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RESEARCH ARTICLE

A theory of National Development Bank: long-term investment and the agency problem

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Abstract
This paper applies the contract theory to study the role of National Development Bank (NDB) in financing infrastructure investment. We first show that to mitigate overrun issues resulting from the agency problem during the infrastructure construction, the government uses mixed financing strategy combining fiscal funding with NDB loans. We then endogenize the NDB investment strategy to study the determinants of NDB profit and use cross-country panel data to empirically test our model predictions.

Keywords Agency cost · Dynamic contract · National Development Banks · Infrastructure

JEL Classification D80 · G21 · G32

1 Introduction

National Development Banks (NDBs) are prevalent in the world. Unlike profit-driven commercial banks, NDBs focus on investing projects for social welfare improvement, such as long-term infrastructure construction.[1] However, given the large variety of instruments for fiscal and monetary policy at the government's disposal, it is unclear why government needs NDBs to finance infrastructure. Particularly, when government investing infrastructure, it tends to use mixed financing strategy combining fiscal

[1] One hundred and fifty-two out of 218 economies worldwide have established 375 currently-active NDBs (Xu et al. 2021). For example, the German NDB, Kreditanstalt fur Wiederaufbau (KfW), was created in 1948 to finance the long-term reconstruction of Germany after World War II.

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funding with NDB loans.[2] Therefore, our paper aims to answer two questions. First, why are NDBs widely used to finance infrastructural investment? Second, how can NDBs employ optimal debt contracts to mitigate the agency problem in infrastructure investment?

To address the above two questions, we construct a principal–agent model with dynamic contracts to study an infrastructure construction problem. In our framework, the government relies on the NDB loans to provide incentives to the infrastructure developer and lessen the overrun issues resulting from the moral hazard problem during the infrastructure construction.[3]

More specifically, the infrastructure construction requires both the developer's effort and the government's fiscal funding. Because the developer's effort is unobservable, the project may suffer from potential moral-hazard issues. To motivate the developer to deliver effort, the government offers certain fraction of the project's value. More importantly, in addition to using fiscal investment directly, the government deploys NDB loans to the project. If overrun issues occur during the construction, the value of the project would decrease due to the extra holding cost of loans, and thus, the developer would be penalized.[4]

Therefore, our framework can explain why NDB is necessary and why general commercial banks are not satisfactory in addressing such problems. This is mainly because the social value of infrastructure is higher than the market value. The optimal debt contract designed by the government does not necessarily maximize bank profit.[5]

In terms of theoretical setting, we apply the standard continuous-time dynamic contracting approach to characterize the general optimal contract (e.g., DeMarzo and Sannikov 2007). In particular, we consider an infrastructure construction problem in which the time to finish the project is stochastic and the construction follows a Poisson process. The government can simply implement the optimal contract by introducing NDB loans.[6] The debt accumulates over time and reduces the agent's future payoff, providing the incentive to the agent in finishing the project on time.

Furthermore, we show that our model could provide important practical implications. The comparative statics analysis suggests that the NDB's profit could be affected

[2] Considering the example of the Three George Dam—the largest hydropower station in the world, the Chinese government provided about 160 billion Yuan fiscal funding while China National Development Bank granted 30 billion Yuan credit (Source: Audit Report No. 23 of 2013, General Serial No.165 of the China National Audit Office).

[3] Infrastructure construction overrun is a common problem in both developed and developing countries. In the U.K., about 62% of respondents experience time overrun on 10% or more of their projects (Olawale and Sun 2010). In India, 82.33% of infrastructure projects were delayed during the period of 1992–2009 (Singh 2009). A review of common causes of delay issues in infrastructure projects by Khona et al. (2016) found that the contractor negligence and the agency problem cause non-excusable delays, such as faulty work, late supply of items, and shabby subcontractor performance.

[4] Using the case of the China Development Bank, we also provide empirical evidence to show that the involvement of NDBs is positively associated with the decline of firm agency cost. Detailed discussions can be found in the appendix.

[5] Our model can also show that bank profit could be negative under certain conditions.

[6] Smiliar to DeMarzo and Sannikov (2007), the implementation of optimal contract is not unique. In this paper, we are not trying to argue that NDB's loan is the only way that government could use to mitigate the overrun issue, but we will show that it is effective and easy to execute. We provide detailed discussions in Sect. 2.

by three crucial external elements: 1) the infrastructure construction cost, 2) the social welfare generated by the infrastructure project, and 3) the government's ability to manage the infrastructure project without hiring any contractor. Finally, we use a cross-country dataset to show that the regression result is consistent with our model predictions.

Our paper relates to several strands of literature. First, our study contributes to the growing literature on NDB. Recent empirical studies document the role of NDB in mitigating political risks (Hainz and Kleimeier 2012), addressing externality (Schclarek and Xu 2022), providing long-term and high-risk finance (Gurara et al. 2020) and affecting firm investment (Ru 2017). Armendáriz (1999) builds a model to show how NDB fixes a market failure in a decentralized banking system in which banks both underinvest in and under-transmit expertise in long-term industrial finance. In addition, there are groups of the literature on state-owned banks (e.g., La Porta et al. 2002; Sapienza 2004; Carvalho 2014) focusing on the the comparison between state-owned banks and private in terms of investment behaviors and performance. Our paper contributes the literature by carving out the niche of NDBs compared with government fiscal budget in financing infrastructure. Our model is able to answer two important questions: 1) How do NDBs help mitigate the agency problem during the infrastructure construction? and 2) How do country-level characteristics affect NDB profit?

In terms of methodology, our paper adds to the literature on dynamic contracts (e.g., He 2011; Ai and Li 2015; Miao and Zhang 2015; Cooley et al 2020). The idea of implementing the optimal contract in our model shares some similarities with that in DeMarzo and Sannikov (2007) which studies a firm-operating problem with a Brownian motion setting. The main distinction of our paper is that we consider an infrastructure construction problem in which the time to finish the project is stochastic and the construction follows a Poisson process. In addition, our theoretical setting is also related to the optimal dynamic contracting with moral-hazard in a Poisson framework (e.g., Biais et al. 2010; Myerson 2015; Shan 2017; Sun and Tian 2018). Our paper applies this method to study the role of NDBs and contribute the related literature by investigating the contract implementation through an optimal capital structure of an infrastructure project. In sum, we provide a new practical implication of the dynamic contract theory.

Finally, our paper relates to the studies on the contract design of public-private partnership (PPP) projects. Hart (2003) builds a two-period model to discuss the optimal timing for the government to sign a PPP contract in an incomplete contract framework. Arve and Martimort (2016) study optimal PPP contracts in the context of long-lasting services with uncertain add-ons in a two-period model. Rochet and Roger (2016) find that a contract with capital adequacy requirement could reduce the excessive risk in infrastructure projects managed by private firms. Martimort et al. (2005) argue that PPP projects usually raise funds for large-scale and long-term infrastructure by studying a static contracting model with equity finance. Our paper complements the literature by developing a dynamic contracting model in an integrated framework to address the endogenous completion time decision of construction in PPP projects. Therefore, our model is able to analyze the dynamic debt financing from NDBs toward infrastructure projects.

The remainder of the paper proceeds as follows. The next section describes the theoretical model. Section 3 discusses the model implications to NDB profit and Sect. 4 provides an empirical test. Finally, Sect. 5 concludes the paper.

2 Theoretical model

In this section, we construct our theoretical model. Similar to the procedure in DeMarzo and Sannikov (2007) and Müeller et al. (2019), we present our model by two steps. We first study a standard dynamic-contracting problem in infrastructure construction in Sects. 2.1 and 2.2. Our goal of the first step is to find the second-best allocation in general, rather than discuss the tool to implement the contract. In Sect. 2.3, we then focus on how the government implements the optimal contract by applying a mixed financing strategy with both NDB loans and direct fiscal investment.

2.1 Environment

We consider an infrastructure construction problem in a continuous-time environment. In the model, the government (principal) hires a developer (agent) with the managerial skill to construct an infrastructure project. The construction of the infrastructure requires fiscal funds from the government and the effort exerted by the developer.

Most infrastructure constructions are long-term projects, and thus, there exists uncertainty during the construction process. In this case, we assume that the construction process follows a Poisson process with arrival rate λ_t, which implies that in time interval $[t, t+dt]$, the project can be completed with the probability $\lambda_t dt$. Also, the arrival rate λ_t is determined by the agent's effort h_t which is the agent's cost of effort measured in monetary terms. Similar to Biais et al. (2010), the effort level is discrete, and therefore, we simply consider two levels of effort: first, if the agent exerts h effort at time t, the instantaneous arrival rate λ_t is $\overline{\lambda}$; second, if the agent shirks and puts zero effort at time t, the instantaneous arrival rate λ_t changes to $\underline{\lambda} \in (0, \overline{\lambda})$.[7]

Both principal and agent are risk-neutral. The principal has discount rate r and also can take infinite liability with the market interest rate r. Following DeMarzo and Sannikov (2007) and Biais et al. (2010), we assume that the agent has discount rate ρ, which is higher than that of the principal, $i.e.$, $\rho > r$. Otherwise, the principal may forever postpone the payment to the agent.[8] Moreover, we assume that the agent has limited liability and cannot borrow. To simplify our analysis, we also assume that the

[7] Here, we do not consider the case that $\underline{\lambda} = 0$. As pointed out by Sun and Tian (2018), if $\underline{\lambda} = 0$, the optimal contract degenerates to a simple contract in which the principal would never terminate the project and only pay $\frac{h}{\lambda}$ to the agent once the project is completed. Under this circumstance, the principal does not need to provide any time-dependent incentives to the agent, and the agent's expected utility stays at zero. Furthermore, in the reality, even if the developer chooses to shirk, the project could be completed in a small probability given the fiscal fund invested by the government. Therefore, we set $\underline{\lambda} > 0$ in the rest of our paper.

[8] This assumption is also motivated by empirical facts obtained from China Development Bank (CDB). According to CDB's official website, the interest rate for 5 year long-term loan is 4.9% since 2015, which is higher than the market interest rate 4.65–4.8%.

agent's initial wealth is zero, and we do not consider the agent's saving behavior, since the agent has no motivation to save in our model.

In addition to the agent's effort, the construction needs fiscal funds flow μ at each instance to cover other costs as long as the construction continues. Once the construction is finished, it could generate γ perpetual cash flow and η perpetual social welfare flow at each instance. Because we define η as the total social welfare flow of the infrastructure project, including cash flow γ and other positive social externality, so we have $\eta > \gamma$[9]. In sum, a completed infrastructure project has value $\frac{\eta}{r}$ in the perspective of the government, and this value has already included the value of cash flow. We therefore make the following assumptions.

Assumption 1 The expected cash flow of the infrastructure project is less than the expected cost in the first-best case.[10] In the case of no effort delivered, the expected social benefit is larger than the expected cost. Mathematically, we have the following two equations,

$$\bar{\lambda}\gamma < r(h + \mu),$$
$$\underline{\lambda}\eta > r\mu.$$

The first equation in Assumption 1 explains why the infrastructure project cannot be invested by the private institution but requires government's intervention. The second equation implies that the social benefit of this project is large enough such that government would invest the project even without the developer.

In terms of the setting for the private information in the model, we assume that the agent's effort level h_t can not be observed publicly, and thus, moral-hazard exists. There are two instruments that the principal could use to provide incentives. First, the principal could make money transfer c_t at time t if the construction project continues, and an one-time transfer $\bar{w}_t$ to the agent after the project is completed. At time 0, the principal and the agent sign a state-contingent contract that specifies the effort level $\{h_t\}$ and the compensation to the agent $\{c_t, \bar{w}_t\}$.

Thus, the principal's objective function is to minimize expected construction cost and to maximize expected social welfare. The expected payoff of the principal is defined as

$$b_0 = E\left[-\int_0^{\tau\wedge\tilde{\tau}} e^{-rt}(c_t + \mu)dt + \mathbf{1}_{\tau\leq\tilde{\tau}}\left(-e^{-r\tau}\bar{w}_t + \int_\tau^\infty e^{-rt}\eta dt\right) + \mathbf{1}_{\tau>\tilde{\tau}}\left(e^{-r\tilde{\tau}}R\right)\right],$$

where τ is the stochastic stopping time when the construction is completed and $\tilde{\tau}$ is the stochastic stopping time when the project is terminated. In the right-hand side of the above equation, the first term is the expected cost of the principal during the construction; the second term is the expected net payoff of the principal after the

[9] For simplicity, we assume that the infrastructure project generates an exogenous welfare. Baerlocher (2022) and Lin et al. (2020) study how fiscal expense and infrastructure affect household welfare endogenously.

[10] A detailed description for the first-best case is sketched in the Appendix C.

construction is completed; the last term is the expected payoff when the project is terminated.

The expected payoff of the agent under high-effort case is expressed as follows:

$$w_0 = E\left[\int_0^{\tau\wedge\tilde{\tau}} e^{-\rho t}(c_t - h_t)d_t + \mathbf{1}_{\tau\leq\tilde{\tau}}\left(e^{-\rho\tau}\bar{w}_\tau\right)\right].$$

In the right-hand side of the above equation, the first term is the net payoff for the agent during the construction and the second term is the expected payment after the construction. The agent has an outside option, which is simply assumed to be 0. If the agent's continuation payoff is lower than 0, the agent would choose to quit from the contract and the principal would obtain a reserved value R.[11]

Having described the environment, we make further assumptions on the parameters of the model.

Assumption 2 (i) The cost of delivering high effort is less than the marginal social benefit of delivering high effort, *i.e.*,

$$rh < (\overline{\lambda} - \underline{\lambda})\eta; \tag{1}$$

(ii) The payoff of the principal's outside option is relatively small, *i.e.*,

$$R < \frac{\overline{\lambda}}{r+\overline{\lambda}}\frac{\eta}{r} - \frac{1}{r+\overline{\lambda}}(\mu + h) - \frac{\overline{\lambda}+2\underline{\lambda}}{r+\overline{\lambda}}\frac{h}{\overline{\lambda}-\underline{\lambda}}; \tag{2}$$

(iii) The discount rate of the agent is less than the sum of the discount rate of the principal and the arrival rate, *i.e.*,

$$\rho < \overline{\lambda} + r. \tag{3}$$

In the above assumption, Eq. (1) ensures that the high effort is socially preferred in the first-best case. Equation (2) is a sufficient condition to ensure that the reserved payoff is not too large in this long-term investment project. Otherwise, the principal would terminate the project immediately. Equation (3) guarantees that the agent's discounted rate is not too large, otherwise, any delayed transfer would cost too much to the principal, such that the principal would choose to make an immediate transfer to the agent and quit the contract.

2.2 Optimal dynamic contract

In this section, we characterize the optimal contract by applying the standard continuous-time dynamic programming approach in the dynamic contract literature.

[11] For simplicity, we assume that if the agent quits the project, the principal would continue this project by himself. Nevertheless, making the alternative assumption of searching a new developer with a fixed cost would not change the model.

More specifically, we consider the agent's continuation payoff as state variable w_t and denote value function as $b(w_t)$, mapping the agent's continuation payoff to the highest expected payoff of the principal. In the following, we focus on how to solve this value function through the standard Hamilton–Jacobi–Bellman (HJB) equation.

We derive the HJB equation by taking the limit of discrete-time models in which the time interval is set as Δt. At each period, the agent completes the construction with possibility $\lambda_t \Delta t$, and the construction continues with probability $(1-\lambda_t \Delta t)$. Also, at each period, the principal receives payoff $(-c_t-\mu)\Delta t$, while the agents' payoff is $(-h_t+c_t)\Delta t$. Similar to Biais et al. (2010) and Myerson (2015), we first restrict the study to contracts that always recommend high effort, because we consider the case that the social welfare generated by the infrastructure construction is sufficiently large and moral hazard is social costly.[12]

Thus, the value function of the principal can be written as

$$b(w_t) = \max_{c_t, \bar{w}_{t+\Delta t}} \left[-(\mu + c_t)\Delta t + e^{-r\Delta t} \left(\overline{\lambda}\Delta t(\frac{\eta}{r} - \bar{w}_{t+\Delta t}) + (1-\overline{\lambda}\Delta t) b(w_{t+\Delta t}) \right) \right], \tag{4}$$

$$s.t. \quad w_t = (c_t - h)\Delta t + e^{-\rho\Delta t} \left(\overline{\lambda}\Delta t \bar{w}_{t+\Delta t} + (1-\overline{\lambda}\Delta t) w_{t+\Delta t} \right), \tag{5}$$

$$(c_t - h)\Delta t + e^{-\rho\Delta t} \left(\overline{\lambda}\Delta t \bar{w}_{t+\Delta t} + (1-\overline{\lambda}\Delta t) w_{t+\Delta t} \right) \geq c_t\Delta t + e^{-\rho\Delta t} \left(\underline{\lambda}\Delta t \bar{w}_{t+\Delta t} + (1-\underline{\lambda}\Delta t) w_{t+\Delta t} \right). \tag{6}$$

Equation (4) is the standard Bellman equation in discrete time and the state variable w_t is the agent's continuation payoff. $-(\mu + c_t)\Delta t$ is the principal's payoff in the period t, and $\overline{\lambda}\Delta t$ is the probability that the construction would be finished in the next period. If the construction is finished, the principal would obtain the continuation value, $\frac{\eta}{r} - \bar{w}_{t+\Delta t}$. Otherwise, the principal would receive $b(w_{t+\Delta t})$.

Equation (5) is the promise-keeping constraint, ensuring that the contract delivers actual continuation payoff w_t to the agent. Equation (6) is the incentive compatible constraint, ensuring that making high effort would bring a higher continuation payoff to the agent than making low effort.

After taking $\Delta t \to 0$ on Eqs. (4), (5) and (6), we have

$$rb(w) = \max_{c,\bar{w}} [-(\mu + c) + b'(w)\dot{w} + \overline{\lambda}(\eta/r - \bar{w} - b(w))] \tag{7}$$

$$s.t. \quad \dot{w} = \rho w + (h - c) - \overline{\lambda}(\bar{w} - w), \tag{8}$$

$$h \leq (\overline{\lambda} - \underline{\lambda})(\bar{w} - w), \tag{9}$$

in which Eqs. (7), (8) and (9) are HJB equation, promise-keeping constraint and incentive compatible constraint in continuous time, respectively. Note that at $w = 0$, $\dot{w}$ must be negative by promise-keeping constraint and incentive compatible constraint, which implies that in any feasible contract, the agent would choose to quit the contract instantaneously when $w = 0$. Then, the HJB equation satisfies the boundary condition $b(0) = R$.

[12] In the appendix, we provide a sufficient condition to ensure that only high effort is preferred in the optimal contract.

The following proposition summarizes the major results of the HJB equation and the corresponding optimal contract.

Proposition 1 *The optimal HJB equation defined in (7)–(9) together with the boundary condition $b(0) = R$ satisfies the following properties:*

(i) *There exists a value $w^1 \in (0, \frac{\underline{\lambda} h}{\rho(\overline{\lambda}-\underline{\lambda})})$ such that w^1 is the smallest value satisfying $b'(w) = -1$;*

(ii) *$b(w)$ is a continuous and strictly concave function in $[0, w^1)$. $b(w)$ is a linear function with slope −1, if $w \geq w^1$;*

(iii) *If $w \in [0, w^1)$, then $c = 0$, $\dot{w} < 0$, and $\bar{w} = \frac{h}{\overline{\lambda}-\underline{\lambda}} + w$.*[13]

Proposition 1 provides at least three economic intuitions. First, we can show that $b'(w) \geq -1$. The intuition is very similar to DeMarzo and Sannikov (2007). In the contract, the principal can always make a lump-sum transfer $w - \tilde{w} > 0$, making the agent's continuation value jump from w to $\tilde{w}$, and thus, $b(w) \geq b(\tilde{w}) - (w - \tilde{w})$. Taking the limit $\tilde{w} \to w$, we have $b'(w) \geq -1$. Note that at w^1, the following condition is also satisfied.

$$\overline{\lambda}\left(\frac{\eta}{r} - w^1 - b(w^1)\right) - h - \mu = rb(w^1) + \rho w^1.$$

Specifically, the left-hand side of the above equation is the net expected payoff flow generated by the project, and the right-hand side is the expected cash flow required in the contract.

Figure 1 provides further graphical illustration, suggesting that the total expected payoff generated by the project is exhausted at w^1. Any larger promised value for the agent must come from the principal's direct transfer. Therefore, for any $w > w^1$, there would be an immediate payoff $w - w^1$ delivered by the principal, such that $b(w)$ becomes a straight line with $b'(w) = -1$.

Second, we show that c is zero in the range $[0, w^1)$. In other words, the agent is less patient than the principal in the model. Thus, postponing the transfer is always costly for the principal. The only reason for postponing transfer is that the principal tries to provide some incentive to avoid potential moral-hazard behaviors. Such incentive can only be achieved by payment after the construction is completed. Therefore, c is zero after the initial transfer. In addition, because the principal is inclined to transfer the payoff as early as possible, it is not optimal to retain $\bar{w}$ higher than the minimum level that incentive—compatible constraints require. Thus, incentive compatible—constraints are always binding, i.e.,

$$\bar{w} = \frac{h}{\overline{\lambda} - \underline{\lambda}} + w \tag{10}$$

Next, we discuss why $\dot{w}$ is less than zero. Consider a simple contract, in which the principal never terminate the construction and would pay $\frac{h}{\overline{\lambda}-\underline{\lambda}}$ to the agent once the

[13] The formal proof of Proposition 1 is in the Appendix D.

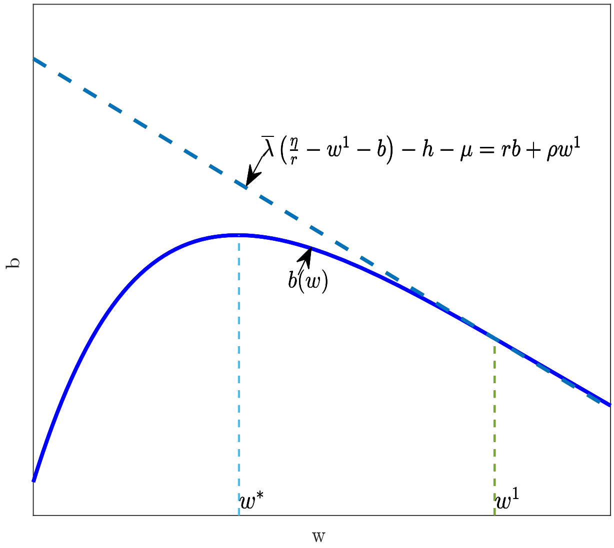

Fig. 1 Value function for the principal $b(w)$

construction is completed. Such contract is incentive compatible, and it delivers the agent with the expected payoff $\frac{\underline{\lambda} h}{\rho(\overline{\lambda}-\underline{\lambda})}$. w in the optimal contract after time zero should be smaller than $\frac{\underline{\lambda} h}{\rho(\overline{\lambda}-\underline{\lambda})}$ by two reasons. First, the principal might terminate the project after a long waiting time. Second, any transfer that is not used to provide incentives should be made at the beginning of the contract. Then, according to Eqs. (8) and (10), we have $\dot{w} < 0$.

In the last part of this subsection, we discuss how the contract regulates the initial value of w_0. In general, w_0 is determined by the bargaining power of the principal and the agent. Apart from DeMarzo and Sannikov (2007) which considers competitive investors, we assume that the government has complete bargaining power. This assumption is intuitive when the government faces many competitive potential contractors. We therefore endogenize the initial w_0 by using the following Lemma.

Lemma 1 *The value function is firstly increasing with* w *and then decreasing in* $[0, w^1]$. *There exists a unique point* $w^* \in (w, w^1)$ *that maximizes* $b(w)$.

The above Lemma is directly from the property of the HJB equation and Assumption 2. The intuition is as follows: when the reserved value R is relatively small, on one hand, offering small promised value would cause early termination of the project. In such case, the principal's expected payoff is increased by the promised value for the agent.

On the other hand, offering larger promised value results in too much transfers to the agent, which would decrease the principal's payoff. Therefore, there exits a w^* maximizing the expected payoff of the principal. In the rest of the paper, we assume that the government always choose w^* to start the contract.

Having characterized the general optimal contract, we show in the next section that the optimal contract could be implemented by a simple capital structure with NDBs' outside financing.

2.3 Optimal capital structure in the infrastructure project

In this subsection, we study how the government relies on NDBs to implement the optimal contract.[14] We first describe the institutional environment in our model.

We assume that the government and the developer jointly found an infrastructure firm to construct and to operate the infrastructure project. This type of arrangement is widely considered in the public–private partnership (PPP) contracts. In addition, because of certain legal and political restrictions, the government cannot issue debts to firms and hence needs to establish a national development bank. As a result, NDB raises funds at the rate of r in the capital market, and issues loans at the rate of ρ, with $\rho > r$. All NDB profits are collected by the government.[15]

We begin our discussion with the case that the managerial cost is relatively small, while non-managerial construction cost is relatively large. To simplify our discussions we first make the assumption outlined below, and we then relax this assumption later in this section.

Assumption 3 Compared to the cash flow generated by the project, the managerial cost is smaller and the non-managerial cost is larger. Mathematically, we have the following two inequalities:

$$\frac{h}{\bar{\lambda} - \underline{\lambda}} \leq \frac{\gamma}{r}, \quad and \tag{11}$$

$$r\mu \geq \underline{\lambda}\gamma. \tag{12}$$

Under the above assumption, the government could implement the optimal contract by setting a simple capital arrangement. The arrangement contains four parts. First, the government shares a fraction β of total equity of the infrastructure firm to the developer. Second, during construction of the project, instead of directly investing μ, the government invests only $(1 - \alpha)\mu$ and asks NDB to issue $\alpha\mu$ loans to the project developer at interest rate ρ. All the loan needs to be paid back when the project is completed. Third, the government issues state-contingent bond w^* to the developer. This bond is matural when the project is completed and is paid at interest rate ρ. If the project is terminated, it delivers zero to the developer. Finally, the government sets a debt limit $\bar{B}$. If total loans are over $\bar{B}$, the project is terminated and all debt is defaulted.

[14] In general, the implementation of optimal contract is not unique (e.g., DeMarzo and Sannikov 2007). There are two reasons why we study how the government employs NDBs' loans to achieve the second best. First, this implementation provides a plausible explanation for NDBs' mixed financing strategy. Second, it is simple and easy to execute.

[15] We do not consider the case of central banks in our model because in most countries central banks are not allowed to issue loans to firms.

Based on this implementation, we can define the total debt of the infrastructure firm at time t during construction as

$$B_t = \int_0^t e^{\rho(t-s)}(\alpha\mu)ds. \tag{13}$$

If the project is completed, the value of the firm equals to the discount sum of cash flow generated by the infrastructure minus the total debt, which can be rewritten as

$$V_t = \frac{\gamma}{r} - B_t. \tag{14}$$

To better illustrate how this implementation works, we denote $\{w_t^I, \bar{w}_t^I\}$ as the developer's expected payoff and the money transfer to the developer in this implementation at time t, respectively. Moreover, we denote τ as the stochastic stopping time when the project is completed and define $\tilde{\tau}$ as the time when the firm's debt reaches the limit. In this case, the developer receives β share of firm's value and the payoff of government bonds, which implies the following condition:

$$\bar{w}_t^I = e^{\rho t} w^* + \beta V_t. \tag{15}$$

Similarly, the developer's expected payoff w_t^I can be represented as

$$w_t^I = E_t[\mathbf{1}_{\tau \le \tilde{\tau}} \left(e^{-\rho(\tau - t)} \bar{w}_\tau^I \right)]. \tag{16}$$

We can also define NDB's expected profit as

$$\pi = E\left[-\int_0^{\tau \wedge \tilde{\tau}} e^{-rt}\alpha\mu dt + \mathbf{1}_{\tau \le \tilde{\tau}} \left(e^{-r\tau} \int_0^\tau e^{\rho(\tau - t)} \alpha\mu dt \right) \right], \tag{17}$$

where $\int_0^{\tau \wedge \tilde{\tau}} e^{-rt}\alpha\mu dt$ is the market value of total NDB loans. If the project is completed, the NDB obtains spread income $e^{-r\tau} \int_0^\tau e^{\rho(\tau-t)}\alpha\mu dt$, otherwise the NDB receives zero value. And, we can redefine the optimization problem of the government under this specific debt structure

$$\max_{\alpha,\beta,\bar{B},w^*} E\left[-\int_0^{\tau \wedge \tilde{\tau}} e^{-rt}(1-\alpha)\mu dt + \mathbf{1}_{\tau \le \tilde{\tau}} \left(e^{-r\tau}(-e^{\rho\tau} w^* + \frac{\eta - \gamma}{r} + (1-\beta)V_\tau) \right) + \mathbf{1}_{\tau > \tilde{\tau}} \left(e^{-r\tilde{\tau}} R \right) \right] + \pi \tag{18}$$

subjected to Eq. (15), (24), and

$$\bar{B} = \int_0^{\tilde{\tau}} e^{\rho(\tilde{\tau} - s)}(\alpha\mu)ds, \tag{19}$$

$$h \leq (\bar{\lambda} - \underline{\lambda})(\bar{w}_t^I - w_t^I). \tag{20}$$

In Eq. (18), the government searches for $\{\alpha, \beta, \bar{B}, w^*\}$ to maximize its expected payoff. The government payoff includes four terms: first, $-\int_0^{\tau\wedge\tilde{\tau}} e^{-rt}(1-\alpha)\mu dt$ is the fiscal expense during the construction; second, once the construction is completed, the government needs to pay state-contingent bond $e^{\rho\tau}w^*$ to the developer, and obtain the infrastructure's externality $\frac{\eta-\gamma}{r}$ and a share of the infrastructure firm $(1-\beta)V_\tau$; third, if the project fails, the government receives R; fourth, all NDB's profit π belongs to the government. The government's optimization problem faces several constraints. Equation (15) and (24) can be transformed to a promise-keeping constraint equation (8). Equation (19) can be viewed as a participation constraint of the developer, and Eq. (20) is the incentive-compatible constraint in this implementation. Note that as the construction continues, the debt B_t accumulates, which would reduce the firm's value V_t and the developer's future payoff $\bar{w}_t^I$. Such mechanism provides incentives for the developer to complete the project as soon as possible. We solve this implementation problem in Proposition 2.

Proposition 2 *The optimal contract can be implemented if the following four conditions are satisfied*[16]*:*

$$\alpha = \frac{\underline{\lambda}\gamma}{r\mu},$$
$$\beta = \frac{rh}{\gamma(\bar{\lambda} - \underline{\lambda})}, \quad \textit{and}$$
$$\bar{B} = \frac{\frac{\alpha\mu}{\rho}w^*}{\frac{\alpha\beta\mu}{\rho} - w^*}.$$

In Proposition 2, w^* is defined in Lemma 1. α and β are smaller than 1. We could also prove that $\bar{B} > 0$. Thus, this capital structure is well-defined.

The intuitions of Proposition 2 are as follows: first, a certain share of equity is issued to the agent, because this share could serve as a reward to the developer in completing the construction, which would also provide incentive to the developer. Second, the debt could generate a state-contingent payoff to the agent. If the construction continues, both the value of the firm and the agent's expected payoff would decrease due to the debt accumulation. Third, both the government bond and debt limit are designed to satisfy the promise-keeping constraint. As the debt reaches the limit, the continuation payoff of the developer also reaches zero, resulting in the government to terminate the contract.

Having shown that the capital structure implements the optimal contract in the above proposition, the first thing we want to explain is why the loan must be issued by NDBs rather than general commercial banks. Consider a general commercial bank, which searches for the optimal loan size (normalized by μ) α and liquidation condition

[16] The formal proof of Proposition 2 can be found in the appendix.

$\tilde{\tau}$ to maximize the bank's profit, such as

$$\max_{\alpha,\tilde{\tau}} E\left[-\int_0^{\tau\wedge\tilde{\tau}} e^{-rt}\alpha\mu dt + \mathbf{1}_{\tau\le\tilde{\tau}}\left(e^{-r\tau}\int_0^{\tau} e^{\rho(\tau-t)}\alpha\mu dt\right)\right]$$

It is clear that the loan size and the liquidation condition would be different from what we characterize in Proposition 2. One example is that when ρ is close to r, the spread income is almost zero but NDB still suffer from default risks. Thus, the expected profit of the loan is negative, and a profit-driven bank, i.e., a commercial bank, would choose $\alpha = 0$ and $\tilde{\tau} = 0$ to avoid lose of the loan, while NDB could still support such financing, because NDB's investment decision is not profit-driven and is based on social-welfare concern. Admittedly, in theory, commercial banks could play similar role if the government is allowed to make well-designed state-contingent money transfers to commercial banks. However, this type of money transfer is not commonly found in reality, because it could induce additional issues, such as the moral hazard problem (e.g., Allen et al. 2018).

We next compare our mechanism with standard PPP arrangement. Suppose that the government covers directly the construction cost μ and issues $\tilde{\beta}$ fraction of total equity to the developer, but does not consider any debt. These types of mechanism are widely considered in standard (e.g., Hart 2003). To ensure the incentive–compatible condition, $\tilde{\beta}$ satisfies the following condition:

$$\frac{\overline{\lambda}}{\rho+\overline{\lambda}}\frac{\tilde{\beta}\gamma}{r} - \frac{1}{\rho+\overline{\lambda}}h \ge \frac{\underline{\lambda}}{\rho+\underline{\lambda}}\frac{\tilde{\beta}\gamma}{r},$$

which also implies

$$\tilde{\beta} \ge \left(1+\frac{\underline{\lambda}}{\rho}\right)\frac{rh}{\gamma(\overline{\lambda}-\underline{\lambda})} = \left(1+\frac{\underline{\lambda}}{\rho}\right)\beta.$$

Intuitively, the above equation suggests that in order to provide the incentive, the government needs to issue more equity to the developer than that in our model.[17] Thus, such PPP contract is more costly and less efficient. This is because the debt issued by NDB creates an extra penalty for the developer. In other words, the longer the construction duration takes, the lower the firm's value is.

We also argue that, even if Assumption 3 is violated, a slightly change of the debt-equity structure could still implement the optimal contract. More specifically, if Eq. (11) dose not hold, then the cash flow generated by the project would be too small to provide incentives. In this case, to provide sufficient incentives, the government needs to set $\beta = 1$ and promises capital injection with the amount $(\frac{h}{\overline{\lambda}-\underline{\lambda}} - \frac{\gamma}{r})$ to the firm after the project is completed.

If equality (12) does not hold, then the non-managerial cost is too small. To induce the firm to take extra debts, the government could set $\alpha = 1$ and require the firm to

[17] Nevertheless, we could also prove that the transfer payment in such contract is higher than that in our model.

issue a console bond with a face value $(\frac{\underline{\lambda}h}{\overline{\lambda}-\underline{\lambda}} - \mu)/r$ to the government. As a result, the firm has to take more debts to pay the interest of the bond during the construction.

In sum, the idea of implementing the optimal contract in our model shares some similarities with that in DeMarzo and Sannikov (2007), but there are some distinctions. Their paper considers a firm-operating problem—in which the firm's cash flow follows a Brownian motion. The principal can track historic firm performance through the firm's debt, and only if firm debt decreases to zero the agent will receive payoff. Instead, we consider an infrastructure construction problem in which the time to finish the project is stochastic and the construction follows a Poisson process. The debt accumulates over time and reduces the agent's future payoff, providing incentive for the agent to finish the project on time.

3 NDB profit

3.1 Determinants of NDB profit

Having endogenously modeled the government's investment strategy, we use our model to investigate the determinants of the NDB's performance. Specifically, we conduct comparative statics analysis on the NDB profit.

Recall that the expected profit of NDB is defined in Eq. (17) as:

$$\pi = E\left[-\int_0^{\tau\wedge\tilde{\tau}} e^{-rt}\alpha\mu dt + \mathbf{1}_{\tau\leq\tilde{\tau}}\left(e^{-r\tau}\int_0^{\tau} e^{\rho(\tau-t)}\alpha\mu dt\right)\right],$$

Therefore, π is determined by nine exogenous parameters in which we focus our discussion on three of them (η, R, μ) and fix the other six parameters ($\overline{\lambda}$, ρ, r, h, $\underline{\lambda}$, γ).[18] R measures the reserved value that the government receives if the government decides to fire a developer. η measures the social welfare that the infrastructure generates. μ measures the investment flow required by the construction. The comparative statics result can be summarized in Proposition 3.

Proposition 3 *The NDB's expected profit is increasing in the social welfare parameter, η and decreasing in the reserved value parameter, R and the construction cost parameter, μ.*[19]

Proposition 3 provides three practical implications. First, the effect of the social welfare η is positive. When the social welfare generated by the infrastructure project is high, the government tends to increase the debt limit. This makes NDB loans less possible to be defaulted, and thus increases the NDB's profit.

Second, the effect of reserved value R is negative. In short, R is the infrastructure project return without hiring a contractor. A government with higher ability would

[18] In principle, we can do comparative statics on all of nine parameters, however, some of them such as r and ρ are similar with these in commercial banks, and others such as $\overline{\lambda}$, $\underline{\lambda}$, h and γ are hard to find the corresponding measures in data.

[19] The formal proof for Proposition 3 can be found in the appendix.

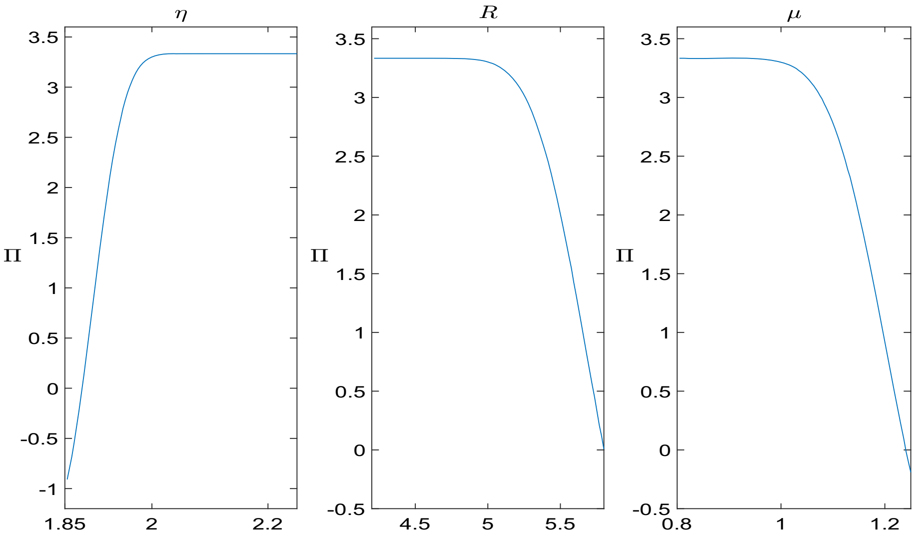

Fig. 2 Comparative statics on η, R and μ

have a higher R. In other words, when the government's reserved value is high, the government's opportunity cost of terminating the project is low. Therefore, the government would set a low debt limit, which increases the default probability and lowers the NBD profit.

Third, the effect of the construction cost μ is straightforward and intuitive. When the construction cost is high, the infrastructure is less attractive to the government, which decreases the debt limit of the project and reduces the NBD expected profit.

To better illustrate Proposition 3, we provide a numerical example of our comparative statics analysis in the Fig. 2.[20] There are three findings in this numerical exercise: First, the NDB's expected profit could be both positive and negative. Second, Proposition 3 continues to hold whenever the expected profit is positive or negative. Third, when η is large enough, or R and μ are small enough, the curve of NDBs' expected profit is flat. This is because the government would set extremely high debt limit and thus the NDB's expected profit converges to the level with zero probability.

Overall, our model suggests that the assignment of the loan size and the debt limit is based mainly on the social welfare and the construction cost. This is consistent with the reality. For example, considering the case of Three George Dam—the largest hydropower station in the world—CDB was the only bank willing to finance this construction in 1990s and granted 30 billion Yuan credit line with 15 years maturity. The loan size was 27 times of CDB's average level.

[20] The parameters are chosen as $\overline{\lambda} = 0.2$, $\underline{\lambda} = 0.1$, $h = 0.5$, $\gamma = 1$, $r = 0.1$, $\rho = 0.2$. Moreover, $\eta = 2$, $R = 5$, and $\mu = 1$ in the benchmark.

4 Extension—empirical test to NDB profit

In this section, we also use a cross-country dataset to provide the empirical support on how country level characteristics affect bank profit, i.e., three predictions in Proposition 3. Specifically, our empirical analysis relies on a panel for 209 countries from 2008 to 2017. The data is merged by three databases: 1) Moody's Analytics Bank-Focus database that provides balance sheet information for most banks in the world, including NDBs and commercial banks (CBs), 2) World Bank database that provides country level geographic, political and economic variables and indexes, and 3) IMF Investment and Capital Stock Dataset which contains information on public, private, and PPP investment flows across countries in the world. We are inclined to exploit the best corresponding measures from the available datasets to test our model predictions.

In our empirical analysis, we use the ratio of profit to total assets to measure bank profit, i.e., π in the model. Based on Proposition 3, we are particularly interested in three variables and apply the following three corresponding measures:

1. Use the current quality index of infrastructure, including road, railway, port, and airport, to proxy η—the return generated by the infrastructure. Our assumption is that the high quality of current infrastructure indicates an abundant infrastructure stock, which lowers the marginal social return of infrastructure investment.
2. Use the government managerial quality index to proxy R—the ability that the government executes the infrastructure project without hiring any contractors. In this case, we assume that government with higher managerial ability would implement the project better.
3. Use the percent of arable land in total land area of a country to proxy the difficulty of infrastructure construction μ, where we make the assumption that a country with more arable land has lower land altitude and thus lower construction cost.[21]

We also include a rich set of control variables and fixed effects to capture other parameters in our model, and therefore regress the following equation:

$$\pi_{ijt} = \alpha + \beta_1 Quality_{jt} + \beta_2 Land_{jt} + \beta_3 Gov_{jt} + \gamma X_{jt} + \delta_j + \theta_t + \epsilon_{ijt},$$

In this empirical specification, π_{ijt} is the profit of bank i in country j at time t; $Quality_{jt}$ refers to the current quality of infrastructure, including road, railway, port, and airport in country j at time t; Gov_{jt} refers to the index of government managerial quality in country j at time t; $Land_{jt}$ refers to the percent of arable land in country j at time t; X_{jt} refers to country level controls, including economic, political, geographic and demographic variables[22]; δ_j is country fixed effect; θ_t is time fixed effect; ϵ_{ijt} is

[21] In terms of cross-country data, the World Bank database provides indexes for infrastructure quality (ranking from 0 to 7) and managerial/regulatory quality (ranking from 0 to 100), while the percent of arable land in a country is the best measure that we could use to capture the difficulty of infrastructure construction from the available data.

[22] The complete set of control variables includes country level economic variables (GDP, stock market capitalization), political variables (corruption level, voice and accountability), public capital investment variables (government, private and PPP investment), and other geographic and demographic variables (the percent of forest land, Internet coverage and innovation level).

Table 1 Bank profit and country characteristics

Dependent variable: bank profit (π)	(1) NDBs	(2) CBs
Quality (η)	– 0.016**	0.002
	(0.007)	(0.011)
Land (μ)	1.278***	– 1.745
	(0.24)	(2.897)
Gov (R)	– 0.03*	0.052
	(0.016)	(0.047)
Controls	Yes	Yes
Country FE	Yes	Yes
Year FE	Yes	Yes
R-squared	0.48	0.019
Observations	372	7009

The dependent variable is bank profit, measured by the ratio of total profit to total assets. *Quality* refers to the index for the quality of a country's infrastructure including road, railway, port, and airport. *Land* refers to the percent of arable land in a country. *Gov* refers to the index for a country's managerial/regulatory quality. The number in the parentheses refers to the standard error clustered at the country level. ***, **, or *indicates that the coefficient estimate is significant at the 1%, 5%, or 10% level, respectively

the error term. We use fixed effects to absorb other unobserved country characteristics and also cluster standard errors at the country level.

We focus on the signs and significance levels of β_1, β_2 and β_3, and we expect that the signs of β_1, β_2 and β_3 are negative, positive and negative, respectively.[23] Table 1 presents the estimates of bank profit from the above regression. We emphasize on Column (1) that reports the regression result for NDBs. First, the coefficient of Quality (η) is negative and statistically significant, suggesting that higher current infrastructure quality induces the lower the marginal social benefit of infrastructure investment and hence reduces the bank profit. Second, the coefficient of Land (μ) is positive and statistically significant, indicating that a lower infrastructure construction cost leads to a higher profit. Third, the sign and significant level of the coefficient of Gov (R) is also consistent with our model prediction. Intuitively, higher reserve value causes the government to set a lower debt limit and thus leads to a higher default probability and a lower NDB profit.

Finally, as the robustness check to show that we do not obtain similar patterns from commercial banks (CBs), we repeat the above regression exercise by using a sample of CBs. Column (2) reports the corresponding result and shows that the signs and significance levels of these three coefficients (η, μ and R) are completely different from what we find in NDBs.

[23] Appendix A provides the summary statistics for the main variables used in Table 1.

5 Conclusion

In this paper, we apply the dynamic contract theory to study the role of NDBs in financing an infrastructure project. In our model, because the agent's (infrastructure project developer) effort is unobservable, the project may suffer from potential overrun issues due to the agency problem. To implement the optimal capital contract, the principal (government) establishes an NDB and issues loans to the agent. The debt accumulates over time and reduces the future payoff of the agent, which provides incentive for the agent to finish the project on time.

There are two main contributions of our paper. The first contribution is to improve the understanding of NDBs. We show that the government could employ NDB loans to implement an optimal capital structure and reduce overrun the agency problem during the infrastructure construction. The second one is to enrich the practical implication of the dynamic contract theory. We apply the theory to explain the importance of NDBs by investigating the contract implementation through an optimal capital structure of an infrastructure project. Moreover, we endogenizes NDB investment strategy to investigate the determinants of NDB profit and empirically test our model predictions.

In conclusion, NDBs play an increasingly important role in financing long-term investment, such as infrastructure construction in our case. As we have pointed out, very few studies have explored the question as to why governments initiate NDBs and what additional merits NDBs can offer, compared with other policy instruments. Although our paper provides one plausible explanation, there is still a large gap to be filled by the future theoretical and empirical studies.

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Data Availability The data used in this study is available upon request.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

Appendix A: Data

Tables 2 and 3 provide summary statistics for the main variables used in the cross-country test for NDB profit and the empirical test for the link between NDB and agency cost.

Table 2 Summary statistics I

Variable	Observations	Mean	SD	Min	Max
$Profit$	1296	0.113	0.118	0.011	0.816
$Quality$	1583	4.185	1.061	2.228	6.456
$Land$	5333	0.015	0.052	0	0.568
Gov	3968	0.14	0.873	− 2.344	2.098
$log(GDP)$	5579	4.523	2.175	− 2.04	9.879
$Capitalization$	5643	34.123	49.990	− 2.04	9.879
$Infra\_priv$	5506	165.01	399.83	0	5427.38
$Infra\_gov$	5506	59.06	224.39	0.005	3338.58
$Infra\_ppp$	4891	3.145	8.323	0	100.016

Profit is the ratio of total profit to total assets. *Quality* is the index for the quality of a country's infrastructure including road, railway, port, and airport, taking the value from 0 to 7. *Land* is the percent of arable land in a country. Gov refers to the index for a country's managerial/regulatory quality, taking the value from 0 to 100. $log(GDP)$ is the natural logarithm of real GDP. $Capitalization$ is the ratio of stock market value to GDP. $Infra\_priv$ is real private investment on infrastructure. $Infra\_gov$ is real government investment on infrastructure. $Infra\_ppp$ is real public-private partnership investment on infrastructure

Table 3 Summary statistics II

Variable	Observations	Mean	SD	Min	Max
Agency Cost	759	0.113	0.118	0.011	0.816
NDB	790	0.284	0.451	0	1
Ownership	790	0.600	0.490	0	1
Liquidity	784	0.147	0.151	0.001	0.715
Leverage	790	0.493	0.220	0.054	1.0097

Agency Cost is the ratio of managerial expenses to total sales. *NDB* is an indicator equaling to one if a firm obtains capital injections from the CDB. $Ownership$ is an indicator equaling to one if the firm is state-owned. *Liquidity* is the ratio of inventory to total assets. *Leverage* is the ratio of total debts to total assets

Appendix B: Empirical evidence from the China Development Bank

In this section, using the case of the China Development Bank (CDB),[24] we provide empirical evidence to show that the involvement of NDBs is positively associated with the decline of firm agency cost. In contrast, we do not obtain similar result from commercial banks (CBs), including Industrial and Commercial Bank of China, China Construction Bank, Agricultural Bank of China, and Bank of China.

The data in our empirical study comes from two sources: one is China Stock Market and Accounting Research Database (CSMAR), the counterpart of Computstat in China, providing financial information of China's public listed companies. The other is the State Administration for Market Regulation (SAMR) system in which we obtain firm registration records and corporate share holdings information. We use SAMR system to find out how many public listed firms receive capital injections from CDB in the infrastructure sector.[25] Our final sample is from 2003 to 2018. In a given year, some sample firms may have received capital investment from CDB while others may have not. Both groups experience the same time-specific changes, and thus, the differences in their agency costs provide an estimate of the effect of CDB's capital injections on firms. We make an assumption that a firm having CDB capital injection would be more connected to CDB and hence is more likely to receive CDB loans. Therefore, we estimate the following equation.

$$Agency_{i,t} = \alpha + \beta NDB_{i,t} + \gamma X_{i,t} + \delta_t + \epsilon_{i,t},$$

where $Agency_{i,t}$ refers to the agency cost of firm i at time t. Following Ang and Cole (2000), we use the ratio of managerial expenses to total sales to measure firm agency cost. $NDB_{i,t}$ is an indicator that firm i obtains capital injections from the CDB at time t. $X_{i,t}$ are control variables. δ_i is time fixed effects. $\epsilon_{i,t}$ is the error term.

In the above equation, we are interested in the sign and significant level of the coefficient β. Table 4 presents the corresponding result. Column (1) only includes the variable for CDB's capital injections, while column (2) adds control variables which are firm ownership, leverage and liquidity. Column (3) further includes time fixed effects. Overall, the coefficient β is negative and statistically significant, suggesting a negative relationship between the involvement from CDB and the agency cost for firms in the infrastructure sector. In other words, capital injections from NDBs are positive associated with the decline of firm agency cost.

We next repeat the above empirical test for commercial banks. Table 5 presents the corresponding result, indicating that capital injections from CBs do not have any significant effect on firm agency cost. In sum, we do not obtain similar result as we did for CDB.

In sum, these empirical findings serves as a motivation for us to develop a model to further understand the role of NDBs in mitigating the agency problem. We are not

[24] Founded in 1994, CDB is the largest NDB in the world, with total assets of more than USD 2.36 trillion in 2019. CDB is on par with the largest U.S. bank—J.P. Morgan—and is bigger than the World Bank and main regional development banks combined.

[25] We use the industry classification of infrastructure from the World Bank to identify firms in the infrastructure sector.

Table 4 Empirical evidence (NDB)

Dependent variable: agency cost	(1)	(2)	(3)
NDB	− 0.037***	− 0.037***	− 0.037*
	(0.013)	(0.014)	(0.022)
Ownership		− 0.024	− 0.023
		(0.022)	(0.026)
Leverage		0.054	0.063
		(0.048)	(0.045)
Liquidity		− 0.17***	− 0.15***
		(0.051)	(0.052)
Year FE	No	No	Yes
R-squared	0.028	0.091	0.182
Observations	154	154	154

The dependent variable is firm agency cost, measured by the ratio of managerial expenses to total sales. NDB is an indicator equaling to one if a firm obtains capital injections from the CDB. *Ownership* is an indicator equaling to one if the firm is state-owned. *Leverage* refers to the ratio of total debts to total assets. *Liquidity* refers to the ratio of inventory to total assets. The number in the parentheses refers to the robust standard error. ***, **, or *indicates that the coefficient estimate is significant at the 1%, 5%, or 10% level, respectively

Table 5 Empirical evidence (CB)

Dependent variable: agency cost	(1)	(2)	(3)
CB	0.015	0.011	0.02
	(0.013)	(0.015)	(0.014)
Ownership		−0.016	−0.011
		(0.011)	(0.011)
Leverage		−0.087***	−0.074***
		(0.028)	(0.027)
Liquidity		0.024	−0.035
		(0.219)	(0.196)
Year FE	No	No	Yes
R-squared	0.002	0.075	0.133
Observations	306	306	306

The dependent variable is firm agency cost, measured by the ratio of managerial expenses to total sales. *CB* is an indicator equaling to one if a firm obtains capital injections from commercial banks. *Ownership* is an indicator equaling to one if the firm is state-owned. *Leverage* refers to the ratio of total debts to total assets. *Liquidity* refers to the ratio of inventory to total assets. The number in the parentheses refers to the robust standard error. ***, **, or *indicates that the coefficient estimate is significant at the 1%, 5%, or 10% level, respectively inclined to identify a casual relation, but highlight the connection between CDB and firm agency cost.

Appendix C: The first-best case

In the first-best cases, we assume that high effort is always delivered, then, the expected social profit equals to

$$E[-\int_0^{\tau} e^{-rt}(h+\mu)dt + e^{-r\tau}\frac{\eta}{r}]$$

where τ is the stochastic stopping time when the project is finished. Based on the assumption of Poisson process, the expectation above equals to

$$\int_0^{\infty}\left[e^{-r\tau}\left(\frac{\eta}{r}-\frac{h+\mu}{\overline{\lambda}}\right)\right]\overline{\lambda}e^{-\overline{\lambda}\tau}d\tau$$
$$=\frac{\overline{\lambda}}{\overline{\lambda}+r}\frac{\eta}{r}-\frac{1}{\overline{\lambda}+r}(h+\mu)$$

Appendix D: Proofs for propositions

Before sketching the formal proofs of all Propositions in the paper, we first construct an auxiliary function f. The f function is defined as

$$\left[0, \frac{\underline{\lambda}h}{\rho(\overline{\lambda}-\underline{\lambda})}-\epsilon\right],$$

where ϵ is a sufficient small positive number, and f satisfies the following ODE and boundary condition

$$f'(w)=\frac{(r+\overline{\lambda})f(w)+\mu-\overline{\lambda}\left(\eta/r-\frac{h}{\overline{\lambda}-\underline{\lambda}}-w\right)}{\rho w-\frac{\underline{\lambda}}{\overline{\lambda}-\underline{\lambda}}h} \tag{21}$$
$$s.t.\quad f(0)=R$$

Note function f is the solution of Eq. (7) under condition that $c=0$ and IC constraints are always biding. The following lemma characterizes the properties of function f.

Lemma 2 *For a sufficient small $\epsilon>0$, there exists a point w^1 in $(0, \frac{\underline{\lambda}h}{\rho(\overline{\lambda}-\underline{\lambda})}-\epsilon]$, at which $f'(w^1)=-1$. Moreover, a unique strictly concave and continuous function f satisfies equation (21) and the boundary condition on $[0, w^1)$.*

Proof The right-hand side of Eq. (21) satisfies Lipschitz condition, thus there exists a $\mathcal{C}^1$ function f satisfying equation (21) and initial condition.

The following proof is separated into three steps: firstly, we show that $f'(0) > -1$;secondly, we prove that $f(w)$ is strictly concave when $f'(w) \geq -1$; lastly, we show there exists a w^1 satisfying $f'(w^1) = -1$.

Firstly, at the initial point $w = 0$, note that the assumption 2 requires $R < \frac{\overline{\lambda}}{r+\overline{\lambda}}\frac{\eta}{r} - \frac{1}{r+\overline{\lambda}}(\mu + h)$, which suggests that

$$f'(0) = \frac{(r+\overline{\lambda})R + \mu - \overline{\lambda}\left(\frac{\eta}{r} - \frac{h}{\overline{\lambda}-\underline{\lambda}}\right)}{-\frac{\underline{\lambda}}{\overline{\lambda}-\underline{\lambda}}h} > -1.$$

Next, differentiating equation (21) on both sides,

$$f''(w) = \frac{(r+\overline{\lambda}-\rho)f'(w) + \overline{\lambda}}{\rho w - \frac{\underline{\lambda}}{\overline{\lambda}-\underline{\lambda}}h} \tag{22}$$

which implies f is of class $\mathcal{C}^2$ on $[0, \frac{\underline{\lambda}h}{\rho(\overline{\lambda}-\underline{\lambda})} - \epsilon]$. Also, note that $\rho w - \frac{\underline{\lambda}}{\overline{\lambda}-\underline{\lambda}}h < 0$ in the function domain. Therefore, if $f'(w) \geq -1$,

$$f''(w) \leq \frac{\rho - r - \overline{\lambda} + \overline{\lambda}}{\rho w - \frac{\underline{\lambda}}{\overline{\lambda}-\underline{\lambda}}h} < 0.$$

f is strictly concave when $f'(w) \geq -1$.

Lastly, we argue that there exists a w^1 satisfying $f'(w^1) = -1$. Suppose not, by the continuity of $f'(w)$ we have $f'(w) > -1$ and $f''(w) < \frac{\rho-r}{\rho w - \frac{\underline{\lambda}}{\overline{\lambda}-\underline{\lambda}}h}$ in the domain $[0, \frac{\underline{\lambda}h}{\rho(\overline{\lambda}-\underline{\lambda})} - \epsilon]$. Integrating $f''(w)$ in the domain,

$$\int_0^{\frac{\underline{\lambda}h}{\rho(\overline{\lambda}-\underline{\lambda})}-\epsilon} f''(w)dw < \int_0^{\frac{\underline{\lambda}h}{\rho(\overline{\lambda}-\underline{\lambda})}-\epsilon} \frac{\rho - r}{\rho w - \frac{\underline{\lambda}}{\overline{\lambda}-\underline{\lambda}}h}dw$$

$$= \frac{\rho - r}{\rho}\left(\log(\rho\epsilon) - \log\left(\frac{\underline{\lambda}}{\overline{\lambda}-\underline{\lambda}}h\right)\right).$$

ϵ is a sufficiently small number such that $f'(\frac{\underline{\lambda}h}{\rho(\overline{\lambda}-\underline{\lambda})} - \epsilon) < f'(0) + \frac{\rho-r}{\rho}\Big(\log(\rho\epsilon) - \log\left(\frac{\underline{\lambda}}{\overline{\lambda}-\underline{\lambda}}h\right)\Big)$, which is arbitrarily negative. This is contradicted with that all $f'(w) > -1$. □

Proof of Proposition 1 We first show that incentive-compatible constraint is binding if $b'(w) > -1$. Setting ν as the Lagrange multiplier associated with incentive compatible constraint (9), the first order condition for $\bar{w}$ implies

$$\overline{\lambda}(-b'(w) - 1) + (\overline{\lambda} - \underline{\lambda})\nu = 0.$$

If $b'(w) > -1$ and $\nu > 0$, then the incentive compatible constraint is binding.

Secondly, we show that $b(w) = f(w)$ when $w \in [0, w^1]$. The first-order condition on c suggests that if $b'(w) > -1$, $c = 0$. Given the facts that the incentive compatible constraint is binding and $c = 0$, $b(w)$ satisfies equation (21). To verify $b(w) = f(w)$, note that when $w = 0$, $\frac{dw}{dt} < 0$, which implies that when w reach 0, the agent would choose to quit, then $b(w) = R$.

Based on Lemma 2, there exists a unique solution satisfying the ODE (21) and initial condition, so we finish prove $b(w) = f(w)$ in $[0, w^1)$. In last part of this step, we verify $b(w^1) = f(w^1)$. Note that since at w^1, strategy $c = 0$ and $\bar{w} = \frac{h}{\bar{\lambda}-\underline{\lambda}} + w$ is still feasible, which generates continuation payoff $f(w^1)$, so $f(w^1) \leq b(w^1)$. Also, it is impossible that $b(w^1) > f(w^1)$, otherwise principal can let agent deliver 0 effort to increase w from a value in a small left-neighborhood of w^1 to w^1 and gain strictly larger payoff.

Lastly, from any w principal can make a lump-sum transfer $C > 0$ and move agent's continuation value to $w - C$, which implies $b(w - C) \leq b(w) - C$. Taking limit on C, we have $b'(w) \geq -1$. Since $f''(w^1) < 0$, if $w > w^1$, it is optimal for principal to pay a lump-sum transfer $w - w^1$ immediately and agent's continuation value jumps to w^1. □

Proof of Proposition 2 The proof for Proposition 2 consists of two parts. In the first part, we show the implementation generates the same agent's state-contingent payoff as in the optimal contract. In the second part, we show the implementation delivers the same expected payoff to the principal.

Firstly, we show the implementation generates the same w_t during construction. Based on the optimal contract, the law of motion of w_t satisfies

$$\begin{aligned} \dot{w}_t &= \rho w_t + h - \bar{\lambda}(\bar{w}_t - w_t), \\ \frac{h}{\bar{\lambda} - \underline{\lambda}} &= \bar{w}_t - w_t. \end{aligned}$$

Since in the optimal contract w_0 starts at w^*, then until the project is terminated we have

$$\begin{aligned} w_t &= e^{\rho t} w^* - \int_0^t e^{\rho(t-s)} \left(\frac{\underline{\lambda} h}{\bar{\lambda} - \underline{\lambda}} \right) ds \\ \bar{w}_t &= e^{\rho t} w^* - \int_0^t e^{\rho(t-s)} \left(\frac{\underline{\lambda} h}{\bar{\lambda} - \underline{\lambda}} \right) ds + \frac{h}{\bar{\lambda} - \underline{\lambda}} \end{aligned}$$

Denote $\{w_t^I, \bar{w}_t^I\}$ as the expected payoff if the agent in the implementation and the money transfer to the agent if the project is completed at time t respectively. From Eq. (15), we have

$$\bar{w}_t^I = e^{\rho t} w^* + \beta \frac{\gamma}{r} - \beta \int_0^t e^{\rho(t-s)} (\alpha \mu) ds,$$

$$= e^{\rho t} w^* + \frac{h}{\bar{\lambda} - \underline{\lambda}} - \int_0^t e^{\rho(t-s)} \left(\frac{\underline{\lambda} h}{\bar{\lambda} - \underline{\lambda}} \right) ds.$$

The termination condition $\tilde{\tau}$ is determined by debt limit $\bar{B}$. $\bar{B} = \frac{\frac{\alpha\mu}{\rho} w^*}{\frac{\alpha\beta\mu}{\rho} - w^*}$, which implies

$$e^{\rho\tilde{\tau}} w^* = \int_0^{\tilde{\tau}} e^{\rho(\tilde{\tau}-t)} \left(\frac{\underline{\lambda} h}{\bar{\lambda} - \underline{\lambda}} \right) dt. \tag{23}$$

Note that, w_t^I can be formulated as

$$\begin{aligned} w_t^I &= \int_t^{\tilde{\tau}} \bar{\lambda} e^{-(\rho+\bar{\lambda})(s-t)} \left(\bar{w}_s^I - \frac{h}{\bar{\lambda}} \right) ds, \\ &= \int_t^{\tilde{\tau}} \bar{\lambda} e^{-(\rho+\bar{\lambda})(s-t)} \left[e^{\rho s} \left(w^* - \frac{\underline{\lambda} h}{\rho(\bar{\lambda} - \underline{\lambda})} \right) + \frac{\bar{\lambda} + \rho}{\bar{\lambda}} \frac{\underline{\lambda} h}{\rho(\bar{\lambda} - \underline{\lambda})} \right] ds, \\ &= \bar{\lambda} e^{(\bar{\lambda}+\rho)t} \left[\frac{1}{\bar{\lambda}} \left(w^* - \frac{\underline{\lambda} h}{\rho(\bar{\lambda} - \underline{\lambda})} \right) (e^{-\bar{\lambda} t} - e^{-\bar{\lambda}\tilde{\tau}}) - \frac{1}{\bar{\lambda}} \frac{\underline{\lambda} h}{\rho(\bar{\lambda} - \underline{\lambda})} (e^{-(\bar{\lambda}+\rho)\tilde{\tau}} - e^{-(\bar{\lambda}+\rho)t}) \right], \\ &= e^{\rho t} \left(w^* - \frac{\underline{\lambda} h}{\rho(\bar{\lambda} - \underline{\lambda})} \right) + \frac{\underline{\lambda} h}{\rho(\bar{\lambda} - \underline{\lambda})} \\ &\quad + e^{(\bar{\lambda}+\rho)(t-\tilde{\tau})} \left[-e^{\rho\tilde{\tau}} w^* + e^{\rho\tilde{\tau}} \frac{\underline{\lambda} h}{\rho(\bar{\lambda} - \underline{\lambda})} - \frac{\underline{\lambda} h}{\rho(\bar{\lambda} - \underline{\lambda})} \right]. \end{aligned}$$

Note that by Eq. (23), the term in the last bracket is zero. Then we obtain

$$\begin{aligned} w_t^I &= e^{\rho t} \left(w^* - \frac{\underline{\lambda} h}{\rho(\bar{\lambda} - \underline{\lambda})} \right) + \frac{1}{\rho} \frac{\underline{\lambda} h}{\bar{\lambda} - \underline{\lambda}} \\ &= e^{\rho t} w^* - \int_0^t e^{\rho(t-s)} \left(\frac{\underline{\lambda} h}{\bar{\lambda} - \underline{\lambda}} \right) ds. \end{aligned} \tag{24}$$

Since $\bar{w}_t^I - w_t^I = \frac{h}{\bar{\lambda} - \underline{\lambda}}$, the implementation satisfies incentive-compatible constraints. From Eq. (24), it is straightforward that the implementation shares the same termination condition in optimal contract. Thus, we have proved the implementation generates the same law of motion of w_t as in optimal contract.

In the last part of the proof, we verify that the implementation generates the same expected payoff of the government.

Note that the total expected payoff of government includes not only the direct government's expenditure and potential benefit, but also the expected profit of NDB. The expected profit of NDB is from Eq. (17). We can write the expected total payoff of the government by

$$b_0^I = E \left[- \int_0^{\tau \wedge \tilde{\tau}} e^{-rt} (1 - \alpha) \mu dt + \mathbf{1}_{\tau \leq \tilde{\tau}} \left(e^{-r\tau} (-e^{\rho\tau} w^* + \frac{\eta - \gamma}{r} + (1 - \beta) V_\tau) \right) \right.$$

$$+\mathbf{1}_{\tau>\tilde{\tau}}\left(e^{-r\tilde{\tau}}R\right)\Bigg]+\pi$$

$$=E\left[\int_0^{\tau\wedge\tilde{\tau}}e^{-rt}\mu dt+\mathbf{1}_{\tau\leq\tilde{\tau}}\left(e^{-r\tau}\left(\frac{\eta}{r}-\bar{w}_\tau\right)\right)+\mathbf{1}_{\tau>\tilde{\tau}}\left(e^{-r\tilde{\tau}}R\right)\right],$$

which generates the same expected payoff as in the optimal contract. □

Proof of Proposition 3 The proof for Proposition 3 has two parts: in the first part, we study how the parameters affects w^*; in the second part, we study how the paratmeters affects NDB's profit π.

Note that w^* is the initial promised payoff of the agent, which maximizes the principal's initial expected payoff. The first-order condition $b'(w)=0$ implies

$$(r+\overline{\lambda})b(w^*)+\overline{\lambda}w^*=-\mu+\overline{\lambda}\left(\eta/r-\frac{h}{\overline{\lambda}-\underline{\lambda}}\right). \tag{25}$$

Similar with DeMarzo and Sannikov (2007), rewrite $b(w)$ and w^* as functions of some parameter θ and denote them as $b(w,\theta)$ and $w^*(\theta)$, where $\theta=\eta, R$, or μ. Differentiating Equation (25) with respect to θ yields

$$\begin{aligned}\overline{\lambda}\frac{dw^*(\theta)}{d\theta}&=\frac{\partial(-\mu+\overline{\lambda}(\eta/r-\frac{h}{\overline{\lambda}-\underline{\lambda}}))}{\partial\theta}-(r+\overline{\lambda})\left(\frac{\partial b(w^*(\theta),\theta)}{\partial\theta}+\frac{\partial b(w^*(\theta),\theta)}{\partial w}\frac{dw^*(\theta)}{d\theta}\right),\\&=\frac{\partial\left(-\mu+\overline{\lambda}\left(\eta/r-\frac{h}{\overline{\lambda}-\underline{\lambda}}\right)\right)}{\partial\theta}-(r+\overline{\lambda})\frac{\partial b(w^*(\theta),\theta)}{\partial\theta}.\end{aligned} \tag{26}$$

The second equality holds because $\frac{\partial b(w^*(\theta),\theta)}{\partial w}=0$. By the definition, the principal's payoff $b(w^*,\theta)$ satisfies

$$b(w^*,\theta)=E\left[-\int_0^{\tau\wedge\tilde{\tau}}e^{-rt}\mu dt+\mathbf{1}_{\tau\leq\tilde{\tau}}\left(e^{-r\tau}(\frac{\eta}{r}-\bar{w}_\tau)\right)+\mathbf{1}_{\tau>\tilde{\tau}}\left(e^{-r\tilde{\tau}}R\right)\mid w(0)=w^*\right].$$

Note that when w^* is fixed, change of η, R and μ doesn't affect $\tilde{\tau}$, which implies,

$$\begin{aligned}\frac{\partial b(w^*,\eta)}{\partial\eta}&=E\left[\mathbf{1}_{\tau\leq\tilde{\tau}}\left(e^{-r\tau}\frac{1}{r}\right)\mid w(0)=w^*\right],\\&=\frac{\overline{\lambda}}{r(\overline{\lambda}+r)}(1-e^{-(r+\overline{\lambda})\tilde{\tau}}).\\\frac{\partial b(w^*,R)}{\partial R}&=E\left[\mathbf{1}_{\tau>\tilde{\tau}}\left(e^{-r\tilde{\tau}}\right)\mid w(0)=w^*\right],\\&=e^{-(\overline{\lambda}+r)\tilde{\tau}}.\\\frac{\partial b(w^*,\mu)}{\partial\mu}&=E\left[-\int_0^{\tau\wedge\tilde{\tau}}e^{-rt}dt\mid w(0)=w^*\right],\end{aligned}$$

$$= -\frac{1}{\overline{\lambda}+r}(1-e^{-(r+\overline{\lambda})\tilde{\tau}}).$$

Combining Equation (26), we have

$$\frac{\partial w^*}{\partial \eta} = \frac{1}{r}e^{-(r+\overline{\lambda})\tilde{\tau}} > 0, \tag{27}$$

$$\frac{\partial w^*}{\partial R} = -\frac{r+\overline{\lambda}}{\overline{\lambda}}(e^{-(r+\overline{\lambda})\tilde{\tau}}) < 0, \tag{28}$$

$$\frac{\partial w^*}{\partial \mu} = \frac{1}{\overline{\overline{\lambda}}}\left(-1+(1-e^{-(r+\overline{\lambda})\tilde{\tau}})\right) < 0. \tag{29}$$

Now we turn to study the change of NDB's profit π. Differentiating Equation (23) with respect to θ yields

$$\frac{\partial w^*}{\partial \theta} = e^{-\rho\tilde{\tau}}\frac{\underline{\lambda}h}{\overline{\lambda}-\underline{\lambda}}\frac{\partial \tilde{\tau}}{\partial \theta}, \tag{30}$$

thus $\frac{\partial w^*}{\partial \theta}$ and $\frac{\partial \tilde{\tau}}{\partial \theta}$ have the same signs.

Note that if $R = \frac{\overline{\lambda}}{r+\overline{\lambda}}\frac{\eta}{r} - \frac{1}{r+\overline{\lambda}}(\mu+h) - \frac{\overline{\lambda}}{r+\overline{\lambda}}\frac{h}{\overline{\lambda}-\underline{\lambda}}$, $b'(0)=0$ and $w^*=0$. Then, under Assumption 2, Eq. (28) implies

$$w^* > \frac{1}{\overline{\lambda}+\rho}\frac{\underline{\lambda}h}{\overline{\lambda}-\underline{\lambda}} \quad \text{and} \quad e^{\rho\tilde{\tau}} > \frac{\overline{\lambda}+\rho}{\overline{\lambda}}.$$

Based on Eq. (17), we have

$$\begin{aligned}
\pi &= \int_0^{\tilde{\tau}}\left(\overline{\lambda}e^{-(\overline{\lambda}+r)\tau}\left(-\frac{\alpha\mu}{\overline{\lambda}} + \int_0^{\tau} e^{\rho(\tau-t)}\alpha\mu dt\right)d\tau\right) \\
&= \int_0^{\tilde{\tau}}\left(\frac{\overline{\lambda}\underline{\lambda}\gamma}{r}e^{-(\overline{\lambda}+r)\tau}\left(\frac{e^{\rho\tau}}{\rho} - \left(\frac{1}{\rho}+\frac{1}{\overline{\overline{\lambda}}}\right)\right)d\tau\right).
\end{aligned}$$

Then

$$\frac{\partial \pi}{\partial \tilde{\tau}} = \frac{\overline{\lambda}\underline{\lambda}\gamma}{r}e^{-(\overline{\lambda}+r)\tilde{\tau}}\left(\frac{e^{\rho\tilde{\tau}}}{\rho} - \left(\frac{1}{\rho}+\frac{1}{\overline{\overline{\lambda}}}\right)\right) > 0.$$

Finally, since $\frac{\partial \Pi}{\partial \theta}$ has the same sign as $\frac{\partial w^*}{\partial \theta}$ for $\theta = \eta$, R, or μ, we therefore finish the proof. □

Appendix E: A sufficient condition of no-shirking

In this section, we provide a sufficient condition of no-shirking. Suppose that the principal allows the agent to shirk in a small time interval $[t, t+dt)$. Since the agent does not need to put effort in the time interval, it is optimal for the principal not to provide any transfer to the agents. Law of motion of the agent's continuation value would be as

$$dw_t = \rho w_t dt.$$

If high effort is always preferred in the optimal contract, then the following condition must be satisfied

$$b(w_t) > \left(-\mu + \frac{\underline{\lambda}\eta}{r} - \frac{\underline{\lambda}h}{\overline{\lambda}-\underline{\lambda}} - \underline{\lambda}w\right)dt + e^{-rdt}b(w_t + dw_t),$$

in which $b(w_t)$ is the continuation value of the principal with no shirking. After taking the limit of dt, we have

$$rb(w_t) > \left(-\mu + \frac{\underline{\lambda}\eta}{r} - \frac{\underline{\lambda}h}{\overline{\lambda}-\underline{\lambda}} - \underline{\lambda}w\right) + b'(w_t)\rho w_t$$

Note that

$$rb(w_t) = \left(-\mu + \frac{\overline{\lambda}\eta}{r} - \frac{\overline{\lambda}h}{\overline{\lambda}-\underline{\lambda}} - \overline{\lambda}w\right) + b'(w_t)\left(\rho w_t - \frac{\underline{\lambda}h}{\overline{\lambda}-\underline{\lambda}}\right)$$

which implies

$$\begin{aligned}
&\frac{\overline{\lambda}\eta}{r} - \frac{\overline{\lambda}h}{\overline{\lambda}-\underline{\lambda}} - \overline{\lambda}w - b'(w)\frac{\underline{\lambda}h}{\overline{\lambda}-\underline{\lambda}} > \frac{\underline{\lambda}\eta}{r} - \frac{\underline{\lambda}h}{\overline{\lambda}-\underline{\lambda}} - \underline{\lambda}w_t,\\
&\frac{\eta}{r} > \frac{h}{\overline{\lambda}-\underline{\lambda}} + w_t + b'(w_t)\frac{\underline{\lambda}h}{(\overline{\lambda}-\underline{\lambda})^2}.
\end{aligned}$$

Since $w_t \in [0, \frac{\underline{\lambda}h}{\rho(\overline{\lambda}-\underline{\lambda})})$ and $b'(w) \in [-1, b'(0)]$, then when the following condition holds

$$\frac{\eta}{r} > \frac{h}{\overline{\lambda}-\underline{\lambda}} + \frac{\underline{\lambda}h}{\rho(\overline{\lambda}-\underline{\lambda})} + b'(0)\frac{\underline{\lambda}h}{(\overline{\lambda}-\underline{\lambda})^2},$$

the optimal contract always recommend no shirking. The economic intuition of this condition is that, fixed all other parameters, when the social benefit is sufficiently large, the principal would always prefer to high effort.

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