for which the value is higher under government's operation for some realizations, it might be the case that the government would be better off tying its own hands and never privatize them.

6 Concluding comments

6.1 The magnitude of the model's effects

For the effects demonstrated in this paper to have a sizable explanatory power in the real world, it must be the case that the probability of (partial) default F is sufficiently large. This is because the severity of the dynamic inconsistency and adverse selection problems depends on the weight F given to the credit market's misassessment of monetary revenue $(x^e - x)$ in the valuation formula (7).

A cursory glance at bond prices might incorrectly suggest that the implied probability of default is not very large. For example, even during the recent financial crisis, Italian 10-year bonds has only yielded about 1% above the benchmark German bonds (perceived to be the safest in the Euro zone). However, deriving the correct value of F in our model from these bond yields involves three modifications that amplify the result significantly.

First, actual spreads are expressed in annual terms, while the appropriate unit of time in our model is a period of several years. It includes the time from the project's inception (period 1), through the point at which it becomes operational, and until a "middle" point in the operational phase (period 2). Thus, the annual yields need to be multiplied by the total number of years.

Second, note that in the event of default, the amount of debt that will not be repaid can vary depending on the severity of economic distress (s in our model). Yield spreads in the data reflect the expectations over that proportion of the total debt that will not be repaid.

In contrast, F in our model is the marginal probability of default, i.e. the probability that at least one dollar of debt will not be repaid. It is thus much higher than the yield spread.

Third, even the benchmark German debt – with respect to which the above spread is calculated – should not be considered immune to default in terms of our model. This is because part of the debt may be deflated away by unexpected inflation, which would be classified as a partial default in our model. (Note that this risk component of German debt is not even reflected in the price of Credit Default Swaps, since these instruments only cover events of "declared" default.)

6.2 Taxation

Our model assumes that in the case of a severe income shock the government is obliged to renege on some of its debt. The possibility of increasing taxes as an alternative to defaulting is thus assumed away. Would our qualitative results change in a model that allows for taxes?

Assume that in period 2, a government that suffers an income shock (low s) and does not have sufficient funds to pay its debt has the option to increase taxes. It will choose this option if the shadow cost of collecting the marginal dollar of taxes is below L – the loss from every dollar of unpaid debt. There are, then, two possibilities:

1. **Taxation is always preferred to default:** Given the optimal level of debt, for all possible realizations of the income shock s, the government prefers to meet all its obligations by raising taxes. As in the model without taxes, the value of a project's monetary benefits equals 1 and that of social benefits equals δ. That is, the government still prefers X to Y. The difference $1-\delta$ equals the (discounted) *option value* of X to reduce the cost of additional taxation when s is low. However, in contrast to the model without taxes, where in the event of default there is an external cost to creditors, in this case the entire cost associated with not having sufficient revenue to pay the debt – the cost of additional taxation – is internalized by the government. Consequently, the *credit market value* of X is null and all the informational problems discussed in this paper do not exist.

2. **The government sometimes prefers to default:** Given the optimal level of debt, there are realizations of s for which the marginal cost of taxation is higher than that of defaulting, and therefore the government prefers not to repay all its debt. In this case, our

qualitative results hold, with F, the probability of default, representing those cases (i.e., the event that s is below the level at which the government starts resorting to default). Since there is an externality on creditors, X has a positive credit market value and the informational problems are present in this case.

Which case better describes a specific real-world scenario? Note that whenever the yield on a government bond is higher than the lowest yield in the market for a bond with the same terms, it must be that the market attributes a positive probability to default. Then, case 2 is the more appropriate model and the insights of this paper are relevant. Moreover, even for those governments whose bond yields are at the lowest tier, it may well be that the credit market is still factoring in a possibility of default (see the previous remark).

6.3 Infinite horizon with debt rollover

Our modeling approach adopted the simplest framework which still captures the idea that governments ignore the externality on debtholders and place insufficient weight on the monetary revenue of public projects. One of our main simplifying assumptions has been that of only two periods. In reality, there is never a final period and typically governments refinance part of their aggregate debt period by period. How dependent are the results on the two-period setting? Could concerns regarding the terms of future debt rollover correct the government's incentives and restore the appropriate weight on X in its decisions? Or, in more formal terms, would the equilibrium in such an infinite horizon game include effective enforcement strategies on the part of the buyers of the new debt, which would deter the government from behaving opportunistically?

We argue that our insights would remain qualitatively valid even in the infinite horizon setting. There are at least four reasons why effective enforcement is not likely in our context.

First, in many circumstances the market only imperfectly monitors the government's decisions regarding projects. That is, over an extended period x might not be fully revealed and only a noisy signal is obtained. This signal could be, for example, the aggregate financial state at period 2 ($X + s$ in our model) or, even worse, the binary variable of whether a default has taken place. As shown in the vast literature on imperfect monitoring, it is often hard to enforce non-opportunistic behavior in such environments.

Second, even if eventually the credit market accurately observes the project's x, the punishment strategies needed to sustain cooperative behavior by the government will be ineffective if its discounting of the future is severe. One could expect this to often be the case: recall that the time horizon from project initiation to operation may be long, and that governments may be myopic due to uncertain re-election prospects.

Third, punishment strategies, by which a deviation by the government from the "correct" x is followed by the credit market charging a higher interest rate on the new debt, are limited, in our context, to those in which the new interest rate reflects the true default probability. Repeated game equilibria in which the credit market demands an interest rate that is higher than the competitive equilibrium rate are not possible because each new small bondholder would free-ride on the others' punishment and buy more debt. Thus, effective enforcement is possible only if the continuation game has multiple rational expectations equilibria, each with different government behavior and default probability, and the government's past behavior serves as a sunspot that determines which of the equilibria is selected.

Finally, note that even if such history-dependent equilibrium does exist, there always exists another equilibrium in which the credit market ignores the history of government actions. In such an equilibrium, the government necessarily acts in an opportunistic fashion. In other words, the infinite horizon model always has an equilibrium that replicates that of our two-period model.

A Proofs

Theorem 1.

For clarity of exposition we present the proof for the case in which the market's belief x^e is single valued. At the end, we explain how the proof can be modified for the case of a stochastic belief.

Assume that the initial stocks of monetary and social benefits are X and Y, respectively. By (3), the government's utility after adding a small project $(x, y; x^e)$ is:

$$\hat{U}(x, y; x^e) = \max_d R(d, X + x^e) - I + \delta (X + x + Y + y + E_s [s - e^* (d, X + x, s) - L^* (d, X + x, s)]) .$$

(Note that R, period 1 revenue from issuing the debt, depends on the market's perception x^e, while all period 2 values depend on the true x.) By the envelope theorem, the indirect effect due to debt reoptimization is negligible. Thus, the first-order approximation to the change in the government's utility, $\hat{U}(x, y; x^e) - \hat{U}(0, 0; 0)$ is:

$$V(x, y; x^e) = y \frac{\partial \hat{U}(0, 0; 0)}{\partial y} + x \frac{\partial \hat{U}(0, 0; 0)}{\partial x} + x^e \frac{\partial \hat{U}(0, 0; 0)}{\partial x^e}$$

Since $\frac{\partial \hat{U}(0,0;0)}{\partial y} = \delta$, the first summand is simply δy. We now compute the second and third summands. Note that:

$$\begin{aligned}
\frac{\partial \hat{U}(0, 0; 0)}{\partial x} &= \delta \cdot \left(1 - \frac{\partial E_s [e^* (d, X, s)]}{\partial X} - \frac{\partial E_s [L^* (d, X, s)]}{\partial X}\right) \\
\frac{\partial \hat{U}(0, 0; 0)}{\partial x^e} &= \frac{\partial R(d^*, X)}{\partial X} = \frac{\partial E_s [e^* (d, X, s)]}{\partial X},
\end{aligned}$$

and that:

$$\begin{aligned}
\frac{\partial E_s [L^* (d, X, s)]}{\partial X} &= \frac{\partial}{\partial X} \left(\int_{s=0}^{d-X} L \cdot (d - X - s) f(s) + \int_{s=d-X}^{\bar{s}} 0 \cdot f(s) \right) \\
&= -L \cdot 0 \cdot f(d - X) - \int_{s=0}^{d-X} L \cdot f(s) + 0 \cdot f(d - X) = -F(d - X) \cdot L \\
\frac{\partial E_s [e^* (d, X, s)]}{\partial X} &= \frac{\partial}{\partial X} \left(\int_{s=0}^{d-X} (X + s) f(s) + \int_{s=d-X}^{\bar{s}} d \cdot f(s) \right) \\
&= -d \cdot f(d - X) + \int_{s=0}^{d-X} f(s) + d \cdot f(d - X) = F(d - X) .
\end{aligned}$$

Thus, the second summand (the internal value of the project) is $x \cdot \delta (1 - F(d - X) + F(d - X) \cdot L)$. By the first-order condition for the debt (4), this is simply $x \cdot [1 - F(d - X)]$. The third summand (the credit market value) is $x^e \cdot F(d - X)$. Summing the three elements yields Equation 6. Setting $x = x^e$ yields Equation 5.

In the case where x^e is stochastic, and since the credit market is risk neutral, the revenue from the debt d is $R(d, X + x^e) = E_{s,x^e}[e^*(d, X + x^e, s)]$. Expanding the notion of "small project" to imply that any value in the whole support of x^e is small relative to the debt d, and since x^e is independent of s, we have $E_{x^e} \frac{\partial E_s[e^*(d,X,s)]}{\partial X} x^e = \frac{\partial E_s[e^*(d,X,s)]}{\partial X} E_{x^e}[x^e]$. Abusing notation and writing x^e instead of $E[x^e]$, all the calculations above remain the same. *QED*.

Theorem 2.

The government's ex ante utility under asymmetric information is:

$$\begin{aligned} U_{AI} &= \sum_{(x,y)\in GOV} (V(x, y; x^e) - 1) G((x, y)) \\ &= \sum_{(x,y)\in GOV} (x + \delta y + F \cdot (x^e - x) - 1) G((x, y)). \end{aligned}$$

Since $x^e = E[x|(x, y) \in GOV]$, then $\sum_{(x,y)\in GOV} (x^e - x) G((x, y)) = 0$. We thus have:

$$\begin{aligned} U_{AI} &= \sum_{(x,y)\in GOV} (x + \delta y - 1) G((x, y)) \\ &= \sum_{(x,y)\in GOV} (V(x, y) - 1) G((x, y)). \end{aligned}$$

This is, of course, less than the government's utility under symmetric information, $\sum_{(x,y)\in GOV_{CI}} (V(x, y) - 1) G((x, y))$, which involves the same summand but summed exactly over the set of points, GOV_{CI} where it is positive. *QED*.

Theorem 5.

First note that in any equilibrium, all the projects $h \in GOV$ that the government undertakes must generate the same monetary revenue $x_{gov}(h)$. Otherwise, there would exist a project $h \in GOV$ with $x_{gov}(h)$ above the average x^e. However, in that case, $V(x_{po}(h), y_{po}(h)) \geq V(x_{gov}(h), y_{gov}(h)) > V(x_{gov}(h), y_{gov}(h), x^e)$, implying that the government would be better off privatizing it – a contradiction. Thus, in any equilibrium, GOV is either empty or there exists some x^1 such that for all $h \in GOV$, $x_{gov}(h) = x^1 = x^e$.

Since $x^1 = x^e$, there are no cross-subsidies between projects undertaken by the government: $V(x_{gov}(h), y_{gov}(h), x^e) = V(x_{gov}(h), y_{gov}(h))$ for all $h \in GOV$. Thus, $h \in GOV$ implies $h \in GOV_{CI}$, i.e. $GOV \subset GOV_{CI}$.

We next show that x^1 must equal $\underline{x}$. By the definition of $\underline{x}$, and since $GOV \subset GOV_{CI}$, it cannot be that $x^1 < \underline{x}$. On the other hand, if it were the case that $x^1 > \underline{x}$, then for any project

$h \in GOV_{CI}$ with $x_{gov}(h) = \underline{x}$ we would have $V(x_{po}(h), y_{po}(h)) = V(x_{gov}(h), y_{gov}(h)) < V(x_{gov}(h), y_{gov}(h), x^e = x^1)$, implying that the government would be better off undertaking it – a contradiction.

Clearly, if GOV_{CI} is empty, then $GOV \subset GOV_{CI}$ is also empty. However, if GOV_{CI} is nonempty, it still can be the case that GOV is empty. For example, if there exists a potential project h with $x_{gov}(h) < \underline{x}$ such that $V(x_{gov}(h), y_{gov}(h)) < 1$ and $\max\{1, V(x_{po}(h), y_{po}(h))\} < V(x_{gov}(h), y_{gov}(h), x^e = \underline{x})$ then in any equilibrium in which GOV is nonempty (and thus $x^e = \underline{x}$), the government will prefer to undertake the project h. Note that to support an equilibrium in which GOV is empty, we must specify the market's belief regarding $x_{gov}(h)$ in the case that the government deviates and undertakes a project. Clearly, the belief that in the case of a deviation $x_{gov}(h)$ is the minimal one over all projects h in the distribution would do; in many cases other beliefs would also. *QED*

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