The Effect of Bank Recapitalization Policy on Corporate Investment: Evidence from a Banking Crisis in Japan*

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Abstract

In this paper, we quantitatively examine the effect of government capital injections into financially troubled banks on the level of corporate investment during the Japanese banking crisis. To this end, we develop a dynamic structural model of firm investment which incorporate endogenous borrowing constraints, where the real interest rates endogenously depend on firm's state variables which include productivity, collateral, debt, and the Basel I capital adequacy ratio of its main bank. In the model, lowering the main bank's capital adequacy ratio leads to a tighter borrowing constraint and lower firm's investment. Combining the corporate finance data from the Development Bank of Japan with the Nikkei NEEDS's bank balance sheet data, we estimate the structural model and conduct counter-factual policy experiments to quantitatively assess the effect on investment of capital injection that took place in March 1998 and 1999 in Japan. The results of counterfactual experiments indicate that the total amount of aggregate investment in 1998 would have been lower by 1.84 percent if there had been no capital injection in 1998 while it would have been higher by 8.32 percent if the 1999 capital injection (7.5 trillion yen) had taken place in 1998 on the top of the 1998 capital injection (1.8 trillion yen).

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1 Introduction

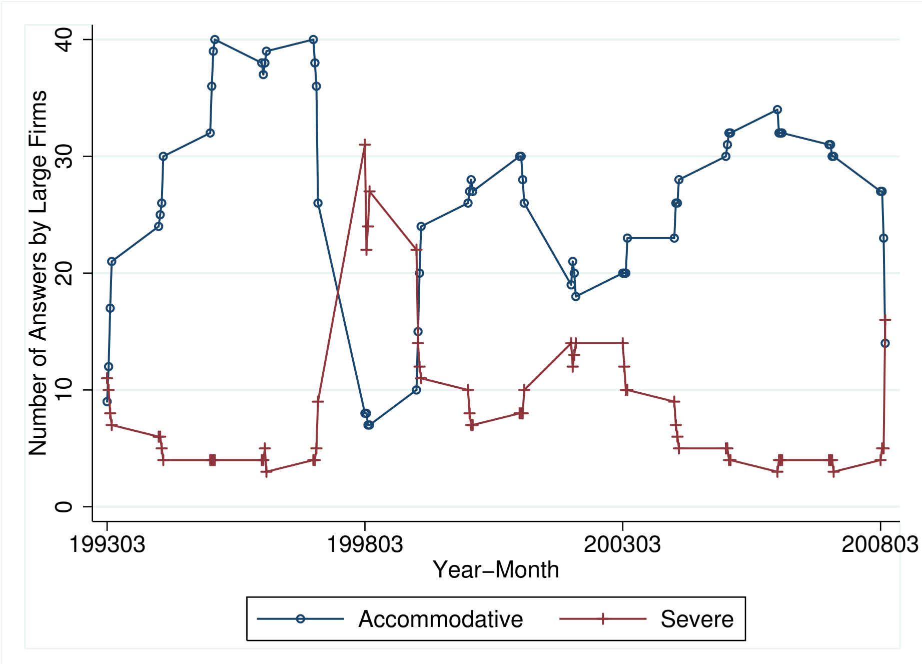
This paper examines the effect of government capital injections into financially troubled banks on the level of firm's investment during the Japanese banking crisis. During the banking crisis of 1997, under tighter risk-based capital requirements imposed on banks, Japan experienced a sharp decline in bank loans to firms, and Japanese corporate investment fell in 1998 and 1999. According to Tankan Survey by the Bank of Japan, there was a sharp deterioration of "banks' willingness to lend" during the first quarter of 1998 (Figure 1). In order to cope with the banking crisis, the Japanese government conducted capital injections of 1.8 trillion Japanese yen in March 1998 and 7.5 trillion Japanese yen in March 1999 into the top city, trust and long-term credit banks, and other regional banks in the form of purchases of preferred stock, subordinated debt, or as a subordinated loan. These capital injections helped many banks to improve their capital ratios and to clear the 8% capital to risk weighted asset ratio required under the Basel Accord, which was formally implemented by the Japanese government through the Law to Ensure the Soundness of Financial Institutions.[1] As Figure 2 shows, the distributions of Basel I capital adequacy ratios substantially shifted upward between 1996 to 1999.

One of the primary goals for the capital injection plan in Japan was to promote firm's investment by improving bank capital ratios in the hope of increasing bank lending to firms (Montgomery and Shimizutani (2009)). Did the capital injection promote investment in Japan? If so, how large was the effect? Given that over 10 trillion yen of Japanese taxpayers' money (roughly equal to 2% of Japan's nominal GDP) was spent on capital injections into troubled banks, these are important policy questions. However, while a large body of studies investigates whether the credit crunch in Japan constrained firm investments (Caballero et al. (2008); Hayashi and Prescott (2002); Hori et al. (2006); Hosono (2006); Ito and Sasaki (2002); Motonishi and Yoshikawa (1999); Peek and Rosengren (2000); Woo (2003)), few existing empirical studies quantitatively assess how much government capital

[1] The Japanese government introduced the Law to Ensure the Soundness of Financial Institutions in April 1998 which enabled regulators to order remedial actions to troubled banks, depending on the banks' Basel I capital adequacy ratios.

injections affected firm investments by relaxing their firm's financial constraint.

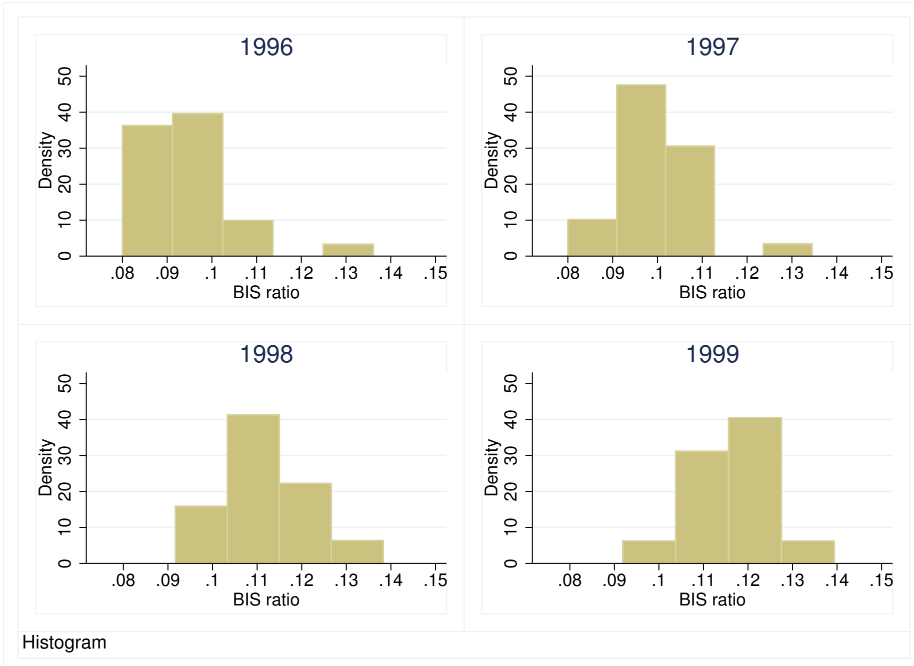
Figure 1: Bank Attitudes toward Lending (Tankan Survey, Bank of Japan)



To examine the effect on firm's investment of the capital injection into banks, we have constructed a unique data set. This combines Japanese firm-level data from the Development Bank of Japan (DBJ), which reports firm-level data on outstanding long-term loans *by each financial institution*, with bank's balance sheet information from the Nikkei NEEDS data set. To quantify the effect of capital injections, we develop a dynamic structural model of firm investment with endogenous borrowing constraints, where the real interest rate is endogenously determined by the balance sheet of its "main bank" as well as a firm's default probability which in turn depends on productivity, collateral, debt. In the model, when the main bank's capital adequacy ratio is low, a firm faces a higher borrowing rate and does not invest even if the return from investment is high. Consistent with the model's implication, the descriptive analysis reveals that the firm's investment tends to be low when its main bank's capital adequacy ratio is low, especially for firms that are predicted to be financially constrained (high productivity, high debt, low collateral).

Using the estimated model, we conduct counter-factual policy experiment on what would

Figure 2: Distribution of Basel I Capital Adequacy Ratios, 1996-1999



have been the aggregate investment in 1998 (i) if there had been no capital injection 1n 1998 and (ii) if the 1999 capital injection had happened in 1998. The results of our counterfactual experiments suggest that, had there been no capital injection in 1998, the total amount of aggregate investment would have been lower by 1.34 percent in because firms would have invested less due to tighter financial constraints caused by substantially lower bank's capital ratio. We also found that, if additional 7.5 trillion of capital injection had happened in 1998 instead of 1999, the total amount of aggregate investment in 1998 would have been higher by 8.32 percent.

This paper contributes to the existing literature as follows. First, as we experienced in the recent banking crisis, capital injections have become an important policy instrument for governments to deal with financial crises. However, few existing empirically studies quantitatively examine the effect of capital injections because identifying the effect of capital injections separately from other macroeconomic shocks is difficult. Using the unique micro-level data set, this paper provides one of the first empirical studies that quantify the policy effect of capital injections on investment by focusing on a specific mechanism, i.e., its effect on investment through relaxing borrowing constraints. On the other hand, the objective of the paper is limited in scope and is not aiming at examining the effect of capital injection in general. This is an important limitation because capital injection is likely to have had important impacts on the Japanese economy through other mechanisms, such as promoting write-offs of non-performing loans and stabilizing the financial system.

Second, this paper contributes to the empirical literature on the effect of financial constraints on firm's investment (e.g., Fazzari et al. (1988); Hoshi et al. (1991); Kaplan and Zingales (1997)). The existing empirical papers on the effect of financial constraints use various observed measures of "financial constraint," such as cash flow, the size of firms, and the years of establishment, to examine the effect of financial constraint on investment. It is often difficult, however, to interpret these empirical results because these measures of "financial constraint" can be viewed as endogenous variables and correlated with the firm's efficiency measure that also explains investment. For example, the positive estimate of cash flow coefficient may just reflect its positive correlation with firm's efficiency. This paper examines how the Basel I capital ratio of the bank which a firm has relationship with influences firm's investment decisions. To the extent that the Basel I capital ratio measure is viewed as more exogenous that other measures of "financial constraint," this paper's result shed further light on the impact of financial constraint on investment.

The remainder of this paper is organized as follows. Section 2 describes our data sources and reports descriptive statistics. Section 3 presents a model of investment with endogenous borrowing constraints. Section 4 explains how to estimate the structural model. Section 5 reports estimation results and counterfactual experiments.

2 Data and descriptive statistics

2.1 Data sources and variable definition

To examine the effect of changes in bank's Basel I capital adequacy ratio on corporate investment, we combine corporate investment data with bank's balance sheet data.[2] For corporate balance sheet information, we use the data set compiled by the Development Bank of Japan (DBJ). Because the DBJ data set does not contain data for financial institutions, we take data on bank's balance sheet information from Nikkei NEEDS.

The DBJ data set contains detailed corporate balance sheet information for the firms listed on the Tokyo Stock Exchange. In particular, it provides data on the fixed asset at its component level such as land, building, and machinery. Furthermore, it provides data on outstanding long-term loans by financial institution that we use to combine the DBJ data with Nikkei NEEDS data. Nikkei NEEDS provides data on bank's Basel I capital ratio and non-performing loans as well as standard balance sheet information. Appendix A explains how we construct variables we use in our analysis from the original data in details. Table 1 reports the summary statistics for the variables we use in our empirical analysis.

For each firm in the DBJ sample, we define a variable "$Basel1$" by computing the weighted average of the difference between bank's Basel I capital ratio and the required ratio under the Basel I regulation in Japan (8% for internationally operated banks and 4% for domestic banks) over the city and regional banks, with the outstanding long-term loans from the banks, available in the DBJ data, as weights. **?** argue that bank health was much better reflected by stock returns than reported risk-based capital ratios do because there were a variety of techniques for Japanese banks to hide losses on their balance sheets during the 1990s. In this paper, we use the Basel I capital ratio because we are interested in a specific mechanism: the effect of Basel I capital ratio reported on their balance sheets on investment through borrowing constraint under the Basel I regulation rather than the effect of bank's health in general. In this context, the use of the reported Basel I capital adequacy ratio may be justified to the extent that the Basel I regulation directly applies to the Basel

[2] We follow Nagahata and Sekine (2005) in combining the two data sets.

Table 1: Summary Statistics (1997–1998)

		Mean	Median	Std. Dev.	Min	Max
$Basel1$	1997	0.015	0.128	0.007	0.001	0.056
	1998	0.021	0.020	0.008	0.005	0.069
TFP	1997	7.626	7.599	0.592	5.828	9.831
	1998	7.476	7.462	0.607	5.476	9.636
$\ln K_m$	1997	15.331	15.333	1.637	7.828	20.423
	1998	15.206	15.265	1.625	7.805	20.528
$Debt$	1997	243	623	651	-9960	8600
	1998	214	605	606	-1140	8960
$\ln Land$	1997	16.079	15.998	1.368	9.754	20.618
	1998	15.926	15.864	1.358	9.679	20.401

Notes. $Basel1$ represents the difference between the bank's Basel I capital ratio and the required ratio under the Basel I regulation. TFP is the total factor productivity. $\ln K_m$ is the logarithm of the stock of the sum of machinery and transportation equipment. $Debt$ is net debt, defined as the total interest bearing debt including loans and bonds less deposit measured in 100 thousand yen. $\ln Land$ is the logarithm of the land stock. All monetary values are deflated by CGPI for all goods with January 1979 as the base month-year. (Sources: DBJ Corporate Finance Data, Nikkei NEEDS)

I capital ratio reported on their balance sheets. Further, the use of the Basel I capital ratio is essential for quantifying the counterfactual policy effect of capital injection because we may construct the counterfactual value of the Basel I capital ratio without capital injection from the detailed bank-level information of capital injection in 1998-1999 but constructing the counterfactual stock returns would be difficult.[3]

In our empirical analysis, we treat $Basel1$ as an exogenous variable. The endogeneity of $Basel1$ variable is a potential concern because there might be a positive assortive matching such that firms that are efficient in implementing investment projects have the high Basel I capital ratio banks as their main banks.[4] If a positive assortive matching is driven by unobserved factors, the estimated effect of the Basel I capital ratio on investment may be positively biased. The endogeneity bias might not be a major concern for the following

[3]On the other hand, bank's health in general, such as non-performing loan that were not reported on the balance sheets, may affect bank's lending decisions and, thus, our results require a careful interpretation. Also, our analysis is limited in scope because the capital injection may affect investment through different mechanisms, such as stabilizing financial system, other than relaxing firm's borrowing constraint.

[4]For instance, a dynamic interaction between banks and firms may possibly lead to a positive correlation between unobserved factors and bank's Basel I capital ratio because good firms have lower default probability and thus tend to improve their main bank's balance sheets over time.

Table 2: Correlation Coefficient with $Basel1$ (1997–1998)

Corr. with $Basel1$	$\ln TFP$	$\ln K_m$	$Debt$	$\ln Land$
1997	-0.0536	-0.0046	-0.0607	-0.0171
	(0.1777)	(0.9081)	(0.1267)	(0.6681)
1998	-0.0370	0.0906	-0.0032	-0.0028
	(0.3482)	(0.0213)	(0.9361)	(0.9436)

Notes. p-values for testing the null hypothesis of no correlation are in parentheses. (Sources: DBJ Corporate Finance Data, Nikkei NEEDS)

reasons. First, the main source of assortive matching may be captured by the TFP measure that is included as one of the state variables. Second, as Table 2 reports, the correlation between the Basel I capital ratio and the log of TFP are negative and insignificant in 1997-1998. To the extent that the TFP measure is correlated with unobserved factors, a lack of correlation between the Basel I capital ratio and TFP suggests a lack of high correlation between the Basel I capital ratio and unobserved factors. The correlations of the Basel I capital ratio with capital, debt, and land holding are also negative and insignificant except for its correlation with the log of machine capital in 1998.[5]

2.2 Sample selection

Table 3 describes our benchmark sample selection. For the benchmark analysis, we restrict the sample to the manufacturing firms to control for the heterogeneity not taken into account by the model that we present in Section 3. We mainly focus on the decision for machine investment although we also provide robustness check using total investment that includes buildings. Our sample period runs from 1994 to 1999 although our empirical analysis mostly focuses on 1997 and 1998. The initial data for 1994-1999 has 11956 firm-year observations. We drop observations with outliers or missing information as follows. We first drop observations with missing data on investment rates or Basel I capital ratios. Dropping

[5]The change in the correlation pattern between the Basel I capital ratio and the log of capital from 1997 and 1998 may be explained by endogenous investment decisions in 1997—firms with high Basel I capital ratio may have invested more than those with low Basel I capital ratio in 1997, which may have resulted in the positive correlation between BIS and capital in 1998.

Table 3: Benchmark Sample Selection

	Observations deleted	Remaining observations
Initial data for 1994-1999 (manufacturing)		11956
Missing data (I_m/K_m, Basel I capital ratio)	6321	5635
$I_m/K_m > 2$ or $I_m/K_m < -2$	4	5631
Large long-term loan with missing Basel I capital ratio	388	5243
More loans from 'other banks'	931	4312
Benchmark sample		**4312**

Notes. I_m/K_m represents the ratio of machine investment to machine capital stock. 'Large long-term loan with missing Basel I capital ratio' drops firms that owe more than 20% of the total outstanding long-term loans to banks whose data on Basel I capital ratio are missing in Nikkei NEEDS data. 'Other banks' include insurance companies and government financial institutions such as the Development Bank of Japan. (Sources: DBJ and Nikkei NEEDS)

6321 out of 11956 initial observations, this is the main source of sample selection.[6] We then drop observations with the machine investment rate (the ratio of machine investment to machine capital stock) greater than 2 or smaller than −2. We further drop observations of the firms that owe more than 20% of the total outstanding long-term loans to banks whose data on Basel I capital ratio are missing in Nikkei NEEDS data in some year over the 1994–1998 period.[7] Finally, we drop observations of the firms borrowing mainly from insurance companies and government financial institutions, because they are not under the Bank regulations and thus no data on the Basel I capital ratio or non-performing loans are available in Nikkei NEEDS for those institutions.

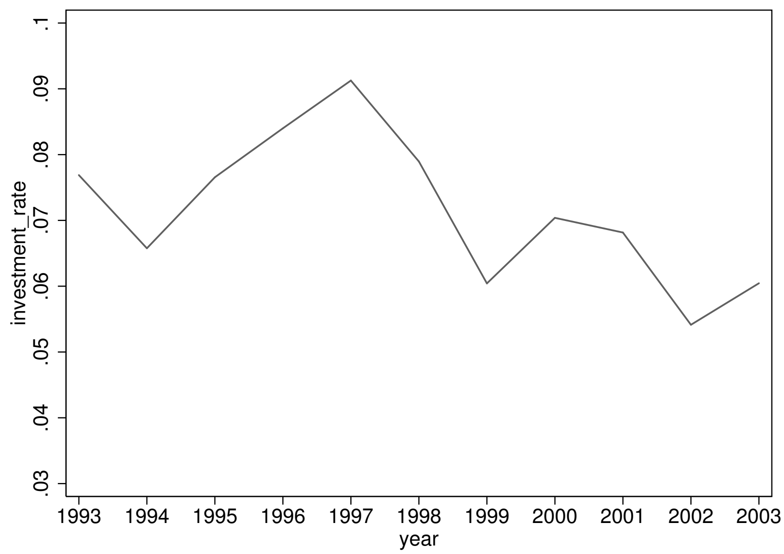
[6]The means of observable variables, including the revenue, the labor, and the land-holding, of the observations that are dropped by this criteria are similar to those of the selected observations. An exception is the debt holding, where the average debt holdings of the dropped sample and the selected sample are 51 and 367 hundred thousand yens, respectively.

[7]Because data on Basel I capital ratio for most of the regional banks are missing in 1999, we refer to the 1994–1998 period for this sample selection.

2.3 Changes in median investment

Figure 3 shows the evolution of the median machine investment rate (the ratio of the machine investment to the machine capital stock) over the 1993–2003 period.[8] The median investment rate fell in 1998 and 1999. Note that the decline occurred despite the fact that Japanese banks received capital injections in March of 1998 and 1999. The investment decline in 1998 and 1999 is likely to be due to negative macroeconomic shocks and, possibly, the investment rate could have been even lower in 1998 and 1999 if there had been no capital injections. But, in the presence of other macroeconomic shocks, it is difficult to identify the effect of capital injections from the time series aggregate statistics. As we discuss next, the cross-sectional distribution of investment rate and Basel I capital ratios may help us to identify the effect of capital injections.

Figure 3: Median I_m/K_m (DBJ)



2.4 Machine Investment rate and Basel I capital ratio

The model we present in Section 3 suggests that firm's investment and borrowing decisions depend on their capital stock, collateral, the total factor productivity (TFP), and bank's

[8]For Figure 3, we use the original sample, keeping all the observations of the manufacturing firms.

Table 4: Machine Investment Rates by Basel I capital ratio and TFP (1997–1998)

	Low Machine Capital Stock			
	Low TFP		High TFP	
	$Basel1 \leq 0.02$	$Basel1 > 0.02$	$Basel1 \leq 0.02$	$Basel1 > 0.02$
<u>Mean Investment rates</u>				
1997	0.0975	0.0818	0.1067	0.3404
	(0.0103)	(0.0221)	(0.0134)	(0.1017)
1998	0.0775	0.0655	0.0582	0.1203
	(0.0146)	(0.0120)	(0.0094)	(0.0418)
<u>Observations</u>				
1997	144	28	121	20
1998	125	97	59	46

Notes. Each entry refers to the mean of the investment rate for machinery in the given bin. The variable "$Basel1$" represents the difference between the bank's Basel I capital ratio and the required ratio under the BIS regulation. The columns labeled 'Low TFP' reports results for firms with TFP below the median in the pooled sample for 1997–1998. Standard errors are in parentheses. (Sources: DBJ Corporate Finance Data, Nikkei NEEDS)

Basel I capital ratio. Here, we examine how firm's machine investment rates are related to their capital stock, collateral, TFP, and bank's Basel I capital ratio in the data, where we use the value of land for collateral while the TFP is measured by the residual from the production function estimated using the System GMM method of **?** as explained in Appendix B.

Table 4 shows how average investment rates for firms with low machine capital stock are related to TFP and bank's Basel I capital ratio for 1997-1998. We group the firm's observations with machine capital stock below the median into 4 subgroups according to the value of TFP and bank's Basel I capital ratio. The variable "$Basel1$" represents the difference between the bank's Basel I capital ratio and the required ratio under the Basel I regulation, and we classify firms with $Basel1 \leq 0.02$ as low Basel I capital ratio firms while those with $Basel1 > 0.02$ as high Basel I capital ratio firms, where 0.02 is the median value of $Basel1$ variable in 1998. Each cell in the upper panel of Table 1 reports average investment rates for each subgroup. In 1997, in the upper right panel, average investment rate for firms with low capital and high TFP is 34.04 percent if their bank's Basel I capital ratio is high but it is only 10.67 percent if their bank's Basel I capital ratio is low. This seems to suggest the possibility of borrowing constraints for low Basel I capital ratio firms with opportunity to invest. The firms with high TFP and low capital stock have a high marginal return from investment but may not be able to invest because of borrowing constraints when the bank's Basel I capital ratio is low. It is also interesting that, in the upper left panel, average investment rates of firms with low capital and low TFP are not significantly different between high and low Basel I capital ratios. The firms with low capital and low TFP are not likely to face a good opportunity for major investment project and, thus, borrowing constraint may not be important for them.

To further examine how firm's investment rates are related to TFP, capital stock, collateral, and bank's Basel I capital ratio, we regress the machine investment rate on TFP, machine capital stock, Basel I capital ratio, the debt to collateral ratio, and their interaction terms using the data for 1997 and 1998. We use two different measures for collateral. The first measure, denoted by "$Land$," is the amount of land a firm owns. The second measure combines land and capital stock as $0.6777Land + 0.1537K_m$, where the weights are from Ogawa and Suzuki (2000) as we discuss in Section 5.1, and is denoted by "$Collat.$". The use of the debt to collateral ratio as one of the regressors is motivated by the model presented in Sections 3 and 4. We also include year dummy and allow for year-specific coefficient for TFP. The results are reported in Table 5. In the table, D_{Basel1} is a dummy variable that is equal to one if $Basel1 > 0.02$.

In column (1), the coefficient of TFP is significantly positive, where the point estimate implies that a 100 percent increase in TFP leads to a 2 percentage point increase in investment rate. In column (2), the interaction term between D_{Basel1} and TFP is positive and significant, indicating that the effect of TFP on investment rate is large when the main bank's Basel I capital ratio is high. One possible interpretation is that, facing high return from investment, firm can borrow from the bank to finance its investment only when its main bank's Basel I capital ratio is high. On the other hand, the interaction term between debt-to-land ratio and TFP is significantly negative in column (2), which is consistent with the presence of borrowing constraint for high TFP firms with a large debt.

In column (3), the interaction term between D_{Basel1} and debt-to-land ratio is negative

Table 5: Linear Investment Model (Dependent Variable: I_m/K_m)

	(1)	(2)	(3)	(4)	(5)	(6)
TFP	0.0205**	0.0242**	0.0229**	0.0182	0.0227**	0.0184
	[0.009]	[0.010]	[0.010]	[0.011]	[0.010]	[0.011]
$\ln K_m$	0.0009	0.0010	0.0010	0.0025	0.0009	0.0026
	[0.003]	[0.003]	[0.003]	[0.004]	[0.003]	[0.004]
D_{Basel1}	0.0159	0.0180	0.0300**	0.0276*	0.0344**	0.0320**
	[0.012]	[0.012]	[0.014]	[0.015]	[0.015]	[0.016]
$D_{Basel1} \times TFP$		0.0412**	0.0441**	0.0393**	0.0380**	0.0332*
		[0.016]	[0.018]	[0.019]	[0.017]	[0.017]
$\frac{Debt}{Land}$	-0.0016	-0.0016	0.0007	0.0018		
	[0.002]	[0.002]	[0.003]	[0.003]		
$\frac{Debt}{Land} \times TFP$		-0.0071**	-0.0069	-0.0069		
		[0.003]	[0.004]	[0.005]		
$D_{Basel1} \times \frac{Debt}{Land}$			-0.0101**	-0.0095*		
			[0.005]	[0.005]		
$D_{Basel1} \times \frac{Debt}{Land} \times TFP$			-0.0037	-0.0006		
			[0.007]	[0.008]		
$\frac{Debt}{Collat.}$					0.0002	0.0017
					[0.003]	[0.003]
$\frac{Debt}{Collat.} \times TFP$					-0.0055	-0.0058
					[0.004]	[0.005]
$D_{Basel1} \times \frac{Debt}{Collat.}$					-0.0122**	-0.0113*
					[0.006]	[0.006]
$D_{Basel1} \times \frac{Debt}{Collat.} \times TFP$					0.0023	0.0043
					[0.006]	[0.006]
Lagged Investment				0.1896***		0.1876***
				[0.064]		[0.065]
$Year98$	-0.0240**	-0.0267***	-0.0257***	-0.0293***	-0.0253***	-0.0293***
	[0.009]	[0.010]	[0.009]	[0.010]	[0.009]	[0.010]
$Year98 \times TFP$	-0.0101	-0.0262*	-0.0239	-0.0220	-0.0236	-0.0216
	[0.012]	[0.015]	[0.015]	[0.016]	[0.015]	[0.016]
Constant	0.0962*	0.0958*	0.0929*	0.0461	0.0949*	0.0453
	[0.054]	[0.053]	[0.053]	[0.057]	[0.053]	[0.058]
Observations	1,280	1,280	1,280	1,102	1,280	1,102

Note: Robust standard errors in brackets. *** 1 percent, ** 5 percent, * 10 percent. The dependent variable is the ratio of machine investment to machine capital stock. The variable TFP is the total factor productivity defined by $TFP = \ln(Y) - \hat{\alpha}_k \ln(K)$, where Y and K are gross output and total capital stock, respectively. D_{Basel1} is equal to one if $Basel1 > 0.02$ and zero, otherwise. The variable $\frac{Debt}{Land}$ represents the debt to land ratio while the variable $\frac{Debt}{Collat.}$ represents the debt to collateral ratio, where $Collat.$ is computed as $0.1537K_m + 0.6777Land$. $Year98$ is year dummy for 1998.

and significant, suggesting that the extent to which the high Basel I capital ratio relaxes firm's borrowing constraint depends on the amount of debt. When a firm has a large amount of debt, then the high Basel I capital ratio does not necessarily promote firm's investment because banks are not willing to lend to such a risky firm even when their Basel I capital ratio is high. In column (4), last year's investment rate is included to control for serially correlated errors but the result remains similar to that of column (3). In columns (5) and (6), we use the debt-to-collateral ratio in place of the debt-to-land ratio in the specification of columns (3) and (4) and the results are similar to those reported in columns (3) and (4).

3 An empirical model of investment with endogenous borrowing constraints

There is a large number of heterogeneous firms. Each firm faces productivity shock v_{it} that follows a Markov chain. Let K_{it} and N_{it} denote capital and land which firm i owns in the beginning of period t. Due to the computational burden of endogenizing the choice of land holdings, we assume that N_{it} is exogenous and, further, is constant over time. Thus, in what follows, we omit the subscript t in N_{it}. The law of motion for capital is given by $K_{it+1} = (1-\delta)K_{it} + I_{it}$, where δ is a depreciation rate and I_{it} is firm i's investment in period t.

3.1 Profit, capital adjustment cost, and dividend

Let π_{it} denote firm's profits in period t that exhibit a decreasing returns to scale in capital:

$$\pi_{it} = \pi(v_{it}, K_{it}, I_{it}) = \begin{cases} \exp(\alpha_0 + \alpha_K \ln K_{it} + v_{it}) & \text{if } I_{it} = 0 \\ \lambda_I \exp(\alpha_0 + \alpha_K \ln K_{it} + v_{it}) & \text{if } I_{it} \neq 0, \end{cases} \tag{1}$$

where $\alpha_K \in (0,1)$. The variable v_{it} represents productivity shock.[9] Following Cooper and Haltiwanger (2006), we consider an opportunity cost of investment so that, if there is

[9] Our interpretation of π_{it} is a profit after maximizing out flexible variables, including labor, energy, and materials. The productivity shock v_{it} captures both aggregate shock and idiosyncratic shock.

any capital adjustment (i.e., $I_{it} > 0$), then firm's profit falls by a factor of $(1 - \lambda_I)$, where $\lambda_I < 1$.[10] This adjustment cost captures the need for restructuring production processes during the adjustment period.

In addition, firms pay capital adjustment costs, denoted by $\psi(K_{i,t+1}, K_{it}, \epsilon_{it}^k)$, as follows:

$$\psi(K_{i,t+1}, K_{it}, \epsilon_{it}^k) = \begin{cases} \frac{\gamma}{2}\left(\frac{I_{it}}{K_{it}}\right)^2 K_{it} + e^{\epsilon_{it}^k} I_{it} & \text{if } I_{it} \geq 0, \\ \frac{\gamma}{2}\left(\frac{I_{it}}{K_{it}}\right)^2 K_{it} + p_s e^{\epsilon_{it}^k} I_{it} & \text{if } I_{it} < 0, \end{cases} \tag{2}$$

where γ is a parameter determining the magnitude of convex adjustment cost, $p_s < 1$ is a parameter representing the degree partial irreversibility. The term $e^{\epsilon_{it}^k}$ represents an idiosyncratic shock to the relative unit price of investment goods. We assume that ϵ^k is independently drawn from $N(-0.5\sigma_k^2, \sigma_k^2)$ so that the average unit price of investment goods is equal to one.

Both capital and land serve a role of collateral. The resale value of capital $K_{i,t+1}$ and land N_i in period $t+1$ is subject to an idiosyncratic shock ϵ_{it}^b and is given by

$$\Phi(K_{i,t+1}, N_i, \epsilon_{it}^b) = e^{\epsilon_{it}^b}(\lambda_K K_{i,t+1} + \lambda_N N_i), \tag{3}$$

where the parameters λ_K and λ_N represent the fractions of asset values recovered from re-selling K and N, respectively. We assume that ϵ_{it}^b is independently drawn from $N(-0.5\sigma_b^2, \sigma_b^2)$ and is known to both firm i and its banks in period t.[11]

Let $Basel1_i$ denote the weighted average of the Basel I capital ratios of the banks that lend to the firm i. We assume that $Basel1_i$ is exogenous and constant over time.[12]

Let b_{it} denote firm i's (net) short-term debts at the beginning of period t. Here, b_{it} refers to the amount that the firm i is supposed to repay in period t. In this paper, we mainly consider bank loans as debts and explicitly take into account the possibility that the borrowing rate may depend on firm's state variables. Let $s_{it} = (v_{it}, K_{it}, b_{it}, N_i, Basel1_i)$ be the observable state variables. Then, the bond price for $b_{i,t+1}$, denoted by q^b, depends on

[10] In this version, we set $\lambda_I = 1$.

[11] One may interpret that ϵ_{it}^b represents state variables that affect the resale value of capital and land, which is observable to firms and banks but unobserved to econometrician.

[12] We plan to relax this assumption in the future.

the state variables as

$$q^b(s_{it}, K_{i,t+1}, b_{i,t+1}, \epsilon^b_{it}) = \begin{cases} 1/(1 + r^b(s_{it}, K_{i,t+1}, b_{i,t+1}, \epsilon^b_{it})) & \text{if } b_{i,t+1} > 0 \\ 1/(1 + r) & \text{if } b_{i,t+1} \leq 0 \end{cases} \quad (4)$$

where $r^b(s_{it}, K_{i,t+1}, b_{i,t+1}, \epsilon^b_{it})$ represents the borrowing rate for the loan $b_{it+1} > 0$ while we assume that a firm earns the real interest rate r when $b_{i,t+1} \leq 0$. As we discuss below, the bond price schedule q^b is endogenously derived through the zero profit condition for the financial intermediaries.

The dividend is given by $d(s_{it}, K_{i,t+1}, b_{i,t+1}, \epsilon^k_{it}, \epsilon^b_{it})$ where

$$d = \pi(v_{it}, K_{it}, N_i, I_{it}) - \psi(K_{i,t+1}, K_{it}, \epsilon^k_{it}) - c_f - b_{it} + q^b(s_{it}, K_{it+1}, b_{it+1}, \epsilon^b_{it})b_{i,t+1},$$

where c_f is a deterministic part of the fixed cost of operating in the market as inHopenhayn (1992). If $d < 0$, it means that the firm issues new equity by $|d|$. Following Cooley and Quadrini (2001), we define the cost of issuing new equity $\kappa(d)$ as follows.[13]

$$\kappa(d) = \begin{cases} 0 & \text{if } d \geq 0, \\ \lambda_d |d| & \text{if } d < 0. \end{cases}$$

3.2 Firm's dynamic decisions

At the beginning of a period, after observing the realization of state variables, a firm makes a decision among: (1) continuing to operate in the market, (2) exit without default, and (3) default. Denote these choices by $\chi \in \{1, 2, 3\}$, where $\chi = 1$ indicates "stay" in the market while $\chi = 2$ and 3 implies exit without default and default, respectively. There is an idiosyncratic cost shock to a fixed cost of operating in the market, $\rho\epsilon^\chi(1)$, and cost shocks to exit without default and to default, $\rho\epsilon^\chi(2)$ and $\rho\epsilon^\chi(3)$, respectively. We assume that $\epsilon^\chi = (\epsilon^\chi(1), \epsilon^\chi(2), \epsilon^\chi(3))$ is drawn independently from standard Type-I extreme-value distribution.

We assume the following timing of events within a period. Firm i enters period t with state s_{it}. Then, firm i observes exiting cost shocks ϵ^χ_{it} and decides whether stay, exit, or

[13] Alternatively, we may consider a quadratic convex cost of issuing new equity as in Covas and denHaan (2010).

default. If the firm decides to stay, then investment price shock ϵ_{it}^k and bond price shock ϵ_{it}^b are realized, and the firm chooses K_{it+1} and b_{it+1}. The state variable v_{it} evolves exogenously.

Firm's decision problem is written recursively in Bellman equation:

$$
\begin{aligned}
V(s,\epsilon^{\chi}) &= \max\{\underbrace{E_{\epsilon^k,\epsilon^b}[W(s,\epsilon^k,\epsilon^b)] + \rho\epsilon^{\chi}(1)}_{\text{stay}},\ \underbrace{J(s) + \rho\epsilon^{\chi}(2)}_{\text{exit}},\ \underbrace{\rho\epsilon^{\chi}(3)}_{\text{default}}\} \qquad (5)\\
W(s,\epsilon^k,\epsilon^b) &= \max_{b',K'} \quad d - \kappa(d) + \beta E[V(s',\epsilon^{\chi'})|s] \qquad (6)\\
&\quad s.t.\ \ d = \pi(v,K,N,I) - \psi(K',K,\epsilon^k) - c_f - b + q^b(s,K',b',\epsilon^b)b'\\
J(s) &= (1-\delta)K + N - b, \qquad (7)
\end{aligned}
$$

where $V(s,\epsilon^{\chi})$ is the value of a firm with the state (s,ϵ^{χ}) at the beginning of period, which is the maximum of three alternative choices: stay, exit without default, and default. $E_{\epsilon^k,\epsilon^b}[W(s,\epsilon^k,\epsilon^b)] + \rho\epsilon^{\chi}(1)$ represents the expected value of a firm when a firm chooses to stay in the market. The value $J(s) + \rho\epsilon^{\chi}(2)$ represents the exiting value of a firm without default. A defaulting firm will get the zero resale value because both capital and land are captured by bank.

Using the property of Type I extreme value distribution, we have

$$
\begin{aligned}
E_{\epsilon^{\chi}}[V(s,\epsilon^{\chi})] &= \rho \times \text{Euler's constant} + \rho \ln\left\{\exp\left(E_{\epsilon^k,\epsilon^b}[W(s,\epsilon^k,\epsilon^b)]/\rho\right) + \exp(J(s)/\rho) + 1\right\}\\
\Pr(\chi = 1|s) &= \int\int \left(\frac{\exp\left(E_{\epsilon^k,\epsilon^b}[W(s,\epsilon^k,\epsilon^b)]/\rho\right)}{\exp\left(E_{\epsilon^k,\epsilon^b}[W(s,\epsilon^k,\epsilon^b)]/\rho\right) + \exp(J(s)/\rho) + 1}\right) f(\epsilon^k,\epsilon^b)d\epsilon^b d\epsilon^k\\
\Pr(\chi = 2|s) &= \int\int \left(\frac{\exp(J(s)/\rho)}{\exp\left(E_{\epsilon^k,\epsilon^b}[W(s,\epsilon^k,\epsilon^b)]/\rho\right) + \exp(J(s)/\rho) + 1}\right) f(\epsilon^k,\epsilon^b)d\epsilon^b d\epsilon^k
\end{aligned}
$$

while $\Pr(\chi = 3|s) = 1 - \Pr(\chi = 2|s) - \Pr(\chi = 1|s)$, where $f(\epsilon^k,\epsilon^b) = [\phi(\epsilon^b/\sigma_b)\phi(\epsilon^k/\sigma_k)]/(\sigma_b\sigma_k)$ is a joint density function of (ϵ^k,ϵ^b).

3.3 Financial intermediaries and state-dependent bond price

Financial intermediaries are assumed to be risk-neutral and have the information about the firm's state variables, the shock to the resale value of collateral ϵ^b, and firm's decisions on investment and debt holdings. We assume that the financial intermediaries earn zero profit in equilibrium so that

$$E[\Pr(\chi' = 3|s')|s, K', b']\Phi(K', N', \epsilon^b) + (1 - E[\Pr(\chi' = 3|s')|s, K', b'])b' = \frac{q^b(s, K', b', \epsilon^b)b'}{q(Basel1)} \quad (8)$$

for $b' > \Phi(K', N', \epsilon^b)$ while $q^b(s, K', b', \epsilon^b) = q(Basel1)$ for $\Phi(K', N', \epsilon^b) \geq b' > 0$. The left hand side of (8) is the bank's expected return from lending the amount $q^b(s, K', b', \epsilon^b)b'$ to a firm with the current state s who chooses the next period's capital K' and debts b'. The firm will default next period with probability $E[\Pr(\chi' = 3|s')|s, K', b']$, in which case the bank will recover the resale value of collateral, $\Phi(K', N', \epsilon^b)$. The equation (8) is a zero profit condition that the expected return from lending to a firm is equal to the bank's cost of raising $q^b(s, K', b', \epsilon^b)b'$ in the market, $\frac{q^b(s,K',b',\epsilon^b)b'}{q(Basel1)}$, where $q(Basel1)$ is the price of bond issued by the bank to raise funds in the market. On the other hand, $q^b(s, K', b', \epsilon^b) = q(Basel1)$ holds when $\Phi(K', N', \epsilon^b) \geq b' > 0$ because, in such a case, the debt is fully backed by the collateral and is risk free for the bank.

Here, the price of bond issued by the bank, $q(Basel1)$, is a function of $Basel1$, and thus we allow for the possibility that the bank's cost of raising funds depends on a bank's Basel I capital ratio ($Basel1$). If bank's Basel I capital ratio does not affect the bank's ability to raise funds in the market, then $q(Basel1) = 1/(1 + r)$. We expect that $q(Basel1)$ is increasing in $Basel1$: when a bank's Basel I capital ratio is low, the bank's default probability is high so that the bank faces a higher risk premium.

From (4) and (8), the state dependent bond price $q^b(s, K', b', \epsilon^b)$ for a firm choosing (K', b') given the state s is

$$q^b(s, K', b', \epsilon^b) = \begin{cases} q(Basel1)\left\{E[\Pr(\chi' = 3|s')|s, K', b'](\Phi(K', N', \epsilon^b)/b' - 1) + 1\right\} & \text{if } b' > \Phi(K', N', \epsilon^b), \\ q(Basel1) & \text{if } \Phi(K', N', \epsilon^b) \geq b' > 0, \\ 1/(1 + r) & \text{if } b' \leq 0. \end{cases} \quad (9)$$

Our modeling choice of the bank's behavior is simplistic and ignore some realistic features of bank's behavior that are relevant for the policy effect of capital injection. For example, zero profit condition may not hold under the Japanese main bank system where firms and banks have long-term relationship. Further, our model ignores an important dynamic feedback effect from firm's performance to bank's balance sheet. Nonetheless, our specification of the state dependent bond price in (9) highlights an essence of the mechanism we are interested in examine empirically in this paper: conditioning on other state variables (TFP, capital, debt, and land), an increase in the bank's Basel I capital ratio may promote investment by relaxing borrowing constraint.

4 Structural Estimation

In this section, we explain how to estimate the structural model given the data $\{\{v_{it}, K_{it}, b_{it}\}_{t=1}^{T_i}, Basel1_i, N_i\}_{i=1}^{n}$ where T_i is the last period for a firm i is observed in the data.

Using the continuous variable v_{it}, we assume

$$v_{it} = \varrho_v v_{i,t-1} + \epsilon_{it}^v,$$

where ϵ_{it}^v is iid draw from $N(0, \sigma_v^2)$ and estimate (ϱ_v, σ_v^2) by the maximum likelihood estimation (MLE). With the estimate of (ϱ_v, σ_v^2), we discretize the state space of v_{it} into M^v grids as $\mathcal{V} = \{\bar{v}_1, ..., \bar{v}_{M_v}\}$ and construct the $M^v \times M^v$ transition matrix of v that approximate the AR(1) process of v_{it} by Tauchen's method, which we denote by $f_v(v'|v)$. Given the transition matrix of v estimated at the first stage, we estimate other structural parameters by maximizing the log-likelihood function. Appendix B discusses how we have constructed the measure for v_{it}.

To numerically solve the Bellman equation, we discretize the state space using M^j grids for variable j. Let $\mathcal{K} = \{\bar{K}_1, ..., \bar{K}_{M^K}\}$, $\mathcal{B} = \{\bar{b}_1, ..., \bar{b}_{M^b}\}$, $\mathcal{N} = \{\bar{N}_1, ..., \bar{N}_{M^N}\}$, and $\mathcal{B}\dashv\int\rceil\updownarrow\infty = \{\overline{Basel1}_1, ..., \overline{Basel1}_{M^{Basel1}}\}$ be the discrete state space of K, b, N and $Basel1$, respectively. Let $S = \mathcal{V} \times \mathcal{K} \times \mathcal{B} \times \mathcal{N} \times \mathcal{B}\dashv\int\rceil\updownarrow\infty$ be the space of observable state variables. We also discretize the unobserved state variables ϵ^b and ϵ^k into $E^b = \{\bar{\epsilon}_1^b, ..., \bar{\epsilon}_{M^\epsilon}^b\}$ and $E^k = \{\bar{\epsilon}_1^k, ..., \bar{\epsilon}_{M^\epsilon}^k\}$. We approximate the normal distribution of (ϵ^k, ϵ^b) by the multinomial distribution of (ϵ^k, ϵ^b) on the grids, which we denote by $f_\epsilon(\epsilon^k, \epsilon^b)$. Note that $f_\epsilon(\epsilon^k, \epsilon^b)$ depends on their variances, σ_k^2 and σ_b^2.

4.1 The state dependent bond price $q^b(s, K', b', \epsilon^b)$

Solving the equilibrium state dependent bond price (9) together with the firm's decision problem is challenging. The bond price schedule (9) depends on the firm's default probabilities but computing the default probabilities requires the solution to the Bellman equations (5)-(7) which in turn depends on the bond price schedule (9). The estimation requires repeatedly solving the fixed point of (9) and (5)-(7) for each candidate parameter to maximize the log-likelihood function, which is not feasible computationally.

For this reason, we approximate the expected default probabilities, $E[\Pr(\chi' = 3|s')|s, K', b']$, in (9) by using the following parametric logit-specification as

$$E[\Pr(\chi' = 3|s')|s, K', b'] = \frac{\exp(\beta_0^d + \beta_1^d v + \beta_2^d \ln K' + \beta_3^d (b'/K') + \beta_4^d \ln N + \beta_5^d Basel1)}{1 + \exp(\beta_0^d + \beta_1^d v + \beta_2^d \ln K' + \beta_3^d (b'/K') + \beta_4^d \ln N + \beta_5^d Basel1)}. \tag{10}$$

while we specify the bank's cost of obtaining funds as

$$q(Basel1) = c + (1 - c)\frac{\exp(\beta_0^b + \beta_1^b Basel1)}{1 + \exp(\beta_0^b + \beta_1^b Basel1)} \tag{11}$$

for some choice of constant $c \in (0, 1]$. Plugging the specification (10) of $E[\Pr(\chi' = 3|s')|s, K', b']$, the collateral value (3), and the bank's premium (11) into (9), we have a parametric specification for $q^b_{\theta_1}(s, K', b', \epsilon^b)$, where $\theta_1 = (\lambda_K, \lambda_N, \lambda_{Basel1}, \beta_0^b, \beta_1^b, \{\beta_j^d\}_{j=0}^5)$ is an unknown parameter vector.

In addition to the computational advantage, using the specification of (10) has advantage in that it is more robust against misspecification than the specification (9) that is implied by fixed point constraint. On the other hand, its disadvantage is a possible loss of efficiency when (9) is correctly specified while it could be subject to Lucas critique when the parameters recovered under the specification of (10) is not invariant against the counterfactual policy experiments we conduct in Section 5.4.

4.2 The Bellman equation

Define $\bar{V}(s) = E_{\epsilon^{\chi}}[V(s, \epsilon^{\chi})]$. Given the bond pricing function $q^b_{\theta_1}(s, K', b', \epsilon^b)$, the Bellman equation (5)-(7) is written as

$$\begin{aligned}
\bar{V}(s) &= \rho \times \text{Euler's constant} \\
&\quad + \rho \ln \left\{ \exp\left(\sum_{j_k=1}^{M^\epsilon} \sum_{j_b=1}^{M^\epsilon} f_\epsilon(\bar{\epsilon}^k_{j_k}, \bar{\epsilon}^b_{j_b}) W(s, \bar{\epsilon}^k_{j_k}, \bar{\epsilon}^b_{j_b})/\rho \right) + \exp(J(s)/\rho) + 1 \right\}, \quad (12) \\
W(s, \epsilon^k, \epsilon^b) &= \max_{K', b'} \quad d - \kappa(d) + \beta \sum_{j=1}^{M^v} f_v(\bar{v}_j | v) \bar{V}(\bar{v}_j, K', b', Basel1, N) \quad (13) \\
&\quad s.t. \;\; d = \pi(v, K, N, I) - \psi(K', K, \epsilon^k) - c_f - b + q^b_{\theta_1}(s, K', b', \epsilon^b) b', \\
J(s) &= (1 - \delta)K + N - b,
\end{aligned}$$

where $(K, b, Basel1, N)$ is evaluated on the grids on $\mathcal{S}$. Given $q^b_{\theta_1}(s, K', b', \epsilon^b)$ and the parameter $\theta_2 = (\alpha_0, \alpha_K, \alpha_N, \alpha_{Basel1}, \gamma, p^s, c_f, \lambda_d, \lambda_{Basel1}, \sigma^2_k, \sigma^2_b, \rho)$, we numerically solve the fixed point of this discreteized Bellman equation by successive approximation. Let $\theta = (\theta_1, \theta_2)$ be the parameter to be estimated. Let $\bar{V}_\theta$, W_θ, and J_θ be the fixed point of the Bellman equation under the parameter value θ, and denote the optimal decision rule for K' and b' by $K^*_\theta(s, \epsilon^k, \epsilon^b)$ and $b^*_\theta(s, \epsilon^k, \epsilon^b)$, respectively.

4.3 The likelihood function

The probabilities of choosing (K', b') given the state s are given by the indicator functions as

$$\Pr_\theta(K', b' | s, \epsilon^k, \epsilon^b) = 1[K' = K^*_\theta(s, \epsilon^k, \epsilon^b)] \times 1[b' = b^*_\theta(s, \epsilon^k, \epsilon^b)]. \quad (14)$$

But using the indicator functions to evaluate the choice probabilities will lead to non-smooth likelihood function, which is difficult to numerically maximize. For this reason, we add Type I extreme value shocks to each choice of K' and b' on the grids so that the indicator functions in (14) are replaced by logit probabilities as

$$\widetilde{\Pr}_\theta(K', b' | s, \epsilon^k, \epsilon^b) = \frac{\exp(w_\theta(K', b', s, \epsilon^k, \epsilon^b)/\tau)}{\sum_{(\tilde{K}, \tilde{b}) \in \mathcal{K}' \times \mathcal{B}'} \exp(w_\theta(\tilde{K}, \tilde{b}, s, \epsilon^k, \epsilon^b)/\tau)}, \quad (15)$$

where $\mathcal{K}' \times \mathcal{B}'$ is the discretized state space for (K', b') and

$$w_\theta(K', b', s, \epsilon^k, \epsilon^b) = d - \kappa(d) + \beta \sum_{j=1}^{M^v} f_v(\bar{v}_j|v)\bar{V}_\theta(\bar{v}_j, K', b', Basel1, N)$$

with $d = \pi(v, K, N) - \psi(K', K, \epsilon^k) - c_f - b + q^b_{\theta_1}(s, K', b', \epsilon^b)b'$. In solving the Bellman equation, we also evaluate (13) with Type I extreme value shocks for each choice of K' and b' so that the conditional choice probabilities (15) are consistent with the solution to the Bellman equation. Here, τ is a smoothing parameter such that $\widetilde{\Pr}_\theta(K', b'|s, \epsilon^k, \epsilon^b)$ gets closer to the indicator functions in (14) as $\tau \to 0$.

Accordingly, the likelihood of observing the choice $\{\chi_{it} = 1, K_{i,t+1}, b_{i,t+1}\}$ conditional on s_{it} is

$$\begin{aligned} \Pr_\theta(\chi_{it} = 1, K_{i,t+1}, b_{i,t+1}|s_{it}) &= \sum_{j_k=1}^{M^\epsilon} \sum_{j_b=1}^{M^\epsilon} f_\epsilon(\bar{\epsilon}^k_{j_k}, \bar{\epsilon}^b_{j_b})\widetilde{\Pr}_\theta(K_{i,t+1}, b_{i,t+1}|s_{it}, \bar{\epsilon}^k_{j_k}, \bar{\epsilon}^b_{j_b}) \\ &\times \left(\frac{\exp\left(W_\theta(s_{it}, \bar{\epsilon}^k_{j_k}, \bar{\epsilon}^b_{j_b})/\rho\right)}{\exp\left(W_\theta(s_{it}, \bar{\epsilon}^k_{j_k}, \bar{\epsilon}^b_{j_b})/\rho\right) + \exp(J_\theta(s_{it})/\rho) + 1} \right), \end{aligned} \quad (16)$$

where $\widetilde{\Pr}_\theta(K', b'|s, \epsilon^k, \epsilon^b)$ is given by (15).

On the other hand, the likelihood of observing the exit/default choice of $\chi_{it} \neq 1$ conditional on the past state variables $s_{i,t-1}$ is

$$\Pr_\theta(\chi_{it} \neq 1|s_{i,t-1}) = \sum_{v_{it}\in\mathcal{V}} \sum_{j_k=1}^{M^\epsilon} \sum_{j_b=1}^{M^\epsilon} f_\epsilon(\bar{\epsilon}^k_{j_k}, \bar{\epsilon}^b_{j_b}) f_v(v_{it}|v_{i,t-1})\Pr_\theta(K_{it}, b_{it}|s_{i,t-1})\Pr_\theta(\chi_{it} \neq 1|s_{it}) \quad (17)$$

where

$$\Pr_\theta(\chi_{it} \neq 1|s_{it}) = \sum_{j_k=1}^{M^\epsilon} \sum_{j_b=1}^{M^\epsilon} f_\epsilon(\bar{\epsilon}^k_{j_k}, \bar{\epsilon}^b_{j_b}) \left(\frac{\exp(J_\theta(s_{it})/\rho) + 1}{\exp\left(W_\theta(s_{it}, \bar{\epsilon}^k_{j_k}, \bar{\epsilon}^b_{j_b})/\rho\right) + \exp(J_\theta(s_{it})/\rho) + 1} \right).$$

Note that the conditional choice probabilities (16) and the probability of not staying (17) can be only evaluated at the discretized state space $\mathcal{K}' \times \mathcal{B}' \times \mathcal{S}$. On the other hand, the observations for $(K_{i,t+1}, b_{i,t+1}, s_{it})$ is not on the grids. We use interpolation to evaluate the likelihood (16) and (17) for the observations outside of the grids.[14]

[14]Suppose that $(K_{i,t+1}, b_{i,t+1})$ is outside of the grids such that $\ln \bar{K}_{j^k} < \ln K_{i,t+1} < \ln \bar{K}_{j^k+1}$ and $\bar{b}_{j^b} <$

4.4 The maximum likelihood estimator (MLE)

Suppose we have the panel data $\{\{v_{it}, K_{it}, b_{it}\}_{t=1}^{T_i}, Basel1_i, N_i\}_{i=1}^{n}$, where n is the sample size while T_i is the year in which firm i either exits or defaults.

The likelihood contribution from firm i's observation is given by

$$L_i(\theta) = \begin{cases} \Pr_\theta(\chi_{it} \neq 1 | s_{i,t-1}) \prod_{t=1}^{T_i-1} \Pr_\theta(\chi_{it} = 1, K_{i,t+1}, b_{i,t+1} | s_{it}) & \text{if } T_i < T \\ \prod_{t=1}^{T_i-1} \Pr_\theta(\chi_{it} = 1, K_{i,t+1}, b_{i,t+1} | s_{it}) & \text{otherwise,} \end{cases}$$

where T is the length of the panel data.

The maximum likelihood estimator $\hat{\theta}_{MLE}$ is defined by the maximizer of the following log likelihood function:

$$\hat{\theta}_{MLE} = \arg\max_{\theta \in \Theta} \sum_{i=1}^{n} \ln L_i(\theta). \quad (18)$$

5 Results

In this section, we report the results from the structural estimation and counterfactual experiments on the capital injection policies that took place in March 1998 and March 1999 in Japan. For the current version of the estimation, we only use the cross-section data for 1998, $\{K_{i,1998}, b_{i,1998}, N_{i,1998}, Basel1_{i,1998}, K_{i,1999}, b_{i,1999}\}_{i=1}^{N}$.

For estimation, we parameterize the bond price function as (9), where $E[\Pr(\chi' = 3|s')|s, K', b']$ and $q(Basel1)$ are given by (10) and (11). After trying several different values of c, we decided to choose $c = 0.6$ in (11) because the estimated model provides a good fit with $c = 0.6$. This specification implies that the value of $q(Basel1)$ is restricted between 0.6 and 1.

$b_{i,t+1} < \bar{b}_{j^b+1}$, where $(\bar{K}_{j^k}, \bar{K}_{j^k+1})$ and $(\bar{b}_{j^b}, \bar{b}_{j^b+1})$ are nearest grid points for $K_{i,t+1}$ and $b_{i,t+1}$. Then, for instance, if s_{it} is on the grid, we evaluate $\Pr_\theta(K_{i,t+1}, b_{i,t+1}|s_{it})$ by taking the weighted averages of probabilities across four grid points as $\sum_{s^k=0}^{1} \sum_{s^b=0}^{1} \psi_{j^k+s^k} \psi_{j^b+s^b} \Pr_\theta(\bar{K}_{j^k+s^k}, \bar{b}_{j^b+s^b}|s_{it})$, where $\psi_{j^k+s^k} = |\ln \bar{K}_{j^k+s^k} - \ln K_{i,t+1}|/(\ln \bar{K}_{j^k+1} + \ln \bar{K}_{j^k})$ and $\psi_{j^b+s^b} = |\bar{b}_{j^k+s^k} - b_{i,t+1}|/(\bar{b}_{j^k+1} - \bar{b}_{j^b})$. When s_{it} is also outside of the grids, we take the weighted averages of probabilities across 2^x grid points where x is the number of variables outside of the grids.

Table 6: Externally Set Parameters

Parameter	Description	Value
β	Discount factor	0.9000
ρ_v	Autocorrelation of v	0.8391
α_K	Curvature of profit function	0.5970
r	(saving) interest rate	0.0019
δ	Depreciation rate	0.0954
λ_K	Resale value of capital	0.1537
λ_N	Resale value of land	0.6777
λ_I	Opportunity cost	1.0000

5.1 Externally Set Parameters

Table 6 reports parameter values that we set externally. We set the discount factor β to 0.9. We estimate the curvature of profit function and the autocorrelation of v by the System GMM of **?** as explained in Appendix B. The risk-free interest rate for saving, r, is the average deposit rate over the 1995–2000 period. The depreciation rate for machinery plus transportation equipment, δ, is the weighted average of the corresponding depreciation rates taken from Hayashi and Inoue (1991). The parameters determining the resale values of capital and land, λ_K and λ_N, are taken from Ogawa and Suzuki (2000).

5.2 Parameter estimates

Given the externally set parameter values, we estimate the rest of the structural parameters by MLE. Table 7 reports estimates for the parameters in the profit function, capital adjustment costs, and unobserved shocks. The curvature of the quadratic adjustment cost is estimated high at 31.8 while the estimated relative resale price of capital is low at 0.0005, suggesting that both the convex and the non-convex adjustment cost are important to explain investment decisions although it is important to note that the latter effect is imprecisely estimated.[15] The standard deviations of the collateral shock and investment cost shock are estimated high at 0.21 and 1.6, respectively. The large variance of idiosyncratic shocks indicates that there are unobserved factors for investment that are not fully explained by the observed state variables in the model, which is not surprising because empirically explaining a large portion of the cross-sectional variation in investment by observed variables has been found to be difficult in the literature. The parameter λ_d is estimated at 1.807, which implies that the equity issuing cost is high and that the finance through borrowing from banks is important for firm's investment decisions.

Table 8 reports estimates for the parameters in the state-dependent bond price function. The coefficient on Basel I capital ratio in $q(Basel1)$ function, $\hat{\beta}_1^b$, is significantly positive, suggesting that the higher the bank's Basel I capital ratio, the lower the borrowing cost for firms.

The implications of the parameter estimates on the state-dependent borrowing interest rates r^b are summarized in Table 9, where $r^b = 1/q^b - 1$ as implied by (4). Column (1) reports how the interest rate r^b depends on the bank's Basel I capital ratio when the firm's state variable is at their median values. The interest rate for a median firm is quite high at 35.1-47.5 percent if its main bank's Basel I capital ratio is lower than 0.02. Changing the value of $Basel1$ from 0.00 to 0.04 decreases the interest rate by $(47.5 - 22.2 =)25.3$ percentage points, suggesting that the effect of $Basel1$ on investment could be substantial. On the other hand, even at $Basel1 = 0.04$, the implied interest rate for a median firm is still high at 22.2 percent. This suggests that the high implied investment cost is necessary to explain the low investment rate observed in the data. The estimated high investment cost perhaps reflects the "Japan premium," which is an extra interest charged on offshore

[15] These estimates are sensitive to our specification of adjustment cost function ψ in (2). When we specify the adjustment cost function as

$$\psi(K_{i,t+1}, K_{it}, \epsilon_{it}^k) = \begin{cases} e^{\epsilon_{it}^k}\{\frac{\gamma}{2}\left(\frac{I_{it}}{K_{it}}\right)^2 K_{it} + I_{it}\} & \text{if } I_{it} \geq 0, \\ e^{\epsilon_{it}^k}\{\frac{\gamma}{2}\left(\frac{I_{it}}{K_{it}}\right)^2 K_{it} + p_s I_{it}\} & \text{if } I_{it} < 0, \end{cases}$$

we find that the estimate of γ and p_s are 9.949 and 0.641 with small standard errors while the standard deviation of the investment cost shock is estimated at 0.137. We are in the process of checking the robustness of our results using this alternative specification.

loans to Japanese banks relative to similarly risky banks from other countries during the banking crisis.

Table 9 reports how the interest rate r^b depends on the value of state variables. Column (2) of Table 9 compares the interest rate r^b evaluated at the 25 percentile value of b' with that at the 75 percentile of b', which corresponds to "Low b'" and "High b'" in Table 9, respectively, when other state variables are evaluated at their median values. At $Basel1 = 0.02$, an increase in the value of b' from its 25 percentile value to its 75 percentile value increases the interest rate by $(69.7 - 34.8 =)34.9$ percentage points, indicating that a large amount of debt discourages investment by tightening the borrowing constraint. In Columns (3) and (4), at $Basel1 = 0.02$, an increase in land holding N and capital stock K' from their 25 percentile values to their 75 percentile value decreases the interest rate by 4.8 and 3.8 percentage points. In the model, having a large amount of land and capital relaxes borrowing constraint because they serve a role of collateral. On the other hand, Column (5) indicates that the effects of TFP on investment cost is small.

We do not literally interpret the interest rates reported in Table 9 as the interest rates banks actually offered to firms during the banking crisis in 1998. While our model focuses on the bond price channel as the only channel through which financial constraint operates, in reality, bank's lending decision is more complicated than just offering the borrowing rates to firms. In particular, the bank's lending decision is likely to involve not only the price (i.e., interest rate) but also the quantity (i.e., the amount of lending). Our estimate of state-dependent interest rate captures both aspects of bank's lending decision. For example, when we evaluate the interest rate r^b at the 90 percentile value of b' with other state variables at their median values, the implied interest rate becomes more than 800 percent (not reported in the table). This can be interpreted as bank's decision on the quantity of lending: banks do not approve any investment finance when the amount of the debt is very large.

Table 10 compares the mean investment rates by Basel I capital ratio, debt-collateral ratio, capital, and TFP for the 1998 data with the corresponding values predicted by the estimated model, where, following the model's implication, we use $b'/(\lambda_K K' + \lambda_N N)$ with

Table 7: Estimates of Structural Parameters: Profit and Capital Adjustment

$\hat{\alpha}_0$	$\hat{\gamma}$	$\hat{p}_s$	$\hat{\sigma}^b$	$\hat{\sigma}^k$	$\hat{\lambda}_d$
6.468	31.808	0.005	0.214	1.598	1.807
(0.008)	(0.756)	(0.785)	(0.0003)	(0.037)	(0.001)

Notes. Standard errors are in parentheses.

Table 8: Estimates of Structural Parameters: Bond Price

$\hat{\beta}_0^b$	$\hat{\beta}_1^b$	$\hat{\beta}_0^d$	$\hat{\beta}_1^d$	$\hat{\beta}_2^d$	$\hat{\beta}_3^d$	$\hat{\beta}_4^d$
-1.401	39.971	-0.389	-1.125	-0.018	0.647	-0.182
(0.029)	(0.797)	(0.481)	(0.099)	(0.022)	(0.055)	(0.015)

Notes. Standard errors are in parentheses.

Table 9: Estimates of State Dependent Real Interest Rate: $r^b = 1/q^b - 1$

	State Dependent Real Interest Rate: $r^b = 1/q^b - 1$								
$Basel1$	(1)	(2)		(3)		(4)		(5)	
	Median	Low b'	High b'	Low N	High N	Low K'	High K'	Low v	High v
0.000	0.475	0.473	0.853	0.525	0.473	0.516	0.473	0.476	0.474
0.020	0.351	0.348	0.697	0.396	0.348	0.388	0.348	0.352	0.350
0.040	0.222	0.220	0.535	0.263	0.220	0.256	0.220	0.223	0.221
0.060	0.123	0.121	0.410	0.160	0.121	0.154	0.121	0.124	0.122
0.080	0.062	0.060	0.334	0.098	0.060	0.092	0.060	0.063	0.061

Notes. Column (1) reports the estimated value of r^b evaluated at the median values of v, K', N, and b'. In Column (2)-(5), for $x = b'$, K', N, and v, "Low x" and "High x" report the estimated value of r^b evaluated at the 25 percentile and the 75 percentile of the variable x, respectively, where other state variables are evaluated at their median values.

$\lambda_K = 0.1537$ and $\lambda_N = 0.6777$ as a measure of debt-collateral ratio.[16] To construct Table 10, we first classify the observations into (2^4=)16 subgroups based on four binary variables that classify Basel I capital ratio, debt-collateral ratio, capital, and TFP into high and low values using their median value as a threshold. For each observation, we compute the mean investment rate implied by the estimated investment function evaluated at each observation's observed state variables, and then we take the average of the predicted mean investment rates across firms within each subgroup. Table 10 shows that the model captures the patterns of investment rates observed in the data reasonably well although the model under-predicts investment rates for firms with high capital, low TFP, and low debt-collateral ratio. Among different subgroups, the model predicts that the effect of Basel I capital ratio on investment rates is the largest for the group of firms with low capital, high TFP, and low debt-to-collateral ratio as reported in the upper right panel of Table 10, which is largely consistent with the results of our regression analysis in Table 5.

We also note that, in some cases, predicted investment rates appears to be at odd with the estimated state dependent interest rate reported in Table 9. For instance, among firms with low capital, low TFP, and low debt-collateral ratio in the upper left panel of Table 9, predicted average investment rates are higher for firms with low Basel1 at 0.0605 than for firms with high Basel1 at 0.0505. This is because the distribution of other state variables (debt-collateral ratio, capital, and TFP) is different between firms with low Basel1 and firms with high Basel1 even within each subgroups of firms.[17]

[16]We also constructed the similar table using the ratio of the beginning-of-period debt to land, b/N, in place of $b'/(\lambda_K K' + \lambda_N N)$. The result is very similar to Table 10.

[17]In particular, within the subgroup of firms with low capital stock, low TFP, and low debt-collateral ratio, the average log capital stock is 13.65 for firms with low Basel1 while it is 14.09 for firms with high Basel1 as reported in Appendix C. In general, the effect of capital stock on investment rate depends on two effects with opposite directions: the marginal rate of return from investment is decreasing in capital stock given the profit function (1) with $\alpha_K = 0.6$ while the real interest rate r^b is decreasing in capital stock because capital stock plays the role of collateral. In this case, at the low level of capital stock, the first effect dominates the combined effect of the second effect and the effect of Basel I capital ratio. As a result, the model predicts that firms with low Basel1 and low capital has higher incentive to invest than firms with high Basel1 and high capital.

Table 10: Machine Investment Rates by Basel I capital ratio, Debt/Land, Capital and TFP (1998)

	Low Machine Capital Stock			
	Low TFP		High TFP	
	$Basel1 \leq 0.02$	$Basel1 > 0.02$	$Basel1 \leq 0.02$	$Basel1 > 0.02$
Low $b'/(\lambda_K K' + \lambda_N N)$				
Data (1998)	0.1023	0.0720	0.0633	0.1255
	(0.0294)	(0.0202)	(0.0122)	(0.0410)
Model Prediction	0.0605	0.0505	0.0511	0.1053
High $b'/(\lambda_K K' + \lambda_N N)$				
Data (1998)	0.0568	0.0571	0.0518	0.1140
	(0.0100)	(0.0085)	(0.0148)	(0.0788)
Model Prediction	0.0528	0.0425	0.0613	0.0762
	High Machine Capital Stock			
	Low TFP		High TFP	
	$Basel1 \leq 0.02$	$Basel1 > 0.02$	$Basel1 \leq 0.02$	$Basel1 > 0.02$
Low $b'/(\lambda_K K' + \lambda_N N)$				
1998	0.1366	0.1054	0.1042	0.1167
	(0.0193)	(0.0099)	(0.0122)	(0.0094)
Model Prediction	0.0645	0.0667	0.1349	0.1413
High $b'/(\lambda_K K' + \lambda_N N)$				
1998	0.1017	0.0824	0.1218	0.0985
	(0.0252)	(0.0135)	(0.0151)	(0.0111)
Model Prediction	0.0615	0.0714	0.1247	0.1305

5.3 Counterfactual experiments: effects of capital injection in 1998/3 and 1999/3

Using the estimates reported in Section 5.2, we conduct counterfactual experiments to examine the effects of the capital injection in March 1998 and March 1999 on corporate investment. Specifically, we ask two counterfactual questions. The first is what would have happened to investment in 1998 if there had been no capital injection in March 1998. The second is what would have happened to investment in 1998 if the 1999 capital injection (7.5 trillion yen) had taken place in 1998 on the top of the 1998 capital injection (1.8 trillion yen).

To implement the first experiment, we first construct the counterfactual value of each bank's Basel I capital ratio without the 1998 capital injection by subtracting the amount of the public funds injected into banks' Tier I and Tier II capital by the Japanese government in 1998 from the actual bank capital in 1998, and then compute the counterfactual investment rate for each firm by evaluating the estimated model at the counterfactual value of bank's Basel I capital ratio.[18] Similarly, we implement the second experiment by constructing the counterfactual Basel1 variable by adding the amount of the public funds injected into banks' capital in 1999 to the actual bank capital in 1998.

Table 11 reports the effect of capital injection on aggregate investment level. The results indicate that, had there been no capital injection in 1998, the total amount of aggregate investment in 1998 would have lower by 1.34%. The effect of the 1998 capital injection was especially large for firms with low capital and high TFP: the total amount of the aggregate investment among firms with low capital and high TFP in 1998 would have been lower by 3.31% if the 1998 capital injection had not happened. On the other hand, if the 1999 capital injection had happened in 1998, the total amount of the aggregate investment in 1998 would have been higher by 8.32% across all sample while the total amount of the aggregate investment among the firms with low capital stock and high TFP would have been higher by 16.46%.

[18] Table 1 of Montgomery and Shimizutani (2009) provides detailed information on the amount of public funds used in the capital injection policies.

Table 12 reports the counterfactual values of average investment rates in the experiments within each of 8 subgroups of firms classified by machine capital, Basel I capital ratio, and TFP. The effect of capital injection is especially large for the groups of firms with high TFP. For instance, for the group of firms with low capital, high TFP, and low Basel1 reported in the upper right panel of Table 12, the average investment rate for these firms would have been lower by (5.56-5.24=)0.32 percentage points if there had been no capital injection in 1998 while it would have been higher by (7.96-5.56=)2.4 percentage points if the 1999 capital injection had happened in 1998. In contrast, for the group of firms with low capital, low TFP, and low Basel1 reported in the upper left panel, the corresponding numbers are smaller by an order of magnitude with (5.63-5.59=)0.04 and (5.83-5.63=)0.2 percentage points, respectively. We also note that, in all sample, the experiments suggest that average investment rate would have been lower by 0.21 percentage points without the 1998 capital injection while it would have been higher by 0.9 percentage points (not reported in the table).[19]

Table 11: Counterfactual Experiments: Aggregate Investment in 1998

	All Sample	Low K_m and High TFP
No injection in 1998	-1.34%	-3.31%
Sum of 1998 and 1999 injections	8.32%	16.46%

[19]Here, the magnitude of the effects of capital injection on the total amount of aggregate investment reported in Table 11 is much larger than that of (unweighted) average investment rates reported in Table 12 because aggregate investment is equal to weighted average investment rate using capital stock as weights and the effect of capital injection on investment rates is larger for firms with high capital stocks within each subgroup of Table 12.

Table 12: Machine Investment Rates by Machine Capital, Basel I capital ratio and TFP (1998)

	Low TFP		High TFP	
	$Basel1 \leq 0.02$	$Basel1 > 0.02$	$Basel1 \leq 0.02$	$Basel1 > 0.02$
Low Capital Stock				
Model (Actual)	0.0563	0.0470	0.0556	0.0920
Model (No injection)	0.0559	0.0465	0.0524	0.0841
Model (Sum 1998-1999)	0.0583	0.0491	0.0796	0.1032
High Capital Stock				
Model (Actual)	0.0629	0.0695	0.1290	0.1353
Model (No injection)	0.0617	0.0675	0.1268	0.1321
Model (Sum 1998-1999)	0.0720	0.0809	0.1447	0.1541

Appendix A: The Development Bank of Japan (DBJ) Data

The data set compiled by the Development Bank of Japan (DBJ) contains detailed corporate balance sheet/income statement data for the firms listed on the Tokyo Stock Exchange. In our analysis, we deflate all nominal variables by monthly Corporate Goods Price Index (CGPI) for all goods. Because firm's financial data do not necessarily refer to a calendar year, we assign year t to an observation if the given firm's closing date is between June of year t and May of year $t+1$.[20] If firms change their closing dates, the data after the change may refer to less than 12 months. When it occurs, we multiply the data x_{it} by $12/m$ where m represents the number of months to which the data refer. The rest of this section explains how we construct variables from the original data.

A.1 Variable construction

Stock of Machine Capital

In the benchmark analysis, we use data on machinery and transportation equipment as machine capital. We construct the real machine capital stock in the DBJ data by the

[20] More than 80 percent of the manufacturing firms have their closing dates in March in the DBJ data for 1990–2008. For those firms, for example, the data reported in March 1999 refer to a period from April 1998 to March 1999. We assign the year of 1998 to such observations.

perpetual inventory method following Hayashi and Inoue (1991). First, we construct a series of nominal investment in machinery and transportation equipment. Let $(pI)_{it}$ denote firm i's nominal investment in period t. Let K_{it}^{book} denote the book value of the stock of machine capital in the *end* of period t. Let δK_{it}^{book} denote a depreciated value of machinery. Then, we compute $(pI)_{it}$ by the following formula: $(pI)_{it} = K_{it}^{book} - K_{it-1}^{book} + \delta K_{it-1}^{book}$.

Second, we deflate the nominal investment data by the CGPI for machinery and transportation equipment. Denote the real investment by I_{it}. Third, we construct data on real capital stock by the perpetual inventory method. Let K_{it} denote firm i's real capital stock in period t. Then we compute $\{K_{it}\}_t$ by $K_{it+} = (1-\delta)K_{it} + I_{it}$ where the depreciation rate, δ, is taken from Hayashi and Inoue (1991). The initial base year is 1969. For firms entering the sample after 1969, we set the base year to their first year in the sample. We assume that the book value is equal to the market value for the base year, and deflate the book value by the corresponding CGPI. If the stock value becomes negative in the process of the perpetual inventory method, reset the stock value to the book value for the year. We multiply the real capital stock by the corresponding CGPI series to obtain data on machine capital stock in the current yen.

Stock of Land

Setting the depreciation rate of land to zero and using the LIFO method to evaluate inventory, we construct nominal investment as follows:

$$(pI)_{it} = \begin{cases} K_{it}^{book} - K_{it-1}^{book} & \text{if} \quad K_{it}^{book} \geq K_{it-1}^{book} \\ (K_{it}^{book} - K_{it-1}^{book})(p_t^{land}/p_s^{land}) & \text{if} \quad K_{it}^{book} < K_{it-1}^{book}, \end{cases}$$

where p_s^{land} is the price of land at which land was last bought. (Hoshi and Kashyap (1990) and Hayashi and Inoue (1991)).

With the nominal investment series and the depreciation rate, which is set to zero, we construct data on the nominal stock of land through the perpetual inventory method, $(pK)_{it} = (p_t/p_{t-1})(pK)_{it-1} + (pI)_{it}$ where $(pK)_{it}$ represents the value of firm i's land stock in the current yen in period t, $(pI)_{it}$ the value of land investment in the current yen, p_t the price of land in period t. For the base year, we use a book-to-market ratio to convert the book value of land stocks into the market value. For the book-to-market ratio, following Hayashi and Inoue (1991), we take an estimate of the market value of land owned by nonfinancial corporations from the National Income Accounts and the book value from the Corporate Statistics Annual.

Net Debt

For debt, we use the sum of short- and long-term borrowing and corporate bonds. Net debt is then computed by subtracting the amount of deposit from the debt.

Output

Nominal output for period t is total sales plus changes in inventories of finished goods.

Appendix B: The Estimation of Production Function and the TFP measure

To obtain the TFP measure, we consider the following production function:

$$y_{it} = \alpha_0 + \alpha_k k_{it} + \alpha_l l_{it} + z_{it} \tag{19}$$

$$z_{it} = \rho z_{i,t-1} + \omega_{it} \tag{20}$$

where y_{it} is the logarithm of total gross output, k_{it} is the logarithm of capital input, l_{it} is the logarithm of labor input. The variable z_{it} represents the total factor productivity and follows the AR(1) process, where ω_{it} is independent of $z_{i,t-1}$.

One of the main econometric issues in estimating the production function (19)-(20) is the simultaneity of a productivity shock z_{it} and input decisions. All of input variables, k_{it} and l_{it}, are likely to be correlated with productivity shock z_{it}, and the OLS estimate will be biased.

To estimate the production function consistently, we first take a "quasi-difference,"

$y_{it} - \rho y_{i,t-1}$, to eliminate z_{it} and $z_{i,t-1}$ as

$$\begin{aligned} y_{it} &= \rho y_{i,t-1} + \alpha_k k_{it} - \rho \alpha_k k_{i,t-1} + \alpha_l l_{it} - \rho \alpha_l l_{i,t-1} + \omega_{it} \\ &= \rho y_{i,t-1} + \alpha_k k_{it} + \beta_k k_{i,t-1} + \alpha_l l_{it} + \beta_l l_{i,t-1} + \omega_{it}. \end{aligned}$$

Then, we apply the System GMM estimator of **?** to estimate the parameter ρ, α_k, β_k, α_l, β_l without imposing the cross-parameter constraints. We also include the year dummies. Here, k_{it} is predetermined variable so that $E[\Delta\omega_{it} k_{i,t-s}] = 0$ holds for $s = 1, 2, ...$ while l_{it} is an endogenous variable, where $E[\Delta\omega_{it} l_{i,t-s}] = 0$ holds for $s = 2, 3, ...$ We use a full set of moment conditions available including the moment condition implied by the initial condition under stationarity.

The above GMM estimation procedure does not impose the cross parameter constraint, such as $\beta_k = -\rho\alpha_k$, and hence inefficient. Using the consistent estimator of ρ, denoted by $\hat{\rho}$, we construct quasi-differenced variables as $\tilde{y}_{i,t} = y_{it} - \hat{\rho} y_{i,t-1}$, $\tilde{k}_{i,t} = k_{it} - \hat{\rho} k_{i,t-1}$, $\tilde{l}_{i,t} = l_{it} - \hat{\rho} l_{i,t-1}$, and estimate α_k and α_l by applying the GMM estimation method to

$$\tilde{y}_{i,t} = \alpha_k \tilde{k}_{it} + \alpha_l \tilde{l}_{it} + \omega_{it} + \eta_{it},$$

where η_{it} contains the first-stage estimation error of ρ. We use $k_{i,t}$ and $l_{i,t-1}$ as our instruments for $\omega_{it} + \eta_{it}$ and estimate α_k and α_l.

To obtain the value of the parameter α_K in profit function (1) from the estimates of α_k and α_l, denoted by $\hat{\alpha}_k$ and $\hat{\alpha}_l$, we assume that a firm operates in monopolistically competitive environment with the constant price elasticity η. In such an environment, the profit maximization implies that α_K in profit function is related to $\hat{\alpha}_k$, $\hat{\alpha}_l$, and the price elasticity η as $\alpha_K = \frac{(1-\eta)\hat{\alpha}_k}{(1-(1-\eta)\hat{\alpha}_l)}$. We evaluate the value of α_K by assuming $\eta = 0.2$ which implies the price mark-up of 25 percent. In monopolistically competitive environment with the constant price elasticity, profit is proportional to gross revenue and, thus, we compute the TFP measure in the structural model, v_{it}, as $v_{it} = y_{it} - \alpha_K k_{it}$.

Appendix C: Additional Tables

Table 13 reports the average of the logarithm of machine capital stock within each subgroup of firms reported in Table 10. The average values of the logarithm of machine capital stock are substantially different across four different subgroups for "Low Machine Capital Stock" as reported in the upper panel of Table 13, suggesting that the distribution of capital stocks differ across these subgroups. In particular, in the upper left panel of Table 13, the average capital stock for firms with low $Basel1$ is lower than that for firms with high $Basel1$ within the subgroup of low machine capital stock, low TFP, and low debt-collateral ratio. As discussed in the last paragraph of Section 5.2, the difference in the distribution of the state variables across different subgroups makes it somewhat difficult to interpret the model's prediction reported in Table 10.

Table 13: $\ln K_m$ by Basel I capital ratio, Debt/Land, Capital and TFP (1997–1998)

	Low Machine Capital Stock			
	Low TFP		High TFP	
	$Basel1 \leq 0.02$	$Basel1 > 0.02$	$Basel1 \leq 0.02$	$Basel1 > 0.02$
Low $b'/(\lambda_K K' + \lambda_N N)$				
1998	13.6450	14.0926	13.8647	14.2520
	(0.1808)	(0.1280)	(0.1659)	(0.1761)
High $b'/(\lambda_K K' + \lambda_N N)$				
1998	13.7996	14.1820	14.0226	14.2180
	(0.1490)	(0.1195)	(0.2125)	(0.2081)
	High Machine Capital Stock			
	Low TFP		High TFP	
	$Basel1 \leq 0.02$	$Basel1 > 0.02$	$Basel1 \leq 0.02$	$Basel1 > 0.02$
Low $b'/(\lambda_K K' + \lambda_N N)$				
1998	15.9838	15.9984	16.4561	16.6954
	(0.1285)	(0.0891)	(0.1817)	(0.1573)
High $b'/(\lambda_K K' + \lambda_N N)$				
1998	16.1948	16.3672	16.8241	16.8111
	(0.1291)	(0.1034)	(0.1676)	(0.1243)

Notes. Each entry refers to the mean $\ln K_m$ in the given bin. The variable "$Basel1$" represents the difference between the bank's Basel I capital ratio and the required ratio under the Basel I regulation. The columns labeled 'Low TFP' reports results for firms with TFP below the median in the pooled sample for 1997–1998. The rows labeled 'Low b/N' report results for firms with the debt to land ratio below the median over the 1997–1998 period. The rows labeled 'High b/N' report results for firms with the debt to land ratio above the median. Standard errors are in parentheses. (Sources: DBJ Corporate Finance Data, Nikkei NEEDS)

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