Financing Infrastructure in the Shadow of Expropriation*

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Abstract

We examine the optimal financing of infrastructure when governments can expropriate rents from private sector firms that manage infrastructure. While private firms need incentives to implement projects well, governments need incentives to limit expropriation. This double moral hazard limits the willingness of outside investors to fund infrastructure projects. Optimal financing contracts involve government guarantees to investors against project failure to incentivize the government to agree not to expropriate which improves private sector incentives and project quality. The contract also reflects several other features prevalent in infrastructure financing in practice such as government co-investment, tax subsidies, and development rights.

JEL: D82, G30, G32, G38, H20, H41, H54.

Keywords: double moral hazard, public-private partnerships, government guarantees, development rights.

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1 Introduction

Investment in infrastructure is known to contribute valuably to economic productivity and growth.[1] Yet, there are significant gaps in the financing of infrastructure all over the world. For instance, the 2017 Global Infrastructure Outlook provides estimates for infrastructure gaps between 2016 and 2040 that can be as high as $1.9 and $1.2 trillion in China and Brazil, respectively [see Katseff, Peloquin, Rooney and Wintner (2020)]. In the U.S., aging infrastructure reaching or beyond its average life expectancy, as shown in Figure 1, requires large investments to prevent breakdowns and collapses. For example, as of 2023, 36% of existing U.S. bridges needed replacement or repair, and almost 7% of them were classified as structurally deficient.[2] However, despite the centrality of infrastructure for the functioning of the country, the infrastructure investment gaps between 2016-2025 are estimated to be $2.1 trillion [see Tankersley (2021)].

One view is that there is insufficient private capital to fund these infrastructure needs. However, given the size of global capital markets and the impact of infrastructure on economic growth, this seems difficult to fully reconcile. Hence, we entertain the alternate view that it may be difficult for private capital to ensure its returns from infrastructure projects are adequate even if the underlying returns on infrastructure are sufficiently high.

Why might this be the case? A proximate cause, we argue, is the risk of expropriation of project returns by the government. Governments tend to opportunistically limit user fees that can be charged by private operators who build and manage infrastructure; for instance, governments can limit tariffs or give "toll holidays" to appease the voting public. Indeed, with some exceptions, user fees on infrastructure are invariably at subsidized levels well below marginal costs.[3] Additionally, governments may reduce the cash flows received by the private sector through changes in ownership (such as privatizations or early termination of concessions) or through regulatory changes (such as unexpected phasing out of technology);

[1] Aschauer (1989) finds that core infrastructure investments have significant explanatory power for the productivity of the economy. Barro (1990) provides international evidence that *"the typical country comes close to the quantity of public investment that maximizes the growth rate."* Rioja (2013) shows that investment in existing public infrastructure can have a positive effect on GDP (using Latin American countries as the context). Roller and Waverman (2001) show that an increase in the penetration rate of telecommunications generated significant aggregate economic output in twenty OECD countries over the period 1970 to 1990. Finally, Gibson and Rioja (2020) note that *"public infrastructure is one of the foundations for the economic growth of a country"* and show that, irrespective of how infrastructure investments are financed, they lead to significant welfare effects.

[2] See the American Road and Transportation Builders Association report, https://artbabridgereport.org/, last accessed April 8, 2024.

[3] See Alm (2010), Butler, Fauver and Mortal (2009). Lewis and Bajari (2014), Liu and Mikesell (2014), and Gardner and Henry (2023) .

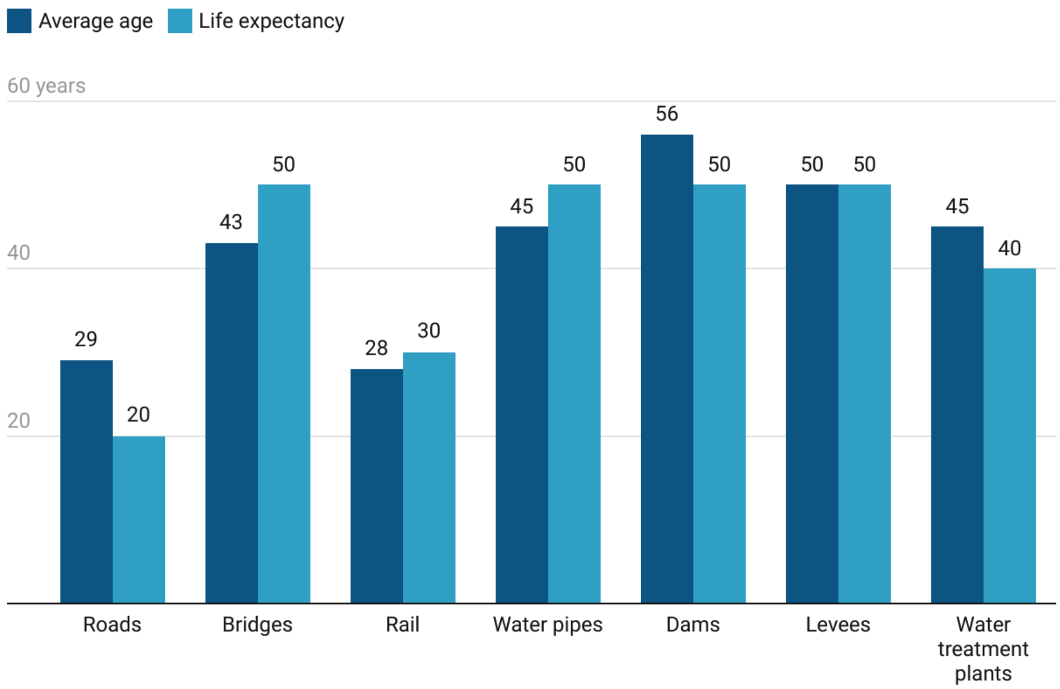


Figure 1: Average age and life expectancy of infrastructure in the United States as of 2022.

Source: American Society of Civil Engineers, https://infrastructurereportcard.org/, reproduced from Chinowsky (2021).

such changes by the government are often motivated by politics or regulatory capture.[4] Regardless of its form and motivation, we refer broadly to the possibility of the government's rent extraction from the private sector as *expropriation risk* and theoretically analyze how infrastructure should be financed in the shadow of such expropriation risk.

Our model embeds an important starting observation that, in contrast to other types of private and public investment, typical infrastructure financing is structured most commonly as public-private partnerships. Distinctively, infrastructure projects involve (i) the government, (ii) private sector operators that build and manage, and (iii) private outside financiers who supply financing. The model features these three players with investments in an infrastructure project funded by private financiers and potentially also co-investment by the government, provided that their opportunity cost of capital is met by the expected repayments. The payoffs from the project are distributed among the three participating parties according to contracts between the private parties and the government. The operator's compensation is determined by an *operational*

[4]See the 2015 World Economic Forum report on strategic infrastructure (pp. 14-18).

contract while the financiers are compensated according to a *financial contract*, contracts whose incentive-efficient design is the focus of our analysis.

Whether the private investors' rationality constraint is met or not depends on the efforts expended by the other two players. The operator develops, maintains, and shapes the project's quality with her input. Given her private benefits from shirking [Jensen and Meckling (1976)], the operator will only provide inputs at the efficient level if she has incentives to do so. The government in turn has incentives to expropriate the project's cash flows once realized (divert, retroactively tax, restrict price-setting, etc.) as it has direct and indirect benefits from doing so. Such expropriation of economic rents by the government weakens the private-sector operator's incentives. However, the government can choose to limit expropriation in the operational contract (agreeing contractually to reasonable user fees, e.g.) provided it has the incentives to do so given its financial contract with the infrastructure's financiers. We assume that conditional on authorizing the infrastructure project and arranging its financing and operation, the government is not productive nor necessary to operate the project. From this perspective, we think of rents that accrue to the government as a result of its coercive rights to tax or extract cash flows. This is what we interpret as expropriation in the context of our model.

Our main contribution is to characterize the optimal infrastructure financing contract in the presence of this *double moral hazard* problem – the confluence of the private sector and government moral hazards.[5] The second-best contract maximizes the expected profit from the infrastructure investment subject to the individual rationality constraints of financiers and the government, and the incentive compatibility constraints of the operator and the government. The principal insight that emerges from the solution to this constrained optimization problem is that if the moral hazard of the private sector is more severe, then so is the government's moral hazard in that its incentives to expropriate become stronger. In other words, the strength of the double moral hazard is intimately linked to the strength of the private sector moral hazard. This is because a stronger private sector moral hazard requires the government to leave more cash flows for the operator to achieve efficiency; in so doing, however, fewer resources are available to repay the financiers, which limits the scale (*intensive margin*) and potentially also the feasibility (*extensive margin*) of the infrastructure

[5] Evidence cited for developed economies in Footnote 2 is elaborated in Section 6, where we document as well – in the context of highway and power plants in India – that private and public moral hazards seem to be prevalent features in infrastructure projects also in developing economies.

project.[6] We show that to ameliorate the resulting inefficiencies in feasibility and scale, the optimal design of infrastructure financing features the following salient characteristics:

1. **Government guarantees** to financiers against project failure. Such guarantees expose the government to the risk of project failure and if sufficiently high induce it to commit in the operational contracts to not expropriate, which in turn improves the private sector's incentives to provide effort. This way, government guarantees to financiers expand the overall size of the project's cash flows, including to repay financiers. The extent of commitment over fiscal resources that the government can set aside for the provision of such guarantees naturally affects the feasibility and the scale-up to which infrastructure projects will be funded by private financiers. An implication is that while government guarantees might be more desirable in emerging market economies, they might be visible more commonly in developed economies due to their greater fiscal feasibility.

2. **Co-investment** between the government and the private sector. Such co-investment arises, however, only when the return of the infrastructure project is high relative to the severity of the double moral hazard. On the one hand, investment by the government reduces the resources available to provide guarantees to financiers; this makes it harder for the government to internalize the failure of the infrastructure project and agree to limit expropriation. On the other hand, government investment increases the scale and therefore the payoff from the infrastructure project available to repay private financiers relaxing their participation constraint. This trade-off implies that when the double moral hazard is severe, government guarantees are more valuable than government co-investment in financing the project; however, when the severity of the double moral hazard is low, co-investment by the government can dominate the provision of guarantees.

In effect, the model delivers a pecking order as to how the government should use its limited fiscal resources to improve the efficiency of infrastructure financing and project outcomes. In particular, when the double moral hazard is severe, it employs government guarantees only, but as the moral hazard's severity declines, it switches gradually to include co-investment.

[6] The lack of willingness on the part of financiers to fund infrastructure arises in our model even absent any risk-premium considerations; it arises purely due to the impact of the private sector and government moral hazard problems on the expected cash flows from infrastructure projects.

To show the robustness of the analysis in the baseline model, we analyze several practically relevant extensions. Our first extension considers a costly state verification game between financiers and the government. This extension microfounds the minimum return "coupon" required by financiers in the event of project success to participate in the infrastructure project. Second, we introduce limited commitment for the government in its contract with financiers. This limited commitment arises from (unmodeled) costs associated with renegotiating or defaulting on financial contracts that can have reputational consequences with the suppliers of capital and inflict collateral damage on the domestic financial sector.[7] Third, to consider how the risk of expropriation and not just the threat of it affects the optimal financing contract, we allow for government expropriation to occur in equilibrium. We do so by considering the random enforcement of operational contracts, the probability of which captures the strength of the institutions governing contracts (such as the independence of the judiciary). Finally, we consider how externalities that accrue to the government (growth multipliers, for example) or the private parties (real-estate development, for example) affect the financing of infrastructure projects. We show that these additions to the model imply that the optimal infrastructure financing contract will in general feature tax subsidies and accordance to private parties of development rights around the infrastructure, as observed in practice.

Our paper relates to three important strands of literature: first, on the implications of expropriation by governments on growth; second, on infrastructure financing in the context of public-private partnerships; and, third on the specific framework we employ to study infrastructure financing, viz., double moral hazard.

A small but growing literature on sovereign debt explores how the risk of expropriation and lack of commitment by governments affects economic outcomes. Aguiar, Amador, and Gopinath (2009a, b) and Aguiar and Amador (2011) extend the Myers (1977) idea of debt overhang in a neoclassical model of investment and growth, showing that in the presence of sovereign debt, there is a natural ex-post risk of expropriation by governments; this reduces ex-ante sovereign debt capacity and investment and myopic governments can adversely affect the level of, or the rate of convergence to, the steady state endowment of the economy. Gourinchas and Jeanne (2013) attributes weak growth rate associated with higher (foreign) sovereign debt

[7] The sovereign debt literature justifies such costs theoretically [Eaton and Gersovitz (1981), Sandleris (2008), Broner, Martin and Ventura (2010), Bolton and Jeanne (2011), Acharya, Drechsler and Schnabl (2014), Farhi and Tirole (2018), among others] and provides some empirical support [see Basu (2009), Acharya et al. (2014), Gennaioli, Martin and Rossi (2014)]. Nevertheless, government commitment to repay is argued to be potentially ineffective from a theoretical standpoint [notably in Bulow and Rogoff (1989a,b)] and also found to be limited empirically [e.g., Eichengreen (1987) and Arellano (2008)].

to correlated underlying conditions of these economies that can also result in a poor investment environment. In Acharya and Rajan (2013) and Acharya, Rajan and Shim (forthcoming), technology is owned by the private sector and governments are not only myopic but endowed with a preference for wasteful diversion and expenditures; sovereign debt can lengthen government horizons and even produce growth boosts in some cases, but otherwise lead to economic and/or financial repression of private investments. DeMarzo, He and Tourre (2023) examines myopic governments with limited commitment and ability to trade dynamically in debt markets, wherein patient citizenry is left worse off as a result of sovereign debt ratcheting; the underlying cash flow (income) structure is, however, exogenous to debt dynamics.

Our paper is related to this important strand but differs in significant ways. Unlike this literature, we focus on infrastructure and hence consider public-private partnerships rather than investments that are entirely public or private. In our setting with a public-private partnership, expropriation by governments aggravates private sector moral hazard, amplifying the impact on cash flows and in turn the willingness of financiers to fund projects. Furthermore, we take limited sovereign debt capacity as given but ask the question of how it can be used in an incentive-efficient manner to finance public-private partnerships in infrastructure. This way, our framework not only helps understand why the risk of expropriation can limit the scale and feasibility of infrastructure financing, but it also shows that the second-best contract maps into the institutional details prevalent in infrastructure financing.

Secondly, the existing theoretical literature on infrastructure financing mostly focuses on partnerships between the private and public sectors either as co-owners/co-managers of the projects or as co-investors. In Perotti (1995) partial privatization allows the government to credibly signal that it will not behave opportunistically upon privatization (such as decreasing or even eliminating tolls, once the toll highways are privatized). The government's behavior is determined by its type and it cannot be incentivized not to misbehave–there is no moral hazard. Hence, privatization serves as a way of revealing the government's private information. Relatedly, Martimort and Sand-Zantman (2006) considers the classic infrastructure problem in which the government can deliver a public good or service under public ownership or outsource the activity to the private sector. They examine the optimal delegated management contract when the government has private information about the project's quality and the private sector's effort is not verifiable.[8]

[8]More recently, Fay, Martimort and Straub (2021) provide conditions under which both public and private finance of infrastructure projects coexist in a costly state verification contracting model.

In both of these papers, the ownership structure of the project partially resolves a problem of asymmetric information between the government and the private sector. In contrast, we abstract from asymmetric information and instead consider how infrastructure financing should be optimally designed given that the government has incentives to expropriate upon project completion (which weakens incentives of operators who build and maintain infrastructure), but the government can commit not to do so by using its limited fiscal resources in a state-contingent manner. To emphasize the implications of the double moral hazard on the financing of infrastructure projects, we take the need for delegated management as given.[9]

Finally, our double moral hazard model of infrastructure financing is an application of the literature of contracting under agency problems [see Tirole (2006) and Bolton and Dewatripont (2004) for textbook analyses]. More specifically, contracts under double moral hazard are considered, for example, in Repullo and Suarez (1998), Hellmann and Puri (2000), Casamatta (2003), and Inderst and Mueller (2009) in the context of venture capital; in Cooper and Ross (1985), Eswaran and Kotwal (1985), and Demski and Sappington (1991) as applied to product warranties, agricultural risk-sharing arrangements and labor buyouts, respectively; and in Tirole (2003) for looking at foreign lending, among others. These papers focus mostly on the risk-sharing features of the contracts. Surprisingly, there is only a sparse literature focused on providing the agency-theoretic foundations of infrastructure financing when there is a risk of expropriation by governments which endangers private sector participation and can explain the observed infrastructure gaps globally. Our paper fills this important gap.

2 Model

In this section, we develop our baseline model of public-private partnership in the shadow of expropriation to understand how double moral hazard, in particular the interaction between the government's moral hazard and the private sector's moral hazard, affects the private financing of infrastructure projects.

We consider an infrastructure project to be run by a private-sector project operator, to whom we will refer simply as the "operator". The project can be financed by private investors (or financiers) and the

[9] Another part of the literature has focused on the implications of jointly owned investment options. Banerjee, Gucbilmez and Paulina (2014) provide a real-options framework to investigate the optimal investment timing in the presence of such joint ownership, bargaining, and side payments. On the private equity and venture capital front, recent empirical research by Andonov, Kraussl and Rauh (2021) suggests that infrastructure assets display cash flow properties akin to private equity investments. They report that public institutional investors implicitly subsidize infrastructure investments in a significant way.

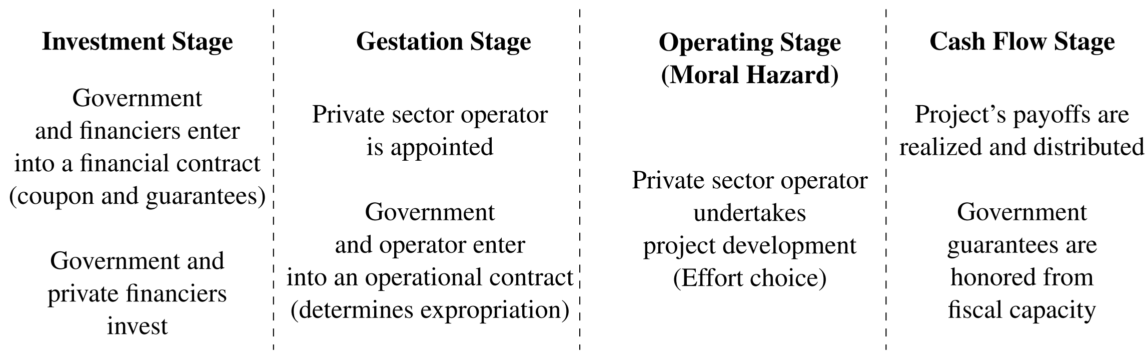


Figure 2: Timeline of the model

government. The project has constant returns to scale up to a maximum scale $\bar{I}$.[10] We denote by I_f and I_g the amounts invested by the financiers and the government, respectively, where the total scale of the project is $I \equiv I_f + I_g \leq \bar{I}$. We will refer to this as the Maximum Scale or MS constraint. The project is risky and has a per unit payoff of $R > 1$ if it is successful and zero otherwise.

As shown in Figure 2, the project is implemented over four stages: an *investment* stage, a *gestation* stage, an *operating* stage, and a *cash flow* stage. First, in the investment stage, a – possibly state contingent – *financial contract* between the financiers and the government is determined and the financiers and the government then invest in the project. Then, in the *gestation* stage, an operator is appointed and an *operational contract* between the government and the operator is determined. In the operational contract, the government agrees to a fraction of the project return to be shared with the operator, this is effectively its expropriation policy as the residual project return is diverted by the government. Next, in the *operating* stage, the operator chooses the effort level while developing the project and the project's outcome – success or failure – is determined. Finally, in the *cash flow* stage, the project's payoffs are realized and distributed among the involved parties according to the financial and operational contracts.

The operator's effort choice and the government's expropriation threat in the operating stage lead to a *double moral hazard* problem, which is at the center of our analysis. More specifically, the operator can affect the probability of the project's success, which we model along the lines of Holmstrom and Tirole (1998). If the operator exerts high effort and provides a high input, the project's probability of success is $p_h \in (0,1)$, else it is p_l, where $0 < p_l < p_h$. We denote by Δp the difference in these probabilities:

[10]We microfound this limit in an extension in Section 4.2.

$\Delta p \equiv (p_h - p_l)$ and we assume that $p_l R < 1 < p_h R$ so that the project is worth pursuing only if the operator exerts high effort and provides a high input. Moreover, if the operator does not exert high effort, she derives a non-pecuniary benefit of BI, where $B > 0$. We assume that the effort exerted by the operator is not observable and therefore the operator is subject to a moral hazard problem in the operating stage.

Additionally, in the operating stage, the government can expropriate the project's cash flows from the operator and keep them to itself. For example, the government can limit tariffs or give "toll holidays" to appease the voting public. However, the government can choose not to expropriate a given amount of the project's return from the operator by agreeing to "user fees" $R_o I$ in the operational contract signed at the preceding gestation stage. If the government expropriates all the funds from the operator upon the project's success, it receives a payoff of CI in the cash flow stage, which can be positive or negative. The higher the C, the more costly it is for the government not to expropriate. $C > 0$ implies the government receives benefits from expropriation, for example by lowering user fees below their marginal cost or increasing the likelihood of reelection. On the other hand, $C < 0$ implies the government faces costs from expropriating, which can stem for instance from a worsened reputation due to an increased concern about its counterparty risk in operational contracts ("ease of doing business"). Whether the net benefit of expropriation for the government is positive or negative depends on the quality of institutions in the country and the independence of the judiciary in arbitrating contract disputes. In general, one can think of $C > 0$ as infrastructure being developed in economies where political and reelection concerns tend to dominate any potential punishment from contractual breaches that the government faces from expropriation, and $C < 0$ as infrastructure being developed in economies with stronger institutions. Importantly, it is the government's discretion whether to expropriate and it cannot be forced into any specific contract. Hence, the government will agree not to expropriate only if it has the incentive to do so. In this sense, the possibility of government expropriation is akin to the government facing a moral hazard problem in the operating stage.

In each state of the world at the cash flow stage, financiers are paid out from the project's return and possibly also by the government as per the financial contract. The payment to financiers in the event of the project's success $R_f I$ can be considered a "coupon". The payment to financiers in the event of the project's failure $K_g I$ can be considered a government "guarantee". The guarantee compensates the financiers in part for their anticipated loss of return in case of an eventual project failure, which is more likely if the government engages in expropriation and induces low effort by the operator.

The government has fiscal resources $\overline{K}_0$ available in the investment stage, of which it uses I_g to invest directly in the infrastructure project and saves the rest to make payments to financiers. Additionally, the government has fiscal resources $\overline{K}_1$ available when the payoffs of the project are realized and these can only be used to pay financiers.

The payoffs from the infrastructure contracts are distributed among the financiers, the government, and the operator are denoted as follows: If the project succeeds, the financiers receive a payoff $R_f I$, the operator receives a payoff $R_o I$, and the government receives the residual payoff from the project, $R_g I$, where $R_g \equiv (R - R_f - R_o)$. The fiscal implications for the government are accounted for separately as follows. If the project fails, the financiers receive $K_g I$, the government receives $-K_g I$, and the operator receives no payoff. The resulting state space of outcomes for the project, the project's payoff, and the payoffs to the various parties (the financiers, the operator, and the government) are summarized in Figure 3.

Finally, we assume that both the financiers and the government require an ex-ante (date 0) net expected rate of return $r > 1$ on their respective investments in the project and financiers require a minimum gross ("coupon") return $\underline{R}I$ if the project succeeds in the operating stage. We provide a microfoundation for $\underline{R}$ in an extension in Section 5.1. To keep the analysis as general as possible within the simple structure of the model, we make the following parametric assumptions on $\overline{I}$, $\underline{R}$, and C:

Assumption 1. *a) (Maximum project scale) The maximum scale of the project is larger than the scale that could be attained if the government invested all its fiscal resources in the infrastructure project and pledged all its fiscal resources in the cash flow stage as guarantees while paying financiers their minimum required repayment in the event of success, i.e.,* $\overline{I} \geq \overline{K}_0 + \frac{(1-p_h)\overline{K}_1 + p_h \underline{R}\overline{I}}{r}$.

b) (Minimum repayment for financiers) The minimum repayment required by the financiers in the event of success is not sufficient to incentivize them to invest, i.e., $\underline{R} < \frac{r}{p_h}$.

c) (Government's payoff from expropriation) The government's payoff from expropriation is high enough to give rise to double moral hazard, i.e., $C > -\frac{B}{\Delta p}$.

Two assumptions of our model are worth discussing further: the government's moral hazard and the absence of government guarantees for the operator in the event of the project's failure.

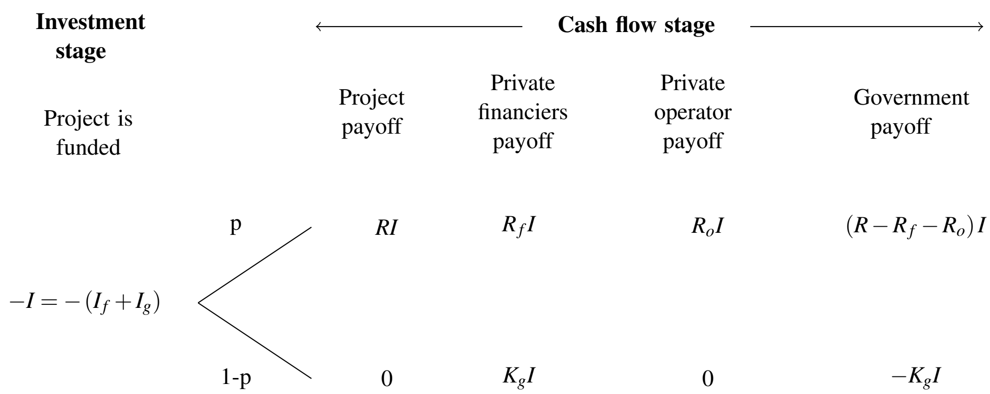


Figure 3: State space of possible outcomes and corresponding payoffs for various economic agents.

Government's moral hazard. The government's ability to choose "user fees" in the operational contract is what leads to the government's moral hazard problem. If the government could be forced to agree to any user fees ex ante, the second-best contract would leave just enough of the infrastructure project's return for the operator to exert high effort and the remaining return to the financiers to incentivize them to finance the project. Effectively, this is akin to the infrastructure project being entirely private. In this case, as we show formally in Section 3.1, the project's scale would not be restricted whenever it is feasible and the private moral hazard would solely affect the region of parameters in which the project is feasible.

Guarantees to the operator. In our model setup, we set the payoff to the operator in the event of project failure to zero. Suppose instead we allow the government to give a guarantee to the operator in the event of project failure. Since all guarantees are funded by the government's fiscal resources $\overline{K}$, offering a guarantee to the operator implies that fewer resources are left to offer a guarantee to the financiers, generally leading to a smaller project scale. Moreover, a guarantee to the operator exacerbates her moral hazard problem and requires a higher payoff to the operator when the project succeeds, again reducing the resources left to offer to the financiers. Therefore, the optimal contract sets guarantees to the operator in case of project failure to zero and our assumption is without loss of generality.[11]

[11] Medda (2007) argues in the case of large-scale public-private partnerships if the guarantees provided exceed the potential financial losses of the operator, it can lead to strategic behavior and problems of moral hazard emanating from the guarantees. In our model, the government provides guarantees to financiers and *not* to operators.

3 Analysis

We are interested in the socially optimal (i.e., constrained efficient) contract that is feasible given the double moral hazard introduced in the previous section. In the analysis that follows, we consider in turn the two incentive compatibility constraints (one each for the operator and the government), the two individual rationality constraints (one each for the financiers and the government), and the government's no-default conditions on the financial contract given its fiscal capacity and default costs.

Incentive compatibility for the operator. The operator will exert effort as long as the expected payoff from exerting high effort is not dominated by the expected payoff (inclusive of the private benefits) from exerting low effort. If the project is successful, the operator receives a payoff R_oI. If the operator exerts high effort, the probability of success of the project is p_h. Otherwise, the probability of success is p_l and the operator experiences additional private benefits BI. Therefore, the incentive compatibility constraint of the operator is given by

$$p_hR_oI \geq p_lR_oI + BI \; . \tag{ICO}$$

The operator's incentive compatibility constraint imposes a limit on the amount the government can expropriate from the operator while implementing the high effort. To see this, note that the incentive compatibility constraint ICO can be written as the following familiar Holmstrom and Tirole (1998) condition:

$$R_o \geq A_o \equiv \frac{B}{\Delta p} \; ,$$

where A_o represents the agency rent of the operator, i.e., the minimum return required by the operator in the event of project success to exert high effort.

Incentive compatibility for the government. The government will never agree to give the operator more than A_o to induce high effort. Moreover, if the government sets R_o less than A_o the operator will not exert effort and the probability of success of the project will be p_l. Therefore, the government will give nothing to the operator if it expects her to exert no effort. Thus, the government will agree not to expropriate A_o and implement p_h by the operator if the following incentive compatibility constraint is satisfied:

$$p_hR_g - (1-p_h)\,K_g \geq p_l\,(R - R_f + C) - (1-p_l)\,K_g, \tag{ICG}$$

where $R_g = (R - A_o - R_f)$ is the government's maximum payoff from the project's cash flows that induces the operator to exert high effort. If the government does not expropriate A_o from the operator, it receives a return R_g with probability p_h and has to pay guarantees K_g to the financiers with probability $(1 - p_h)$. This expected payoff for the government has to be larger than that of expropriating. If the government engages in the expropriation of A_o and does not induce high effort, it receives with probability p_l the project's return net of the return promised to financiers plus the government's benefit from expropriating and with probability $(1 - p_l)$ it has to pay guarantees to the financiers.

Hence, the benefit of expropriating for the government is receiving an additional payoff $[(R - R_f + C) - R_g] = A_0 + C$ with probability p_l. This comes at the cost of reducing the probability of project success by Δp. Hence, one can rewrite the ICG as follows:

$$K_g + R_g \geq A_g \ ,$$

where $A_g \equiv \frac{p_l(A_0+C)}{\Delta p}$ represents the "agency rent" of the government. Note that Assumption 1c guarantees $A_g > 0$ and will give rise to the double moral hazard at the center of our analysis.

The higher the return offered to the government in the event of success (R_g) or the higher the penalty for failing (K_g), the costlier it is for the government to let the project fail and the easier it is to incentivize it to not expropriate A_o from the operator. Since a higher R_f reduces the return for the government when the project succeeds, there is a clear difference between the two ways in which financiers can be compensated: guarantees K_g ameliorate the government's moral hazard while shared returns R_f exacerbate it.

Participation constraint for financiers. The financiers must also be left with an adequate share of the project's payoff plus expected guarantees to be willing to finance the infrastructure project. The financiers' expected share of the project's payoff, $p_h R_f I$, and the expected value of the government guarantee, $(1 - p_h) K_g I$, together need to compensate them for an adequate rate of return on their investment in the project. This yields the financiers' individual rationality constraint:

$$rI_f \leq p_h R_f I + (1 - p_h) K_g I \tag{IRF}$$

or substituting $I = I_f + I_g$ and rearranging

$$\frac{r}{(1-p_h)}\frac{I_f}{(I_f+I_g)} \leq K_g + \frac{p_h}{(1-p_h)}R_f \, .$$

Participation constraint for the government. At the time of investment, the government also has to have incentives to participate in the financial contract with the financiers and undertake the infrastructure project. The individual rationality constraint for the government states that the expected payoff from the project has to be greater than the government's outside option. Formally,

$$[p_h R_g - (1-p_h) K_g] I \geq r I_g \, . \tag{IRG}$$

Feasibility constraints for the government. The government's fiscal resources impose limits on the terms of the financial contract to which the government can credibly agree. More specifically, the promised payments to the financiers, guarantees, and shared returns, must meet the government's ability-to-pay constraint. Formally, the payment $R_f I$ to the financiers and the government guarantee $K_g I$ need to satisfy

$$R_f I \leq (R - A_o) I + \overline{K}_0 + \overline{K}_1 - I_g \quad \text{and} \tag{NDR}$$

$$K_g I \leq \overline{K}_0 + \overline{K}_1 - I_g \, . \tag{NDK}$$

Note that we allow the government to use its idle fiscal capacity to repay the financiers regardless of whether the project is successful. Therefore, in principle, one could have $R_f > (R - A_o)$.

Finally, the government's investment I_g cannot exceed its available fiscal resources in the investment stage, i.e., $I_g \leq \overline{K}_0$. This constraint limits the scale of the investment by limiting the amount the government can invest and by partly restricting the size of the guarantees provided by the government to the financiers.

3.1 Benchmarks

Before characterizing the second-best contract, we briefly discuss how the moral hazards of the operator and the government, each in isolation, affect the financing contract. These benchmarks highlight the importance of their interaction – the double moral hazard – in leading to the results that follow.

3.1.1 No government moral hazard; only private sector operator moral hazard

Suppose the government has no incentives to expropriate, i.e., that its expropriation rent $A_g = 0$. This is equivalent to setting the government's payoff from expropriating C to $-A_o = -\frac{B}{\Delta p}$ where $B > 0$. Then, the only friction in the model is given by the moral hazard of the operator who will be willing to exert high effort as long as she receives $R_o \geq A_o$. Moreover, financiers will invest in the project only if $R_f \geq \frac{r}{p_h}$.

Proposition 1. ***(No government moral hazard)*** *When $A_g = 0$ and $B > 0$, the operator's moral hazard on its own limits the feasibility of the infrastructure project but not its scale.*
a. ***(Feasibility)*** *If $(R - A_o) < \frac{r}{p_h}$, the project is not funded even when it is efficient to do so, i.e., when $R > \frac{r}{p_h}$.*
b. ***(Scale)*** *If $(R - A_o) > \frac{r}{p_h}$, the project is funded, the scale of the project is maximal, i.e., $I_f = \bar{I}$, and the distribution of investment between the financiers and the government is indeterminate. Furthermore, the project can be undertaken at its maximal scale without government guarantees.*

The proposition above shows that the operator's moral hazard creates inefficiencies only on the extensive margin of the project since some low-return infrastructure projects are not undertaken even if their NPV is positive, i.e., $p_h R > r$ but $(R - A_o) < \frac{r}{p_h}$. For these projects, the return would be enough to compensate the financiers and government but there would not be enough left to incentivize the operator to exert high effort. However, once the project's return is high enough to compensate the financiers and the government for their outside option and the operator for the effort cost, the scale of the project is maximal.

3.1.2 No private sector operator moral hazard; only government moral hazard

Suppose that the government's moral hazard is the only friction in the economy. This is equivalent to setting $B = 0$ and $C > 0$. In this case, the government's expropriation does not affect the probability of success of the project.

Proposition 2. ***(No private sector operator moral hazard)*** *When $B = 0$ and $A_g > 0$, the government's moral hazard on its own does not affect the feasibility nor the scale of the project.*
a. ***(Feasibility)*** *If $R > \frac{r}{p_h}$, the project is funded.*
b. ***(Scale)*** *If the project is funded, the scale of the project is maximal, i.e., $I = \bar{I}$, and the distribution of investment between the financiers and the government is indeterminate. Furthermore, the project can be*

undertaken at its maximal scale without government guarantees.

When the government's moral hazard is the only agency problem in the economy, the financing of the infrastructure project is efficient, that is, the project is always financed when it has a positive NPV and the scale is always maximal. Without private moral hazard, the expropriation policy of the government does not affect the probability of success of the project nor the incentives of the financiers to fund it (given we assume that there is commitment on the financial contract).

In contrast to these benchmarks, we show that when *both* the operator's moral hazard and the government's moral hazard are present, they interact and the resulting double moral hazard problem affects the optimal financing contract in intricate ways, helping us relate to several features that are observed in infrastructure financing practices.

3.1.3 Link between operator's and government's moral hazard

A high agency rent for the operator A_o implies that *both* moral hazard problems in infrastructure financing are severe – the operator moral hazard (effort aversion) as well as the government moral hazard (expropriation). When A_o is high, it is tempting for the operator to reap the private benefits of providing low effort. In this case, the operator requires a high payoff to be incentivized to exert high effort. In turn, this implies that the opportunity cost of the government of expropriating is low, or equivalently, the payoff to the government from expropriating is high. Formally, the agency rent of the government $A_g \equiv \frac{p_l(A_o+C)}{\Delta p}$, is increasing in A_o and so is the severity of the government's moral hazard. Note that even when the government has no benefit from expropriating, i.e., $C = 0$, the ability of the government to expropriate gives rise to moral hazard for the government whenever $B > 0$.

3.2 Optimal financing contract

While the model is conceptually easy to understand, there are multiple linear constraints that lead to many cases to be considered when characterizing the optimal financing contract. For the sake of clarity, we focus on the economic properties of the solution and relegate all technical details to the Appendix.

The objective of the planner is to choose a financing contract, inclusive of government investment, to maximize the net present value of the infrastructure project, $[p_h R - r]\,I$, that is, its expected payoff net of the cost of investment (as all other payoffs are simply transfers between the government and the private sector), subject to the constraints above:

$$\max_{I_g \in [0,K_0],\, I_f \geq 0,\, K_g \geq 0,\, R_f \geq \underline{R}} \left(p_h R - r\right)\left(I_g + I_f\right)$$

subject to

$$\left(1-p_h\right)K_g + p_h R_f \geq r\frac{I_f}{I_f+I_g}, \tag{IRF}$$

$$\left(1-p_h\right)K_g + p_h R_f + r\frac{I_g}{I_f+I_g} \leq p_h\left(R-A_o\right), \tag{IRG}$$

$$K_g + \left(R - A_o - R_f\right) \geq A_g, \tag{ICG}$$

$$K_g\left(I_f+I_g\right) \leq \overline{K}_1 + \overline{K}_0 - I_g, \tag{NDK}$$

$$R_f\left(I_f+I_g\right) \leq \left(R-A_o\right)\left(I_f+I_g\right) + \overline{K}_1 + \overline{K}_0 - I_g, \quad \text{and} \tag{NDR}$$

$$I_g + I_f \leq \bar{I}, \tag{MS}$$

where $A_g \equiv \frac{p_l(A_o+C)}{\Delta p}$ is the agency rent of the government and we used that the payoff of the operator is set just high enough to incentivize her to exert effort, i.e., $R_o = A_o$, and that $R_g = (R - A_o - R_f)$.

The total scale of the project is limited by the ability-to-pay constraints of the government in the financial contract, stated in the no-default conditions NDR and NDK. Note that the NDR constraint cannot bind as that would violate the government's individual rationality constraint IRG. Hence, unless the scale of the project is maximal, the government's no-default condition on its guarantees will be binding, i.e., I satisfies

$$I = \min\left\{\frac{\overline{K}_1 + \overline{K}_0 - I_g}{K_g}, \bar{I}\right\}.$$

The expression above shows that the total scale of the project is determined by the promised payments to the financiers in the event of default (government guarantees), which in turn need to satisfy the individual rationality constraint of the financiers, IRF, and the incentive compatibility constraint of the government, ICG. A key result is that the interaction between the moral hazard of the operator and the moral hazard of the government shapes the constrained-efficient financing contract and imposes limits on the feasibility and scale of the infrastructure project. The proposition below characterizes the resulting inefficiencies:

Proposition 3. ***(Inefficiency of double moral hazard)*** *The double moral hazard affects* _both_ *the feasibility and the scale of the infrastructure project:*

a. ***(Feasibility)*** *There exist thresholds $\underline{\Gamma}$, $\overline{\Gamma}$, and $\Gamma^{\star}$, where $\overline{\Gamma}$ and $\Gamma^{\star}$ are increasing in the severity of the double moral hazard measured by the agency rents of the operator A_o and the government A_g, such that:*

i. If $(R-A_o)<\underline{\Gamma}$, the project is not funded even in the absence of any government moral hazard.

ii. If $\underline{\Gamma}\leq(R-A_o)<\overline{\Gamma}$, the project is not funded in the presence of government moral hazard.

iii. Otherwise, the project is funded.

b. ***(Scale)*** *If the project is funded, the optimal scale is weakly increasing in the project's return R and weakly decreasing in the severity of the moral hazard of the operator and the government, respectively measured by A_o and A_g. If $(R-A_o)>\Gamma^{\star}$, the scale of the project is maximal.*

The proposition shows that the double moral hazard problem imposes inefficiencies in the financing of infrastructure projects, either by rendering the projects infeasible (extensive margin) or by limiting their scale (intensive margin). The thresholds that determine the regions described in Proposition 3 (and in Proposition 4 below) are explicitly characterized in Table 1. As can be seen from these thresholds, the type and magnitude of these inefficiencies depend on the size of the project's return R relative to the severity of the moral hazards, measured by the agency rents of the operator A_o and the government A_g.

Next, note that when the project's return is low relative to the severity of the operator's agency rent, i.e., when $\underline{\Gamma}\equiv\frac{r}{p_h}>(R-A_o)$, it is not possible to incentivize the financiers to fund the project even if the government could agree in the operational contract to give its entire payoff from the project. In this case, the project is not funded, even without government moral hazard. Conversely, when the project's return is high enough to be funded in the absence of government moral hazard, i.e., $\underline{\Gamma}\leq(R-A_o)$, the government's moral hazard imposes further limits on the project's feasibility. In particular, for returns of the project such that $\underline{\Gamma}\leq(R-A_o)<\overline{\Gamma}$, the project is not funded when the government can expropriate the project's return but it would be funded otherwise.

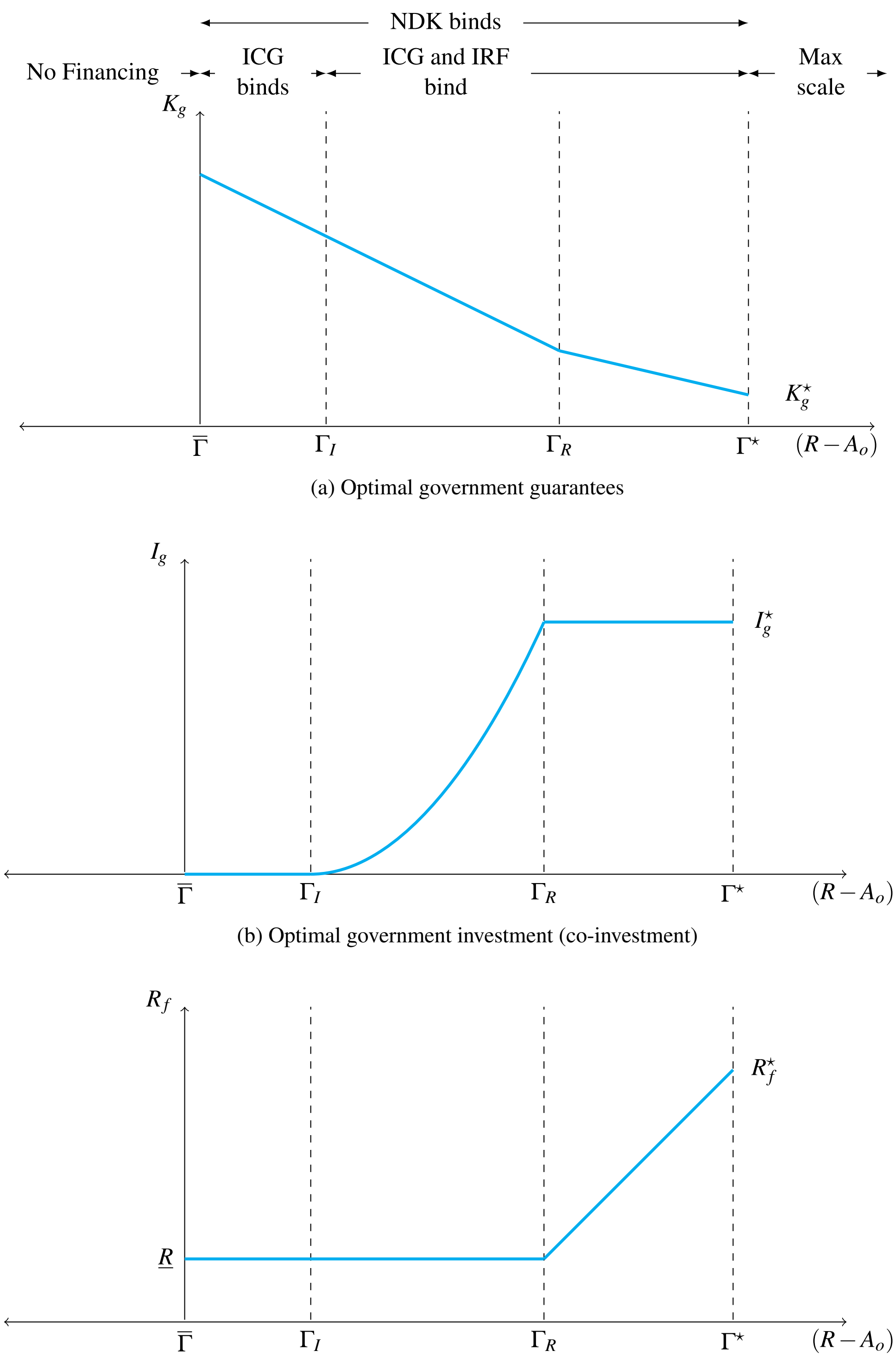
At even higher levels of the project's return, i.e., $\overline{\Gamma}\leq(R-A_o)$, the project is undertaken even in the presence of government moral hazard. However, government guarantees are needed for the project to be funded, i.e., $K_g > 0$, and the scale of the project is limited. In this case, as the severity of the operator's moral hazard decreases relative to the project's return, so does that of the government, and lower guarantees are needed to incentivize the government not to expropriate the entire project's return from the operator. Similarly, as the project's payoff increases, the government's payoff from expropriating decreases, and it can provide lower guarantees while still satisfying its incentive compatibility constraint. Eventually, when $(R - A_o) \geq \Gamma^{\star}$, the payoff from the project is high enough to sustain the the project's maximal scale, i.e., the contracting outcome entails no inefficiency.

Recall that there are two ways in which the financiers can be compensated for their investment in the infrastructure project, viz., government guarantees and a share of the project's return if it is successful and that they have opposite effects on the government's moral hazard. On the one hand, higher government guarantees ameliorate the government's moral hazard by increasing its costs if the project fails and incentivizing it to agree to higher user fees (R_o) in the operational contract. On the other hand, a larger share of the project's return assigned to the financiers increases the government's incentives to expropriate. Therefore, financiers receive a share of the project's return that is higher than the minimum they require only if the financiers' individual rationality constraint is binding.

Note also that the direct government investment (or co-investment) also affects the participation constraint of the financiers. As can be seen from constraint IRF above, the government's investment in the project relaxes the individual rationality constraint of the financiers: all else being equal, the larger the government investment, the greater the project scale, and therefore more resources there are to pay financiers. However, government investment also increases the cost to the government from participating, as seen from constraint IRG. Moreover, for each unit the government invests directly there is one less unit of resource available to provide guarantees to the financiers in the event of project failure, which makes it harder for the government to internalize the project's downside and decreases its incentives to induce high effort from the operator. In this case, government investment makes its moral hazard more severe. The optimal government investment reflects this trade-off. The following proposition characterizes the resulting pecking order of the tools used in the optimal financing contract:

Proposition 4. ***(Pecking order)***

There exist thresholds Γ_I, Γ_R, and $\Gamma^{\star}$, with $\Gamma_I < \Gamma_R < \Gamma^{\star}$,such that in the optimal infrastructure financing



(a) Optimal government guarantees

(b) Optimal government investment (co-investment)

(c) Optimal return to financiers

Figure 4: Optimal guarantee, government co-investment, and return to financiers as a function of the project's return net of agency rents for the operator, $(R - A_o)$.

$\underline{\Gamma}$	$\frac{r}{p_h}$
$\overline{\Gamma}$	$(1-p_h)A_g+\underline{R}$
Γ_I	$A_g-\frac{r-\underline{R}}{1-p_h}$
Γ_R	$A_g-\frac{(r-\underline{R})\overline{K}_1-\underline{R}r\overline{K}_0}{\left(r\overline{K}_0+(1-p_h)\overline{K}_1\right)}$
$\Gamma^{\star}$	$\frac{r}{p_h}+A_g-\frac{\overline{K}_1+r\overline{K}_0}{p_h\overline{I}}$

Table 1: Equilibrium thresholds

contract:

a. If $(R-A_o)<\Gamma^{\star}$, government guarantees K_g are positive and they are decreasing in $(R-A_o)$.

b. Government investment I_g is positive and weakly increasing in $(R-A_o)$ if $\Gamma_I<(R-A_o)<\Gamma^{\star}$. Moreover, $I_g=\overline{K}_0$ if $\Gamma_R\leq(R-A_o)<\Gamma^{\star}$.

c. The share of the project's return received by financiers R_f is strictly greater than $\underline{R}$ if $\Gamma_R<(R-A_o)<\Gamma^{\star}$.

d. If $(R-A_o)>\Gamma^{\star}$ the financing contract is not uniquely determined.

Figure 4 shows the optimal government guarantees, optimal government investment, and optimal return to financiers as a function of the project's return net of the operator's agency rent for the region in which the optimal contract is uniquely determined, i.e., $(R-A_o)\leq\Gamma^{\star}$. When $(R-A_o)\geq\Gamma^{\star}$, the project's payoff at the maximum scale is high enough to compensate financiers while also satisfying the incentive compatibility and individual rationality constraints of the government and the optimal contract is indeterminate.[12]

Government guarantees are positive ($K_g>0$) in the optimal financing contract when $(R-A_o)\leq\Gamma^{\star}$ and they decrease with the project's return net of the operator's agency rent $(R-A_o)$ whenever the optimal financing contract is uniquely determined. Whether the government invests in the project directly depends on the value of the optimal guarantee and the project's return p relative to the severity of the moral hazard. When $(R-A_o)$ is low, the incentive compatibility constraint of the government binds and the government's direct investment tightens the constraint by restricting the size of the government guarantees. In this case, it is optimal to set the government's investment to zero ($I_g=0$). As the project's return increases, it is easier to satisfy the government's incentive compatibility constraint with a lower guarantee, which leads to

[12]We provide a characterization of the optimal contract in this region in the Appendix and show that when the project's return is high enough, the project is feasible without government guarantees.

an increase in the scale of the infrastructure project. However, as the government guarantee becomes lower, the payoff shared with the financiers when the project succeeds needs to increase to satisfy the individual rationality constraint of the financiers. Therefore, it becomes optimal for the government to invest in the infrastructure project ($I_g > 0$). Once the government exhausts all its available resources to invest in the project directly, the financiers receive a share of the project's return when it succeeds that is greater than the minimum they require, i.e., $R_f > \underline{R}$, as financiers increase their investment to increase the project's scale.

3.3 Infrastructure Financing in Developed vs. Developing Economies

There are many differences between developed and developing economies. Two that are particularly important in the context of financing infrastructure in the shadow of expropriation are the (inverse) strength of the institutions governing the enforcement of contracts, and the fiscal resources of the government destined to infrastructure, respectively captured by C and the pair $\{\overline{K}_0, \overline{K}_1\}$ in our model.[13] As shown in Proposition 3, our model predicts that economies where the government has higher benefits from expropriation, and hence more severe government moral hazard, experience higher infrastructure gaps due to projects not being undertaken (decreased feasibility) or projects being executed at a lower scale. Moreover, the government's benefits C also affect the optimal infrastructure financing contract.

Proposition 5. ***(Government's benefit of expropriating)*** *The higher the government's benefit from expropriating, the higher the guarantees and the lower the coupon paid to the financiers in the optimal financing contract, i.e.,* $\frac{\partial K_g^\star}{\partial C} > 0$ *and* $\frac{\partial R_f^\star}{\partial C} \leq 0$.

As Proposition 5 shows, the higher C and therefore the more severe the government's moral hazard, the higher the guarantees needed in the optimal contract to incentivize the government to implement high effort by the operator and not expropriate. These higher guarantees make it easier to satisfy the individual rationality constraint of financiers so they can be incentivized to invest at a lower coupon. However, governments with high C usually have limited fiscal resources to devote to infrastructure projects, impacting the optimal financing contract.

Proposition 6. ***(Government's fiscal resources)*** *The government's fiscal resources increase the scale of the*

[13] All propositions in this section focus on the parameter region in which the optimal financing contract is uniquely determined, i.e., $(R - A_o) \leq \Gamma^\star$.

infrastructure project and how it is financed but do not affect its feasibility.

a. ***(Feasibility)*** *The feasibility of the project does not depend on the government's fiscal resources as long as they are positive, i.e.,* $\frac{\partial \overline{\Gamma}}{\partial \overline{K}_0} = \frac{\partial \overline{\Gamma}}{\partial \overline{K}_1} = 0$.

b. ***(Scale)*** *The government's fiscal resources increase the scale of the project and decrease the project's minimum return needed to attain the maximum scale, i.e.,* $\frac{\partial I^{\star}}{\partial \overline{K}_t} \geq 0$ *and* $\frac{\partial \Gamma^{\star}}{\partial \overline{K}_t} < 0$ *for* $t = 0, 1$.

c. ***(Timing)*** *The timing of the government's fiscal resources affects the level of government guarantees:*

- *i. Fiscal resources at the financing stage weakly decrease government guarantees, i.e.,* $\frac{\partial K_g^{\star}}{\partial \overline{K}_0} \leq 0$.
- *ii. Fiscal resources at the cash flow stage weakly increase government guarantees, i.e.,* $\frac{\partial K_g^{\star}}{\partial \overline{K}_1} \geq 0$.

Proposition 6 shows that, as one would expect, higher fiscal resources, $\overline{K}_0$ and $\overline{K}_1$, increase the infrastructure project's scale. Recall that the guarantees offered by the government determine the scale. However, the feasibility of the project does not depend on the fiscal resources of the government as long as these are positive. If the government has no fiscal resources to devote to infrastructure, only those projects that have a return high enough to compensate the operator and the government for their agency rents and the financiers for their opportunity cost would be undertaken, i.e., those with returns such that $(R - A_o) \geq \frac{r}{p_h} + A_g$.

The timing of the fiscal resources has differential effects on the optimal financing contract. On the one hand, higher fiscal resources at the financing stage $\overline{K}_0$ increase the amount the government can invest in the infrastructure project and, in doing so, decrease the guarantees needed to incentivize the government not to expropriate. On the other hand, higher fiscal resources at the cash flow stage $\overline{K}_1$ increase the guarantees that can be offered by the government when co-investment is maximal simply by expanding the resources available in the cash flow stage for co-investment.

Put together, Propositions 5 and 6 imply that while economies with higher benefits of expropriation benefit more from offering government guarantees, the inability of their governments to commit fiscal resources to infrastructure projects limits the guarantees that can be offered, further limiting the scale and feasibility of the infrastructure project. Put differently, while our model predicts developing economies to benefit more from offering higher guarantees to financiers, the lower level of their available fiscal resources can deter investment in infrastructure projects and increase the infrastructure gap. Taken to an extreme, if a government had no resources available to commit to infrastructure, one should only expect projects with very high returns to be undertaken without government guarantees.

4 Extensions

In this section, we extend our baseline analysis in several directions that demonstrate the robustness of the insights developed in Section 3 and also allow us to further map the optimal financing contract to additional features of infrastructure projects observed in practice (beyond government guarantees and co-investment).

4.1 Minimum Return for Financiers

So far, we have assumed an exogenous minimum required return for the financiers in the event of success, $\underline{R}$. This minimum return can be microfounded as the outcome of the costly state verification game between the financiers and the government described below.[14]

Suppose the operator and the government observe the project's success but it is costly for the financiers to verify the project's outcome. More specifically, we assume that the financiers can only verify the state of the project by forcing its liquidation, in which case the project's return is given by $(\underline{R}+A_o)$, where $(\underline{R}+A_o) < R$ if the project had been successful and zero otherwise.[15] The liquidation value net of operating costs $\underline{R}$ represents the cash flows generated by the project net of any delays or inefficiencies associated with litigation. We assume that if $R_f \geq \underline{R}$ and the project is verified to be successful, the government is liable to financiers for the amount $(R_f - \underline{R})I$ and to operators for their agency rent $R_o = A_o$. Moreover, if the project is verified to be unsuccessful, the liquidation value is zero and the government is liable for the full guarantee amount of $K_g I$.

Given these assumptions, verification is costless for the government if the project fails, i.e., if the project fails the government has a payoff of $\left(\overline{K}_0 + \overline{K}_1 - I_g\right) - K_g I$ regardless of the verification decision of the financiers. However, if the project succeeds, the government receives $\left(\overline{K}_0 + \overline{K}_1 - I_g\right) - (R_f - \underline{R})I$ if there is state verification and a payoff of $\left(\overline{K}_0 + \overline{K}_1 - I_g\right) + (R - A_o - R_f)I$ if there is no verification. Hence, verification costs the government $(R - A_o) - \underline{R} > 0$ when the project succeeds.

In this setting, an optimal strategy for the financiers is to commit to verifying the state whenever the

[14]See Townsend (1979) and Gale and Hellwig (1985) for a microfoundation of debt contracts as the outcome of costly state verification.

[15]This assumption is consistent with the evidence in Mehta and Thomas (2022) that shows government guarantees are obtained through litigation which halts the projects. Absent this assumption, the optimal contract involves financiers ”shorting” the project's success when the project's return is low.

return they receive is less than $\underline{R}$. Given this strategy, it is optimal for the government to set $R_f \geq \underline{R}$ to avoid verification in the high state, which is the assumption in our baseline model. Finally, the government has no incentives to misreport only if $R_f \geq K_g$, which yields either risk-free debt ($R_f = K_g > \underline{R}$) or risky debt ($R_f \geq \underline{R} > K_g$) as the optimal financial contract. When debt is risky it coincides with the optimal contract in Section 2. Assumption 1(a) and the government's truthful reporting condition at $R_f = \underline{R}$ imply

$$\frac{p_h}{(1-p_h)}\underline{R} < K_g \leq \underline{R}.$$

Hence, only projects with low success probability, i.e., with $p_h < 0.5$, can have $R_f = \underline{R}$. Otherwise, the risky debt region corresponds to the parameter region where $(R - A_o) > \Gamma_R$.

4.2 Government's limited commitment to financiers

In the baseline model, we assume an exogenous maximum capacity for the infrastructure project. In this section, we show that the maximum scale of the project can be determined in equilibrium by the government's limited commitment to its promises to financiers, as in the literature on sovereign debt. More specifically, we assume that the model is the same as in the baseline model with two modifications. First, there is no exogenous limit to the size of the infrastructure project, i.e., $\bar{I} \to \infty$. Second, we assume that the government's willingness to pay is determined by the costs that it incurs from defaulting on financial contracts, which we denote by Φ.[16] Given the government's lack of commitment, the amount the government can credibly provide is limited by its resources and its willingness to pay Φ since the government will choose to default on any payment above Φ. These constraints change the no-default conditions as follows:

$$R_f I \leq \min\left\{\Phi, (R - A_o)I + \overline{K}_0 + \overline{K}_1 - I_g\right\} \quad \text{and} \tag{NDR-LC}$$

$$K_g I \leq \min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g\right\} \ . \tag{NDK-LC}$$

The total scale of the project is limited by the willingness-to-pay and the ability-to-pay constraints of the government, as stated respectively in NDR-LC and NDK-LC. Note that the government will never agree to using all of its resources to pay the financiers if the project succeeds (IRG would not be satisfied). Then, the

[16]See footnote 5 on justifications for such default penalty in the sovereign debt literature.

optimal scale of the project is given by

$$I^{\star} = \min\left\{\frac{\Phi}{R_f^{\star}}, \frac{\min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g^{\star}\right\}}{K_g^{\star}}\right\}.$$

We know from the analysis in Section 3 that when the project's return is high enough, ICG is slack. However, in this case, the scale of the project is maximized when IRP, NDR-LC and NDK-LC bind at the same time when the government has limited commitment. Otherwise, one could decrease $R_f^{\star}$ or $K_g^{\star}$ and increase the scale of the project while satisfying all the relevant constraints. Moreover, when IRP binds, it is optimal for the government to co-invest as much as possible, i.e., $I_g^{\star} = \overline{K}_0$. These observations imply that the maximal scale of the project is given by

$$\bar{I} = \frac{r\overline{K}_0 + (1 - p_h)\min\left\{\Phi, \overline{K}_1\right\} + p_h\Phi}{r}. \tag{1}$$

We show that the government's limited commitment limits the project's scale but not its feasibility.

Proposition 7. ***(Limited commitment to financiers)*** *The government's limited commitment in financial contracts limits the scale of the infrastructure project but not its feasibility:*
a. ***(Feasibility)*** *Whether the project is financed is independent of the government's commitment, i.e.,* $\frac{\partial \overline{\Gamma}}{\partial \Phi} = 0$.
b. ***(Scale)*** *Greater commitment, measured by the size of the default penalty* Φ*, increases the maximum size of the project, i.e.,* $\frac{\partial \bar{I}}{\partial \Phi} > 0$.

Note from Equation (1) that $\lim_{\overline{K}_1 \to \infty} \bar{I} < \infty$ and $\lim_{\Phi \to \infty} \bar{I} = \infty$. Hence, while fiscal resources $\overline{K}_1$ restrict the scale of the infrastructure for low-return projects, the government's limited commitment limits the project's maximum scale even absent other frictions.

4.3 Expropriation in Equilibrium

In our baseline model, there is no expropriation by the government in equilibrium if the contract with the operator induces high effort. Suppose now that the government cannot fully commit to the expropriation rule in the operational contract. Instead, suppose that if the government agrees to a contract, there is a probability $\delta < 1$ that the courts will enforce the contract and a probability $(1 - \delta)$ that the government will be able to renege the contract and expropriate from the operator. In this case, the incentive compatibility constraint of the operator becomes $\delta R_o \geq \frac{B}{\Delta p}$, so the operator's agency rent is now $\hat{A}_o \equiv \frac{B}{\delta \Delta p}$, and the incentive compatibility constraint of the government becomes

$$K_g + \left(R - \hat{A}_o - R_f\right) \geq \hat{A}_g,$$

where $\hat{A}_g \equiv \frac{(p_l - p_h(1-\delta))}{\Delta p}\left(\hat{A}_o + C\right)$ represents the government's agency rent. Note that a lower probability of enforcement δ implies a higher agency rent for the operator. However, the overall effect on the agency rent of the government is ambiguous. On the one hand, the higher agency rent of the operator increases the government's agency rent due to the interaction of the two moral hazard problems. On the other hand, conditional on $\hat{A}_o$, a lower δ reduces the government's agency rent as agreeing to an expropriation rule is less costly when the contract is less enforceable. Which effect dominates depends on the private benefits for the operator, B, and the government, C. Interestingly, the higher the government's benefit of expropriating (all else being equal), the more likely it is that lower enforceability reduces the government's agency rent.

Note that the project's return has to be greater than the agency rent of the operator for the project to be financed, i..e, $R \geq \hat{A}_o$. In this case, the optimal financing contract solves

$$\max_{I_g \in [0, K_0],\, I_f \geq 0,\, K_g \geq 0,\, R_f \geq \underline{R}} \left(p_h R - r\right)\left(I_g + I_f\right)$$

subject to

$$\left(1 - p_h\right) K_g + p_h R_f \geq r \frac{I_f}{I_f + I_g}, \tag{IRF}$$

$$\left(1 - p_h\right) K_g + p_h R_f + r \frac{I_g}{I_f + I_g} \leq p_h \left(R - \delta \hat{A}_o\right), \tag{IRG}$$

$$K_g + \left(R - \hat{A}_o - R_f\right) \geq \hat{A}_g, \tag{ICG}$$

$$K_g \left(I_f + I_g\right) \leq \overline{K}_1 + \overline{K}_0 - I_g, \tag{NDK}$$

$$R_f \left(I_f + I_g\right) \leq \left(R - \hat{A}_o\right)\left(I_f + I_g\right) + \overline{K}_1 + \overline{K}_0 - I_g, \quad \text{and} \tag{NDR}$$

$$I_g + I_f \leq \bar{I}, \tag{MS}$$

The parameter δ, like the (inverse of) parameter C, measures the quality of the institutions in the economy. On the one hand, $\delta = 1$ implies the contract between the operator and the government is always enforced and there is no expropriation in equilibrium. On the other hand, $\delta = 0$ implies that the government always expropriates and the operator can never be incentivized to exert effort. The lower the δ, the higher the compensation the operator requires to exert high effort (the agency rent) and the higher the return needed for investment to be positive. In other words, if we allow for expropriation in equilibrium, the feasibility of the infrastructure project would be further restricted at the extensive margin. However, since IRG does not bind in the optimal contract, conditional upon the project being feasible, the restated optimization program above implies that the qualitative properties of infrastructure financing would correspond to those in our baseline model. Formally, conditional on the project being financed, the solution is the same as that in the baseline model with agency rents for the operator and government given by $\hat{A}_o$ and $\hat{A}_g$, respectively.

4.4 Externalities and Tax Subsidies

We now turn our attention to the role externalities play in the financing of infrastructure projects. We consider two types of externalities that arise in a state-contingent manner, specifically only if the project succeeds: those that accrue only to the private parties, which we denote by DI, and those that accrue to the government only, which we denote by XI. We interpret DI as the value of development rights (e.g., real estate development) that accrue to financiers or the operator because of the success of the infrastructure project. On the other hand, XI represents the additional payoffs that accrue to the government if the infrastructure project succeeds, which may come, for example, from an increase in the probability of reelection. Note that, being state contingent, these externalities differ from the fiscal resources $\overline{K}_1$, which are available at the cash flow stage regardless of the project's outcome. We start by assuming these externalities cannot be directly transferred between the government and the private sector.

The development rights D can be distributed to the financiers or the operator. The amount received by the financiers, D_f, relaxes the individual rationality constraint of the financiers' IRF by increasing their payoff if the project succeeds. The operators receive $(D - D_f)$ if the project succeeds which increases their incentives to supply effort and decreases their agency rent which now becomes $\tilde{A_o} \equiv \frac{B}{\Delta p} - (D - D_f)$. Hence, the portion of the development rights allocated to the operator reduces the double moral hazard in the economy.

The externalities that accrue to the government make it easier to convince the government to undertake infrastructure development. More importantly, the externalities X (conditional on process success) reduce the agency rent of the government which now becomes $\tilde{A}_g \equiv \frac{p_l(\tilde{A}_o+C)}{\Delta p} - X$, making it easier for the government to agree not to expropriate, reducing the severity of its moral hazard problem. Proposition 8 summarizes the effects of development rights D and externalities X on the optimal financing contract:

Proposition 8. ***(Externalities)*** *The externalities generated by the infrastructure project for the private sector and the government, respectively D and X, increase the feasibility of the infrastructure project, i.e., size of the region in which the infrastructure project is financed, and its scale when financed.*

Essentially, externalities lower the government guarantees necessary to incentivize the government not to expropriate from the operator. In turn, this translates into more resources being available for the government to invest directly in the infrastructure project and allows a larger fraction of the project's return to be credibly promised to the financiers. All these effects increase both the feasibility and the scale of the project.

The distribution of the development rights between the financiers and the private sector operator depends on which marginal agent is restricting the project's size. Intuitively, when the project's payoff is low, the government has more incentives to expropriate since inducing high effort from the operator does not increase its payoff much. In this case, compensating the operator is relatively harder than providing guarantees to the financiers. By allocating all the development rights to the operator, the government can induce high effort from the operator while increasing its payoff from not expropriating. On the other hand, when the project's payoff is high, the government has low incentives to expropriate. In this case, it is relatively easy to induce high effort from the operator and harder to provide guarantees to the financiers. By allocating all the development rights to the financiers, the planner reduces the payoff the government needs to agree not to expropriate to incentivize the financiers to participate in the project.

Proposition 9. ***(Distribution of development rights)*** *There exists a threshold $\Gamma_D > \overline{\Gamma}$ such that the development rights are assigned entirely to the operator if and only if $\left(R - \tilde{A}_o\right) \leq \Gamma_D$.*

In practice, government externalities can accrue from an increase in its tax revenue, which can usually be shared with the private sector by offering tax subsidies. Formally, suppose that a fraction τ of the government's tax revenue T generated by the infrastructure project can be shared with the private sector

Table 2: Share of disputes by the phase of the contract life-cycle for disputed highway projects in India from 2007 to 2020

Phase of the contract life-cycle	Share (% of Total)	Number of cases
Pre-award	2%	11
Post-award / Construction	66%	420
Post-completion	0%	1
Unclear/No data	32%	203
Total	100%	635

Table reprinted from Mehta, C. and S. Thomas. (2022) Identifying roadblocks in highway contracting: lessons from NHAI litigation, The Leap Blog (July 13), https://blog.theleapjournal.org/2022/07/identifying-roadblocks-in-highway.html last accessed February 2024.

either as a tax subsidy to financiers or a tax abatement for the operator. This setting is nested in the model above by setting externalities $X = (1-\tau)T$ and development rights $D = \tau T$. In this context, we can ask what is the optimal sharing rule of the government's tax revenues to maximize the cash flows from the infrastructure project. On the one hand, a low τ translates to higher externalities X, which ameliorate the government's moral hazard. On the other hand, a high τ increases the development rights, which can be used to ameliorate the operator's and the government's moral hazards if assigned to the operator or to relax the individual rationality constraint of the financiers if assigned to them. Since an increase in development rights can be used flexibly to tackle the relevant binding constraint in the economy, it is optimal to set $\tau = 1$ and maximize the tax subsidies to the private sector.

5 Discussion

In this section, we provide evidence consistent with the model's assumptions and predictions.

5.1 Evidence of Double Moral Hazard

The main assumption of our model is the joint presence of private moral hazard and government moral hazard. In our model, this double moral hazard is the limiting factor to efficient infrastructure financing. In this subsection, we show how this relation extends to practice by focusing on two types of infrastructure projects in India: highways and power plants, and citing ample evidence of double moral hazard worldwide.

Table 3: Number of cases by drivers of litigation for disputed highway contracts in India from 2007 to 2020

Cause of dispute	**Number of cases**	**Share (% of Total)**	**NHAI as petitioner**	**Firm as petitioner**
Arbitration proceeds related	260	68%	123	137
Payments related	90	24%	15	75
Wrongful termination/debarment	32	8%	1	31
Total	382	100%	139	243

Table reprinted from Mehta, C. and S. Thomas. (2022). Identifying roadblocks in highway contracting: lessons from NHAI litigation, The Leap Blog (July 13, 2022), https://blog.theleapjournal.org/2022/07/identifying-roadblocks-in-highway.html last accessed February 25, 2024.

Double Moral Hazard in Highway Contracting in India. Indian highway contracting is plagued with contractual failures that lead to high rates of litigation between the involved parties that contribute to delays in project execution. Using data from the Delhi High Court case orders, the National Highway Authority of India (NHAI) contracts, and the NHAI Draft Red Herring Prospectus (DRHP), Mehta and Thomas (2022) shows that the NHAI was involved in $1,165$ cases, which is 40% of a total of $2,912$ cases of contractual dispute between 2007 and 2020 that involved highways. As shown in Table 2, these contractual disputes mostly occur in the post-award phase, consistent with our model assumption of moral hazard in the operating stage. Moreover, as shown in Table 3, the NHAI and private firms have a nearly equal propensity to initiate arbitration-related litigations. However, in cases related to payments and wrongful termination or debarment, the NHAI frequently finds itself on the defensive end of litigation. We interpret these findings in Mehta and Thomas (2020) as consistent with double moral hazard in practice with private firms at the receiving end of payments and coercive-termination related irregularities by the government.

Double Moral Hazard in Power Projects in India. We further show evidence of double moral hazard in infrastructure by looking at the thermal power sector in India in detail. We construct a data set comprising 34 stressed coal-fueled power plants, primarily using monthly Broad Status Reports from the Central Electricity Authority.[17] Our data set includes each plant's inception year, the initial year of stress, the primary causes of failure, and the project life-cycle phase when significant stress emerged. Initiated between 2007 and 2011, these plants encountered substantial stress between 2013 and 2015. Consistent with our discussion

[17]We take the classification of stressed assets from Ministry of Power of India (March 2018) whereby stressed assets are "those accounts where there has been a delay in payment of interest/principal by a stipulated date, as against the repayment schedule, on account of financial difficulty faced by the borrower."

Table 4: Share of cases by the phase of the contract life-cycle for stranded or stressed thermal power plants in India initiated between 2007 and 2011

Phase of the contract life-cycle	**Share (% of Total)**	**Number of cases**
Pre-award	6%	2
Post-award / Construction	94%	32
Post-completion	0%	0
Unclear/No data	0%	0
Total	100%	34

This table categorizes the 34 stressed Indian thermal power plants by their phase of contract life-cycle, when the assets became stranded. The classification draws upon the status of projects as delineated in the monthly Broad Status Reports by the Central Electricity Authority.

on highway projects in India, most (in fact, almost all) plant failures occur in the post-award phase of the project, as shown in Table 4.

In Table 5 we classify the cause of failure for the thermal power plants in our data. While many contributing forces lead to the failure of these plants (as listed row-wise in the table), by analyzing each case individually we can further characterize the failure causes into private moral hazard and public moral hazard, with the former referring to issues stemming from the plant or private entities, and the latter involving government processes or agencies (see Appendix C.2 for examples). Only 6% of the cases do not fall into any of these categories, highlighting the prevalence of at least one of private or public moral hazards. Moreover, our analysis reveals that, while private moral hazard is at play (22% of the cases), an overwhelming majority (72%) of these failures were due to public moral hazard, underscoring the government's critical role in determining the outcome of infrastructure projects. Appendix C contains more details on the causes of failure for these plants and their classification.

Double Moral Hazard Around the World. While expropriation risk by the government has traditionally been associated with developing countries, its relevance has expanded to developed countries in recent years mainly driven by political or regulatory decisions related to financial stability and climate-related policies. According to the 2015 World Economic Forum report on strategic infrastructure, the number of cases following the rules of the International Centre for the Settlement of Investment Disputes (ICSID) involving developed economies was 30% in 2014, up from 7% in 2010 (see Figure 4, page 13 in the report). The report documents such instances in the context of infrastructure for both developing and developed

Table 5: Number of cases by drivers of fatal cause for stranded or stressed thermal power plants in India initiated between 2007 and 2011

Cause of failure	**Number of cases**	**Share (% of Total)**	**Private moral hazard**	**Public moral hazard**	**Unclassified**
Paucity of funds	17	26%	NA	NA	17
Law and order problem	9	14%	NA	NA	9
Legal issue	4	6%	NA	NA	4
Delay of project status/clearances	3	5%	0	3	0
Delay in acquisition/physical handover of land	11	17%	0	10	1**
Coal supply issues	9	14%	0	8	1**
Missing supply/transmission infrastructure	3	5%	3	0	0
Operational issues/delays or other reasons	6	9%	5	1**	0
Non-availability of PPAs	4	6%	0	4	0
Total	**66 (34 total projects)**	**100%**	**22%**	**72%**	**6%**

The aggregate count of cases does not equate to the total of 34 stressed thermal power plants, as the analysis enumerates each reason for failure independently. This approach allows for a more nuanced understanding of the diverse factors leading to plant non-performance. **See Appendix C for more details on these cases.

countries. Figure 5, reproduced from the report, documents several examples of these different types of government expropriation risk. Expropriation risk is present in the planning phase (e.g., the cancelation of the Lisbon-Madrid high-speed line due to austerity measures in Portugal), in the operation phase (e.g., asset-specific regulation in Switzerland to reduce aircraft noise), and in the termination phase (e.g., the phase-out of nuclear power plants in Germany). Moreover, beyond the risks affecting specific projects, some non-targeted political and regulatory decisions also generate expropriation risk in infrastructure (such as the judicial reform in Italy impeding investment).

Beyond the examples in Figure 5, there is ample evidence of government and operator moral hazard in infrastructure financing worldwide, in developed and developing economies. In the United States, Lewis and Bajari (2014) finds concrete evidence of operator moral hazard in highway procurement projects from Minnesota highway construction. Using day-by-day information on work plans, hours worked, and delays, the paper finds that contractors adjust their effort level during the contract in response to unanticipated productivity shocks: they exert more effort to avoid delays (and penalties) but do not exert high effort otherwise, which is exhibited by the bunching of completion times around the penalty threshold.

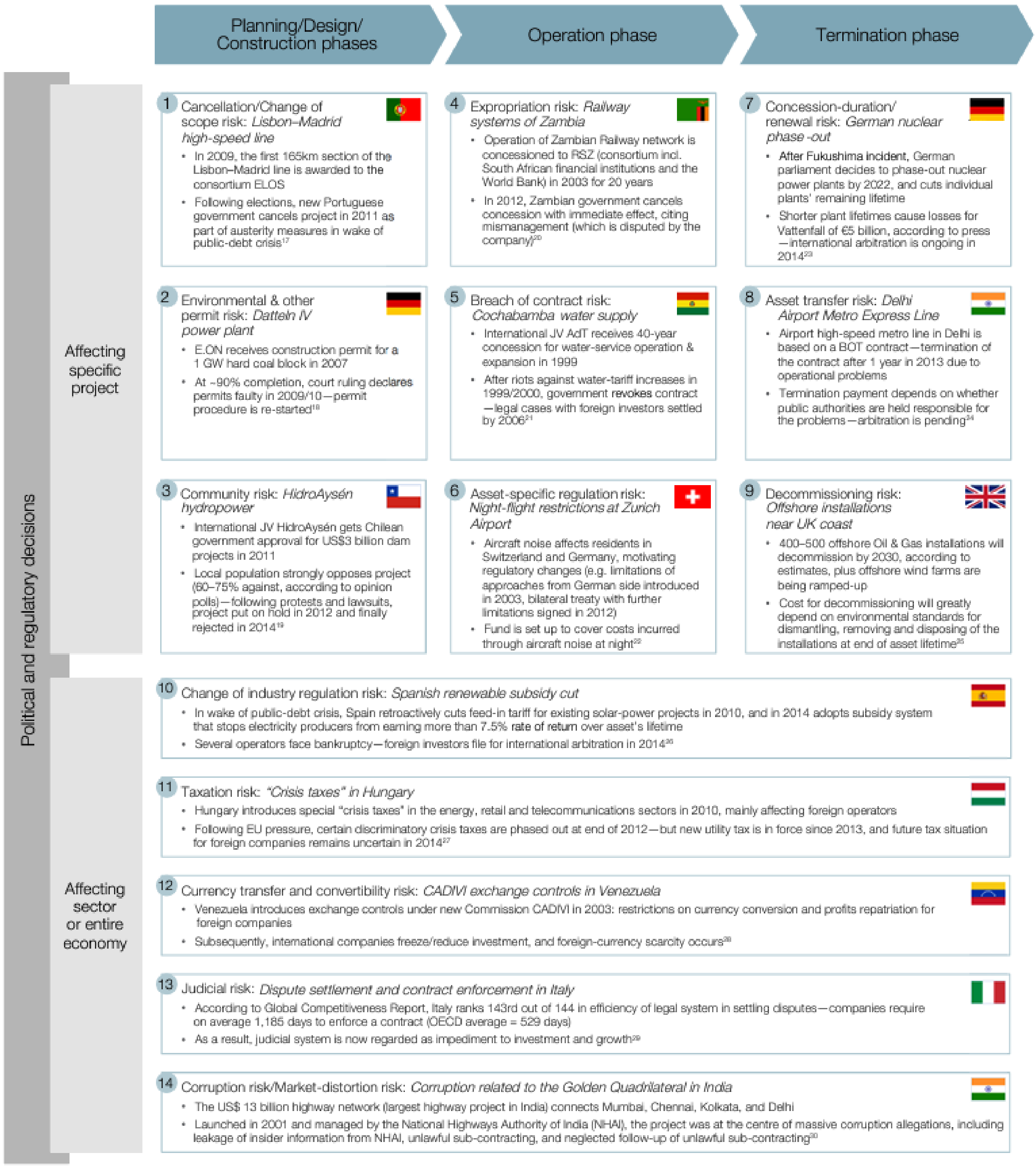


Figure 5: Examples of government expropriation affecting infrastructure projects.

Source: World Economic Forum in collaboration with The Boston Consulting Group (2015), page 16.

Furthermore, Gardner and Henry (2023) identifies government moral hazard – in particular, a lack of willingness on the government's part to honor the terms of the underlying project agreement – as one of the important constraining factors in infrastructure investment in rich and poor countries, especially when the projects are built or operated by foreign investors. The paper highlights the case of Aguas del Illimani, a consortium owned by a French company, that brought water and sewage systems to El Alto, Bolivia. In 2007, after being in operation for ten years, the Bolivian authorities terminated the consortium's contract following community protests claiming that Aguas del Illimani had failed to expand its services and overcharged poor residents. Moreover, Alm (2010) notes that sub-national roads in Bangladesh were not properly maintained by the local governments (operators) due to the lack of incentives provided by the central government, which did not share any revenues generated by the roads with them.

5.2 Infrastructure Financing in Practice

Over time, governments and private sector firms involved in many infrastructure investments have come up with varying contractual arrangements to design and execute projects. We document below that the salient features identified in our (second-best) financing of infrastructure in the shadow of expropriation find immediate counterparts in such arrangements. In particular, the government is directly involved as a guarantor and occasionally also as a co-lender or as a supplier of capital. This role is played explicitly by the government or its agencies or supranational institutions with implicit or explicit backing. Infrastructure contracts observed in practice also seek to monetize and efficiently allocate associated externalities.

Government guarantees. A key result of our analysis is the need for government guarantees to offset the threat of government expropriation. In practice, government guarantees are used in the financing of infrastructure across the world. For example, in the United States, "loan guarantees" to institutional investors who fund transportation projects of national or regional significance are available through the Transportation Infrastructure Finance and Innovation Act (TIFIA) of 1998.[18] In France, a two-pronged approach is used to offer guarantees to investors in infrastructure. First, the French government provides guarantees to bank loans that are directed specifically towards infrastructure projects. Second, the government has established

[18]TIFIA was passed by Congress in 1998 to leverage federal dollars and attract private and non-federal capital into transportation infrastructure. See "Transportation Infrastructure Finance and Innovation Act" (2011) for details, https://www.fhwa.dot.gov/ipd/finance/tools_programs/federal_credit_assistance/tifia/ last accessed February 25, 2024.

another guarantee program to promote debt financing, allowing infrastructure projects to be funded at relatively low costs.[19] Similar contractual arrangements are used in Australia through a government-designed guarantee program to address the funding gap in infrastructure financing.[20]

Government co-investment. There are many examples of governments co-investing with the private sector to help infrastructure projects achieve the closure of their initial financing. For instance, under TIFIA the United States government offers secured direct loans to the private sponsors of infrastructure projects in the transportation industry. In the United Kingdom too, the Treasury has established since 2009 a unit that co-lends along with private sector lenders to fund privately financed infrastructure initiatives, the stated goal being to exit the investment by selling the loans in the private capital markets once the projects become self-sustaining. The Australian government also has co-lending facilities, whereby it lends on commercial terms along with private sector banks to fill the funding gap in infrastructure projects.

Development rights and tax subsidies. Additional cash flows not generated directly by infrastructure projects are also at times used to incentivize financiers and operators to take part in them. These cash flows can come as the rights to develop lands and buildings adjoining newly developed infrastructure or as tax exemptions or abatements.[21] For example, so-called "Rail plus Property" model involves the distribution of the development rights of land close to the stations of the Hong Kong Mass Transit Railway Corporation (MRTC). These development rights were an important consideration to all parties in the contracting arrangements to fund the project at its various stages since 1975.[22] Turning to tax subsidies, in the United States, the interest income from municipal bonds, which are usually used to fund infrastructure projects, is tax-exempt from the perspective of private investors (see Green (1993), Ang, Bhansali and Xing (2010), and Longstaff (2011) for analyses of the tax treatment of municipal bonds).

The examples above on infrastructure financing refer to developed economies. Given our discussion in

[19] See "Public and private financing of infrastructure Policy challenges in mobilizing finance", European Investment Bank (EIB) Papers Volume 15 No 2, 2010.

[20] See "Infrastructure Partnerships Australia: Financing Infrastructure in the Global Financial Crisis," March 2009, https://infrastructure.org.au/wp-content/uploads/2016/12/IPA_Financing_Infra_in_GFC_FINAL.pdf last accessed February, 2024.

[21] Gupta, van Nieuwerburgh and Kontokosta (2022) shows that the new transit infrastructure project in New York City (Second Avenue subway line) increased local real estate prices as a result of shorter commute times.

[22] See "Land Value Capture Mechanism: The Case of the Hong Kong Mass Transit Railway" by Mathieu Verougstraete and Han Zeng (July 2014), www.unescap.org/sites/default/files/Case%204_Land%20Value_Hong-Kong%20MTR.pdf and "The 'Rail plus Property' model: Hong Kong's successful self-financing formula" By Lincoln Leong, www.mckinsey.com/capabilities/operations/our-insights/the-rail-plus-property-model, all last accessed February 25, 2024.

Section 3.3, it is not surprising that examples of government guarantees and government co-investment are hard to encounter in developing economies, as they typically have limited fiscal resources that are furthermore not destined to infrastructure projects. In the presence of double moral hazard, these fiscal limitations substantially limit the infrastructure projects that can be funded, widening their infrastructure gap.

Finally, our model implies that third-party guarantees for infrastructure financing, such as those from the World Bank and other multilateral agencies, may fail to address infrastructure gaps as they do not tackle double moral hazard. Put differently, only guarantees offered by the government affect the government's choice not to expropriate. Then, it follows that multilateral agency efforts might be more successful at closing infrastructure gaps when devoted instead to building fiscal capacity and governance of institutions in developing economies.[23]

6 Conclusion

We analyze the optimal design of infrastructure financing in the presence of private moral hazard and the threat of government expropriation. The private sector operators need incentives to exert effort to implement projects well and governments that can expropriate cash flows from such projects need incentives to agree to sharing the projects' returns with the private sector (for instance, by not restricting the user fees). This double moral hazard problem limits the willingness of outside investors to fund infrastructure projects. The limited financial commitment of governments and the shadow of their expropriation limits the feasibility and scale of infrastructure, explaining potentially the large infrastructure gaps observed globally. The optimal (second-best) design of infrastructure finance can ameliorate these two moral hazards using (I) government guarantees to investors; (II) direct government investment for projects with high returns; (III) bundling of development rights for the private parties; and (IV) tax subsidies to the private parties. All of these features are prevalent in the practice of infrastructure financing, highlighting the relevance of the double moral hazard we considered as a unifying framework to understand infrastructure finance.

Indeed, our framework appears relevant also to the provision of public goods such as public health infrastructure (sufficient capacities of hospital beds, medical equipment, and human capital in healthcare

[23]In contrast, co-investments by third parties perform a similar function as those by the government as they relax the participation constraint of financiers. However, as our model shows, this effect applies only to relatively better-quality infrastructure projects.

professionals). These were found critical – and wanting – in the wake of the pandemic in 2020, and yet it is difficult to elicit private investments in public health infrastructure. In contrast, a clear recent example in healthcare of success in public-private partnerships has been investment in the development and production of vaccines for the COVID-19 virus. Typically, patents or monopoly power are thought to be ex-ante desirable to incentivize efficient technological innovation. However, public health concerns are likely to lead the government to lower the user fees of vaccines ex post, discouraging private investment. To restore the willingness of the private sector to invest, the government can then either commit to paying the difference between the market user fee and the public cap on the fee, or simply co-invest. Our theoretical framework suggests that one alternate way to subsidize investment in vaccine development is for the government to provide guarantees in the event of a failure of the investment in such projects. There seems ample scope for such applications of our primary insights in other settings.

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APPENDIX

A Proofs Section 3

In this section, we present proofs for the propositions in Section 2 and characterize the optimal contract for the model presented in it. A more detailed characterization of the optimal contract can be found in the Online Appendix.

A.1 Characterization of optimal contract in benchmark models

First, we characterize the optimal contract in the benchmark models with private sector moral hazard only (Section 3.1.1) and with government moral hazard only, i.e., $B = 0$ (Section 3.1.2).

Proof of Proposition 1 (No government moral hazard)

With private moral hazard and no government moral hazard, the optimal infrastructure financing contract solves

$$\max_{I_f \geq 0,\, I_g \in \left\{0, \overline{K}_0\right\},\, K_g \geq 0,\, R_g \geq 0,\, R_f \geq 0,\, R_o \geq 0} \left(p_h R - r\right)\left(I_g + I_f\right)$$

subject to

$$p_h R_f + (1-p_h) K_g \geq r \frac{I_f}{I_g + I_f}, \quad \text{(IRF)}$$

$$p_h R_g - (1-p_h) K_g \geq r \frac{I_g}{I_g + I_f}, \quad \text{(IRG)}$$

$$p_h R_o \geq p_l R_o + B, \quad \text{(ICO)}$$

$$R_o + R_g + R_f = R, \quad \text{and} \quad \text{(Feasibility)}$$

$$I_g + I_f \leq \bar{I}, \quad \text{(MS)}$$

where R_o, R_f, and R_g are the returns assigned respectively to the private operator. financiers, and government in the event of success, IRF and IRG are the individual rationality constraints of the financiers and government respectively, ICO is the incentive compatibility constraint of the operator, Feasibility is the feasibility constraint on the distribution of returns, and MS is the maximum scale constraint. Putting together IRF and IRG we have

$$p_h \left(R_g + R_f\right) \geq r\,.$$

Note that guarantees are just transfers between the government and financiers and do not affect the feasibility or the scale of the project. Then, we can set $K_g = 0$ without loss of generality. Then, the financiers are willing to finance any scale of the project $I_f \leq \bar{I}$ as long $R_f \geq \max\left\{\underline{R}, \frac{r}{p_h}\right\}$ and won't finance the project otherwise. Similarly, the government is willing to invest $I_g \leq \overline{K}_0$ in the project as long as $R_g \geq \frac{r}{p_h}$. Moreover, the operator will exert effort and implement p_h only if $R_o \geq A_o \equiv \frac{B}{\Delta p}$. Then, the optimal financing contract is such that the project is financed if $R \geq \max \frac{r}{p_h} + A_o$, in which case $I_f = \bar{I}$ and the optimal return split between government, financiers and the operator is indeterminate and satisfies

$$R_g \in \left[\frac{r}{p_h}, R - A_o\right], \quad R_f \in \left[\frac{r}{p_h}, R - A_o - R_g\right], \quad \text{and} \quad R_o = R - R_f - R_g.$$

This proves the proposition.

Proof of Proposition 2 (No private moral hazard)

Without moral hazard for the operator, i.e., $B = 0$, the expropriation policy of the government has no effect on the project's probability of success. In particular, the ICG becomes

$$K_g - R_f \geq -R, \tag{ICG}$$

which always holds for $R_g \leq R$ and $K_g \geq 0$. Hence, the government will give the operators 0 and the optimal contract solves

$$\max_{I_g \in \{0, K_0\},\, I_f \geq 0,\, K_g \geq 0,\, R_f \geq \underline{R}} (p_h R - r)\left(I_g + I_f\right)$$

subject to

$$\begin{aligned}
(1-p_h)\, K_g + p_h R_f &\geq r \frac{I_f}{I_f + I_g}, && \text{(IRF)}\\
(1-p_h)\, K_g + p_h R_f + r \frac{I_g}{I_f + I_g} &\leq p_h R, && \text{(IRG)}\\
K_g \left(I_f + I_g\right) &\leq \overline{K}_1 + \overline{K}_0 - I_g, && \text{(NDK)}\\
R_f \left(I_f + I_g\right) &\leq R\left(I_f + I_g\right) + \overline{K}_1 + \overline{K}_0 - I_g, && \text{(NDR)}\\
R_o + R_g + R_f &= R, \quad \text{and} && \text{(Feasibility)}\\
I_g + I_f &\leq \overline{I} && \text{(MS)}
\end{aligned}$$

where IRF and IRG are the individual rationality constraints of the financiers and the government, respectively, NDK and NDR are the no-default constraints on K_g and R_f, respectively, Feasibility is the feasibility constraint on the distribution of returns, and MS is the maximum scale constraint. Note that NDR will never be binding as this would violate IRG. Then, the total investment is given by

$$I = \min\left\{\overline{I}, \frac{\overline{K}_1 + \overline{K}_0 - I_g}{K_g}\right\}.$$

Note that, as long as $p_h R > r$, the project can be funded at its maximal scale $\overline{I}$ by setting $I_g = 0$, $I_f = \overline{I}$, $K_g = 0$ and $R_f = R$. Moreover, the shares of investment and return assigned to the financiers and the government, and the guarantees are indeterminate and satisfy

$$\begin{aligned}
I_f + I_g &= \overline{I}\\
(1-p_h)\, K_g + p_h R_f &\geq r \frac{I_f}{\overline{I}}\\
(1-p_h)\, K_g + p_h R_f + r \frac{I_g}{\overline{I}} &\leq p_h R\\
K_g &\leq \frac{\overline{K}_1 + \overline{K}_0 - I_g}{\overline{I}}.
\end{aligned}$$

This proves the proposition.

A.2 Characterization of optimal contract in baseline model

In this section, we provide a detailed characterization of the optimal financial contract for the model presented in the baseline model. We assume the parametric assumption on $\overline{I}$ stated in the text holds.

The optimal financing contract solves

$$\max_{I_g\in[0,K_0],\, I_f\geq 0,\, K_g\geq 0,\, R_f\geq \underline{R}} (p_h R - r)\left(I_g + I_f\right)$$

subject to

$$(1-p_h)K_g + p_h R_f \geq r\frac{I_f}{I_f+I_g}, \tag{IRF}$$

$$(1-p_h)K_g + p_h R_f + r\frac{I_g}{I_f+I_g} \leq p_h(R-A_o), \tag{IRG}$$

$$K_g + \left(R - A_o - R_f\right) \geq A_g, \tag{ICG}$$

$$K_g\left(I_f+I_g\right) \leq \overline{K}_1 + \overline{K}_0 - I_g, \tag{NDK}$$

$$R_f\left(I_f+I_g\right) \leq (R-A_o)\left(I_f+I_g\right) + \overline{K}_1 + \overline{K}_0 - I_g, \quad \text{and} \tag{NDR}$$

$$I_g + I_f \leq \bar{I}, \tag{MS}$$

where IRF is the individual rationality constraint of the financiers, IRG is the individual rationality constraint of the government, ICG is the incentive compatibility constraint of the government, NDK and NDR are the feasibility constraints on government guarantees and promised returns, and MS is the maximum scale constraint. Note that to have IRG and IRP satisfied at the same time it has to be the case that

$$0 \leq p_h(R-A_o) - r.$$

Moreover, the no-default conditions impose upper bounds on the total scale of the infrastructure project. Note that NDR cannot bind as it would violate IRG. Then, since the infrastructure project is positive NPV, either the constraint NDK or the maximum scale constraint or both have to bind, which implies

$$I = \min\left\{\bar{I}, \frac{\overline{K}_1 + \overline{K}_0 - I_g}{K_g}\right\}.$$

To characterize the optimal financing contract one needs to consider three possible cases, that depend on which constraints are binding. Below, we consider each case separately and characterize the parameter regions in which they are relevant.

Case 1: ICG binds and IRF and ICG are slack If ICG binds, the government guarantees are given by

$$K_g^\star = A_g - (R-A_o) + R_f$$

and total investment is given by

$$I^\star = \min\left\{\bar{I}, \frac{\overline{K}_1 + \overline{K}_0 - I_g^\star}{A_g - (R-A_o) + R_f^\star}\right\},$$

which is decreasing in $R_f^\star$ and $I_g^\star$. Then, it is optimal to set $R_f^\star$, and $I_g^\star$ as small as possible to maximize the scale of the project. More specifically, it is optimal to set $R_f^\star = \underline{R}$, and $I_g^\star = 0$ which implies

$$K_g^\star = A_g + \underline{R} - (R-A_o) \quad \text{and} \quad I^\star = \frac{\overline{K}_1 + \overline{K}_0}{A_g + \underline{R} - (R-A_o)}.$$

Finally, to satisfy IRF and IRG it has to be the case that

$$\max\left\{\underline{\Gamma}, \overline{\Gamma}\right\} \leq (R-A_o) \leq \Gamma_I,$$

where $\underline{\Gamma} \equiv \frac{r}{p_h}$, $\overline{\Gamma} \equiv (1-p_h)A_g + \underline{R}$ and $\Gamma_I \equiv A_g - \frac{r-\underline{R}}{1-p_h}$. Note that in this region we have $K_g^\star > 0$.

Case 2: ICG and IRF bind First, note that if IRF and IRG bind we have

$$R_f^\star = r\frac{I^\star - I_g^\star}{I^\star} - (1-p_h)(A_g - (R-A_o)) \quad \text{and}$$
$$K_g^\star = r\frac{I^\star - I_g^\star}{I^\star} + p_h(A_g - (R-A_o)).$$

In this case, the total scale of the project is given by

$$I^\star = \min\left\{\bar{I}, \frac{\left(\overline{K}_1 + \overline{K}_0 + I_g^\star(r-1)\right)}{r + p_h(A_g - (R-A_o))}\right\},$$

where $I_g^\star$ is constrained by the lower bound on R_f, which given our assumptions on $\bar{I}$, is equal to

$$I_g^\star \leq \frac{(r - \underline{R} + (1-p_h)((R-A_o)-A_g))\left(\overline{K}_1 + \overline{K}_0\right)}{r + \underline{R}(r-1) + ((1-p_h)-r)((R-A_o)-A_g)}$$

Note that $I^\star$ is increasing in $I_g^\star$ since $r > 1$. Then, it is optimal to set $I_g^\star$ as high as possible and in the optimal contract $R_f^\star = \underline{R}$,

$$I_g^\star = \frac{(r - \underline{R} + (1-p_h)((R-A_o)-A_g))\left(\overline{K}_1 + \overline{K}_0\right)}{r + \underline{R}(r-1) + ((1-p_h)-r)((R-A_o)-A_g)},$$
$$K_g^\star = \underline{R} - ((R-A_o)-A_g), \quad \text{and}$$
$$I^\star = \frac{r\left(\overline{K}_1 + \overline{K}_0\right)}{(r + \underline{R}(r-1) + ((1-p_h)-r)((R-A_o)-A_g))}.$$

as long as $I_g^\star \leq \overline{K}_0$ which holds for $(R-A_o) \leq \Gamma_R$, where Γ_R is given by

$$\Gamma_R \equiv A_g - \frac{(r-\underline{R})\overline{K}_1 - \underline{R}r\overline{K}_0}{\left(r\overline{K}_0 + (1-p_h)\overline{K}_1\right)}.$$

If $(R-A_o) \geq \Gamma_R$, then $I_g^\star = \overline{K}_0$ and $R_f^\star$ is given by

$$R_f^\star = r\frac{I^\star - \overline{K}_0}{I^\star} + (1-p_h)((R-A_o)-A_g),$$

where

$$I^\star = \frac{\overline{K}_1 + r\overline{K}_0}{(r - p_h((R-A_o)-A_g))}.$$

We have $I^\star \leq \bar{I}$ as long as $(R-A_o) \leq \Gamma^\star$, where $\Gamma^\star$ is given by

$$\Gamma^\star \equiv \frac{r}{p_h} + A_g - \frac{\overline{K}_1 + r\overline{K}_0}{p_h\bar{I}}.$$

In this region, we have

$$R_f^\star = r\frac{\overline{K}_1}{\overline{K}_1 + r\overline{K}_0} + \left(\frac{r\overline{K}_0 + (1-p_h)\overline{K}_1}{\overline{K}_1 + r\overline{K}_0}\right)((R-A_o)-A_g) \quad \text{and}$$
$$K_g^\star = (r - p_h((R-A_o)-A_g))\frac{\overline{K}_1}{\overline{K}_1 + r\overline{K}_0}.$$

Case 3: Maximal scale of the project For $(R-A_o) > \Gamma^\star$, the maximum scale of the project is binding and we have $I^\star = \overline{I}$. In this region, the optimal financing contract is indeterminate, with $I_g \in \left[0, \overline{K}_0\right]$, $I_f = \overline{I} - I_g$, $R_f \geq \underline{R}$ and R_f and K_g satisfying

$$\max\left\{0, \frac{1}{(1-p_h)}\left(r\frac{\overline{I}-I_g}{\overline{I}} - p_h R_f\right), A_g + R_f - (R-A_o)\right\} \leq K_g \leq \min\left\{\overline{K}_0, \frac{\overline{K}_1 + \overline{K}_0 - I_g}{\overline{I}}, \frac{1}{(1-p_h)}\left(p_h(R-A_o) - r\frac{I_g}{\overline{I}} - p_h R_f\right)\right\}.$$

Note that if

$$\max\left\{\underline{R}, \frac{r}{p_h}\frac{\overline{I}-I_g}{\overline{I}}\right\} \leq R_f \leq (R-A_o) - A_g,$$

one can implement the second best financing contract without government guarantees., i.e., with $K_g^\star = 0$. This inequality can be satisfied as long as $\Gamma^{\star\star} \leq (R-A_o)$, where $\Gamma^{\star\star} \equiv \max\left\{\underline{R}, \frac{r}{p_h}\frac{\overline{I}-\overline{K}_0}{\overline{I}}\right\} + A_g$.

Summary of Optimal Financial Contract

The characterization above yields the following optimal financial contract for $(R-A_o) \leq \Gamma^\star$. The optimal government investment is

$$I_g^\star = \begin{cases} 0 & \text{if} \quad \overline{\Gamma} \leq (R-A_o) < \Gamma_I \\ \frac{\left(r - \underline{R} + (1-p_h)\left((R-A_o)-A_g\right)\right)}{r + \underline{R}(r-1) + ((1-p_h)-r)\left((R-A_o)-A_g\right)}\left(\overline{K}_1 + \overline{K}_0\right) & \text{if} \quad \Gamma_I \leq (R-A_o) < \Gamma_R \\ \overline{K}_0 & \text{if} \quad \Gamma_R \leq (R-A_o) < \Gamma^\star, \end{cases} \tag{A.1}$$

the optimal government guarantees

$$K_g^\star = \begin{cases} \underline{R} - ((R-A_o)-A_g) & \text{if} \quad \overline{\Gamma} \leq (R-A_o) < \Gamma_R \\ (r - p_h((R-A_o)-A_g))\frac{\overline{K}_1}{\overline{K}_1 + r\overline{K}_0} & \text{if} \quad \Gamma_R \leq (R-A_o) < \Gamma^\star, \end{cases} \tag{A.2}$$

and the optimal "coupon" for the financiers is

$$R_f^\star = \begin{cases} \underline{R} & \text{if} \quad \overline{\Gamma} \leq (R-A_o) < \Gamma_R \\ r\frac{\overline{K}_1}{\overline{K}_1 + r\overline{K}_0} + \left(\frac{r\overline{K}_0 + (1-p_h)\overline{K}_1}{\overline{K}_1 + r\overline{K}_0}\right)((R-A_o)-A_g) & \text{if} \quad \Gamma_R \leq (R-A_o) < \Gamma^\star. \end{cases} \tag{A.3}$$

The optimal scale of the project is given by

$$I^\star = \begin{cases} 0 & (R-A_o) < \overline{\Gamma} \\ \frac{\overline{K}_1 + \overline{K}_0}{\underline{R} - \left((R-A_o)-A_g\right)} & \text{if} \quad \overline{\Gamma} \leq (R-A_o) < \Gamma_I \\ \frac{r\left(\overline{K}_1 + \overline{K}_0\right)}{r + \underline{R}(r-1) + ((1-p_h)-r)\left((R-A_o)-A_g\right)} & \text{if} \quad \Gamma_I \leq (R-A_o) < \Gamma_R \\ \frac{\overline{K}_1 + r\overline{K}_0}{r - p_h\left((R-A_o)-A_g\right)} & \text{if} \quad \Gamma_R \leq (R-A_o) < \Gamma^\star \\ \overline{I} & \text{if} \quad \Gamma^\star \leq (R-A_o). \end{cases} \tag{A.4}$$

$\underline{\Gamma}$	$\frac{r}{p_h}$
$\overline{\Gamma}$	$(1-p_h)A_g+\underline{R}$
Γ_I	$A_g-\frac{r-\underline{R}}{1-p_h}$
Γ_R	$A_g-\frac{(r-\underline{R})\overline{K}_1-\underline{R}r\overline{K}_0}{\left(r\overline{K}_0+(1-p_h)\overline{K}_1\right)}$
$\Gamma^\star$	$\frac{r}{p_h}+A_g-\frac{\overline{K}_1+r\overline{K}_0}{p_h\overline{I}}$

Table A.1: Equilibrium thresholds

Finally, the thresholds $\underline{\Gamma}$, $\overline{\Gamma}$, Γ_I, Γ_R, and $\Gamma^\star$ are summarized in Table A.1.

Proof of Proposition 3 (Inefficiency of double moral hazard)

a. **(Feasibility)** Define $\underline{\Gamma}$, $\overline{\Gamma}$ and $\Gamma^\star$ as in Table A.1. Then, for the participation constraints of the investors and the government to be satisfied at the same time it must be the case that $(R-A_o)\geq\underline{\Gamma}$. Otherwise, the contract is not funded even in the absence of moral hazard, which proves the statement in part i. of the proposition.

Using the definitions of $\underline{\Gamma}$ and $\overline{\Gamma}$ and Eq. (A.4) in the analysis above, we have that, in the presence of moral hazard, the project will be financed as long as $\max\left\{\underline{\Gamma},\overline{\Gamma}\right\}\leq(R-A_o)$. Hence, using part a.i., it follows that if $\underline{\Gamma}\leq(R-A_o)<\overline{\Gamma}$ the project is not funded in the presence of moral hazard. These two statements prove parts ii. and iii. of the proposition.

b) **(Scale)** The results follow directly from the characterization of the optimal guarantee and optimal scale in Equations (A.2) and (A.4), respectively.

Proof of Proposition 4 (Pecking order)

The proof follows directly from the characterization of the optimal contract in Equations (A.1), (A.2), and (A.3).

Proof of Proposition 5 (Government's benefit of expropriating)

The proof follows from differentiating $K_g^\star$ and $R_f^\star$ in Equations A.2 and A.3, respectively, with respect to C noting that $A_g=\frac{p_l(A_0+C)}{\Delta p}$.

Proof of Proposition 6 (Government's fiscal resources)

Part a. follows from $\overline{\Gamma}\equiv(1-p_h)A_g+\underline{R}$, which is independent of $\overline{K}_0$ and $\overline{K}_1$. Part b. follows from differentiating $I^\star$ in Equation A.4 and $\Gamma^\star$ in Table A.1 with respect to K_t for $t=0,1$. Part c. follows from the definition of $K_g^\star$ in Equation A.2.

B Proofs Section 4:

In this section, we characterize the optimal financing contract for the extensions presented in Section 4. To present the results in a more compact way, we present the results in a model with limited commitment (Section 4.2) and externalities (Section 4.4) instead of introducing one extension at a time as in the text.

In the presence of limited commitment from the government and externalities, the optimal financing contract solves

$$\max_{I_g \in \{0,K_0\},\, I_f \geq 0,\, K_g \geq 0,\, R_f \geq 0,\, D_f \in [0,D]} \left(p_h\left(R+X+D\right)-r\right)\left(I_g+I_f\right)$$

subject to

$$(1-p_h)K_g + p_h\left(R_f+D_f\right) \geq r\frac{I_f}{I_f+I_g}, \tag{IRF}$$

$$(1-p_h)K_g + p_h\left(R_f+D_f\right) + r\frac{I_g}{I_f+I_g} \leq p_h\left(R-A_o\right) + p_h\left(X+D\right), \tag{IRG}$$

$$K_g + \left(R - \left(A_o - \left(D-D_f\right)\right) - R_f\right) \geq A_g - X - \frac{p_l}{\Delta p}\left(D-D_f\right), \tag{ICG}$$

$$K_g\left(I_f+I_g\right) \leq \min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g\right\}, \tag{NDK-LC}$$

$$R_f\left(I_f+I_g\right) \leq \min\left\{\Phi, \left(\left(R-A_o\right)+\left(D-D_f\right)\right)\left(I_f+I_g\right) + \overline{K}_1 + \overline{K}_0 - I_g\right\}, \tag{NDR-LC}$$

$$\text{and} \quad I_g + I_g \leq \bar{I} \tag{MS}$$

where IRF is the individual rationality constraint of the financiers, IRG is the individual rationality constraint of the government, ICG is the incentive compatibility constraint of the government, NDK-LC and NDR-LC combine the no-default conditions for the government and the feasibility constraints on government guarantees and promised returns. Note that to have IRG and IRF satisfied at the same time it has to be the case that

$$0 \leq p_h\left(R - \frac{B}{\Delta p}\right) + p_h\left(X+D\right) - r.$$

Moreover, the no-default conditions impose upper bounds on the total scale of the infrastructure project. Therefore, since the infrastructure project is positive NPV, either the constraint NDK or the constraint NDR or both have to bind, which implies

$$I = \min\left\{\frac{\min\left\{\Phi, \left(\left(R-\frac{B}{\Delta p}\right)+\left(D-D_f\right)\right)I + \overline{K}_1 + \overline{K}_0 - I_g\right\}}{R_f}, \frac{\min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g\right\}}{K_g}\right\}.$$

Therefore, the scale of the project will be determined either by the promised return to financiers R_f or by the government guarantees K_g or by both. Which is the case depends on whether the incentive compatibility constraint of the government and the participation constraint of the financier bind. As it is the case in this type of problem with multiple linear constraints, there are several possible cases to consider depending on the parameter values. To keep the Appendix brief, we provide a characterization of each of these cases and the parameter regions in which they are relevant in the Online Appendix.

Optimal financial contract

The optimal development rights assigned to the financiers are

$$D_f^\star = \begin{cases} 0 & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_D \\ \dfrac{(R-A_o)-\left(A_g-\frac{p_h}{\Delta p}D-X\right)}{\frac{p_h}{\Delta p}} & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \quad \text{and} \quad \Phi < \overline{K}_1 \\ \dfrac{\left(p_h\Phi+r\overline{K}_0+\overline{K}_1(1-p_h)\right)\left((R-A_o)-\left(A_g-\frac{p_h}{\Delta p}D-X\right)\right)-\left(\Phi-\overline{K}_1\right)r}{\left(p_l\Phi+r\overline{K}_0+\overline{K}_1(1-p_l)\right)\frac{p_h}{\Delta p}} & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \quad \text{and} \quad \Phi > \overline{K}_1 \\ D & \text{if} \quad \hat{\Gamma}^\star \leq (R-A_o), \end{cases} \tag{B.1}$$

the optimal government guarantee is given by

$$K_g^\star = \begin{cases} A_g - X - \frac{p_h}{\Delta p}D + \underline{R} - (R-A_o) & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_R \\ r\frac{\min\left\{\Phi,\overline{K}_1\right\}}{\min\left\{\Phi,\overline{K}_1\right\}+r\overline{K}_0} + \frac{p_h\min\left\{\Phi,\overline{K}_1\right\}}{\min\left\{\Phi,\overline{K}_1\right\}+r\overline{K}_0}\left(A_g - \frac{p_h}{\Delta p}D - (R-A_o) - X\right) & \text{if} \quad \hat{\Gamma}_R \leq (R-A_o) < \hat{\Gamma}_D \\ r - p_h D_f^\star - \frac{r\overline{K}_0}{I^\star} + p_h\left(A_g - \frac{p_h}{\Delta p}\left(D - D_f^\star\right) - (R-A_o) - X\right) & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \\ \frac{\min\left\{\Phi,\overline{K}_1\right\}}{r\overline{K}_0+(1-p_h)\min\left\{\Phi,\overline{K}_1\right\}+p_h\Phi}\,(r-p_hD) & \text{if} \quad \hat{\Gamma}^\star \leq (R-A_o), \end{cases} \tag{B.2}$$

the optimal government investment is given by

$$I_g^\star = \begin{cases} 0 & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_I \\ \dfrac{\left(r-\underline{R}-(1-p_h)\left(A_g-\frac{p_h}{\Delta p}D-(R-A_o)-X\right)\right)}{\left(A_g-\frac{p_h}{\Delta p}D-(R-A_o)-X\right)}\min\left\{\frac{\Phi}{r}, \dfrac{\left(A_g-\frac{p_h}{\Delta p}D-(R-A_o)-X\right)\left(\overline{K}_1+\overline{K}_0\right)}{\left(\left(A_g-\frac{p_h}{\Delta p}D-(R-A_o)-X\right)(r-(1-p_h))+r-\underline{R}\right)}\right\} & \text{if} \quad \hat{\Gamma}_I \leq (R-A_o) < \hat{\Gamma}_R \\ \overline{K}_0 & \text{if} \quad \hat{\Gamma}_R \leq (R-A_o), \end{cases} \tag{B.3}$$

the optimal return promised to financiers is

$$R_f^\star = \begin{cases} \underline{R} & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_R \\ r\frac{\min\left\{\Phi,\overline{K}_1\right\}}{\min\left\{\Phi,\overline{K}_1\right\}+r\overline{K}_0} - \left(\frac{r\overline{K}_0+(1-p_h)\min\left\{\Phi,\overline{K}_1\right\}}{\min\left\{\Phi,\overline{K}_1\right\}+r\overline{K}_0}\right)\left(A_g - \frac{p_h}{\Delta p}D - (R-A_o) - X\right) & \text{if} \quad \hat{\Gamma}_R \leq (R-A_o) < \hat{\Gamma}_D \\ r - p_h D_f^\star - \frac{r\overline{K}_0}{I^\star} - (1-p_h)\left(A_g - \frac{p_h}{\Delta p}\left(D - D_f^\star\right) - (R-A_o) - X\right) & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \\ \frac{\Phi}{r\overline{K}_0+(1-p_h)\min\left\{\Phi,\overline{K}_1\right\}+p_h\Phi}\,(r-p_hD) & \text{if} \quad \hat{\Gamma}^\star \leq (R-A_o), \end{cases} \tag{B.4}$$

and the optimal scale of the project is given by

$$I^\star = \begin{cases} 0 & (R-A_o) < \hat{\hat{\Gamma}} \\ \dfrac{\min\left\{\Phi,\overline{K}_1+\overline{K}_0\right\}}{A_g-X-\frac{p_h}{\Delta p}D+\underline{R}-(R-A_o)} & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_I \\ \dfrac{r\left(\overline{K}_1+\overline{K}_0\right)}{r+\underline{R}(r-1)+((1-p_h)-r)\left((R-A_o)-A_g\right)} & \text{if} \quad \hat{\Gamma}_I \leq (R-A_o) < \hat{\Gamma}_R \\ \dfrac{\min\left\{\Phi,\overline{K}_1\right\}+r\overline{K}_0}{\left(r+p_h\left(A_g-X-\frac{p_h}{\Delta p}D-(R-A_o)\right)\right)} & \text{if} \quad \hat{\Gamma}_R \leq (R-A_o) < \hat{\Gamma}_D \\ \dfrac{\overline{K}_1+r\overline{K}_0}{r-p_hD_f^\star+p_h\left(A_g-\frac{p_h}{\Delta p}\left(D-D_f^\star\right)-(R-A_o)-X\right)} & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \\ \dfrac{r\overline{K}_0+(1-p_h)\min\left\{\Phi,\overline{K}_1\right\}+p_h\Phi}{(r-p_hD)} & \text{if} \quad \hat{\Gamma}^\star \leq (R-A_o), \end{cases} \tag{B.5}$$

where the thresholds $\underline{\hat{\Gamma}}, \hat{\hat{\Gamma}}, \hat{\Gamma}_I, \hat{\Gamma}_R, \hat{\Gamma}_D$, and $\hat{\Gamma}^\star$ are summarized in Table B.1.

$\underline{\hat{\Gamma}}$	$\frac{r}{p_h} - (X + D)$
$\hat{\overline{\Gamma}}$	$\max\left\{\frac{r}{p_h} - X - D, (1-p_h)A_g - p_h\frac{(1-p_l)}{\Delta p}D - X + \underline{R}\right\}$
$\hat{\Gamma}_I$	$A_g - \frac{p_h}{\Delta p}D - X - \frac{r-\underline{R}}{1-p_h}$
$\hat{\Gamma}_R$	$A_g - X - \frac{p_h}{\Delta p}D - \frac{(r-\underline{R})\min\left\{\overline{K}_1,\Phi\right\}}{\left(r\left(\overline{K}_1+\overline{K}_0\right)-(r-(1-p_h))\min\left\{\overline{K}_1,\Phi\right\}\right)}$
$\hat{\Gamma}_D$	$\max\{A_g - X - \frac{p_h}{\Delta p}D + \frac{\Phi-\min\left\{\Phi,\overline{K}_1\right\}}{\left(r\overline{K}_0+(1-p_h)\min\left\{\Phi,\overline{K}_1\right\}+p_h\Phi\right)}r,$ $\frac{\Phi-\overline{K}_1}{\overline{K}_1+r\overline{K}_0+p_h\left(\Phi-\overline{K}_1\right)}\left(r + p_h\left(A_g - X - \frac{p_h}{\Delta p}D\right)\right) - \frac{\left(\overline{K}_1+r\overline{K}_0\right)}{\left(\overline{K}_1+r\overline{K}_0+p_h\left(\Phi-\overline{K}_1\right)\right)}D\}$
$\hat{\Gamma}^\star$	$\max\left\{\frac{\left(\Phi-\overline{K}_1\right)}{\left(\left(\Phi-\overline{K}_1\right)p_h+r\overline{K}_0+\overline{K}_1\right)}(r - p_h D) + A_g - X, A_g - X\right\}$

Table B.1: Equilibrium thresholds

Proof of Proposition 7 (Limited commitment to financiers)

From the definition of $\hat{\overline{\Gamma}}$ in Table B.1 it follows that $\frac{\partial\hat{\overline{\Gamma}}}{\partial\Phi} = 0$, which proves a. From the characterization of $I^\star$ in Equation (B.5) it follows that $I \leq \bar{I}$, where

$$\bar{I} \equiv \frac{r\overline{K}_0 + (1-p_h)\min\left\{\Phi,\overline{K}_1\right\} + p_h\Phi}{(r - p_h D)},$$

which is increasing in Φ.

Proof of Proposition 8 (Externalities)

From the definition of $\overline{\Gamma}$ in Table B.1 it follows that $\frac{\partial\hat{\overline{\Gamma}}}{\partial X} < 0$ and $\frac{\partial\hat{\overline{\Gamma}}}{\partial D} < 0$, which increase the region in which the project is feasible. From the definition of $I^\star$ in Equation (B.5) we have $\frac{\partial I^\star}{\partial X} \geq 0$ and $\frac{\partial I^\star}{\partial D} \geq 0$, which proves the proposition.

Proof of Proposition 9 (Distribution of development rights)

The proof follows from the characterization of the optimal development rights assigned to the financier characterized in Equation (B.1).

C Coal-Fueled Thermal Power Plants in India

In this section, we describe in more detail the evidence presented in Section 5.

C.1 Stressed coal-fueled thermal Power Plants

Table C.1 presents the list of stressed coal-fueled thermal Power Plants in our sample, their inception date, the start of the distress period, their capacity, and their debt outstanding.

Table C.1: List of stranded coal-fueled thermal power plants

Power plant	**State**	**Year zero**	**Start of distress**	**Capacity (MW)**	**Debt outst. (Rs in bio.)**[1]
Adani Power Maharashtra Ltd.	MH	2008	2011	3300	117.65
Adhunik Power & Natural Resources Ltd.	JH	2009	2018	540	24.74
Athena Chhattisgarh Power Ltd.	CH	2011	2015	1200	70.86
Avantha Power (Jhabua)	MP	2010	2015	600	49.20
Avantha Power (Korba)	CH	2009	2016	600	30.99
Coastal Energen Pvt. Ltd.	TN	2009	2015	1200	64.83
Damodar Valley Corporation Raghunathpur	WB	2007	2013	1200	23.18
DB Power Ltd.	CH	2010	2015	1200	67.21
East Coast Energy Pvt. Ltd.	AP	2010	2015	1320	49.06
Essar Power Jharkhand Ltd.	JH	2008	2013	1200	36.50
Essar Power Mahaan Ltd.	MP	2007	2015	1200	59.84
GMR Chhattisgarh Energy Ltd.	CH	2010	2015	1370	81.74
GMR Kamalanga Energy Ltd.	OD	2009	2013	1050	41.00
GMR Warora Energy Ltd.	MH	2009	2015	600	29.05
GVK Industries Ltd. (Goindwal Sahib)	PB	2010	2013	540	43.46
Ind Bharath (Utkal) Ltd.	OD	2009	2015	700	48.93
Jaypee Power Ventures Pvt. Ltd. (Bina)	MP	2009	2015	540	22.54
Jaypee Power Ventures Pvt. Ltd. (Nigrie)	MP	2009	2015	1320	62.11
Jindal India Thermal Power Ltd.	OD	2008	2013	1200	55.07
Kanti Bijlee Utpadan Nigam Ltd.	BR	2010	2014	390	25.06
KSK Mahanadi Power Co. Ltd.	CH	2009	2015	3600	208.25
KVK Nilachal Power Ltd.	OD	2009	2015	350	10.62
Lanco Amarkantak Power Ltd.	CH	2009	2014	1920	90.03
Lanco Anpara Power Ltd.	UP	2008	2014	1200	30.71
Lanco Babandh Power Ltd.	OD	2009	2015	1320	82.17
Lanco Vidarbha Thermal Power Ltd.	MH	2010	2013	1320	48.85
Monnet Power Co. Ltd.	OD	2009	2015	1050	58.74
Prayagraj Power Generation Company Ltd. (jaypee)	UP	2010	2015	1980	114.94
Rattan India Power Ltd. (Nasik)	MH	2009	2013	1350	71.08
RKM Powergen Private Ltd.	CH	2007	2017	1440	91.46
Simhapuri Energy Ltd.	AP	2009	2012	600	26.08
SKS Power Generation Chattisgarh Ltd.	CH	2011	2013	600	48.01
Vandana Vidhyut Ltd.	CH	2008	2012	270	26.78
Visa Power Ltd.	CH	2010	2015	600	14.81

Source Ministry of Power of India (2020-21).

For some plants, an official 'date zero' is not available in the Broad Status Reports. Consequently, we have utilized alternative significant dates to provide context. The details for each of these cases are as follows:

- Avantha Power (Korba): Financial closure was achieved in June 2009, with the Main Plant Order dated April 2009.
- Essar Power Jharkhand Ltd.: Main Plant Order dated August 2008.
- GMR Kamalanga Energy Ltd.: Letter of Award dated August 2009.
- Jindal India Thermal Power Ltd.: Letter of Award and Main Plant Order dated December 2008, with financial closure achieved in March 2010.
- RKM Powergen Private Ltd.: Letter of Award dated November 2007.
- Vandana Vidhyut Ltd.: Main Plant Order dated November 2008, financial closure in August 2009, and Letter of Award dated September 2009.

C.2 Representative Cases for Drivers of fatal Cause

Table C.2 highlights a representative case for each type of fatal cause. Each case in the table is associated with several factors contributing to the fatal outcomes. The category "Non-availability of PPAs" refers to PPAs at remunerative tariffs.

Two cases in Table 5 in the main text cannot be classified as public or private moral hazard. These cases, which remain unclassified in the Table, refer to Prayagraj Power Generation Company Ltd. (Jaypee) and Adhunik Power & Natural Resources Ltd. For Prayagraj Power Generation Company Ltd., land acquisition was halted by court order due to local resistance. Adhunik Power & Natural Resources Ltd. faced the cancellation of coal block allocations by the Supreme Court on the grounds that the process of allocation was arbitrary and illegal. These causes of failure do not reflect neither private nor public moral hazard and therefore remain unclassified in our analysis. One more case is worth highlighting. For Lanco Anpara Power Ltd., one of the main causes of failure was the shortage of manpower (BHEL scope). Since BHEL is a government-owned company, we count this as delays in operation caused by the government.

Table C.2: Representative cases for drivers of fatal cause

Cause of failure	Representative case	Description
Paucity of funds	Lanco Amarkantak Power Ltd.	Lanco Amarkantak Power Ltd. has suffered from a paucity of funds due to a variety of reasons, including a substantial increase of interest rates, an unprecedented rupee depreciation, and higher coal acquisition costs.
Law and order problem	East Coast Energy Pvt. Ltd.	For East Coast Energy Pvt. Ltd., local resistance not only disrupted work but also led to an order from the Ministry of Environment, Forest and Climate Change (MoEFCC) to suspend work for an extended period.
Legal issue	KVK Nilachal Power Ltd.	The Honorable High Court of Odisha mandated the work on the plant of KVK Nilachal Power Ltd. to stop due to law and order concerns, effective from May 18, 2012.
Delay of project status/clearances	Essar Power Jharkhand Ltd.	For Essar Power Jharkhand Ltd., the absence of environmental clearance and Mega Power Project status from the government (MoEF and MoP, respectively) halted the plant's work and prevented progress to the construction phase.
Delay in acquisition/physical handover of land	Lanco Amarkantak Power Ltd.	For Lanco Amarkantak Power Ltd., the process of acquiring land was delayed due to government process delays and local resistance.
Coal supply issues	KSK Mahanadi Power Co. Ltd.	KSK Mahanadi Power Co. Ltd.'s coal supply was canceled due to actions by the Supreme Court and the Ministry of Coal.
Missing supply/transmission infrastructure	Rattan India Power Ltd. (Nasik)	The project faced delays in completing the railway siding necessary for coal transportation.
Operational issues/delays or other reasons	Ind Bharath (Utkal) Ltd.	Some of the operational challenges faced by the plant included slow civil work progress, supply challenges, unprepared power evacuation systems, and technical flaws in crucial components.
Non-availability of PPAs	Mutiara TPP (Coastal Energen)	For Mutiara TPP (Coastal Energen), the absence of a PPA with TANGEDCO for was a major concern and contributed to investor unease.

ONLINE APPENDIX

A Extensions: Characterization of optimal financial contract

In this section, we provide a detailed characterization of the optimal financial contract for the model presented in Section 4. We assume the parametric assumptions stated in the text hold.

The optimal financing contract solves

$$\max_{I_g \in \{0,K_0\}, I_f \geq 0, K_g \geq 0, R_f \geq \underline{R}, D_f \in [0,D]} \left(p_h\left(R+X+D\right)-r\right)\left(I_g+I_f\right)$$

subject to

$$\left(1-p_h\right)K_g+p_h\left(R_f+D_f\right) \geq r\frac{I_f}{I_f+I_g}, \tag{IRF}$$

$$\left(1-p_h\right)K_g+p_h\left(R_f+D_f\right)+r\frac{I_g}{I_f+I_g} \leq p_h\left(R-A_o\right)+p_h\left(X+D\right), \tag{IRG}$$

$$K_g+\left(R-\left(A_o-\left(D-D_f\right)\right)-R_f\right) \geq A_g-X-\frac{p_l}{\Delta p}\left(D-D_f\right), \tag{ICG}$$

$$K_g\left(I_f+I_g\right) \leq \min\left\{\Phi,\overline{K}_1+\overline{K}_0-I_g\right\}, \quad \text{and} \tag{NDK}$$

$$R_f\left(I_f+I_g\right) \leq \min\left\{\Phi,\left(\left(R-A_o\right)+\left(D-D_f\right)\right)\left(I_f+I_g\right)+\overline{K}_1+\overline{K}_0-I_g\right\}, \tag{NDR}$$

where IRF is the individual rationality constraint of the financiers, IRG is the individual rationality constraint of the government, ICG is the incentive compatibility constraint of the government, and NDK and NDR combine the no-default conditions for the government and the feasibility constraints on government guarantees and promised returns. Note that to have IRG and IRP satisfied at the same time it has to be the case that

$$0 \leq p_h\left(R-A_o\right)+p_h\left(X+D\right)-r.$$

Moreover, the no-default conditions impose upper bounds on the total scale of the infrastructure project. Note that NDR cannot bind as it would violate IRG. Therefore, since the infrastructure project is positive NPV, either the constraint NDK or the maximum scale constraint or both have to bind, which implies

$$I=\min\left\{\frac{\min\left\{\Phi,\left(\left(R-A_o\right)+\left(D-D_f\right)\right)I+\overline{K}_1+\overline{K}_0-I_g\right\}}{R_f},\frac{\min\left\{\Phi,\overline{K}_1+\overline{K}_0-I_g\right\}}{K_g}\right\}.$$

To characterize the optimal financing contract one needs to consider three possible cases, that depend on which constraints are binding. Below, we consider each case separately and characterize the parameter regions in which they are relevant.

Case 1: ICG binds and IRF is slack

If ICG binds, the government guarantees are given by

$$K_g=A_g-\frac{p_h}{\Delta p}\left(D-D_f\right)-\left(R-A_o\right)-X+R_f$$

and total investment is given by

$$I = \min\left\{ \frac{\min\left\{\Phi, ((R-A_o)+(D-D_f))I+\overline{K}_1+\overline{K}_0-I_g\right\}}{R_f}, \frac{\min\left\{\Phi, \overline{K}_1+\overline{K}_0-I_g\right\}}{A_g-\frac{p_h}{\Delta p}(D-D_f)-(R-A_o)-X+R_f} \right\},$$

which is decreasing in R_f, D_f, and I_g. Then, it is optimal to set R_f, D_f, and I_g as small as possible to maximize the size of the investment. More specifically, it is optimal to set $R_f^\star = \underline{R}$, $D_f^\star = 0$, and $I_g^\star = 0$, which implies

$$K_g^\star = A_g - X - \frac{p_h}{\Delta p}D + \underline{R} - (R-A_o) \quad \text{and} \quad I^\star = \frac{\min\left\{\Phi, \overline{K}_1+\overline{K}_0\right\}}{A_g-X-\frac{p_h}{\Delta p}D+\underline{R}-(R-A_o)}.$$

Finally, to satisfy the IRF and IRG it has to be the case that $\hat{\hat{\Gamma}} \leq (R-A_o) \leq \hat{\Gamma}_I$, where

$$\hat{\hat{\Gamma}} \equiv \max\left\{\frac{r}{p_h} - X - D, (1-p_h)A_g - p_h\frac{(1-p_l)}{\Delta p}D - X + \underline{R}\right\} \quad \text{and}$$
$$\hat{\Gamma}_I \equiv A_g - \frac{p_h}{\Delta p}D - X - \frac{r-\underline{R}}{1-p_h}.$$

Note that if this region is not empty we have $K_g^\star > 0$.

Case 2: ICG and IRF bind

First, note that if IRF binds, ICG is given by

$$R_f^\star = r\frac{I^\star - I_g^\star}{I^\star} - p_h D_f^\star - (1-p_h)\left(A_g - X - \frac{p_h}{\Delta p}\left(D-D_f^\star\right) - (R-A_o)\right) \tag{OA.1}$$

and

$$K_g^\star = r\frac{I^\star - I_g^\star}{I^\star} - p_h D_f^\star + p_h\left(A_g - X - \frac{p_h}{\Delta p}\left(D-D_f^\star\right) - (R-A_o)\right). \tag{OA.2}$$

In this case, the total scale of the project is given by

$$I^\star = \min\left\{ \frac{\min\left\{\Phi, \left((R-A_o)+\left(D-D_f^\star\right)\right)I^\star+\overline{K}_1+\overline{K}_0-I_g^\star\right\}}{R_f^\star}, \frac{\min\left\{\Phi, \overline{K}_1+\overline{K}_0-I_g^\star\right\}}{K_g^\star} \right\},$$

where $I_g^\star$ and $D_f^\star$ are constrained by the non-negativity constraints on K_g and R_f. Since $I^\star$ is increasing in $I_g^\star$, it is optimal to set $I_g^\star$ as high as possible conditional on satisfying these constraints. Since $I^\star$ is decreasing in $R_f^\star$, it is optimal to set $I_g^\star$ such that $R_f^\star = \underline{R}$ as long as $I_g^\star < \overline{K}_0$. Setting $R_f^\star = \underline{R}$ in Equation OA.1 implies

$$r - \underline{R} - p_h D_f^\star + (1-p_h)\left((R-A_o) - (A_g - X) + \frac{p_h}{\Delta p}\left(D-D_f^\star\right)\right) = r\frac{I_g^\star}{I^\star}. \tag{OA.3}$$

If the scale of the project is given by $K_g^\star$, i.e., $I = \frac{\min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g\right\}}{K_g}$ we have

$$I^\star = \frac{\min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g^\star\right\} + rI_g^\star}{\left(r - \underline{R} - p_h D_f^\star + p_h\left(A_g - X - \frac{p_h}{\Delta p}\left(D - D_f^\star\right) - (R - A_o)\right)\right)},$$

which together with Equation (OA.3) gives

$$I^\star = \frac{\min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g^\star\right\}}{\left(A_g - X - \frac{p_h}{\Delta p}\left(D - D_f^\star\right) - (R - A_o)\right)},$$

where $I_g^\star$ is given by the solution to

$$\frac{rI_g^\star}{\min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g^\star\right\}} = \frac{\left(r - \underline{R} - p_h D_f^\star - (1 - p_h)\left(A_g - X - \frac{p_h}{\Delta p}\left(D - D_f^\star\right) - (R - A_o)\right)\right)}{\left(A_g - X - \frac{p_h}{\Delta p}\left(D - D_f^\star\right) - (R - A_o)\right)}.$$

Note that $I^\star$ in the equation above is decreasing in $D_f^\star$. Therefore, it is optimal to set $D_f^\star = 0$ as long as $I_g^\star \leq \overline{K}_0$. Solving for $I_g^\star$ setting $D_f^\star = 0$ implies

$$I_g^\star = \begin{cases} \frac{\left(r-(1-p_h)\left(A_g-X-\frac{p_h}{\Delta p}D-(R-A_o)\right)-\underline{R}\right)}{\left(A_g-X-\frac{p_h}{\Delta p}D-(R-A_o)+\underline{R}\right)}\frac{\Phi}{r} & \text{if} \quad (R-A_o) \leq A_g - X - \frac{p_h}{\Delta p}D - \frac{(r-\underline{R})\Phi}{rK_0-(r-(1-p_h))\Phi+r\min\left\{\overline{K}_1,\Phi\right\}} \\ \frac{\left(r-\underline{R}-(1-p_h)\left(A_g-X-\frac{p_h}{\Delta p}D-(R-A_o)\right)\right)}{\left(r-\underline{R}+(r-(1-p_h))\left(A_g-X-\frac{p_h}{\Delta p}D-(R-A_o)\right)\right)}\left(\overline{K}_1+\overline{K}_0\right) & \text{if} \quad (R-A_o) \leq A_g - X - \frac{p_h}{\Delta p}D - \frac{(r-\underline{R})\overline{K}_1}{\left(r\overline{K}_0+(1-p_h)\overline{K}_1\right)} \\ & \text{and } (R-A_o) > A_g - X - \frac{p_h}{\Delta p}D - \frac{(r-\underline{R})\Phi}{\left(r\left(\overline{K}_1+\overline{K}_0\right)-(r-(1-p_h))\Phi\right)}, \end{cases}$$

where the second case is only feasible when $\Phi > \overline{K}_1$. Since $I_g^\star \leq \overline{K}_0$, we have that $D_f^\star = 0$ if and only if $(R - A_o) \leq \hat{\Gamma}_R$, where

$$\hat{\Gamma}_R \equiv A_g - X - \frac{p_h}{\Delta p}D - \frac{(r - \underline{R})\min\left\{\overline{K}_1, \Phi\right\}}{\left(r\left(\overline{K}_1 + \overline{K}_0\right) - (r - (1 - p_h))\min\left\{\overline{K}_1, \Phi\right\}\right)}.$$

In this region, $R_f^\star = \underline{R}$ and investment is positive as long as $A_g - X - \frac{p_h}{\Delta p}D \geq (R - A_o)$.

If $(R - A_o) \geq \hat{\Gamma}_R$, then $I_g^\star = \overline{K}_0$, $D_f^\star = 0$ and $R_f^\star$ is given by

$$R_f^\star = r - r\frac{\overline{K}_0}{I^\star} - (1 - p_h)\left(A_g - X - \frac{p_h}{\Delta p}D - (R - A_o)\right),$$

where

$$I^\star = \frac{\min\left\{\Phi, \overline{K}_1\right\} + r\overline{K}_0}{\left(r + p_h\left(A_g - X - \frac{p_h}{\Delta p}D - (R - A_o)\right)\right)}.$$

Putting these two equations together gives

$$R_f^\star = r\frac{\min\left\{\Phi, \overline{K}_1\right\}}{\min\left\{\Phi, \overline{K}_1\right\} + r\overline{K}_0} - \left(\frac{r\overline{K}_0 + (1 - p_h)\min\left\{\Phi, \overline{K}_1\right\}}{\min\left\{\Phi, \overline{K}_1\right\} + r\overline{K}_0}\right)\left(A_g - X - \frac{p_h}{\Delta p}D - (R - A_o)\right),$$

which will satisfy NDR, the willingness-to-pay and ability-to-pay constraints for R_f, as long as $(R-A_o) \leq \hat{\Gamma}_D$, where

$$\hat{\Gamma}_D \equiv \max\{A_g - X - \frac{p_h}{\Delta p}D + \frac{\Phi - \min\left\{\Phi, \overline{K}_1\right\}}{\left(r\overline{K}_0 + (1-p_h)\min\left\{\Phi, \overline{K}_1\right\} + p_h\Phi\right)}r,$$
$$\frac{\Phi - \overline{K}_1}{\overline{K}_1 + r\overline{K}_0 + p_h\left(\Phi - \overline{K}_1\right)}\left(r + p_h\left(A_g - X - \frac{p_h}{\Delta p}D\right)\right) - \frac{\left(\overline{K}_1 + r\overline{K}_0\right)}{\left(\overline{K}_1 + r\overline{K}_0 + p_h\left(\Phi - \overline{K}_1\right)\right)}D\},$$

which implies $I^\star \geq 0$ and $K_g^\star > 0$.

If $(R-A_o) > \hat{\Gamma}_D$, we have $I_g^\star = \overline{K}_0$ and the no-default conditions for R_f and K_g bind. In this case, $D_f^\star$ is given by the solution to

$$\frac{\min\left\{\Phi, \left((R-A_o) + \left(D - D_f^\star\right)\right)I^\star + \overline{K}_1 + \overline{K}_0 - I_g^\star\right\}}{R_f^\star} = \frac{\min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g^\star\right\}}{K_g^\star},$$

where $R_f^\star$ is given by Equation (OA.1) and $K_g^\star$ is given by Equation (OA.2). This holds as long as $(R-A_o) \leq \hat{\Gamma}^\star$, where

$$\hat{\Gamma}^\star \equiv \max\left\{\frac{\left(\Phi - \overline{K}_1\right)}{\left(\left(\Phi - \overline{K}_1\right)p_h + r\overline{K}_0 + \overline{K}_1\right)}(r - p_h D) + A_g - X, A_g - X\right\}.$$

At $(R-A_o) = \hat{\Gamma}^\star$, six constraints are binding: IRF, ICG, the no-default constraints on $R_f^\star$ and $K_g^\star$, and we have $I_g = \overline{K_0}$ and $D_f^\star = D$.

Case 3: IRF binds, ICG is slack

If $(R-A_o) > \hat{\Gamma}^\star$, then IRF binds and ICG is slack. In this case

$$I^\star = \min\left\{\frac{\min\left\{\Phi, \left((R-A_o) + \left(D - D_f^\star\right)\right)I^\star + \overline{K}_1 + \overline{K}_0 - I_g^\star\right\}}{R_f^\star}, \frac{(1-p_h)\left(\min\left\{\Phi, \overline{K}_1 + \overline{K}_0 - I_g^\star\right\}\right) + rI_g^\star}{r - p_h\left(R_f^\star + D_f^\star\right)}\right\}$$

so it is optimal to choose $D_f^\star = D$, $I_g^\star = \overline{K}_0$, and $R_f^\star$ such that the no-default conditions for $R_f^\star$ and $K_g^\star$ are binding, i.e.,

$$\min\left\{\Phi, (R-A_o)I^\star + \overline{K}_1\right\}\left(r - p_h\left(R_f^\star + D\right)\right) = \left((1-p_h)\min\left\{\Phi, \overline{K}_1\right\} + r\overline{K}_0\right)R_f^\star.$$

Note that it has to be the case that $\Phi < (R-A_o)I^\star + \overline{K}_1$. Otherwise, we would have $\Phi > \overline{K}_1$ and

$$R_f^\star = \frac{\overline{K}_1(r - p_h D) + \left((1-p_h)\overline{K}_1 + r\overline{K}_0\right)(R-A_o)}{\left(\overline{K}_1 + r\overline{K}_0\right)},$$

which would imply $\Phi < (R-A_o)I^\star + \overline{K}_1$, contradicting our initial assumption.

Therefore, when $(R-A_o) \geq \hat{\Gamma}^\star$ it has to be the case that $\Phi < (R-A_o)I^\star + \overline{K}_1$ and we have

$$R_f^\star = \frac{\Phi}{r\overline{K}_0 + (1-p_h)\min\left\{\Phi, \overline{K}_1\right\} + p_h\Phi}(r - p_h D), \tag{OA.4}$$

$$K_g^\star = \frac{\min\left\{\Phi, \overline{K}_1\right\}}{r\overline{K}_0 + (1-p_h)\min\left\{\Phi, \overline{K}_1\right\} + p_h\Phi}(r - p_h D), \quad \text{and} \tag{OA.5}$$

$$I^\star = \frac{r\overline{K}_0 + (1-p_h)\min\left\{\Phi, \overline{K}_1\right\} + p_h\Phi}{(r - p_h D)}. \tag{OA.6}$$

To be in this case we need $\Phi < (R-A_o)I^\star + \overline{K}_1$ which is the same as

$$\frac{\left(\Phi - \overline{K}_1\right)}{r\overline{K}_0 + (1-p_h)\min\left\{\Phi, \overline{K}_1\right\} + p_h\Phi}(r - p_h D) < (R - A_o).$$

This condition will be satisfied as long as ICG is satisfied, which is the same as

$$(R-A_o) \geq A_g - X + \left(\frac{\Phi(1-p_h) - \min\left\{\Phi, \overline{K}_1\right\}}{r\overline{K}_0 + (1-p_h)\min\left\{\Phi, \overline{K}_1\right\} + p_h\Phi}\right)(r - p_h D).$$

Optimal financial contract

The optimal development rights assigned to the financiers are

$$D_f^\star = \begin{cases} 0 & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_D \\ \frac{(R-A_o)-\left(A_g - \frac{p_h}{\Delta p}D - X\right)}{\frac{p_h}{\Delta p}} & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \quad \text{and} \quad \Phi < \overline{K}_1 \\ \frac{\left(p_h\Phi + r\overline{K}_0 + \overline{K}_1(1-p_h)\right)\left((R-A_o)-\left(A_g - \frac{p_h}{\Delta p}D - X\right)\right) - \left(\Phi - \overline{K}_1\right)r}{\left(p_l\Phi + r\overline{K}_0 + \overline{K}_1(1-p_l)\right)\frac{p_h}{\Delta p}} & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \quad \text{and} \quad \Phi > \overline{K}_1 \\ D & \text{if} \quad \hat{\Gamma}^\star \leq (R-A_o), \end{cases} \tag{OA.7}$$

the optimal government guarantee is given by

$$K_g^\star = \begin{cases} A_g - X - \frac{p_h}{\Delta p}D + \underline{R} - (R-A_o) & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_R \\ r\frac{\min\left\{\Phi, \overline{K}_1\right\}}{\min\left\{\Phi, \overline{K}_1\right\} + r\overline{K}_0} + \frac{p_h \min\left\{\Phi, \overline{K}_1\right\}}{\min\left\{\Phi, \overline{K}_1\right\} + r\overline{K}_0}\left(A_g - \frac{p_h}{\Delta p}D - (R-A_o) - X\right) & \text{if} \quad \hat{\Gamma}_R \leq (R-A_o) < \hat{\Gamma}_D \\ r - p_h D_f^\star - \frac{r\overline{K}_0}{I^\star} + p_h\left(A_g - \frac{p_h}{\Delta p}\left(D - D_f^\star\right) - (R-A_o) - X\right) & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \\ \frac{\min\left\{\Phi, \overline{K}_1\right\}}{r\overline{K}_0 + (1-p_h)\min\left\{\Phi, \overline{K}_1\right\} + p_h\Phi}(r - p_h D) & \text{if} \quad \hat{\Gamma}^\star \leq (R-A_o), \end{cases} \tag{OA.8}$$

the optimal government investment is given by

$$I_g^\star = \begin{cases} 0 & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_I \\ \frac{\left(r-\underline{R}-(1-p_h)\left(A_g-\frac{p_h}{\Delta p}D-(R-A_o)-X\right)\right)}{\left(A_g-\frac{p_h}{\Delta p}D-(R-A_o)-X\right)} \min\left\{\frac{\Phi}{r}, \frac{\left(A_g-\frac{p_h}{\Delta p}D-(R-A_o)-X\right)\left(\overline{K}_1+\overline{K}_0\right)}{\left(\left(A_g-\frac{p_h}{\Delta p}D-(R-A_o)-X\right)(r-(1-p_h))+r-\underline{R}\right)}\right\} & \text{if} \quad \hat{\Gamma}_I \leq (R-A_o) < \hat{\Gamma}_R \\ \overline{K}_0 & \text{if} \quad \hat{\Gamma}_R \leq (R-A_o), \end{cases} \tag{OA.9}$$

the optimal return promised to financiers is

$$R_f^\star = \begin{cases} \underline{R} & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_R \\ r\frac{\min\left\{\Phi,\overline{K}_1\right\}}{\min\left\{\Phi,\overline{K}_1\right\}+r\overline{K}_0} - \left(\frac{r\overline{K}_0+(1-p_h)\min\left\{\Phi,\overline{K}_1\right\}}{\min\left\{\Phi,\overline{K}_1\right\}+r\overline{K}_0}\right)\left(A_g-\frac{p_h}{\Delta p}D-(R-A_o)-X\right) & \text{if} \quad \hat{\Gamma}_R \leq (R-A_o) < \hat{\Gamma}_D \\ r-p_hD_f^\star-\frac{r\overline{K}_0}{I^\star}-(1-p_h)\left(A_g-\frac{p_h}{\Delta p}\left(D-D_f^\star\right)-(R-A_o)-X\right) & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \\ \frac{\Phi}{r\overline{K}_0+(1-p_h)\min\left\{\Phi,\overline{K}_1\right\}+p_h\Phi}(r-p_hD) & \text{if} \quad \hat{\Gamma}^\star \leq (R-A_o), \end{cases} \tag{OA.10}$$

and the optimal scale of the project is given by

$$I^\star = \begin{cases} 0 & (R-A_o) < \hat{\hat{\Gamma}} \\ \frac{\min\left\{\Phi,\overline{K}_1+\overline{K}_0\right\}}{A_g-X-\frac{p_h}{\Delta p}D+\underline{R}-(R-A_o)} & \text{if} \quad \hat{\hat{\Gamma}} \leq (R-A_o) < \hat{\Gamma}_I \\ \frac{r\left(\overline{K}_1+\overline{K}_0\right)}{r+\underline{R}(r-1)+((1-p_h)-r)((R-A_o)-A_g)} & \text{if} \quad \hat{\Gamma}_I \leq (R-A_o) < \hat{\Gamma}_R \\ \frac{\min\left\{\Phi,\overline{K}_1\right\}+r\overline{K}_0}{\left(r+p_h\left(A_g-X-\frac{p_h}{\Delta p}D-(R-A_o)\right)\right)} & \text{if} \quad \hat{\Gamma}_R \leq (R-A_o) < \hat{\Gamma}_D \\ \frac{\overline{K}_1+r\overline{K}_0}{r-p_hD_f^\star+p_h\left(A_g-\frac{p_h}{\Delta p}\left(D-D_f^\star\right)-(R-A_o)-X\right)} & \text{if} \quad \hat{\Gamma}_D \leq (R-A_o) < \hat{\Gamma}^\star \\ \frac{r\overline{K}_0+(1-p_h)\min\left\{\Phi,\overline{K}_1\right\}+p_h\Phi}{(r-p_hD)} & \text{if} \quad \hat{\Gamma}^\star \leq (R-A_o), \end{cases} \tag{OA.11}$$

where the thresholds $\underline{\hat{\Gamma}}$, $\hat{\hat{\Gamma}}$, $\hat{\Gamma}_I$, $\hat{\Gamma}_R$, $\hat{\Gamma}_D$, and $\hat{\Gamma}^\star$ are summarized in Table OA.1.

B Financing Multiple Infrastructure Projects

Finally, we analyze the case in which multiple projects need to be financed and allow for the government to pool the resources from both projects to raise funds and invest in them.

Specifically, governments may have access to multiple sources of cash flows to pay the financiers. So far, we have implicitly considered "revenue-only" (RO) financing, i.e., only the cash flows associated with the infrastructure project (including attendant spillovers) and the government's fiscal capacity for guarantees can be used to pay financiers. However, in many instances, cash flows from other projects are also used to pay financiers, for example, in "general obligation" (GO) financing which is supported by overall tax collections at municipality or city level. To encompass this feature we expand the set of projects and financing contracts.

We consider two infrastructure projects and model general obligation financing as a cross-guarantee between the projects. Formally, we consider two ex-ante identical, independent infrastructure projects,

$\underline{\hat{\Gamma}}$	$\frac{r}{p_h} - (X + D)$
$\hat{\overline{\Gamma}}$	$\max\left\{\frac{r}{p_h} - X - D, (1-p_h)A_g - p_h\frac{(1-p_l)}{\Delta p}D - X + \underline{R}\right\}$
$\hat{\Gamma}_I$	$A_g - \frac{p_h}{\Delta p}D - X - \frac{r-\underline{R}}{1-p_h}$
$\hat{\Gamma}_R$	$A_g - X - \frac{p_h}{\Delta p}D - \frac{(r-\underline{R})\min\left\{\overline{K}_1,\Phi\right\}}{\left(r\left(\overline{K}_1+\overline{K}_0\right)-(r-(1-p_h))\min\left\{\overline{K}_1,\Phi\right\}\right)}$
$\hat{\Gamma}_D$	$\max\{A_g - X - \frac{p_h}{\Delta p}D + \frac{\Phi-\min\left\{\Phi,\overline{K}_1\right\}}{\left(r\overline{K}_0+(1-p_h)\min\left\{\Phi,\overline{K}_1\right\}+p_h\Phi\right)}r,$ $\frac{\Phi-\overline{K}_1}{\overline{K}_1+r\overline{K}_0+p_h\left(\Phi-\overline{K}_1\right)}\left(r + p_h\left(A_g - X - \frac{p_h}{\Delta p}D\right)\right) - \frac{\left(\overline{K}_1+r\overline{K}_0\right)}{\left(\overline{K}_1+r\overline{K}_0+p_h\left(\Phi-\overline{K}_1\right)\right)}D\}$
$\hat{\Gamma}^{\star}$	$\max\left\{\frac{\left(\Phi-\overline{K}_1\right)}{\left(\left(\Phi-\overline{K}_1\right)p_h+r\overline{K}_0+\overline{K}_1\right)}(r - p_hD) + A_g - X, A_g - X\right\}$

Table OA.1: Equilibrium thresholds

$i = a,b$. Each project is subject to moral hazard from the respective private sector operator. The government can choose to expropriate the returns of the projects after they are realized and decides whether to do so in each project independently of what it does in the other project (say, the projects are under different operating arms of the government bureaucracy). To finance the projects, the government offers to financiers of project i a guarantee $K_g^i I^i$, $i = a,b$ if the project fails, and an additional transfer or cross-guarantee $K^i I^i$ from the cash flows from project $j \neq i$ if project i fails and project j succeeds. We denote by $\alpha \equiv \frac{I^a}{I^a+I^b}$ the fraction of total investment in project a. To simplify the analysis and focus on the interaction between the double moral hazard and the choice of infrastructure financing, we ignore the possibility of direct government investment by setting $\overline{K}_0 = 0$, set $\underline{R} = 0$ and $C = 0$, and assume the government can commit to any feasible finite terms of the financing contract by letting $\Phi \to \infty$ (i.e., there is always the willingness to pay).

Note that since cross-guarantees can always be chosen to be zero, general obligation financing can only increase the scale of the project relative to revenue-only financing (benchmark model). Hence, the analysis of interest is when general obligation financing features positive cross-guarantees, or in other words, strictly dominates revenue-only financing.

The incentive compatibility constraint of the private sector operator in each project i is the same as the one considered in the benchmark model, i.e.,

$$\left[R - \left(R_f^i + R_g^i\right)\right] \geq \frac{B}{\Delta p}, \quad i = a,b,$$

where R_f^i and R_g^i are, respectively, the return to the financiers and the government from project i if it succeeds. As in the benchmark model, the government will expropriate all it can from the private sector operator while providing the private sector incentives to exert effort. Hence, $R_g^i = \overline{R}_g^i \equiv \left[(R - A_o) - R_f^i\right]$ for $i = a,b$, where $A_o \equiv \frac{B}{\Delta p}$ is the agency rent of the operator. Moreover, the government will only commit to sharing part of the project's payoff with the financiers if their participation constraint is binding.

The incentive compatibility constraint of the government in each project now takes into account the expected transfers made and received from the other project. Formally,

$$p_h\overline{R}_g^i I^i - (1-p_h)K_g^i I^i - p_h(1-p_h)K^i I^i - p_h(1-p_h)K^j I^j \geq$$
$$p_l\overline{R}_g^i I^i + p_l\frac{B}{\Delta p}I^i - (1-p_l)K_g^i I^i - p_h(1-p_l)K^i I^i - p_l(1-p_h)K^j I^j,$$

or

$$\left(p_h K^i - (1-p_h)K^j\frac{1-\alpha}{\alpha} + K_g^i - R_f^i\right) \geq A_g - (R - A_o), \tag{ICG–GO}$$

for $i \neq j$ and $i,j = a,b$, where $A_g \equiv p_l\frac{B}{\Delta p}$. Cross-guarantees, which appear in the terms with $p(1-p)$, have two opposing effects on the government's incentives to expropriate. On the one hand, providing a guarantee K^i when project i fails and project j succeeds makes it more costly for the government to expropriate and have the private sector operator not exert effort in project i. This mechanism decreases the government's incentives to expropriate. On the other hand, providing a guarantee K^j to financiers from project i to project j (when project j fails and i succeeds) lowers the government's payoff from not expropriating and tightens its incentive compatibility constraint. It turns out that which of these two effects dominates, depends on the probability of success of the projects.

The participation constraints of the financiers and the government when cross-guarantees are allowed are analogous to the ones in the baseline model with the innovation that they now take into account the cross-transfers among projects. We formally state these participation constraints and the feasibility constraints on guarantees in the Appendix.

Since projects are identical and the optimal financing contract maximizes the sum of the expected payoff of the projects, it is optimal to maximize the joint scale of the projects. Since the scale of the projects is determined by the government guarantee required by the financiers, it is optimal to undertake the project with the lowest required guarantee. Therefore, if both projects are undertaken it has to be the case that the government guarantees required for financiers in both projects are the same. We then obtain the following result on when general obligation financing, i.e., cross-guarantees, are desirable:

Proposition OA1. ***(RO vs. GO)*** *Whether general obligation financing is preferred to revenue-only financing depends on $(R - A_o)$, each project's return net of the moral hazard:*

a. If $(R - A_o) < \underline{\Gamma}$, projects are not funded even in the absence of any government moral hazard.

b. If $\underline{\Gamma} \leq (R - A_o) < \overline{\Gamma}$, projects are not funded in the presence of government moral hazard.

c. Otherwise, projects are funded as follows:

i. If $p_h \geq \frac{1}{2}$, general obligation financing is strictly preferred to revenue-only financing; in other words, the optimal cross-guarantees are positive ($K^a = K^b > 0$).

ii. If $p_h < \frac{1}{2}$, general obligation financing is strictly preferred to revenue-only financing only if the return of the project is high enough; in particular, the optimal cross-guarantees are positive ($K^a = K^b > 0$) if

$$(R - A_o) > \left[\frac{\overline{\Gamma}}{(1-p_h)} - \frac{r}{(1-p_h)}\right].$$

Furthermore, if the return on projects is high enough, they do not require any additional government guarantees, i.e., $K_g^a = K_g^b = 0$, when cross-guarantees are chosen optimally.

Proposition (OA1) shows that general obligation financing (weakly) increases the scale of the project. However, it does not increase the likelihood of the project being financed, at least in the symmetric case.

Intuitively, cross-guarantees mainly affect the government's incentives to expropriate from the operator. By expropriating, the government cannot induce high effort from the private sector operator. Low effort by the operator in project a implies a higher probability of paying the cross-guarantee from project b to project a. The increase in this probability is $[p_h(1-p_l)-p_h(1-p_h)]$, where p_h and p_l are the project's success probabilities when the private sector operator exerts high and low effort, respectively. At the same time, it decreases the probability with which the cross-guarantees will be paid to project b from project a. The decrease in this probability is $[p_l(1-p_h)-p_h(1-p_h)]$. When both projects are symmetric, the cross-guarantees are the same from a to b and from b to a. Therefore, the increase in the incentives to expropriate based on the cross-guarantees is given by

$$-p_h\Delta p+\Delta p(1-p_h)=\Delta p(1-2p_h),$$

where $\Delta p \equiv (p_h-p_l)$. When $p_h<\frac{1}{2}$, cross-guarantee exacerbates the moral hazard of the government and revenue only financing (setting the cross-guarantees to zero) is optimal whenever the payoff of the project is low and the incentive compatibility of the government binds. Alternatively, when $p_h>\frac{1}{2}$, cross-guarantees mitigate the moral hazard of the government and general obligation financing (positive cross-guarantees) are optimal as long as the return of the project is high enough to satisfy the government's participation constraint.

Finally, when the cash flow from the project is high enough, the project is self-financing regardless of whether $p_h \gtrless \frac{1}{2}$. Any dollar pledged in the cross-guarantees cannot be expropriated by the government. As a result, if the expected return of the projects is high enough, then the cross-guarantees are enough to satisfy the individual rationality constraint of the financiers and no additional government guarantee is needed for the project to be undertaken.

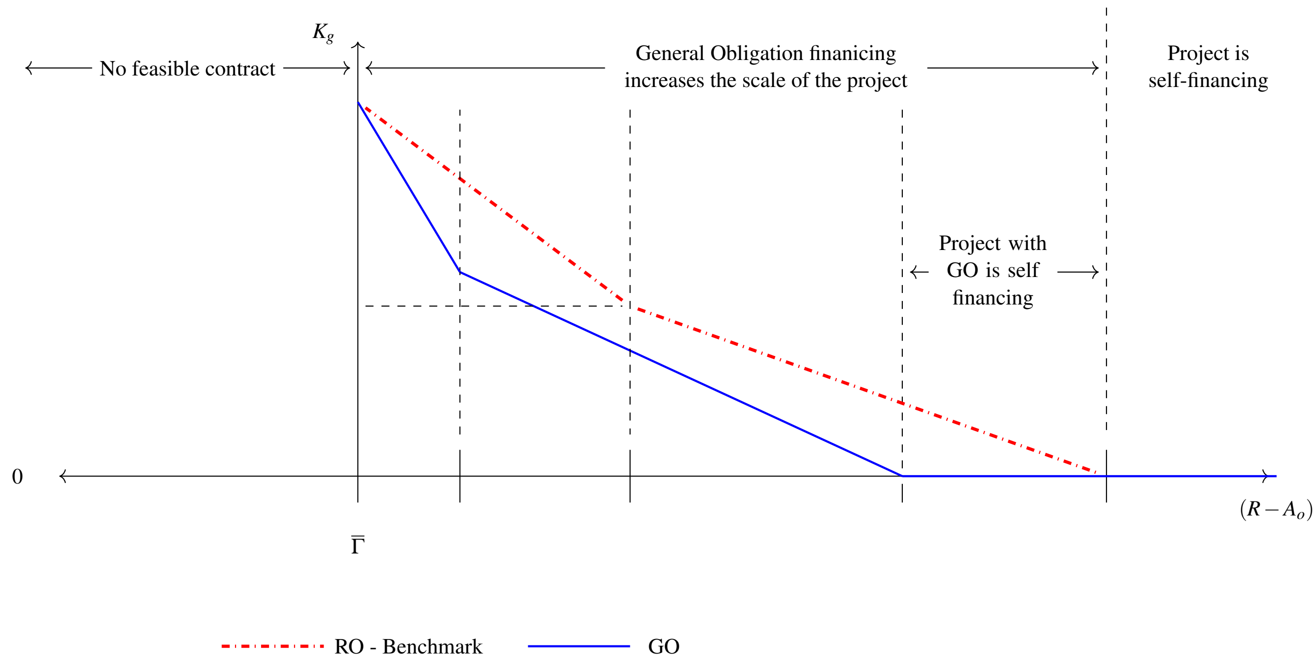
In summary, revenue-only financing can only be optimal when the quality and the return of the projects are low, and in this case, having general obligation financing available does not affect the scale of the project. However, when the return of the project is high, cross-guarantees create value and are positive whenever the project is implemented; in this case, general obligation financing increases the scale of the project.

Figures OA.1 show the optimal government guarantees with cross-guarantees compared with the optimal guarantees in the benchmark model without cross-guarantees. Figure OA.1a shows the case when $p_h>\frac{1}{2}$ and Figure OA.1b shows the case when $p_h<\frac{1}{2}$.

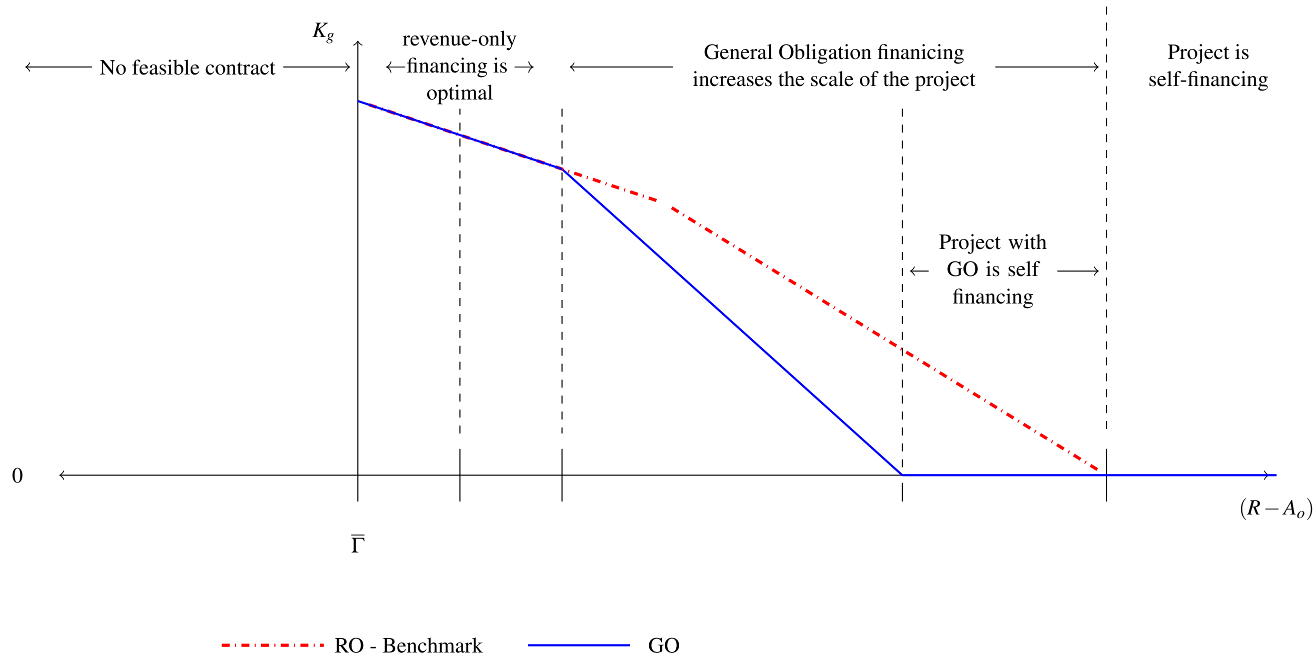
Our model suggests that this may be the case because of a high severity of moral hazard in these lower quality projects; in these cases, providing cross-guarantees across projects in the form of general obligation bonds would lead to an increase in the inefficiency by weakening the government's incentives to participate or conditional on participation not to expropriate.

B.1 Development Rights and General Obligation Financing

We further explore the choice between general obligation and revenue-only financing in the presence of development rights. Formally, we consider the same model as in Section B with the addition that each project i generates an additional payoff DI^i with $D>0$ that is accrued if the project is successful, which we refer to as development rights. As in Section 4.4 in the main text, this payoff can only be distributed to the financiers and the private sector operator and cannot be extorted by the government. We denote by $D_I^i I^i$ the portion of the payoff from the development rights that is assigned to the financiers in project i. The residual, $\left(D-D_I^i\right)I^i$, is distributed to the private sector operator of project i. With respect to the model with general obligation financing, development rights affect the incentive compatibility constraint of the financiers, which



(a) Optimal government guarantees under cross-guarantees (GO) and under the benchmark (RO) model when $p_h > 0.5$.



(b) Optimal government guarantees under cross-guarantees (GO) and under the benchmark (RO) model when $p_h < 0.5$.

Figure OA.1: Optimal government guarantees when there are cross-guarantees available in turn changes the maximum amount that the government can extort from the private sector operator while still inducing high effort; development rights also affect the individual rationality constraint of the financiers.

The incentive compatibility constraint of the private sector operator in project i now takes the form:

$$p_h \left[R - \left(R_f^i + R_g^i\right) + D - D_I^i\right] I \geq p_l \left[R - \left(R_f^i + R_g^i\right) + D - D_I^i\right] I + BI \,, \tag{ICP–GO-DR}$$

or,

$$(R - A_o) - R_f^i + \left(D - D_I^i\right) \geq \overline{R}_g^i \,.$$

Since the government cannot extort any proceeds from the development rights, the maximum payoff for the government from project i is

$$\overline{R}_g^i = (R - A_o) - R_f^i + \left(D - D_I^i\right) \,.$$

The individual rationality constraint of the financiers in project i now becomes

$$p_h \left(R_f^i + D_I^i\right) + (1 - p_h) K_g^i + (1 - p_h) p_h K^i \geq r \tag{IRF–GO-DR}$$

or,

$$K_g^i \geq \frac{r - p_h \left(R_f^i + D_I^i\right)}{1 - p_h} - p_h K^i \,.$$

We then obtain the following result on how development rights affect infrastructure financing in the presence of cross-guarantees.

Proposition OA2. ***(RO vs. GO with Development Rights)*** *Development rights ($D > 0$) reduce the inefficiencies imposed by double moral hazard, i.e., they increase the scale of the projects and the parameter space in which the projects are financed, even in the presence of cross-guarantees. Moreover, when the quality of the projects is low, i.e., $2p_h < 1$, the parameter region over which general obligation financing is strictly preferred is increasing in the value of the development rights, D.*

Proposition OA2 shows that, as in the benchmark model in Section 2, development rights decrease the inefficiencies imposed by the double moral hazard by increasing the scale of the projects and expanding the set of parameters under which the projects are undertaken. Moreover, if the quality of the projects is low, i.e., $2p_h < 1$, their presence can affect whether infrastructure financing involves positive cross-guarantees. In particular, development rights increase the parameter region over which projects are financed with general obligation financing (positive cross-guarantees). Intuitively, development rights ameliorate the government's moral hazard problem on each project, and in turn, increase the size of the cross-guarantees that can be provided.

B.2 Proofs

In this section, we characterize the optimal contract for the model in Section B when there are cross-guarantees and provide the proofs of the results in this section.

Characterization of optimal contract

In this case, the government solves

$$\max_{\substack{K^iI^i \in \left[0,(R-A_o)I^j\right],\\ \alpha\in[0,1],\, K_g^j\geq 0}} (p_hR-r)I$$

s.t.

$$\frac{r}{1-p_h} \leq p_hK^a + K_g^a + \frac{p_h}{1-p_h}R_f^a, \tag{IRFA–GO}$$

$$\frac{r}{1-p_h} \leq p_hK^b + K_g^b + \frac{p_h}{1-p_h}R_f^b, \tag{IRFB–GO}$$

$$(1-p_h)\left[p_h\left(K^a\alpha+K^b(1-\alpha)\right)+\left(K_g^a\alpha+K_g^b(1-\alpha)\right)\right] \leq p_h(R-A_o)-\alpha R_f^a-(1-\alpha)R_f^b, \tag{IRG–GO}$$

$$p_hK^a-(1-p_h)K^b\frac{1-\alpha}{\alpha}+K_g^a-R_f^a+(R-A_o)\geq A_g, \tag{ICGA–GO}$$

$$p_hK^b-(1-p_h)K^a\frac{\alpha}{1-\alpha}+K_g^b-R_f^b+(R-A_o)\geq A_g, \quad \text{and} \tag{ICGB–GO}$$

$$\alpha IK_g^a+(1-\alpha)IK_g^b\leq \overline{K}. \tag{Fiscal-Constraint–GO}$$

Fiscal-Constraint–GO holds with equality in equilibrium. Therefore, one can rewrite the objective function as follows

$$(p_hR-1)\frac{\overline{K}}{\alpha K_g^a+(1-\alpha)K_g^b}.$$

Lemma. *If both projects are undertaken, then the government guarantee is the same for both projects, i.e., $K_g^a=K_g^b=K_g$ and the scale of each project is $\frac{1}{2}\frac{\overline{K}}{K_g}$.*

Proof. Suppose to the contrary that $K_g^b>K_g^a$ and $\alpha\in(0,1)$. Then, one could increase α and increase K^b while still satisfying all the constraints and increasing the objective function. Note that an increase in α would relax ICGA–GO and the upper bound on K^b while tightening ICGB–GO. But one could increase K^b to guarantee that IRFB–GO and ICGB–GO hold while still satisfying the rest of the constraints. Analogously if $K_g^b<K_g^a$. Hence, if both projects are undertaken, then we must have $K_g^a=K_g^b$. □

Using the Lemma above, the problem becomes

$$\max_{\substack{K^iI^i \in \left[0,\left(R-A_o-R_f^j\right)I^j\right],\\ \alpha\in[0,1],\, K_g\geq 0}} (p_hR-r)\frac{\overline{K}}{K_g}$$

$$\frac{r}{1-p_h} \leq p_hK^a + K_g + \frac{p_h}{1-p_h}R_f^a, \tag{IRFA–GO}$$

$$\frac{r}{1-p_h} \leq p_hK^b + K_g + \frac{p_h}{1-p_h}R_f^b, \tag{IRFB–GO}$$

$$p_h(1-p_h)\left(\alpha K^a+(1-\alpha)K^b\right)+(1-p_h)K_g\leq p_h(R-A_o)-p_h\alpha R_f^a-p_h(1-\alpha)R_f^b, \tag{IRG–GO}$$

$$p_hK^a-(1-p_h)K^b\frac{1-\alpha}{\alpha}+K_g-R_f^a\geq A_g-(R-A_o), \text{ and} \tag{ICGA–GO}$$

$$p_hK^b-(1-p_h)K^a\frac{\alpha}{1-\alpha}+K_g-R_f^b\geq A_g-(R-A_o). \tag{ICGB–GO}$$

To be able to satisfy the three individual rationality constraints it must be the case that

$$\frac{r}{p_h} \leq (R - A_o) \ . \tag{OA.12}$$

Moreover, the individual rationality constraints of the investor and the incentive compatibility constraints of the government impose lower bounds on the government guarantee K_g as follows:

$$K_g \geq \max\left\{ \frac{r - p_h R_f^a}{1 - p_h} - p_h K^a, \frac{r - p_h R_f^b}{1 - p_h} - p_h K^b, A_g - (R - A_o) + R_f^a - \left(p_h K^a - (1 - p_h) K^b \frac{1 - \alpha}{\alpha} \right), \right.$$
$$\left. A_g - (R - A_o) + R_f^b - \left(p_h K^b - (1 - p_h) K^a \frac{\alpha}{1 - \alpha} \right), 0 \right\} .$$

Note that this constraint is minimized at $\alpha = \frac{1}{2}$, which implies

$$K_g \geq \max\left\{ \frac{r - p_h R_f^a}{1 - p_h} - p_h K^a, \frac{r - p_h R_f^b}{1 - p_h} - p_h K^b, A_g - (R - A_o) + R_f^a - \left(p_h K^a - (1 - p_h) K^b \right), \right.$$
$$\left. A_g - (R - A_o) + R_f^b - \left(p_h K^b - (1 - p_h) K^a \right), 0 \right\} .$$

Moreover, the constraint is also minimized when $K^a = K^b$ and $R_f^a = R_f^b$. Hence,

$$K_g \geq \max\left\{ \frac{r - p_h \hat{R}_b}{1 - p_h} - p_h \hat{K}, A_g - (R - A_o) + \hat{R}_b - (2p_h - 1)\hat{K}, 0 \right\} ,$$

where $K^a = K^b = \hat{K}$, $R_f^a = R_f^b = \hat{R}_b$, and

$$0 \leq \hat{K} \leq (R - A_o) - \hat{R}_b \, .$$

1) If only the individual rationality constraint of the investors binds, then

$$K_g = \frac{r}{1 - p_h} - \frac{p_h}{1 - p_h} \hat{R}_b - p_h \hat{K} \ .$$

Then, it is optimal to set $\hat{R}_b = \frac{r}{p_h} - (1 - p_h)\hat{K}$ and the project is self-financing, i.e., $K_g = 0$.

The incentive compatibility constraint of the government will be satisfied as long as

$$(R - A_o) \geq A_g + \frac{r}{p_h} - p_h \hat{K}$$

and the feasibility constraint on $\hat{R}_b$ implies $\hat{K} \leq \frac{1}{p_h(1-p_h)} r$.

If $(R - A_o) \geq \frac{1}{1-p_h} \frac{r}{p_h}$ all constraints are slack and $\hat{R}_b = 0$ and $K_g = 0$.

2) If the incentive compatibility constraint of the government is binding and the individual rationality constraint of the investors is slack, then

$$K_g = A_g - (R - A_o) + \hat{R}_b - (2p_h - 1)\hat{K} \ .$$

The incentive compatibility constraint of the government with respect to the private sector implies $\hat{R}_b = 0$. Moreover, whether $\hat{K}$ increases or decreases the scale of the project depends on the value of $2p_h - 1$.

a) If$2p_h < 1$, then K_g is increasing in $\hat{K}$ and it is optimal to set $\hat{K} = 0$. This will be the case when

$$(1 - p_h) A_g \leq (R - A_o) \leq A_g - \frac{r}{1 - p_h} \ ,$$

which implies that the individual rationality constraints of investors and the government, and the feasibility constraints are satisfied. In this case,

$$K_g = A_g - (R - A_o) \ .$$

b) If $2p_h > 1$, then K_g is decreasing in $\hat{K}$ and it is optimal to set $\hat{K}$ as large as possible. To satisfy the incentive compatibility constraint of the government and the feasibility constraints it must be the case that

$$\hat{K} = \max\left\{0, \min\left\{(R-A_o), \frac{1}{1-p_h}\left(\frac{1}{1-p_h}(R-A_o) - A_g\right), \frac{1}{2p_h - 1}(A_g - (R - A_o))\right\}\right\}.$$

If

$$(1-p_h)A_g \leq (R-A_o) \leq \frac{(1-p_h)}{p_h(2-p_h)}A_g$$

then

$$\hat{K} = \frac{1}{1-p_h}\left(\frac{1}{1-p_h}(R-A_o) - A_g\right) \quad \text{and} \quad K_g = \frac{p_h}{1-p_h}\left(A_g - \frac{p_h}{1-p_h}(R-A_o)\right) \ .$$

If

$$\frac{(1-p_h)}{p_h(2-p_h)}A_g \leq (R-A_o) \leq \frac{1}{2p_h}A_g$$

then

$$\hat{K} = (R-A_o) \quad \text{and} \quad K_g = A_g - 2p_h(R-A_o) \ .$$

If

$$\frac{1}{2p_h}A_g \leq (R-A_o) \leq A_g - \frac{(2p_h-1)}{(1-p_h)}\frac{r}{p_h} \ ,$$

then

$$\hat{K} = \frac{1}{2p_h-1}(A_g - (R-A_o)) \quad \text{and} \quad K_g = 0 \ .$$

3) If the individual rationality constraint of the investors and the incentive compatibility constraint of the government bind, then

$$\hat{R}_b = (1-p_h)\left((R-A_o) + \frac{r}{1-p_h} - A_g - (1-p_h)\hat{K}\right) \ ,$$

which implies

$$K_g = r - p_h\left((R-A_o) - A_g + p_h\hat{K}\right) \ .$$

To satisfy the feasibility constraint on K_g and $\hat{R}_b$, using that $(R-A_o) < A_g - \frac{(2p_h-1)}{p_h(1-p_h)}r$, it has to be the case that

$$\frac{1}{1-p_h}\left((R-A_o) + \frac{(2p_h-1)}{p_h(1-p_h)}r - A_g\right) \leq \hat{K} \leq \frac{1}{1-p_h}\left((R-A_o) + \frac{r}{1-p_h} - A_g\right) \ .$$

Note that if $2p_h > 1$, $(R-A_o) \leq \frac{1}{1-p_h}\left((R-A_o) + \frac{r}{1-p_h} - A_g\right)$ and it can't be the case that both constraints bind at the same time unless the inequality above holds with equality .

If $2p_h < 1$, since K_g is decreasing in $\hat{K}$ and it must be the case that $0 \leq \hat{K} \leq \frac{r}{p_h(1-p_h)}$ and $K_g \geq 0$, we have

$$\hat{K} = \frac{1}{1-p_h}\left((R-A_o) + \frac{r}{1-p_h} - A_g\right), \hat{R}_b = 0 \ ,$$

and

$$K_g = r - \frac{p_h}{1-p_h}\left((R-A_o) + \frac{r}{1-p_h} - A_g\right)$$

when

$$A_g - \frac{r}{1-p_h} \leq (R-A_o) \leq A_g - \frac{(2p_h-1)}{p_h(1-p_h)} r \, .$$

Note that the individual rationality constraint of the government will be satisfied as long as $(R-A_o) \geq \frac{r}{p_h}$.

Proof of Proposition OA1 (RO vs. GO)

a. Using that $\underline{\Gamma} = \frac{r}{p_h}$ and Eq. (OA.12) it follows that the project is not undertaken even in the absence of moral hazard when $(R-A_o) < \underline{\Gamma}$.

b. From the analysis above, it follows that if $\overline{\Gamma} \equiv (1-p_h)A_g > (R-A_o)$ there is no feasible contract that satisfies the incentive compatibility of the government and the individual rationality constraint of the investors and the projects are not financed in the presence of moral hazard.

c. If $\overline{\Gamma} \leq (R-A_o)$, the projects are financed.

i) If $2p_h > 1$, from the analysis above it follows that the optimal cross-guarantee satisfies

$$\hat{K} = \min\left\{ (R-A_o), \frac{1}{1-p_h}\left(\frac{1}{1-p_h}(R-A_o) - A_g\right), \frac{1}{2p_h-1}\left(A_g - (R-A_o)\right) \right\} \, ,$$

which is greater than 0 for $\overline{\Gamma} < (R-A_o)$. Then, cross-guarantees are always positive and general obligation financing is always preferred in this case.

ii) If $2p_h < 1$, from the analysis above it follows that the optimal cross guarantees will be positive if

$$A_g - \frac{r}{1-p_h} < (R-A_o)$$

and revenue-only financing is preferred if

$$(1-p_h)A_g \leq (R-A_o) \leq A_g - \frac{r}{1-p_h} \, .$$

If $2p_h > 1$ and

$$\overline{\Gamma}^* \equiv \frac{1}{2p_h} A_g \leq (R-A_o) \, ,$$

we have $K_g = 0$ and the projects are self-financing when cross-guarantees are chosen optimally.

If $2p_h \leq 1$, $K_g = 0$ and the projects are self-financing when cross-guarantees are chosen optimally if

$$\underline{\Gamma}^* \equiv A_g - \frac{(2p_h-1)}{p_h(1-p_h)} r \leq (R-A_o) \, .$$