How Much do Bank Shocks Affect Investment? Evidence from Matched Bank-Firm Loan Data

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How Much do Bank Shocks Affect Investment?

- Since the principal reason firms borrow is to finance capital expenditures, this is the critical question for understanding the link between financial and real sectors

- Main problem has been endogeneity issues surrounding separating firm and bank shocks
  - Studies have had to rely on proxy variables correlated with bank shocks in extraordinary situations, e.g. Khwaja and Mian (2008)

Our Approach

- We overcome endogeneity issues by developing a new methodology using matched bank-firm data to identify bank and firm shocks
  - We estimate the effect of bank shocks on investment in all time periods
  - Develop a theoretically sound way to aggregate these shocks and explain aggregate fluctuations
  - Show that bank shocks matter a lot for firm and aggregate investment

Methodological Contribution

- Develop a new methodology that enables us to provide the first decomposition of lending into common shocks, industry shocks, firm-borrowing shocks and bank-supply shocks
  - Bank-supply shocks measure movements of the loan supply of financial institutions that cannot be explained by common credit shocks or movements in credit demand
  - Firm-borrowing shocks measure borrower credit movements that cannot be explained by the lending behavior of their financial institutions
  - Build on Gabaix (2011) to develop a theoretically sound aggregation method that enables us to aggregate these idiosyncratic firm and bank shocks into "granular shocks" that matter for national accounts

Results

- Loan-dependent firms have investment rates that are very sensitive to bank-supply shocks from banks that supply them with credit
- Granular bank shocks account for 40 percent of the fluctuations in aggregate lending and investment

Literature Survey I: Studies Based on Types of Firms or Industries

- Studies of cash-flow sensitivity of constrained firms
  - Fazzari, Hubbard, and Petersen (1988), Hoshi, Kashyap, and Scharfstein (1991), and Gan (2007)
  - Our methodology is different because we are focused on whether investment rates are determined by bank-supply shocks
- Studies examining financial sensitivities of classes of firms:
  - Gertler and Gilchrist (1994), Kashyap, Lamont, and Stein (1994), Dell'Ariccia, Detragiache, and Rajan (2008), Kamlemli-Ozcan et al (2010), and Chava and Purnanandam (2011) do not link industries or firm fluctuations to the affected banks.
  - Braun and Larrain (2005) argue it is the sectors that are more externally finance dependent that are more cyclical and this cyclicality may be particularly manifest during banking crises.

Literature Survey II: Matched Bank-Firm Data Studies

- Studies using bank-level or matched bank-firm data provide evidence that deteriorations in bank health or increases in the cost of raising capital cause banks to contract lending, raise rates, and/or have impacts on foreign markets
  - Peek and Rosengren (1997; 2000), Klein, Peek, and Rosengren (2002), Khwaja and Mian (2008), Paravisini (2008), Amiti and Weinstein (2011), Santos (2012), Chodorow-Reich (2013), Ongena, Peydro, and van Horen (2013)
  - None of these papers address whether credit shocks affect the overall investment rates of borrowers from these institutions.

Literature Survey III: Heterogeneous Effects

- Studies showing impacts of bank shocks may not be general
  - Kashyap, Stein, and Wilcox (1993), Kroszner, Laeven, and Klingebiel (2007), Khwaja and Mian (2008), and Adrian, Colla, and Shin (2012) show that some types firms are able to substitute other forms of credit supply in the presence of loan supply shocks.
- Ashcraft (2006) argues that “these effects are likely to be very small and unworthy of concern” because “while small firms might view bank loans as special, they are not special enough for the lending channel to be an important part of how monetary policy works.”

Literature Survey IV: Granular Bank Shocks

- Studies showing relationship between granular bank shocks and cross-country GDP growth
  - Buch and Neugebauer (2011), Bremus, Buch, Russ, and Schnitzer (2013)
  - These papers don't separate firm-borrowing shocks from bank supply shocks.

Econometric Strategy

Estimating Firm and Bank Shocks

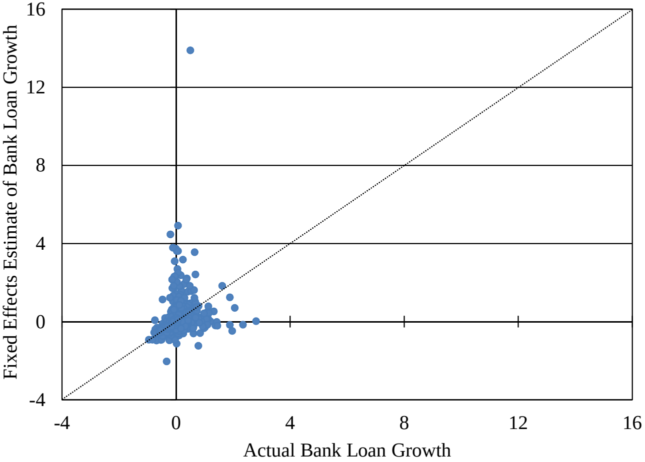
- We can decompose the growth in lending from institution b to firm f as

$$\frac{L_{fbt} - L_{fbt-1}}{L_{fbt-1}} = \alpha_{ft} + \beta_{bt} + \varepsilon_{fbt} \tag{1}$$

  - α_{ft} is a firm-specific shock to borrowing
  - β_{bt} is a bank-specific shock to lending
  - ε_{fbt} is an error term

- In principle, α_{ft} and β_{bt} could be identified using fixed effects, but estimation is difficult because matched data is rare, and fixed effects estimation is inefficient because it ignores adding up constraints

Why not OLS?



Fixed-effects estimates do a poor job of matching changes in a bank's total loans. $R^2 = 0.08$

The Standard Solution

- Prior work found a partial solution
  - Find a proxy variable, z_{bt}, which is correlated with β_{bt} but not with α_{ft} or ε_{fbt}
  - Estimate $\Delta \ln L_{fbt} = \gamma z_{bt} + \alpha_{ft} + \varepsilon_{fbt}$, where $\gamma = cov(z_{bt}, \beta_{bt}) / var(z_{bt})$
  - Conclude bank shocks matter if $\gamma \neq 0$
  - Problem is that it's hard to find these proxy variables and no identification of β_{bt}.

Identification Strategy

- Our approach is to use fixed effects *and* exploit adding up constraints to improve efficiency
  - In particular, a firm cannot borrow more without at least one bank lending more and a bank cannot lend more without at least one firm borrowing more.
  - This implies that there must be general equilibrium linkages between the α_{ft}'s and the β_{bt}'s.

Adding-Up Constraints

- We begin by aggregating individual loan growth into aggregate firm or bank borrowing:

$$D_{ft}^{F} \equiv \sum_{b} \left(\frac{L_{fbt} - L_{fbt-1}}{L_{fbt-1}} \right) \theta_{fb,t-1} \tag{2}$$

$$D_{bt}^{B} \equiv \sum_{f} \left(\frac{L_{fbt} - L_{fbt-1}}{L_{fbt-1}} \right) \phi_{fb,t-1} \tag{3}$$

where

$$\phi_{fb,t-1} \equiv \frac{L_{fb,t-1}}{\sum_{f} L_{fb,t-1}}, \ \theta_{fb,t-1} \equiv \frac{L_{fbt-1}}{\sum_{b} L_{fbt-1}}$$

Decomposition of Aggregate Bank Lending

- If we substitute equation $\frac{L_{fbt}-L_{fbt-1}}{L_{fbt-1}} = \alpha_{ft} + \beta_{bt} + \varepsilon_{fbt}$ into equation 3, we obtain

$$D_{bt}^{B} = \beta_{bt} + \sum_{f} \phi_{fb,t-1}\alpha_{ft} + \sum_{f} \phi_{fb,t-1}\varepsilon_{fbt}. \tag{4}$$

- Since $\phi_{fb,t-1}$ is predetermined, we can impose $E[\sum_f \phi_{fb,t-1}\varepsilon_{fbt}] = \sum_f \phi_{fb,t-1}E[\varepsilon_{fbt}] = 0$. Thus, we will pick α_{ft}'s and β_{bt}'s such that the following holds:

$$D_{bt}^{B} = \beta_{bt} + \sum_{f} \phi_{fb,t-1}\alpha_{ft} \tag{5}$$

Decomposition of Aggregate Firm Borrowing

- Substitution of the decomposition of changes of loan amounts gives us
$$D_{ft}^F = \alpha_{ft} + \sum_b \theta_{fb,t-1}\beta_{bt} + \sum_b \theta_{fb,t-1}\varepsilon_{fbt} \tag{6}$$
- As in the case of bank lending, we can impose $E[\sum_b \theta_{fb,t-1}\varepsilon_{fbt}] = 0$ since $\theta_{fb,t-1}$ is predetermined, and so equation 6 becomes

$$D_{ft}^F = \alpha_{ft} + \sum_b \theta_{fb,t-1}\beta_{bt} \tag{7}$$

We have $F+B$ equations and $F+B$ unknowns, so we can solve for α_{ft} and β_{bt}

Bank Decomposition

It is possible to exactly decompose each firm's aggregate borrowing and each bank's aggregate lending into four terms as in the equations below:

$$\underbrace{\boldsymbol{D_{Bt}}}_{\%\Delta\text{Bank Lending}} = \underbrace{\left(\bar{A}_t + \bar{B}_t\right)\mathbf{1_B}}_{\text{Common Shock}} + \underbrace{\boldsymbol{\Phi_{t-1}N_t}}_{\text{Ind. Shock}} + \underbrace{\boldsymbol{\Phi_{t-1}\tilde{A}_t}}_{\text{Firm Shock}} + \underbrace{\boldsymbol{\tilde{B}_t}}_{\text{Bank Shock}}, \qquad (8)$$

- **Common shocks** - changes in lending that are common to all lending pairs eg interest rate changes.
- **Industry shocks** - a bank-specific weighted average of the industry shocks affecting each of the bank's borrowers.
- **Firm-borrowing shocks** - changes in a bank's lending arising from idiosyncratic changes in borrowing demand of their clients.
- **Bank-supply shocks** - changes in bank's loan supply that are independent of anything related to firms, industries, or common shocks hitting the economy.

Moving from Micro to Macro Data

- We take a weighted average of each of the above terms to get a decomposition of aggregate lending.
- Let w_{bt}^{B} be the share of financial institution b in total lending in year t
- Define $\boldsymbol{W_{Bt}} \equiv \left[w_{1t}^{B}, \cdots, w_{Bt}^{B}\right]$. We now can write

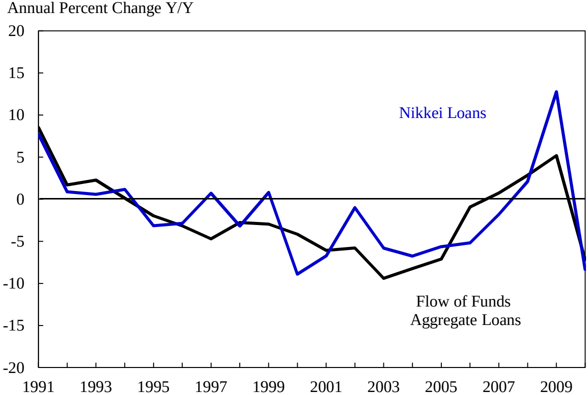
$$\underbrace{\boldsymbol{W_{B,t-1}D_{Bt}}}_{\%\Delta\text{Lending}} = \underbrace{\left(\bar{A}_t + \bar{B}_t\right)}_{\text{Common Shock}} + \underbrace{\boldsymbol{W_{B,t-1}}\Phi_t\boldsymbol{N_t}}_{\text{Gran. Ind. Shock}} + \underbrace{\boldsymbol{W_{B,t-1}}\Phi_t\boldsymbol{\tilde{A}_t}}_{\text{Gran. Firm Shock}} + \underbrace{\boldsymbol{W_{B,t-1}\tilde{B}_t}}_{\text{Gran. Bank Shock}}$$

Data

- We use lending data from Nikkei FinancialQUEST covering all loans from all private financial institutions each year to every firm listed on any Japanese stock exchange between 1990 and 2010
    - Financial institutions cover all Japanese city, trust, regional, mutual banks, insurance companies, and holding companies.
    - Clean data by dropping loans to financial and insurance firms or institutions that make fewer than 5 loans
    - Leaves us with 300K loans
- Japanese fiscal year ends in March for 80 percent of firms so restrict sample to only firms whose books close in March
    - Note: FY2010 ends in March 2010 so the bulk of the FY2010 data corresponds to CY2009

Nikkei Data vs. Flow of Funds

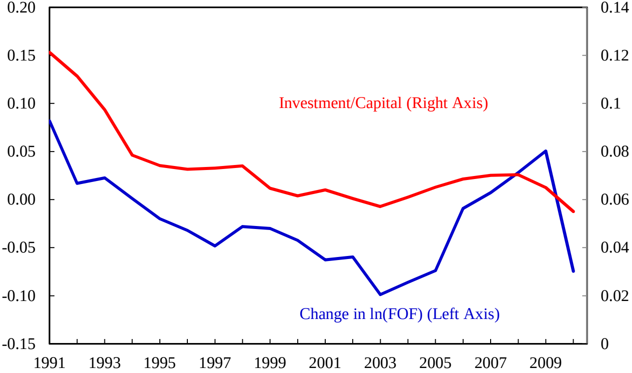
- Nikkei data accounts for 17 percent of total Japanese lending
  - Need to verify that it tracks aggregate lending growth
- Lending to listed firms tracks aggregate corporate lending data closely
  - $corr\left(\Delta L_t^{FOF}, \boldsymbol{W_{B,t-1} D_{Bt}}\right) = 0.81$



Note: Years are fiscal years which roughly correspond to the calendar year plus one.

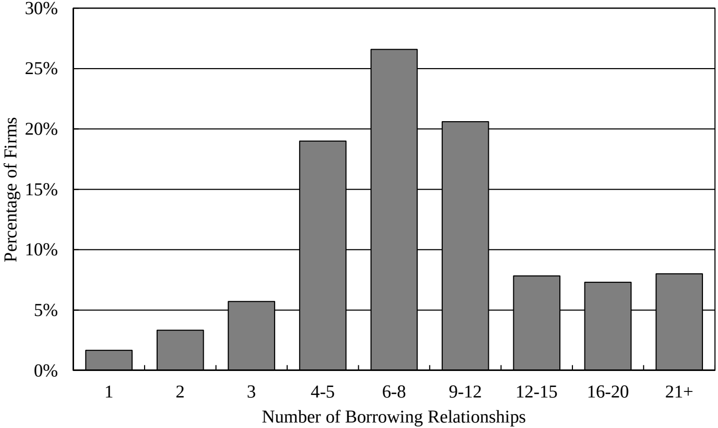
Flow of Funds and Aggregate Investment Rate

- Lending growth is highly correlated with investment rates (correlation = 0.72)



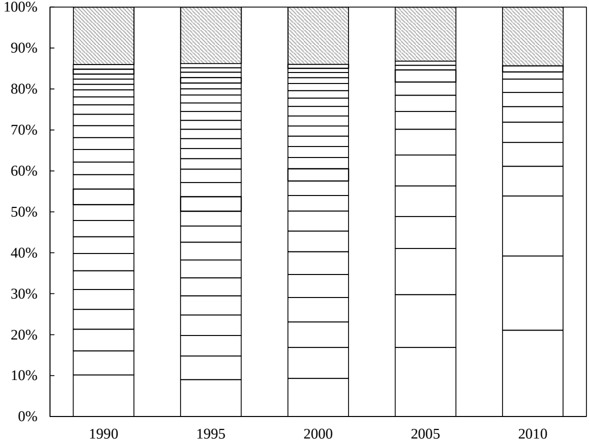
Note: Years are fiscal years which roughly correspond to the calendar year plus one.

Distribution of Number of Loans per Firm



Financial Institution Loan Shares: 1990 - 2010

Bank Concentration is High



Note: Banks with <1% share in any given year are aggregated in the shaded columns

Japanese Financial Markets are Not Concentrated by International Standards

- FRB data indicate that the largest three institutions in the US—Bank of America, JP Morgan, and Citigroup—held 49 percent of all banking assets
  - This number is remarkably close to the 54 percent number in our Japanese sample
- Buch and Neugebauer (2011) find bank Herfindahl indexes for many western European countries that are similar to those that we find for Japan.

Estimation

What are the major bank shocks?

Bank Name	Year	Reason	Contribution to Aggregate Lending
Nippon Life	2008	The Japanese Financial Services Agency found that these four insurance companies had illegally denied 40 billion yen in benefits and payments to policyholders.	-0.0328
Meiji Yasuda Life Insurance Co.	2008		-0.0316
Sumitomo Life Insurance Co.	2008		-0.0246
Dai-ichi Mutual Life Insurance Co.	2008		-0.0189
Dai-ichi Mutual Life Insurance Co.	2006	It was realized that a computer error had withheld payments from 47,000 policyholders for the last two decades.	-0.0186
Mitsubishi-UFJ	2005	In the process of a large, tumultuous merger, FSA revealed that the UFJ had a less healthy balance sheet than previously thought.	-0.0237
Mizuho Financial Group	2002	After it acknowledged a large number of non-performing loans on its balance sheet, the bank's share price dropped 63 percent. Later that year, the banks ATM system collapsed.	-0.0181
Mizuho Financial Group	2003	The bank posted "the biggest loss in Japanese corporate history".	-0.0224
Mizuho Financial Group	2005	A trader, intending to sell one share at 610,000 yen, mistyped and sold 610,000 shares for 1 yen.	-0.0132
Industrial Bank of Japan	1999	After all other long term credit banks failed, this bank was given a large capital injection.	0.0128

Validation of Bank Shocks

- Our bank shocks are correlated with proxy variables, i.e., estimating $\gamma = cov(z_{bt}, \beta_{bt}) / var(z_{bt})$

Dependent Variable: Bank Shock$_{b,t}$	(1)	(2)	(3)
Risk-Based Capital Ratio$_{b,t}$	0.015***		
	(0.004)		
Capital Injection$_{b,t}$		0.085***	
		(0.019)	
Δ ln(Market-to-Book Value$_{b,t-1}$)			0.075**
			(0.032)
Year Fixed Effects	Yes	Yes	Yes
Observations	657	405	843
R^2	0.037	0.030	0.012

Bank Impact on Firm-Level Investment Rates (1)

Dependent Variable: $\text{Investment}_{f,t}/\text{Capital}_{f,t-1}$	(1)	(2)	(3)	(4)	(5)
$\text{Cash Flow}_{f,t}/\text{Capital}_{f,t-1}$	0.048***	0.047***	0.047***	0.047***	0.048***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$\text{Market-to-Book Value}_{f,t-1}$	0.011***	0.011***	0.011***	0.011***	0.012***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$\text{Bank Shock}_{f,t}$			-0.151***	-0.149***	-0.110**
			(0.044)	(0.048)	(0.044)
$(\text{Bank Shock}_{f,t})$*(Mean Loan-to-Asset Ratio_f)			0.732***	0.730***	0.809***
			(0.192)	(0.192)	(0.190)
$(\text{Bank Shock}_{f,t})$*(Mean Bond-to-Asset Ratio_f)				-0.040	
				(0.420)	
$\text{Firm Shock}_{f,t}$					0.013**
					(0.006)
$(\text{Firm Shock}_{f,t})$*(Mean Loan-to-Asset Ratio_f)					0.245***
					(0.038)
$\text{Industry Shock}_{f,t}$		0.070***	0.069***	0.069***	0.067***
		(0.017)	(0.018)	(0.018)	(0.018)
R^2	0.307	0.307	0.308	0.308	0.323

Note: All regressions include firm and year fixed effects. The number of observations is 21,701.

Note: $BankShock_{ft} = \sum_b \theta_{fbt}\beta_{bt}$

Bank Impact on Firm-Level Investment Rates (2)

Dependent Variable: $Investment_{f,t}/Capital_{f,t-1}$	(1) Lagged Firm Shock	(2) Only Bank Shocks	(3) Crisis Years Excluded	(4) 1991-2000	(5) 2001-2010	(6) Healthy / Unhealthy Firms
$Cash Flow_{f,t}/Capital_{f,t-1}$	0.045***		0.044***	0.163***	0.043***	0.047***
	(0.007)		(0.007)	(0.016)	(0.008)	(0.006)
Market-to-Book $Value_{f,t-1}$	0.013***		0.013***	0.009***	0.014***	0.012***
	(0.002)		(0.002)	(0.003)	(0.003)	(0.002)
Bank $Shock_{f,t}$	-0.112**	-0.148***	-0.114**	-0.130*	-0.054	-0.099**
	(0.046)	(0.045)	(0.051)	(0.075)	(0.062)	(0.040)
(Bank $Shock_{f,t}$)*	0.760***	0.692***	0.902***	1.090***	0.585**	0.629***
(Mean Loan-to-Asset $Ratio_f$)	(0.203)	(0.192)	(0.209)	(0.297)	(0.264)	(0.170)
Firm $Shock_{f,t}$	0.015**		0.019***	0.005	0.022***	0.014**
	(0.006)		(0.006)	(0.008)	(0.007)	(0.005)
Firm $Shock_{f,t-1}$	0.008***					
	(0.003)					
(Firm $Shock_{f,t}$)*	0.246***		0.192***	0.301***	0.185***	0.240***
(Mean Loan-to-Asset $Ratio_f$)	(0.041)		(0.042)	(0.065)	(0.044)	(0.038)
Industry $Shock_{f,t}$	0.075***	0.082***	0.088***	0.094***	0.049**	0.063***
	(0.021)	(0.017)	(0.021)	(0.027)	(0.022)	(0.017)
Observations	18,656	21,701	17,897	9,595	12,106	21,684
R^2	0.307	0.291	0.320	0.389	0.377	0.321

Note: All regressions include firm and year fixed effects.

Decomposing Aggregate Lending

- Regression of aggregate lending on our decomposition.

$$\Delta L_t^{FOF} = \boldsymbol{W_{B,t-1}D_{Bt}} + \varepsilon_t$$

$$\Delta L_t^{FOF} = \delta + \gamma_1 \left(\bar{A}_t + \bar{B}_t\right) + \gamma_2 \boldsymbol{W_{B,t-1}}\Phi_{\boldsymbol{t}}\boldsymbol{N_t} + \gamma_3 \boldsymbol{W_{B,t-1}}\Phi_{\boldsymbol{t}}\boldsymbol{\tilde{A}_t} + \gamma_4 \boldsymbol{W_{B,t-1}\tilde{B}_t} + \varepsilon_t$$

- γ's should equal one if we had all of the data
  - But don't have all data, so we can test how well the firm data matches the aggregate data and the relative importance of each shock for explaining aggregate lending

Aggregate Loan and Investment Decomposition

Dependent Variable:	Percentage Change in Flow of Funds$_t$			Investment$_t$ /Capital$_{t-1}$		
	(1)	(2)	(3)	(4)	(5)	(6)
Common Shock$_t$	0.492*	1.212***	1.196***	0.206**	0.475***	1.274***
	(0.261)	(0.182)	(0.180)	(0.094)	(0.113)	(0.303)
Industry Shock$_t$	0.513	1.391***	0.595***	-0.117	0.211	0.246
	(0.329)	(0.275)	(0.118)	(0.183)	(0.192)	(0.223)
Firm Shock$_t$	0.215	0.318**	0.257**	-0.037	0.001	0.003
	(0.145)	(0.144)	(0.117)	(0.079)	(0.060)	(0.132)
Bank Shock$_t$		1.170***	1.042***		0.437***	1.057***
		(0.232)	(0.207)		(0.124)	(0.300)
Constant	-0.018*	-0.003	0.000	0.076***	0.081***	0.000
	(0.009)	(0.006)	(0.118)	(0.004)	(0.004)	(0.144)
Standardized Variables	No	No	Yes	No	No	Yes
Observations	20	20	20	20	20	20
R^2	0.420	0.782	0.782	0.303	0.675	0.675

Much of aggregate loan growth and investment is driven by granular bank shocks

Conclusion

- Our paper provides a methodology for identifying bank-supply and firm-borrowing shocks
- We find
  - Firm investment rates are very sensitive to lender shocks if they borrow a lot from banks
  - Bank shocks account for 40 percent of aggregate lending movement
  - Bank shocks account for 40 percent of aggregate investment rate movements

Appendix

Explanation of Terms

- Firm credit shocks, α_{ft}, are firm-specific changes in lending that are orthogonal to what is happening at the lending institution
    - For example, firm-level productivity shocks, changes in other factor costs, changes in investment demand, firm-level credit constraints etc. would be in α_{ft}
- Lender supply shocks, β_{bt}, capture all factors that cause loan supply of an institution to change *irrespective* of the credit conditions of its borrowers, e.g. capital adequacy problems, capital injections, bank productivity, etc.
    - By construction, these shocks are orthogonal to borrower credit shocks.

Matrix Notation

Letting

$$\boldsymbol{A_t} \equiv \begin{pmatrix} \alpha_{1t} \\ \vdots \\ \alpha_{Ft} \end{pmatrix}, \boldsymbol{B_t} \equiv \begin{pmatrix} \beta_{1t} \\ \vdots \\ \beta_{Bt} \end{pmatrix}, \boldsymbol{D_{Ft}} \equiv \begin{pmatrix} D^F_{1t} \\ \vdots \\ D^F_{Ft} \end{pmatrix}, \boldsymbol{D_{Bt}} \equiv \begin{pmatrix} D^B_{1t} \\ \vdots \\ D^B_{Bt} \end{pmatrix} \tag{9}$$

$$\Theta_{\boldsymbol{t}} \equiv \begin{pmatrix} \theta_{11t} & \dots & \theta_{1Bt} \\ \vdots & \ddots & \vdots \\ \theta_{F1t} & \dots & \theta_{FBt} \end{pmatrix}, \Phi_{\boldsymbol{t}} \equiv \begin{pmatrix} \phi_{11t} & \dots & \phi_{F1t} \\ \vdots & \ddots & \vdots \\ \phi_{1Bt} & \dots & \phi_{FBt} \end{pmatrix} \tag{10}$$

we can rewrite equation 6 as

$$\boldsymbol{A_t} = \boldsymbol{D_{Ft}} - \Theta_{\boldsymbol{t-1}} \boldsymbol{B_t} \tag{11}$$

and equation 5 as

$$\boldsymbol{B_t} = \boldsymbol{D_{Bt}} - \Phi_{\boldsymbol{t-1}} \boldsymbol{A_t} \tag{12}$$

Normalization

- If we impose $\alpha_{1t} = 0$ (equivalently, $k_t = \alpha_{1t}$), we can write a normalized system with $F + B - 2$ equations and unknowns:

$$\hat{\boldsymbol{A}}_{\boldsymbol{t}} = \hat{\boldsymbol{D}}_{\boldsymbol{Ft}} - \hat{\Theta}_{\boldsymbol{t-1}} \hat{\boldsymbol{B}}_{\boldsymbol{t}} \tag{13}$$

$$\hat{\boldsymbol{B}}_{\boldsymbol{t}} = \hat{\boldsymbol{D}}_{\boldsymbol{Bt}} - \hat{\Phi}_{\boldsymbol{t-1}} \hat{\boldsymbol{A}}_{\boldsymbol{t}} \tag{14}$$

- Where

$$\hat{\boldsymbol{A}}_{\boldsymbol{t}} \equiv \begin{pmatrix} \alpha_{2t} - \alpha_{1t} \\ \vdots \\ \alpha_{Ft} - \alpha_{1t} \end{pmatrix}, \hat{\boldsymbol{B}}_{\boldsymbol{t}} \equiv \begin{pmatrix} \beta_{2t} - \beta_{1t} \\ \vdots \\ \beta_{Bt} - \beta_{1t} \end{pmatrix} \tag{15}$$

$$\hat{\boldsymbol{D}}_{\boldsymbol{Ft}} \equiv \begin{pmatrix} D^F_{2t} - D^F_{1t} \\ \vdots \\ D^F_{Ft} - D^F_{1t} \end{pmatrix}, \hat{\boldsymbol{D}}_{\boldsymbol{Bt}} \equiv \begin{pmatrix} D^B_{2t} - D^B_{1t} \\ \vdots \\ D^B_{Bt} - D^B_{1t} \end{pmatrix} \tag{16}$$

$$\hat{\Theta}_{\boldsymbol{t}} \equiv \begin{pmatrix} \theta_{22t} - \theta_{12t} & \dots & \theta_{2Bt} - \theta_{1Bt} \\ \vdots & \ddots & \vdots \\ \theta_{F2t} - \theta_{12t} & \dots & \theta_{FBt} - \theta_{1Bt} \end{pmatrix}, \hat{\Phi} \equiv \begin{pmatrix} \phi_{22t} - \phi_{21t} & \dots & \phi_{F2t} - \phi_{F1t} \\ \vdots & \ddots & \vdots \\ \phi_{2Bt} - \phi_{21t} & \dots & \phi_{FBt} - \phi_{F1t} \end{pmatrix} \tag{17}$$

Normalization, continued

- We can solve the system of equations as:

$$\hat{\boldsymbol{B}}_{\boldsymbol{t}} = \hat{\boldsymbol{D}}_{\boldsymbol{Bt}} - \hat{\Phi}_{\boldsymbol{t-1}}[\hat{\boldsymbol{D}}_{\boldsymbol{Ft}} - \hat{\Theta}_{\boldsymbol{t-1}}\hat{\boldsymbol{B}}_{\boldsymbol{t}}] \tag{18}$$

$$(\boldsymbol{I}_{\boldsymbol{B-1}} - \hat{\Phi}_{\boldsymbol{t-1}}\hat{\Theta}_{\boldsymbol{t-1}})\hat{\boldsymbol{B}}_{\boldsymbol{t}} = \hat{\boldsymbol{D}}_{\boldsymbol{Bt}} - \hat{\Phi}_{\boldsymbol{t-1}}\hat{\boldsymbol{D}}_{\boldsymbol{Ft}} \tag{19}$$

- Using the adding up constraint and taking $\alpha_{1t} = 0$, we can compute β_{1t} through two equivalent methods:

$$\beta_{1t} = D^F_{1t} - \sum_{b \neq 1} \theta_{1b,t-1}(\beta_{bt} - \beta_{1t}) \tag{20}$$

$$\beta_{1t} = D^B_{1t} - \sum_{f \neq 1} \phi_{f1,t-1}\alpha_{ft} \tag{21}$$

- Thus we have a full set of bank and firm shocks.

Unique Firm Decomposition

- In order to separate macro shocks from the idiosyncratic firm shocks, we define the macro firm shock as the median firm shock, i.e. $\bar{A}_t = \text{median}_f\left(\alpha_{ft}\right)$ and the idiosyncratic firm loan demand shock as $\dot{\boldsymbol{A}}_{\boldsymbol{t}} \equiv \boldsymbol{A}_{\boldsymbol{t}} - \bar{A}_t \mathbf{1}_{\boldsymbol{F}}$.
- Analagously, we define the macro bank shock as $\bar{B}_t = \text{median}_b(\beta_{bt})$ and the idiosyncratic bank loan supply shock as $\dot{\boldsymbol{B}}_{\boldsymbol{t}} \equiv \boldsymbol{B}_{\boldsymbol{t}} - \bar{B}_t \mathbf{1}_{\boldsymbol{B}}$.
- Therefore, for our solution we can rewrite equation 11 as

$$
\begin{aligned}
\boldsymbol{D}_{\boldsymbol{Ft}} &= \boldsymbol{A}_{\boldsymbol{t}} + \Theta_{\boldsymbol{t-1}} \boldsymbol{B}_{\boldsymbol{t}} \\
&= \dot{\boldsymbol{A}}_{\boldsymbol{t}} + \bar{A}_t \mathbf{1}_{\boldsymbol{F}} + \Theta_{\boldsymbol{t-1}} \dot{\boldsymbol{B}}_{\boldsymbol{t}} + \bar{B}_t \Theta_{\boldsymbol{t-1}} \mathbf{1}_{\boldsymbol{B}} \\
&= \dot{\boldsymbol{A}}_{\boldsymbol{t}} + \Theta_{\boldsymbol{t-1}} \dot{\boldsymbol{B}}_{\boldsymbol{t}} + \left(\bar{A}_t + \bar{B}_t\right) \mathbf{1}_{\boldsymbol{F}}
\end{aligned} \tag{22}
$$

- A critical feature of equation 22 is that our choice of numeraire, k_t, doesn't matter

Bank Decomposition

- Analogously, we can decompose the changes in bank lending by rewriting equation 12 as

$$\begin{aligned} \boldsymbol{D_{Bt}} =& \dot{\boldsymbol{B}}_{\boldsymbol{t}} + \Phi_{\boldsymbol{t-1}} \dot{\boldsymbol{A}}_{\boldsymbol{t}} + \left(\bar{B}_t \mathbf{1}_{\boldsymbol{B}} + \Phi_{\boldsymbol{t-1}} \bar{A}_t \mathbf{1}_{\boldsymbol{F}}\right) \\ =& \dot{\boldsymbol{B}}_{\boldsymbol{t}} + \Phi_{\boldsymbol{t-1}} \dot{\boldsymbol{A}}_{\boldsymbol{t}} + (\bar{A}_t + \bar{B}_t) \mathbf{1}_{\boldsymbol{B}} \end{aligned} \tag{23}$$

Bank Decomposition Intuition

$$\boldsymbol{D_{Bt}} = \boldsymbol{\tilde{B}_t} + \Phi_{\boldsymbol{t-1}}\boldsymbol{\tilde{A}_t} + \Phi_{\boldsymbol{t-1}}\boldsymbol{N_{Ft}} + \left(\bar{A}_t + \bar{B}_t\right)\mathbf{1}_{\boldsymbol{B}}$$

- Each financial institution's lending is decomposed into four elements
  - The first term is the "idiosyncratic bank shock" because it measures changes in bank loan supply that are independent of anything related to firms, industries or common shocks.
  - The second term is the "idiosyncratic firm shock" because it captures changes in a bank's lending arising from idiosyncratic credit shocks of its borrowers
  - The third term is the "industry shock", capturing a bank-specific weighted average of the industry shocks affecteing each of the bank's borrowers
  - The last term is the common shock, capturing loan growth of the median firm and median bank.

Aggregation Intuition

$$\boldsymbol{W_{B,t-1}D_{Bt}} = \boldsymbol{W_{B,t-1}\tilde{B}_t} + \boldsymbol{W_{B,t-1}}\Phi_t\boldsymbol{\tilde{A}_t} + \boldsymbol{W_{B,t-1}}\Phi_{\boldsymbol{t-1}}\boldsymbol{N_t} + \left(\bar{A}_t + \bar{B}_t\right)$$

- The first term is the impact of granular loan supply shocks on aggregate lending
- The second term is the impact of granular firm demand shocks on aggregate lending
- The third term is the impact of granular industry shocks on aggregate lending
- The last term is the impact of common shocks

Industry Shocks

- We can examine industry shocks by defining an idiosyncratic firm shock $\tilde{\boldsymbol{A}}_{\boldsymbol{t}} = \dot{\boldsymbol{A}}_{\boldsymbol{t}} - \text{median}_{f \in n}(\dot{\boldsymbol{A}}_{\boldsymbol{t}})$, where we are taking the median of entries in $\dot{\boldsymbol{A}}_{\boldsymbol{t}}$ among firms f in industry n. The idiosyncratic bank shock $\tilde{\boldsymbol{B}}_{\boldsymbol{t}}$ is defined similarly. Then, denoting the vector of these industry level medians as $\boldsymbol{N}_{\boldsymbol{Ft}}$,we can rewrite equations 22 and 23 as

$$\boldsymbol{D}_{\boldsymbol{Ft}} = \tilde{\boldsymbol{A}}_{\boldsymbol{t}} + \boldsymbol{N}_{\boldsymbol{Ft}} + \Theta_{\boldsymbol{t-1}} \tilde{\boldsymbol{B}}_{\boldsymbol{t}} + \left(\bar{A}_t + \bar{B}_t\right) \mathbf{1}_{\boldsymbol{F}} \tag{24}$$

$$\boldsymbol{D}_{\boldsymbol{Bt}} = \tilde{\boldsymbol{B}}_{\boldsymbol{t}} + \Phi_{\boldsymbol{t}} \tilde{\boldsymbol{A}}_{\boldsymbol{t}} + \Phi_{\boldsymbol{t-1}} \boldsymbol{N}_{\boldsymbol{Ft}} + \left(\bar{A}_t + \bar{B}_t\right) \mathbf{1}_{\boldsymbol{B}} \tag{25}$$

Firm Decomposition with Industry Shock

$$\boldsymbol{D_{Ft}} = \tilde{\boldsymbol{A}}_{\boldsymbol{t}} + \boldsymbol{N_{Ft}} + \Theta_{\boldsymbol{t-1}} \tilde{\boldsymbol{B}}_{\boldsymbol{t}} + \left(\bar{A}_t + \bar{B}_t\right) \mathbf{1}_{\boldsymbol{F}}$$

- This equation decomposes firm loan growth into four elements.
  - The first term is an idiosyncratic loan demand shock that captures shocks to loan demand not common to all firms
  - The second is an industry level shock common to all firms in each industry.
  - The third is a firm-level idiosyncratic financial institution shock that will differ across firms if there is heterogeneity in financial shocks and differences in firm dependence on particular financial institutions. This third term captures how financial shocks are transmitted to each firm.
  - The last term captures how common (or macro) shocks affect the demand of loans by a particular firm

Aggregating Total Lending

Let w^B_{bt} be the share of financial institution b in total lending in year t , and let w^F_{ft} be the share of firm f in total borrowing in year t . Define $\boldsymbol{W_{Bt}} \equiv \left[w^B_{1t}, \cdots, w^B_{Bt}\right]$ and $\boldsymbol{W_{Ft}} \equiv \left[w^F_{1t}, \cdots, w^F_{Ft}\right]$. We now use equation 24 to write

$$\boldsymbol{W_{F,t-1}} \boldsymbol{D_{Ft}} = \boldsymbol{W_{F,t-1}} \boldsymbol{\tilde{A}_t} + \boldsymbol{W_{F,t-1}} \boldsymbol{N_t} + \boldsymbol{W_{F,t-1}} \Theta_{\boldsymbol{t-1}} \boldsymbol{\tilde{B}_t} + \left(\bar{A}_t + \bar{B}_t\right). \quad (26)$$

Similarly, one can use equation 25 to obtain

$$\boldsymbol{W_{B,t-1}} \boldsymbol{D_{Bt}} = \boldsymbol{W_{B,t-1}} \boldsymbol{\tilde{B}_t} + \boldsymbol{W_{B,t-1}} \Phi_{\boldsymbol{t-1}} \boldsymbol{\tilde{A}_t} + \boldsymbol{W_{B,t-1}} \Phi_{\boldsymbol{t-1}} \boldsymbol{N_t} + \left(\bar{A}_t + \bar{B}_t\right). \quad (27)$$

Summary Statistics

By Year	**Mean**	**Median**	**SD**	**Minimum**	**Maximum**
Percent Change in Flow of Funds$_t$	-0.023	-0.029	0.048	-0.099	0.082
Investment$_t$ /Capital$_{t-1}$	0.073	0.069	0.017	0.055	0.121
Common Shock$_t$	-0.010	-0.010	0.047	-0.142	0.066
By Bank					
Bank Shock$_{b,t}$	0.010	0.000	0.182	-0.548	0.934
Capital Injection$_{b,t}$	0.096	0.000	0.295	0.000	1.000
Risk-Based Capital Ratio$_{b,t}$	8.796	9.120	1.766	2.820	13.610
Δ ln(Market-to-Book Value$_{b,t-1}$)	-0.099	-0.107	0.225	-0.684	0.572
By Firm					
Investment$_{f,t}$ /Capital$_{f,t-1}$	0.118	0.080	0.167	-0.398	1.745
Cash-Flow$_{f,t}$ /Capital$_{f,t-1}$	0.335	0.209	0.719	-1.569	15.410
Market-to-Book Value$_{f,t}$	1.696	1.295	1.377	0.234	10.367
Bank Shock$_{f,t}$	-0.011	-0.012	0.051	-0.173	0.151
Firm Shock$_{f,t}$	0.059	0.000	0.393	-0.760	3.252
Industry Shock$_{f,t}$	0.003	0.002	0.077	-0.658	2.492
Mean Loan to Asset Ratio$_f$	0.196	0.174	0.123	0.001	0.748
Mean Bond to Asset Ratio$_t$	0.048	0.029	0.057	0.000	0.359