

# Essays on Finance and Macroeconomics

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## ABSTRACT

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My dissertation studies the impact of banks on macroeconomic outcomes. Chapter 1 explores the effects of bond market growth on the financing decisions of firms, the lending behavior of banks, and the resulting equilibrium allocation of credit and capital. This chapter makes three contributions to understand the impact of bond market liberalization. First, using evidence from reforms in Japan that gave borrowers selective access to bond markets during the 1980s, it shows that firms that obtained access to the bond market used bond issuance to pay back bank debt. More importantly, this large, positive funding shock led banks to increase lending to small and medium enterprises and real estate firms. Second, it proposes a model of financial frictions that is consistent with the empirical findings, and uses the model to derive general conditions under which bond liberalization has this effect on banks. The model predicts that bond liberalization can significantly worsen the quality of the pool of bank borrowers, and so lower bank profitability. These results suggest that Japan's bond market liberalization contributed to both the real estate bubble in the 1980s and bank problems in the 1990s. Third, the model implies that bond markets amplify the effects of shocks to the risk-free rate and firm borrowing, in addition to attenuating the effects of financial shocks.

In Chapter 2, I explore how the incentives of domestic banks and sovereign governments interact. I build a model of government default and banks that invest in the debt of their own sovereign. In the model, banks demand safe assets to use as collateral, and default affects bank equity. These losses inhibit banks' ability to attract deposits, leading to lower private credit provision, and lower output. This disincentivizes the

sovereign from defaulting. The extent of output losses depends on characteristics of the banking system, including sovereign exposures, equity, and deposits. In turn, bank exposures are affected by default risk. The model is also used to show that policies such as financial repression can improve welfare, but worsen output losses in the event of default, and may also worsen losses in some non-default states.

Underlying much research on the role of financial intermediaries in macroeconomics is an implicit recognition that there is matching between banks and firms, which I turn to in Chapter 3. Matching between banks and firms has implications for both the transmission of macroeconomic shocks and for empirical estimates of the effects of such shocks. This paper presents a theory of matching in corporate loan markets, between heterogeneous banks and heterogeneous firms. The model demonstrates how assortative matching can cause shocks to have distributional consequences, where particular types of banks and firms are disproportionately affected. The framework is used to show (1) why growth without financial development is limited, (2) how capital inflows affect bank and firm outcomes, and (3) how financial regulation for certain banks also has implications for other borrowers and lenders. Further, this theory demonstrates that matching in corporate lending markets is analytically tractable, and generates predictions that are consistent with existing empirical evidence.

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# Chapter 1

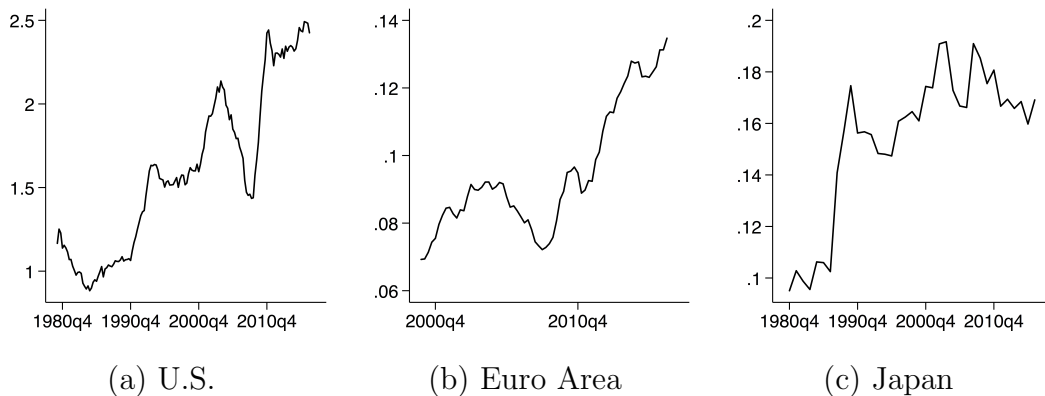
## Inflows and spillovers: Tracing the impact of bond market liberalization

## 1.1 Introduction

Bond financing is growing in many markets. The total outstanding debt securities of US non-financial corporations grew from \$3.2 to \$5.8 trillion between 2006 and 2016, and relative to the stock of bank loans has more than doubled since 1990, as shown in Figure 1.1. Elsewhere in the world, including Europe and especially China, bond markets have also grown rapidly, as shown in Table 1.1. The shift to bond financing is partly a product of government support for market-based financing, and partly a result of borrowers seeking alternative forms of financing in the context of recent banking crises. This shift raises a number of important questions, of which this chapter focuses on three. First, how does access to bond markets affect firm borrowing and bank lending? Second, what are the consequences of growing bond markets for the aggregate allocation of capital? Third, how do bond markets affect the reaction of an economy to capital inflows, financial crises, and other shocks?

In this paper, I exploit a natural experiment in Japan to study the consequences of a transition from bank-centered to market-based financing. Japan liberalized its bond markets during the 1980s, giving specific types of firms permission to issue bonds and

Figure 1.1: Debt securities / bank loans of private non-financial corporations (%)



Sources: US Flow of Funds Table B.103, Euro Area Flow of Funds, Japan Flow of Funds.

Table 1.1: Total debt securities outstanding, non-financial corporations (US\$ bn)

Year	Developed				Emerging	
	US	EU	Japan	Other	China	Other
2006	3,157	1,387	654	448	173	215
2016	5,825	1,978	669	945	5,116	534
Average growth rate (%)	6.3	3.6	0.2	7.7	40.3	9.5

Notes: The EU figures include the UK. Other developed markets includes Australia, Canada, and Singapore. China figures include HK issuance. Other emerging markets include Argentina, Chile, Israel, Malaysia, Peru, Russia, Thailand and Turkey. Source: BIS.

legalizing both foreign and equity-linked bond issuance. Japan's experience offers a useful setting for studying the effect of an increased range of financing options because this bond liberalization initially allowed only certain types of firms access to bond markets, and took place in a period of relative calm. It occurred after the high growth period of the 1950s to mid-1970s, and before the collapse of the stock market and asset prices and subsequent wave of bank problems and consolidation in the 1990s. In addition, the liberalization was designed in several stages, which generate variation in the exposure of firms and banks to bond markets. Finally, the existence of rich micro data from the period allows for close examination of the interaction between bond market liberalization and firm financial decisions, as well as how it affected Japanese banks.

There are two main empirical results. The first result is that firms used bonds primarily as a substitute for bank loans. The criteria for access to unsecured bond markets were based on threshold levels of five to six firm characteristics. These were introduced in 1979 and revised in 1983, 1985, and 1987. Because I have precise knowledge of the rules determining access to bond markets, I use access as an instrument for bond issuance. Firm leverage was stable over the 1980s, and the pace and timing of declines in firms' bank debt coincide with both regulatory reforms and bond issuance. Identifying the effect of access to bond markets on bank loans exploits the

differential behavior of firms that obtain access to bond markets, relative to similar firms that do not have access. The panel dimension of the data allows me to control for time-invariant firm characteristics, via firm fixed effects. I compare firms in the same industries and regions, and of similar size and profitability, to rule out the possibility that declines in bank borrowing are driven by characteristics that are correlated with access. Because each firm can be linked to its lenders, I run specifications that include lender-year fixed effects, to absorb variation that is due to changes in banks' credit supply. The main identifying assumption here is that any trends among firm types are uncorrelated with the regulatory changes. I also control for smooth functions of the characteristics that determine access, and look at subsets of firms that are close to the regulatory thresholds. Provided that there are no jumps in other firm characteristics around the thresholds for access, this isolates the effect of liberalization from other drivers of changes in bank debt.

It is surprising that the firms directly targeted by the liberalization of bond markets do not borrow more overall: their bond issuances are primarily used to pay back bank debt. One implication of this is that these firms were not financially constrained. Firms' choices of total borrowing quantities did not change in response to the availability of a new source of financing, although the mix of debt shifted away from bank debt towards greater use of the bond market.

The second main empirical result is that the shift away from bank debt large firms gaining access to the bond market led banks to increase lending to other firms. Bond issuers' repayment of bank debt constituted a large, positive funding shock for banks. To show this, I construct a measure of each bank's exposure to the liberalization shock using the predicted repayments of firms that gained access to bond markets, and the network of bank-firm ties in Japan. These ties and the timing of the revisions to the access criteria generate both time and cross-sectional variation in the exposure of banks

to firms making liberalization-related repayments. I show that these liquidity shocks are associated with increases in lending to other firms, relative to unshocked banks. The main identifying assumption here is that these repayment shocks are uncorrelated with other factors affecting bank lending. Because firms borrow from multiple banks, I use firm fixed effects to demonstrate that spillovers are not being driven by differences in the borrowers that are matched to exposed versus unexposed banks.

As a further consequence of liberalization-related repayments, banks increased lending to small and medium enterprises and real estate firms. Real estate lending in particular proved to be problematic after the collapse of the real estate bubble in the early 1990s. Banks' real estate lending during this period has been shown to contribute to regional variation in asset prices (Mora, 2008), as well as non-performing loan rates (Hoshi, 2001) and declines in lending and investment during the 1990s (Gan, 2007a,b).

It is striking that the main effects of the liberalization were therefore indirect. This policy change causes banks to lose profitable customers which banks then replace with lending to other firms. If one looked only at the direct effects of the liberalization on targeted firms, one might conclude that the liberalization did not matter much. However, the major effect of the bond market liberalization was to alleviate the financial constraints of the banks. Ignoring these spillover effects of the liberalization, mediated via the banking sector, would substantially underestimate its importance.

These findings are inconsistent with frictionless models, and with models that feature representative firms. Faced with decreased bank dependence among an important part of their customer base, banks could have invested in safe assets or returned funds to depositors. Instead bank lending increased, but to a shifting pool of borrowers. This indicates that banks were constrained in their lending. A model with representative firms would be unable to capture the treatment of a specific subset of firms, and the resulting spillover effects. While the firms targeted by the liberalization policy were

not financially constrained, other firms that obtained loans from affected banks seem to have been financially constrained ex-ante.

While the empirical findings point to constrained banks and heterogeneous firms as key features that lead to the results in Japan, this leaves open a number of other questions that are beyond the scope of reduced form empirical work. The empirical findings show relative rather than aggregate effects. One would like to know what other factors were critical in the Japanese case, and whether the Japanese experience has external validity in a more general setting. In addition, there are a number of counterfactual policy experiments for which we do not have data, but would be useful to think about in a model disciplined by the empirical results.

To address further questions regarding the causes and effects of bond market liberalization, I develop a new model of financial frictions with both bank-level financial constraints and firm heterogeneity. The key features of the model are heterogeneous entrepreneurs, constrained banks, and foreign investors. Heterogeneous entrepreneurs decide whether to save or produce. In equilibrium, entrepreneurs with low productivity become savers, and those with high productivity borrow and invest. Because productive firms did not borrow more in response to the availability of new sources of financing, I model firms' demand for external finance as bounded, and bonds and loans as substitutes. To borrow, all firms must first approach a bank, but then can issue lower-cost bonds in exchange for a fixed cost.

Using the model, I explore the consequences of bond market liberalization for firms' borrowing and issuance decisions, bank lending portfolios, and aggregate output and productivity. In response to a reduction in the fixed cost of issuing bonds, firms issue bonds to repay bank debt and reduce their dependence on banks. Only entrepreneurs with sufficient assets can afford to pay the fixed cost and issue bonds.

In a closed economy, the substitution away from bank debt among borrowers must



be funded by savers shifting from bank deposits to investing in bonds. Importantly, the availability of bonds lowers the effective cost of financing for entrepreneurs with many assets. As a result, large firms with lower productivity find it profitable to borrow after the liberalization takes place. This increases the overall demand for funds, which causes an increase in the interest rate on bank loans. While this allows large marginal firms to grow, it crowds small firms with relatively higher productivity out of the borrowing market. As a result, this leads to a decline in both output and productivity. These predictions do not match the Japanese case, however, because the Japanese economy was not closed.

At the same time as the bond market was liberalized, Japan also took steps to deregulate foreign exchange transactions. For much of the 1980s, foreign issuance was more than half of total bonds issued. In addition, reforms to deposit markets were not implemented until later in the decade, as a consequence of which savers were not fully able to diversify away from bank deposits as the liberalization took place. This led banks to have excess deposits.

In the model, I show that financial repression and foreign inflows to bond markets - as well as a more general set of conditions in which there are foreign inflows to banks or banks are constrained - lead to a pattern of spillovers via banks that matches the empirical findings. When depositors are prevented from substituting investment in bonds for bank deposits, and foreign investors purchase bonds. In equilibrium, there is a decline in the interest rate on loans, and more entrepreneurs with low productivity endogenously decide to invest and produce. This leads to an increase in output but a decline in productivity, and in particular a decline in the size and productivity of firms that borrow from banks.

Japan is not the only country where understanding the transition from bank-centered to market-based financing is important. As shown in Table 1.1, bond finance is

growing rapidly in many markets, and the macroeconomic implications of this have not yet fully been explored. The model is consistent with existing empirical evidence and theory for other forms of capital account liberalization, and generates new predictions about how bond markets interact with shocks to the risk free rate, firm borrowing, and bank shocks. The effect of a fall in the risk free rate is similar to bond market liberalization, and consistent with the model and evidence of Gopinath et al. (2017). However, the increase in output caused by a decline in interest rates is amplified by the existence of bond markets, relative to an economy with banks alone. In line with dynamic models of financial frictions (e.g., Midrigan and Xu, 2014; Buera and Moll, 2015) and evidence in Eastern Europe (Larrain and Stumpner, 2017), an increase in firm borrowing limits improves the allocation of capital, but only if banks are constrained. When banks are constrained, bond markets amplify the effect of an increase in firm borrowing on output, but attenuate the effect this has on improving the efficiency of capital allocation. Finally, the model predicts a retrenchment in bank lending in response to bank shocks, as do De Fiore and Uhlig (2015) and Crouzet (2016). Here, the model highlights distributional consequences of how bond markets dampen the bank lending channel. Importantly, this framework suggests that the substitution of bonds for bank loans among high quality firms decreases bank profitability, as well as the pace of or scope for bank recovery.

The rest of the chapter is structured as follows. The remainder of this section reviews related literature. Section 1.2 describes the institutional context in Japan in the 1970s and 80s, as well as the data I use in this paper. The empirical strategy and results are described in Section 1.3. The model is presented in Section 1.4, where the aggregate effects of bond market liberalization are explored. Further implications of the model are developed in Section 1.5. Section 1.6 concludes.

### 1.1.1 Related literature

This chapter relates to work on financial frictions and bond markets, historical evidence on the period in Japan, and research on capital account liberalization and misallocation.

There is a large existing literature on how financial frictions affect firms, and the potential for bond markets to mitigate these frictions. In the model of Kiyotaki and Moore (1997), the expansion of credit is facilitated by the rising value of collateral. This is one reason Japanese banks favored real estate lending during the 1980s. While financial frictions can amplify and propagate shocks (e.g. Bernanke et al., 1999), this mechanism depends on firm financial constraints and the limited ability of firms to substitute other forms of finance for bank loans. Recent work also models borrowing constraints for the financial sector (Gertler and Kiyotaki, 2010). However, these papers focus primarily on shocks that affect banks, which bond markets then mitigate. In contrast, I focus on the reverse direction of causality: the effect of bond markets on banks.

There is an extensive theoretical literature on corporate debt structure, including Diamond (1991), Rajan (1992), and Besanko and Kanatas (1993). A key idea in these theories is the incentives of banks to monitor, which diffuse groups of investors do not have. Banks also provide firms with greater flexibility in times of financial distress, relative to market debt (Bolton and Scharfstein, 1996). Holmstrom and Tirole (1997) argue that complementarities between direct and intermediated finance allow some firms to borrow from bond markets alone, while others combine bonds and bank debt. Bolton and Freixas (2006) argue that monetary policy affects bank lending by changing the spread of bank loans over corporate bonds. In this paper, I make simplifying assumptions that build on the insights of this literature, for the sake of analytical tractability.

There is also a substantial body of empirical evidence on firm corporate debt choices.

Among rated U.S. firms, the majority borrow simultaneously from banks and bond markets (Rauh and Sufi, 2010). There is substantial empirical evidence that large firms substitute bonds for bank debt over the business cycle, while small firms are typically bank dependent. This substitution over cycles is documented by Kashyap et al. (1993), and again more recently by Adrian et al. (2013) and Becker and Ivashina (2014). The sorting of heterogeneous firms between bank debt and bond markets is central to the predictions of my model.

A number of recent papers study the shift into bonds after 2008, and explore its macroeconomic consequences. Building on the idea that banks have greater flexibility to renegotiate debt, Crouzet (2016) develops a model in which large firms use market debt exclusively, while other firms mix bonds with bank debt. In his framework, a contraction in bank credit leads to an increase in bond issuance that is insufficiently large to offset the decline in aggregate borrowing and investment, due to precautionary motives. De Fiore and Uhlig (2011) build an asymmetric information model to explain the long-run differences between the composition of corporate financing in Euro Area and the US, and in a companion paper (De Fiore and Uhlig, 2015) extend the model to see what shocks could account for the shift in borrowing behavior and increase in spreads observed in the Euro Area in 2008-2009. To match both the shift in the importance of market debt to firms and the observed rise in spreads, their model requires a decrease in bank efficiency, and two shocks to the uncertainty faced by firms. In addition to these findings, there are a number of other questions regarding the transition to increased reliance on bonds. The model presented here has implications for how bond markets affect the overall allocation of capital, and interact with different types of inflows, in addition to financial shocks.

Two recent empirical papers on the European Central Bank's expansion of quantitative easing into corporate bond purchases, formally called the Corporate Sector

Purchase Program (CSPP), find evidence that is consistent with the “spillover” effects I document in Japan. Grosse-Rueschkamp et al. (2017) demonstrate that firms that are eligible for the CSPP substitute bonds for bank debt, and that banks with a high proportion of CSPP-eligible firms in their portfolios increase their lending to private ineligible firms. Using a sample of Spanish firms, Arce et al. (2017) similarly find an increase in bond issuance volume for eligible firms and an increase in lending to non-bond issuing firms.

Japan’s financial liberalization in the 1980s is described in detail by Hoshi and Kashyap (2004). They provide suggestive evidence that bond market liberalization played a role in driving banks to invest in real estate, which may have contributed to the rise in land prices. I provide micro-evidence in support of this claim. Hoshi et al. (1989) study the effects of decreased bank dependence among firms that gained access to bond markets on the sensitivity of firms’ investment to liquidity, and argue that the investment of firms that decreased their bank dependence became more sensitive to liquidity after the liberalization. Weinstein and Yafeh (1998) study the hold-up problem of firms in the pre-liberalization period, and Hoshi et al. (1993) focus on determining what characteristics increase firms’ propensity to issue public debt. Mora (2008) links the bond market liberalization to regional variation in land prices, which peaked in 1991, and rules out that banks chose to lend to real estate because they perceived it to be a good opportunity. Mora instruments for the supply of real estate loans using the declining share of bank loans to keiretsu borrowers. In contrast, I use the bond issuance criteria as an instrument for firms’ bond issuance, and link firms’ repayment of bank debt to banks using the network of bank-firm ties.

Several studies focus on the subsequent collapse of the Japanese stock market and land prices and its effects on the domestic economy (Gan, 2007a,b), real activity in the United States (Peek and Rosengren, 2000), and the behavior of Japanese banks in

misallocating credit in the 1990s (Peek and Rosengren, 2005; Caballero et al., 2008). However, these studies of the later period take the problems of the banking sector as given. In contrast, I examine the period that precedes this, with the objective of better understanding why banks' exposures evolved in a manner that led the fallout from the asset price collapse to become so widespread. Hoshi (2001) finds a positive relationship between banks' level of non-performing loans in 1998 and their share of real estate lending in the 1980s. Ueda (2000) includes the bond market liberalization in his study of the causes of the Japanese banking sector's collapse, and links a proxy measure of liberalization to real estate lending and bad loans. In contrast, I trace these real estate exposures back to policy changes that began in the mid-1970s.

This chapter also relates to studies of capital account liberalization, misallocation, and the limited absorptive capacity of financial systems. Reis (2013) argues that in Portugal in the 2000s, financial integration exceeded financial deepening. Building on Hsieh and Klenow (2009), Gopinath et al. (2017) present evidence of increased dispersion in the marginal revenue product of capital (MRPK) in Spain and Southern Europe over the decade following the introduction of the Euro. Asker et al. (2014) show that such dispersion arises naturally in response to idiosyncratic productivity shocks and investment adjustment costs. The evidence in Japan is partly between sectors, where services and real estate typically have lower productivity than traded goods firms (i.e. manufacturing), and partly regarding size, which has been robustly linked to productivity (Bartelsman et al., 2013). Khwaja et al. (2010) study a positive liquidity shock to Pakistani banks following the re-establishment of normal diplomatic relations with the US after 9/11. Banks were unable to intermediate the resulting inflows, which subsequently led to a bubble in real estate and stock prices. My results suggest that in the Japanese case banks channeled money to the real estate sector, a change that was caused in part by the liberalization of bond markets.

## 1.2 Institutional background and data

During the high-growth period from the mid-1950s to the early 1970s, Japanese firms depended primarily on banks for external funds, due to restrictions on bond issuance.<sup>1</sup> Prior to 1975, all firms wanting to issue bonds had to apply to a Bond Issuance Committee. The amounts requested were typically rationed. All domestically issued bonds were required to be fully collateralized, whereas most bank debt was uncollateralized. Foreign bond issuances required government permission, which was not normally granted. In addition, interest rate ceilings reduced demand for bonds.<sup>2</sup> As a result, between 1970 and 1975, roughly 90 percent of firm external finance came from banks. In 1975, the committee began to allow firms to issue the amounts they requested, instead of rationing issuance quantities.

Beginning in 1976, the government introduced specific accounting criteria for access to secured bond markets. The criteria for bond issuance consisted of a minimum level of net worth, dividends and profits per share, plus either one or two additional requirements. The detailed criteria are shown in Panel A of Table A.1, in the Appendix. Firms that met the criteria were permitted to issue secured convertible bonds.

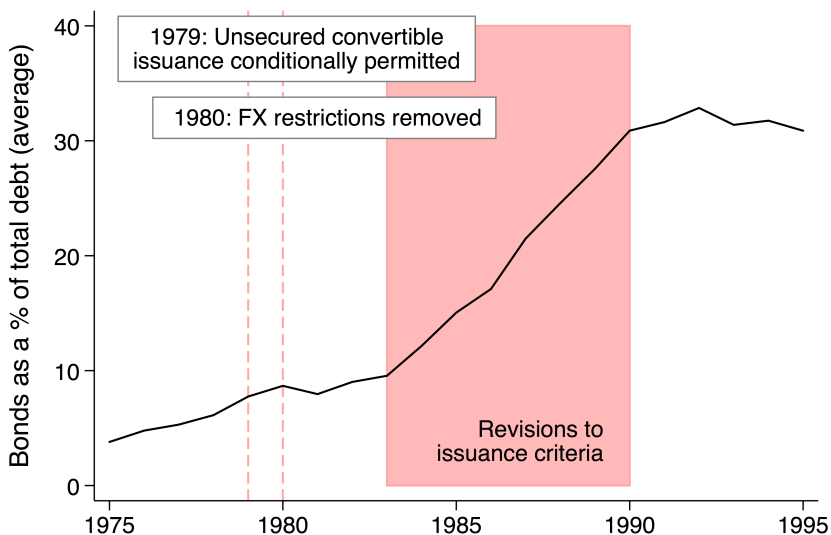
In 1979, more stringent criteria were established for unsecured convertible bonds, as shown in Panel B of Table A.1. The criteria were initially so strict that only two firms qualified. These criteria were relaxed several times at specific dates over the 1980s. A larger group of firms become eligible following the criteria revision in 1983, and a more significant revision was introduced in 1985, bringing the total number of firms eligible

---

<sup>1</sup>Capital markets had dominated firm financing from the Meiji restoration until the 1930s, so this had not been the case historically. A wave of bond defaults in the 1920s, followed by increased government control of the economy during World War II contributed to the importance of banks. After the war, the Japanese government continued to restrict the options of savers mainly to bank deposits, so as to give itself continued discretion over the allocation of scarce capital. This allowed the government to support industries deemed to be strategic through its influence over banks. Interest rates including deposit rates and loan rates were controlled from 1947 until 1992.

<sup>2</sup>Although interest rate ceilings also applied to bank loans, in practice banks circumvented these regulations by requiring that firms hold interest-free accounts at banks.

Figure 1.2: Major policy changes and bonds as a fraction of total debt



Notes: This figure shows the average bonds as a percentage of total debt of listed non-financial firms in Japan. Although bond issuance was possible prior to 1975, firms had to apply to a Bond Issuance Committee for permission to issue bonds, and the amounts requested were often rationed. Reforms began in 1975 when firms were permitted to issue the amounts firms requested, followed by the liberalization of the secured convertible bond market in 1976. In this paper, I focus on the unsecured convertible bond market, which was liberalized in 1979.

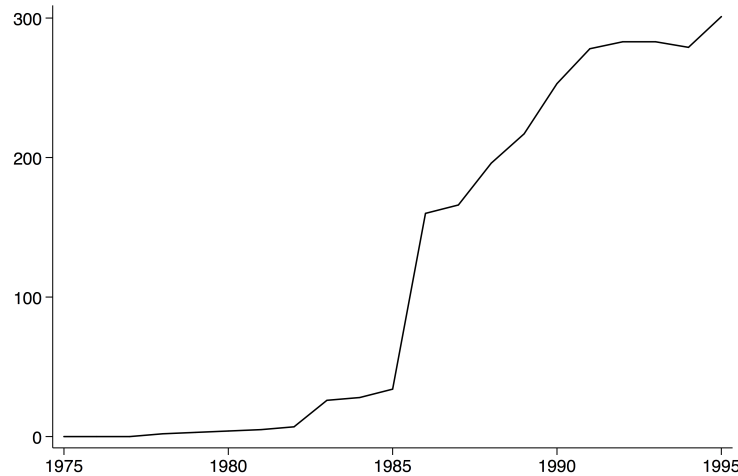
to issue unsecured bonds to more than 150. From July 1987, firms could instead meet ratings criteria to issue unsecured bonds, as shown in Table A.2.

Over the 1980s, bond issuance increased rapidly, as shown in Figure 1.2. The total number of qualified firms in the unsecured bond market is shown in Figure 1.3. As a consequence of these reforms, firm borrowing patterns changed dramatically. In 1975, for example, firms borrowed on average less than 5 percent of their debt from bond markets, as shown in Figure 1.2. By 1990, the average was over 30 percent.

Importantly, the rules governing foreign exchange were also substantially relaxed in 1980. Foreign issuance had previously required explicit government permission. Reforms to the Foreign Exchange Law in 1980 changed this to allowing companies to notify the Ministry of Finance, instead of requiring a formal permit (Kester, 1991). Firms issuing foreign bonds still had to meet the relevant issuance criteria, but foreign



Figure 1.3: Firms qualified to issue unsecured convertible bonds under accounting criteria

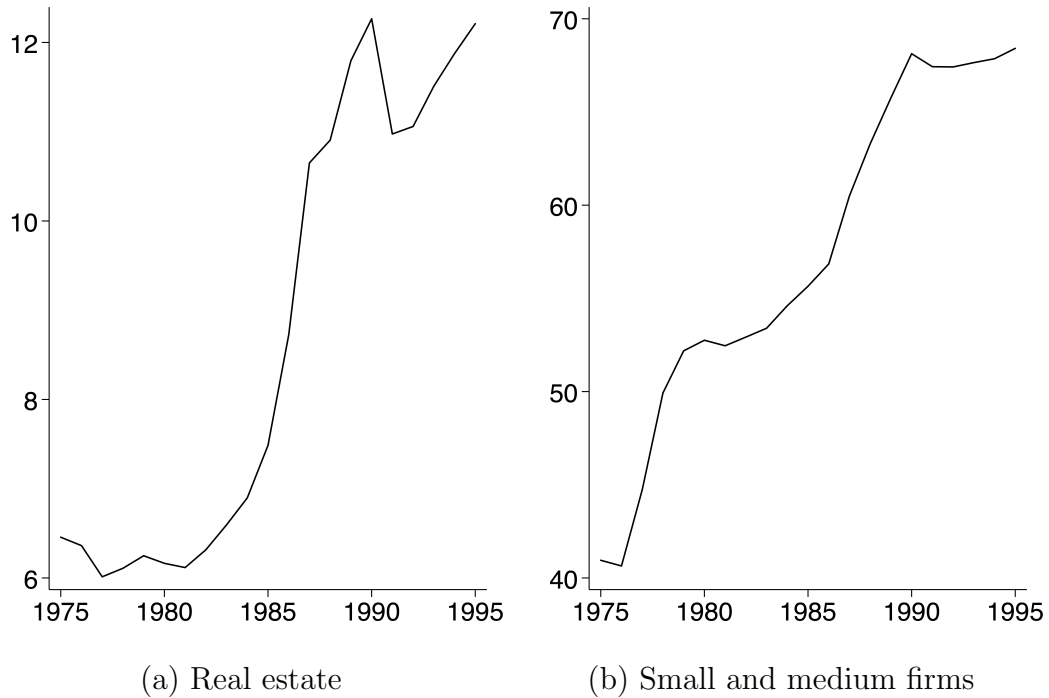


Notes: This figure shows the number of firms that qualify to issue unsecured convertible bonds in each year, according to the accounting criteria. Eligibility is determined using firm balance sheet data from DBJ. The accounting criteria are listed in Table A.1 in the appendix. The number of qualified firms is underestimated after 1987, when ratings criteria were introduced; firms that qualify under the ratings criteria are not counted here.

fees were significantly lower than the fees for domestic issuance.

Over the 1980s, there are several dimensions in which bank activity expanded. Banks grew substantially larger, extending credit to new firms, small and medium-sized firms in particular. Banks also increased their exposures to real estate through both loans and investments. These overall shifts are shown in Figure 1.4. There was also a rapid increase in asset prices in the late 1980s in Japan, both in the stock market and land prices. Most explanations for the bubble blame monetary policy (e.g. Ueda, 2000). Interest rates were low and had fallen from mid-1980 until May of 1989. The stock market peaked in 1989, and land prices began to fall in 1991. Following the collapse of equity and land prices, both banks and firms faced significant difficulties, which led to lower lending and investment, and eventually a wave of bank failures, mergers, and recapitalizations in the late 1990s. My results suggest that Japan's bond market liberalization contributed to both the real estate bubble in the 1980s and bank

Figure 1.4: Loans as a % of total bank lending



Notes: These figures show the percentage of total bank lending that is allocated to real estate firms and small and medium firms over the period 1975-95. The percentages are calculated using the sum of bank-level financial reports from March 31 of each year shown, which is the fiscal year end for most major banks in Japan.

problems in the 1990s.

### 1.2.1 Data

I use two main sources of data in this paper: firm-level financial data from the Development Bank of Japan (DBJ), and bank financial statements from Nikkei NEEDS Financial Quest.

Firm financial data comes from the DBJ, which compiles regulatory findings from the universe of listed firms in Japan. This data begins in 1956, and by 1980 includes 1,599 firms. By 1990, the sample has grown to 2,133. The detailed firm level data is used to determine when firms become eligible to issue different types of bonds. In the

empirical analysis, I use the subset of firms that report a fiscal year end of March, which is the majority of Japanese listed firms. This simplifies the analysis and is common in other studies of Japan (e.g. Amiti and Weinstein, 2017). Because I use a subset of firms, my estimates of the effects of the liberalization on banks are conservative.

In addition, the DBJ data includes disclosures on which banks lent to each firm in each year, which allows the firm-level effects of the bond market liberalization to be linked to the outcomes of banks they borrow from. This data is available beginning in 1982; in prior years, it is aggregated by bank type. In 1982, on average firms borrowed from 14 lenders (median 11). By 1990, this had fallen to 10 (median 8).

Finally, bank balance sheet data is taken from the Nikkei NEEDS Financial Quest database, to test the effect of liberalization on various bank outcomes and to control for other bank characteristics.

## **1.3 Empirical evidence**

In this section I show that firms that gained access to bond markets issued bonds as a substitute for bank debt, and that as a result of the repayment of bank debt, banks lent more to other firms. In particular, the bond liberalization contributed to bank lending to small firms and real estate.

### **1.3.1 Firm level effects of bond liberalization**

This section examines the impact of bond market liberalization on firms' repayment of bank debt, using the changes to the criteria for access to unsecured convertible bond markets as an instrument for bond issuance. In looking at firm-level effects I use an unbalanced panel of firms over the period 1977-1990, which includes the entire liberalization period.

The first test is how the changes in policy that allowed certain firms to access the unsecured convertible bond market affected bond issuance. Using the firm level data and the criteria for access, I determine when each firm gained access to the unsecured bond market, which is denoted by a dummy variable  $Access_{j,t}$ . By identifying when each firm obtained access to new bond instruments, one can test for the effect of access on bond issuance in a regression of the form:

$$B_{j,t} = \lambda Access_{j,t} + \eta_j + \delta_t + \gamma_1 Controls_{j,t} * \delta_t + e_{1j,t}, \quad (1.1)$$

where  $B_{j,t}$  is the ratio of bonds to total assets of firm  $j$  in time  $t$ ,  $\eta_j$  is a firm fixed effect,  $\delta_t$  is a time fixed effect, and  $Controls_{j,t}$  is a vector of additional control variables, interacted with year dummies. The control variables include firm characteristics such as size, profitability, industry, region, and lenders, and are discussed in more detail below.<sup>3</sup>

The main empirical test of this section estimates how bond issuance affects firms' bank debt, using a regression of the form:

$$L_{j,t} = \beta B_{j,t} + \eta_j + \delta_t + \gamma_2 Controls_{j,t} * \delta_t + e_{2j,t}, \quad (1.2)$$

where  $L_{j,t}$  is the bank debt to total assets ratio of firm  $j$  in time  $t$ . The coefficient on  $B_{j,t}$  measures the extent to which bond issuance and bank debt are complements or substitutes. Firm fixed effects control for time-invariant firm characteristics that affect firms' choice of bank debt. Time fixed effects filter out the effects of common macroeconomic shocks on firms' bank borrowing. Importantly, OLS estimates of equation (1.2) do not have a causal interpretation, because a contraction in bank lending may cause firms to issue bonds.

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<sup>3</sup>Prior to the liberalization, some firms issued straight bonds, though the amounts were rationed up to 1975, and issuance volumes were low. Many firms had access to the secured convertible bond market, for which criteria were introduced in 1976. However, access to secured bond issuance did not have a large impact upon introduction. Access to the domestic unsecured bond market is useful in that it generates an increase in the probability of issuance, by granting firms access to the domestic unsecured market, as well.

To assess the effect of bond issuance on bank lending, I instrument for  $B_{j,t}$  using the dummy variable that indicates whether firm  $j$  has access to bond markets in year  $t$ ,  $Access_{j,t}$ . This empirical strategy uses equation (1.1) as a first stage for equation (1.2). This compares the outcomes of firms that get access to the unsecured convertible bond market to firms without access, by looking at firms' bond issuance and bank debt before and after the policy changes are introduced. Because firms obtain access to the bond market at different times, one needs to rule out other reasons why firms' bank borrowing may have changed, insofar as other drivers may be correlated with reforms to the bond market. Further, because access is not randomly assigned, it is also necessary to control for the characteristics that determine access.

To control for changes in banks' credit supply, I run specifications that include lender-year fixed effects. Firms' lenders are reported in the DBJ data. Although firms borrow from multiple banks, lender-year fixed effects are added for the banks from which firms obtain the largest share of their loans, conditional on their share being larger than 20 percent.<sup>4</sup>

Since there may also be changes in firm demand for bank debt, such as demand shocks, I include specifications with industry-year and region-year fixed effects. Industry-year fixed effects control for demand shocks that are industry specific. Region-time dummies control for economic differences across Japan's 47 prefectures, such as growth, unemployment, demographics, and inflation.

Because the rules granting firms access to bond markets were based on firm characteristics, firms that gained access to bond markets were larger and more profitable than firms that did not. Other firm characteristics interacted with year dummies control for the possibility that the change in bank debt is driven by firm characteristics in the same years that certain types of firms gain access.

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<sup>4</sup>This is analogous to using firm-year fixed effects to control for changes in firm-level credit demand, which also exploits the fact that firms borrow from multiple banks.

In addition, I run specifications that include as controls linear functions of the characteristics that determine access, interacted with year dummies. Since access is based on observable characteristics, this is analogous to a regression discontinuity design.<sup>5</sup> To control for the effects of the observable characteristics on firm behavior, I include the characteristics that are used to determine access as control variables (i.e. running variables), interacted with year dummies. The key identification assumption here is that there are no jumps in other firm characteristics around the thresholds for and timing of the regulatory changes to access. Because there is a panel dimension to the data, this implies that there are no changes in the trends for different groups of firms that happen to coincide with the threshold of a particular policy change. Finally, I run these same regressions on a sub-sample of the firms that are closer to the cutoffs, by discarding very large and very small firms.

These specifications aim to capture the variation in bank borrowing that is attributable to the liberalization policy. The interactions between year dummies and firm characteristics control for the borrowing behavior of similar firms. The interpretation of the coefficient  $\beta_{IV}$  is the effect of bond issuance on bank borrowing, for a firm that gains access, relative to a firm in the same industry and region, of the same size and profitability, controlling for bank credit supply.

## **Firm-level results**

Table 1.2 shows the effect of bond market access on bond issuance. Access to domestic unsecured convertible bond markets is associated with an increase in bonds over assets of roughly 3 percentage points, on average, controlling for year and firm fixed effects, as shown in column 1. Controlling for lender-year fixed effects has little effect on the

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<sup>5</sup>Because bond issuance is not deterministic, but instead a probabilistic function of the access criteria, this corresponds to fuzzy RD. In other words, there are some firms that get access and do not issue bonds, so not every firm is a “Complier.”

Table 1.2: The effect of bond market access on bond issuance, 1977-90

Dependent variable:  $Bonds_{j,t} / assets_{j,t-1} (B_{j,t})$

	Baseline results				Linear control variables		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Access_{j,t}$	0.031*** (0.004)	0.029*** (0.004)	0.028*** (0.004)	0.016*** (0.005)	0.022*** (0.004)	0.012*** (0.004)	0.010** (0.005)
Firm fixed effects	Y	Y	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y	Y
Controls*year dummies:							
Main bank		Y					
Industry & region			Y				
Size bin				Y			
Profitability bin				Y			
Net worth					Y	Y	Y
Capital ratio						Y	Y
Other criteria							Y
Observations	13,600	13,600	10,137	13,600	13,600	13,600	11,840
R-squared	0.62	0.64	0.68	0.65	0.63	0.64	0.66

Notes:  $Access_{j,t}$  is a dummy variable denoting whether firm  $j$  meets accounting criteria to issue unsecured convertible bonds in year  $t$ .  $Bonds_t / assets_{t-1}$  is winsorized at the top and bottom one percent of observations. The size bins are divided at 1 million, 10 million, and 100 million. The profitability bins are divided at 4 percent and 9 percent, which correspond to the 25th and 75th percentiles of profitability in the sample. Other criteria includes business profits as a percentage of assets, the ratio of net worth to paid in capital, and the interest coverage ratio. Standard errors are clustered at the firm and year level, shown in parentheses. \*, \*\*, and \*\*\* indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

point estimate in column 2. Adding controls for industry-year and prefecture-year fixed effects reduces the size of this coefficient only slightly, shown in column 3, and controlling for the effects of size and profitability interacted with year dummies changes the estimates to 1.5 percentage points, as in column 4. Including linear control variables interacted with year dummies reduces the size of bond issuance associated with gaining access to bond markets to 1-2 percentage points of firm assets, as shown in columns 5-7. In column 7, all of the criteria on which access are based are included as control variables, with the exception of dividends. Because the dividend rule is discrete and backward looking, there is not a simple way to include this as a control variable. In all specifications, the estimated effects of access on bond issuance are statistically and economically significant.

In Figure 1.5 panel (a), the trends of the bonds to assets ratio of firms that gain

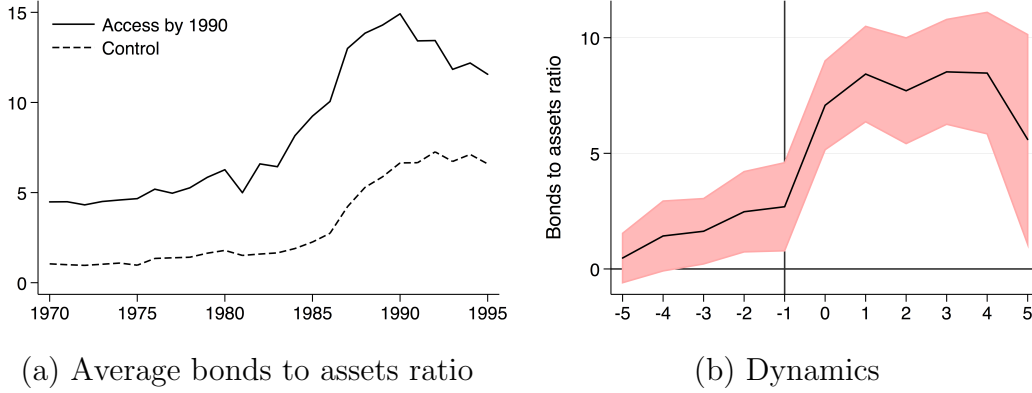
access to the unsecured convertible bond market by 1990 are compared to the firms that do not gain access. The group of firms that gain access begin to issue bonds earlier and in larger volumes than the firms without access. In panel (b), I plot the estimated coefficients from a dynamic version of regression (1.1) that includes leads and lags of the year in which firms gain access ( $t = 0$ ):  $B_{j,t} = \sum_{k=-5}^5 \lambda_{t-k} Access_{j,t-k} + \eta_j + \delta_t + \gamma_1 Controls_{j,t} * \delta_t + e_{1j,t}$ . Although firms have some ability to issue bonds before gaining access to the unsecured market, upon gaining access, there is a significant and persistent increase in the bonds to assets ratio of firms.

Similarly, in Figure 1.6 panel (a), the trends of the bank debt to assets ratio of firms that gain access to the unsecured convertible bond market by 1990 are compared to the firms that do not gain access. Although both groups of firms are deleveraging as they come out of the high growth period which ends in the early 1970s, the group of firms that does not gain access maintains a bank to asset ratio of roughly 25-30 percent throughout the 1980s. In contrast, the firms that gain access to the bond market are able to continue to shift away from banks, and reduce their bank debt to asset ratios to below 20 percent, on average. In panel (b), I plot the estimated coefficients estimated from a dynamic version of the reduced form regression that includes leads and lags of the time that firms gain access ( $t = 0$ ):  $L_{j,t} = \sum_{k=-5}^5 \beta_{t-k} Access_{j,t-k} + \eta_j + \delta_t + \gamma_0 Controls_{j,t} * \delta_t + e_{0j,t}$ . Although firms have some ability to anticipate that access will allow them to shift away from banks, and begin reducing their bank debt in the year prior to when they gain access, this shift continues after access is granted and persists for four years after firms obtain access to the bond market.

Table 1.3 shows the elasticity of bank debt to bond issuance, as estimated using regression (1.2). Using OLS, the relationship between bonds and bank loans is negative: as shown in column 1, a one percentage point increase in bonds to assets is associated with a 0.45 percentage point decrease in the ratio of bank loans to assets, controlling for

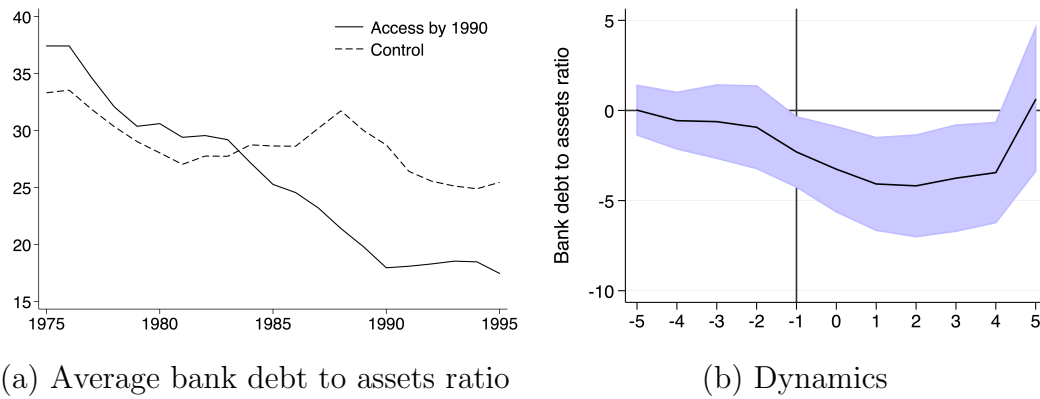


Figure 1.5: Bond issuance pre-trends and dynamics



Notes: Panel (a) shows the average bond to assets ratio of firms that are granted access to the unsecured convertible bond market by 1990, compared to firms that do not obtain access. Panel (b) plots the coefficients estimated from a dynamic version of regression (1.1) that includes leads and lags of the year that firms gain access ( $t = 0$ ):  $B_{j,t} = \sum_{k=-5}^5 \lambda_{t-k} Access_{j,t-k} + \eta_j + \delta_t + \gamma_1 Controls_{j,t} * \delta_t + e_{1j,t}$ .

Figure 1.6: Bank debt pre-trends and dynamics



Notes: Panel (a) shows the average bank debt to assets ratio of firms that are granted access to the unsecured convertible bond market by 1990, compared to firms that do not obtain access. Panel (b) plots the coefficients estimated from a dynamic version of the reduced form regression that includes leads and lags of the year that firms gain access ( $t = 0$ ):  $L_{j,t} = \sum_{k=-5}^5 \beta_{t-k} Access_{j,t-k} + \eta_j + \delta_t + \gamma_0 Controls_{j,t} * \delta_t + e_{0j,t}$ .

year and firm fixed effects. The point estimate from the regression in which I instrument for the bonds to assets ratio using access to the unsecured bond market in column (2) reveals that a bond issuance of one percent of assets due to the liberalization results in a contemporaneous repayment of bank debt of one percent of assets. This estimate is fairly stable to the inclusion of additional fixed effects, with the smallest estimated coefficient being with the inclusion of industry-year and region-year fixed effects.

When linear functions of the main characteristics that determine access are included in columns (6) and (7), the point estimates are similar. The most saturated specification in column (8) is no longer statistically significant, but the point estimate also indicates that the sizes of bond issuance and bank debt repayment are roughly proportional. Finally, in Table 1.4, the same specifications are run using two smaller subsamples of the data which exclude firms that are above or below specific sizes. It is not surprising that after discarding more than two-thirds of the sample, the estimates are no longer statistically significant. However, the point estimates remain very stable and indicate that most bond issuance is being used to repay bank debt.

I also explore the effect of bond market access on other firm outcomes. This is done using the regression specifications in equation (1.1), with other firm level-outcomes as the dependent variables. The results of these regressions are shown in Appendix B. Despite a fall in funding costs of approximately 1-2 percentage points (shown in panel 2 of Appendix B), firms' total leverage does not increase (panel 3). There is also no effect of bond market access on investment, employment, asset growth, or sales growth (panels 4-7). In response to gaining access to bond markets, firms hold more cash, less inventory, and seem to reduce their book equity (panels 8-10). These outcomes are puzzling because they indicate that firms facing a decline in funding costs do not undertake marginal investment projects.

Table 1.3: The effect of bond issuance on bank borrowing, 1977-90

Dependent variable: Bank debt $_{j,t}$  / assets $_{j,t-1}$  ( $L_{j,t}$ )

	$B_{j,t}$ instrumented using $Access_{j,t}$							
	OLS (1)	Baseline results			Linear control variables			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bonds $_{j,t}$ / assets $_{j,t-1}$ ( $B_{j,t}$ )	-0.45*** (0.02)	-1.08*** (0.28)	-1.02*** (0.29)	-0.51** (0.25)	-1.33* (0.74)	-0.84** (0.38)	-0.89* (0.49)	-0.86 (0.61)
Firm fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls*year dummies:								
Main bank			Y					
Industry & region				Y				
Size bin					Y			
Profitability bin					Y			
Net worth*year						Y	Y	Y
Capital ratio*year							Y	Y
Other criteria*year								Y
Observations	12,582	12,582	12,582	9,325	12,582	12,582	12,582	11,019
R-squared	0.81							
First stage F-stat		37.0	33.6	21.5	12.9	22.8	53.1	29.2

Notes: Notes:  $Access_{j,t}$  is a dummy variable denoting whether firm  $j$  meets accounting criteria to issue unsecured convertible bonds in year  $t$ . Bonds $_t$  / assets $_{t-1}$  and bank debt $_t$  / assets $_{t-1}$  are winsorized at the top and bottom one percent of observations. The size bins are divided at 1 million, 10 million, and 100 million. The profitability bins are divided at 4 percent and 9 percent, which correspond to the 25th and 75th percentiles of profitability in the sample. Other criteria includes business profits as a percentage of assets, the ratio of net worth to paid in capital, and the interest coverage ratio. Standard errors are clustered at the firm and year level, shown in parentheses. \*, \*\*, and \*\*\* indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table 1.4: The effect of bond issuance on bank borrowing, discontinuity sample, 1977-90

Dependent variable: Bank debt $_{j,t}$  / assets $_{j,t-1}$  ( $L_{j,t}$ )

All columns: 2SLS	Discontinuity sample 1			Discontinuity sample 2		
	(1)	(2)	(3)	(4)	(5)	(6)
Bonds $_{j,t}$ / assets $_{j,t-1}$	-1.25* (0.67)	-0.73 (0.50)	-0.73 (0.80)	-1.03 (0.66)	-1.17 (0.84)	-1.33 (1.59)
Firm fixed effects	Y	Y	Y	Y	Y	Y
Controls*year dummies:						
Net worth	Y	Y	Y	Y	Y	Y
Capital ratio		Y	Y		Y	Y
Other criteria			Y			Y
Observations	3,700	3,700	3,421	2,452	2,452	2,291

Notes:  $Access_{j,t}$  is a dummy variable denoting whether firm  $j$  meets accounting criteria to issue unsecured convertible bonds in year  $t$ . Bonds $_t$  / assets $_{t-1}$  and bank debt $_t$  / assets $_{t-1}$  are winsorized at the top and bottom one percent of observations. Other criteria includes business profits as a percentage of assets, the ratio of net worth to paid in capital, and the interest coverage ratio. Columns (1)-(3) include firms above the lowest and below the highest cutoff for equity, which are 20 bn and 600 bn, respectively. Columns (4)-(6) include firms with equity greater than 33 bn and less than 500 bn. Standard errors are clustered at the firm and year level, shown in parentheses. \*, \*\*, and \*\*\* indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

### 1.3.2 Spillovers via the banking system

In this section, I estimate how the shift away from banks among firms issuing bonds led to a positive liquidity shock for banks, and how this affected bank lending. By exploiting the timing of the changes in liberalization policy and the relative exposure of banks to firms gaining access, these shocks are plausibly exogenous to other drivers of changes in the loan portfolio of banks. For this analysis I focus on the sub-period from 1983 to 1987. Specific data on the identity of matched borrower-lender pairs is not available until 1982, and I focus on the five year period following this, prior to the serious bubble years.

To construct a measure of the size of the repayment shock affecting each bank, I first calculate the predicted repayments of each firm and then aggregate them into repayments at a bank level, using the network of bank-firm lending relationships. A firm's predicted repayment is calculated as follows. For firms that gain access to the bond market, the predicted issuance  $\widehat{B}_{j,t}|Access_{j,t} = 1$  estimated in regression (1.1) is multiplied by the repayment coefficient estimated using regression (1.2):

$$\widehat{\Delta L}_{j,t} = \widehat{\beta}_{IV} * \left[ \widehat{B}_{j,t}|Access_{j,t} = 1 \right].$$

Predicted issuance is used instead of actual issuance in constructing the predicted repayments, because predicted issuance is less likely to be correlated with bank-level variables. The main identifying assumption here is that the time and cross-sectional variation in banks' exposure to firms that gain access to the bond market is uncorrelated with other factors that affect bank lending.

At the bank level, the repayment shock  $R_{i,t}$  is calculated as the sum of predicted repayments made by firms that borrowed from bank  $i$  in period  $t-1$ , denoted  $j \in M_{i,t-1}$ , and that gained access to the bond market, divided by total bank lending to listed firms:

$$R_{i,t} = \frac{\sum_{j \in M_i} \text{Predicted repayments}_{j,t}}{\text{Total loans}_{i,t-1}} = \frac{\sum_{j \in M_i|A_j=1} \Theta_{ij,t-1} \widehat{\Delta L}_{j,t} * \text{Assets}_{j,t-1}}{\sum_{j \in M_{i,t-1}} \ell_{ij,t-1}},$$

where  $\ell_{ij}$  is the nominal size of a loan from bank  $i$  to firm  $j$ . To obtain a nominal firm-level repayment, the predicted repayment  $\widehat{\Delta L}_{j,t}$  is multiplied by lagged firm assets. These repayments are also weighted by the share of bank  $i$  in firm  $j$ 's total borrowing:  $\Theta_{ij} = \frac{\ell_{ij}}{\sum_{i \in M_j} \ell_{ij}}$ . For example, a firm that borrows equal amounts from two banks will have  $\Theta_{ij} = \Theta_{i'j} = 0.5$ , which scales the amount each bank is predicted to be repaid from that firm to half of the nominal total.<sup>6</sup>

One test of the effect of the repayment shocks on bank lending is to regress the growth rate of lending between bank  $i$  and firm  $j$  on the bank shock  $R_{i,t}$ :

$$\Delta \log \ell_{ij,t} = \beta R_{i,t} + \eta_{j,t} + \epsilon_{ij,t}. \quad (1.3)$$

where  $\eta_{j,t}$  is a firm-year fixed effect. The firm-year fixed effects address the concern that results are being driven by demand shocks affecting firms that happen to borrow from shocked banks. The coefficient on  $R_{i,t}$  measures the effects of the bank-level repayment shock at bank  $i$  on firm  $j$ , relative to firm  $j$ 's borrowing from other unshocked banks. A positive coefficient indicates that a bank shock is associated with higher lending, relative to firm borrowing from other banks without repayment shocks.

In linking the bond liberalization shocks to bank outcomes, the key identifying assumption is that the timing and relative exposure of banks to firms that gain access to bond markets is uncorrelated with other shocks that affect bank lending. In other words, banks did not lend to these large, profitable clients because of characteristics of the rest of their loan portfolio. Although banks that lend to large, profitable firms and are therefore disproportionately affected by the bond market liberalization may lend to different types of firms than other banks, the within-firm comparisons provide a good

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<sup>6</sup>One concern is whether firms indeed repay their banks in proportion to the past lending shares. Since firms borrowed from many banks (14 on average in 1982), it is possible that strategic considerations were taken into account when firms decided which banks to repay. While this would increase the explanatory power of the repayment shocks, it is also more likely to be endogenous to bank characteristics.

test of the supply side effects of the repayment shocks. Using predicted rather than actual bond issuance in constructing the shocks furthers this argument.

Another test of where capital allocated as a result of the liberalization is whether the repayment shocks cause banks to lend more to other specific groups of firms or industries. Regression (1.4) tests whether the repayment shocks are associated with different values of a bank-level variable  $\Delta \log Y_{i,t}$ :

$$\Delta \log Y_{i,t} = \beta R_{i,t} + \zeta_i + \delta_t + e_{i,t}, \quad (1.4)$$

where  $R_{i,t}$  is the repayment shock described in the previous section,  $\zeta_i$  is a bank fixed effect, and  $\delta_t$  is a time fixed effect. The outcomes I focus on for  $\Delta \log Y_{i,t}$  are the change in the log of lending to small and medium firms and real estate firms.

### **Bank-level results**

On average, the actual bond issuance that can be traced back to banks totals three percent of bank loans to listed firms. The repayment shocks are constructed using the coefficients in column 1 of Table 1.2 in the years each firm has access, multiplied by lagged firm assets. Given the results at the firm level, I construct firm level repayments by assuming that each yen of this issuance was repaid. Using the credit registry to determine which firms borrowed from what banks, and the shares of each predicted repayment to attribute to each bank, the predicted firm-level repayments are added up at the bank level in each year. The repayment shocks predicted from the bond market liberalization range between 0 and 6 percent of loans, and are summarized in Table 1.5. The average repayment shock associated with access to the unsecured convertible bond market is 0.5 percent of total lending to listed firms. Although the average shocks are small, certain banks were more affected than others.

Table 1.6 compares characteristics of banks by the tercile of repayment shock that they are subject to. Although banks in the first tercile of shocks are smaller than

Table 1.5: Repayment shocks, 1983-87 (%)

<b>Type</b>	<b>Mean</b>	<b>Median</b>	<b>p75</b>	<b>p95</b>	<b>N</b>
Long-term credit	0.7	0.1	1.7	2.2	15
City bank	0.9	0.3	1.6	3.2	65
Trust bank	0.7	0.1	1.5	2.0	35
Regional bank	0.4	0.0	0.8	1.9	286
Total	0.5	0.0	1.1	2.1	401

Notes: This table shows summary statistics for the repayment shocks associated with bond market liberalization calculated for banks between 1983 and 1987. The shocks are scaled using total loans to listed firms.

banks in the other terciles, on other observable characteristics the banks are closely comparable. They have similar levels of leverage, return on assets, and profitability. In addition, the shares of lending to real estate and small firms are relatively close, and there are almost no changes in the shares of loans to these sectors in the two years prior to the period in which the repayment shocks are calculated.

Table 1.7 shows the effects of the repayment shock on bank lending to listed firms, which corresponds to regression (1.3). In columns 1 and 2, the sample includes firms without access to unsecured bond markets. Column 1 shows that a one percentage point increase in the repayment shock is associated with an increase in borrowing of 2 percentage points relative to its borrowing from an unaffected bank, controlling for firm-year fixed effects. If instead we control for firm and year fixed effects, the size of the coefficient is essentially unchanged. Columns 3 and 4 restrict the sample further to firms with no bonds at all, and finds smaller but still statistically and economically significant responses to the shock. The size of the coefficients with and without firm-year fixed effects are roughly the same in size, which indicates that it is unlikely that demand shocks are positively correlated with the repayment shocks.

Table 1.8 shows the effect of the repayment shock on lending to real estate firms and small and medium enterprises. A one percentage point increase in the repayment shock is associated with an increase in lending to real estate firms of 2-3 percentage points,

Table 1.6: Balancing of covariates in the sample, 1983-87 (%)

	Quantile of $R_{i,t}$			Memo: std. dev.
	1	2	3	
Total Assets (¥tr)	1,390	10,010	7,360	6,761
Leverage	38.1	42.5	39.4	10.6
ROA (%)	0.52	0.48	0.53	0.15
NIM (%)	2.2	1.1	1.6	0.6
Real estate loans / total, 1982 (%)	6.9	7.7	6.4	4.0
$\Delta$ share, 1980-1982 (%)	0.5	0.1	0.1	0.9
Small firms loans / total, 1982 (%)	79.9	47.8	60.0	19.0
$\Delta$ share, 1980-1982 (%)	-0.3	-0.9	-0.7	0.4

Notes: This table compares the characteristics of banks by tercile of repayment shocks  $R_{i,t}$  in the sample.

as shown in columns 1 and 2. The effect on lending to small and medium firms is 1-2 percentage points, on average, and still statistically significant, as shown in columns 3 and 4.

Figure 1.7 compares the lending behavior of banks with positive repayment shocks to those with no repayments. While the patterns of lending are similar in the early years of the liberalization, there is a substantial divergence between the growth rates of lending to real estate beginning in 1985, and to small and medium firms beginning in 1986.

The evidence presented in this section demonstrates that the bond market liberalization in Japan led more firms to issue bonds and pay back bank debt. Among banks, these repayments led to greater lending to other listed firms, as well as lending to small firms and real estate. This evidence indicates that Japan's bond market liberalization contributed to the economic problems that Japan began to face a few years later, following the collapse of asset prices and the stock market bubble. Banks' exposures to real estate in the late 1980s have been shown to predict loan delinquency rates and declines in lending in the 1990s (Hoshi, 2001; Gan, 2007b). However, to explore the aggregate implications of bond market liberalization, to determine the key factors driv-



Table 1.7: The effect of repayment shocks on bank lending, 1983-1987

Dependent variable: $\Delta \text{Log loan size}_{ij,t}$	Firms with $A_{j,t}^{unsecured} = 0$		Bank dependent firms only	
	(1)	(2)	(3)	(4)
Repayment shock $_{i,t}$	1.93*** (0.27)	1.88*** (0.27)	0.96** (0.40)	1.11*** (0.39)
Firm*year f.e.s	Yes		Yes	
Year fixed effects	Yes		Yes	
Firm fixed effects	Yes		Yes	
Observations	44,295	44,295	19,844	19,844
R-squared	0.37	0.16	0.38	0.14

Notes: The dependent variables are calculated as changes in logs (i.e. percentages). Repayment shock $_{i,t}$  is measured as a fraction of the total loan portfolio to listed firms. The interpretation of the coefficient for example in column 2 is that a one percentage point increase in the repayment shock is associated with a two percentage point increase in lending to other firms. The repayment shocks and the dependent variables are winsorized at the top and bottom one percent of observations. Standard errors are clustered at the bank and year level, and shown in parentheses. \*, \*\*, and \*\*\* indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

ing the outcomes observed in Japan, and to explore how general these results can be expected to be, however, requires a model. I turn to this task in the following section.

## 1.4 Model

In this section, I present a model in which firms can finance themselves using bonds, in addition to borrowing from banks. By modeling both bond markets and banks, I provide a simple framework to characterize the interaction between the two markets. Using this framework, I demonstrate how the empirical finding that bond liberalization leads banks to increase lending to less productive firms depended in Japan's case on inflows to bond markets and financial repression of savers. However, these outcomes also result from more general conditions of capital inflows or bank financial constraints.

Table 1.8: The effect of repayment shocks on bank lending, 1983-1987

Dependent variable:				
$\Delta$ Log loans to	Real estate		Small/medium firms	
	(1)	(2)	(3)	(4)
Repayment shock $_{i,t}$	3.3*** (1.0)	2.3** (1.0)	2.5*** (0.8)	1.3** (0.6)
Year fixed effects	Yes	Yes	Yes	Yes
Bank fixed effects		Yes		Yes
Observations	393	393	400	400
R-squared	0.13	0.56	0.09	0.60

Notes: The dependent variables are calculated as changes in logs (i.e. percentages). Repayment shock $_{i,t}$  is measured as a fraction of the total loan portfolio to listed firms. The interpretation of the coefficient for example in column 2 is that a one percentage point increase in the repayment shock is associated with a two percentage point increase in lending to real estate firms. The repayment shocks and the dependent variables are winsorized at the top and bottom one percent of observations. Standard errors are clustered at the bank and year level, and shown in parentheses. \*, \*\*, and \*\*\* indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

### 1.4.1 Setup

There are three types of agents in the model: entrepreneurs, banks, and foreign investors.

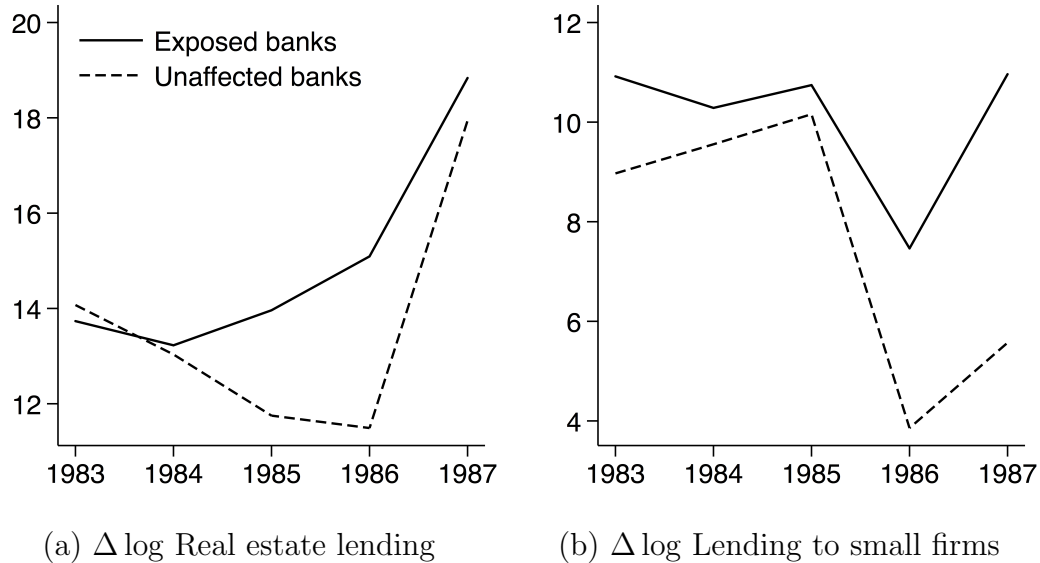
#### Entrepreneurs

Entrepreneurs exist on a joint distribution  $G(a, z)$  of assets  $a$  and productivities  $z$ . Each unit decides whether to save, invest without borrowing, or borrow bank debt  $\ell$  and bonds  $b$  to invest, in which case their capital is:

$$k = \ell + b + a. \tag{1.5}$$

Production is constant returns to scale, so output is the product of capital and entrepreneurs' productivity  $z$ . Output is homogenous.

Figure 1.7: Comparison between affected and unaffected banks



Notes: Panel (a) shows the average change in the log of lending to real estate firms of banks with positive repayment shocks compared with the average among banks with no repayments, and panel (b) shows the comparison for the average change in the log of lending to small and medium firms. While the patterns of lending are similar in the early years of the liberalization, there is a substantial divergence between the growth rates of lending to real estate beginning in 1985, and to small and medium firms beginning in 1986.

Firms' total borrowing is limited to some multiple of the value of their assets:

$$\ell + b \leq \theta a, \quad (1.6)$$

where  $\theta > 1$  represents in a reduced form way the fact that firms' demand for external finance is bounded.<sup>7</sup> This constraint limits the total demand for debt of firms.

The gross interest rate on bank loans is  $r$ . Bond funding is cheaper than bank loans, assumed to be equal to the interest rate paid on deposits,  $r_f$ .<sup>8</sup> However, to gain access

<sup>7</sup>Another way to limit firms' demand for external funds would be for production to be decreasing returns to scale. However, since in the empirical findings firms do not borrow more in response to a decline in borrowing costs, the constraint in equation (1.6) is consistent with the empirical findings of Section 1.3.

<sup>8</sup>An interest rate on bonds equal to the risk-free rate is of course a simplification. The spread on bonds over the risk-free rate varies over time and has been shown to exceed the interest rate on loans in times of stress. However, adding bond spreads is inessential to the main results. A model of households with mean-variance preferences and endogenous bond spreads is Adrian, Colla, and Shin (2013).

to bond markets, firms must pay a fixed cost  $f$ . This prevents small firms from issuing bonds, and can be thought of as either the actual costs involved in arranging a bond issuance, or a reduced form way to represent the size threshold necessary for bonds to be sufficiently liquid to attract investor interest.<sup>9</sup>

All firms that borrow require a bank to monitor production. Bondholders do not monitor. There is a cost to monitor firms, denoted  $m(a)$ , and banks' nominal return on a loan  $\ell$  must be at least as large as banks' monitoring cost. This places an additional constraint on corporate debt structure, as a function of loan size and the spread of the lending rate over the deposit rate:

$$(r - r_f)\ell \geq m(a). \tag{1.7}$$

The monitoring cost is increasing in the size of entrepreneurs' assets,  $m'(a) > 0$ ,  $m''(a) \leq 0$ . This represents the operational costs a bank incurs, such as loan officer salaries. Banks' minimum loan sizes could imply that some firms are too small to borrow from banks. However, this does not play an interesting role in the subsequent analysis, so in what follows I assume that  $m(0) = 0$ . This reduced form constraint pins down the mix of funding demanded by firms.<sup>10</sup>

If an entrepreneur decides not to produce, they can save in banks or invest in bonds. The return on savings is  $r_f$ . Since the return on bonds is the same as bank deposits, households are indifferent between the two assets. Aggregate savings  $S$  are invested in both bank deposits  $D$  and bonds  $B$ :

$$S = D + B, \tag{1.8}$$

---

<sup>9</sup>Blackwell and Kidwell (1988) show that public debt has greater fixed costs, and that this makes large firms more likely to issue public debt.

<sup>10</sup>That all firms that borrow must have a bank loan is motivated by the substantial theoretical evidence on the monitoring role of banks (e.g. Diamond, 1991), the complementarity between informed (i.e. bank) and uninformed capital (Holmstrom and Tirole, 1997), and the flexibility to renegotiate in financial distress (Bolton and Scharfstein, 1996) - against the lower cost of bonds. Empirically, most small firms borrow from banks, and banks are responsible for arranging bond issuances.

where capital letters are used to denote aggregate outcomes. Aggregate loan demand is denoted by  $L$ , and total bond supply  $B^S$ .

Entrepreneurs choose whether to save or invest in order to maximize:

$$\max_{\{b,m\}} \{za, zk - r\ell - r_f b - f \cdot 1\{b > 0\}, r_f a\}, \quad (1.9)$$

where the first term is the return to investing without debt (i.e. self-financing), the second term is the return to borrowing and investing, and the third term is the return to saving. This choice depends on the interest rates  $r$  and  $r_f$ , which are taken as given by entrepreneurs, and is subject to the capital constraint equation (1.5), the borrowing constraint (1.6), and the minimum loan size (1.7).

## Banks

Banks have an endowment of initial equity  $E$ , raise deposits, and lend to firms. The bank balance sheet consists of bank loans  $L$  on the asset side, and the sum of household deposits  $D$ , foreign deposits  $D^F$ , and equity  $E$  on the liability side:

$$L = D + D^F + E. \quad (1.10)$$

Banks require both that firm borrowing is no greater than a multiple of their existing assets in equation (1.6), and that their loans generate enough revenue to cover the associated monitoring cost in equation (1.7). In the spirit of Gertler and Kiyotaki (2010), the deposits banks can attract are limited to a multiple of bank equity:

$$D + D^F \leq \phi E, \quad (1.11)$$

where  $\phi > 0$  is a bank borrowing constraint. When equation (1.11) binds, the banks' balance sheet equation (1.10) becomes:

$$L = (\phi + 1)E. \quad (1.12)$$

This constraint implies either that banks have a limited capacity to intermediate domestic savings, in which case some domestic savings are invested abroad, or else that banks may raise more deposits from foreign sources than they are able to raise domestically.

The banking sector is perfectly competitive and chooses the supply of loans  $L$  and deposit demand  $D$  to maximize profits:

$$\Pi = rL - r_f D - M(L), \quad (1.13)$$

subject to the balance sheet identity (1.10) and where  $M(L)$  is the total monitoring cost associated with the loan portfolio  $L$ .

### Foreign investors

Foreign investors play a reduced role in the model. When foreign deposits are permitted, foreign investors provide bank deposits  $D^F$  up to the maximum allowed by the constraint in equation (1.11). I consider cases in which  $D^F$  is exogenously given at some level below the maximum.

Foreign demand for bonds adds to domestic bond demand:

$$B^S = B + B^F, \quad (1.14)$$

which allows consideration of cases in which bond liberalization interacts directly with capital inflows. Similarly to foreign bank deposits, I consider cases in which  $B^F$  is given. In the absence of such assumptions, bond inflows could entirely displace domestic investors in bond markets.

## 1.4.2 Equilibrium

In a competitive equilibrium, entrepreneurs and banks maximize subject to constraints, and the markets for loans, bonds, and savings clear. Bank equity  $E$ , the risk free rate  $r_f$ , and inflows  $D^F$  and  $B^F$  are taken as given, and  $r$  is determined in equilibrium.

To see this, note that the sum of bank loans and bond supply must equal the sum of household savings, bank equity, foreign deposits, and foreign demand for bonds:

$$L + B^S = S + E + D^F + B^F. \quad (1.15)$$

The demand for funds is decreasing in  $r$ , because fewer entrepreneurs choose to borrow when the interest rate is high. The supply of savings is increasing in  $r_f$ : higher returns on savings discourage entrepreneurs from production. Since  $r_f$  is taken as given, in equilibrium  $r$  rises or falls until investment demand equal savings plus bank equity. Inflows to banks or bonds,  $D^F$  and  $B^F$ , add to the total supply of capital in the economy; this reduces the interest rate.

In an economy without bond markets, i.e.  $f = \infty$ , all entrepreneurs with productivity higher than  $r_f$  invest in production, and those with productivity greater than  $r$  borrow to invest. When  $f = \infty$ , entrepreneurs' decision to save or invest depends on the return to saving, relative to the profits of production funded with or without bank debt. Comparing the returns to investing only one's own assets to the returns to saving yields a simple rule to invest in production if  $z > r_f$ . Comparing the returns to investing without bank debt to the returns to investing using bank debt leads entrepreneurs to borrow if their productivity exceeds the interest rate on bank debt, i.e.  $z > r$ . These thresholds are plotted in  $(a, z)$  space in panel (a) of Figure 1.8, assuming finite bounds on both entrepreneurs' assets  $[\underline{a}, \bar{a}]$  and productivity  $[\underline{z}, \bar{z}]$ .

When bond markets exist, i.e.  $f < \infty$ , firms pay to access bond markets if the cost savings that result from bond issuance exceed the fixed cost of issuing a bond:

$$r\theta a - \left[ \frac{rm(a)}{r - r_f} + r_f \left( \theta a - \frac{m(a)}{r - r_f} \right) \right] \geq f.$$

Using a linear monitoring cost function  $m(a) = m_1 a$ , this can be simplified to a decision to issue bonds if assets are larger than  $a^*$ :

$$a \geq a^* \equiv \frac{f}{\theta(r - r_f) - m_1}. \quad (1.16)$$

Only entrepreneurs with sufficient assets can issue enough bonds to make paying the fixed cost worthwhile. For firms with assets  $a$  below the threshold  $a^*$ , the participation decision remains to invest if  $z > r$ . However, for firms with enough assets to enter the bond market  $a \geq a^*$ , the lower average cost of funding encourages lower productivity firms to enter production, leading to a decision to invest if:

$$z > z^*(a) \equiv r_f + \frac{m(a) + f}{\theta a} \quad \text{if } a \geq a^*. \quad (1.17)$$

When both bank debt and bonds are available, the decision to invest depends on not only productivity but also assets, which allow firms to take advantage of the lower cost of bond finance. The entrepreneurs' decisions with both funding options are shown in Figure 1.8 panel (b). In contrast to panel (a), entrepreneurs with high productivity and high assets borrow from banks and issue bonds. The advantage conferred by size decreases the borrowing threshold for large firms, leading to a lower threshold  $z^* < r$  that is decreasing in the level of assets. As a consequence, the interest rate also affects the mix of funding demanded by a subset of firms. When  $r$  rises, demand for bank loans decreases because some entrepreneurs no longer borrow from banks, and because firms switch to issuing bonds. Firms with  $a > a^*$  and  $z > z^*$  continue to borrow from banks, because banks' monitoring costs lead to a minimum bank loan size in equation (1.7).

The aggregate outcomes in the economy are expressed as functions of the distribution of entrepreneurs' assets and productivity  $G(a, z)$ . Savings are given by:

$$S = \int_{\underline{a}}^{\bar{a}} \int_{\underline{z}}^{r_f} a dG(a, z), \quad (1.18)$$

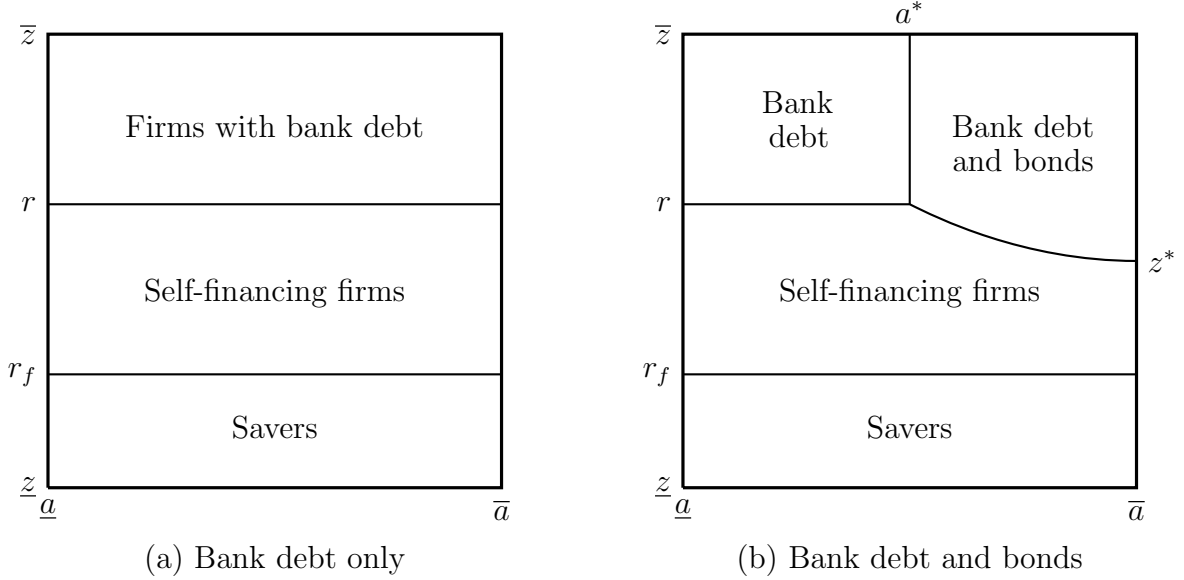
while the demand for bank debt is:

$$L = \int_{\underline{a}}^{a^*} \int_r^{\bar{z}} \theta a dG(a, z) + \int_{a^*}^{\bar{a}} \int_{z^*(a)}^{\bar{z}} \frac{m(a)}{r - r_f} dG(a, z), \quad (1.19)$$

where the first term is the bank debt demanded by firms that do not issue bonds, and the second term is the sum of the minimum loan sizes demanded by firms with mixed



Figure 1.8: Entrepreneurs' decisions



Notes: Panel (a) shows the decisions of a joint distribution of entrepreneurs that are heterogenous in assets and productivity, in the case when bond issuance is infinitely costly, i.e.  $f = \infty$ , and banks are the only source of capital. Panel (b) shows the pattern of entrepreneurs' decisions for a finite  $f' < f = \infty$ .

funding structures. The supply of bonds comes from firms that mix bonds and bank loans:

$$B^S = \int_{a^*}^{\bar{a}} \int_{z^*(a)}^{\bar{z}} \theta a - \frac{m(a)}{r - r_f} dG(a, z), \quad (1.20)$$

where each firm issues the difference between the maximum in equation (1.6) and the minimum bank share in equation (1.7). Total demand for funds in the economy is the sum of demand for bank loans and bond issuance, which together add up to each entrepreneurs' borrowing constraint.

Total output in the economy is:

$$Y = \int_{\underline{a}}^{\bar{a}} \int_{r_f}^{\min\{r, z^*\}} z a dG(a, z) + \int_{\underline{a}}^{\bar{a}} \int_{\min\{r, z^*\}}^{\bar{z}} z \theta a dG(a, z), \quad (1.21)$$

which includes both the output of self-financed entrepreneurs (first term) and the output of firms that borrow up to  $\theta$  and produce (second term). An expression for aggregate

productivity is:

$$Z = \frac{Y}{\min \left\{ \int_{\underline{a}}^{\bar{a}} \int_{\underline{z}}^{\bar{z}} a dG(a, z) + D^F, (\phi + 1)E \right\} + B^F} \quad (1.22)$$

which is the ratio of output to inputs, so the denominator includes both domestic capital and any foreign inflows.

In this economy, the optimal allocation of capital absent borrowing constraints would be for the highest productivity firms to invest all of the capital in the economy. In this setting, misallocation arises because firms' bounded demand for debt  $\theta$  prevents capital from being allocated optimally. As the threshold for entry into borrowing markets falls, this decreases productivity  $Z$ , because the marginal borrowers entering have lower productivity than existing market participants. In addition, the bias towards large firms introduced by bond markets leads to further declines in productivity, or equivalently, increases in misallocation.

### 1.4.3 Results

To consider the impact of a bond market liberalization, I compare the effect of a decline in the fixed cost of issuing bonds from  $f = \infty$  to some lower  $f' < f$ . Since the equilibrium described above is static, the results are discussed using comparative statics.<sup>11</sup>

First, assume the economy is closed, i.e.  $D^F = B^F = 0$ , and that banks are unconstrained, i.e.  $S < \phi E$ . Under these assumptions, the main effect of bond market liberalization is to increase the demand for funds of marginal firms that can access both banks and bond markets. Absent additional capital, this diverts funds from smaller firms, through an increase in the lending rate. This result is formalized in Proposition 1.1.

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<sup>11</sup>Dynamics can be considered as a sequence of static equilibria with evolving bank equity and entrepreneur asset holdings.

**Proposition 1.1.** *Unconstrained closed economy bond market liberalization. If  $D^F = B^F = 0$  and  $S < \phi E$ , (i)  $B = B^S$ , and (ii) a reduction in the fixed cost of issuing bonds to  $f' < f = \infty$ :*

1. *decreases  $a^*$  (new issuers);*
2. *decreases  $z^*$  (marginal large firms enter);*
3. *increases  $r$  (marginal small firms exit);*
4. *decreases  $Y$  (output); and,*
5. *decreases  $Z$  (productivity).*

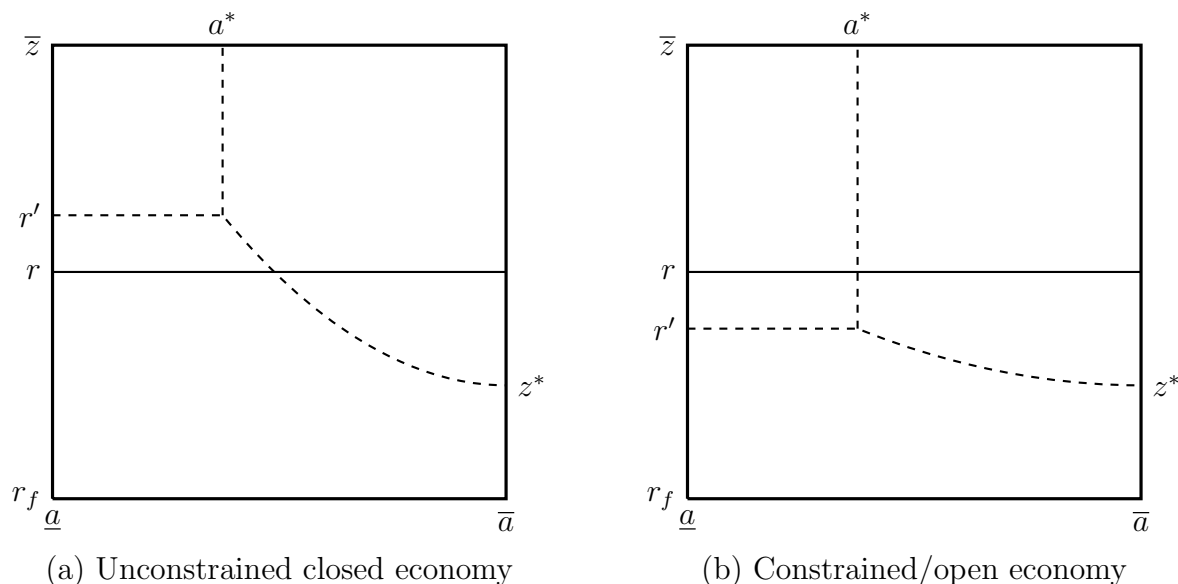
The results of the introduction of a bond market is on shown graphically in panel (a) of Figure 1.9. Decreasing the fixed cost of bond issuance leads more firms to issue bonds. Firms with  $a > a^*$  and  $z > r$  issue bonds, and use the bonds as a substitute for bank debt. Taken alone, the shift in  $a^*$  has no impact on the interest rate because savers are indifferent between bank deposits and bonds.

However, marginal entrepreneurs with many assets begin to borrow from banks and bond markets instead of self-financing, because the lower fixed cost improves the return to borrowing and investing. This arises because the threshold  $z^*$  at which large firms borrow is lower than  $r$ , and increases overall demand for loans and bonds. The increase in demand leads to an increase in the equilibrium interest rate  $r$ , which discourages marginal small firms from borrowing. Higher bank lending rates also encourage additional firms to issue bonds instead of bank debt, which adds to the downwards shift in the bond issuance cutoff  $a^*$ .

Because the closed economy bond market reallocates capital from small productive firms to less productive large firms, all else equal, the bond market liberalization decreases both output and aggregate productivity.

To more closely capture the dynamics of the bond market liberalization in Japan, now consider modified version of Proposition 1.1. As the fixed cost of issuing bonds is

Figure 1.9: Bond market liberalization



Notes: The solid lines represent the decision thresholds of entrepreneurs for  $f = \infty$ , and the dashed lines represent the equilibrium result for  $f' < f$ . Panel (a) shows the effect of a liberalization in which there is no foreign investment and banks are unconstrained. In contrast, panel (b) shows the outcome when domestic savers hold only deposits, and foreign investors purchase all bonds.

reduced to  $f' < f = \infty$ , consider the impact of also allowing inflows. There are three separate sufficient conditions for the bond market liberalization to lead to a decline in  $r$  instead of an increase: financial repression ( $B = 0$ ) and inflows to the bond market ( $B^F > 0$ ), inflows to banks ( $D^F > 0$ ), or if banks are domestically constrained ( $S > \phi E$ ). This result is formalized in Proposition 1.2.

**Proposition 1.2.** *Constrained bond market liberalization. If  $B = 0$  and  $B^F > 0$ , or  $D^F > 0$ , or  $S > \phi E$ , a reduction in the fixed cost of issuing bonds to  $f' < f = \infty$ :*

1. decreases  $a^*$  (new issuers);
2. decreases  $z^*$  (marginal large firms enter);
3. decreases  $r$  (marginal small firms enter);
4. increases  $Y$  (output); and,

5. *decreases  $Z$  (productivity).*

These results are shown in panel (b) of Figure 1.9. As in the case of a closed economy liberalization, the assets threshold  $a^*$  for bond issuance falls because of the fall in  $f$ , and more firms issue bonds. Firms that switch from bank to bond financing repay bank debt, and marginal large firms choose to enter the borrowing market as  $f$  declines, as before. These firms demand bank loans and issue bonds, but their demand for bank debt is less than the repayment of bank debt by firms issuing bonds. This leads to a decline in demand for loans.

To make clear the effect of bond inflows, consider the case in which domestic savers are not permitted to invest in bonds, i.e.  $B = 0$ , and foreign investors purchase bonds. When savers can frictionlessly substitute investing in bonds for bank deposits, this reallocates savings from banks to bond markets. When  $B = 0$ , however, this sets  $S = D$  in equation (1.8), and all bonds are purchased by foreign investors, i.e.  $B^S = B^F$ . Preventing savers from substituting from deposits to bonds leads to excess deposits relative to declining loan demand. A fall in the lending rate brings the market back into equilibrium, but necessitates more lending to entrepreneurs with low productivity. Although output rises due to the increases in entrepreneurs who borrow and invest, productivity falls.

In the more general case when  $B^F > 0$  but  $B \neq 0$ , foreign inflows to the bond market still cause some savers to be crowded out of investing in bonds. This leads to the same effect as described above, although to a lesser extent if domestic households have some ability to shift savings into the bond market.

The bond liberalization leads to spillovers because banks lose a portion of their loan volume to bond issuance, and then hold excess deposits relative to their remaining portfolio of loans. Returning deposits to households is ruled out by the exogenous risk-free rate. Absent other safe assets or investment options, and assuming firms' total

borrowing remains unchanged, banks lend to marginal firms.<sup>12</sup>

These outcomes are in fact isomorphic to a bond market liberalization in which banks are constrained, in which equation (1.11) binds because either  $S > \phi E$  or  $D^F > 0$ . When constrained banks limit productive investment, bond market liberalization allows more firms to invest. Substitution away from banks frees up bank funds to lend to other firms, which leads to declines in the thresholds for borrowing and bond issuance. In particular, if banks borrow from abroad up to the constraint in equation (1.11), firms' substitution into bonds leads to inflows either to banks or to domestic bond issuance. This also leads to a decline in the interest rates and a fall in the productivity of marginal large and small borrowers.

In relaxing banks' borrowing constraints, bonds can be particularly useful in allowing the economy to grow. Consider the case in which banks do not have sufficient equity to intermediate domestic savings ( $S > \phi E$ ). In this case, banks borrowing constraint limits their ability to lend. By allowing firms other financing options, bond markets free up capital that banks can lend elsewhere. Any increased demand for funds, for example, due to a productivity shock, leads to an increase in  $r$ . The growth impact of a productivity shock is limited by the ability of banks to immediately intermediate sufficient capital. Bond markets allow firms an alternative source of financing, and an increase in the lending rate makes issuing bonds more attractive relative to bank debt. By providing an alternate form of financing, bond markets increase output relative to a case in which there are banks alone. This is because some firms can obtain funds by issuing bonds, and so are not bound by the bank borrowing constraint.

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<sup>12</sup>The implications of altering the risk-free rate or borrowing limits are explored in Section 1.5.

#### 1.4.4 Discussion

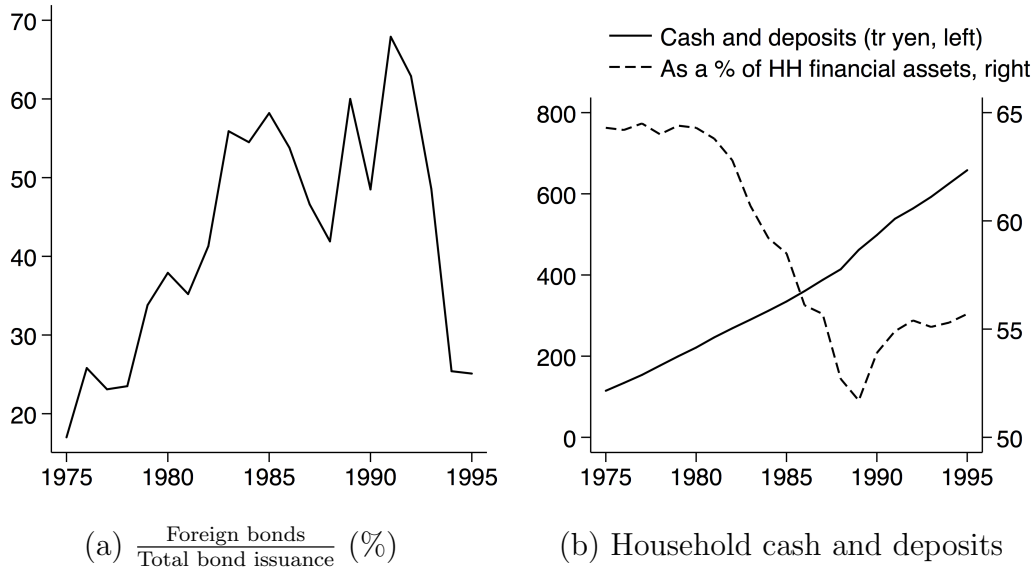
This model generates predictions consistent with the empirical finding that bond market liberalization indirectly affected bank lending. Firms that gained access to bond markets used bonds primarily as a substitute for bank debt. Bonds and bank loans are assumed to be substitutes in the model. As the fixed cost of bond issuance  $f$  falls, the threshold for bond issuance  $a^*$  falls. The extent of substitution is determined by  $m(a)$ . Banks face repayments due to the decline in  $a^*$ , which leads to a fall in demand for bank loans. That banks repaid as a result of the liberalization lend more to smaller firms and real estate is captured in the model results by declines in the lending rate  $r$  and the threshold for borrowing for firms with assets  $z^*$ .

In Japan, bond liberalization coincided with reduced restrictions on foreign exchange. The initial reforms to issuance criteria were followed by reforms in 1980 that allowed foreign bond issuances. Although firms still had to meet issuance requirements, less restrictive regulations applied to foreign bond issuance than to domestic bonds. Domestic issuances were required to be managed by trustee banks that charged high fees, and the fees for foreign issuance were much lower. A substantial portion of bonds issued from 1983 to 1993 went to foreign investors, as shown in Figure 1.10 panel (a).

Over the same period, deposits in the Japanese banking system grew steadily. This was partly due to the fact that savings options had been restricted during the post-war period, to allow the government control over which projects obtained funding through state influence over banks. Regulatory changes to deposit markets began after the liberalization of bond markets was well under way. Reforms to deposit markets allowed households to access a slowly expanding range of savings instruments, however, deposits in the banking system remained more than half of household financial assets over the 1980s, as shown in Figure 1.10 panel (b).

The model generates predictions for the effects of bond market liberalization which

Figure 1.10: Foreign bond issuance and bank deposits



Notes: Over the 1980s, a significant portion of bond issuance consisted of foreign bonds. Over the same period, deposits remained more than half of total household financial assets, and the deposits in the banking system grew steadily in nominal terms. Source: Hoshi and Kashyap (2004).

demonstrate that the key factors contributing to the spillover effects described in Section 1.3 were foreign inflows and financial repression. The results indicate that these outcomes are also what would occur in an environment with inflows to the banking sector or constrained banks. Because bond market liberalization has these effects, it leaves open questions as to how this differs from other forms of capital account liberalization, and whether the size of bond markets has an impact on how an economy reacts to other shocks. These questions are explored in Section 1.5.

## 1.5 Implications

In this section I consider how bond market liberalization differs from other forms of capital account liberalization, and how the size of bond markets affects the reaction of an economy to other shocks. The other forms of liberalization I consider are a decline



in the risk free rate and changes in firm borrowing limits.

### 1.5.1 Decreasing the risk-free rate

One way in which capital account liberalization is often modeled is as a decline in the risk free rate. For example, a closed economy with a high internal risk-free rate opens its financial markets to abroad, and domestic agents can borrow more cheaply. To explore how a fall in the risk-free rate compares to liberalization that occurs primarily in the bond market, I consider four cases: an economy with banks only, an economy with only bonds, an economy where all firms mix between bonds and bank debt, and a case in which some firms borrow from banks and some firms mix. These cases demonstrate how bonds amplify the effects of a decline in  $r_f$  on interest rates, output, and productivity.

In an economy where the only option for financing is banks, the reduction in  $r_f$  passes through to the lending rate  $r$ , due to competition among banks.<sup>13</sup> Declining borrowing costs increase the incentives of firms to borrow. An increase in loan supply is only possible if domestic banks are not constrained, and if inflows provide additional deposits for banks to intermediate. If banks are unconstrained, inflows lead to a decline in  $r$  and an increase in output, until banks' constraint binds, at which point  $r$  cannot fall.

When there is only direct finance, a decline in  $r_f$  makes financing cheaper for all firms. Without banks, the lending rate equals the risk-free rate. A decline in  $r_f$  encourages marginal firms to take out loans. Inflows drive down the interest rate, which discourages saving and encourages entry. This leads to a boom in output. As in the bank-only case, because marginal entrants have lower productivity than the existing group of active firms in the economy, productivity falls. However, the effect of a decline in  $r_f$  is larger relative to the bank-only case, because banks' borrowing

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<sup>13</sup>The extent of pass through observed empirically varies, see Harimohan et al. (2016), for example.

constraint provides an upper bound on inflows. Bond markets are not subject to such frictions, and thus a decline in  $r_f$  may lead to greater increases in output, relative to the banks only case.

In an economy in which all firms issue bonds and also borrow from banks, i.e.  $f = 0$  and  $m(a) > 0$ , there is a single participation threshold for borrowing that depends on firm assets:  $z^* = r_f + \frac{m(a)}{\theta a}$ . A decline in  $r_f$  leads to a decline in  $z^*$ , as well as a shift in savings behavior. All firms can expand by borrowing more from bond markets, but due to the minimum loan size requirement the entry threshold is lower for large than for small firms.

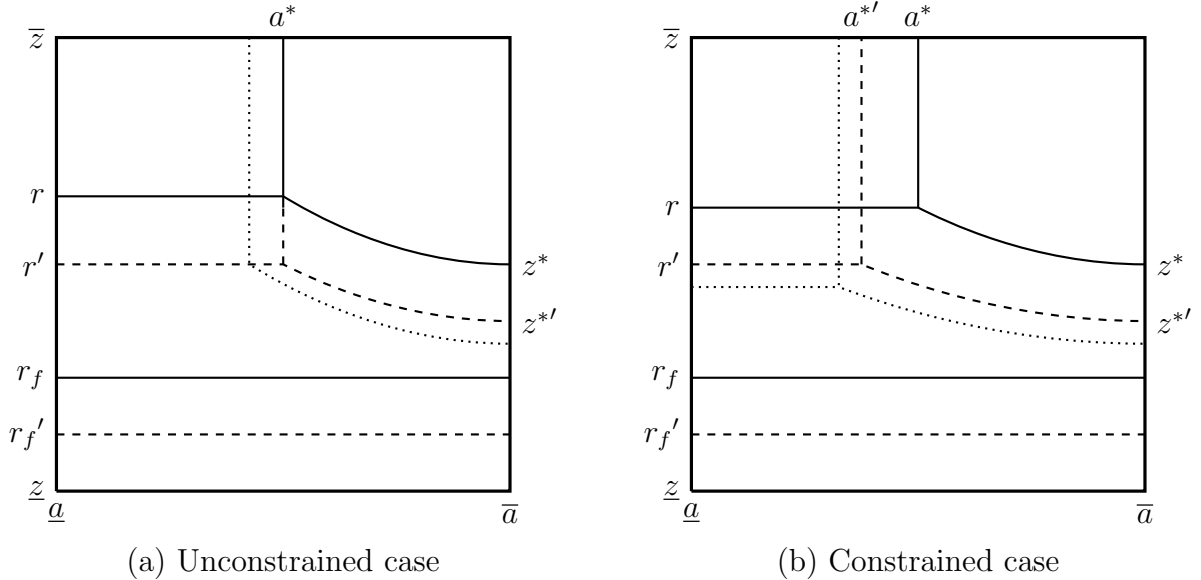
When only a subset of firms issue bonds, the effect of a fall in  $r_f$  on  $z^*$  is negative, as in the case above. When banks are unconstrained, the decline in  $r_f$  does not affect the size threshold for bond issuance  $a^*$ , which is a function of the spread  $r - r_f$ . However, when banks are constrained, the constraint limits the pass through of  $r_f$  to  $r$ , and cause  $a^*$  to shift to the left. This implies more firms issue bonds. The shift in  $a^*$  leads firms to depend less on the banking sector, but amplifies the effect of the decline in  $r_f$  among firms large enough to issue bonds. As in the case of bond market liberalization, that firms can access bond markets relaxes bank constraints, and allows banks to lend more to small firms with marginal productivity.

The changes that result from a decline in  $r_f$  are summarized in Proposition 1.3, and shown graphically in Figure 1.11.

**Proposition 1.3.** *Decline in the risk free rate. A decrease in  $r_f$ :*

1. *weakly decreases  $a^*$  (new issuers);*
2. *decreases  $z^*$  (marginal large firms enter), provided  $f < \infty$ ;*
3. *decreases  $r$  (marginal small firms enter), by more for  $f' < f$ ;*
4. *increases  $Y$  (output), by more for  $f' < f$ ; and,*
5. *decreases  $Z$  (productivity), by more for  $f' < f$ .*

Figure 1.11: Decline in the risk free rate



Notes: Panel (a) shows the effect of a decline in the risk-free rate for the case when banks are unconstrained. The solid lines represent the decision thresholds of entrepreneurs for some initial  $r_f$ , while the dashed lines represent a decrease in the risk-free rate to  $r_f' < r_f$ . The dotted line indicates the implications of larger bond markets on the change. Panel (b) shows the case of constrained banks. Again, the solid line shows the initial participation decisions, while the dashed lines represent the outcomes at  $r_f' < r_f$ , and the dotted line demonstrates how bond markets amplify the response.

*That is, bond markets amplify effects on  $r$ ,  $Y$ , and  $Z$ , i.e. 3-5 are decreasing in  $f$ .*

Banks attenuate the full consequences of a decline in  $r_f$ , in particular when they are constrained. This could be seen as an impediment to growth, which bond markets alleviate. However, in the context of inflows, bank constraints can also be seen as limiting excessive capital from entering an economy. In this vein, bond markets may augment the ability of an economy to attract foreign capital. As a result, bond markets amplify the effects of a decline in  $r_f$  on interest rates, output, and productivity.

The decline in productivity predicted here is consistent with the evidence of Reis (2013) in Portugal during the 2000s, in which entrepreneurs' participation in production is also based on the relative returns of investing versus saving. These predictions also relate to the model and empirical findings of Gopinath et al. (2017), who examine the

efficiency of capital allocation in Spain and Southern Europe following the adoption of the Euro. The authors show increasing dispersion of the marginal revenue product of capital within manufacturing industries, which is consistent with the broader range of participation in production that results from a fall in the risk free rate in this framework.

Another common explanation for the real estate and stock market bubbles of the 1980s in Japan was the decline in interest rates, which fell from late 1980 until May of 1989. Given the similarities between Propositions 1.2 and 1.3, the aggregate implications of a fall in the risk free rate would go in the same direction as a bond market liberalization, potentially amplifying the bond market's effects.

### **1.5.2 Increasing firm borrowing**

An increase in the parameter  $\theta$ , which bounds the demand of firms for external financing, increases firms' borrowing. This can be interpreted either as an increase in demand, a loosening of a binding firm borrowing constraint, or an increase in the collateralizability of firm assets. In either case, the leverage firms can obtain is higher as a result of the increase in  $\theta$ .

Given a limited quantity of available funds, an increase in the demand for debt or borrowing limits of individual firms allows higher productivity firms to reach a larger scale, and crowds marginal borrowers out of the market for bank loans. To make clear how the inclusion of bond markets affects the impact of an increase in firm borrowing limits, I consider the same four cases as in the previous section: banks alone, bonds alone, all firms mix, and some firms remain bank-dependent.

With bank debt alone and no bond market, banks' borrowing constraints limit the capital that banks can extend to firms. As a result, an increase in  $\theta$  leads to an increase in  $r$ , and marginal entrepreneurs no longer borrow and invest. A smaller subset of firms obtain more funds, which is positive for both output and aggregate productivity. In the

case where banks are unconstrained, however, the increase in  $\theta$  would have no impact on  $r$ .

Without banks, if all projects are financed directly by household investment in bonds, an increase in  $\theta$  requires additional savings. Inflows fund the gap between new demand and domestic savings, because there is no impediment to investment flowing from abroad into bonds. There is no impact on  $r$ , and so the economy expands by more than in the banks-only case. This increases productivity, because the scale of all active firms increases.

When all firms mix between bank debt and bonds, an increase in  $\theta$  can be met with increased bond issuance. Bond markets provide a way around the bank constraint. However, when some firms are bank-dependent, bond markets allow more large firms to benefit from the increase in leverage, but small bank-dependent firms may be crowded out. These effects are summarized in Proposition 1.4 and Figure 1.12.

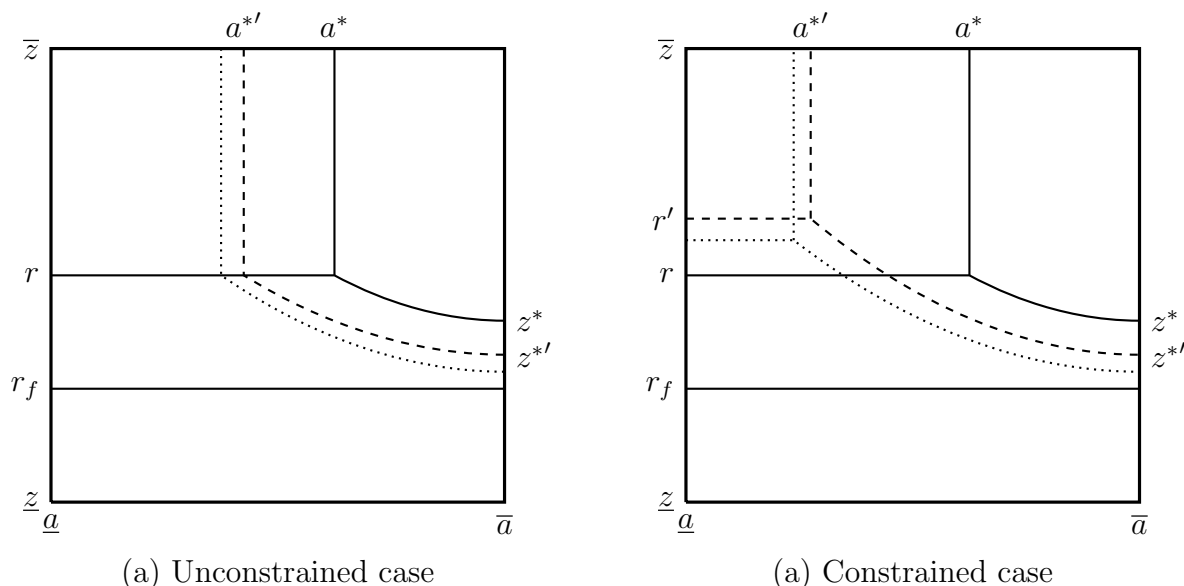
**Proposition 1.4.** *Increase in firms' borrowing. An increase in  $\theta$ :*

1. *decreases  $a^*$  (new issuers);*
2. *decreases  $z^*$  (marginal large firms enter), provided  $f < \infty$ ;*
3. *increases  $r$  (marginal small firms exit), by less for  $f' < f$ ;*
4. *increases  $Y$  (output), by more for  $f' < f$ ; and,*
5. *increases  $Z$  (productivity), by less for  $f' < f$ .*

*That is, bond markets amplify increases in  $Y$ , but attenuate changes in  $r$  and  $Z$ .*

When banks have a limited capacity to intermediate funds, bond markets provide an additional source of financing for firms. With banks alone, a rise in  $\theta$  leads to an improvement in the efficiency of capital allocation, as higher productivity firms are able to produce more, and some marginal firms are crowded out of the borrowing market. With bond markets, however, the effect on capital misallocation is less positive: given

Figure 1.12: Increasing firm borrowing



Notes: Panel (a) shows the effect of an increase in firm borrowing to  $\theta' > \theta$  for the case when banks are unconstrained. The solid lines represent the decision thresholds of entrepreneurs for some initial  $r_f$ , while the dashed lines represent a decrease in the risk-free rate to  $\theta' > \theta$ . The dotted line indicates the implications of larger bond markets on the change. Panel (b) shows the case of constrained banks. Again, the solid line shows the initial participation decisions, while the dashed lines represent the outcomes at  $\theta' > \theta$ , and the dotted line demonstrates how bond markets amplify the response.

additional supply of funds via bond investors, the increase in  $\theta$  simply increases leverage across all borrowing firms. Further, the preference for large issuers in the bond markets distorts the allocation of capital towards large firms, and may crowd smaller firms out of the market.

This result also relates to recent research on capital misallocation and financial frictions. Dynamic models of financial frictions predict that financial liberalization is associated with a better allocation of resources across firms (Midrigan and Xu, 2014; Buera et al., 2011). This conclusion is supported by empirical evidence in Eastern Europe since the collapse of the Soviet Union (Larrain and Stumpner, 2017), where lower borrowing costs are understood as having allowed firms to borrow greater amounts against existing collateral. However, bond issuance was extremely limited in these settings.

The bond market liberalization in Japan was first designed to allow secured bond issuance, followed by unsecured bond issuance later on. Arguably the former and certainly the latter reform aimed to allow firms to issue debt beyond what they could obtain in collateralized lending from banks. This could be interpreted as an increase in  $\theta$ . However, Japanese firms' leverage was for the most part stable or falling during the 1980s, so if anything this suggests that  $\theta$  was declining. A decline in  $\theta$  could also put additional downwards pressure on lending rates, allowing more marginal firms to borrow and produce, increasing output, but decreasing productivity.

The results of this section suggest that the growing influence of market-based financing may affect future developments that affect demand for external finance or allow firms to increase leverage. In both the Eastern and Southern European cases, banks received considerable inflows, which is evidence that a constraint on banks was far from binding, at least in the early 2000s. This changed dramatically after 2008, when many banks faced serious difficulties, either due to their own loan portfolios and the economic downturn, or through exposures to troubled sovereigns. The effects of such bank shocks are explored in the next section.

### **1.5.3 Bank shocks**

The availability of substitutable forms of finance is understood to dampen the impact of bank shocks, and yet such shocks still played a significant role in the fall in output post-2008 (e.g., Chodorow-Reich, 2014). Similarly, banks in Japan suffered a large shock following the collapse of land prices and the stock market bubble in the early 1990s. Gan (2007b) estimates the effect of the collapse of land prices on bank lending, using variation in banks' exposure to real estate, including land holdings.

In the model presented here, a shock of this nature corresponds to a decline in either banks' borrowing constraint  $\phi$  or bank equity  $E$ . If banks are unconstrained such a

shock has no effect, as shown in panel (a) of Figure 1.13. For constrained banks, the effects are explored in Proposition 1.5.

**Proposition 1.5.** *Decrease in banks' borrowing capacity. When  $D = \phi E$ , a decrease in  $\phi$  or  $E$ :*

1. *decreases  $a^*$  (new issuers);*
2. *does not change  $z^*$  (no change for large firms);*
3. *increases  $r$  (marginal small firms exit), by less for  $f' < f$ ;*
4. *decreases  $Y$  (output), by less for  $f' < f$ ; and,*
5. *increases  $Z$  (productivity), by less for  $f' < f$ .*

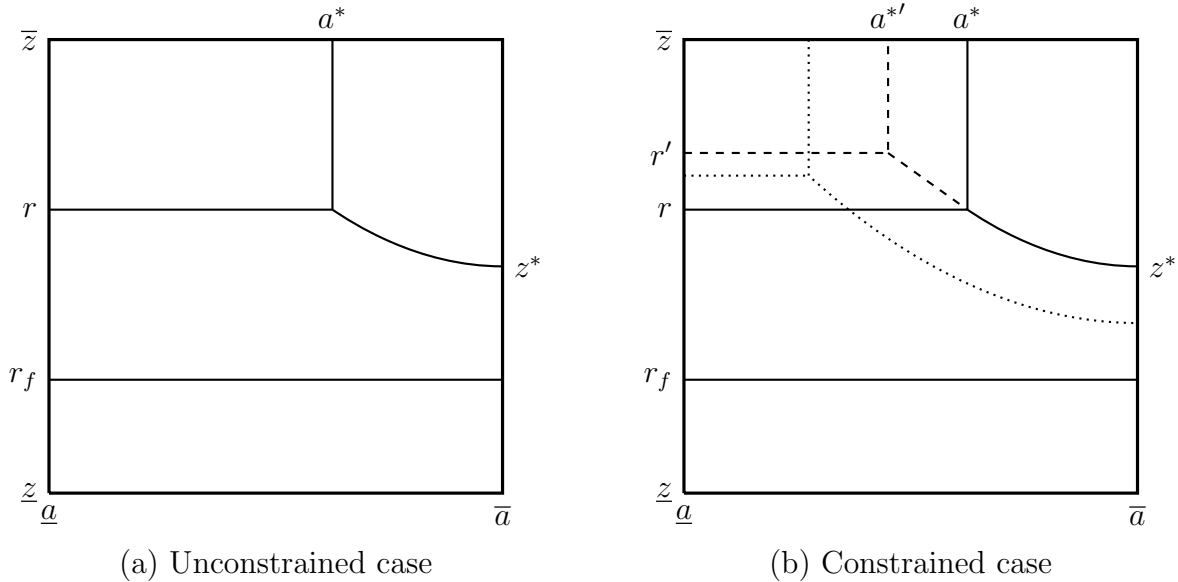
*That is, bond markets attenuate the increases in  $r$  and  $Z$ , and the decreases in  $Y$ .*

A shock to bank borrowing  $\phi$  or bank equity  $E$  causes the deposit demand of the financial sector to fall. The fall in loan supply leads to an increase in  $r$ . When loans are more expensive, fewer firms borrow, and more firms issue bonds (i.e.  $a^*$  falls), as shown in panel (b) of Figure 1.13. Output contracts and productivity improves, because firms that continue to have access to external finance are more productive than firms that can no longer borrow. The increase in  $r$  increases bank profits, and decreases entrepreneurs' profits.

Bond markets cushion the impact of the initial shock on interest rates: as  $r$  rises, more firms issue bonds instead of bank debt, which allows for more production than if banks were to intermediate capital alone. Bond markets thus attenuate the decline in output. To see this, consider an economy without bonds. A shock to bank equity leads to a decline in loan supply. For the lending market to clear, a large increase in  $r$  is necessary. The savings that banks cannot intermediate because of the bank borrowing constraint flow abroad. With bond markets, the increase in  $r$  not only discourages borrowing from banks, but also makes issuing bonds more attractive. Some savings



Figure 1.13: Bank shocks



Panel (a) shows the effect of a tightening of bank borrowing limits  $\phi' < \phi$  for the case when banks are unconstrained. When banks' constraint does not bind, this has no effect. Panel (b) shows the case of constrained banks. Here, the solid line shows the initial participation decisions, while the dashed lines represent the outcomes at  $\phi' < \phi$ , and the dotted line demonstrates how a larger bond markets further dampens the effects of the shock.

can move from bank deposits to investing in bonds. As a result,  $r$  increases by less, relative to the case in which there is no direct finance.

In dampening the effects of a financial shock on the economy, however, bond markets also slow the pace of bank recovery. At a lower  $r$ , bank profits are lower. Consequently, there is slower growth in bank net worth. This has implications for policies that encourage bond issuance. For example, in reducing bond yields, quantitative easing may limit the prospects for bank recovery.

Japan's bond market liberalization seemed like a positive liquidity shock for banks. However, a different perspective is that the loss of large, highly profitable borrowers negatively impacted banks' long-run franchise value. The collapse of the asset price bubble affected the operations of banks that had increasingly lent to real estate companies. The real estate companies held assets that had grown enormously in value and

were a common form of loan collateral. Later, banks evergreened loans to avoid losses to bank equity. As higher capital requirements were introduced in the 1990s, banks acted to avoid shocks to their net worth that would require contemporaneous decreases in the sizes of their lending portfolios. Ultimately, the consolidation and contraction necessary among Japanese financial institutions is a problem that continues to have implications today.

## 1.6 Conclusion

This chapter revisits the bond market liberalization in the 1980s in Japan as a case that highlights the interactions between bond markets and banks. I demonstrate that the liberalization led firms to issue bonds that were primarily used to repay bank debt. The repayment of bank debt was a positive liquidity shock for banks that lent to firms affected by the liberalization shock. This liquidity shock was transmitted by banks to firms in other parts of the economy, namely bank dependent firms, small and medium firms and real estate companies. This expansion in bank activity led to increased bank exposure to riskier segments of the economy.

I develop a model to make sense of the empirical evidence, in which firms borrow from banks and issue bonds. The model matches the empirical evidence and demonstrates that the key factors that led the bond market liberalization to have spillover effects via banks were the repression of domestic savers, combined with foreign investment in the bond market. This in particular contributed to excess deposits at banks, which then drove lending to marginal borrowers in the economy. The Japanese case is in this respect similar to other liberalization episodes. However, the channel by which inflows affected Japan differed, by flowing through corporate borrowers and indirectly reaching banks and other firms.

The transition to greater market-based financing is also relevant in other markets.

China has successfully established a large and fast-growing corporate bond market over the past decade. Despite increased offshore issuance in recent years, foreign investment in Chinese bond markets remains limited. However, new programs introduced to allow foreign investors to buy onshore bonds via the Hong Kong bond market are estimated to spark inflows of up to US\$ 250 million by 2020.<sup>14</sup> China's inclusion in emerging-market bond indices is likely to encourage further foreign investment in Chinese bonds. The model and results presented here suggest policymakers should be wary of how this impacts Chinese lenders.

In developed markets also, the importance of bond markets has grown steadily in recent years, encouraged by both the slow post-crisis recoveries of many banks and policies that facilitate bond issuance and/or reduce bond yields. The evidence in this chapter suggests that this will affect not only bank outcomes but also the reaction of economies to future shocks. In particular, bond markets appear to amplify positive shocks such as increases in firm borrowing and declines in the risk-free rate, while attenuating the impact of negative financial shocks. In relaxing banks borrowing constraints, bond markets surge both in booms, and when there are financial crises. These results suggest that characterizing bond markets and these asymmetries is important to refining the approaches that incorporate financial frictions in macroeconomic models.

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<sup>14</sup>The Economist, "Financial assets, made in China." June 22, 2017.

# Chapter 2

## Default, commitment, and domestic bank holdings of sovereign debt

### 2.1 Introduction

Financial institutions generally hold large amounts of sovereign debt, and, in particular, the debt of their own sovereign. A recent literature has documented this globally (Gennaioli et al., 2014a), and specifically in the context of the European sovereign debt crisis (Broner et al., 2014; Brutti and Saure, 2014). In turn, a growing literature has explored the implications of these holdings for sovereign default, noting that the ability of foreigners to sell their bonds to domestic investors makes selective defaults difficult (Broner et al., 2010), emphasizing that with large bank holdings, sovereign default leads to contractions in credit and output losses (Gennaioli et al., 2014b; Perez, 2015), and arguing that financial repression may explain some of these holdings, and that such policies may be motivated by generating a commitment to not default (Becker and Ivashina, 2014; Chari et al., 2015).

This chapter provides a three-period model to further explore how domestic bank holdings of sovereign debt interact with sovereign default and financial repression. In particular, I provide a joint answer to the following three questions: How do domestic banks affect the default incentives of the sovereign? Second, how does sovereign risk

affect domestic demand for government debt? Third, how do these holdings affect government policy towards banks, and in particular, financial repression?

The model has two central ingredients and a series of predictions that follow from them. First, banks demand government debt because it serves as collateral in interbank markets, which is valuable for liquidity management, modeled as banks being matched with investment projects that exceed what they collect as deposits. This use of government debt is emphasized by Bolton and Jeanne (2011) and Gorton and Ordoñez (2013). It implies that banks' demand for government bonds is downward-sloping, and depends on the extent of liquidity needs as well as on the expected return on the bond. Banks with access to investment opportunities choose to invest in government debt in order to collateralize interbank lending. Without access to alternative safe assets, higher sovereign risk may increase demand for sovereign debt because banks require government assets to pledge as collateral.

Second, banks are a crucial source of credit to firms. However, banks are constrained in their lending by the amount of equity they hold. Financial frictions in the form of an agency problem on bankers that can divert funds puts a limit on banks' ability to attract deposits. When there is a default on government bonds, bank equity falls, which reduces the ability of banks to attract deposits. This in turn limits the bank funding available to the real economy and leads to declines in output. These endogenous output losses provide a commitment technology to sovereigns, and default costs increase with domestic banks' holdings of government debt. This also provides a microfounded explanation for the secondary market theory of Broner et al. (2010), demonstrating one way in which bonds are more valuable in the hands of domestic agents.

As in any canonical model of sovereign default, the probability of default is increasing in the amount of foreign borrowing and there is a Laffer curve on the total amount of resources borrowed from abroad. However, the output losses from default in this model

are endogenous. Because the output losses are endogenous, the model can generate positive holdings of risky debt and default in equilibrium. Moreover, the model makes the surprising prediction that default is more likely when banks are well-capitalized. In the model, there can be deposit flight both in anticipation of and as a consequence of default, and higher levels of initial deposits are shown to lead to lower default risk.

Like in Gennaioli et al. (2014b) and Perez (2015), sovereign defaults are followed by large contractions in private credit, and default has more severe effects but is less likely when banks hold more public debt. Unlike these authors, banks demand public debt to use as collateral, instead of as a store of liquidity. Relative to Perez (2015), this chapter assumes that banks with investment opportunities have a motive to hold government bonds, and that default disrupts deposits. In contrast to Gennaioli et al. (2014b), lending to public and private projects is contemporaneous, the return on both is uncertain, and the probability of default is determined endogenously as a function of the realized level of private productivity.

In addition, banks choose how many bonds to hold to maximize profits, but the government chooses to default to maximize social welfare. Because domestic banks take bond prices and default probabilities as given, yet their holdings of bonds affect the incentives of the policymaker to default, there is a pecuniary externality. Financial repression can increase welfare, since the competitive equilibrium leads to under-holding of government bonds. However, financial repression can seldom prevent default entirely, and in the event of default leads banks and households to be strictly worse off.

The rest of the chapter is structured as follows. The remainder of this section reviews related literature. In Section 2.2, I present the model and define equilibrium. The results of the model are described in Section 2.3. Section 2.4 explores the externality that arises from domestic holdings of sovereign debt, and discusses the optimality of financial repression. In Section 2.5, I discuss two extensions of the model, which

incorporate a second safe asset, and foreign capital inflows to banks. The final section concludes.

### 2.1.1 Related literature

This chapter relates to research on sovereign default, financial frictions, and bank holdings of government debt.

There is a considerable literature in economics focused on sovereign default.<sup>1</sup> Canonical sovereign default models (Eaton and Gersovitz, 1981; Arellano, 2008) consider exclusion from financial markets and exogenously assumed output losses to discipline borrowers. That sovereign crises are often coincident with banking crises is shown by Reinhart and Rogoff (2008).<sup>2</sup> Gennaioli et al. (2014b) model banks that lend to the government as a store of liquidity, and can then make fewer private investments in the event of nonrepayment. They also provide empirical evidence that banks' sovereign exposures are associated with post-default declines in credit. The current chapter instead models a contemporaneous choice between public and private investment, and assumes public debt is necessary to collateralize interbank lending. In addition, in this chapter the productivity of private investment is subject to uncertainty, and its realization affects bank and household income, which leads default to be a function of the realization of productivity as well as other parameters in the model. This characterization allows further scrutiny of the interaction between government and bank incentives.

A number of papers provide quantitative assessments of the link between government debt, domestic banks, and the real economy. Sosa Padilla (2015) provides a quantitative closed-economy model in which banks lend to the government and firms, and firms

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<sup>1</sup>For surveys, see Eaton and Fernandez (1995) and Aguiar and Amador (2014).

<sup>2</sup>A number of authors note that this link has been particularly important in the evolving European crises, for example, Angeloni and Wolff (2012), Popov and van Horen (2013), and Brunnermeier et al. (2011).

require external financing to pay workers up front. Other authors focus on identifying the balance sheet channel in addition to other effects: Bocola (2015) incorporates a risk channel by which banks lend less to a worsening economy, with exogenous default, and Perez (2015) considers the reduced value of public debt as liquidity, with endogenous default. In contrast, the main mechanism by which bank losses occur in this chapter are via deposits, which shrink in anticipation and as a consequence of default.

In addition to the costs of exclusion and bank losses, well-functioning secondary markets can help support risky sovereign debt. Broner et al. (2010) argue that if domestic bondholders are relatively more capable of extracting value from a sovereign following a default, or if the sovereign is less likely to default on them, then in anticipation of a default foreigners sell their debts to domestic agents via secondary markets. As a result, it is difficult for governments to default selectively on foreigners. I show that secondary market theory has an additional underlying driver, in the commitment value of domestic creditors. In this model, domestic creditors affect the repayment incentives of debt in a way that better supports the value of debt, which produces a similar outcome as the political economy explanation that domestic agents are more likely to receive compensation from the government after a default.

Although I do not model secondary markets explicitly, I assume that the sovereign is unable to default selectively on foreign lenders. Sturzenegger and Zettelmeyer (2008) document empirically that following a sovereign default, both domestic and foreign creditors suffer losses. Erce (2012) explores historical patterns of selective default, and finds that it is more common for governments to default on domestic creditors when the banks are not weak, a key prediction of my model.

In addition, I draw from a large literature on the impact of credit disruptions on the real economy. Much research has shown how financial frictions can worsen an economic slump (Bernanke and Gertler, 1989; Bernanke et al., 1999). I adopt financial frictions



following the form of Gertler and Kiyotaki (2010), and expand the role of government to allow for sovereign default.<sup>3</sup> This provides a simple microfoundation for the credit disruption that occurs when a sovereign defaults on domestic banks.

There is also a large body of research that considers what motivates bank portfolios of sovereign debt. In advanced economies, many financial intermediaries use sovereign assets for risk and liquidity management purposes. In developing countries, bank holdings of government bonds may also be driven by a lack of alternatives due to the relatively underdeveloped nature of financial systems (Woodford, 1990; Holmstrom and Tirole, 1998; Kumhof and Tanner, 2008). Given that government debt often has a nearly “risk-free” status, banks use government debt as collateral for interbank loans or repos (Bolton and Jeanne, 2011). Based on this idea, I model banks requiring government debt for use as collateral in interbank markets. Sovereign debt is also used to access to public liquidity: banks can often access cheap lending from central banks collateralized by government debt and other highly rated securities.

As for why banks demand debt of their own sovereign specifically, a number of theories complement the explanations above. Standard theories of portfolio allocation and home bias have some portion of each bank’s portfolio held domestically. Financial repression consists of governments forcing banks to hold sovereign debt or using “moral suasion,” to compel them to do so, and has been a prominent explanation both historically and in present times (Reinhart et al., 2003; Reinhart, 2012; Becker and Ivashina, 2014). In addition, governments may provide incentives for banks to hold domestic sovereign bonds. For example, in Europe, EU government debt receives a zero percent risk weight on the balance sheets of European banks, and is exempt from limits on large exposures.

Finally, this chapter relates to a growing body of empirical research on the shifting

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<sup>3</sup>An additional reference for Gertler and Kiyotaki (2010) are teaching notes by Christiano and Zha (2010) and Groth (2011), who demonstrate a two-period version of the model.

patterns of sovereign debt ownership in current-day Europe. The height of the European debt crisis coincided with the beginning of a large-scale “repatriation” of sovereign debt holdings, particularly in Greece, Ireland, Italy, Portugal, and Spain (GIIPS). The percentage of debt held by domestic creditors in these countries increased since the mid-2000s, and rose dramatically around the height of the crisis. A number of explanations for this have been put forth: secondary market theory (Broner et al., 2014; Brutti and Saure, 2014), financial repression (Becker and Ivashina, 2014), ECB policy (Crosignani et al., 2015), and reaching for yield (Acharya and Steffen, 2015). This model provides a framework for thinking about risky sovereign debt that is owed both domestically and abroad, and how domestic holdings and default incentives interact.

## 2.2 Model

The model combines a canonical model of sovereign default with Gertler and Kiyotaki (2010) style financial frictions, to characterize the interaction between foreign lenders, government default and domestic banks. This is introduced using a three period setup, where the government can borrow only in  $t = 0$  debt that is due in  $t = 1$ . By using this framework, I abstract from the potential for exclusion from foreign financial markets, to characterize more sharply the role of domestic banks and endogenous output losses.

### 2.2.1 Setup

The timing of the model is as follows:

- In  $t = 0$ , the government borrows from foreign lenders and domestic banks to invest in a public project of fixed size  $g$ . Households begin with an initial endowment that they can consume or save at banks. Banks lend to the government, to

other banks, and to firms. Foreign investors lend to the government. The realization of underlying productivity  $A_1$  is uncertain at  $t = 0$ , for some  $A_1 \in [\underline{A}, \bar{A}]$ .

- In  $t = 1$ , the productivity level  $A_1$  of the economy is realized, and firms produce. Given  $A_1$ , the government decides whether to repay its debt or default. Default leads to financial frictions in the form of an incentive constraint on domestic banks. Households consume and save, and bankers lend to firms.
- In  $t = 2$ , firms produce, and banks shut down and return their net worth to households, who consume.

The detailed optimization problem of each group of agents is described below.

## 2.2.2 Households

Households are assumed to be risk-neutral savers who care equally about all three periods, and choose consumption to maximize:

$$c_0 + \mathbb{E}[c_1 + c_2], \quad (2.1)$$

subject to the budget constraints:

$$c_0 + d_0 = y_0,$$

$$c_1 + d_1 = R_1 d_0 - b^{tot} \cdot \mathbb{I}_{\{D=0\}}, \quad (2.2)$$

$$c_2 = R_2 d_1 + n_2. \quad (2.3)$$

Households receive an initial endowment  $y_0$ , earn gross interest rates of  $R_1$  and  $R_2$  on intertemporal deposits  $d_1$  and  $d_2$ , and are assumed to receive a transfer of the equity remaining in banks  $n_2$  at  $t = 2$ . If the government does not default, denoted by  $D = 0$ , then households pay taxes in order to repay the country's total debt  $b^{tot}$ .

### 2.2.3 Government

The government's optimal program satisfies:

$$V_0 = \max_{b^{tot}} \left[ c_0 + \mathbb{E} \left[ \max_{D \in \{0,1\}} \{V_1, V_1^d\} \right] \right], \quad (2.4)$$

where  $D$  denotes the government's default decision, and the government is assumed to choose foreign borrowing  $b^*$  to meet a fixed exogenous level of public spending:

$$g = qb^{tot},$$

where  $q$  is the price. Of the total debt issued by the government, some portion  $b$  will be held by domestic banks, and the remainder  $b^*$  is assumed to be held by foreign lenders:

$$b^{tot} = b + b^*.$$

The continuation values in period 1 are given by:

$$V_1(b, b^*, A_1) = c_1 + c_2,$$

$$V_1^d(b, b^*, A_1) = c_1^d + c_2^d,$$

where  $c_t$  and  $c_t^d$  denote consumption conditional on no default and default, respectively, and  $A_1 \in [\underline{A}, \bar{A}]$  is the stochastic realization of private productivity in  $t = 1$ .

The default set is defined as the set of realizations for which default is optimal, given  $b$  and  $b^*$ :

$$\Delta(b, b^*) = \{A_1 \in A : V_1 < V_1^d\}.$$

Default probabilities and default sets are related in the following way:

$$p(b, b^*) = \int_{\Delta(b, b^*)} f(A) dA, \quad (2.5)$$

where  $f(\cdot)$  is a probability density function for the realizations of  $A_1$ .

## 2.2.4 Foreign lenders

Foreign lenders are assumed to be risk neutral and to lend at an interest rate that compensates them for default risk, maximizing profits in each period. Their opportunity cost is assumed to be the gross risk-free rate,  $R$ , yielding profits:

$$\phi = qb^* - \frac{1 - p(b, b^*)}{R}b^*.$$

In what follows, it is assumed that the government issues enough debt that both domestic and foreign lenders hold bonds, and the price of government debt is accordingly:

$$q = \frac{1 - p(b, b^*)}{R}, \tag{2.6}$$

where  $q$  takes values on a bounded interval  $q \in [0, \frac{1}{R}]$ .

## 2.2.5 Banks

Banks begin with initial equity  $n_0$  and accept deposits  $d_0$  from households. The main mechanisms of the model arise from two financial frictions: interbank lending that must be collateralized, and an agency problem in deposit markets. I describe each of these in turn.

### Collateralized interbank lending

Following Bolton and Jeanne (2011), I assume that banks have heterogeneous access to investment projects, but demand deposits homogeneously.

Specifically, at  $t = 0$ , a fraction  $\omega$  of banks get access to the production technology, while  $1 - \omega$  do not. Banks with projects demand domestic government debt in order to be able to borrow on interbank markets. The size of interbank loans is limited by the value of collateral. Eligible securities are in this case only government bonds, which

are assumed to be collateralized with some haircut  $\lambda \geq 1$ .<sup>4</sup> Banks holding government debt of  $qb$  can borrow up to a limit:

$$i \leq \lambda qb.$$

Banks are assumed to act competitively in the market for sovereign debt, i.e., taking the price  $q$  as given. Government debt is first assumed to be the only asset that can be used to collateralize interbank loans, an assumption that is relaxed in Section 5.

Equity and deposits form the liabilities side of banks' balance sheets, and can be invested in government bonds  $qb$  or lent to firms  $k_1$ . I also allow banks to invest excess funds in a risk-free asset that pays  $R$ , and denote excess funds by  $x$ . The balance sheets of banks with and without investment projects are shown in Figure 2.1.

Banks with projects		Without projects	
Assets	Liabilities	Assets	Liabilities
$k_1$	$\omega d_0$	$i$	$(1 - \omega)d_0$
$qb$	$\omega n_0$	$x_1$	$(1 - \omega)n_0$
	$i$		

Figure 2.1: Heterogeneous bank balance sheets

The rate paid on interbank lending is assumed to equal the overall return earned on private investment and government debt. This makes depositors indifferent between banks with and without investment projects, and allows banks to be treated as homogenous, in aggregate.

At  $t = 0$ , banks without investment projects have  $(1 - \omega)(n_0 + d_0)$  of liabilities that can only be productively invested in interbank markets, government bonds, or the risk

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<sup>4</sup>In general,  $\lambda \geq 1$ , because for lower values of the haircut domestic banks are able to borrow less than one dollar on interbank markets for each dollar they lend to the government. If  $\lambda < 1$ , banks are better off not lending to the sovereign at all.

free asset. This places a constraint on the supply of interbank funds:

$$i \leq (1 - \omega)(n_0 + d_0).$$

In equilibrium, banks with projects invest in government debt; banks without projects make collateralized loans to banks with projects.

For a given  $q$ , banks with projects demand a sufficient level of government debt to borrow all the funds at banks without investment projects. This assumes that the resources held by productive banks is larger than  $(1 - \omega)(n_0 + d_0)/\lambda$ . This leads to domestic demand for government debt of:

$$b^{opt} = \frac{(1 - \omega)(n_0 + d_0)}{\lambda q}, \quad (2.7)$$

which allows all funds in the economy to be intermediated. If the government issues less debt than the amount in equation (2.7), the lack of collateral hinders interbank lending and leads to efficiency losses. For a given  $b$ , the amounts of interbank lending and remaining excess funds are given by:

$$\begin{aligned} i &= \min \left\{ \frac{b}{b^{opt}}, 1 \right\} (1 - \omega)(n_0 + d_0), \\ x &= \max \left\{ 1 - \frac{b}{b^{opt}}, 0 \right\} (1 - \omega)(n_0 + d_0). \end{aligned} \quad (2.8)$$

In what follows I focus on cases in which  $b^{tot} > b^{opt}$ .

In the three-period model, sovereign debt and interbank markets are only open once, from  $t = 0$  to  $t = 1$ . At  $t = 1$ , all banks are assumed to have equal access to investment projects (as there is no longer a market for government debt, and therefore no collateral).

If  $b \geq b^{opt}$ , the balance sheet constraints of the aggregate banking system are:

$$k_1 + qb = n_0 + d_0, \quad (2.9)$$

$$k_2 = n_1 + d_1. \quad (2.10)$$

Banks choose government debt holdings, lending to firms, and deposits to maximize expected equity in  $t = 2$ :

$$\mathbb{E}[n_2], \tag{2.11}$$

where equity evolves according to:

$$n_1 = A_1 k_1 + b \cdot \mathbb{I}_{\{D=0\}} - R_1 d_0, \tag{2.12}$$

$$n_2 = A_2 k_2 - R_2 d_1. \tag{2.13}$$

For banks that have access to the production technology, investment capital yields constant returns to scale, where  $A_1$  is stochastic, but  $A_2$  is fixed. If the government defaults, banks suffer a loss to equity relative to the no default case.

So that households are not insulated from the productivity realization in the economy, I assume that the interest rate on deposits in period 1 is state-contingent, i.e. the interest rate on deposits is given by:

$$R_1 = A_1.$$

While many countries insure deposits, this characterization of the return on deposits is helpful in that it exposes both banks and depositors to the realization of productivity in the economy. If  $R_1$  were fixed, this would allow banks to become very rich when the realization of productivity is high, but cause them to have outsized losses when the realization of productivity is low. Similarly, if there are no financial frictions in  $t = 1$ :

$$R_2 = A_2.$$

These assumptions also ensure that banks do not end up with negative equity. Although the possibility of bank failures is not considered explicitly in the model, this would likely worsen the consequences of default.



## Deposit market frictions

Financial frictions are assumed to arise in interbank markets when bank equity is low, so that depositors are concerned about the health of banks. Following Gertler and Kiyotaki (2010), this is modeled as an agency problem in that bankers are capable of diverting a fraction  $\theta$  of bank assets. This adds an incentive constraint to the banks' problem: the profits of operations must be greater than the value of assets bankers can divert. In the case that financial frictions arise as a consequence of default, this incentive constraint can be written as:

$$A_2 k_2 - R_2 d_1 \geq \theta A_2 k_2. \quad (2.14)$$

Using equation (2.10), the constraint can also be written as a condition on deposits:

$$d_1 \leq \frac{(1-\theta)A_2}{R_2 - (1-\theta)A_2} n_1. \quad (2.15)$$

This inequality can only hold if  $R_2 > (1-\theta)A_2$ . Bankers' demand for funds is thus a well-defined function of  $R_2$  in the interval  $((1-\theta)A_2, A_2]$ , and decreasing in  $R_2$ . Deposit demand approaches infinity as  $R_2 \rightarrow (1-\theta)A_2$ , and approaches  $\frac{1-\theta}{\theta}n_1$  as  $R_2 \rightarrow A_2$ . When  $R_2 = A_2$ , deposit demand is bounded:

$$0 \leq d_1 \leq \frac{1-\theta}{\theta} n_1.$$

The deposit demand of banks in the case of financial frictions therefore follows:

$$d_1^{demand} = \begin{cases} \frac{(1-\theta)A_2}{R_2 - (1-\theta)A_2} n_1 & \text{if } R_2 < A_2 \\ \text{Indeterminate in } [0, \frac{1-\theta}{\theta} n_1] & \text{if } R_2 = A_2 \\ 0 & \text{if } R_2 > A_2 \end{cases}.$$

With risk neutral households that care equally about each period, any interest rate

greater than 1 will induce them to save everything, so deposit supply follows:

$$d_1^{supply} = \begin{cases} R_1 d_0 & \text{if } R_2 > 1 \\ \text{Indeterminate in } [0, R_1 d_0] & \text{if } R_2 = 1 \\ 0 & \text{otherwise} \end{cases} .$$

This can be combined with the bound  $d_1 \leq \frac{1-\theta}{\theta} n_1$  to solve for the bound on bank equity below which financial frictions arise:

$$n_1 \geq \frac{\theta}{1-\theta} R_1 d_0 = \tilde{N}. \quad (2.16)$$

Combining deposit demand and deposit supply results in equilibrium in the deposit market, which pins down both  $d_1$  and  $R_2$ . For any shock that causes bank equity to decrease below the threshold in (2.16), banks continue to operate but are subject to an additional incentive constraint given by equation (2.14). For equation (2.14) to hold, either the return on deposits must fall, or the amount of deposits must fall, or both. In this way, a government default causes stress in the banking system, and generates an endogenous cost of default.

In the event of default, households have more wealth because they do not pay taxes to repay debt, as in equation (2.2). Because the households are wealthier, for deposits in the economy to fall, rather than rise, it must be that the savings that are deposited under financial frictions in equation (2.15) are less than deposits if there is no default:  $\frac{(1-\theta)A_2}{R_2-(1-\theta)A_2} n_1^d < R_1 d_0 - b^{tot}$ . If the equilibrium in deposit markets is such that the level of deposits is less than the frictionless level, it can only be that the deposit demand condition intersects deposit supply on the vertical line where  $R_2 = 1$ . This is shown graphically in Figure 2.2.

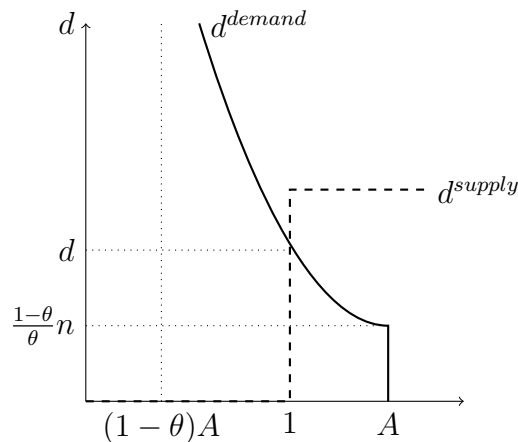


Figure 2.2: For deposits to fall after default, assuming  $n_1^d < \tilde{N}$

## 2.2.6 Equilibrium

Equilibrium in this economy consists of the government maximizing welfare, households maximizing expected utility, banks and foreign investors maximizing expected profits, and market clearing for deposits, interbank lending, and sovereign debt.

**Definition 2.1.** *Equilibrium in this economy is defined as a set of policy functions for consumption  $\{c_0, c_1, c_2\}$ , deposits  $\{d_0, d_1\}$ , lending  $\{k_1, k_2\}$ , government asset holdings  $\{b, b^*\}$ , default sets  $\Delta(b, b^*)$  and bond prices  $q(b, b^*)$  such that:*

1. *Taking as given government policies and bond prices, consumption and deposit supply plans  $\{c_0, c_1, c_2\}$  and  $\{d_0, d_1\}$  maximize households' expected utility subject to their budget constraints.*
2. *Taking as given government policies and bond prices, banks choose deposits and lending to the government and firms to maximize expected equity  $\mathbb{E}[n_2]$ , subject to balance sheet constraints, the evolution of net worth, and an incentive constraint that occasionally binds; and, interbank markets clear.*
3. *Deposit markets clear, meaning that deposit demand and supply from the banks' and households' programs determine the level of deposits and the deposit rate.*

4. *Taking as given bond prices, the government's asset holdings  $b$  and  $b^*$ , and default sets  $\Delta(b, b^*)$  satisfy the government's optimization problem.*
5. *Bond prices  $q(b, b^*)$  reflect the government's default probabilities and are consistent with foreign lenders' expected zero profits.*

The model can be solved backwards, by first determining the solutions to the problem at  $t = 1$ . Since there is no uncertainty after  $A_1$  is realized, it is possible to compare  $V_1$  and  $V_1^d$  for given levels of  $b$ ,  $b^*$ , and realizations of  $A_1$  to determine when default will be optimal. These solutions can then be considered in  $t = 0$  along with an assumed probability distribution for the possible realizations of  $A_1$ , to determine the optimal  $b$  and  $b^*$ .

## 2.3 Results

This section characterizes the equilibrium outcomes in the model. First, domestic debt is shown to be a commitment device. Second, the implications of domestic banks' characteristics for sovereign default are explored: default is more likely on well-capitalized banks, and default risk decreases with the level of bank deposits. Next, because the usefulness of debt as collateral is tied to its value, domestic demand for sovereign debt increases with default risk. Two features of canonical sovereign default model remain true in this setup: default incentives increase in the level of foreign lending, and default occurs in equilibrium. Finally, the model is used to show that financial frictions and deposit flight in anticipation of default are likely to increase the costs of default, while also making default more likely.

Three basic properties of the model are first discussed, before turning to the main results. For the model to generate interesting predictions, one additional restriction is

necessary. Banks are assumed to have only a limited amount of equity, which can be stated as a condition on model parameters.

**Assumption 2.1.** *Initial bank equity is assumed to be lower than the threshold:*

$$n_0 < d_0 \left[ \frac{1}{A_2(1-\theta)} \frac{\lambda}{\lambda + \omega - 1} - 1 \right].$$

Assumption 2.1 guarantees that default occurs when productivity is low.<sup>5</sup> However, in the absence of domestic bond holdings, there is no cost to default. In equilibrium, domestic holdings of sovereign debt must be large enough that a default results in financial frictions in order for there to be any cost associated with non-repayment.

**Lemma 2.1.** *Domestic bond holdings must be (i) strictly positive and (ii) sufficiently high so that a default results in financial frictions, in order for foreign lending to be supportable in equilibrium.*

*Proof.* All proofs are included in the Appendix. □

In this three period setup, there is no threat of exclusion from financial markets to discipline government borrowers. If the government has no borrowings from domestic banks, then for any positive value of foreign lending default is certain. Therefore, no lending can be supported in equilibrium. Similarly, for a level of borrowing too small to cause distortions in the domestic banking sector, there is no cost to defaulting to encourage the government to repay. However, to the extent that domestic holdings of sovereign debt can disrupt the banking sector and become a source of output losses in the event of default, foreign lending can be supported in equilibrium.

If domestic banks are the only holders of sovereign debt, then default is trivial, because it generates output losses as a result of financial frictions, without providing

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<sup>5</sup>The condition in Assumption 2.1 is derived in the proof of Lemma 3.

any benefits from retaining resources that would otherwise be transferred abroad. This is demonstrated in the following Lemma, which considers the case where foreigners hold no debt, i.e.  $b^* = 0$ .

**Lemma 2.2.** *If  $b > 0$  and  $b^* = 0$ , then  $\Delta(b, b^*) = \emptyset$ , i.e., when all sovereign debt is held by domestic banks, default is never optimal.*

The government default decision involves a tradeoff between the benefit of lower lump-sum taxes, and the costs of default on the banking system. A default exclusively on domestic bondholders is never optimal, since this comes with costs and has no associated benefits. Default merely causes a redistribution of wealth from banks to households. Households then cannot save as much at impaired banks, and investment and output fall. Since taxation is lump sum and bank equity is returned to households in  $t = 2$ , this makes households worse off.

Models of non-contingent sovereign debt typically find that defaults occur when output is low. Given Assumption 2.1, this is also true in this model, and there is some threshold value of  $A_1$  below which default is optimal.

**Lemma 2.3.** *If for a level of borrowing  $(b, b^*)$  default is optimal for some  $A_1$ , then default is also optimal for all  $A'_1 < A_1$ . Therefore, there exists a threshold level of productivity  $\tilde{A} \in [\underline{A}, \bar{A}]$  below which it is optimal for the government to default.*

It follows from Lemma 2.3 that for each level of domestic and foreign debt, the set of productivity realizations that trigger default is an interval. This simplifies solving the model, because the default probability in equation (2.5) can be rewritten as:

$$p(b, b^*) = F(\tilde{A}),$$

where  $F(\tilde{A}) = \int_{\underline{A}}^{\tilde{A}} f(A) dA$  is the cumulative distribution function of the possible realizations of productivity  $A_1$ . By extension, agents' expectations can be written as the sum of two integrals, taken over the default and no default regions of  $[\underline{A}, \bar{A}]$ .

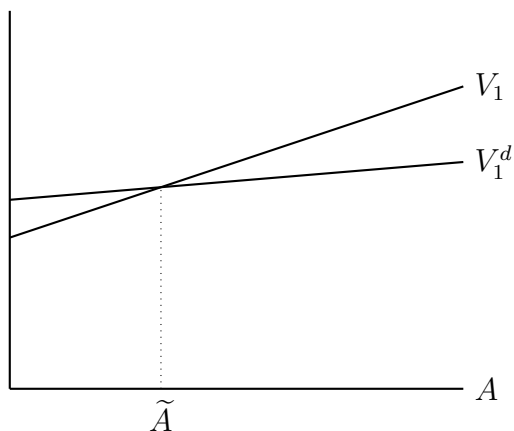


Figure 2.3: Threshold level of  $A_1$

### 2.3.1 Commitment

Taken together, Lemmas 2.1-2.3 demonstrate the importance of domestic bond holders in contributing to the commitment of a sovereign in repaying its debts, through the endogenous costs of default. This result is stated formally in Proposition 1.

**Proposition 2.1.** *For  $b < b'$ ,  $\Delta(b', b^*) \subseteq \Delta(b, b^*)$ , i.e. the default set is decreasing in the amount of domestically held sovereign debt.*

In the model, the government can borrow from abroad because defaulting leads to financial frictions that limit the ability of banks to channel savings to productive investment. Greater domestic holdings of sovereign debt lead to more severe effects on the banking system in the event of default, which lowers default risk. This is the only effect which serves to discourage default in this model. In reality, other disciplining devices play a role as well, such as exclusion, reputation, secondary markets, etc.

From the perspective of the government issuer, domestic holders are distinct because their bond holdings come with additional associated losses if the sovereign defaults. This helps to support the value of sovereign debt, by raising the price  $q$ , or equivalently lowering the default probability  $p$ . In this sense, a bond in the hands of domestic

investors is more valuable due the effect that endogenous output losses have on default incentives.

Importantly, this property of domestic bond holders provides a microfoundation for the assumption in secondary market theory that domestic shareholders place relatively more value on government debt in times of sovereign stress. This can be framed in terms of political economy explanations, such as that domestic creditors are more likely to be able to extract value from the government following a default, perhaps because domestic bond holders are more concentrated and have more sway in domestic political processes. However, the same conclusion - that there is more value to debt in the hands of domestic creditors - emerges from the framework of this model, driven by commitment. Domestic creditors support the value of sovereign debt precisely because defaulting on them is costly.

### 2.3.2 Bank health

An extension of the idea of domestic banks as a commitment device is how default incentives depend on characteristics of the banking system. A well-capitalized banking system is more easily able to weather a sovereign default. In contrast, fragile banks are more costly for the sovereign to default on. This is the intuition of Proposition 2.2.

**Proposition 2.2.** *Holding constant the level of foreign debt,  $\Delta(b, b^*)$  is increasing in  $n_0$ , i.e. default is more likely if banks have more equity.*

In the event of default, financial frictions limit bank deposits to some multiple of bank equity. When initial bank equity is low, a default leads to a tighter constraint on deposits, which leads to a higher cost of default. In comparison, a well-capitalized banking system is less constrained in the event of default, leading default to be less costly, and therefore more probable.



Proposition 2.2 is consistent with the empirical evidence of Erce (2012), who finds default on domestic banks to be less likely when the banking sector is weak. This lends an additional argument to why governments may not want to recapitalize banks during a crisis. Aside from standard moral hazard arguments, Acharya et al. (2014) explore the pressures bank bailouts place on sovereign creditworthiness. Crosignani (2015) argues that governments may avoid recapitalizing banks because they want banks to act as lenders of last resort during crises. If in addition to these factors a stronger banking system increases sovereign risk because it makes sovereign default less costly, then this could contribute to the incentives to not provide bank bailouts when sovereign risk is high.

In contrast, the probability of default is decreasing in the level of household deposits.

**Proposition 2.3.**  *$\Delta(b, b^*)$  is decreasing in  $d_0$ , i.e. default is less likely when banks have more deposits.*

This result arises from the distortion to deposit markets in the case of a default. If the sovereign defaults, deposits are limited to a multiple of bank equity. The more deposits households have in excess of this, the greater the distortion and the corresponding disincentive to default.

### 2.3.3 Domestic demand for government debt

Domestic demand for sovereign debt is determined by banks' optimization problem, and features a tradeoff between the use of government bonds as collateral in interbank markets, and the risks of non-repayment. Banks demand government debt in order to intermediate all the assets in the financial system.

Domestic demand for government debt depends on a number of factors. First, domestic demand for government debt increases with the size of the banking system, which constitutes both deposits and equity. Second, it is increasing in  $1 - \omega$ , the

extent of assets to be borrowed from nonproductive banks. Third, domestic demand for government debt decreases in the “haircut” applied to collateral  $\lambda$ : the larger amount of interbank loans that can be collateralized by one unit of sovereign debt, the lower is domestic demand.

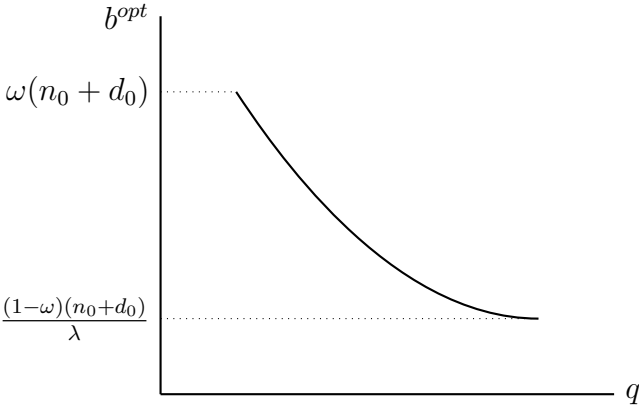


Figure 2.4: Domestic demand for government debt

Fourth, if bond prices fall, more domestic debt is required to provide adequate collateral for the banking system. Following equation 2.7, this relationship is shown in Figure 2.4. Since the price of government bonds  $q$  is decreasing in the probability of default  $p$ , domestic demand for sovereign debt may increase with sovereign risk.

**Proposition 2.4.** *Domestic demand for government debt  $b$  is weakly increasing in sovereign risk  $p$ .*

This dynamic derives from the idea that increased sovereign risk lowers the value of a “safe” asset or collateral. As the value of collateral falls, banks require more of it in order to borrow the same amount on interbank markets. The expected return on government debt is always  $R$ , so risk-neutral banks prefer government bonds over an alternative safe asset that pays a return  $R$  but cannot be used as collateral.

Realistically, other safe assets can likely also be used as collateral, so that banks can substitute away from risky sovereign debt. I discuss this bias and the possibility of

alternative collateralizable safe assets in Section 2.5.

In addition, this model provides a simple lens through which to consider the observed heterogeneity in bank exposures to domestic sovereign debt. As European countries experienced increases in the risk profile of their debt, there was a concurrent repatriation of sovereign ownership from foreign to domestic investors. Brutti and Saure (2014) document the recent European repatriation of sovereign debt in greater detail, and argue that the evidence is consistent with secondary market theory, rather than standard theories of portfolio allocation or home bias. Some of the increases in exposure may be driven by banks being forced to hold additional debt, as argued by Becker and Ivashina (2014). However, to the extent that domestic banks require sovereign bonds to collateralize interbank lending, rising sovereign risk can also lead to increases in domestic demand due to effects on the value of collateral.

Another way to characterize demand for  $b$  is to consider domestic holdings as a share of the total face value of debt raised by the government. As shown in Figure 2.5, for low levels of total debt, domestic banks demand the full share. Once  $b = b^{opt}$ , this demand levels off, and there is a region over which each marginal bond issued by the government is purchased by foreigners. This can be described as a “safe borrowing region,” in that  $q = 1/R$  for some range of total issuance  $b^{tot} \in (*, **)$ . Once  $b^*$  reaches a certain level, debt becomes risky, and as  $b^{tot}$  increases,  $p$  increases, which increases domestic demand for sovereign debt  $b$ .

### 2.3.4 Foreign lending and bond prices

With respect to foreign debt, default is increasingly likely for higher levels of borrowing from foreigners. This is consistent with canonical models of sovereign default.

**Proposition 2.5.** *For  $b^* < b^*$ ,  $\Delta(b, b^*) \subseteq \Delta(b, b^*)$ , i.e. the default set is increasing in the level of borrowing from abroad.*

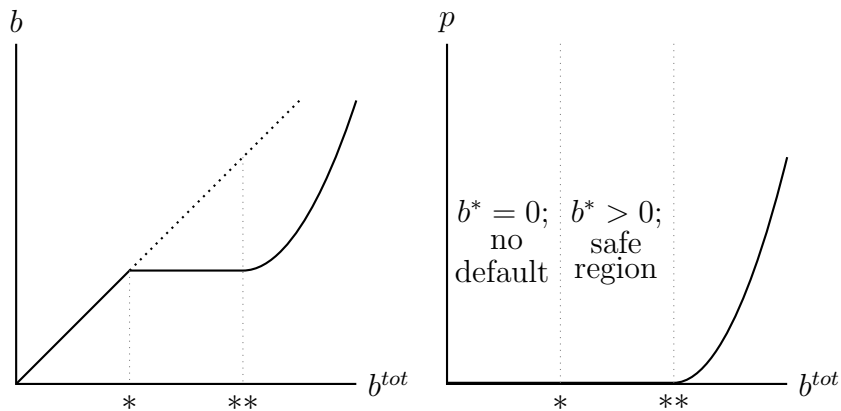


Figure 2.5: Domestic share of total debt

Proposition 2.5 implies that there exists some maximum level of foreign debt that is supportable in equilibrium. In other words, foreign debt is bounded. This is equivalent to a no-ponzi condition. If  $A_1$  is bounded, and the default set is increasing in foreign debt, then there is some level of foreign debt that results in default for sure, and is thus unsupported in equilibrium. However, since default incentives depend on domestic bond holdings, this bound depends on them, as well.

In the model, the government needs to raise a fixed, exogenous  $g$ . However, the total resources borrowed by the government is the product of the face value of debt and its price  $q$ . The total resources borrowed from abroad follow an endogenous Laffer curve. This is shown along with the bond price in Figure 2.6, assuming a normal distribution for the potential realization of productivity. For low levels of foreign borrowing from abroad,  $b^* \in (0, \underline{b}^*)$ , sovereign debt is safe and  $q = 1/R$ , so the bond price is defined by the risk free rate. For levels of foreign borrowing  $b^* \in (\underline{b}^*, \tilde{b}^*)$ , borrowing is risky. The government never optimally chooses  $b^{tot}$  such that  $b^* > \tilde{b}^*$ , because the same amount of total resources can be obtained by choosing a lower level of debt. The shape of the Laffer curve matches Arellano (2008), but in this case the costs which support risky debt are endogenous costs that arise via the banking system.

The total resources borrowed from domestic bondholders is a function of domestic

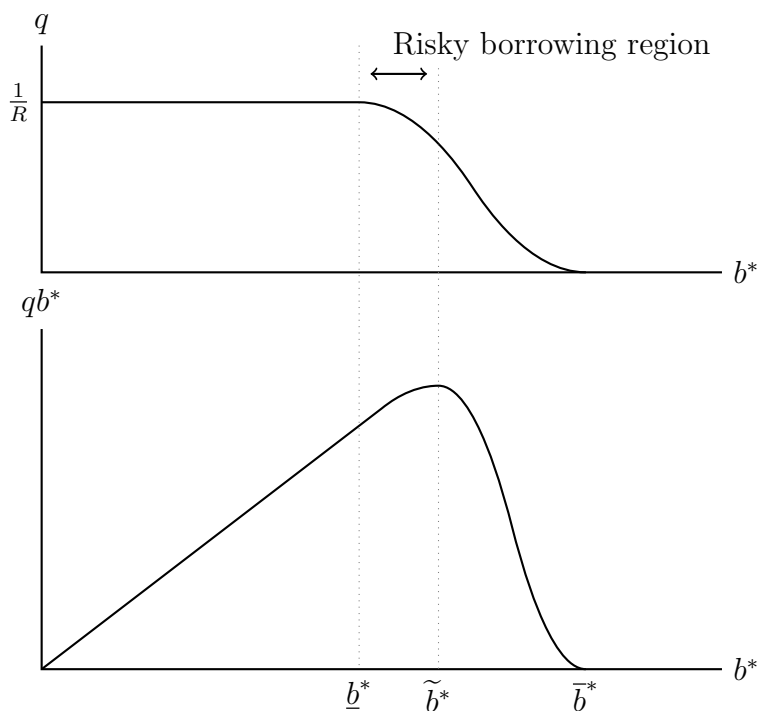


Figure 2.6: Bond price and total resources borrowed from abroad

banks' characteristics. From equation (2.7) and Proposition 2.4,  $qb = (1-\omega)(n_0+d_0)/\lambda$ . As a result, the total resources borrowed from domestic banks does not change with  $q$ , but the face value of domestic debts increases mechanically as  $q$  declines.

In the model, the exogenous level of  $g$  and the characteristics of the banking system then pin down the optimal  $b$ , which jointly determines the specific amount of resources that need to be borrowed from abroad and the bond price. Since the level of government spending  $g$  must be met, whatever the government does not get willingly from domestic banks, it must seek from abroad. An illustrative example of this is shown in Figure 2.7.

To understand the effect of domestically held debt on both the potential and realized level of borrowing, consider an exogenous change in the characteristics of the banking system such that more sovereign debt is naturally demanded by domestic agents. This could be a decrease in  $\omega$  or  $\lambda$ , or an increase in  $n_0$  or  $d_0$ . In this case, the additional domestic debt  $b' > b$  lowers the probability of default for any given level of  $b^*$ , so  $q$

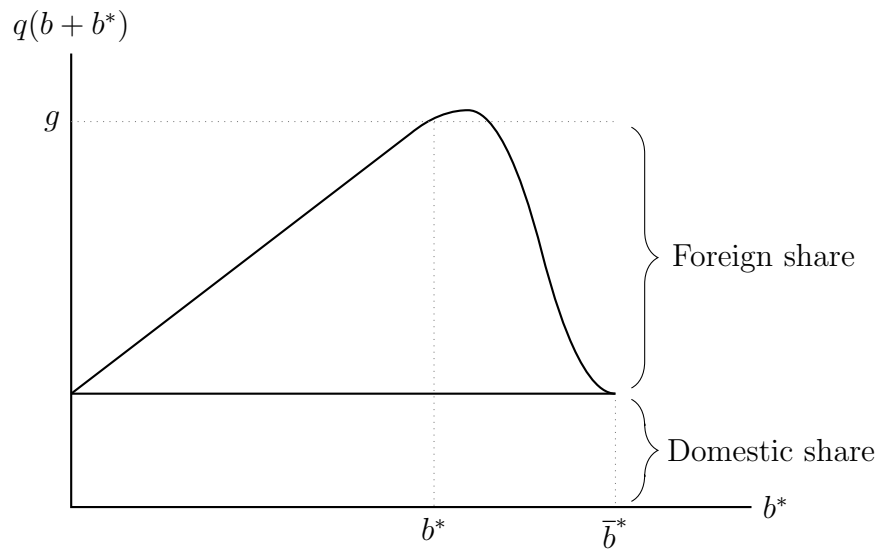


Figure 2.7: Total resources borrowed

risers. The effect that this shift has on the total resources borrowed is shown in Figure 2.8. An increase in  $b$  shifts the endogenous Laffer curve up and out, leading to a larger range of possible government spending, and shifts the risky borrowing region to the right.

### 2.3.5 Default in equilibrium

Domestic debt discourages, but does not prevent default. This is a direct implication of Lemma 2.3. Whether default may occur in equilibrium depends in particular on the fiscal needs of the government in  $t = 0$ , and the characteristics of the banking system.

**Proposition 2.6.** *Default can occur in equilibrium, in spite of large domestic holdings of sovereign debt.*

Whether default occurs in equilibrium depends on the realization of  $A_1$  and the parameters of the model, and in particular the level of government spending  $g$ . If the government were to choose  $g$  optimally, in this setting there is no incentive to borrow from abroad, because government spending does not enter the households utility

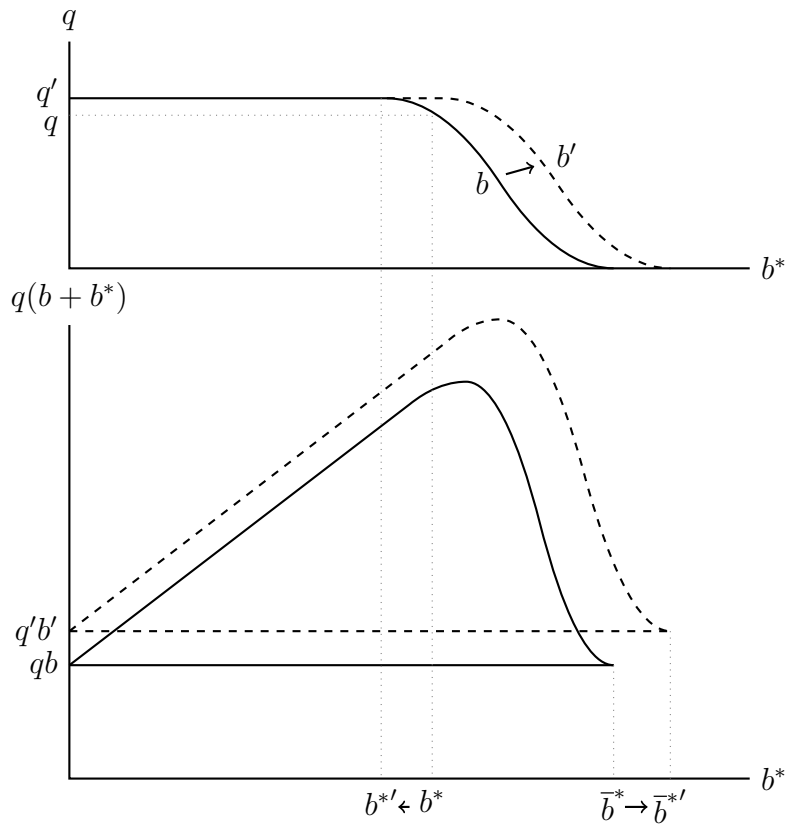


Figure 2.8: Effect of increasing domestically held debt

function and resources borrowed from abroad are not invested productively. With an exogenously determined  $g$ , which could for example capture fiscal obligations that are difficult to alter in the short run, it may be necessary to borrow from abroad to such an extent that default is a possibility. In this sense, domestic bank holdings of sovereign debt can be thought of as an imperfect commitment device, since despite large domestic holdings, sovereign debt may still be risky.

### 2.3.6 Financial frictions in anticipation of default

The above results focus on the implications of default on banks, assuming that banks are not initially subject to financial frictions. However, it is also possible that default risk has effects on the banking system in anticipation of default.

If bank equity is low enough in  $t = 0$ , then households choose to limit the deposits they channel to the banking system. This can be thought of as a form of deposit flight. Importantly, this reduces the funds available to the banking system to invest, which lowers potential output. This highlights an important limitation of Proposition 2.2. While weaker banks are in general more costly to default on, if low levels of bank equity act as a constraint on deposits, undercapitalized banks can be associated with higher default risk due to deposit flight.

**Proposition 2.7.** *Deposit flight that occurs due to financial frictions in  $t = 0$  makes default more likely.*

If banks are sufficiently poorly capitalized that financial frictions arise in  $t = 0$ , then households save less in the banking system and consume more in  $t = 0$ . This negatively affects investment and output. Since households have less wealth in  $t = 1$ , there is less at stake to be affected by a default. This highlights one way in which sovereign and financial crises are interconnected, as sovereign risk may lead to problems in the financial system that reinforce the default risk of the sovereign.

An additional effect of deposit flight is to reduce the size of the banking system ( $n_0 + d_0$ ), which causes the level of debt demanded domestically to fall. This also contributes to heightened default risk, in that a greater portion of fiscal needs may need to be raised from foreign lenders. Alternately, it may increase the desirability of financial repression, as discussed in the next section.

## 2.4 Externalities and financial repression

In setting domestic demand for government debt, banks do not internalize the effect they have on default incentives. In other words, they take  $q$  as given, but  $q$  depends on  $b$ . Taking  $q$  and  $\tilde{A}$  as given leads the banks' optimization to be a problem of taking



expectations over intervals:

$$\max_b E[n_2] = \int_{\underline{A}}^{\tilde{A}} n_2^d f(A) dA + \int_{\tilde{A}}^{\bar{A}} n_2 f(A) dA.$$

In contrast, if banks were to fully internalize the effect of their debt holdings on bond prices and the default incentives of the sovereign, then the banks' optimization problem would also consider the effect of their choice of  $b$  on  $\tilde{A}$ ,  $p$ ,  $q$ , and  $b^*$ . This affects the banks' expectations of equity in the cases of default and no default, as well as the threshold  $\tilde{A}$ . In this case, solving the banks' problem requires first integrating and then taking a first order condition with respect to  $b$ .

In this section, the model is altered slightly to accommodate a specific form of government intervention in domestic sovereign debt markets, financial repression. Assume now that the government chooses  $b$  for the banks, which changes the government's optimization problem in equation (2.4) to a maximization over  $b$  and  $b^*$ , rather than over just  $b^{tot}$ , which can be written in terms of intervals:

$$V_0 = \max_{b, b^*} \left[ c_0 + \int_{\underline{A}}^{\tilde{A}(b)} V_1^d f(A) dA + \int_{\tilde{A}(b)}^{\bar{A}} V_1 f(A) dA \right].$$

Because domestic banks do not internalize the effect of their holdings on default risk, the government may have an incentive to choose a higher level of domestic bond holdings than the banks choose on their own. This increases the potential cost of default, which increases the prices at which the government issues debt. At the expense of crowding out private investment, the government can lower its tax bill in  $t = 1$ .

When the government increases domestic holdings of sovereign debt from  $b$  to  $b'$ , the effects can be understood in the following way. The reduction in external debt  $b^*$  to  $b'^*$  comprises two effects: a mechanical reduction in  $b^*$  which occurs because the total fiscal need  $g$  is fixed, and an effect via improvement in the price:

$$\frac{db^*}{db} = - \left[ 1 + \frac{g}{q^2} \frac{dq}{db} \right] < 0.$$

From Proposition 2.1, an increase in domestic bond holdings decreases default risk,  $dq/db > 0$ , and thus  $db^*/db < 0$ .

However, any increase in  $b$  beyond the amount required to intermediate all the assets in the banking system leads to crowding out:

$$\frac{dk_1}{db} = - \left[ \frac{dq}{db} b + q \right] < 0.$$

Since  $q \in [0, \frac{1}{R}]$  and  $dq/db > 0$ , this is unambiguously negative, as well. Whether financial repression has the potential to improve welfare depends on whether the reduction in external debt outweighs the cost of crowding out.

**Proposition 2.8.** *When debt is risky, financial repression crowds out private investment, but can improve welfare. A necessary condition under which financial repression can improve welfare is:*

$$\frac{dV_1}{db} \Big|_{b=\frac{(1-\omega)(n_0+d_0)}{\lambda q}} > 0 .$$

The idea behind Proposition 2.8 is shown in Figure 2.9, for an increase in domestic bond holdings from  $b$  to  $b'$ . It is possible that despite crowding out private investment, the decrease in the face value of foreign debt that this achieves will increase welfare if the realization of productivity is such that default does not occur. Financial repression also lowers the threshold  $\tilde{A}$  below which default occurs, which leads to welfare improvements for productivity realizations between  $\tilde{A}'$  and  $\tilde{A}$ .

However, for realizations of productivity below the new threshold, financial repression leads to an unambiguous decrease in welfare. This perhaps relates to historical default episodes such as Argentina in 2001 or Russia in 1998. In these latter two default episodes, domestic banks seem to have piled up on domestic debt, only to then suffer even greater losses when the respective defaults took place (Basu, 2010). In some sense,

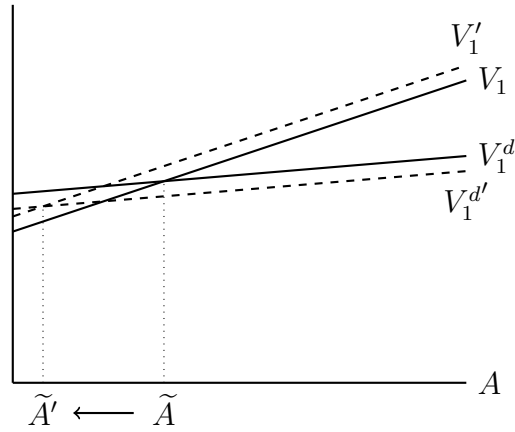


Figure 2.9: Financial repression can increase welfare

financial repression can be seen as taking a gamble that does not necessarily prevent default, and which makes outcomes all the more worse if default occurs.

In addition, the improvements in welfare that result from financial repression are decreasing in the realization of  $A_1$ . This can be shown by the negative second derivative:

$$\frac{d^2 V_1}{db d A_1} = A_2 \left[ -\frac{dq}{db} - q \right] < 0.$$

Although there may then be some range of productivity realizations over which financial repression improves welfare, for high realizations of productivity the losses due to crowding out increase relative to the gains of reduced external debts.

Finally, there are also realizations of  $A_1$  in which despite avoiding default, welfare declines. This is shown in area of Figure 2.9 where  $A_1$  is higher than  $\tilde{A}'$ , where  $V_1'$  is lower than  $V_1^d$ . Overall, there are limits to the extent to which financial repression can be relied upon to avoid a potential default.

This section relates to the findings of Chari et al. (2015), who argue that when the government cannot commit to repay debts, financial repression may be optimal. In their model, regulation motivates bank holdings of government bonds. While the basic intuition of domestic bank holdings of sovereign debt as commitment is the same, in this setting banks have an added motive to hold government debt as collateral. As

such, financial repression must be understood as inducing demand above and beyond what banks would choose to invest in on their own.

With risk-averse households and centralized borrowing (where the government transfers its borrowings to households, instead of spending it on  $g$  directly), financial repression can have further benefits in terms of facilitating the ability of households to smooth consumption. In this case, by increasing domestically held sovereign debt, the government can borrow more from abroad, benefiting its citizens directly. A related case is explored in Section 2.5, where foreign lenders can channel capital inflows to banks.

## 2.5 Extensions

Two limitations of the model are that domestic sovereign debt is assumed to be the only eligible type of collateral, and that foreign capital is borrowed exclusively by the government, while in reality banks and firms also receive foreign inflows. In this section, I first discuss the implications of allowing a second safe asset to be used as collateral, and then argue that allowing banks to borrow from abroad in addition to the government reinforces the main mechanisms described in Sections 2.3 and 2.4.

### 2.5.1 Second safe asset

An easy objection to the role of sovereign debt as collateral in motivating demand for domestic sovereign debt is the presence of alternative safe assets, for example, U.S. Treasuries. If banks are able to costlessly use alternative safe assets as collateral in interbank transactions, then there is little motive to invest in risky domestic sovereign debt. When other assets can also be used as collateral, they could in theory confer all of the same benefits as domestic sovereign debt, and have none of the associated risks.

Under the assumption that a second safe asset is available and completely safe, and if domestic sovereign debt is risky, domestic banks in this model would strictly

prefer to use the safe asset instead of the domestic one. In this situation, some form of regulation, moral suasion, or financial repression would be necessary to have non-zero domestic holdings of sovereign debt. As discussed in Section 2.4, there is some scope to undertake these policies while improving overall welfare. Where second safe assets are perfect substitutes for domestic sovereign debt, financial repression is necessary to enable the government to raise its fiscal needs  $g$ . However, in the presence of regulations that require domestic intermediaries to hold domestic sovereign debt, or that provide incentives for domestic government bondholdings over foreign alternatives, banks face a tradeoff between these factors and the risks of non-repayment.

It may also be that banks can more easily invest in domestic sovereign debt due to issues of proximity, exchange risk, jurisdiction, etc. Diversification of sovereign debt within a bank's portfolio may require infrastructure in which the bank must invest, raising the barriers to doing so. This would lessen the need for explicit financial repression.

More generally, it is worthwhile to consider to what extent alternative safe assets exist. Some have noted the apparent shortage of safe assets in the global economy (Caballero et al., 2008; Caballero and Farhi, 2015), as well as the consequences of low public debt issuance for the creation of private “safe” securities (Krishnamurthy and Vissing-Jorgensen, 2012, 2013). Issues such as these complicate the ability of banks to diversify sovereign debt holdings. To the extent that banks and investors demand “safe” assets that are in limited global supply, a security with government backing may be an acceptable alternative. Such preferences are also consistent with “risk-shifting” by banks that maximize their profits, conditional on the absence of a government default.

## 2.5.2 Capital inflows to banks

In many countries, a substantial portion of capital inflows are intermediated by banks rather than flowing directly to the government. Allowing banks to borrow from abroad generates some additional implications in the framework of this model.

Assume that foreign lenders are now willing to lend to domestic banks in wholesale markets, and that these loans go into specific foreign-owned investment projects. Consider foreign lending to be similar to domestic interbank lending, in that it requires collateral in the form of government debt and occurs at some (foreign) haircut. At the outset, providing an additional role for collateral would likely increase the domestic demand for sovereign assets, depending of course on the presence of alternative collateralizable securities.

If foreign inflows to banks pay a return that is fixed in advance, a low realization of productivity can lead to even lower equity in the banking sector. This would lead either to financial frictions that are more severe, or in some cases, solvency problems for the banking sector, which may then default on its obligations. One could consider whether bank defaults lead the government to step in and guarantee private sector debts, as occurred in Ireland. If so, a private sector default could precipitate a sovereign default, linking financial and sovereign crises.

Suppose that a sovereign default leads the private sector to also default. This is often effectively the case following a sovereign default due to policies implemented to prevent capital from flowing out of the country, such as deposit freezes, capital controls, and/or exchange controls. In this case, sovereign risk is tied to private risk, and so when sovereign risk rises it has the additional negative effect of limiting inflows into the banking system. This provides an additional benefit for policies that reduce sovereign risk, such as financial repression, because they facilitate the intermediation of private capital flows to productive investment.

A related policy introduced in the recent European crisis was the provision of long-term refinancing operations (LTROs). Specifically, these refinancing operations offered euros to banks in exchange for a wide array of collateral, including peripheral government debt. This was aimed to prevent liquidity shortages at European banks, but is shown by Crosignani et al. (2015) to have contributed to increased bank sovereign exposures. By providing an additional role for collateral, LTROs increased banks' holdings of domestic sovereign debt.

The banking sector is critical to both facilitating productive investment and also mitigating sovereign risk, and when banks also borrow from abroad, there is more at stake in a sovereign default. LTROs can be thought of as providing not only liquidity, but also as an additional driver of domestic exposure to sovereign debt, and thus reduced default risk. However, this may also worsen outcomes in the event of default, since domestic banks are more exposed to sovereign risk.

## 2.6 Conclusion

In this chapter, I present a model of domestic banks and sovereign default that illustrates the role of domestic banks in supporting risky sovereign debt, through endogenous output losses that result from sovereign default. This provides a specific microfoundation for a political economy argument made in secondary market theory, and a new lens through which to consider the recent trends in ownership of government debt in the European periphery. In addition, the model predicts that default incentives are tied to the health of the banking system and the level of borrowing from abroad, and demonstrates that there are cases where policies such as financial repression can be welfare improving. Importantly, while domestic holdings of sovereign debt can be understood as strengthening commitment, sovereign governments may default in spite of large domestic exposures to their debt.

In a number of ways, this model is highly stylized and should be taken with a full understanding of its limitations. The treatment of the substitutability of domestic and foreign safe assets is simplistic, default is assumed to be non-selective, and bank recapitalizations are ruled out. I assume banks do not default as a result of a sovereign default. In a sense, the results may then be a lower bound on the endogenous cost of sovereign default, assuming that outright bank failures are more disruptive than financial frictions.

It would be useful to further explore the quantitative importance of the mechanisms described in this chapter. For example, it would be interesting to test how much of a quantitative effect incremental increases in domestic bond holdings have on default incentives, conditional on the existing level of exposures. It would also be informative to compare how the costs of financial frictions compare to disruptions to interbank lending, or to multi-period exclusion from international financial markets. I leave these questions to future work.



## Chapter 3

# Matching in corporate loan markets and macroeconomic shocks

## 3.1 Introduction

What is the effect of bank-firm matching on economic outcomes, such as lending, leverage, and output? In this paper, I develop an assignment model of the corporate lending market, with heterogeneous banks and heterogeneous firms. The model is used to demonstrate an analytically tractable characterization of bank-firm matching, and to explore the implications of macroeconomic shocks to borrowers and lenders for firm-level, bank-level, and aggregate outcomes.

Matching in corporate loan markets is important because it has distributional implications for the transmission of shocks, and because matching can lead to bias in empirical work using loan-level data. For example, if certain banks are relatively more affected by monetary policy shocks, this could disproportionately affect a particular subset of firms. In empirical work, inference about the effects of bank shocks depends on assumptions about matching, because of the potential for confounding treatment and selection effects. An ability to better characterize matching patterns in corporate lending would be helpful both in understanding distributional consequences of shocks and improving empirical estimates of their effects.

To demonstrate a tractable theory of matching between banks and firms, I develop a model that builds on Holmstrom and Tirole (1997), with the additional assumptions of (i) heterogeneity among financial intermediaries and (ii) firms with heterogeneous productivity levels. There are two periods, and three types of agents: a continuum of firms, a continuum of banks, and uninformed investors. In the first period, firms seek loans in order to undertake investment projects. Firm investments depend on both firm and bank characteristics, and include internal firm capital, loans from intermediaries, and loans from uninformed investors. In the second period, returns are realized and claims are settled. All parties are risk neutral and assumed to be protected by limited liability.

Banks start with some initial capital, i.e. equity, and higher skill banks monitor at a lower cost. Uninformed investors are only willing to lend alongside banks, and can be thought of as depositors or other funding sources for the banking system. With some probability, successful projects generate a return that is constant returns to scale but depends on firm productivity. Otherwise projects return zero. There is assumed to be a double moral hazard problem, in that the probability of a project's success is higher if firm managers exert effort and the bank monitors, and both actions come at a cost.

Matching in the model is determined as follows: firms choose a bank and its associated lending terms to maximize profits, and banks set loan terms and select firms in order to maximize returns. The moral hazard problems pin down the returns paid to firm managers and banks, and thus the investment size chosen by each firm. Investment size increases in both firm productivity and bank skill. Higher productivity firms are able to pledge more future profits to attract uninformed investors. Similarly, higher skill banks require less absolute return to maintain incentive compatibility, leaving a greater share of future profits to be pledged to uninformed investors.

In particular, firms' investments are log-supermodular in firm productivity and bank skill. This facilitates drawing from methods that have been adopted in matching theory and models in international trade, which explore comparative statics predictions that result from log-supermodularity (e.g. Costinot, 2009; Costinot and Vogel, 2010). One contribution of this chapter is to show that the same mathematical property also has useful applications for modeling financial intermediaries.

In equilibrium, there exists a continuous and strictly increasing matching function that maps firms to banks. The matching function is defined in terms of an ordinary differential equation determined by market clearing. Although the matching result is strict in that it matches each firm to one bank, and predicts perfect sorting, this can be relaxed in a number of ways. If banks limit the size of their exposure to any one

particular firm, firms are matched with an interval of banks, whose endpoints are weakly decreasing in firm productivity. Alternately, if banks are subject to idiosyncratic shocks that occur after matches have been determined, but before lending disbursements, firms have an incentive to diversify their borrowing partners. Finally, if the characteristics of banks or firms are not perfectly observable, less strict patterns of matching are obtained. For simplicity, I focus on the basic prediction of strict matching, but expect that the model predictions follow for richer cases, as well.

Based on the matching that occurs in competitive equilibrium, I demonstrate a number of reasons why matching and its impact on lending is important. First, the model predicts positive assortative matching in firm productivity and bank skill. High skill banks have a tendency to lend to high quality firms, so low skill banks are only able to capture a low quality segment of the market. As a result, it is likely that bank portfolios are concentrated, in the sense that firms of a particular type tend to borrow from the same or similar banks.

Second, better banks are also more able to leverage their own capital, and thus can lend to a wider range of projects. This implies that the capital available to high productivity firms is greater than that of other firms, which cannot take advantage of higher skilled bank capital because of capacity constraints on high productivity banks. This leads not only to higher leverage among high bank and firm types, but amplifies the advantages that high types have, since they also benefit from assortative matching.

Third, the model facilitates a number of interesting comparative statics predictions. A positive productivity shock to firms leads to a decrease in lending to existing firms, and a decrease in lending on the extensive margin. This is because higher productivity firms crowd other firms out of borrowing from top banks. The model shows how capital inflows can lead to different effects, depending on whether inflows are managed by uninformed investors or banks. In particular, if capital flows principally to banks,

this leads to increases in both intensive and extensive margin lending, and thus declines in overall credit quality. Finally, a reallocation of capital from high to low skill banks leads to a decrease in both intensive and extensive margin lending, and increases in bank leverage that are more pronounced among banks of lower skill. This has implications for financial regulation, and how regulations that focus on large banks may affect all firms in the economy, and lead to leverage increases at smaller banks.

The rest of the chapter is structured as follows. In the remainder of this section I review the relevant related literature. Section 3.2 presents the model. Section 3.3 discusses the applications. The final section concludes.

### **3.1.1 Related literature**

This chapter relates to two broad categories of research, the first being financial intermediation. How credit disruptions impact the broader economy has been a subject of economic interest since at least the Great Depression.<sup>1</sup> It has been shown how bank shocks can have real effects in theoretical and empirical settings. Of the many existing models of financial intermediation, in this chapter I take as a basis Holmstrom and Tirole (1997).

At the same time, many researchers have shown that banks gain firm-specific information via lending, which leads to “stickiness” in bank-borrower relationships. This leads to less than perfect substitutability between loans from different banks, since cost and effort are required to establish new relationships with lenders.

While much of the aforementioned research recognizes that banks and firms are in some sense searching for and matching with lending partners, there are only a few papers that study two-sided matching between banks and firms explicitly. Chen and Song (2013) provide empirical evidence that geographic proximity, sizes, and prior loan

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<sup>1</sup>For example, see Fisher (1933).

relationships are important drivers of lending partners. Chen (2013) explores the consequences of matching for loan spreads. Duprey (2016) models two-sided group matching between banks and entrepreneurs, but focuses on screening efficiency and explores implications for aggregate productivity and lending fluctuations. I model matching in a static context, and focus mainly on implications for matching, leverage, and output.

Financial frictions have also been incorporated into models to demonstrate how intermediaries can amplify business cycles and in particular worsen economic slumps. The canonical models in this class are Bernanke et al. (1999) and Kiyotaki and Moore (1997). Ultimately, allowing for cross-sectional variation in the quality of banks' endogenous portfolios may be valuable in considering changes in aggregate credit quality, and how these changes contribute to cyclicalities. I see this chapter as a first step in this direction, although I abstract from dynamics in this setting to show implications in a static context.

The second research area to which this chapter relates is search and matching. Search and matching models are increasingly applied in labor markets (Menzio and Shi, 2011; Kaas and Kircher, 2015) and international trade (e.g. Davis and Dingel, 2012). There are also applications of these methods to specific financial markets, e.g. OTC markets (Duffie et al., 2005). Ottonello (2017) models search in markets for physical capital, which he shows can contribute to the persistence of recessions. This chapter relates most closely to this work, but takes as its object bank loans, or financial capital, which firms require to invest. In particular, I draw from methods which have been adopted in models in international trade, which explore comparative statics that result from the assumed property of log-supermodularity (Costinot, 2009; Costinot and Vogel, 2010). The contribution of this chapter is to show that the same mathematical property also has useful applications for modeling financial intermediaries.

## 3.2 Model

The model has three types of agents: firms, intermediaries, and uninformed investors. This section builds on Holmstrom and Tirole (1997) by adding (i) heterogeneity among financial intermediaries and (ii) firms with heterogeneous productivity levels, in order to explore the pattern of matching and its consequences.

There are two periods. In the first period, financial contracts are signed and investment decisions are made. In the second, returns are realized and claims are settled. All parties are risk neutral and protected by limited liability.

### 3.2.1 Firms

Firms are endowed with one unit of initial capital and vary in terms of the rate of return  $r \in R$  that they generate if their projects are successful. The distribution of potential firms with return  $r$  is denoted  $\mathcal{F}(r) \geq 0$ . Of these, a subset  $F \subset \mathcal{F}$  obtain financing, and there is some productivity cutoff below which firms are unable to obtain external funds. The firms that obtain external financing are denoted by  $R \equiv \{r \in \mathbb{R} | F(r) > 0\}$ .

Firms borrow from banks and uninformed investors to make an investment of variable size  $I(s, r)$ , where  $s$  indexes the skill of the bank, and  $r$  indexes the return on investment of each firm. The funds to be invested include one unit of internal firm capital, plus investments from intermediaries  $I_m$  and uninformed investors  $I_u$ :

$$I(s, r) = 1 + I_m + I_u. \tag{3.1}$$

Successful projects generate a return of  $rI$ . Otherwise projects return zero. The probability of success when firm managers exert effort is denoted by  $p_H$ , and if they do not,  $p_L < p_H$ . It is assumed that  $\Delta p = p_H - p_L > 0$ . In the absence of incentives, firm managers may choose to exert less effort. Formally, entrepreneurs choose between two versions of the project, shown in Table 3.1.

Table 3.1: Available projects

Project	Good	Bad
Effort required per unit of investment	e	0
Probability of success	$p_H$	$p_L$

The returns on investment are used to make payments to each group:

$$rI(s, r) = R_f + R_m + R_u. \quad (3.2)$$

For it to be incentive compatible for firm managers to exert effort, firms' internal return must satisfy:

$$R_f(r) \geq \frac{eI(s, r)}{\Delta p}. \quad (IC_f)$$

The problem of an individual firm is to choose  $I_m$ ,  $I_u$ ,  $R_m$  and  $R_u$  to maximize:

$$\pi_f(r) = rI(s, r) - R_m - R_u - eI(s, r). \quad (3.3)$$

When combined with equation (3.2), equation (3.3) is equivalent to maximizing  $R_f$ , which is bounded below by  $(IC_f)$ . Since managers must be compensated for the effort they exert, and their effort is increasing in the size of the investment, individual firm managers have an incentive to maximize the size of their investment project. This is equivalent to maximizing the leverage obtained from banks and uninformed investors in equation (3.1).

### 3.2.2 Banks

Banks exist on a continuum indexed by skill  $s \in \mathbb{R}$ . Banks of skill  $s$  have capital  $k_m(s)$  available to lend, and choose borrowers in order to maximize expected profits. In particular, a bank with higher skill monitors projects more efficiently: it costs a better bank less to monitor projects. This cost is denoted by  $c(s)$ , which is decreasing in skill  $c'(s) < 0$ . The equilibrium rate of return on bank loans is denoted by  $\beta$ .



Banks are also assumed to be subject to moral hazard. For it to be incentive compatible for the bank to monitor, it must be that they are paid a return  $R_m(s)$ :

$$R_m(s) \geq \frac{c(s)I(s,r)}{\Delta p}, \quad (IC_m)$$

where  $c(s)$  is the monitoring cost for a bank of skill  $s$ . The incentive constraint  $(IC_m)$  implies that banks earn positive profits. As in Holmstrom and Tirole (1997), I assume that competition reduces this surplus by forcing monitors to contribute to the firms' investment in the first period. The expected return on intermediary capital must be at least the market return  $\beta$ :

$$p_H R_m \geq \beta I_m, \quad (3.4)$$

where  $\beta$  is set in equilibrium so that the market for informed capital clears. Combining  $(IC_m)$  and (3.4) gives the bank loan as a function of bank skill  $s$ , firm productivity  $r$  and success probability  $p_H$  and  $\Delta p$ , and the market return  $\beta$ :

$$I_m(s,r,\beta) = \frac{p_H c(s) I(s,r)}{\beta \Delta p}. \quad (3.5)$$

The problem of a bank is to choose which firms to lend to, and how much to lend. For each bank  $s \in S$ , the bank's problem is to choose borrowers and loan sizes to maximize profits:

$$\Pi_m(s) = \int_{r \in R} [p_H R_m(s,r) - c(s) I(s,r)] L(s,r) dr, \quad (3.6)$$

subject to a budget constraint:

$$k_m(s) = \int_{r \in R} I_m(s,r) L(s,r) dr, \quad (3.7)$$

where  $L(s,r)$  is the number of firms with return  $r$  to which banks with skills  $s$  lend. The bank choice of borrowers sets the function  $L(s,r)$ .

At minimum,  $\beta$  must be high enough that banks prefer monitoring to investing capital in the open market, where it would earn a return of  $\gamma$ :

$$\gamma I_m = \gamma \left[ \frac{p_H c(s) I(s, r)}{\Delta p \beta} \right] \leq \frac{p_H c(s) I(s, r)}{\Delta p} - c(s) I(s, r).$$

This sets the minimum  $\beta$ :

$$\underline{\beta} = p_H \gamma / p_L. \tag{3.8}$$

If the banking sector is perfectly competitive, i.e. with free entry at each level of skill, banks at each skill level will earn this minimum return  $\underline{\beta}$ .<sup>2</sup>

### 3.2.3 Uninformed investors

Uninformed investors in the economy are willing to invest alongside a bank, but unable to monitor. As such, they earn a lower rate of return  $\gamma < \beta$ , where  $\gamma$  is set exogenously by some other instrument in which uninformed investors can invest, such as a risk free bond.<sup>3</sup> Uninformed capital can be thought of as banking sector liabilities, such as deposits, wholesale funding, or interbank loans.

The maximum income that can be pledged to uninformed investors while maintaining incentive compatibility must be enough to pay uninformed investors a return  $\gamma$  on their contribution to the project:

$$p_H R_u \geq \gamma I_u. \tag{IC_u}$$

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<sup>2</sup>The main results of the chapter also hold if the return  $\beta$  varies in skill. This would correspond to cases in which there is imperfect competition, so long as banks do not act as monopolists. In the monopolistic case, banks can extract all the surplus that firms gain from borrowing from a better bank, as a result of which investment sizes are no longer increasing in bank skill. The case with  $\beta(s)$  is shown in the Appendix.

<sup>3</sup>Alternately,  $\gamma$  can be set in equilibrium when faced with a supply schedule for uninformed capital.

Suppose  $(IC_f)$  and  $(IC_m)$  bind. The maximum return which can be promised to uninformed investors is therefore:

$$R_u(s, r) = I(s, r) \left[ r - \frac{e + c(s)}{\Delta p} \right]. \quad (3.9)$$

Since uninformed investors are assumed to have an opportunity cost of  $\gamma$ , this pins down the maximum investment possible from uninformed investors:

$$I_u(s, r, \gamma) = \frac{p_H R_u(s, r)}{\gamma}. \quad (3.10)$$

Combining equations (3.9) and (3.10) it is evident that the maximum share of funds available from uninformed investors is increasing in both bank skill and firm productivity, as shown in Figure 3.1.

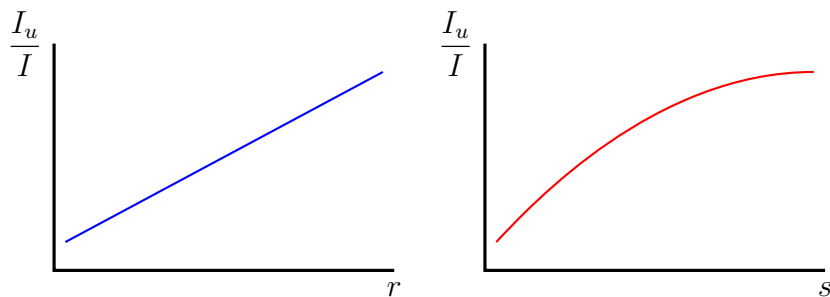


Figure 3.1: Share of uninformed capital

Higher productivity firms have more returns available to pledge to uninformed investors, and are therefore able to attain a greater share of leverage from them. Higher skill banks have a lower per unit cost of monitoring, and so require lower returns to maintain incentive compatibility. As a result, more returns can be pledged to attract uninformed investors if a firm is matched with a high skill bank. These patterns will subsequently drive the overall investment size of firms to be increasing in  $r$  and  $s$ , as shown in the following section.

### 3.2.4 Competitive equilibrium

With these assumptions about banks and uninformed investors, the maximum level of investment that a firm can make is given by combining (3.1), (3.5), (3.9), and (3.10) to obtain:

$$I(s, r) = \frac{1}{1 - \frac{p_H c(s)}{\beta \Delta p} - \frac{p_H}{\gamma} \left[ r - \frac{e+c(s)}{\Delta p} \right]}. \quad (3.11)$$

The investment of a firm is also a measure of firm leverage, since each firm is endowed with one unit of capital. For example, if both types of capital are infinitely expensive, i.e.  $\beta = \gamma = \infty$  the firm cannot borrow at all. As the denominator above approaches zero, the size of the total investment goes to infinity. The two fractions that enter negatively in the denominator of equation (3.11) reflect the share of  $I(s, r)$  contributed from informed and uninformed investors, respectively.

Since  $\gamma < \beta$ , firm managers prefer to maximize the investment from uninformed capital rather than bank loans. As a result,  $(IC_m)$  will bind, i.e. banks will be paid the minimum that is incentive compatible for them to monitor. To maximize firm profits, it is also optimal that  $(IC_f)$  binds, because firm returns are also increasing in total investment size. Paying more than the minimum  $(IC_f)$  reduces the returns available to be pledged to uninformed investors, and therefore the total investment size. As a result, the firm problem can be stated as maximizing (3.3) subject to (3.1), (3.2), (3.4),  $(IC_f)$  and  $(IC_m)$  holding with equality, (3.9), and (3.10). Equivalently, (3.11) can be taken as the maximal level of investment that result from the firm optimization problem.

From equation  $(IC_m)$ , banks' returns are increasing in the size of the firm's investment. This gives banks an incentive to lend to projects that are of the highest productivity possible given the firms and other banks in the economy.<sup>4</sup> From equations (3.4) and (3.11) it is possible to see a basic form of complementarity: the size of an

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<sup>4</sup>When  $\beta$  is uniform this preference is weak; it is a strict preference when  $\beta$  is a function of skill.

investment depends positively on both bank skill  $s$  and firm productivity  $r$ .

**Lemma 3.1.** *Investment size is increasing in both  $s$  and  $r$ , i.e.  $dI/ds > 0$  and  $dI/dr > 0$ .*

*Proof.* All proofs are included in the Appendix. □

As bank skill increases, the cost of monitoring declines, which leaves firms with more returns that can be pledged to uninformed investors. A high skill bank makes a smaller loan because it has a lower monitoring cost, and so requires a lower gross return to maintain incentive compatibility. Consequently, a high skill bank is more able to attract leverage uninformed capital. The change in financing mix lowers the overall cost of capital for the firm. In this way, a more efficient bank allows a firm to undertake a larger investment. Similarly, a higher productivity firm can make a larger investment because more funds are generated that can be used to attract investors. These properties are shown graphically in Figure 3.2.

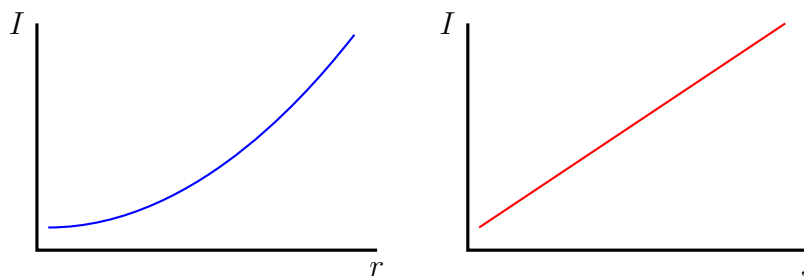


Figure 3.2: Investment size

The complementarity between firms and banks also has a particular property that is useful for analyzing matching between banks and firms, namely that it is log-supermodular.

**Lemma 3.2.**  *$I(s, r)$  is strictly log-supermodular.*

Log-supermodularity gives that:

$$I(s', r')I(s, r) > I(s, r')I(s', r) \quad \text{for all } s' > s \text{ and } r' > r. \quad (\text{LSM})$$

Since  $I$  is strictly positive, (LSM) can be rearranged as:

$$\frac{I(s', r')}{I(s, r')} > \frac{I(s', r)}{I(s, r)}.$$

Lemma 3.2 states that high productivity firms benefit relatively more from matching with a high skill bank. In other words, high-skill banks have a comparative advantage in lending to high productivity firms. Although the assumptions in this setup are based on a stylized case of heterogeneity among banks and firms, this demonstrates an instance in which the size of financed projects is complementary. Log-supermodularity is useful because it allows for comparative static predictions to be made for broad classes of functions which satisfy this property. Importantly, in this setting, log-supermodularity is derived rather than assumed. To justify the application of this property in a novel setting, I demonstrate its microfoundations in a model of firms and banks. Although log-supermodularity is shown here using a specific model, I expect the general results to extend to other production functions in which log-supermodularity holds.

Intuitively, log-supermodularity in this setting can be understood in a similar way as Lemma 3.1. The relative advantage of high productivity firms in borrowing from high skill banks derives from their ability to attract more uninformed capital compared to low skill banks, and because this uninformed capital is relatively cheaper. Not only do the overall loaned funds increase, but also the overall cost of capital falls.

In a competitive equilibrium, all firms and banks maximize profits, and all markets clear. Profit maximization by firms requires:

$$rI(s, r) - R_m(s) - R_u(s, r) - R_f(r) \leq 0 \quad \text{for all } s \in S, \quad (3.12)$$

$$rI(s, r) - R_m(s) - R_u(s, r) - R_f(r) = 0 \quad \text{for all } s \in S \text{ s.t. } L(s, r) > 0.$$

Goods market clearing:

$$F(r) = \int_{s \in S} L(s, r) ds \quad \text{for all } r \in R \quad (3.13)$$

Banks:

$$\max_{L(s, r)} \Pi_m(s) = \int_{r \in R} [p_H R_m(s, r) - c(s) I(s, r)] L(s, r) dr \quad \text{for all } s \in S. \quad (3.14)$$

Lending market clearing:

$$k_m(s) = \int_{r \in R} I_m(s, r) L(s, r) dr \quad \text{for all } s \in S. \quad (3.15)$$

Formally, a competitive equilibrium is defined as follows:

**Definition 3.1.** *A competitive equilibrium is a set of functions  $L : S \times R \rightarrow \mathbb{R}^+$ ,  $R_m : S \rightarrow \mathbb{R}^+$ ,  $R_f : R \rightarrow \mathbb{R}^+$ ,  $I_m : S \times R \rightarrow \mathbb{R}^+$ ,  $I_u : S \times R \rightarrow \mathbb{R}^+$  and prices  $\gamma$  and  $\beta$  such that conditions (3.12)-(3.15) hold.*

### 3.2.5 Bank-firm matching function

The setup of the model imposes restrictions on competitive equilibria, such that it is possible to solve for a function that matches firms and banks.

**Lemma 3.3.** *In a competitive equilibrium, there exists a continuous and strictly increasing matching function  $M : R \rightarrow S$  such that (i)  $L(s, r) > 0$  if and only if  $M(r) = s$ , and (ii)  $M(\underline{r}) = \underline{s}$  and  $M(\bar{r}) = \bar{s}$ .*

Lemma 3.3 can be interpreted in the following way: since firm output and profits are increasing in bank quality, firms prefer to be matched with the best bank possible. This is because good banks have a comparative advantage in providing financing to the higher productivity firms in the economy, and allow firms to undertake larger investments. For example, this property could capture the fact that high productivity firms have broad banking needs (e.g. various credit lines and loan facilities, trade credits, exchange rate

services, etc.) which allow it to benefit relatively more from a higher skill bank than a low productivity firm that requires only a loan.

Importantly, the upper bounds of bank skill and firm productivity and the lower bound of bank skill are assumed to be exogenous, but the lower bound of firm productivity is set endogenously.

The remainder of the analysis relies on the following Lemma.

**Lemma 3.4.** *In a competitive equilibrium, the matching function satisfies*

$$\frac{dM}{dr} = \frac{I_m(M(r), r)F(r)}{k_m(M(r))}, \quad (3.16)$$

with  $M(\underline{r}) = \underline{s}$  and  $M(\bar{r}) = \bar{s}$ .

The matching function in Lemma 3.4 is an ordinary differential equation, determined by market clearing. The intuition for the matching function is that its slope equates firms' demand for capital with supply.

Importantly, the matching process in this economy leads to bank portfolios that are concentrated and heterogeneous. Concentration derives from the fact that firms aim to match with the best banks possible. Thus, the best banks lend to the best firms, and for some interval of firms that are closely related in terms of productivity, they are likely to be matched banks of similar skill. I explore this idea using two graphical examples, shown in Figures 3.3 and 3.4.

Figure 3.3 demonstrates a simple case in which there are three banks ordered in terms of skill,  $s_1 < s_2 < s_3$ . Strictly speaking, discrete banks differ from the continuum under which the results of the chapter are proved, but the basic intuition is the same. For simplicity, each bank has the same initial capital  $k_m(s) = k_m$  and firms are uniformly distributed along a continuum,  $F(r) \sim U[\underline{r}, \bar{r}]$ . Since  $I_m$  is smaller for the bank of high skill, the best bank can make smaller investments in a larger number of projects, leading the banks' range of matches in  $r$  to be increasing in skill.



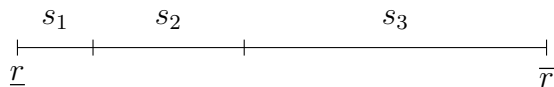


Figure 3.3: Matching pattern for discrete banks

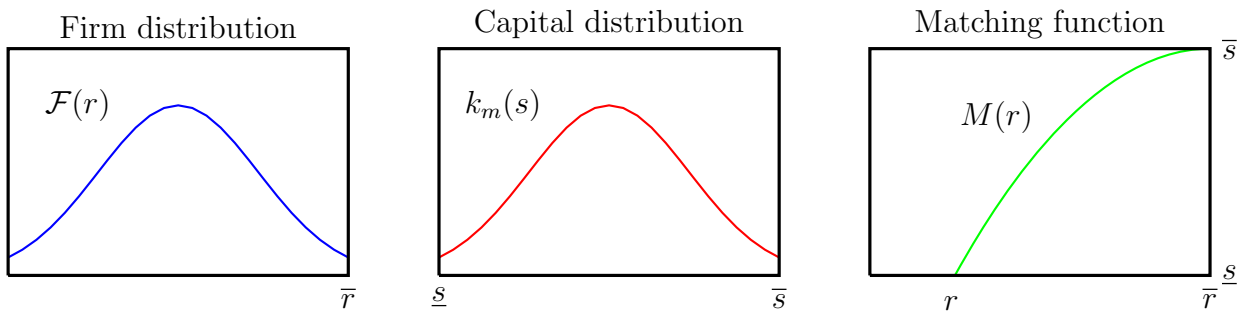


Figure 3.4: Firm distribution, capital distribution, and matching

A more general case is shown in Figure 3.4. For a given distribution of firms (left panel) and capital across banks (center panel), it is possible to solve for a matching function that takes the shape shown in the right panel. The matching function maps firms of a particular productivity  $r$  to a bank of skill  $s$ . The concave shape stems from the fact that  $I_m$  is decreasing in skill, so in general higher skill banks are able to capture a relatively large share of the lending market. The exact shape of the matching function depends on not only the distribution of firms and bank capital, but also on the shape of the cost function  $c(s)$ .

Figure 3.5 shows the patterns of firm and bank leverage in equilibrium. Since firms all begin with one unit of capital, their investment  $I(s, r)$  is also a measure of leverage. For banks, as a proxy for leverage I use the ratio of the sum of their capital and uninformed capital in the firm-specific investment they are mapped to, to the size of each bank's loan. Positive assortative matching in the economy leads to higher leverage among the top quality banks and highest productivity firms.

The pattern of matching is strict in the sense that each firm is matched to a single bank. This can be relaxed in a number of ways. First, banks could limit the size of

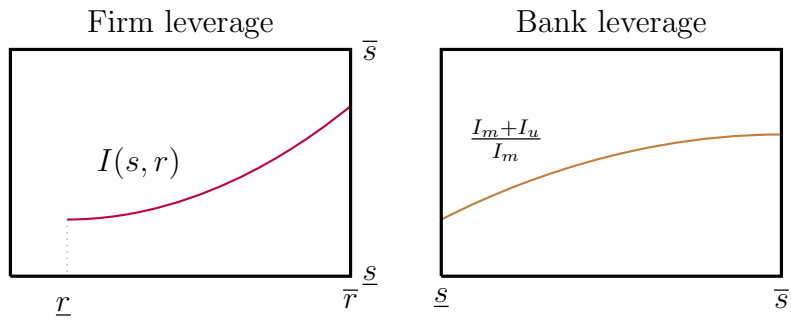


Figure 3.5: Firm and bank leverage

their exposure to any one particular firm, which would lead to firms being matched with an interval of banks, whose endpoints are weakly decreasing in firm productivity. This pattern is shown in Figure 3.6. Second, banks could be subject to idiosyncratic shocks that occur after matches have been determined, but before lending disbursements. This would lead to the same general pattern as in the first case. Third, if the characteristics of banks or firms are not perfectly observable, this could lead to less strict patterns of matching, as well. However, for simplicity I focus on the basic prediction of strict matching, with the assumption that this general pattern follows for richer cases, as well.

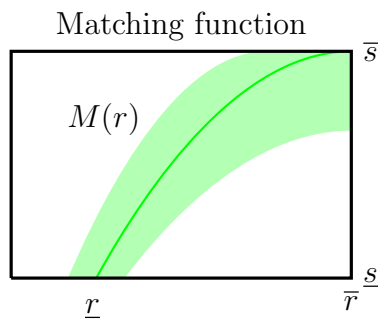


Figure 3.6: Multiple bank matches

### 3.3 Applications

Given the matching function characterized in Section 3.2, I now explore how a variety of macroeconomic shocks affect the pattern of matching, lending, leverage, and output.

#### 3.3.1 Productivity shocks

Consider a productivity shock that leads there to be more high productivity firms in an economy, as shown in the top left panel of Figure 3.7. If banks' capital is unaffected, then the funds banks have available must then be allocated among a shifted distribution of firms. This leads to a downwards shift in the matching function:

**Proposition 3.1.** *Suppose  $F'(r')F(r) > F(r')F'(r)$  for all  $r' > r$ . Then  $M'(r) \leq M(r)$  for all  $r \in R \cap R'$ .*

The productivity shock described Proposition 3.1 causes the distribution of firms over  $r$  to shift to the right. In response to an increase in the number of high productivity firms, banks lend more to higher productivity firms, but this ties up bank capital in a way that causes a downwards shift in the matching function  $M(r)$ . Graphically, this is shown in the top right panel of Figure 3.7. As a result, firms match with worse banks. This leads to a decrease in lending on the extensive margin, in that some low productivity firms will now be crowded out of the market.

For a given productivity level, firm leverage is lower, because firms are matched with worse banks. Yet, bank leverage rises because banks are matched with better firms, with larger effects on worse banks. These results are shown in the bottom panels of Figure 3.7. Because the shift in the matching function causes firms to match with lower skilled banks, output rises by less than the increase in productivity could generate if banks were able to obtain additional capital. In this way, growth without financial development may pose limits to the firms that exist in the economy.

To summarize, a positive productivity shock to firms in the economy causes:

1. An downwards shift in the matching function, such that firms match with worse banks, and a decrease in lending on the extensive margin;
2. A decrease in firm leverage at a given  $r$ , with larger effects for worse firms;
3. An increase in bank leverage, with larger effects for worse banks; and
4. A less than proportional increase in overall output.

### 3.3.2 Uninformed capital inflows

A second application of the model is to capital inflows and credit quality. Capital inflows and credit booms often precede financial crises (Schularick and Taylor, 2012; Jorda et al., 2013), and also seem to lead to higher bank risk taking (Shin, 2009; Dell’Ariccia and Marquez, 2006). This is consistent with the idea that banks’ moral hazard problems are worsened by higher liquidity (Diamond and Rajan, 2001). This model tells a complementary story. If the universe of potential firms is unlimited, but

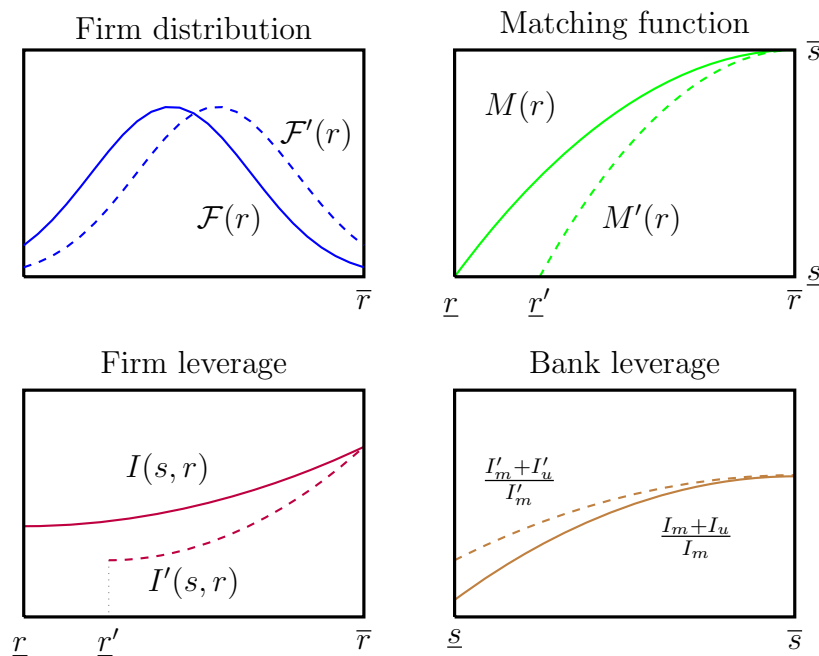


Figure 3.7: Productivity shock

high quality firms are in limited supply, then capital inflows can cause both increases in leverage and increased lending on the extensive margin, to new lower productivity firms.

There are two ways to consider capital inflows in the context of this model, the first of which is an exogenous fall in the cost of uninformed capital  $\gamma$ .

**Proposition 3.2.** *A decline in  $\gamma$  leads to  $M'(r) \leq M(r)$  for all  $r \in R \cap R'$ .*

If uninformed capital is cheaper, firms demand more of it. If  $\gamma$  falls, by equation (3.8)  $\beta$  also falls, making bank loans cheaper as well. This increases the size of investment that can be undertaken by any firm of given  $r$ , as shown in the top left panel of Figure 3.8. Importantly, the loan  $I_m$  increases with  $I$  in order to maintain incentive compatibility. The top bank, then, must use more capital in each project. This causes the matching function to shift down, mapping firms to worse banks than they had borrowed from before the shock. Without additional capital flowing into the system, the overall result will be to raise  $\underline{r}$ , i.e. the overall quality of firms in the economy increases. This result shown in the top right panel of Figure 3.8.

The effect that this has on firm and bank leverage are then a combination of the fall in  $\gamma$ , which would tend to increase leverage, and the change in the matching function. Firms matched with worse banks can borrow less from uninformed investors, which leads to increase in their cost of capital. Overall, this drives an increase in leverage for the best firm, but the size of the increase is smaller for less productive firms. There may be a subset of firms for whom the fact of re-matching dominates the cheaper cost of uninformed capital, and for whom leverage falls.

Likewise, for the top bank (whose match does not change), leverage increases. This effect is amplified for low-skilled banks, that match with better firms as a result of the shock. The combined result is to lead to the largest increases in leverage for low-skilled banks. Output increases for the top firm, but may not increase for marginal firms who

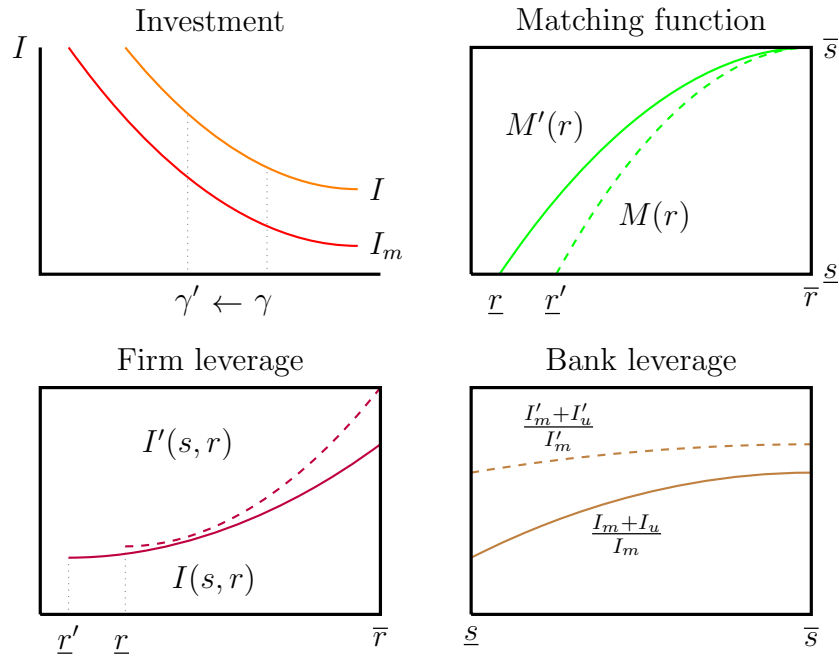


Figure 3.8: A fall in  $\gamma$

are now matched with worse banks.

Inflows of uninformed capital therefore leads to:

1. An downwards shift in the matching function, such that firms match with worse banks, and a decrease in lending on the extensive margin;
2. An increase in firm leverage for the best firm, which declines as firm productivity falls;
3. An increase in bank leverage for the top bank, which increases as bank skill falls;
4. An increase in output for the top surviving firm, which decreases as firm productivity falls.

### 3.3.3 Capital inflows to banks

An alternate scenario in which capital inflows may impact lending markets is if they are channeled to banks, through wholesale markets or interbank lending. In this case, the

effects of capital inflows are distinct from the case in the previous section. Proposition 3.3 considers the effect of inflows that increase the capital of all banks.

**Proposition 3.3.** *Suppose  $k'_m(s) > k_m(s)$ , for all  $s$ . Then  $M'(r) \geq M(r)$  for all  $r \in R \cap R'$ .*

Since banks each have more capital available to lend, this allows better skilled banks to take an even larger share of the market of firms. Importantly, this does not change the size of the investments which can be made by firms. In this way, additional capital can cause  $\underline{r}$  to decline. These patterns are shown in Figure 3.9.

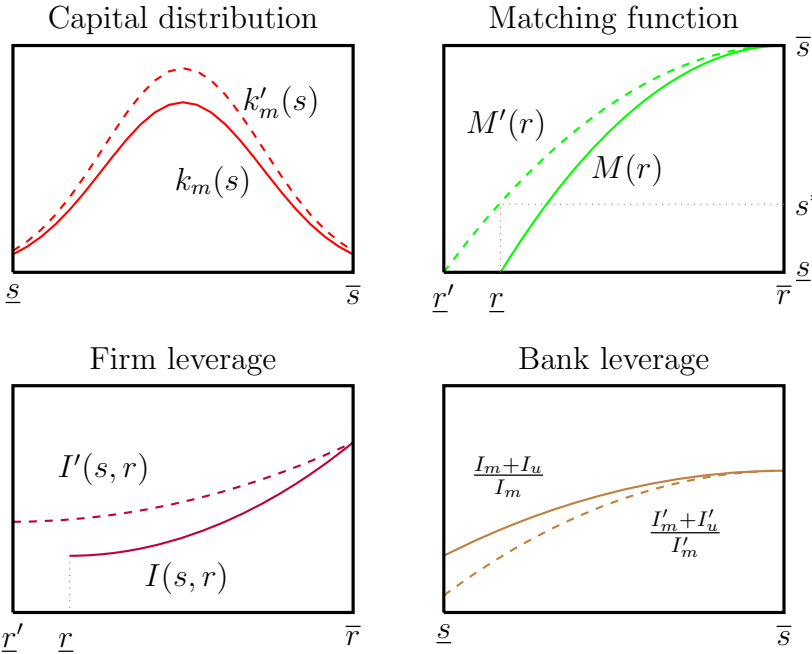


Figure 3.9: Capital inflows to banks

Crucially, all banks with  $s \leq s^*$  are now lending to marginal firms. The shift in matches that results from capital inflows to the banking sector means each firm except the top firm gets a marginal increase in leverage from matching with a better bank. Since banks are matched with worse firms, their leverage declines.

To summarize, an increase in  $k_m(s)$  for banks of all skill levels  $s$  results in:

1. An upwards shift in the matching function, such that firms match with better banks, and an increase in lending on the extensive margin;
2. An increase in firm leverage, with larger effects for worse firms;
3. A decrease in bank leverage, with larger effects for worse banks; and
4. A increase in output for surviving firms.

The first story - a fall in  $\gamma$  - explains why capital inflows may cause bank leverage to increase. The second story is broadly consistent with liquidity leading to higher bank risk taking, and that this behavior is concentrated among certain banks. Further, the two stories are consistent with Jimenez et al. (2014), who find that Spanish banks which received capital inflows lent more to existing borrowers, and also more on the extensive margin. In this case, much capital was channelled to real estate projects which appear to have been risky investments, ex-post.

### 3.3.4 Shocks to high bank types

The final experiment considered in this chapter concerns a shock that disproportionately affects high-skill banks in the economy. This is a relevant case to consider as much recent financial regulation has focused on big banks. To the extent that bank size is a reflection of skill, this theory tells us that these banks are also likely to be the lenders to the highest productivity firms in the economy. Proposition 3.4 explores the effects of a shock that shifts bank capital towards lower skill banks in an economy.

**Proposition 3.4.** *Suppose  $k'_m(s')k_m(s) < k_m(s')k'_m(s)$  for all  $s' > s$ . Then  $M'(r) \leq M(r)$  for all  $r \in R \cap R'$ .*

The initial effect of a shock to high skill banks is straightforward: since they have less capital, they lend to fewer projects. Even if the amount of bank capital in the economy is unchanged, banks lend to fewer firms than before, because the loans of lower skilled



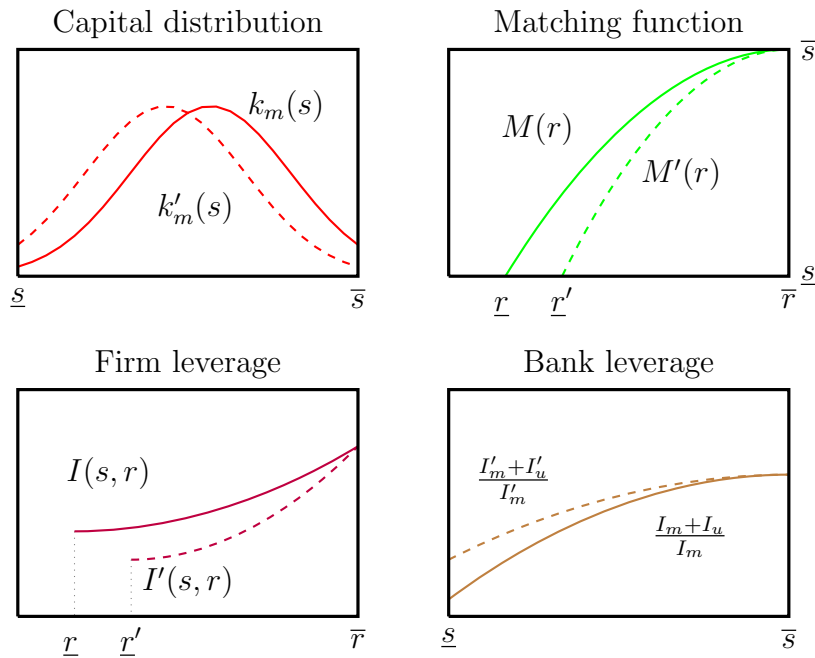


Figure 3.10: Shock to large banks

banks must be larger to maintain incentive compatibility. Therefore, the same amount of bank capital goes less far. Firms matched with worse banks can borrow less, but bank leverage increases as banks are matched with better firms. This is particularly pronounced for low skill banks. Output falls for surviving firms, and overall also due to a reduction in lending on the extensive margin. These effects are displayed graphically in Figure 3.10.

A shock to high-skill banks, such that the distribution of capital in the economy shifts towards low-skill banks:

1. An downwards shift in the matching function, such that firms match with worse banks, and a decrease in lending on the extensive margin;
2. A decrease in firm leverage, with larger effects for worse firms;
3. An increase in bank leverage, with larger effects for worse banks; and
4. A decrease in output for surviving firms, with larger effects for worse firms, and overall.

These results point to potential side effects of regulations that specifically target the high skill banks in an economy: this may lead to less funding for firms in general, and in particular to the exclusion of low productivity firms from the lending market. In addition, increasing leverage at low skill banks may be a concern as well.

### 3.4 Conclusion

This chapter demonstrates a setup in which the matching in corporate loan markets is analytically tractable and can be applied to think about the implications of macroeconomic shocks for lending, leverage, and output. The model predicts that a positive productivity shock to firms leads decreases in extensive and intensive margin lending, which demonstrates the importance of financial development alongside productivity growth. The model provides a framework in which capital inflows influence credit quality and bank and firm leverage, but in which the specific effects depends on whether inflows are primarily uninformed or channeled via the banking system. Finally, shocks to high skilled banks are shown to lead to reductions in intensive and extensive margin lending. There remains much to be explored in terms of the broader ramifications of matching in corporate loan markets.

There are also a number of limitations in the current setup. First, I assume firms differ in terms of their productivity, but are otherwise identical. This is clearly unrealistic, as there are many other dimensions in which firms differ: capital, risk profile, sector, location, position in production chain, etc. Second, this is a static model, and in the context of bank lending there are dynamic effects which are likely to be important. Banks are unlikely to have perfect information about the distribution of agents in the economy, and so this setup abstracts from the effort that banks need to exert in order to screen potential new clients. This cost is likely to play a role in the persistence of bank-firm relationships, which is particularly important to consider in the context of

shocks. I also abstract from the firm-specific advantage gained by banks who lend to firms, because in the model there are no switching costs. Third, this chapter treats risk in a very simple way, in that the success of projects is an exogenous parameter. Banks obviously lend with a richer sense of firm and portfolio risk. At the same time, leverage is likely to influence the outcomes of banks and firms.

Overall, the extent of bank concentration and portfolio heterogeneity may have important aggregate implications, in terms of leverage, credit quality, and the properties of business cycles. It is a topic on which there is much room for future work.

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# Appendix A

## Appendix to Chapter 1

## A.1 Issuance criteria

Table A.1: Accounting Criteria for Issuance of Domestic Convertible Bonds

Panel A: Secured bonds							
	Minimum net worth (billion yen)	Hur- dles	Capital Ratio	Divi- dends per share	Ratio of net worth to paid- in-capital	Business profits as a % of total assets	Ordinary after- tax profit per share
1976 Oct to 1987 Jul	10	1	15	5*	1.2	4	7*
	6	2	20	5*	1.5	5	7*
1987 Jul to 1990 Dec	10	1	10	5*	1.2	5	7*
	6	2	12	5*	1.5	6	7*
	3	2	15	5*	2.0	7	7*

Panel B: Unsecured bonds							
	Minimum net worth (billion yen)	Hur- dles	Capital Ratio	Divi- dends rule	Ratio of net worth to paid- in-capital	Business profits as a % of total assets	Interest coverage
1979 Mar to 1982 Dec	600	3	40*	a	10	4	4
	300	3	45*	a	14	8	6
	150	3	50*	a	18	12	8
1983 Jan to 1985 Jun	110	3	40*	a	10	4	4
1985 Jul to 1987 Jan	150	2	15	b*	6	1.2	1.5
	110	2	20	b*	7	1.5	2
	55	3	40*	a	10	4	4
1987 Feb to 1990 Oct	33	3	50*	a	12	5	5
	110	2	15	c*	6	1.2	1.5
	55	3	30*	a	8	3	3
	33	3	40*	a	10	4	4
	20	3	50*	a	12	5	5

Notes: \* An asterisk indicates criteria that must be met, in addition to the minimum net worth. In addition, one to three other conditions must be satisfied, as indicated in the hurdles column. The capital ratio is calculated as the ratio of equity plus reserves to total assets. Business profits are not explicitly defined in the source, but are calculated using the common definition of operating profits + interest income + dividend income. Interest coverage is also not explicitly defined, but is commonly defined as either business profits divided by interest payments, or income before tax + interest payments divided by interest payments. The dividend rules are defined as follows: (a) dividends per share greater than ¥6 in the five most recent accounting periods, (b) positive dividends in the five most recent accounting periods, and dividends per share greater than ¥5 in the three most recent periods, and (c) dividends per share greater than ¥5 in the three most recent accounting periods. Source: Ministry of Finance, Ōkurashō Shōkenkyoku nenpō (various issues), Hoshi and Kashyap (2001).

Table A.2: Ratings criteria for Issuance of Domestic Convertible Bonds

Panel A: Secured Bonds

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1989 May to 1995 Dec	Rating of BB or higher, dividends per share greater than 5 yen, ordinary after-tax profit greater than 7 yen.
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Panel B: Unsecured Bonds

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1987 Jul to 1988 Oct	Rating of A or higher; or rating of BBB or higher if net worth is greater than 55 billion yen
1988 Nov to 1990 Oct	Rating of A or higher; or rating of BBB or higher if net worth is greater than 33 billion yen
1990 Nov to 1995 Dec	Rating of BBB or higher

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Notes: There were no ratings criteria prior to July 1987, and they were abolished in January 1996. Source: Hoshi and Kashyap (2001).

## A.2 Additional empirical results

Table A.3: The effect of bond market access on other firm outcomes, 1977-90

	Baseline results				Linear control variables		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel 1. Dependent variable: Bank debt $_{j,t}$ / assets $_{j,t-1}$ ( $L_{j,t}$ )							
$Access_{j,t}$	-0.029*** (0.005)	-0.026*** (0.005)	-0.011** (0.005)	-0.016*** (0.006)	-0.014*** (0.005)	-0.009* (0.005)	-0.007 (0.005)
Observations	12,582	12,582	9,325	12,582	12,582	12,582	11,019
R-squared	0.80	0.81	0.84	0.82	0.80	0.86	0.87
Panel 2. Dependent variable: Interest payments $_t$ / debt $_{t-1}$							
$Access_{j,t}$	-0.015** (0.006)	-0.015** (0.006)	-0.003 (0.007)	-0.020** (0.008)	-0.025*** (0.007)	-0.008 (0.007)	-0.005 (0.007)
Observations	12,531	12,531	9,295	12,531	12,531	12,531	10,972
R-squared	0.59	0.60	0.63	0.59	0.59	0.60	0.62
Panel 3. Dependent variable: Total debt $_{j,t}$ / Assets $_{j,t-1}$							
$Access_{j,t}$	-0.025*** (0.007)	-0.025*** (0.007)	-0.009 (0.008)	-0.004 (0.008)	-0.013 (0.008)	-0.000 (0.008)	0.003 (0.009)
Observations	13,132	13,132	9,787	13,132	13,132	13,132	11,416
R-squared	0.49	0.52	0.58	0.51	0.49	0.50	0.56
Panel 4. Dependent variable: Investment $_{j,t}$ / Tangible fixed assets $_{j,t-1}$							
$Access_{j,t}$	-0.040*** (0.009)	-0.034*** (0.009)	-0.013 (0.010)	-0.011 (0.010)	-0.032*** (0.010)	-0.005 (0.010)	0.001 (0.010)
Observations	12,526	12,526	9,326	12,526	12,526	12,526	10,887
R-squared	0.26	0.29	0.34	0.27	0.26	0.26	0.29
Panel 5. Dependent variable: Employees $_t$ / employees $_{t-1} - 1$							
$Access_{j,t}$	-0.004* (0.002)	-0.003 (0.003)	-0.005 (0.003)	0.006** (0.003)	-0.003 (0.003)	0.003 (0.003)	0.004 (0.003)
Observations	13,117	13,117	9,777	13,117	13,117	13,117	11,401
R-squared	0.32	0.36	0.43	0.35	0.33	0.34	0.39
Control variables in all regressions:							
Firm f.e.s	Y	Y	Y	Y	Y	Y	Y
Year f.e.s	Y	Y	Y	Y	Y	Y	Y
Dummies*year:							
Main bank		Y					
Industry			Y				
Region			Y				
Size bin				Y			
Profitability bin				Y			
Net worth					Y	Y	Y
Capital ratio						Y	Y
Other criteria							Y

Notes:  $Access_{j,t}$  is a dummy variable denoting whether firm  $j$  meets accounting criteria to issue unsecured convertible bonds in year  $t$ . The dependent variables are winsorized at the top and bottom one percent of observations. The size bins are divided at 1 million, 10 million, and 100 million. The profitability bins are divided at 4 percent and 9 percent, which correspond to the 25th and 75th percentiles of profitability in the sample. Other criteria includes business profits as a percentage of assets, the ratio of net worth to paid in capital, and the interest coverage ratio. Standard errors are clustered at the firm and year level, shown in parentheses. \*, \*\*, and \*\*\* indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table A.4: The effect of bond market access on other firm outcomes, continued, 1977-90

	Baseline results				Linear control variables		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel 6. Dependent variable: $\text{Assets}_{j,t} / \text{Assets}_{j,t-1} - 1$							
<i>Access</i> <sub><i>j,t</i></sub>	-0.027*** (0.006)	-0.026*** (0.006)	-0.012* (0.007)	-0.010 (0.007)	-0.033*** (0.007)	-0.016** (0.007)	-0.010 (0.008)
Observations	13,132	13,132	9,787	13,132	13,132	13,132	11,416
R-squared	0.36	0.39	0.47	0.38	0.37	0.37	0.42
Panel 7. Dependent variable: $\text{Sales}_{j,t} / \text{Sales}_{j,t-1} - 1$							
<i>Access</i> <sub><i>j,t</i></sub>	-0.025*** (0.007)	-0.025*** (0.007)	-0.009 (0.008)	-0.004 (0.008)	-0.013 (0.008)	-0.000 (0.008)	0.003 (0.009)
Observations	13,132	13,132	9,787	13,132	13,132	13,132	11,416
R-squared	0.49	0.52	0.58	0.51	0.49	0.50	0.56
Panel 8. Dependent variable: $\text{Cash and cash equivalents}_{j,t} / \text{Assets}_{j,t-1}$							
<i>Access</i> <sub><i>j,t</i></sub>	0.032*** (0.004)	0.032*** (0.004)	0.031*** (0.004)	0.028*** (0.004)	0.025*** (0.004)	0.009** (0.004)	0.006 (0.004)
Observations	13,903	13,903	10,332	13,903	13,903	13,903	12,094
R-squared	0.72	0.73	0.76	0.73	0.72	0.73	0.75
Panel 9. Dependent variable: $\text{Inventory}_{j,t} / \text{Assets}_{j,t-1}$							
<i>Access</i> <sub><i>j,t</i></sub>	-0.009*** (0.002)	-0.008*** (0.002)	-0.006*** (0.002)	-0.014*** (0.002)	-0.007*** (0.002)	-0.006*** (0.002)	-0.006*** (0.002)
Observations	13,835	13,835	10,265	13,835	13,835	13,835	12,031
R-squared	0.89	0.90	0.91	0.89	0.89	0.89	0.91
Panel 10. Dependent variable: $\text{Book equity}_{j,t} / \text{Book equity}_{j,t-1} - 1$							
<i>Access</i> <sub><i>j,t</i></sub>	-0.078*** (0.011)	-0.074*** (0.011)	-0.059*** (0.013)	-0.060*** (0.013)	-0.110*** (0.012)	-0.024* (0.013)	-0.007 (0.013)
Observations	13,140	13,140	9,794	13,140	13,140	13,140	11,424
R-squared	0.24	0.29	0.37	0.30	0.25	0.28	0.37
Control variables in all regressions:							
Firm f.e.s	Y	Y	Y	Y	Y	Y	Y
Year f.e.s	Y	Y	Y	Y	Y	Y	Y
Dummies*year:							
Main bank		Y					
Industry			Y				
Region			Y				
Size bin				Y			
Profitability bin				Y			
Net worth					Y	Y	Y
Capital ratio						Y	Y
Other criteria							Y

Notes: *Access*<sub>*j,t*</sub> is a dummy variable denoting whether firm *j* meets accounting criteria to issue unsecured convertible bonds in year *t*. The dependent variables are winsorized at the top and bottom one percent of observations. The size bins are divided at 1 million, 10 million, and 100 million. The profitability bins are divided at 4 percent and 9 percent, which correspond to the 25th and 75th percentiles of profitability in the sample. Other criteria includes business profits as a percentage of assets, the ratio of net worth to paid in capital, and the interest coverage ratio. Standard errors are clustered at the firm and year level, shown in parentheses. \*, \*\*, and \*\*\* indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

## A.3 Proofs

### Proof of Proposition 1.1

*Proof.* Part (i) follows directly from equation (1.14). Part (ii.1) follows from the derivative of equation (1.16) with respect to  $f$ , (ii.2) follows from the derivative of equation (1.17) with respect to  $f$ . The shift down in the  $z^*$  curve leads to increased overall demand for funds (loan demand  $L$  and bond supply  $B^S$ ). For the market to clear in equation (1.15),  $r$  rises giving (ii.3). For (ii.4), output falls as capital is diverted from high productivity small firms to large firms with lower productivity, and by extension  $Z$  falls also, giving (ii.5).  $\square$

### Proof of Proposition 1.2

*Proof.* Part (i) and part (ii.1) and (ii.2) are as in the proof of Proposition 1.1. Part (ii.3) depends on whether banks' balance sheets become smaller or not. When banks borrow up to the constraint in equation (1.11), either because  $S > \phi E$  or because  $D^F > 0$ , the decline in loan demand results in a decline in  $r$ . In the case when  $B = 0$  and  $B^F > 0$ , domestic households cannot invest in bonds, and therefore banks retain their deposits. That overall demand for bank loans declines depends on the decline in bank loans among firms switching to mixed funding structures, compared to the balance of new bank loans demanded by new large borrowers. The change in loan demand is:

$$\frac{\partial L}{\partial f} = \frac{\partial}{\partial f} \left[ \int_{\underline{a}}^{a^*} \int_r^{\bar{z}} \theta a dG(a, z) + \int_{a^*}^{\bar{a}} \int_{z^*(a)}^{\bar{z}} \frac{m(a)}{r - r_f} dG(a, z) \right]$$

Note that  $a^*$  and  $z^*$  are functions of  $f$ , and  $z^*$  also depends on  $a$ . Assuming  $m(a) = m_1$ :

$$\begin{aligned} \frac{\partial a^*}{\partial f} &= \frac{1}{\theta(r - r_f) - m_1} \\ \frac{\partial z^*}{\partial f} &= \frac{1}{\theta a} \end{aligned}$$

The first term is straightforward because the boundaries in  $z$  do not depend on  $f$ :

$$\begin{aligned} \int_{\underline{a}}^{a^*} \int_r^{\bar{z}} \theta a dG(a, z) &= \int_{\underline{a}}^{a^*} \int_r^{\bar{z}} \theta a g(a, z) dz da \\ &= \int_{\underline{a}}^{a^*} \theta a g_A(a)|_r^{\bar{z}} dz \end{aligned}$$

Then using the Leibniz integral rule:

$$\begin{aligned} \frac{\partial}{\partial f} \left[ \int_{\underline{a}}^{a^*} \theta a g_A(a)|_r^{\bar{z}} dz \right] &= \theta a^* g_A(a)|_r^{\bar{z}} \frac{\partial a^*}{\partial f} \\ &= \frac{\theta a^* g_A(a)|_r^{\bar{z}}}{\theta(r - r_f) - m_1} \end{aligned}$$



This term is measures the gross increase in funds demanded by firms that switch from mixed funding structures to bank funding only.

For the second term, both integrals have one bound that depends on  $f$ . This accounts for two things. First, as  $f$  increases, firms switch from mixed funding to bank only. (This is negative, and offsets the positive increase counted in the first term.) Second, large marginal firms that enter at low  $f$  exit the borrowing market as  $f$  rises. This is negative for loan demand as well.

$$\begin{aligned} \int_{a^*}^{\bar{a}} \int_{z^*}^{\bar{z}} \frac{m(a)}{r-r_f} dG(a, z) &= \int_{a^*}^{\bar{a}} \int_{z^*}^{\bar{z}} \frac{m(a)}{r-r_f} g(a, z) dadz \\ &= \int_{a^*}^{\bar{a}} \frac{m(a)}{r-r_f} g_A(a)|_{z^*}^{\bar{z}} da \\ &= \int_{a^*}^{\bar{a}} \frac{m_1 a}{r-r_f} g_A(a)|_{z^*}^{\bar{z}} da \end{aligned}$$

Using  $F(a) = \frac{m_1 a}{r-r_f} g_A(a)|_{z^*}^{\bar{z}}$ , using the Leibniz integral rule:

$$\begin{aligned} \frac{\partial}{\partial f} \left[ \int_{a^*}^{\bar{a}} \frac{m_1 a}{r-r_f} g_A(a)|_{z^*}^{\bar{z}} da \right] &= -F(a^*) \frac{da^*}{df} + \int_{a^*}^{\bar{a}} \frac{\partial F}{\partial f} da \\ &= -\frac{m_1 a^*}{r-r_f} g_A(a^*)|_{z^*}^{\bar{z}} \frac{da^*}{df} + \int_{a^*}^{\bar{a}} \frac{\partial}{\partial f} \left[ \frac{m_1 a}{r-r_f} g_A(a)|_{z^*}^{\bar{z}} \right] da \\ &= -\frac{m_1 a^*}{r-r_f} \frac{g_A(a)|_{z^*}^{\bar{z}}}{\theta(r-r_f) - m_1} + \int_{a^*}^{\bar{a}} \frac{m_1 a}{r-r_f} \frac{\partial}{\partial f} \left[ \int_{z^*}^{\bar{z}} g(a, z) dz \right] da \end{aligned}$$

Using Liebniz for the interior term:

$$\begin{aligned} \frac{\partial}{\partial f} \left[ \int_{z^*}^{\bar{z}} g(a, z) dz \right] &= -g(a, z^*) \frac{\partial z^*}{\partial f} \\ &= -\frac{g(a, z^*)}{a\theta} \end{aligned}$$

Substituting that back in:

$$\begin{aligned} &= -\frac{m_1 a^*}{r-r_f} \frac{g_A(a)|_{z^*}^{\bar{z}}}{\theta(r-r_f) - m_1} - \int_{a^*}^{\bar{a}} \frac{m_1 a}{r-r_f} \frac{g(a, z^*)}{a\theta} da \\ &= -\frac{m_1 a^*}{r-r_f} \frac{g_A(a)|_{z^*}^{\bar{z}}}{\theta(r-r_f) - m_1} - \int_{a^*}^{\bar{a}} \frac{m_1}{r-r_f} \frac{g(a, z^*)}{\theta} da \end{aligned}$$

Adding the terms together, and noting that  $z^*(a^*) = r$ :

$$\begin{aligned} \frac{\partial L}{\partial f} &= \frac{\theta a^* g_A(a)|_r^{\bar{z}}}{\theta(r-r_f) - m_1} - \frac{m_1 a^*}{r-r_f} \frac{g_A(a)|_{z^*}^{\bar{z}}}{\theta(r-r_f) - m_1} - \int_{a^*}^{\bar{a}} \frac{m_1}{r-r_f} \frac{g(a, z^*)}{\theta} da \\ &= \frac{1}{r-r_f} \left[ a^* g_A(a)|_r^{\bar{z}} - \frac{m_1}{\theta} \int_{a^*}^{\bar{a}} g(a, z^*) da \right] \end{aligned}$$

When  $f = \infty$ ,  $a^* = \bar{a}$ , and the second integral is zero. Therefore,  $\frac{\partial L}{\partial f} > 0$ . When  $f$  falls,  $L$  falls, which decreases  $r$ . Parts (ii.4) and (ii.5) follow from (ii.3) and equations (1.21) and (1.22).  $\square$

### Proof of Proposition 1.3

*Proof.* For part (1), note that (1.16) depends on  $r - r_f$ : if  $r$  declines by as much as  $r_f$  (i.e. when banks are unconstrained),  $a^*$  does not change. When the pass through of  $r_f$  to  $r$  is incomplete (i.e. when banks are constrained),  $a^*$  declines. This also depends on the existence of bond markets, i.e.  $f < \infty$ . If  $f < \infty$ , part (2) follows from the derivative of equation (1.17) with respect to  $r_f$ . The pass through of  $r_f$  to  $r$  comes from competition among banks, which gives part (3), provided that banks are not already constrained. When banks are constrained, then  $r$  cannot fall. For part (4), equation (1.21) is increasing in  $r_f$  (first term). Since  $\theta > 1$ , decreases in  $r$  further increase output by shifting entrepreneurs from self-financing into the borrowing market. Although output rises, marginal firms entering self-financing or borrowing markets have lower productivity than existing firms, which implies part (5).

For the effect of bond markets on these responses, note that when banks are constrained, the fall in  $r_f$  results in a shift in  $a^*$  which leads firms to shift away from bank borrowing and towards bond issuance. This relaxes the bank constraint and allows banks to lower  $r$ . As such, the decrease in  $r$ , increase in  $Y$ , and decrease in  $Y$  that result from a decline in  $r_f$  are decreasing in  $f$  (i.e. increasing in the size of bond markets).  $\square$

### Proof of Proposition 1.4

*Proof.* Parts (1) and (2) follow from the derivatives of equations (1.16) and (1.17) with respect to  $\theta$ . The increase in  $\theta$  implies an increase in demand for capital among all firms, which requires either inflows or an increase in  $r$  for market clearing, yielding part (3). Part (4) comes from equation (1.21), where the second term is increasing in  $\theta$ . Any increase in  $r$  reallocates capital from low  $z$  firms to high  $z$  firms, which increases output as well. In an unconstrained case without bond markets, the scale of all firms simply increases, which is neutral for productivity. However, with bond markets, the downward shift in  $z^*$  leads to large marginal firms entering the borrowing market, which lowers  $Z$ .

For the effect of bond markets on these responses, note that when banks are constrained, the fall in  $\theta$  leads to an increase in  $r$ , which amplifies the shift in  $a^*$ . Because this relaxes the bank constraint, the increase in  $r$  is decreasing in the size of bond markets. By providing a source of financing that relaxes bank constraints, bond markets amplify the increase in output  $Y$ , but allow lower productivity firms to remain in or enter the market, thus attenuating the increase in  $Z$ .  $\square$

### **Proof of Proposition 1.5**

*Proof.* When  $D = \phi E$ , a decline in  $\phi$  or  $E$  requires an increase in  $r$  for market clearing, provided that not all firms can issue bonds, which gives part (3). Part (1) follows from the derivative of equation (1.16) with respect to  $r$ . Part (2) follows from the derivative of equation (1.17) with respect to  $r$ . The decline in output comes from equation (1.21), which gives part (4). Part (5) is implied by the increase in  $r$ , which implies an increase in the productivity of the marginal small firm entering the borrowing market.

For the effect of bond markets on these responses, note that  $\partial^2 a^* / \partial r \partial f < 0$ . This implies that a smaller  $f$  (i.e. larger bond market) leads to a larger change in  $a^*$  results from a change in  $r$ . This relaxes bank borrowing constraints and attenuates the increase in  $r$ . This attenuates the effects of the interest rate on output and productivity as well.  $\square$

# Appendix B

## Appendix to Chapter 2

## B.1 Proofs

### Proof of Lemma 2.1.

*Proof.* The lemma is proved by contradiction. First consider property (i). Set  $b = 0$  and consider some  $b^* > 0$ . If a default does not occur, there are no financial frictions, i.e.  $n_1 \geq \tilde{N}$ . In the event of default, the banking sector loses nothing, since  $b = 0$ . As such,  $n_1^d = n_1$ . In either case, there are no financial frictions, and banks pay an equilibrium interest rate which is greater than 1. Risk neutral households consume  $c_1 = 0$ , irrespective of  $D$ . Consumption in  $t = 2$  is given by equation (2.3), the sum of savings and net worth of the banking sector,  $c_2 = R_2 d_1 + n_2$ . Substituting equation (2.13) gives:

$$c_2 = A_2 k_2.$$

Further substituting equations (2.10), (2.12), and (2.2) with  $c_1 = 0$  gives:

$$\begin{aligned} c_2 &= A_2 [A_1 k_1 - b^*], \\ c_2^d &= A_2 [A_1 k_1]. \end{aligned} \tag{B.1}$$

Therefore  $c_2 < c_2^d$  for all  $b^* > 0$ , and thus  $V_1^d > V_1$ . Default is certain, so no lending will occur in equilibrium, contradicting  $b^* > 0$ .

For property (ii), note that  $c_2$  and  $c_2^d$  are unchanged for  $b > 0$ , so long as the equity of the banking sector does not fall below  $\tilde{N}$ , so that there are no financial frictions. As before,  $c_2 < c_2^d$  for all  $b^* > 0$ , and thus  $V_1^d > V_1$ . This contradicts  $b^* > 0$ .  $\square$

### Proof of Lemma 2.2.

*Proof.* For  $n_1^d < \tilde{N}$ , default causes a distortion, and taxation is lump sum, so the result follows directly. For  $n_1^d > \tilde{N}$ , the Lemma can be proved by contradiction. Assume that for some  $n_1^d > \tilde{N}$ , default is optimal, i.e.  $V_1^d > V_1$ . Although bank equity falls by  $b$  relative to the no default case, households get additional income which they would otherwise have paid in taxes. Since there is no distortion, households face the same  $R_2$  in both cases. As a result, households deposit excess funds not paid in taxes to the banking sector, and  $V_1^d = V_1$ , a contradiction.  $\square$

### Proof of Lemma 2.3.

*Proof.* With  $b$  satisfying Lemma 2.1 and  $b^* > 0$ , it is possible to solve for the threshold value of  $A_1$  below which default is optimal by setting  $V_1^d = V_1$ .

In the no default case, as in equation (B.1):

$$V_1 = A_2 [A_1 k_1 - b^*].$$

In the case of default and financial frictions, deposits in the banking system are limited by equation (2.15) with  $R_2 = 1$ . Consumption in  $t = 1$  is the balance of

household wealth that could not be deposited in the banking system,  $c_1^d = R_1 d_0 - d_1^d$ . Consumption in  $t = 2$  is given by the sum of deposits (which earn  $R_2^d = 1$ ) and net worth of the banking system,  $c_2^d = d_1^d + n_2^d$ . The value of default is thus:

$$V_1^d = R_1 d_0 + n_2^d.$$

Substituting equations (2.13) and (2.10) gives:

$$V_1^d = R_1 d_0 + (A_2 - 1)d_1^d + A_2 n_1^d.$$

Substituting equation (2.15) and  $R_2 = 1$  gives:

$$V_1^d = R_1 d_0 + \frac{\theta A_2}{1 - (1 - \theta)A_2} n_1^d.$$

Substituting equation (2.12) and rearranging gives:

$$V_1^d = \frac{\theta A_2 A_1 k_1}{1 - (1 - \theta)A_2} + \left[ \frac{1 - A_2}{1 - (1 - \theta)A_2} \right] R_1 d_0. \quad (\text{B.2})$$

Then, setting  $V_1^d = V_1$ , it is straightforward to solve for the realization of productivity at which they are equal, assuming that  $R_1 = A_1$ :

$$\frac{\theta A_2 A_1 k_1}{1 - (1 - \theta)A_2} + \left[ \frac{1 - A_2}{1 - (1 - \theta)A_2} \right] R_1 d_0 = A_2 [A_1 k_1 - b^*],$$

which can be solved for  $\tilde{A}$ :

$$\tilde{A} = \max \left\{ b^* \left[ \frac{1 - (1 - \theta)A_2}{(A_2 - 1)(\frac{d_0}{A_2} - k_1(1 - \theta))} \right], \underline{A} \right\}. \quad (\text{B.3})$$

For default to occur when the realization of productivity is low, the slope of  $V_1$  with respect to  $A_1$  must be steeper than the slope of  $V_1^d$ . Taking derivatives of equations (B.1) and (B.2) gives:

$$\begin{aligned} \frac{dV_1}{dA_1} &= A_2 k_1, \\ \frac{dV_1^d}{dA_1} &= \frac{\theta A_2 k_1}{1 - (1 - \theta)A_2} + \left[ \frac{1 - A_2}{1 - (1 - \theta)A_2} \right] d_0. \end{aligned}$$

For the slope of  $V_1$  to be steeper than the slope of  $V_1^d$ , it must be that:

$$A_2 k_1 > \frac{\theta A_2 k_1}{1 - (1 - \theta)A_2} + \left[ \frac{1 - A_2}{1 - (1 - \theta)A_2} \right] d_0.$$

Rearranging gives:

$$k_1 < d_0 \frac{1}{A_2(1 - \theta)}.$$

If  $b$  follows equation (2.7), then  $k_1 = \frac{\lambda + \omega - 1}{\lambda}(n_0 + d_0)$ , and the condition can be written on  $n_0$ ,  $d_0$ ,  $A_2$ ,  $\theta$ ,  $\lambda$ , and  $\omega$ :

$$n_0 < d_0 \left[ \frac{1}{A_2(1 - \theta)} \frac{\lambda}{\lambda + \omega - 1} - 1 \right].$$

For parameter values under which this condition holds, when default occurs in equilibrium it will occur for low realizations of output, i.e. below the threshold  $\tilde{A}$ .  $\square$

### Proof of Proposition 2.1.

*Proof.* This follows from Lemma 2.3. Although equation (B.3) does not explicitly include  $b$ , note from equation (2.9) that increasing  $b$  beyond the banks' optimal choice (equation (2.7)) leads to crowding out of private investment, i.e.  $\frac{dk_1}{db} < 0$ . Since  $\tilde{A}$  is increasing in  $k_1$ , it follows that the threshold decreases for increasing levels of  $b$ .

There is a secondary effect of increased  $b$  on  $b^*$  because the level of fiscal spending is fixed, wherein increasing  $b$  decreases  $b^*$ , since  $b^* = g/q - b$ . To the extent that  $\tilde{q}$  rises because of the increase in  $b$ ,  $b^*$  is smaller still. This contributes to the decline in  $\tilde{A}$ .  $\square$

### Proof of Proposition 2.2.

*Proof.* This also follows from Lemma 2.3. Since  $\tilde{A}$  is increasing in  $k_1$ , and  $k_1$  increases with  $n_0$  in equation (2.9), higher  $n_0$  leads to a higher threshold  $\tilde{A}$ .  $\square$

### Proof of Proposition 2.3.

*Proof.* This also follows from Lemma 2.3.  $\tilde{A}$  is decreasing in  $d_0$ , so higher  $d_0$  leads to a lower threshold  $\tilde{A}$ . To the extent that higher deposits lead to higher levels of domestic debt demanded  $b$ , this also decreases the extent of fiscal needs which need to be financed abroad, due to both quantity and price effects, as in Proposition 2.1.  $\square$

### Proof of Proposition 2.4.

*Proof.* To show that domestic demand for sovereign debt is increasing in  $p$ , there are two cases to consider. Provided that equation (2.7) describes the optimal domestic demand for sovereign debt, this follows directly, because the derivative of  $b^d$  with respect to  $p$  is positive. The second case is one in which banks demand more as part of a strategy of reaching for yield.

To show that equation (2.7) indeed pins down the domestic demand for sovereign debt, we proceed in two steps: first, that it is never optimal to demand less than  $b^d$ , and then that if it is optimal to demand more, then demand remains increasing in  $p$ .

The first step is proved by contradiction. Assume that  $0 < b < b^d$  and  $b^* > 0$ , so that  $x > 0$ , i.e. not all of the funds of the banking sector can be invested in productive projects. In this case the  $t = 0$  balance sheet constraint of the aggregate banking system is:

$$k_1 + qb + x = n_0 + d_0.$$

Substituting equations (2.8) and (2.7) gives:

$$k_1 = \omega(n_0 + d_0) + (\lambda - 1)qb, \quad (\text{B.4})$$

and the evolution of bank equity in  $t = 1$  is:

$$n_1 = A_1 k_1 + b \cdot \mathbb{I}_{\{D=0\}} + Rx - R_1 d_0.$$

Although the safe asset returns  $R$ , the risk-adjusted return on government debt is also  $R$ . However, government debt provides the additional benefit from facilitating interbank transactions, and so increasing  $b$  up to  $b^d$  increases  $k_1$ , as shown in equation (B.4).

Since the default threshold is solved for in equation (B.2), the banks' optimization problem can be written as:

$$\max E[n_2] = \int_{\underline{A}}^{\tilde{A}} n_2^d f(A) dA + \int_{\tilde{A}}^{\bar{A}} n_2 f(A) dA. \quad (\text{B.5})$$

Bank equity is given by equation (2.13):

$$n_2 = A_2 k_2 - R_2 d_1.$$

In the no default case, substituting equations (2.10) and  $R_2 = A_2$  gives:

$$n_2 = A_2 n_1. \quad (\text{B.6})$$

In the event of default, substituting equations (2.10), (2.15) and  $R_2 = 1$  gives:

$$n_2^d = \frac{\theta A_2}{1 - (1 - \theta)A_2} n_1^d. \quad (\text{B.7})$$

In either case, bank equity in  $t = 2$  increases monotonically with  $n_1$ . Therefore, it cannot be optimal to have  $x > 0$  if  $0 < b < b^d$ .

To show that it is also not optimal to demand  $b > b^d$ , note that in this case, demand for government debt would crowd out private investment, i.e.  $k_1$  is decreasing in  $b$  if  $b > b^d$ :

$$k_1 = n_0 + d_0 - qb. \quad (\text{B.8})$$

Taking equation (B.5) and substituting equations (B.6), (B.7),  $R_1 = A_1$ , and (2.12) gives:

$$\max E[n_2] = \int_{\underline{A}}^{\tilde{A}} \frac{\theta A_2}{1 - (1 - \theta)A_2} A [k_1 - d_0] f(A) dA + \int_{\tilde{A}}^{\bar{A}} A_2 [A(k_1 - d_0) + b] f(A) dA. \quad (\text{B.9})$$



Substituting equation (B.8) and taking derivatives with respect to  $b$  yields the first order condition for the bank problem:

$$\int_{\underline{A}}^{\tilde{A}} \frac{\theta A_2}{1 - (1 - \theta)A_2} [-Aq] f(A) dA + \int_{\tilde{A}}^{\bar{A}} A_2 [-Aq + 1] f(A) dA. \quad (\text{B.10})$$

If the sum of these two terms is negative, then demand for sovereign debt is at the optimal level, i.e. equation (2.7). The first term is unambiguously negative. However, the second term may be positive or negative. If it is positive and larger than the first term, then domestic demand for sovereign debt increases not only because of the need for collateral, but also because banks are reaching for yield. In other words, the expected return on bonds is higher than the expected losses from crowding out.

From equation (2.6), the second term of equation (B.10) equals:

$$1 - Aq = \frac{R - A(1 - p)}{R},$$

which is also increasing in  $p$ . □

#### **Proof of Proposition 2.5.**

*Proof.* This follows directly from Lemma 2.3. Equation (B.3) is increasing in  $b^*$ , thus the higher foreign debts are, the higher the threshold below which default results. □

#### **Proof of Proposition 2.6.**

*Proof.* This follows directly from Lemma 2.3. □

#### **Proof of Proposition 2.7.**

*Proof.* If financial frictions bind in  $t = 0$ , then bank deposits in  $t = 0$  are limited to a multiple of bank equity:

$$d_0 \leq \frac{(1 - \theta)A_1 \left(\frac{\lambda + \omega - 1}{\lambda}\right)}{R_1 - (1 - \theta)A_1 \left(\frac{\lambda + \omega - 1}{\lambda}\right)} n_0$$

This limits deposits to an increasing function of  $n_0$ . From Proposition 2.3,  $\Delta(b, b^*)$  is decreasing in  $d_0$ . Conversely, if  $d_0$  falls due to a constraint  $t = 0$ , default risk increases. □

### Proof of Proposition 2.8.

*Proof.* Formally, for financial repression to improve welfare requires that  $dV_1/db > 0$ . This condition can be written:

$$\begin{aligned}\frac{dV_1}{db} &= A_2 \left[ A_1 \frac{dk_1}{db} - \frac{db^*}{db} \right], \\ &= A_2 \left[ A_1 \left( -\frac{dq}{db} b - q \right) + \frac{g}{q^2} \frac{dq}{db} + 1 \right], \\ &= A_2 \left[ \frac{dq}{db} \left( \frac{g}{q^2} - A_1 \right) + 1 - qA_1 \right] > 0.\end{aligned}$$

If debt is not risky, i.e.  $q = 1$ , this is unambiguously negative, i.e. financial repression will only decrease welfare. However, for  $q < 1$ , there are cases where  $dV_1/db > 0$ .  $\square$

# Appendix C

## Appendix to Chapter 3

## C.1 Proofs

### Proof of Lemma 3.1.

*Proof.* From equation (3.11), it is straightforward to show that  $\partial I/\partial r > 0$ . Let  $a_1(s, r) = 1 - \frac{p_H c(s)}{\beta \Delta p} - \frac{p_H}{\gamma} \left[ r - \frac{e+c(s)}{\Delta p} \right]$ .

$$\begin{aligned} \frac{\partial I}{\partial r} &= \frac{-1}{a_1(s, r)^2} \frac{\partial a_1}{\partial r} \\ &= \frac{1}{a_1(s, r)^2} \frac{p_H}{\gamma} > 0 \end{aligned}$$

Similarly, for  $\partial I/\partial s > 0$ :

$$\begin{aligned} \frac{\partial I}{\partial s} &= \frac{-1}{(a_1(s, r))^2} \left( -\frac{p_H c'(s)}{\beta \Delta p} - \frac{p_H}{\gamma} \left[ -\frac{c'(s)}{\Delta p} \right] \right) \\ &= -\frac{1}{(a_1(s, r))^2} \frac{p_H c'(s)}{\Delta p} \left( -\frac{1}{\beta} + \frac{1}{\gamma} \right) \\ &= -\frac{1}{(a_1(s, r))^2} \frac{p_H c'(s)}{\Delta p} \left( \frac{\beta - \gamma}{\gamma \beta} \right) > 0 \end{aligned}$$

For informed capital to be invested,  $\beta$  must be larger than  $\gamma$  so the term inside brackets is positive. Monitoring cost  $c(s)$  is decreasing in skill, so  $c'(s)$  is negative. Therefore, investment sizes are strictly increasing in bank skill  $\partial I/\partial s > 0$ .  $\square$

### Proof of Lemma 3.2.

*Proof.*  $I$  is strictly positive and twice differentiable. If  $\partial^2 \ln I/\partial s \partial r > 0$ ,  $I$  is strictly log-supermodular in  $(s, r)$ . Let  $a_1(s, r) = 1 - \frac{p_H c(s)}{\beta \Delta p} - \frac{p_H}{\gamma} \left[ r - \frac{e+c(s)}{\Delta p} \right]$ .

$$\begin{aligned} \frac{\partial}{\partial s} \ln I &= \frac{\partial I/\partial s}{I(s, r)} \\ &= \frac{-1}{(a_1(s, r))^2} \left[ \frac{p_H c'(s)}{\Delta p} \left( \frac{\beta - \gamma}{\gamma \beta} \right) \right] \frac{1}{I(s, r)} \\ &= \frac{-1}{a_1(s, r)} \left[ \frac{p_H c'(s)}{\Delta p} \left( \frac{\beta - \gamma}{\gamma \beta} \right) \right] > 0 \end{aligned}$$

Taking the cross-derivative gives:

$$\begin{aligned} \frac{\partial^2}{\partial s \partial r} \ln I &= \frac{1}{a_1(s, r)^2} \left[ \frac{p_H c'(s)}{\Delta p} \left( \frac{\beta - \gamma}{\gamma \beta} \right) \right] \frac{\partial a_1}{\partial r} \\ &= \frac{-1}{a_1(s, r)^2} \left[ \frac{p_H c'(s)}{\Delta p} \left( \frac{\beta - \gamma}{\gamma \beta} \right) \right] \frac{p_H}{\gamma} > 0 \end{aligned}$$

$\square$

**Proof of Lemma 3.3.**

*Proof.* Throughout the proof, I denote  $R(s) = \{r \in R | L(s, r) > 0\}$  and  $S(r) = \{s \in S | L(s, r) > 0\}$ . Clearly  $r \in R(s) \Leftrightarrow s \in S(r)$ . The proof proceeds in five steps.

Step 1.  $S(r) \neq \emptyset$  for all  $r \in R$  and  $R(s) \neq \emptyset$  for all  $s \in S$ .

Condition (3.13) and  $F(r) > 0$  imply  $S(r) \neq \emptyset$  for all  $r \in R$ . Similarly, condition (3.15) and  $k_m(s) > 0$  imply  $R(s) \neq \emptyset$  for all  $s \in S$ .

Step 2.  $R(\cdot)$  satisfies two properties: (i) for any  $s \in S$ ,  $R(s)$  is a nonempty interval of  $[\underline{r}, \bar{r}]$ , and (ii) for any  $s' > s$ , if  $r' \in R(s')$  and  $r \in R(s)$  then  $r' \geq r$ .

To demonstrate property (i), note that in step 1 it was shown that  $R(s)$  was nonempty. To show  $R(s)$  is an interval, proceed by contradiction. Suppose there exists a bank  $s$  and three firms  $r_1 < r_2 < r_3$  such that  $r_1, r_3 \in R(s)$  but  $r_2 \notin R(s)$ .

Since  $S(r_2) \neq \emptyset$  by step 1, we know there exists some  $s' \neq s$  such that  $r_2 \in R(s')$ . Now suppose that  $s > s'$ . (The argument for the case  $s' > s$  is similar.)

By condition (3.12):

$$r_1 I(s, r_1) - R_m(s) - R_u(s) - R_f(r_1) = 0 \quad (\text{C.1})$$

$$r_1 I(s', r_1) - R_m(s') - R_u(s') - R_f(r_1) \leq 0 \quad (\text{C.2})$$

$$r_2 I(s', r_2) - R_m(s') - R_u(s') - R_f(r_2) = 0 \quad (\text{C.3})$$

$$r_2 I(s, r_2) - R_m(s) - R_u(s) - R_f(r_2) \leq 0 \quad (\text{C.4})$$

Equation (C.1) and inequality (C.2) imply:

$$I(s', r_1) \leq I(s, r_1) \quad (\text{C.5})$$

while equation (C.3) and inequality (C.4) imply:

$$I(s, r_2) \leq I(s', r_2) \quad (\text{C.6})$$

This contradicts that  $I$  is increasing in  $s$ . For the more general case,<sup>1</sup> inequalities (C.5) and (C.6) together imply:

$$I(s', r_1) I(s, r_2) \leq I(s, r_1) I(s', r_2)$$

which contradicts  $I(s, r)$  strictly log-supermodular.

To demonstrate property (ii), we proceed by contradiction. Suppose there exists  $s > s'$  and  $r > r'$  such that  $r' \in R(s)$  and  $r \in R(s')$ . Using condition (3.12):

$$\begin{aligned} r' I(s, r') - R_m(s) - R_u(s) - R_f(r') &= 0 \\ r' I(s', r') - R_m(s') - R_u(s') - R_f(r') &\leq 0 \\ r I(s', r) - R_m(s') - R_u(s') - R_f(r) &= 0 \\ r I(s, r) - R_m(s) - R_u(s) - R_f(r) &\leq 0 \end{aligned}$$

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<sup>1</sup>I prove results based on log-supermodularity rather than for the specific microfoundations of the model. This provides a more general result.

As above, these imply:

$$I(s', r') \leq I(s, r') \quad (\text{C.7})$$

and:

$$I(s, r) \leq I(s', r) \quad (\text{C.8})$$

which together imply:

$$I(s', r')I(s, r) \leq I(s', r)I(s, r') \quad (\text{C.9})$$

which contradicts strict log-supermodularity of  $I(s, r)$ .

Step 3.  $R(s)$  is a singleton for all but a countable subset of  $S$ .

By step 2 property (i), we know  $R(s)$  is measurable for any  $s$ . Let  $S_0$  be the subset of banks such that  $\mu[R(s)] > 0$  where  $\mu$  is the Lebesgue measure over  $\mathbb{R}$ . First show that  $S_0$  is a countable set. Choose an arbitrary bank  $s \in S_0$  and let  $\underline{r}(s) = \inf R(s)$  and  $\bar{r}(s) = \sup R(s)$ . The fact that  $\mu[R(s)] > 0$  has a strictly positive measure implies  $\underline{r}(s) < \bar{r}(s)$ . So for any  $s \in S_0$  there will exist  $j \in \mathbb{N}$  such that  $\bar{r}(s) - \underline{r}(s) \geq \frac{\bar{r} - \underline{r}}{j}$ . By step 2 property (ii), we also know that for any  $s \neq s'$ ,  $\mu[R(s) \cap R(s')] = 0$ . Thus for any  $j \in \mathbb{N}$ , there can be at most  $j$  elements,  $\{s_1, \dots, s_j\} \equiv S_0^j \subset S_0$  for which  $\bar{r}(s_i) - \underline{r}(s_i) \geq \frac{\bar{r} - \underline{r}}{j}$  for  $i = 1, \dots, j$ . By construction, we have  $S_0 = \cup_{j \in \mathbb{N}} S_0^j$  is a countable set. Since the union of countable sets is countable,  $S_0$  must be a countable set. The fact that  $R(s)$  is singleton for all but a countable subset of  $S$  directly derives from this observation and the fact that the only nonempty intervals of  $[\underline{r}, \bar{r}]$  with measure zero are singletons.

Step 4.  $S(r)$  is a singleton for all but a countable subset of  $R$ .

Same arguments as in steps 2 and 3.

Step 5.  $R(s)$  is a singleton for all  $s \in S$ .

We proceed by contradiction. Suppose there exists some  $s \in S$  for which  $R(s)$  is not a singleton. By step 2 property (i), we must have  $\mu[R(s)] > 0$ . By step 4, we know that  $S(r) = \{s\}$  for  $\mu$ -almost all  $r \in R(s)$ . Hence,  $F(r) = \int_{s \in S} L(s, r) ds$  implies

$$L(s, r) = F(r)\delta[1 - \mathbf{1}_{R(s)}] \text{ for } \mu\text{-almost all } r \in R(s) \quad (\text{C.10})$$

where  $\delta$  is the Delta dirac function. By step 3, we must also have  $s' \in S$  for which  $R(s') = \{r'\}$ . Thus  $F(r') = \int_{s \in S} L(s, r') ds$  implies

$$L(s', r') \leq F(r')\delta[1 - \mathbf{1}_{R(s')}] \quad (\text{C.11})$$

Combining equations (3.15), (C.10), (C.11), with  $\mu[R(s)] > 0$ , we obtain:  $Y(r) = +\infty$  and  $Y(r') < +\infty$ . This contradicts equation (3.11), which shows that total investment size is bounded.

Step 5 implies the existence of a function  $H : S \rightarrow R$  such that  $L(s, r) > 0$  if and only if  $H(s) = r$ . By step 2 property (ii),  $H$  must be weakly increasing. Since  $S(r) \neq \emptyset$  for all  $r \in R$  by step 1,  $H$  must also be continuous and satisfy  $H(\underline{s}) = \underline{r}$  and  $H(\bar{s}) = \bar{r}$ . Finally by step 4,  $H$  must be strictly increasing. Therefore, there exists a continuous and strictly increasing function  $H : S \rightarrow R$  such that (i)  $L(s, r) > 0$  if and only if  $H(s) = r$  and (ii)  $H(\underline{s}) = \underline{r}$  and  $H(\bar{s}) = \bar{r}$ . To conclude, set  $M \equiv H^{-1}$ . □

**Proof of Lemma 3.4.**

*Proof.* Lemma 3.3 and  $F(r) = \int_{s \in S} L(s, r) ds$  for all  $r \in R$  imply

$$L(s, r) = F(r)\delta[s - M(r)] \quad \text{for all } r \in R \quad (\text{C.12})$$

where  $\delta$  is the delta Dirac function. At  $s = M(r)$ , we have

$$K_m(M(r)) = \int_{r \in R} I_m(M(r), r')L(M(r), r')dr'$$

Using (C.12),

$$K_m(M(r)) = \int_{r \in R} I_m(M(r), r')F(r)\delta[M(r) - M(r')]dr'$$

By Lemma 2, there exists  $s' \in M(r')$ , which implies

$$K_m(M(r)) = \int_{s' \in S} I_m(M(r), M^{-1}(s'))F(M^{-1}(s'))\delta[M(r) - s']\frac{1}{M_r(M^{-1}(s'))}ds$$

By definition of the delta Dirac function,

$$K_m(M(r)) = \frac{I_m(M(r), r)F(r)}{M_r(r)}$$

Rearranging gives:

$$M_r(r) = \frac{I_m(M(r), r)F(r)}{K_m(M(r))}$$

The equalities  $M(\underline{r}) = \underline{s}$  and  $M(\bar{r}) = \bar{s}$  derive from Lemma 2. □

**Proof of Prop 3.1.**

*Proof.* We proceed by contradiction. Suppose there exists  $r \in R \cap R'$  at which  $M'(r) > M(r)$ . Since  $F'(r')F(r) > F(r')F'(r)$  we know that  $R \cap R' = [\underline{r}', \bar{r}]$ . By Lemma 3.2, we know that  $M$  and  $M'$  are continuous functions such that  $M'(\underline{r}') = \underline{s} \leq M(\underline{r}')$  and  $M(\bar{r}) = \bar{s} \geq M'(\bar{r})$ . So there must exist  $\underline{r}' \leq r_1 < r_2 \leq \bar{r}$  and  $\underline{s} \leq s_1 < s_2 \leq \bar{s}$  such that (i)  $M(r_1) = M'(r_1) = s_1$  and  $M(r_2) = M'(r_2) = s_2$ ; (ii)  $M_r(r_1) \leq M'_r(r_1)$  and  $M_r(r_2) \geq M'_r(r_2)$ ; and, (iii)  $M'(r) > M(r)$  for all  $r \in (r_1, r_2)$ . Condition (ii) implies

$$\frac{M_r(r_1)}{M_r(r_2)} \leq \frac{M'_r(r_1)}{M'_r(r_2)}$$

which combined with equation (3.16) implies:

$$\frac{\frac{I_m(s_1, r_1)F(r_1)}{k_m(s_1)}}{\frac{I_m(s_2, r_2)F(r_2)}{k_m(s_2)}} \leq \frac{\frac{I'_m(s_1, r_1)F'(r_1)}{k'_m(s_1)}}{\frac{I'_m(s_2, r_2)F'(r_2)}{k'_m(s_2)}}.$$

Since  $I_m = I'_m$  and  $k_m = k'_m$ , this implies  $F'(r_2)F(r_1) \leq F'(r_1)F(r_2)$ , which contradicts the original assumption. □

**Proof of Prop 3.2.**

*Proof.* Equation (3.11) shows  $\frac{dI}{d\gamma} > 0$ ; firm investment is increasing in  $\gamma$ . This implies  $\frac{dI_m}{d\gamma} > 0$  in equation (3.5). It follows directly from equation (3.16) that  $\frac{d^2M}{drd\gamma} > 0$ , which implies  $M'(r) \leq M(r)$  for all  $r \in R \cap R'$ .  $\square$

**Proof of Prop 3.3.**

*Proof.* It follows directly from equation (3.16) that  $\frac{d^2M}{drdk_m} < 0$ , which implies  $M'(r) \geq M(r)$  for all  $r \in R \cap R'$ .  $\square$

**Proof of Prop 3.4.**

*Proof.* We proceed by contradiction. Suppose there exists  $r \in R \cap R'$  at which  $M'(r) > M(r)$ . Since  $k'_m(s')k_m(s) < k_m(s')k'_m(s)$  we know that  $R \cap R' = [\underline{r}', \bar{r}]$ . By Lemma 3.2, we know that  $M$  and  $M'$  are continuous functions such that  $M'(\underline{r}') = \underline{s} \leq M(\underline{r}')$  and  $M(\bar{r}) = \bar{s} \geq M'(\bar{r})$ . So there must exist  $\underline{r}' \leq r_1 < r_2 \leq \bar{r}$  and  $\underline{s} \leq s_1 < s_2 \leq \bar{s}$  such that (i)  $M(r_1) = M'(r_1) = s_1$  and  $M(r_2) = M'(r_2) = s_2$ ; (ii)  $M_r(r_1) \leq M'_r(r_1)$  and  $M_r(r_2) \geq M'_r(r_2)$ ; and, (iii)  $M'(r) > M(r)$  for all  $r \in (r_1, r_2)$ . Condition (ii) implies

$$\frac{M_r(r_1)}{M_r(r_2)} \leq \frac{M'_r(r_1)}{M'_r(r_2)}$$

which combined with equation (3.16) implies:

$$\frac{\frac{I_m(s_1, r_1)F(r_1)}{k_m(s_1)}}{\frac{I_m(s_2, r_2)F(r_2)}{k_m(s_2)}} \leq \frac{\frac{I'_m(s_1, r_1)F'(r_1)}{k'_m(s_1)}}{\frac{I'_m(s_2, r_2)F'(r_2)}{k'_m(s_2)}}.$$

Since  $I_m = I'_m$  and  $F = F'$ , this implies  $k'_m(s_1)k_m(s_2) \leq k'_m(s_2)k_m(s_1)$ , which contradicts the original assumption.  $\square$

## C.2 Imperfect competition case

If the banking sector is not perfectly competitive, high skill banks may charge a premium on lending. Because firms gain from matching with a better bank, banks can plausibly extract some of the additional surplus firms gain from banking with an institution of higher skill. High skill banks can thus lend slightly less  $I_m$  compared to worse banks, in order to increase their return  $\beta$ . However, decreasing  $I_m$  also decreases the total investment size  $I$ , and so there is a limit to the skill premium a bank can extract while still remaining the preferred bank for a particular firm. At a maximum, banks extract a skill premium which preserves the preferences of firms for high skill banks, i.e. that  $dI/ds > 0$ . As a result, less than perfect competition will lead bank returns to increase in skill, so that  $\beta$  is a function of  $s$ , such that  $\beta'(s) \geq 0$ .

However, if at each level of skill there is one bank who acts as a monopolist, the premium charged removes all the firms' surplus from borrowing from a better bank.



At this point, firms are indifferent between all the banks in the economy. Below, I derive a condition under which Lemmas 3.1 and 3.2 hold under imperfect competition, and derive the premium monopolistic banks would charge. The main results of this paper hold for all but the case of monopolistic banks, i.e. for any premium below the monopolistic outcome. I find this to be a realistic because banking sectors are typically competitive, and there are few cases where monopolistic banks are entirely insulated from competition.

### Proof of Lemma 3.1, revisited.

*Proof.* The proof that  $\partial I/\partial r > 0$  is unchanged. To show that  $\partial I/\partial s > 0$ , let  $a_1(s, r) = 1 - \frac{p_H c(s)}{\beta \Delta p} - \frac{p_H}{\gamma} \left[ r - \frac{e+c(s)}{\Delta p} \right]$ . Taking derivatives of equation (3.11) with  $\beta$  as a function of  $s$ ,

$$\frac{\partial I}{\partial s} = -\frac{1}{(a_1(s, r))^2} \left[ \frac{p_H c'(s)}{\Delta p} \left( \frac{\beta(s) - \gamma}{\gamma \beta(s)} \right) + \frac{p_H c(s)}{\Delta p} \frac{\beta'(s)}{\beta(s)} \right].$$

To maintain  $dI/\partial s > 0$ , it must be that:

$$\frac{c'(s)}{\Delta p} \left( \frac{\beta(s) - \gamma}{\gamma \beta(s)} \right) + \frac{c(s)}{\Delta p} \frac{\beta'(s)}{\beta(s)^2} < 0. \quad (\text{C.13})$$

This is a necessary and sufficient condition for the size of investments to be increasing in bank skill.

Monopolistic banks can at maximum charge a return premium  $\beta(s)$  which makes equation (C.13) hold with equality. This would mean that firms are indifferent between banks of different skill levels, but would be consistent with profit maximization by monopolistic banks. If (C.13) holds with equality, it can be used to explicitly solve for the premium  $\beta(s)$ :

$$\beta(s) = \frac{\gamma c(s)}{c(s) - K}, \quad (\text{C.14})$$

where  $K$  is an arbitrary constant. If (C.13) holds with equality, then  $\partial I/\partial s = 0$ . However, for any  $\beta < \frac{\gamma c(s)}{c(s) - K}$ , i.e. with a skill premium that is increasing but less than the monopolistic premium in (C.14),  $\partial I/\partial s > 0$

□

### Proof of Lemma 3.2, revisited.

*Proof.* Let  $a_1(s, r) = 1 - \frac{p_H c(s)}{\beta \Delta p} - \frac{p_H}{\gamma} \left[ r - \frac{e+c(s)}{\Delta p} \right]$ . The derivatives of the natural logarithm of  $I$  when  $\beta$  is a function of  $s$  are given by:

$$\frac{\partial}{\partial s} \ln I = -I(s, r) \left[ \frac{p_H c'(s)}{\Delta p} \left( \frac{\beta(s) - \gamma}{\gamma \beta(s)} \right) + \frac{p_H c(s)}{\Delta p} \frac{\beta'(s)}{\beta(s)} \right].$$

By condition (C.13), the term in square brackets is negative, so it follows that this is strictly positive. Taking the cross-derivative gives:

$$\frac{\partial^2}{\partial s \partial r} \ln I = \frac{-1}{a_1(s, r)^2} \left[ \frac{p_H c'(s)}{\Delta p} \left( \frac{\beta(s) - \gamma}{\gamma \beta(s)} \right) + \frac{p_H c(s) \beta'(s)}{\Delta p \beta(s)} \right] \frac{1}{\gamma} > 0.$$

□