Received: 12 April 2021 | Revised: 20 June 2022 | Accepted: 30 July 2022

DOI: 10.1111/irfi.12391

ORIGINAL ARTICLE

INTERNATIONAL REVIEW OF FINANCE WILEY

The maturity-lengthening role of national development banks

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Funding information
Ford Foundation, Grant/Award Numbers: 128664, 139355; National Natural Science Foundation of China, Grant/Award Number: 72141301; National Natural Science Foundation of China - Data Center for Management Science at Peking University, Grant/Award Number: 2017KEY06; National Social Science Foundation of China, Grant/Award Numbers: 17BJL124, 20BJL021; SECYT, UNC, Argentina, Grant/Award Number: 33620180101069CB

[Correction added on 27 October 2022, after first online publication: the affiliation of Jianye Yan has been updated]

Abstract

We analyze why national development banks (NDBs) may provide longer-term loans to firms than private commercial banks (PCBs). If NDB bonds have higher collateral value than PCB bonds, then NDBs may lend longer-term than PCBs. NDBs may enjoy higher recapitalization willingness and capacity by the state and hence greater collateral value than PCBs. Moreover, NDBs may have advantages over state-owned commercial banks if NDB bonds enjoy higher market liquidity. However, NDBs may suffer from poor monitoring quality owing to undue political intervention, thus undermining collateral value. Our study implies that NDBs are not substitutes for but complements to PCBs.

KEYWORDS
collateral capacity, loan maturity, market liquidity, monitoring quality, national development banks, recapitalization

JEL CLASSIFICATION
E44, G01, G21, G28, H81

1 | INTRODUCTION

The availability of long-term finance has a positive and significant impact on long-run growth (Beck, 2012). Moreover, it contributes to higher growth by playing a countercyclical role that lowers macroeconomic volatility (Aghion et al., 2005). When long-term finance is not available for eligible firms, they become vulnerable to rollover risks and may become reluctant to undertake longer-term fixed investments, leading to adverse effects on economic growth and welfare (Diamond, 1991). Despite its significance, long-term finance is in short supply, especially in developing countries.

One way to overcome the scarcity of long-term finance is to establish national development banks (NDBs). NDBs are financial institutions initiated and steered by central governments with the official mission of fulfilling public policy objectives (Xu et al., 2021), such as financing high-risk and long-term projects that go beyond the risk appetite of private commercial banks (Armendáriz de Aghion, 1999). According to the world's first development financing institutions database developed by the Institute of New Structural Economics at Peking University in collaboration with the French Development Agency, the total assets of all NDBs are as much as nine trillion dollars, accounting for about 10% of global gross domestic product.[1] Moreover, during the financial crisis that erupted in 2008, NDBs acted in a countercyclical manner, which helped stabilize the real economy (Brei & Schclarek, 2018). In addition, the global development finance architecture increasingly fosters the cooperation between NDBs and multilateral development banks (Schclarek & Xu, 2022).

Using a comprehensive list of NDBs worldwide, matched with bank-level data by BankFocus (Hu et al., 2022), Figure 1 shows the average ratio of loans to customers with a maturity of longer than 5 years, discriminating among the following bank types: (a) NDBs, (b) state-owned commercial banks (SCBs), and (c) privately owned commercial banks (PCBs). The database consists of a large sample of 1251 banks, of which 58 are NDBs, 112 are SCBs, and 1081 are PCBs, across 106 countries between 2011 and 2018. As clearly shown in Figure 1, and supported by the econometric findings of Hu et al. (2022), which control for bank-level characteristics and macroeconomic factors, NDBs provide longer-term loans to customers than either SCBs or PCBs. Another empirical paper on the importance of NDBs for long-term loans is that of de Luna-Martinez and Vicente (2012), that, for a sample of 90 NDBs in 61 countries, discovered that 54% of loans had a maturity of over 10 years, 29% of loans had a maturity of 6–10 years, and only 16% of loans had a maturity of less than 5 years.

One reason why NDBs may provide long-term finance is that their official mission is development-oriented rather than focusing exclusively on maximizing profits. NDBs are more willing to internalize certain positive externalities of longer-term loans to firms and take on risks that private banks will not (Brei & Schclarek, 2013, 2015, 2018) and optimally lend longer-term than PCBs.[2] Another explanation is that the maturity-lengthening role of NDBs may

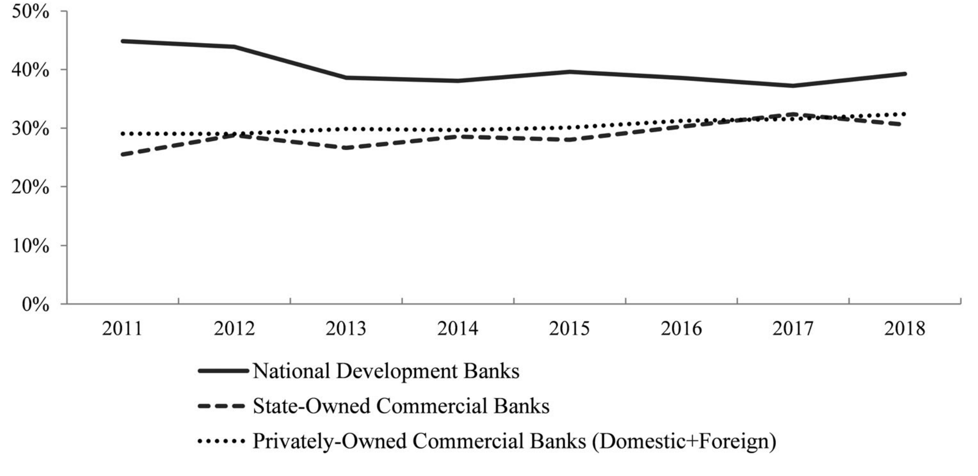

FIGURE 1 Average ratio of loans to customers larger than 5 years. *Source*: Hu et al. (2022) based on BankFocus data, and the first global database on public development banks and development financing institutions (Xu et al.,2021) by the Institute of New Structural Economics at Peking University and French Development Agency available at www.dfidatabase.pku.edu.cn.

be related to the time term of their funding sources (Griffith-Jones et al., 2018). Because PCBs rely predominately on short-term bank deposits, which may be withdrawn at any moment, PCBs are prone to higher maturity mismatch and refinancing risks when providing longer-term loans. In contrast, NDBs have longer-term liabilities, such as bonds, and may rely more on recapitalization to finance their lending. Therefore, NDBs are able to grant longer-term credits without incurring substantial maturity mismatch and refinancing risks.

In our paper, we build on the above ideas and draw on additional insights from in-depth interviews with practitioners from NDBs to propose a novel explanation for the maturity-lengthening role of NDBs. Our core argument is that NDBs may lend longer term to firms than PCBs can, if NDB bonds have higher collateral value than bonds issued by PCBs. Our baseline model starts with a banking system containing PCBs only. PCBs suffer from a maturity mismatch between loans to firms and deposits and thus face liquidity risks, which may require them to issue bonds, or, equivalently, to obtain interbank loans to settle interbank payments (the survival constraint). If we consider that collateral is needed to secure promises because promises without collateral may be broken and difficult to enforce, the maximum amount that banks may obtain by issuing bonds (i.e., the collateral value of the bonds issued by banks) is primarily determined by the collateral capacity of banks' assets (or loans to firms). The collateral value of bank bonds is negatively related to the maturity of the bank loans to firms because long-term loans are often riskier than short-term ones. Thus, PCBs will optimally choose the maturity of loans to firms so that the collateral value of their bonds is high enough to overcome the survival constraint. Next, we introduce an NDB that finances its lending to firms by issuing bonds bought by PCBs. In case the PCBs need to settle interbank payments (the survival constraint), they may sell the NDB bonds instead of issuing their own bonds or, equivalently, requesting an interbank loan.

Our main proposition is that a banking system with both NDBs and PCBs could provide longer-term lending to firms compared with a banking system with PCBs only, if NDB bonds have higher collateral value than bonds issued by PCBs. One reason NDB bonds may enjoy greater collateral value is that NDBs are owned by the government, which may have a higher recapitalization willingness and capacity than private bank owners in case of difficulties in honoring the issued bank bonds. Another advantage may be that NDBs finance themselves through bond issuance rather than deposit-creation and -taking, which implies that the trading volume of NDB bonds is higher than that of any other commercial bank, thus enhancing the market liquidity of NDB bonds. However, if NDBs have a lower level of monitoring skills and quality than PCBs because of undue political intervention, their advantages over PCBs would be reduced in terms of their maturity-lengthening role. In addition, even if both NDBs and SCBs are owned by governments, NDBs may even have an advantage over SCBs in terms of the maturity of loans to firms, if NDB bonds have higher market liquidity than SCB bonds.

Regarding the related literature, the underlying money and banking theory that we use is the "money view" theory, as in Mehrling (2011, 2012). Our reason for using this theory instead of the conventional financial-intermediation theory of banking is that the money view theory is especially suitable for analyzing liquidity problems and the use of bank bonds or interbank loans to settle interbank payments (the survival constraint), in particular when bank deposits are not withdrawn from the banking system as a whole. Regarding the limitations of the conventional financial-intermediation theory of banking for the withdrawal of bank deposits, see, among others, Skeie (2008). Furthermore, we enrich the literature on assets' collateral capacity, as in Adrian and Boyarchenko (2012), Brunnermeier and Pedersen (2009), and Geanakoplos and Fostel (2008), by explicitly linking the collateral capacity of bank loans with the maturity of bank loans. To the best of our knowledge, our paper is the first to analyze this link between the collateral capacity of bank loans and loan maturity. In addition, our paper is also based on the bank-monitoring literature, as in Diamond (1984) and Holmstrom and Tirole (1997), as well as on the market-liquidity literature, as in Amihud et al. (2006), Bao et al. (2011), Pagano (1989), and Vayanos and Wang (2013). Although extensive banking literature has studied both monitoring and market liquidity, to the best of our knowledge, our paper is the first to link these factors with the maturity of bank loans to firms. Finally, our paper follows the literature on the role of the government as a liquidity provider, as in Gorton and Huang (2004) and Holmstrom and Tirole (1998).

The rest of this paper is organized as follows: We present the baseline model in Section 2, where we first analyze a banking system with PCBs only. Next, we introduce an NDB to the banking system and compare how the different prospects for bank recapitalization affect the collateral value of bonds and thus the optimal maturity of bank lending to firms. The endogenous determination of both the amount of lending and the maturity of bank lending is analyzed in Section 3. In Sections 4 and 5, we explore the consequences—for the collateral value of bonds and thus for the maturity of lending by banks–of introducing heterogeneity into both the monitoring quality of banks and into the market liquidity of the bonds issued by banks. Finally, in Section 6, we conclude with key findings and policy implications.

2 | BASELINE MODEL

In this section, our baseline model starts with a banking system with PCBs only. We analyze the determinants of the optimal maturity of bank lending to firms when this lending creates liquidity risks for banks, and interbank payments may be settled by paying with liquid assets or by lending to each other through bank bonds or, equivalently, by making interbank loans. Our results show that the maturity of commercial bank lending to firms is positively related to both the quantity of liquid assets held by PCBs and the recapitalization willingness (or the willingness perceived by bond investors) and the recapitalization capacity of private banks' owners. Then we introduce an NDB to the banking system where the NDB finances its lending to firms by issuing bonds to be purchased by commercial banks. We show that NDB bonds may enjoy greater collateral value than those issued by PCBs. The reason is that the government has greater recapitalization capacity and willingness than that of private bank owners. Thus, we conclude that banking systems with both an NDB and PCBs can lend longer term to firms than banking systems with PCBs only.

2.1 | PCBs-only model

Our model starts by analyzing a case in which there are only PCBs that optimally choose the maturity of their lending to firms. The economy is characterized by a simple model in which decisions are made in the initial period 0; some of the uncertainty is revealed in the intermediate period 1, with its consequences; and the rest of the uncertainty is revealed and all the payoffs are settled in the final period T. Note that the final period T is a decision variable for PCBs, because the maturity of the lending to firms is of a variable length spanning T periods between the initial period 0 and the final period T.

Following Allen and Gale (1998), Brei and Schclarek (2015), and Holmstrom and Tirole (1997), among others, we assume a firm or investor with a real investment project that must be funded through borrowing from banks in the initial period 0 and that pays off in the final period T. We assume that the firm has no liquid assets. Thus, to implement a real investment project of scale I, the firm must borrow I from bank j in the initial period 0. With the funds obtained in the initial period 0, the firm makes all the necessary payments to other agents, such as suppliers and staff, in the intermediate period 1. The real investment project has a stochastic per-period net rate of return $R(T)$, which is increasing in time because we assume that longer-term real investment projects have a higher per-period rate of return. We assume that $R(T)$ is equal to $R \times T$, where R is the stochastic net rate of return of a project of one period of length spanning period 0 and period 1 ($T = 1$). Then, the expected per-period net rate of return of a real investment project of maturity T is $T \cdot E(R)$, and the variance of the per-period net rate of return is $T^2 \times V(R)$. Note that the longer the maturity T of the real investment project, the higher the variance of the per-period net rate of return. Thus, longer-term real investment projects are more risky. Furthermore, and for the sake of simplicity, we assume that all payoffs of the investment project from the different periods materialize in the final period T.[3]

Following the "money view" monetary theory, presented in Mehrling (2011, 2012); Mehrling et al. (2015), PCBs grant loans by creating bank deposits that the firm or investor will use to make payments (see line 1 of Table 1, where we present the balance sheets of the different agents using T-accounts: that is, assets on the left-hand side and liabilities on the right-hand side, following the "money view" monetary theory).[4] It is assumed that PCB j decides

TABLE 1 Solving the liquidity problems and the interbank payments by interbank loans.

T	Bank 1		Bank 2		Firm 1		Firm 2	
	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
0							$Goods_{firm2}$	
1 Loan by Bank 1 to Firm 1	$+Loan^{firm1}_{bank1}$	$+Deposit^{firm1}_{bank1}$			$+Deposit^{firm1}_{bank1}$	$+Loan^{firm1}_{bank1}$		
2 Interbank loan by bank 2 to bank 1	$+Deposit^{bank1}_{bank2}$	$+Inter^{bank1}$ $bankloan_{bank2}$	$+Inter^{bank1}$ $bankloan_{bank2}$	$+Deposit^{bank1}_{bank2}$				
3 Payment by Firm 1 to Firm 2 with account in Bank 2	$-Deposit^{bank1}_{bank2}$	$-Deposit^{firm1}_{bank1}$		$-Deposit^{bank1}_{bank2}$ $+Deposit^{firm2}_{bank2}$	$-Deposit^{bank1}_{bank2}$ $+Goods_{firm2}$		$+Deposit^{firm1}_{bank1}$ $-Goods_{firm2}$	
Final	$Loan^{firm1}_{bank1}$	$+Inter^{bank1}$ $bankloan_{bank2}$	$+Inter^{bank1}$ $bankloan_{bank2}$	$+Deposit^{firm2}_{bank2}$	$Goods_{firm2}$	$Loan^{firm1}_{bank1}$	$Deposit^{firm2}_{bank2}$	

to grant a fixed and given amount of lending D to the firm and creates the amount D of bank deposits in the initial period 0. Bank j, however, must optimally choose the maturity T_j of the lending to the firm in the initial period 0. Note that we are assuming a fixed amount D, instead of taking D as a decision variable, to concentrate exclusively on the determination of the variable T_j. This simplifying assumption does not affect our main results, as discussed in Section 3, where we analyze the endogenous decision of both D and T_j.

Furthermore, bank j charges a per-period interest rate $i_L(T_j)$ for the lending to the firm, which is increasing in the maturity T_j of the lending because we assume there is a term premium. Specifically, we assume that the per-period interest rate earned, $i_L(T_j)$, is equal to $T_j \times i_L$, where i_L is the interest rate charged for a loan of maturity 1 (i.e., that spans period 0 and period 1 ($T = 1$)).[5] Thus, the per-period interest rate $i_L(T_j)$ that the firm has to pay is endogenously determined by the optimal decision of bank j regarding the maturity of the lending to the firm T_j. We also assume that bank deposits do not pay interest (i.e., they have no cost for bank j).[6] Note also that we assume that the maturity of the lending to the firm determines the maturity of the investment project. Thus, it is the optimal decision of bank j that will determine the maturity of the real investment project, which is T_j; the expected per-period net return of the real investment project, which is $T_j \times E(R)$; and its variance, which is $T_j^2 \cdot V(R)$.

In addition, we assume that $E(R) - i_L \geq 0$, so that the real investment project is risky but has an expected per-period rate of return that is enough to pay back the loan and the interest to the bank. Note that the larger the difference $E(R) - i_L$, the higher the expected per-period profits after paying interest, and thus the lower the probabilities that the firm will default on the loan. Note also that the longer the maturity T_j of the lending to the firm, the riskier the loan is; thus, the probability that the firm will default on the loan is higher. The reason is that the longer the maturity T_j, the larger the variance of the per-period net return of the real investment project. In addition, we assume that the firm will only default on its loan in the final period T_j if the realized returns are not enough to pay back the loan capital and interest. Furthermore, we assume that all the capital and interest are paid in the last period T_j, when the rest of the payoffs are realized and settled. All these assumptions imply that PCBs have an incentive to grant longer-term loans to increase the per-period interest rate that they charge to firms on their lending, but this will also increase the risk that firms default on their loans.

The chances of a maturity mismatch between a PCB's assets and liabilities result in its liquidity problems, which hinges on the probability of a net payment by this PCB to another PCB. Specifically, the creation of bank deposits by bank j in period 0 implies a promise to the firm (the deposit holder) that it will be able to use those bank deposits D to settle payments with other agents, such as suppliers and staff, in the intermediate period 1. If the deposit holder pays an agent that has a bank account in the same bank j, then bank j has no liquidity problem because it makes no payment to another bank in the intermediate period 1. However, if the payment recipient has a bank account in a different bank k, bank j must make a payment to bank k in the intermediate period 1 to get bank k to credit the payment to the recipient's bank account (see lines 2 and 3 of Table 1). Note that, if the payment from bank j to bank k is not settled, bank j cannot fulfill the promise made to the deposit holder that it will settle its payments. Consequently, bank j would probably suffer a bank run and bankruptcy. Thus, when bank j provides lending to the firm and creates bank deposits in the initial period 0, it is suffering a maturity mismatch between its assets and liabilities and is exposing itself to liquidity risk in the intermediate period 1. Note, finally, that bank k may also need to make a payment to bank j in the same period in which bank j must make a payment to bank k. This means that it is the *net* payments from bank j to bank k that cause liquidity problems for bank j.

As far as liquidity problems for bank j are concerned, we can establish three possibilities regarding the net flow of payments with bank deposits between banks or the required net payments between banks j and k in the intermediate period 1. We assume that, following a categorical distribution, there is a probability α that there is a net outflow of deposits D from bank j to bank k, which requires a net payment D from bank j to bank k; a probability β that there is a net inflow of deposits D into bank j from bank k, which implies a net payment from bank k to bank j of D; and a probability $1 - \alpha - \beta$ that both banks j and k make payments to each other and that the payments cancel each other out, so there is no net payment between them.[7]

In the case of a net outflow of deposits from bank j to bank k in the intermediate period 1, which requires a net payment of D from bank j to bank k, bank j can pay with the liquid assets A_j that it has available in the intermediate period 1. Alternatively, bank j can settle the payment to bank k by issuing bonds that it hands over to bank k or, equivalently, by obtaining an interbank loan from bank k (see lines 2 and 3 of Table 1).[8] This payment or survival constraint in the intermediate period 1 implies that $D \leq B_j + A_j$, where B_j is the amount obtained by issuing the bonds and handing them over to bank k in the intermediate period 1.

We assume that the bonds issued by bank j pay a coupon rate or interest rate $i_B(T_j)$, which is increasing in the maturity T_j of the bonds. Specifically, we assume that the per-period interest rate that is charged $i_B(T_j)$ is endogenously determined and equal to $T_j \times i_B$ for a bond of maturity T_j, where i_B is given and the interest rate $i_B(T_j)$ is increasing in T_j. In addition, for the sake of simplicity and without affecting our results, we assume that the interbank loan or the bonds are of maturity $T_j - 1$ (i.e., spanning the intermediate period 1 and the final period T_j, when bank j obtains the proceeds from the loan to the firm). Thus, the per-period interest rate that is charged is $(T_j - 1) \times i_B$. Note that bank j could also issue bonds with maturity 1 and roll over the bonds $T_j - 1$ times to minimize the per-period interest rate that it is charged, which would be i_B. However, we assume away this possibility because, in this paper, we are not interested in analyzing the trade-offs between a lower per-period interest rate and the problems that arise when there are rollover risks.[9] In addition, we assume, for simplicity reasons, that $i_L \geq i_B$, which implies that the bank that is issuing the bank bonds is making a profit by lending to firms and can, thus, repay the bonds it issues. In this sense, in our model, as long as $i_L \geq i_B$, there are incentives to buy the bank bonds because the repayment is feasible with the proceeds of the loan to the firm. Note that, when $i_L < i_B$, the bank that wants to issue the bonds is incurring a loss and will not be able to repay the bonds using the proceeds of the loan to the firm. Regarding the liquid assets A_j, we clarify some further aspects below in this same subsection.

We now turn to analyzing what determines the maximum amount of funding that bank j may obtain when issuing bonds and handing them over to bank k in the intermediate period 1, or equivalently, the maximum amount of the interbank loan from bank k to bank j. Following, among others, Adrian and Boyarchenko (2012), Brunnermeier and Pedersen (2009), Fostel and Geanakoplos (2014), and Geanakoplos and Fostel (2008), the maximum amount of funding that a bank can obtain by issuing bonds is related to the value of the assets that explicitly or implicitly backs or guarantees these bonds. Note that the reason for demanding collateral when lending is to secure promises because promises without collateral may be broken and difficult to enforce. Furthermore, any asset has a value as collateral determined by the asset's collateral capacity (i.e., the maximum amount that can be borrowed using this asset as collateral). In addition, the collateral capacity ratio of an asset is the asset's value as collateral divided by the fundamental value of this asset (Geanakoplos & Fostel, 2008). Thus, the maximum amount that bank j may obtain by issuing bonds and handing them over to bank k in the intermediate period 1 is determined by the collateral capacity of bank j's loans to the firm. Note that when referring to the collateral capacity of the bank loan to the firm, the bonds may be explicitly or implicitly guaranteed or backed by the bank loan to the firm. In this paper, we refer to this maximum amount as the collateral value of the bonds issued by bank j given by the collateral capacity of the loan to the firm.

Specifically, the collateral value of the bonds issued by bank j given by the collateral capacity of the loan to the firm is $B_j^L = \tau(T_j) \cdot \frac{((T_j-1) \cdot i_B)^{(T_j-1)}}{((T_j-1) \cdot i_D)^{(T_j-1)}} \cdot D$, where $\tau(T_j)$ is the collateral capacity ratio of the loan to the firm, where $0 \leq \tau(T_j) \leq 1$, and where $\frac{((T_j-1) \cdot i_B)^{(T_j-1)}}{((T_j-1) \cdot i_D)^{(T_j-1)}} \cdot D$ is the present value of the loan to the firm in the intermediate period 1 and $([T_j - 1] \times i_D)$ is the per-period discount rate that is increasing in T_j because of a term premium. Furthermore, we assume that the collateral capacity ratio is a negative function of the variance of the per-period net return of the real investment project, $T_j^2 \cdot V(R)$, which is a measure of the riskiness of the lending to the firm, and thus affects the prospects for paying back the bonds issued by bank j. The exact functional form that is assumed for the collateral capacity ratio is $\tau(T_j) = 1 - \gamma \cdot T_j^2 \cdot V(R)$.[10,11] Note that the collateral capacity ratio of the lending to the firm is negatively related to the maturity T_j of the loan to the firm. The negative relationship between the collateral capacity of an asset and the variance of its return is also highlighted in Brunnermeier and Pedersen (2009) and Fostel and Geanakoplos (2014), among others.

Finally, we assume that the per-period discount rate is equal to the per-period interest rate paid by the bonds (i.e., $i_D = i_B$). We make this assumption to simplify the mathematical model and avoid non-linearities, but it does not affect the main conclusions of this paper. Then, the collateral value of the bonds issued by bank j given by the collateral capacity of the loan to the firm is $B_j^L = \left(1-\gamma \cdot T_j^2 \cdot V(R)\right) \cdot D$, which is lower than D. Moreover, the longer the maturity of the lending of bank j determined in the initial period 0, the lower the collateral capacity of the lending to the firm in the intermediate period 1. Note that, when $i_D = i_B$, the maximum amount of funding that bank j may obtain when issuing bonds is not dependent on the per-period interest rate paid by the bonds, i_B, but by the collateral capacity ratio of the loan to the firm, $\tau(T_j)$.

In addition, we assume that the maximum amount that bank j may obtain by issuing bonds and handing them over to bank k in the intermediate period 1 is also determined by the prospects that bank j will be bailed out or recapitalized by its owner in the final period T_j if it does not have enough liquid funds to pay back the issued bonds in full.[12] The default on the bank bonds could happen if, for example, the firm partially or totally defaulted on the granted bank loan. Thus, the prospects of a recapitalization affect the collateral value of the bank bonds (i.e., the maximum amount that banks may obtain through issuing bonds). We refer to this contribution to the total collateral value of the bank bonds as the collateral value of the bank bonds given by the prospects of a recapitalization, B_j^C. Although we do not discuss the exact form of the bailout or recapitalization, besides arguing that the recapitalization of the bank implies the availability of new liquid assets in period T_j that may be used to pay back the issued bonds, several papers have discussed the best way to carry out bank recapitalizations, such as Beccalli and Frantz (2016), Brei et al. (2013), and Enoch et al. (2001). Moreover, Beccalli and Frantz (2016) and Berger and Bouwman (2013), among others, have discussed the possible reasons for a bailout or recapitalization.

Specifically, the collateral value given by the prospects of a recapitalization B_j^C depends on the bank owners' financial capacity and availability of funds or assets in the final period T_j. Furthermore, even if bank j is fully willing to pay back the bonds, bondholders can be certain of being repaid only if there is a credible commitment from the bank's owners to recapitalize the bank in case there are not enough funds to pay back the bonds in the final period T_j. Thus, the collateral value given by the prospects of a recapitalization B_j^C also depends on the bank's owners' willingness to recapitalize bank j in the final period T_j.[13] We then assume that the collateral value given by the prospects of a recapitalization is $B_j^C = \omega_j \cdot C_j$, where ω_j captures the recapitalization willingness of the owner of bank j in the final period T_j, and C_j is the recapitalization capacity of the owner of bank j in the final period T_j. Furthermore, we assume that $0 \leq \omega_j \leq 1$, implying that the collateral value given by the prospects of a recapitalization B_j^C adopts values between 0 and a maximum value of C_j, the maximum recapitalization capacity for bank j in the final period T_j.

To conclude, the collateral value of the bonds issued by bank j in the intermediate period 1, B_j (i.e., the maximum amount that bank j may obtain by issuing bonds) is equal to the sum of the collateral value given by the collateral capacity of the bank loan to the firm B_j^L and the collateral value given by the prospects of a recapitalization B_j^C (i.e., $B_j = B_j^L + B_j^C$). Note that the fundamental value of the bonds issued by a bank is related to the present value of the bonds' future interest payments, which is a function of the coupon rate (in this paper $i_B(T_j)$), and of the bonds' value upon maturity, also known as its face value or par value (in this paper B_j or $D - A_j$). However, because we follow the above-mentioned literature on the importance of collateral, the maximum amount that the bank may obtain by issuing bonds is not given by the fundamental value of these bonds but by the collateral value of these bonds. This is so because the fundamental value is related to the promise of what you will get if that promise is honored, whereas the collateral value is what you can be certain to get back in the future. Thus, we have the following:

$$B_j = \left(1-\gamma \cdot T_j^2 \cdot V(R)\right) \cdot D + \omega_j \cdot C_j. \tag{1}$$

From equation 1, it is clear that the longer the maturity of the loans to firms T_j, the lower the collateral capacity of these loans, and the lower the collateral value of the bonds that bank j issues B_j. In addition, the higher the recapitalization willingness of the owner of bank j in the final period T_j ω_j and the higher the recapitalization capacity of the owner of bank j in the final period $T_j C_j$, the higher the collateral value of the bonds that bank j issues B_j. Thus, we have the following lemma:

Lemma 1. B_j is decreasing in T_j and increasing in ω_j and C_j.

Then, in the case of a net outflow of deposits from bank j, and taking into account the collateral value of the bonds that bank j can issue in the intermediate period 1 and the liquid assets A_j that it has available in the intermediate period 1, the survival constraint in the intermediate period 1 requires that $D \le \left(1-\gamma \cdot T_j^2 \cdot V(R)\right) \cdot D + \omega_j \cdot C_j + A_j$. Regarding the liquid assets A_j, these can be thought of as bank deposits in another bank, central bank deposits, or, more generally, any real or financial assets whose return is non-stochastic, which implies that their return has a zero variance and, thus, a collateral capacity ratio of 1.[14]

Finally, in the case of a net inflow of deposits to bank j from bank k, the quantity of inflows D, the maturity of the direct lending by bank k, T_k, and the liquid asset holdings of bank k, A_k are given. Furthermore, assuming that bank j grants the interbank loan to bank k in the intermediate period 1, bank j is receiving a per-period interest income of $(T_k - 1) \times i_B \times (D - A_k)$.

With this setup, we can now analyze the optimal behavior of bank j when it must decide the optimal maturity of its lending to the firm in the initial period 0 T_j^*. We assume that the expected utility of banks depends on the mean of the portfolio return given by $E(U) = E(R_P)$, where R_P is the return of the portfolio. Then the banks' maximization problem, analyzed as the maximization of the per-period return, is as follows:

$$
\begin{aligned}
&\max_{T_j}\ \alpha \cdot \left(T_j \cdot i_L \cdot D - \frac{(T_j-1)}{T_j} \cdot (T_j-1) \cdot i_B \cdot (D-A_j)\right) + \beta \cdot (T_j \cdot i_L \cdot D \\
&\quad + \frac{(T_k-1)}{T_k} \cdot (T_k-1) \cdot i_B \cdot (D-A_k)) + (1-\alpha-\beta) \cdot T_j \cdot i_L \cdot D \\
&s.t. \\
&D \le \left(1-\gamma \cdot T_j^2 \cdot V(R)\right) \cdot D + \omega_j \cdot C_j + A_j,
\end{aligned}
\tag{2}
$$

where the first term is the expected per-period return when there is a net outflow of bank deposits in the intermediate period 1, the second term is the expected per-period return when there is a net inflow of bank deposits in the intermediate period 1, and the third term is the expected per-period return when there is no net payment between the banks in the intermediate period 1. Note that we introduce the fractions $\frac{(T_j-1)}{T_j}$ and $\frac{(T_k-1)}{T_k}$ to capture the fact that these interbank loans accrue interest between periods 1 to T_j or T_k, which imply one period less than the lending to the firm, which spans periods 0 and T_j or T_k. Finally, $D \le \left(1-\gamma \cdot T_j^2 \cdot V(R)\right) \cdot D + \omega_j \cdot C_j + A_j$ is the survival constraint.

The maximization problem from equation 2 implies that the optimal maturity of lending by bank j to the firm T_j^* is infinite if the survival constraint is not binding. The reason is that the partial derivative of the objective function from equation 2 is always positive under a reasonable assumption about the relationship between i_L and i_B. Denote $U(T_j)$ as the objective function of equation 2; thus $\frac{\partial U(T_j)}{\partial T_j} = i_L \cdot D - \alpha \cdot i_B \cdot (D - A_j) \cdot \left(1 - \frac{1}{T_j^2}\right) > 0$ as long as $\frac{i_L}{i_B} > \alpha \cdot \left(1 - \frac{A_j}{D}\right)$ given that $T_j \ge 1$. Actually, the requirement $\frac{i_L}{i_B} > \alpha \cdot \left(1 - \frac{A_j}{D}\right)$ is weak and easily satisfied: first, if $i_L \ge i_B$, then the condition is always satisfied; second, when $i_L < i_B$, given that $0 < \alpha < 1$, $0 < \frac{A_j}{D} < 1$, it is still fine as long as i_L is not too much smaller than i_B.[15] Thus, under the reasonable assumption that the absolute difference between i_L and i_B is not too absurdly large, the optimal T_j^* is infinite if the payment or survival constraint is not binding.

However, if the survival constraint is binding and we assume that banks always want to be able to settle payments in the case of a net outflow of deposits in the intermediate period 1, the optimal maturity of lending by bank j to the firm T_j^* is determined by $D = \left(1-\gamma \cdot T_j^{*2} \cdot V(R)\right) \cdot D + \omega_j \cdot C_j + A_j$. This means that bank j will choose the maturity of its loans to the firm in the initial period 0 so that the collateral value of its bonds in the intermediate period 1 is high enough for bank j to use them, in conjunction with its liquid assets A_j, to settle net payment of D with bank k. Note that bank j must take into account this trade-off between the maturity of the lending to the firm and the collateral value of the bonds that it issues. Then, the maximum maturity of the lending to the firm by bank j in the initial period 0, T_j^*, is

$$T_j^* = \frac{\sqrt{\gamma \cdot V(R) \cdot D \cdot (\omega_j \cdot C_j + A_j)}}{\gamma \cdot V(R) \cdot D}. \tag{3}$$

From Equation (3), we have the following proposition:

Proposition 1. The maximum maturity of the lending to the firm by bank j in the initial period 0, T_j^*, is: (a) negatively related to $V(R)$; (b) negatively related to γ; (c) positively related to C_j; (d) positively related to ω_j; (e) positively related to A_j; and (f) negatively related to D.

From Proposition 1, we have the following results, ceteris paribus:

1. From points (a) and (b) of the proposition, a higher variance of the per-period rate of return of a real investment project of maturity 1 (i.e., an increase in the riskiness of the project), $V(R)$, or a higher γ, implies a lower collateral capacity ratio of the bank lending to the firm and a lower collateral value of the bank loan to the firm. This means that bank j will obtain fewer funds from the bond issuance in the intermediate period 1, B_j^L; thus, the maturity of the lending in the initial period 0 is shortened. Note that these results imply that firms and projects that are riskier than others, because of firm characteristics, will obtain shorter term loans from banks. This conclusion is in line with the conclusions of Barclay and Smith (1995) and Graham and Leary (2011), among others;
2. From points (c) and (d) of the proposition, a higher recapitalization capacity of the owner of bank j, C_j, and a higher recapitalization willingness by the owner of bank j, ω_j, imply a higher collateral value of the bonds that bank j issues because there are higher prospects for a recapitalization in the intermediate period 1, B_j^C; thus, the maturity of the lending in the period 0 is lengthened;
3. From point (e) of the proposition, larger holdings of liquid assets by bank j in the intermediate period 1, A_j, imply that there are more liquid assets to settle payments in the case of a net outflow of deposits in the intermediate period 1; thus, the maturity of the lending in the period 0 is lengthened; and.
4. From point (f) of the proposition, a lower amount of bank lending to the firm in the initial period 0, D, implies that fewer funds are needed to settle payments in the intermediate period 1 in the case of a net outflow of deposits; thus, the maturity of the bank loan in period 0 is lengthened.

In the case of the optimal per-period interest rates $i_L^*(T_j)$ and $i_B^*(T_j)$, these are endogenously determined and given by the following:

$$i_L^*(T_j) = T_j^* \cdot i_L, \tag{4}$$

$$i_B^*(T_j) = \left(T_j^* - 1\right) \cdot i_B., \tag{5}$$

Clearly, the per-period interest rates in equations 4 and 5 are endogenously determined by the optimal value of T_j^* and subject to the same explanatory variables and relations from Proposition 1.

2.2 | Model with an NDB

In this subsection, we introduce an NDB that is wholly owned by the government or the state. We assume that the NDB finances its lending to the firms by issuing NDB bonds and selling them to commercial banks to obtain bank deposits at the PCBs. Then, the NDB uses those bank deposits at the PCBs to lend them out to the firms.[16][17] Next, we compare the optimal determination of the maturity of loans to the firms for this banking system with an NDB and PCBs with the alternative banking system with only PCBs that was analyzed in subsection 2.1.

Concretely, we assume that PCB j invests in NDB bonds in the initial period 0 by creating bank deposits D, which are used to pay the NDB (see line 1 of Table 2). With these bank deposits, the NDB grants lending D to the firm in the initial period 0 and transfers its deposits D in PCB j to the firm's account in PCB j (see line 2 of Table 2). In the intermediate period 1, if there is a net outflow of deposits D from PCB j, requiring a net payment D from PCB j to PCB k, PCB j may settle its payments to PCB k by selling its NDB bonds rather than obtaining an interbank loan or issuing its own bonds to bank k, as in subsection 2.1, and using its own liquid assets available in the intermediate period 1 A_j (see lines 3 and 4 of Table 2). Then, the binding survival constraint in the intermediate period 1 for PCB j, analyzed in the last subsection 2.1, is $D \leq B_{NDB} + A_j$.

In the intermediate period 1, the collateral value of the NDB bonds B_{NDB} is determined by the collateral value given by the collateral capacity of the NDB's loan to the firm $B^L_{NDB} = \left(1-\gamma \cdot T^2_{NDB} \cdot V(R)\right) \cdot D$, which is negatively related to the maturity of this lending to the firm, just as in subsection 2.1. Further, it is also determined by the collateral value given by the prospects of a recapitalization B^C_{NDB}, dependent on both the willingness to recapitalize the NDB ω_{NDB} and the recapitalization capacity of the government (the owner of the NDB) in the final period T_{NDB}, C_{NDB}, as analyzed in subsection 2.1. In addition, the collateral value of the NDB bonds is also determined by the NDB's liquid asset holdings $B^A_{NDB} = A_{NDB}$. These liquid asset holdings of the NDB serve as collateral to the NDB bonds, meaning that these liquid assets guarantee the repayment of the NDB bonds once they mature and thus increase the collateral value of the NDB bonds. Here we assume that the collateral capacity ratio of these liquid assets is 1 and thus increases the collateral value of the NDB bonds by A_{NDB}. Recall that we assumed that PCBs use their liquid assets to directly settle payments with other PCBs, but we could also have assumed that PCBs used those liquid assets as collateral to increase the collateral value of their bonds. Thus, the collateral value of the NDB bonds in the intermediate period 1, B_{NDB}, is as follows:

$$B_{NDB} = \left(1-\gamma \cdot T^2_{NDB} \cdot V(R)\right) \cdot D + \omega_{NDB} \cdot C_{NDB} + A_{NDB}. \tag{6}$$

From Equation (6), it is clear that, the longer the maturity of the loans to firms T_{NDB}, the lower the collateral capacity of these loans, and the lower the collateral value of the bonds that the NDB issues B_{NDB}. In addition, the higher the recapitalization willingness of the government in the final period T_{NDB} ω_{NDB} and the higher the recapitalization capacity of the government in the final period T_{NDB} C_{NDB}, the higher the collateral value of the bonds that the NDB issues B_{NDB}. Thus, we have the following lemma:

Lemma 2. B_{NDB} is decreasing in T_{NDB} and increasing in ω_{NDB} and C_{NDB}.

In the initial period 0, when the NDB issues its NDB bonds and must decide the maturity of its loans to the firm, the NDB must take into account the collateral value of the NDB bonds in the intermediate period 1 from Equation (6) and the payment or survival constraint of PCB j in the intermediate period 1 $D \leq B_{NDB} + A_j$. Note that, although it is the NDB that lends to the firm, and not PCB j directly, because it is PCB j that creates bank deposits to finance the NDB in the initial period 0, it is still the case that PCB j faces liquidity risks when buying NDB bonds because bank deposits from PCB j may be transferred in the intermediate period 1 to PCB k, as analyzed in subsection 2.1. Thus, in the initial period 0, the optimal maturity of lending by the NDB to the firm is determined by

TABLE 2 Solving the liquidity problems and the interbank payments by selling NDB bonds.

	NDB		Bank 1		Bank 2		Firm 1		Firm 2	
T	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
0									$+Goods_{firm2}$	
1 Bank 1 buys NDB bonds	$+Deposit^{NDB}_{bank1}$	$+Bonds_{NDB}$	$+Bonds_{NDB}$	$+Deposit^{NDB}_{bank1}$						
2 NDB Loan to Firm 1	$+Loan^{firm1}_{NDB}$ $-Deposit^{NDB}_{bank1}$			$-Deposit^{NDB}_{bank1}$ $+Deposit^{firm1}_{bank1}$			$+Deposit^{firm1}_{bank1}$	$+Loan^{firm1}_{NDB}$		
3 Bank 1 sells NDB bonds to Bank 2			$-Bonds_{NDB}$ $+Deposit^{bank1}_{bank2}$		$+Bonds_{NDB}$	$+Deposit^{bank1}_{bank2}$				
4 Firm 1 pays Firm 2 (with bank account in Bank 2)			$-Deposit^{bank1}_{bank2}$	$-Deposit^{bank1}_{firm1}$		$-Deposit^{bank1}_{bank2}$ $+Deposit^{firm1}_{bank2}$	$-Deposit^{firm1}_{bank1}$ $+Goods^{firm2}$		$+Deposit^{firm2}_{bank2}$ $-Goods_{firm2}$	
Final	$Loan^{firm1}_{NDB}$	$Bonds_{NDB}$			$Bonds_{NDB}$	$Deposit^{firm2}_{bank2}$	$Goods_{firm2}$	$Loan^{firm1}_{bank1}$	$Deposit^{firm2}_{bank2}$	

$D=\left(1-\gamma\cdot T_{NDB}^{*2}\cdot V(R)\right)\cdot D+\omega_{NDB}\cdot C_{NDB}+A_{NDB}+A_j$, meaning that the NDB will choose the maturity of its loans to the firm in the initial period 0 so that the collateral value of the NDB bonds in the intermediate period 1 is high enough for PCB j to be able to use them, in conjunction with its liquid assets A_j, to settle a net payment of D with PCB k. Note that the NDB must take into account this trade-off between the maturity of the lending to the firm and the value of the bonds that it issues.[18] Then, the maximum maturity of the lending to the firm by the NDB in the initial period 0, T_{NDB}^*, is as follows:

$$T_{NDB}^*=\frac{\sqrt{\gamma\cdot V(R)\cdot D\cdot\left(\omega_{NDB}\cdot C_{NDB}+A_{NDB}+A_j\right)}}{\gamma\cdot V(R)\cdot D}. \tag{7}$$

Note that in Equation (7) we not only have the liquid assets of the NDB, A_{NDB}, but also the liquid assets of the PCB j, A_j, because A_{NDB} is used as collateral for the bond issuance, as discussed above, and A_j is used by PCB j to directly settle its payment with PCB k in the intermediate period 1, if needed. Thus, if we compare T_{NDB}^* from Equation (7) with T_j^* from Equation (3), as long as $A_{NDB}>0$, it is clear that $T_{NDB}^*>T_j^*$, meaning that the NDB will provide longer-term loans to the firm than the PCB would. However, this is not an advantage per se of the banking systems with an NDB and PCBs over the alternative banking system with only PCBs but rather the consequence of more liquid assets in the system. If the NDB had no liquid assets, then it would no longer necessarily be true that $T_{NDB}^*>T_j^*$.

From Equation (7), we have the following proposition:

Proposition 2. The maximum maturity of the lending to the firm by the NDB in the initial period 0, T_{NDB}^*, depends on the same factors as in the case of the PCB j, T_j^*, from Proposition 1.

We now compare the maximum maturity of lending to the firm by the NDB, T_{NDB}^*, with that by the PCB j, T_j^*. If the recapitalization capacity of the bank owner C and the willingness to recapitalize the bank by its owner ω are higher for the owner of the NDB than for the private bank owners, implying that $C_{NDB}>C_j$ and $\omega_{NDB}>\omega_j$, then the maximum maturity that the NDB may choose for its lending to the firm in the initial period 0, T_{NDB}^*, is longer term than the maximum maturity that the CB j may choose for its lending to the firm in the initial period 0, T_j^*. Note that this result holds even when $A_{NDB}=0$. Thus, the higher recapitalization capacity and the willingness to recapitalize the NDB by its owner–in comparison with the private bank owners–imply a real advantage of banking systems with an NDB and PCBs over the alternative banking system with only PCBs, analyzed in subsection 2.1. This result is our key explanation for the maturity-lengthening role of NDBs.

Corollary 1. *If* $C_{NDB}>C_j$ *and* $\omega_{NDB}>\omega_j$, *then, from Equations (3) and (7), we have* $T_{NDB}^*>T_j^*$.

To clarify the results above, in Figure 2, we compare the collateral value of the bonds issued by the NDB, B_{NDB}, from Equation (6), with the collateral value of the bonds issued by PCB j, B_j, from Equation (1), representing the maturity of the lending to the firm in the horizontal axis. Note that we assume that the NDB has no liquid assets ($A_{NDB}=0$) to compare two banking systems that have the same total amount of liquid assets. In Figure 2, whereas point X, which represents the case of the PCB, implies the same collateral value (the vertical axis) as point Y, which represents the case of the NDB, point Y implies a longer maturity of the lending to the firm (the horizontal axis) than point X. This longer maturity of the lending to the firm by the NDB in comparison with the PCB j is the result of its higher collateral value given by the prospects of a recapitalization than that of the PCB j.

In addition, given a certain maturity of the lending to the firms by either the PCB j or the NDB, the collateral value of the bonds issued by the NDB is greater than the collateral value of the bonds issued by the PCB j. This result is depicted in Figure 2 by comparing point X (PCB j) and point Z (NDB). This result implies that, given a certain maturity of the lending to the firms, PCB j is better able to cope with interbank payments when holding NDB bonds than

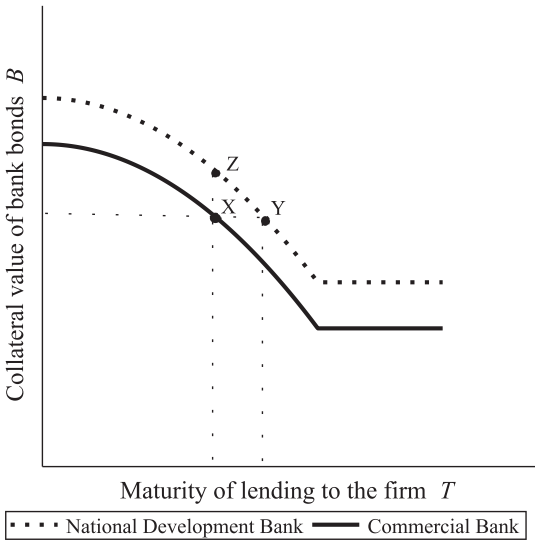

FIGURE 2 Collateral value of bank bonds and maturity of lending to the firm.

when issuing its own bonds. Note, finally, that for both the NDB and PCB *j*, for low values of the maturity of the lending to the firm, there is initially a negative relationship between the collateral value of the bank bonds and the maturity of the lending to the firm, but at high values of the maturity of the lending to the firm, the relationship is horizontal. This horizontal relationship occurs when the collateral value given by the collateral capacity of the bank loan to the firm is zero and the full collateral value of the bank bonds is determined by the collateral value given by the prospects of a recapitalization by the owner of the bank.

The justification for the higher recapitalization capacity of the owner of the NDB (the government) in comparison with that of the owners of the PCBs, following the arguments by Brei and Schclarek (2015, 2018), Gorton and Huang (2004), and Holmstrom and Tirole (1998), among others, is that the government has access to more liquid assets in the final period *T* than the private bank owners. This is because the government may not only have more existing liquid assets in the final period *T* but can also get additional liquid assets by taxing different agents, especially successful investment projects and banks granting loans for the funding of such projects. Instead, the private owners may also have existing liquid assets in the final period *T* with which to recapitalize their banks, but they cannot tax other agents to get additional liquid assets. Note that this argument hinges not only on the size of the government in comparison with the private bank owners, in terms of owning liquid assets, but also fundamentally on the ability to raise taxes given by the legal power of the state. In addition, related to the taxation argument, the government may find it easier and cheaper than private bank owners to access additional capital by borrowing from national or international financial markets. Note, however, that this argument about the higher recapitalization capacity of the government hinges on the assumption that the fiscal stance of the government is strong and sustainable. If the government is in an unsustainable fiscal situation, maybe owing to poor governance, political corruption, or populist policies, the recapitalization capacity of the government will be low, consequently diminishing the advantage of the NDBs. Thus, it is key that the government has a strong and sustainable fiscal stance for a successful recapitalization.

Regarding the willingness to recapitalize, it is likely that the government is more willing to recapitalize the NDB than private bank owners are to recapitalize their PCBs.[19] Given that bank failures may have externalities by affecting other banks through contagion and the economy as a whole, affecting social welfare, the government has more to lose than private owners. Whereas the private bank owners lose only their own capital in the failing banks, the government may, among other consequences, have to increase unemployment benefits, obtain lower tax revenues, lose elections because of voters' dissatisfaction, or be unable to foster more innovative and strategic sectors that require long-term financing. Furthermore, the government may be more eager to recapitalize the NDB to foster and preserve state capacities, such as in-house financial and industrial expertise, that would be lost in case of default and the closure of the NDB (Fernández-Arias et al., 2020).

Moreover, this greater willingness of the government to recapitalize banks is evident when considering that, in many instances, the government has even been willing to bail out private banks to avoid their closure. In the literature, that analyzes bailouts of the private banking system, see, among others, Beccalli and Frantz (2016), Brei et al. (2013), Diamond and Rajan (2005), and Gorton and Huang (2004). Note, however, that these government bailouts of private banks are usually carried out not to save private bank owners, creditors, or bondholders but rather to avoid deposit runs and save small deposit holders. Thus, even if the government bails out private banks, it should be expected that private bank owners, creditors, and bondholders will suffer some losses, even if the private banks are eventually recapitalized. This will undermine the collateral value of private bank bonds, given the probable losses of bondholders. Consequently, even if the government's willingness to bail out private banks, especially big, systemically important, and interconnected private banks, is high, it is not unreasonable to expect that the willingness to bail out a government-owned bank is likely to be higher. Note also that, although it goes beyond the scope of this paper, if for some reason agents have difficulty in correctly evaluating the recapitalization capacity and willingness of the government and the private bank owners, the government may try to correct this imperfect-information problem through banking regulations, such as NDB bonds enjoying zero-risk weighting in their valuation.

Finally, note that, if the government issues its own bonds to PCBs which have a higher collateral value than NDB bonds because of a higher recapitalization willingness, a superior result, in terms of the maturity of lending to the firms other than those in the case analyzed above, may be achieved. In this case, it may be better if the government issues its bonds to PCBs and uses those bank deposits to recapitalize the NDB so the NDB can, in turn, lend to the firms. However, a possible argument in favor of the NDB financing its lending to firms through issuing its own bonds, rather than the government's recapitalization, even when government bonds have a higher collateral value than NDB bonds, is that NDB bonds do not increase the government debt burden, and that the government does not experience fiscal constraints. Furthermore, the financing of NDB lending through NDB bonds may even exert some market discipline on the management of the NDB because, if their lending decisions are not good enough (lending to bad firms or projects), this would be reflected in the collateral value of NDB bonds.

3 | ENDOGENIZING THE AMOUNT OF LENDING TO THE FIRM

In this section, we analyze both the optimal determination of the maturity of the lending to the firm T and the amount of the lending to the firm D (i.e., we are endogenizing the determination of both variables). Recall that, in Section 2, we had assumed that the amount of lending to the firm was fixed and given and analyzed only the optimal determination of the maturity of the loan to the firm.

As in Section 2, banks maximize the per-period return given by Equation (2), but now both D and T are variables that have to be optimally determined. Further, given the constraints discussed in Section 2, Equation (3) is binding, which implies that we can substitute T_j in Equation (2) to obtain the following equation to maximize with respect to D:

$$\max_D \ \alpha \cdot \left(T_j(D) \cdot i_L \cdot D - \frac{(T_j(D)-1)^2}{T_j(D)} \cdot i_B \cdot (D - A_j) \right) + \beta \cdot \left(T_j(D) \cdot i_L \cdot D + \frac{(T_k-1)^2}{T_k} \cdot i_B \cdot (D_k - A_k) \right) + (1-\alpha-\beta) \cdot T_j(D) \cdot i_L \cdot D, \tag{8}$$

where $T_j(D) \equiv \frac{\sqrt{\gamma \cdot V(R) \cdot D \cdot (\omega_j \cdot C_j + A_j)}}{\gamma \cdot V(R) \cdot D}$. Then, the first-order condition with respect to D of the above program 8 can be written as:

$$2\cdot\alpha\cdot i_B - \frac{3\cdot\alpha\cdot i_B}{2\cdot X}\cdot D^{*\frac{1}{2}} + \frac{1}{2}\cdot\left(X\cdot(i_L-\alpha\cdot i_B) - \frac{\alpha\cdot i_B\cdot A_j}{X}\right)\cdot D^{*-\frac{1}{2}}$$
$$-\frac{1}{2}\cdot\alpha\cdot i_B\cdot A_j\cdot X\cdot D^{*-\frac{3}{2}} = 0, \tag{9}$$

where $X \equiv \sqrt{\frac{\omega_j\cdot C_j + A_j}{\gamma\cdot V(R)}}$. It is evident that the above equation 9 is a high-order polynomial equation, which has no analytical solutions for the maximum amount of the lending to the firm by bank j in the initial period 0, D^*. So we have done numerical simulations and come up with the following Figures 3 and 4 to represent the relationships between the endogenized T_j^* and D^* with respect to the recapitalization capacity and willingness of bank j, $\omega_j \times C_j$.[20]

Specifically, in Figure 3, we present the graphical representation of the two roots of Equation (9) having the maximum amount of lending to the firm, D^*, as the dependent variable, and the recapitalization capacity and willingness of bank j, $\omega_j \times C_j$, as the independent variable. For both roots there is a positive relationship between these two variables, meaning that the higher the recapitalization capacity and willingness of bank j, $\omega_j \times C_j$, the higher the maximum amount of lending to the firm, D^*. These results imply that the NDB, which has a higher recapitalization capacity and willingness than the PCB, will optimally choose a larger amount of lending to firms than PCBs.

From Figure 3, we have the following proposition:

Proposition 3. The maximum amount of the lending to the firm by bank j in the initial period 0, D^*, is positively related to C_j and ω_j.

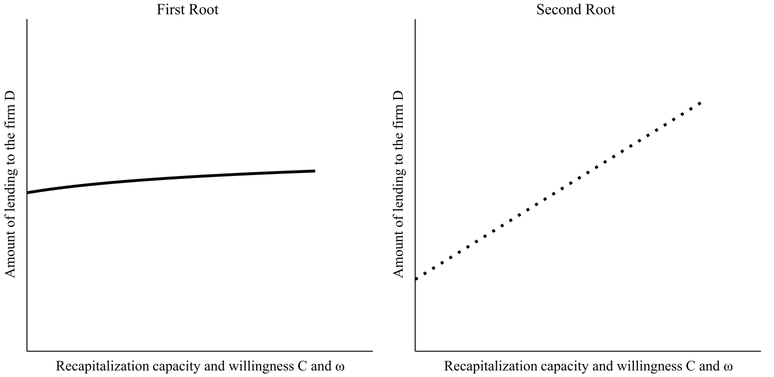

FIGURE 3 Amount of lending to the firm and recapitalization capacity and willingness.

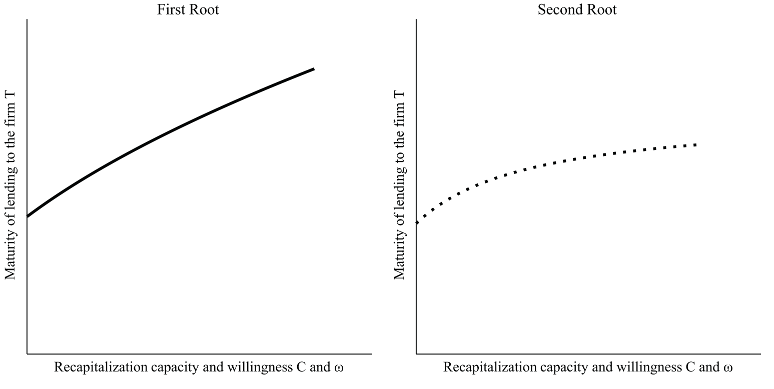

FIGURE 4 Maturity of lending to the firm and recapitalization capacity and willingness.

The maturity of the lending to the firm in the initial period 0, T_j^*, is obtained by combining Equations (9) and (3). Thus, we have that the maximum maturity of the lending to the firm by bank *j* in the initial period 0, T_j^*, is as follows:

$$T_j^* = \frac{\sqrt{\gamma \cdot V(R) \cdot D^* \cdot (\omega_j \cdot C_j + A_j)}}{\gamma \cdot V(R) \cdot D^*}. \tag{10}$$

In Figure 4, we present the graphical representation of the two roots of Equation (10) having the maximum maturity of lending to the firm, T_j^*, as the dependent variable, and the recapitalization capacity and willingness of bank *j*, $\omega_j \times C_j$, as the independent variable. For both roots there is a positive relationship between these two variables, meaning that the higher the recapitalization capacity and willingness of bank *j*, $\omega_j \times C_j$, the higher the maximum maturity of lending to the firm, D^*.

From Figure 4, we have the following proposition:

Proposition 4. The maximum maturity of the lending to the firm by bank *j* in the initial period 0, T_j^*, is positively related to C_j and ω_j.

These results from Proposition 4 imply that, given a certain amount of lending to the firm, the NDB, which has a higher recapitalization capacity and willingness than the PCB, will optimally choose a longer maturity of lending to the firms than PCBs. However, when taking into account the results of both Propositions 3 and 4, it is clear that the NDB will optimally choose a higher amount of lending to the firm than the PCB. Yet, given this higher amount, it is possible, depending on the specific values of the different parameters of Equations (9) and (10), that the maturity of the lending is lower for the NDB than the PCB because there is a negative relationship between the maximum amount of lending D^* and the maximum maturity of lending T_j^* from Equation (10). However, it is worth noting that it is still possible, depending on the specific values of the different parameters of Equations (9) and (10), that the NDB provides both a larger amount and a longer maturity of lending to firms than the PCBs. This possibility is higher, if the NDB enjoys the larger recapitalization capacity and willingness than the PCB does. The reason is that a higher recapitalization capacity and willingness helps mitigate the negative effect of the higher amount of lending on the maturity of bank lending, given by Equation (10).

Corollary 2. *If $C_{NDB} > C_j$ and $\omega_{NDB} > \omega_j$, then, from Equation (9), we have that $D_{NDB}^* > D_j^*$. Further, from Equation (10), we have that T_{NDB}^* may be greater or less than T_j^*, depending on the specific values of the parameters in Equation (10). The higher the values of C_{NDB} and ω_{NDB} in comparison to C_j and ω_j, respectively, the higher the chances that both $D_{NDB}^* > D_j^*$ and $T_{NDB}^* > T_j^*$.*

Clearly, the results of this section reinforce the conclusions from Section 2, namely that, given a certain amount of lending to the firm, the NDB will optimally choose a longer maturity of lending to the firms than PCBs. Therefore, given that the objective of this paper is to compare the maturity of the lending to firms by the NDB and the PCBs and that the analysis is simpler when taking the amount of lending as given and equal for both the NDB and the PCBs, in the rest of the paper we take the amount of lending as given and equal, as in Section 2, instead of endogenizing both the amount and the maturity of the lending to the firm, as in this section.

4 | MONITORING QUALITY AND THE MATURITY OF BANK LENDING

In this section, following the literature on bank monitoring, which includes, among others, Cetorelli and Peretto (2012), Diamond (1984), Eslava and Freixas (2021), and Holmstrom and Tirole (1997), we relax the assumption in the model of Section 2 that each bank has identical monitoring skills. Note that the monitoring skills include skills such as evaluating projects, screening borrowers, and collecting repayments. As will be clarified below, the monitoring skills, which determine the monitoring quality of the banks, affect the collateral value of the bonds issued by those banks and thus affect the maturity of the lending to firms by those banks. Through this mechanism, and if we assume that the monitoring quality of state-owned banks is lower than that of private-owned banks, we add a new channel through which the advantages of state-owned banks, presented in Section 2, are reduced and those of private-owned banks are increased. In this sense, the double-edged sword of state ownership is highlighted here.[21]

Specifically, we now assume that the variance of the per-period net rate of return for an investment project, $T^2 \times V(R)$, is not known with certainty. Thus, banks must assess the true or correct variance of the per-period net rate of return for an investment project. We assume that the idiosyncratic monitoring quality of banks affects their evaluation and discovery of the true variance of the per-period net rate of return for an investment project. Further, we assume that only the bank that is actively involved in the lending to the investment project is able to assess directly the true variance of the investment project. The other banks, which are not actively involved in the lending to the investment project but may later lend to or buy bonds from the active bank, will assess indirectly the true variance of the investment project of the active bank. They will consider the estimation of the true variance of the investment project by the active bank but will also take into consideration the active bank's monitoring skills and quality, which we assume are known by all.[22] Therefore, when a certain bank j estimates that the variance of the per-period net rate of return for an investment project is $T_j^2 \cdot V(R)$, other banks will infer that the true variance of the investment project is $T_j^2 \cdot V(R) \cdot q_j$, where $q_j \geq 1$ is a measure of the monitoring quality of bank j and where the greater value for q_j corresponds to lower monitoring quality. Thus, the lower the monitoring quality of bank j (i.e., the greater the value of q_j), the larger the true variance inferred by the other banks. Note that following this reasoning, the analysis in the last section can be interpreted as a case where bank j is perfect at monitoring ($q_j = 1$), and thus the other banks will be certain that the variance estimated and informed by bank j is the true one.

Taking into account the idiosyncratic monitoring quality of banks, the collateral value of the bonds issued by bank j with monitoring quality q_j in the intermediate period 1, $B_j(q_j)$, is as follows:

$$B_j(q_j) = \left(1 - \gamma \cdot T_j^2 \cdot V(R) \cdot q_j\right) \cdot D + \omega_j \cdot C_j. \tag{11}$$

Thus, given a certain $T_j^2 \cdot V(R)$, banks with better monitoring quality will also be able to issue bonds with higher collateral value. The reason is that the other banks perceive that the collateral value given by the collateral capacity of the bank loan to the firm, $B_j^L(q_j) = \left(1 - \gamma \cdot T_j^2 \cdot V(R) \cdot q_j\right) \cdot D$, has a higher value because of the lower perceived variance of the per-period net rate of return of the investment project, $T_j^2 \cdot V(R) \cdot q_j$.

Now, and following equation 3, the maximum maturity of the lending to the firm by bank j with monitoring quality q_j in the initial period 0, $T_j^*(q_j)$, becomes the following:

$$T_j^*(q_j) = \frac{\sqrt{\gamma \cdot V(R) \cdot q_j \cdot D \cdot (\omega_j \cdot C_j + A_j)}}{\gamma \cdot V(R) \cdot q_j \cdot D}. \tag{12}$$

From Equation (12), we have the following proposition:

Proposition 5. $T^*(q_j)$ is decreasing in q_j.

These results imply that, given a certain collateral value for the bonds issued by the banks, banks with better monitoring quality will be able to lend to firms with longer maturity than banks with lesser monitoring quality. Similarly, given a certain level for the maturity of the lending to the firms, the collateral value of the bonds issued by banks with better monitoring quality is higher than the value of the bonds issued by banks with lesser monitoring quality. In Figure 5, we depict these results by comparing the collateral value of the bonds issued by a bank with high monitoring quality with the collateral value of the bonds issued by a bank with low monitoring quality, representing the maturity of the lending to the firm in the horizontal axis.

We now turn back to the comparison in subsection 2.2 between (a) a banking system in which the NDB grants the loans to the firms financed by PCBs that buy the NDB bonds with (b) a banking system in which the PCBs directly grant the loans to the firms. The analysis of the idiosyncratic monitoring quality may be used to compare the optimal determination of the maturity of the lending to firms by these two types of banks. If we assume that the NDB has a lower monitoring quality than PCBs, meaning that $q_{CB} < q_{NDB}$, this reduces the NDB's advantage over PCBs in terms of the lengthening of the maturity of lending to firms. Recall that, in subsection 2.2, we assumed that the NDB had an advantage over PCBs given by the higher recapitalization capacity and willingness to recapitalize the bank by the government or state over private bank owners (i.e., $C_{NDB} > C_{CB}$ and $\omega_{NDB} > \omega_{CB}$).

Corollary 3. *When monitoring quality is sufficiently low for the NDB, in comparison with the PCBs, the NDB may grant loans of shorter maturity than those of the PCBs, even when* $C_{NDB} > C_{CB}$ *and* $\omega_{NDB} > \omega_{CB}$.

Figure 6 depicts what is expressed in corollary 3 and highlights two subregions where the results are different. In subregion *Z*, although low monitoring quality puts the NDB at a disadvantage, the NDB still benefits from the higher collateral value given by the recapitalization willingness and capacity and thus can still grant loans of longer maturity in comparison with PCBs, given a certain collateral value for the issued bonds. However, in subregion *X*, the PCBs will provide loans of longer maturity than the NDB, given a certain collateral value for the issued bonds, because in this subregion the disadvantage of the NDB resulting from the lower monitoring quality is greater than its advantage of higher recapitalization willingness and capacity.

One possible justification for assuming that the monitoring quality of state-owned banks is lower than that of privately owned banks could be poor governance or political corruption, as argued by LaPorta et al. (2002) and Dinc (2005).[23] The poor governance would negatively affect monitoring skills, such as the evaluation of projects, screening of borrowers, or even collection of repayments by borrowers. This worsening in the monitoring quality would, in turn, increase the variance of the per-period net rate of return of the investment project as perceived by the other

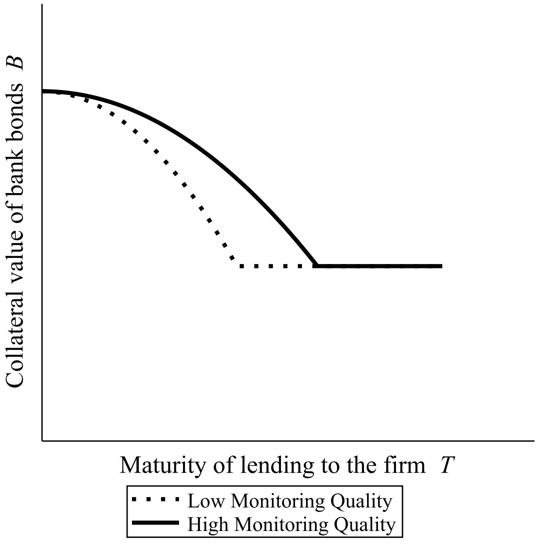

FIGURE 5 Monitoring quality, collateral value of bank bonds, and maturity of lending.

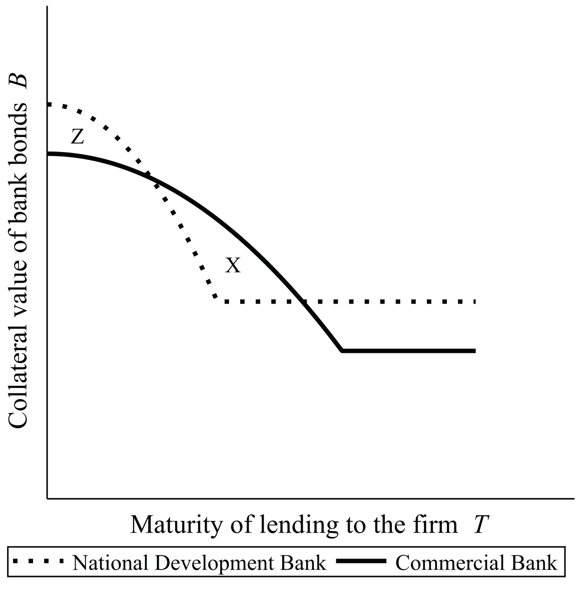

FIGURE 6 NDB with low monitoring quality, collateral value of bank bonds and maturity of lending.

banks that are not actively involved in the lending to the firm but that may eventually buy the bonds issued by the actively involved bank. Note, however, that in this section we are taking the variance of the per-period net rate return of the investment project estimated by the actively involved bank in the lending to the firm as given and equal for all banks that are actively involved in lending to the firms. Thus, the argument in this section is not related to the fact that state-owned banks usually have a mandate to finance high-risk projects, but that the government is worse than the private sector in its monitoring quality, which affects the assessment of the true riskiness of an investment project. Note also that we are not arguing that the state should not steer the corporate strategy of NDBs to ensure that they are development-oriented. Instead, we are arguing that undue political intervention in the bank operation at the micro-level can undermine banks' monitoring skills.[24]

Our conclusion from this analysis is that the quality of monitoring by banks is an important factor that determines banks' maturity-lengthening possibilities. Any improvement in the monitoring quality of a bank will also help the bank in issuing bonds with higher collateral value and thus in being able to lend longer term to firms. Moreover, for NDBs to keep their advantage over PCBs, it is of utmost importance that they improve their monitoring skills, including project evaluation, borrower screening, and repayment collection, and thus achieve high monitoring quality.

5 | MARKET LIQUIDITY OF BONDS AND THE MATURITY OF BANK LENDING

In this section, we relax the assumption in the model of Sections 2 and 4, that the market liquidity of the bonds issued by banks is identical.[25] As we will clarify below, the market liquidity of the bonds issued by banks determines the collateral value of the bonds issued by these banks and thus affects the maturity of the lending to firms by these banks. Through this mechanism, if we assume that the market liquidity of the bonds issued by the NDB is higher than that of commercial banks, we elaborate on a new channel through which the NDB may have an additional advantage over commercial banks. Note also that, through this channel, we are presenting an advantage that the NDB may have over SCBs. In the previous sections, we assumed that the NDB was the only state-owned bank and that all the commercial banks were privately owned. If we had assumed instead the existence of SCBs, and if these SCBs had the same characteristics as the NDB in terms of recapitalization capacity and willingness and monitoring quality, then there would be no advantage in having an NDB when the banking system also has SCBs. However, given the idiosyncratic market liquidity of bonds, we argue for the existence of an NDB, even when there are SCBs in the banking system.

Both the theoretical and empirical literature on market liquidity points out that a bond with lower market liquidity will not only require a higher interest rate at issuance (the coupon rate), but also will be traded at a discount in the secondary market after having been issued (Amihud et al., 2006; Bao et al., 2011; Vayanos & Wang, 2013). Thus, we assume a positive relationship between the market liquidity of bonds and the collateral value of those bonds in the intermediate period 1.[26] Specifically, we assume that the collateral value of the bonds issued by bank j in the intermediate period 1 is a fraction δ_j of the total collateral value given by the collateral capacity of the bank loan and the recapitalization willingness and capacity. The variable δ_j captures the reduction in the collateral value of the bonds of bank j resulting from the level of market liquidity of the bonds of bank j, where $0 \le \delta_j \le 1$. Note that $\delta_j = 1$ means perfect market liquidity and $\delta_j = 0$ means complete market illiquidity. Thus, the collateral value of bonds by bank j with market liquidity δ_j in the intermediate period 1, $B_j(\delta_j)$, is as follows:

$$B_j(\delta_j) = \delta_j\left(\left(1-\gamma\cdot T_j^2\cdot q_j\cdot V(R)\right)\cdot D+\omega_j\cdot C_j\right). \tag{13}$$

Thus, banks that issue bonds with higher market liquidity will also be able to issue bonds with higher collateral value.

Taking into account the idiosyncratic market liquidity of the bonds of bank j, and following equations 3 and 12, the maximum maturity of the lending to the firm by bank j, with market liquidity δ_j, in the initial period 0, $T_j^*(\delta_j)$, becomes the following:

$$T_j^*(\delta_j) = \frac{\sqrt{\delta_j\cdot\gamma\cdot V(R)\cdot q_j\cdot D\cdot\left(\delta_j\cdot\omega_j\cdot C_j-(1-\delta_j)\cdot D+A_j\right)}}{\delta_j\cdot\gamma\cdot V(R)\cdot q_j\cdot D}. \tag{14}$$

From Equation (14), we have the following proposition:

Proposition 6. $T_j^*(\delta_j)$ is increasing in δ_j.

These results imply that, given a certain collateral value for the bonds issued by the banks, the bank with the bonds having higher market liquidity will be able to lend to firms with longer maturity than will the banks with bonds with lower market liquidity. Similarly, given a certain level for the maturity of the lending to the firms, the collateral value of the bonds issued by the banks with bonds with higher market liquidity is higher than the collateral value of the bonds issued by the banks with bonds with lower market liquidity. In Figure 7, we depict these results by comparing the collateral value of the bonds issued by a bank with bonds with high market liquidity with the collateral value of the bonds issued by a bank with bonds with low market liquidity, representing the maturity of the lending to the firm in the horizontal axis.

We now turn back to the comparison in subsection 2.2 between a banking system in which the NDB grants the loans to the firms financed by PCBs that purchase the NDB bonds with a banking system where the PCBs directly grant the loans to the firms, as far as the optimal determination of the maturity of the lending to firms by these two types of banks is concerned. If we assume that the NDB bonds have a higher market liquidity than the bonds issued by PCBs, meaning that $\delta_{NDB} > \delta_{CB}$, then this increases the advantage of the NDB over PCBs in terms of the

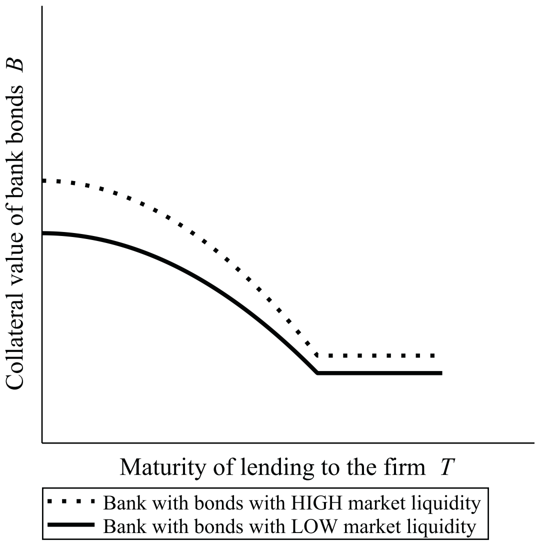

FIGURE 7 Market liquidity of bonds, collateral value of bank bonds, and maturity of lending.

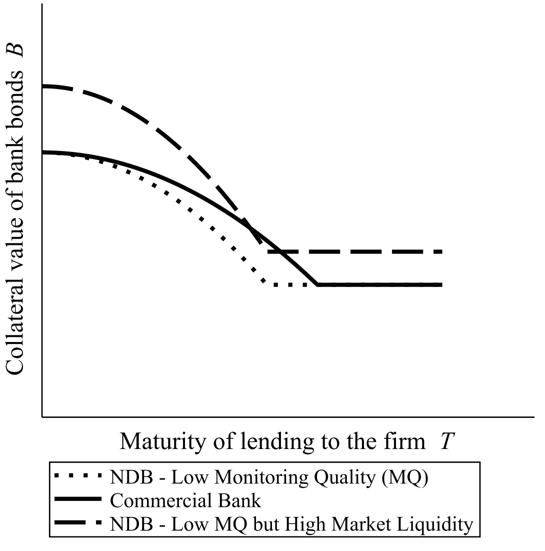

FIGURE 8 NDB with low monitoring quality and high market liquidity of bonds, and maturity of lending.

lengthening of the maturity of lending to the firms. The higher market liquidity of the NDB bonds could offset the disadvantage of having a lower monitoring quality than PCBs analyzed in Section 4.

> **Corollary 4.** *When the market liquidity of the bonds issued by the NDB is sufficiently high, in comparison with the bonds issued by PCBs, the NDB may grant loans of longer maturity than those of the PCBs, even when the NDB has a lower monitoring quality than commercial banks.*

Figure 8 depicts what is expressed in Corollary 4 by comparing situations where the NDB has a lower monitoring quality than the PCBs, which penalizes their ability to lend with longer maturities, but it has a higher market liquidity for its bonds in comparison with the bonds of the PCBs, which gives them an advantage over the PCBs. In that figure, it is clear that an NDB with low monitoring quality, but no advantage over PCBs in terms of the market liquidity of its bonds, would not be able to lend longer term than PCBs. However, an NDB that has a low monitoring quality but a high market liquidity for its bonds, would be able to lend with longer maturities in comparison with PCBs with high monitoring quality but low market liquidity for the bonds. Evidently, the market liquidity of bonds is an important factor that explains the collateral value of bonds and thus influences the maturity of the lending by banks to firms.

Another important proposition that can be made with the introduction of the market liquidity of bonds is to give a rationale for the existence of NDBs, even when the banking system has state-owned commercial banks. Note that, in the last two sections, we assumed that the commercial banks were all privately owned. If we had allowed for the existence of SCBs, and if these banks had had the same characteristics as the NDB, in terms of the recapitalization capacity and willingness to recapitalize the bank by the government or state, as well as the same monitoring quality, then the NDB would have no advantage over the SCBs in terms of the lengthening of the maturity of lending to firms. However, if we now assume that the NDB bonds have a higher market liquidity than the SCB bonds, then our argument favors the existence of NDBs, which finance their lending to firms through issuing bonds to commercial banks, both state and privately owned. In a sense, all these advantages and disadvantages for the different types of banks allow for and justify a complex banking system with a diversity of bank types.

Regarding the possible justifications for assuming that the NDB bonds have a higher market liquidity than the bonds issued by commercial banks, both state-owned and privately owned, we propose several arguments related to the market liquidity literature. Pagano (1989) observed that the volume of trade for an asset is an important factor in explaining the market liquidity for that asset. In this sense, the banking system with an NDB and commercial banks implies that only one type of bond will be issued, the NDB bonds, and that commercial banks will buy that bond. The size of the NDB bond issuance will be systemically large. Instead, the banking system with only commercial banks implies that many different bonds will be issued, one for each commercial bank that issues bonds in the intermediate period 1, and thus no individual bond issuance will be large enough. Thus, the trading volume for NDB bonds is greater than that of any individual CB in the intermediate period 1; therefore, NDB bonds will have a higher market liquidity than commercial bank bonds.[27]

In addition, and also related to the last argument, Vayanos and Wang (2012) argued that agents face costs of market participation (e.g., to monitor market movements and information) to be ready to trade in the secondary bond market. Thus, bonds with lower participation costs will also have higher market liquidity. Now consider the banking system with an NDB that finances its lending by issuing NDB bonds that are bought by commercial banks in the initial period 0. Clearly, all commercial banks must incur the participation costs for the NDB bonds in the initial period 0 to buy them. Therefore, those commercial banks that face a net deposit inflow in the intermediate period 1 and accept NDB bonds to settle payments with the commercial banks that face net deposit outflows are already correctly informed for the trade and do not need to incur additional participation costs in the intermediate period 1.

In contrast, consider the banking system with only commercial banks. In this case, commercial banks are not buying bonds from any commercial bank in the initial period 0 and thus will not have incentives to incur any participation costs in the initial period 0. Only in the intermediate period 1 will the commercial banks that face a net deposit inflow from other commercial banks know which bank bond they will trade in the secondary bond market. This means that these commercial banks will have to face the full market participation costs for these bank bonds in the intermediate period 1. Clearly, NDB bonds have an advantage in terms of lower participation costs over bonds issued by other commercial banks in the intermediate period 1, and thus we may expect that NDB bonds have a higher market liquidity than bonds issued by commercial banks. Hence, ensuring the higher market liquidity of NDB bonds is an important argument in favor of NDBs that follow a business model centered on financing themselves by issuing bonds instead of trying to mimic commercial banks that are in the payment system and are deposit creators and takers.

6 | CONCLUDING REMARKS

In this article, we have theoretically studied the determinants of the maturity of the lending to firms by banks. Our model links the maturity of bank loans to firms with the collateral value of the bonds that banks issue in the interbank market. The collateral value of the bonds issued by banks (i.e., the maximum amount of funding that they can obtain by issuing bonds) is negatively related to the maturity of the bank loans to firms, because long-term loans are often more risky than short-term ones. Furthermore, the collateral value of the bonds also hinges on the recapitalization willingness and capacity of the banks' owners, the market liquidity of the bonds that the banks issue, and the monitoring skills and quality of the banks.

If NDB bonds have higher collateral value than bonds issued by PCBs because of higher recapitalization willingness and capacity, as well as higher market liquidity, NDBs may lend longer term than PCBs, even if PCBs may have higher monitoring skills and quality than NDBs. In our model, NDBs are not substitutes for but complements to PCBs, so the policy discussion is not about PCBs vs. NDBs but rather about a banking system with PCBs only vs. one with PCBs and NDBs. In addition, if the NDB bonds have higher market liquidity than the bonds of commercial banks, NDBs may even have an advantage over SCBs in terms of the maturity of loans to firms, even when SCBs have similar characteristics in terms of the recapitalization willingness and capacity of the state, as well as monitoring skills and quality. These advantages and disadvantages of the different types of banks allow for and justify complex banking systems that have a diversity of bank types.

In terms of policy recommendations, the maturity-lengthening role of NDBs is more feasible if they are well capitalized, have proper liquidity management, and possess adequate amounts of liquid asset holdings. In addition, the maturity-lengthening role of NDBs is more relevant for countries that have governments with stronger credibility, finances, and net worth than countries with governments plagued by credibility concerns, over-indebtedness, and excessive fiscal deficits.

Moreover, it is important that NDBs are well-governed and have high monitoring skills and quality and that the investment projects that obtain loans from NDBs have sufficiently high expected financial or productive returns and sufficiently low risks. Poorly managed NDBs, which do not keep out narrow private and politically vested interests, will probably end up in a fragile financial position with high nonperforming loans and low credibility.

Furthermore, the maturity-lengthening role of NDBs is enhanced by the market liquidity of their bonds if NDBs are larger in terms of their relative bond issuance size in the banking system, which improves their bond market liquidity. Ensuring the higher market liquidity of NDB bonds is an important argument in favor of NDBs that follow a business model centered on financing themselves through bond issuance rather than trying to mimic commercial banks that are in the retail payment system and are deposit creators and takers.

In a nutshell, the advantages of NDBs over PCBs, especially in terms of recapitalization willingness and capacity and bond market liquidity, is what makes them more suitable than PCBs to finance high-risk projects or low-return projects with positive externalities. However, NDBs should be aware of the limits that financing such projects pose in terms of the collateral value of their bonds. NDBs should also be well governed and should not mimic commercial banks to take household deposits to enhance the collateral value of their bonds to unleash their potential for providing long-term finance to fill market gaps.

ACKNOWLEDGMENTS

We are grateful for comments and suggestions from Stephany Griffith-Jones, Daniel Zhiyun Li, Justin Yifu Lin, Ugo Panizza, Thorsten Beck, Horacio Aguirre, Xifang Sun, Yong Wang, Binzhen Wu, Yilin Zhang, and participants at the 2020 SIDI conference (San Martin, Argentina), LVI Reuni'on Anual Asociaci'on Argentina de Econom'ıa Pol'ıtica (Bah'ıa Blanca, Argentina), 2019 IEF Conference on Economic and Financial Development in China (Nanjing, China), the 6th International Conference on NSE (Beijing, China), the 2018 New Structural Economics Annual Conference (Beijing, China), the 2018 International Development Forum of the Chinese Association of World Economy, as well as seminar participants from the Institute of New Structural Economics at Peking University. We acknowledgement the financial support from the National Social Science Foundation of China (20BJL021, 17BJL124), National Natural Science Foundation of China (72141301); the National Natural Science Foundation of China–Data Center for Management Science at Peking University (2017KEY06), the Ford Foundation (128664, 139355), SECYT, UNC, Argentina (33620180101069CB).

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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ENDNOTES

[1] Data source: http://www.dfidatabase.pku.edu.cn/, accessed March 15, 2022.

[2] It is worth noting that key preconditions for providing long-term financing are, among others, that NDBs have a proper corporate governance; good technical, financial and monitoring skills; sound liquidity and risk management; transparency; and efficiency. NDBs often fail in practice because of poor governance or undue political intervention.

[3] Note that we assume that all projects and firms are similar, without distinguishing between project and firm characteristics, with the exception of the maturity of the loans and project length, because in this paper we are not focused on analyzing how variations in project and firm characteristics affect bank decisions, but are interested in analyzing how different bank types affect bank decisions. For a discussion about how firm characteristics affect the lending decisions of banks and the financing decisions of firms, see, among others, Chemmanur and Fulghieri (1994); Faulkender and Petersen (2006); Graham and Leary (2011). For theoretical papers that assume away firm specific characteristics and analyze different bank types, see, among others, Brei and Schclarek (2015); de Blas and Russ (2013); Iacoviello and Minetti (2006); Niepmann (2015).

[4] As will become clearer below, the process of lending to firms by creating bank deposits does not imply that PCBs can create bank deposits without limit. Among other limits, the liquidity risk that this process creates is a key constraint for commercial banks. In addition, there may also be prudential regulations that limit this process, such as the requirement that banks hold a certain quantity of central bank deposits in proportion to the bank deposits. Because our paper aims to offer a basic theoretical explanation of why NDBs are better able to provide long-term finance than PCBs, we will only take into account the limits on the deposit creation placed by liquidity risk and will not analyze the limits imposed by prudential regulations.

[5] Note that, given that we assume all firms and projects are similar, without distinguishing between project and firm characteristics, we assume that banks charge a unique interest rate for a loan of maturity 1 to all projects or firms, ruling out multiple interest rates based on different project and firm characteristics.

[6] This simplifying assumption does not affect our main results.

[7] Note that we assume that the net payment involves the whole quantity of deposits D, and not a fraction of those deposits, to minimize the different possibilities of payments between banks. This simplifying assumption has no consequences for our main results.

[8] Note, however, that solving the liquidity problems still hinges on the willingness of the other PCBs to receive the bonds to settle the payment or, equivalently, to grant the interbank loans. For simplicity reasons, we assume away these willingness concerns and assume that the banks will always be able to settle interbank payments by issuing bonds as long as the collateral value of their assets is high enough. Thus, we assume that the payment system is well-functioning and stable, without credit or market freezes or bank runs. This means that there is no need for a central bank to act as a lender of last resort when others do not want to lend, or as a dealer of last resort when others do not want to buy the assets. Further, for simplicity reasons and without affecting our conclusions about the role of NDBs, we do not explicitly model interbank payments with central bank deposits. We make this simplification, not to deny the paramount role that central banks have, but to focus the analysis on situations where PCBs can settle payments among one another without the need for central bank deposits.

[9] Note also that the results and conclusions of this paper are not affected or driven by the fact that although the loan carries a per-period interest rate of $T_j \times i_L$ spanning T_j periods, the bonds issued by bank j pay a per-period interest rate of $(T_j - 1) \times i_B$ spanning $T_j - 1$ periods.

[10] Note that the collateral capacity ratio should also be positively related to the difference between the expected per-period return of the investment project, $E(R)$, and the per-period interest rate of the lending to the firm, i_L, given that this difference also affects the probability of the firm defaulting on the loan and, thus, the riskiness of the bond issued by bank j. However, for simplicity reasons and without affecting our main results, we omit these factors.

[11] Note also that a higher i_B, given a certain i_D, implies a higher collateral value of the bonds issued by bank j. This result means that the higher the interest rate i_B, the higher amount that bank j can obtain by issuing bonds. Note, however, that this result hinges on the risk of buying the bank bonds being constant. Of course, if the risk is higher (maybe due to poor governance of bank j), a higher interest rate does not necessarily mean that bank j can obtain more funds by issuing these bonds. The exact result, in terms of the amount that the bank can obtain by issuing bonds, will depend on the risk aversion of the bank that buys the bonds. In our paper, we just assume that banks are risk neutral and that they are willing to buy those bank bonds as long as $i_B \leq i_L$ and the collateral value is sufficiently high. In addition, the tightened monetary policies may also increase the interbank borrowing rate. Although studying the consequences of risk aversion and monetary policies upon the interbank lending rate is an interesting and relevant question, it is out of the scope of our paper and is left for future research.

[12] Note that, in reality, the bailout or recapitalization may be carried out by the current owners, new owners, or the government.

[13] We will further discuss the issue of the willingness and financial capacity for a bank recapitalization in subsection 2.2, when we introduce the NDB and the government, which is its owner. Although, to the best of our knowledge, no literature analyzes the willingness and financial capacity for a bank recapitalization, there is a large body of literature, including Sandleris (2016), which analyzes the willingness and financial capacity of governments to pay their issued bonds.

[14] Even more generally, the liquid assets could be real or financial assets whose return is stochastic, but given their collateral capacity have a collateral value of A_j.

[15] Recall that i_L and i_B are taken as given and that their market determination is beyond the scope of this paper.

[16] Note that although NDBs may also create bank deposits, as PCBs can, here we concentrate on analyzing an NDB that does not participate in the retail payment system and therefore cannot create bank deposits to be used in the retail payment system. This assumption is similar to considering that the NDB creates bank deposits but the firms that get those bank deposits operate their payments through PCBs and, thus, will inevitably transfer all those bank deposits from the NDB to a PCB in the initial period 0. Therefore, the NDB will inevitably have to issue bank bonds in the initial period 0 or equivalently request an interbank loan to settle that interbank payment with the PCB.

[17] Note that with the adding of NDB bonds, PCBs have two options for investing: they can either lend directly to the firms, as analyzed in the last subsection 2.1, or they can buy NDB bonds. In this paper, the setup of the model is such that PCBs are completely indifferent to these two options. Thus, we are not analyzing the optimal portfolio choice of PCBs in terms of choosing the proportions of lending directly to the firms and holding NDB bonds.

[18] Note that we assume that, in the initial period 0, the NDB bonds are issued at the same time as the NDB is granting its lending to the firm and choosing the maturity of the lending to the firm, which determines the collateral value of the NDB bond in the intermediate period 1. If the NDB bonds are issued before the NDB determines the maturity of its lending to the firm, the NDB needs to credibly commit to respecting the constraint $D \leq B_{NDB} + A_j$. If the NDB cannot commit to respecting that constraint, commercial banks will undertake additional liquidity risks when buying NDB bonds; thus, will reduce their collateral value of the NDB bonds. This case is not studied in this paper.

[19] If the government is not credible or has a track record of breaking its promises, a more profound credibility analysis should be made, but this is out of the scope of this paper and is left for future research. Further, the possibility of future recapitalization also raises moral hazard considerations that are not analyzed in this paper.

[20] For the numerical simulations, we use the following parameter values: $i_L = 0.05$, $i_B = 0.04$, $A_j = 1$, $V(R) = 0.1$, $\gamma = 0.5$, and $\alpha = 0.5$. Note that we have tested with different parameter values, but the functional form and the relationship did not change between the endogenized T_j^* and D^* with respect to the recapitalization capacity and willingness of bank j, $\omega_j \cdot C_j$. Thus, our conclusions are robust to these parameter changes.

[21] Note that we still assume that projects and firms are similar and rule out the possibility that different types of projects and firms try to exploit these different monitoring skills by approaching different banks to ask for financing. In reality, it is plausible that firms select specific banks according to their monitoring skills to improve their financing conditions. In this sense, it is possible that NDBs are approached by less efficient firms. This issue is not studied here and is left for future research.

[22] These assumptions may be justified by asymmetric information or imperfect information arguments.

[23] The debate on the efficiency of state-owned versus private-owned banks is not completely settled, as Andrianova et al. (2008), Yeyati et al. (2007) and Rodrik (2012), among others, argue.

[24] Note that if NDBs are subject to lending by political connection, and this lending by political connection imply financing riskier firms or projects, then the bank loans of the NDB will have a lower collateral value and NDBs will have to provide shorter maturity loans than PCBs. Although it may go beyond the scope for this paper, this channel is an interesting avenue for researching how firm characteristics, in this case political connections, affect the amount and maturity of lending of NDBs and PCBs.

[25] Market liquidity is the ease with which an asset can be sold to obtain liquidity and settle payments.

[26] Note that all through this paper we are taking the interest rate or coupon of bonds as fixed. Thus, we assume away the effect of the market liquidity on the interest rate of these bonds. This is not to deny the importance of the interest rate but to highlight the different mechanisms that affect the collateral value of bonds, in addition to the interest rate or coupon. This means that in our model, when we focus on the effects of market liquidity, we are considering only the effects of market liquidity on the collateral value of bonds and not on the interest rate or coupon of those bonds.

[27] Note, however, that throughout this paper we have been analyzing pure and extreme examples of banking systems in which either all commercial banks were only buying the NDB bonds or no CB was buying NDB bonds; instead, commercial banks could purchase bonds from other commercial banks. If allowing for a more mixed system, with banks of different types and sizes, we conclude that size matters for market liquidity. Clearly, larger NDBs, in the sense of their relative bond-issuance size in the banking system, will also be able to issue bonds with higher market liquidity and thus will also be able to lend to firms with longer maturities. Similarly, large commercial banks will also have an advantage over small commercial banks in terms of the market liquidity of their bonds.

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How to cite this article: Schclarek, A., Xu, J., & Yan, J. (2022). The maturity-lengthening role of national development banks. *International Review of Finance*, 1–28. https://doi.org/10.1111/irfi.12391