Micro Data for Macro Models

Topic 3: Financial Frictions and Investment

Thomas Winberry

January 28th, 2019
Plan for Topic 3

• Two responses to failure of neoclassical investment model:
  1. Adjustment costs feature nonconvexities
  2. Financial frictions influence investment behavior

• Topic 2 discussed how we think about micro- and macro-level implications of nonconvexities
Plan for Topic 3

- Two responses to failure of neoclassical investment model:
  1. Adjustment costs feature nonconvexities
  2. Financial frictions influence investment behavior

- Topic 2 discussed how we think about micro- and macro-level implications of nonconvexities

- Topic 3 studies financial frictions
  1. Overview of mechanisms and empirical literature
  2. Evidence on heterogeneous responses to macro shocks
  3. Aggregate implications for:
     - Monetary shocks (Ottonello and Winberry 2018)
     - Financial shocks (Khan and Thomas 2013)
Plan for Topic 3

• Two responses to failure of neoclassical investment model:
  1. Adjustment costs feature nonconvexities
  2. Financial frictions influence investment behavior

• Topic 2 discussed how we think about micro- and macro-level implications of nonconvexities

• Topic 3 studies financial frictions
  1. **Overview of mechanisms and empirical literature**
  2. Evidence on heterogeneous responses to macro shocks
  3. Aggregate implications for:
     • Monetary shocks (Ottonello and Winberry 2017)
     • Financial shocks (Khan and Thomas 2013)
Simple Frictionless Model

**In period** $t = 0$: *continuum of firms* $i \in [0, 1]$

- Initial endowment $x_{i0}$ units of numeraire good
- Invest in capital $k_{i1}$ to produce in $t = 1$
  - Equity finance: pay out of current equity
  - Debt finance: borrow $\frac{1}{R} \times b_{i1}$ from lenders
Simple Frictionless Model

In period $t = 0$: **continuum of firms** $i \in [0, 1]$

- Initial endowment $x_{i0}$ units of numeraire good
- Invest in capital $k_{i1}$ to produce in $t = 1$
  - Equity finance: pay out of current equity
  - Debt finance: borrow $\frac{1}{R} \times b_{i1}$ from lenders

In period $t = 1$, **produce and choose whether to repay debt**

- Produce using capital: $z_{i1} \times k_{i1}^\alpha$
  - Productivity $z_{i1}$ stochastic w/ support $[\underline{z}, \bar{z}]$ and CDF $G(z)$
  - Capital fully depreciates after producing
- Repay debt $b_{i1}$
Firm’s Problem

Profit maximization problem:

\[
\max_{k_{i1}, b_{i1}} d_{i0} + \frac{1}{R} \mathbb{E} [d_{i1}]
\]

\[
d_{i0} = x_{i0} + \frac{1}{R} b_{i1} - k_{i1}
\]

\[
d_{i1} = z_{i1} k_{i1}^{\alpha} - b_{i1}
\]
Firm’s Problem

Profit maximization problem:

\[
\max_{k_{i1}, b_{i1}} d_{i0} + \frac{1}{R} \mathbb{E}[d_{i1}]
\]

\[
d_{i0} = x_{i0} + \frac{1}{R} b_{i1} - k_{i1}
\]

\[
d_{i1} = z_{i1}k_{i1}^{\alpha} - b_{i1}
\]

Solution illustrates Modigliani-Miller theorem:

\[
k_{i1} = \left( \frac{\alpha \mathbb{E}[Z_{i1}]}{R} \right)^{\frac{1}{1-\alpha}}
\]

any finite \(b_{i1}\) and \(d_{i0}\) optimal
Profit maximization problem:

$$\max_{k_{i_1}, b_{i_1}} d_{i_0} + \frac{1}{R} \mathbb{E} [d_{i_1}]$$

$$d_{i_0} = x_{i_0} + \frac{1}{R} b_{i_1} - k_{i_1}$$

$$d_{i_1} = z_{i_1} k_{i_1}^\alpha - b_{i_1}$$

Solution illustrates Modigliani-Miller theorem:

$$k_{i_1} = \left( \frac{\alpha \mathbb{E}[z_{i_1}]}{R} \right)^{\frac{1}{1-\alpha}}$$

any finite $b_{i_1}$ and $d_{i_0}$ optimal

→ Frictionless model makes no prediction about financial variables
1. Frictions to equity finance:
   • Cannot raise new equity: \( d_{i0} \geq 0 \)
   • Costly to raise new equity: pay some cost \( \kappa \) if \( d_{i0} < 0 \)
   • Incentive to smooth dividends: \(- \frac{\Phi}{2} (d_{i0} - d^*)^2\)
1. Frictions to **equity finance**:
   - Cannot raise new equity: $d_{i0} \geq 0$
   - Costly to raise new equity: pay some cost $\kappa$ if $d_{i0} < 0$
   - Incentive to smooth dividends: $-\frac{\phi}{2} (d_{i0} - d^*)^2$

2. Frictions to **debt finance**:
   - Collateral constraint: $b_{i0} \leq \theta \times$ some measure of collateral
   - Limited commitment: firms can default in period 1 → lenders charge risk premium
Financial Frictions

1. Frictions to equity finance:
   - Cannot raise new equity: \( d_{i0} \geq 0 \)
   - Costly to raise new equity: pay some cost \( \kappa \) if \( d_{i0} < 0 \)
   - Incentive to smooth dividends: \( -\frac{\phi}{2} (d_{i0} - d^*)^2 \)

2. Frictions to debt finance:
   - Collateral constraint: \( b_{i0} \leq \theta \times \) some measure of collateral
   - Limited commitment: firms can default in period 1 \( \rightarrow \) lenders charge risk premium

Need both types of frictions for financial variables to matter for investment
Example: $d_{i0} \geq 0$ and $b_{i0} \leq z k_{i1}^\alpha$
Example: $d_{i0} \geq 0$ and $b_{i0} \leq zk_{i1}^\alpha$

Unconstrained investment: $k^* = \left(\frac{\alpha E[z_{i1}]}{R}\right)^{\frac{1}{1-\alpha}}$
Example: \( d_{i0} \geq 0 \) and \( b_{i0} \leq zk_{i1}^\alpha \)

If \( x_{i0} \geq \hat{x} = k^* - z(k^*)^\alpha \), firm is unconstrained:

\[
k_{i1} = k^*
\]

any \( b_{i1} \) and \( d_{i0} \) such that \( b_{i1} \leq z(k^*)^\alpha \) optimal
Example: $d_{i0} \geq 0$ and $b_{i0} \leq zk_{i1}^\alpha$

If $x_{i0} < \hat{x}$, firm is constrained:

$$k_{i1} = x_{i0} + \frac{1}{R}zk_{i1}^\alpha$$

$$d_{i0} = 0, \quad b_{i1} = zk_{i1}^\alpha$$
Example: $d_{i0} \geq 0$ and $b_{i0} \leq zk_{i1}^\alpha$

Slope of investment rule for constrained firms is

$$\text{slope of } k_{i1} = 1 + \frac{\alpha \frac{z}{R} k_{i1}^{\alpha - 1}}{1 - \alpha \frac{z}{R} k_{i1}^{\alpha - 1}} > 1$$
Overview of the Empirical Literature

Wave 1


\[ \frac{i_{it}}{k_{it}} = \alpha + \alpha_{\text{cost}} \text{cost}_{it} + \alpha_{\text{cash}} \frac{\text{cash}_{it}}{k_{it}} + \varepsilon_{it} \]

- Interpret $\alpha_{\text{cash}}$ as evidence of financial frictions
Overview of the Empirical Literature

Wave 1

\[
\frac{i_{it}}{k_{it}} = \alpha + \alpha_{\text{cost}} \text{cost}_{it} + \alpha_{\text{cash}} \frac{\text{cash}_{it}}{k_{it}} + \varepsilon_{it}
\]

- Interpret \(\alpha_{\text{cash}}\) as evidence of financial frictions

Wave 2
- Cash flow correlated with serially correlated productivity \(\implies\) carefully specified mapping from cash flows to financial frictions
Overview of the Empirical Literature

Wave 1

- **Investment-cash flow sensitivity regressions**: Fazarri, Hubbard, and Petersen (1988)

\[
\frac{i_{it}}{k_{it}} = \alpha + \alpha_{\text{cost}} \text{cost}_{it} + \alpha_{\text{cash}} \frac{\text{cash}_{it}}{k_{it}} + \varepsilon_{it}
\]

- Interpret \(\alpha_{\text{cash}}\) as evidence of financial frictions

Wave 2

- Cash flow correlated with serially correlated productivity \(\implies\) carefully specified mapping from cash flows to financial frictions

Wave 3

- **Credibly identified** reduced-form studies: Rauh (2006)
- Estimated **structural models**: Hennesy and Whited (2007)
Plan for Topic 3

1. Overview of mechanisms and empirical literature

2. Evidence on heterogeneous responses to macro shocks

3. Aggregate implications for:
   - Monetary shocks (Ottonello and Winberry 2017)
   - Financial shocks (Khan and Thomas 2013)
Gertler and Gilchrist (1994)

- Do financial constraints amplify aggregate response to monetary policy?
  - **Financial accelerator**: indirect effect through net worth $x$

- Test using **cross-sectional** implication: constrained firms more responsive
  - Proxy for financial constraints with size
Gertler and Gilchrist (1994)

- Do financial constraints amplify aggregate response to monetary policy?
  - **Financial accelerator**: indirect effect through net worth $x$

- Test using **cross-sectional** implication: constrained firms more responsive
  - Proxy for financial constraints with size

- **Main finding**: sales + inventory investment decline more for small firms following monetary tightening
Data

- Data derived from Quarterly Financial Reports for Manufacturing Corporations (QFR)
  - Survey of manufacturing firms, 1958 - present
  - Records real + financial information
- Collapse into 8 aggregated time series by nominal assets
  1. Not firm-level data
  2. Inflation creates drift in share of firms in each bin
- **Small firms** = bottom 30th percentile of real sales in quarter $t$
  1. Adjust weighting of asset classes
  2. Adjust for inflation
Are Small Firms More Constrained?

- Small firms more bank dependent
- Large firms have more long term debt + commercial paper
Small vs. Large Firms Over the Cycle

- CC = credit crunch
- R = Romer date for monetary tightening
Small vs. Large Firms Over the Cycle

- CC = credit crunch
- R = Romer date for monetary tightening
- Sales of small firms declines by more in most episodes
Small vs. Large Firms Over the Cycle

- Similar pattern for *inventories*, but less pronounced
Small vs. Large Firms Over the Cycle

- Less clear pattern for short-term debt
Small Firms Contract More Following Romer Dates

- Average time series following Romer dates
Small Firms Contract More Following Romer Dates

![Graphs showing cumulative quarterly growth rates for short-term debt and short-term debt to sales ratio for small, large, and all firms.](image)
Small Firms Contract More Following Romer Dates

**Short-Term Bank Loans**

- Cumulative Quarterly Growth Rates

- Small
- Large
- All

**Short-Term Bank Loans to Sales Ratio**

- Cumulative Quarterly Growth Rates

- Small
- Large
Crouzet and Mehrotra (2017)

- Gertler and Gilchrist (1994) based on aggregated QFR series

- Crouzet and Mehrotra (2017) reassess their findings using micro-data underlying QFR
  - Focus on cyclical sensitivity rather than monetary shocks

- **Main findings:**
  1. Some evidence small firms more sensitive
  2. Does not matter for explaining aggregate fluctuations
  3. Cyclical sensitivity not driven by financial variables
Data

- Data derived from IRS corporate tax returns + survey, 1977 - present
  - Rotating panel of small firms (assets $250k - $250m)
  - Universe of large firms (assets > $250m)
  - Firm time used by researchers, so a lot of work!

- Advantages:
  1. Representative sample of manufacturing firms
  2. High-quality balance sheet information
  3. Quarterly frequency

- Disadvantages:
  1. Only manufacturing firms (so far)
  2. Short panel of small firms
Firms’ Balance Sheets by Size

<table>
<thead>
<tr>
<th>Size group</th>
<th>0-90th</th>
<th>90-99th</th>
<th>99-99.5th</th>
<th>&gt;99.5th</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assets</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial assets, incl. cash</td>
<td>0.149</td>
<td>0.099</td>
<td>0.074</td>
<td>0.055</td>
</tr>
<tr>
<td>Short-term assets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receivables</td>
<td>0.284</td>
<td>0.229</td>
<td>0.165</td>
<td>0.124</td>
</tr>
<tr>
<td>Inventory</td>
<td>0.218</td>
<td>0.241</td>
<td>0.172</td>
<td>0.130</td>
</tr>
<tr>
<td>Other</td>
<td>0.040</td>
<td>0.037</td>
<td>0.042</td>
<td>0.041</td>
</tr>
<tr>
<td>Long-term assets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net property, plant and equipment</td>
<td>0.269</td>
<td>0.288</td>
<td>0.289</td>
<td>0.287</td>
</tr>
<tr>
<td>Other, incl. intangibles</td>
<td>0.050</td>
<td>0.106</td>
<td>0.259</td>
<td>0.362</td>
</tr>
<tr>
<td><strong>Liabilities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Due in 1 year or less</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bank debt</td>
<td>0.083</td>
<td>0.083</td>
<td>0.032</td>
<td>0.016</td>
</tr>
<tr>
<td>Non-bank debt</td>
<td>0.035</td>
<td>0.019</td>
<td>0.019</td>
<td>0.028</td>
</tr>
<tr>
<td>Due in more than 1 year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bank debt</td>
<td>0.107</td>
<td>0.111</td>
<td>0.110</td>
<td>0.072</td>
</tr>
<tr>
<td>Non-bank debt</td>
<td>0.123</td>
<td>0.079</td>
<td>0.141</td>
<td>0.179</td>
</tr>
<tr>
<td>Trade payables</td>
<td>0.156</td>
<td>0.123</td>
<td>0.085</td>
<td>0.071</td>
</tr>
<tr>
<td>Other, incl. capital leases</td>
<td>0.099</td>
<td>0.121</td>
<td>0.187</td>
<td>0.233</td>
</tr>
<tr>
<td><strong>Equity</strong></td>
<td>0.393</td>
<td>0.463</td>
<td>0.426</td>
<td>0.416</td>
</tr>
</tbody>
</table>

- Small firms are more bank dependent and have more short term debt.
- Small firms also have more short-term assets.
Small vs. Large Firms Over the Cycle

- Small firm sales fall more during 1981 and 2008 recession
Small vs. Large Firms Over the Cycle

- Less clear picture for inventories and capital investment
Small vs. Large Firms Over the Cycle

- Results driven by 1981 and 2008 recessions
How to Reconcile with Gertler and Gilchrist?

• Different cyclical responsiveness for monetary shocks vs. recessions
Differences Unimportant for Aggregate Dynamics

- Aggregate decomposition
  \[ G_t = g_{t}^{\text{large}} + s_{t-4} \left( g_{t}^{\text{small}} - g_{t}^{\text{large}} \right) + \text{COV}_t \]
- Counterfactual 1 = \( G_t - s_{t-4} \left( g_{t}^{\text{small}} - g_{t}^{\text{large}} \right) \)
- Counterfactual 2 = \( g_{t}^{\text{large}} \)
Why No Agg. Differences? High Concentration
Direct Test: Differences by Financial Characteristics?
Direct Test: Differences by Financial Characteristics?

Graphs showing the differences in sales, inventory, and fixed investment over quarters between companies with bond market access and those without, as well as between companies with dividends and those without.
Wrapping Up Gerter-Gilchrist and Crouzet-Mehrotra

• Do financial frictions amplify response to shocks?
  
  • Mixed evidence in cross-sectional data
    • Depends on weighting of firms
    • Depends on shock
Plan for Topic 3

1. Overview of mechanisms and empirical literature

2. Evidence on heterogeneous responses to macro shocks

3. **Aggregate implications for:**
   - Monetary shocks *(Ottonello and Winberry 2018)*
   - Financial shocks *(Khan and Thomas 2013)*
Motivation

• Want to understand the role of financial frictions in shaping the investment channel of monetary policy

• Which firms respond the most to monetary policy?
Motivation

• Want to understand the role of financial frictions in shaping the investment channel of monetary policy

• Which firms respond the most to monetary policy?

• Firms more affected by financial frictions:
  • Have steeper marginal cost of investment $\implies$ dampen
  • More sensitive to cash flows + collateral values $\implies$ amplify
    (financial accelerator across firms)

• We revisit this question with
  1. New cross-sectional evidence
  2. Heterogeneous firm New Keynesian model
Our Contributions

**Descriptive evidence on heterogeneous responses** using high-frequency shocks and quarterly Compustat

1. Firms with low leverage, good ratings, and large “distance to default” are more responsive

2. Heterogeneity primarily driven by distance to default
Our Contributions

Descriptive evidence on heterogeneous responses using high-frequency shocks and quarterly Compustat

1. Firms with low leverage, good ratings, and large “distance to default” are more responsive

2. Heterogeneity primarily driven by distance to default

**Heterogeneous firm New Keynesian model**

with financial frictions arising from default risk

1. Model **consistent with heterogeneous responses**
   • Firms with low risk have flatter marginal cost curve

2. Aggregate response **depends on distribution of default risk**
   • Driven by low-risk firms, which is time-varying
Our Contributions

Descriptive evidence on heterogeneous responses using high-frequency shocks and quarterly Compustat

1. Firms with low leverage, good ratings, and large “distance to default” are more responsive

2. Heterogeneity primarily driven by distance to default

Heterogeneous firm New Keynesian model with financial frictions arising from default risk

1. Model consistent with heterogeneous responses
   • Firms with low risk have flatter marginal cost curve

2. Aggregate response depends on distribution of default risk
   • Driven by low-risk firms, which is time-varying

⇒ Default risk dampens response to monetary policy
Related Literature

1. **Household Heterogeneity and Monetary Policy**
   Doepke and Schneider (2006); Auclert (2015); Werning (2015); Wong (2016); Gornermann, Kuester, Nakajima (2016); Kaplan, Moll, and Violante (2018)

2. **Financial Heterogeneity and Investment**
   Khan and Thomas (2013); Gilchrist, Sim and Zakrajsek (2014); Khan, Senga and Thomas (2016)

3. **Financial Frictions and Monetary Transmission**
   - Gertler, and Gilchrist (1994); Kashyap, Lamont, and Stein (1994); Kashyap and Stein (1995); Jeenas (2018)
   - Bernanke, Gertler, and Gilchrist (1999)
Descriptive Empirical Evidence
Data Sources

1. **Monetary policy shocks** $\varepsilon_t^m$: high-frequency identification
   - Compare FFR future before vs. after FOMC announcement
   - Assume nothing else affects FFR in window
   - Time aggregate to quarterly frequency
Data Sources

1. **Monetary policy shocks** $\varepsilon_t^m$: high-frequency identification
   - Compare FFR future before vs. after FOMC announcement
   - Assume nothing else affects FFR in window
   - Time aggregate to quarterly frequency

2. **Firm-level outcomes**: quarterly Compustat
   - Investment $\Delta \log k_{it+1}$: capital stock from net investment
   - Leverage $\ell_{it}$: debt divided by total assets
   - Credit rating $cr_{jt}$: S&P rating of firm’s long-term debt
   - Distance to default $dd_{jt}$: constructed following Gilchrist and Zakrasjek (2012)
1. **Monetary policy shocks** $\varepsilon_t^m$: high-frequency identification
   - Compare FFR future before vs. after FOMC announcement
     - Assume nothing else affects FFR in window
   - **Time aggregate** to quarterly frequency

2. **Firm-level outcomes**: quarterly Compustat
   - **Investment** $\Delta \log k_{it+1}$: capital stock from net investment
   - **Leverage** $\ell_{it}$: debt divided by total assets
   - **Credit rating** $\text{cr}_{jt}$: S&P rating of firm’s long-term debt
   - **Distance to default** $\text{dd}_{jt}$: constructed following Gilchrist and Zakrasjek (2012)

Merge 1990q1 - 2007q2
### Summary Statistics of Firm-Level Variables

#### (a) Marginal Distributions

<table>
<thead>
<tr>
<th>Statistic</th>
<th>$\Delta \log k_{jt+1}$</th>
<th>$l_{jt}$</th>
<th>$\mathbb{I}{cr_{jt} \geq A}$</th>
<th>$dd_{jt}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.005</td>
<td>0.267</td>
<td>0.024</td>
<td>5.744</td>
</tr>
<tr>
<td>Median</td>
<td>-0.004</td>
<td>0.204</td>
<td>0.000</td>
<td>4.704</td>
</tr>
<tr>
<td>S.D.</td>
<td>0.093</td>
<td>0.361</td>
<td>0.154</td>
<td>5.032</td>
</tr>
<tr>
<td>95th Percentile</td>
<td>0.132</td>
<td>0.725</td>
<td>0.000</td>
<td>14.952</td>
</tr>
</tbody>
</table>

#### (b) Correlation Matrix (raw variables)

<table>
<thead>
<tr>
<th></th>
<th>$l_{jt}$</th>
<th>$\mathbb{I}{cr_{jt} \geq A}$</th>
<th>$dd_{jt}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$l_{jt}$</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mathbb{I}{cr_{jt} \geq A}$</td>
<td>-0.02 (0.00)</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>$dd_{jt}$</td>
<td>-0.46 (0.00)</td>
<td>0.21 (0.00)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

#### (c) Correlation matrix (residualized)

<table>
<thead>
<tr>
<th></th>
<th>$l_{jt}$</th>
<th>$\mathbb{I}{cr_{jt} \geq A}$</th>
<th>$dd_{jt}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$l_{jt}$</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mathbb{I}{cr_{jt} \geq A}$</td>
<td>-0.02 (0.00)</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>$dd_{jt}$</td>
<td>-0.38 (0.00)</td>
<td>0.05 (0.00)</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Baseline Empirical Specification

\[ \Delta \log k_{it+1} = \beta y_{it-1} \varepsilon^m_t + \alpha_i + \alpha_{st} + \Gamma' Z_{it-1} + \varepsilon_{it} \]

- **Coefficient of interest** \( \beta \): how semi-elasticity of investment w.r.t. monetary policy depends on leverage

- Want to isolate differences due to leverage
  - \( \alpha_{st} \): compare within a sector-quarter
  - \( Z_{it-1} \): conditional on **financial position** \( y_{it-1} \), sales growth, log total assets, current assets share, fiscal quarter dummy

- Standard errors clustered two-way by firm and quarter
### Low-Risk Firms More Responsive

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>leverage × shock</td>
<td>-0.66**</td>
<td>-0.52**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.27)</td>
<td>(0.25)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mathbb{1}{c_{jt} \geq A}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.69**</td>
<td>(1.16)</td>
</tr>
<tr>
<td>dd × shock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.06**</td>
</tr>
<tr>
<td>ffr shock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Observations**: 239259, 239259, 239259, 151433
- **$R^2$**: 0.108, 0.119, 0.116, 0.137
- **Firm controls**: no, yes, yes, yes
- **Time sector FE**: yes, yes, yes, yes
- **Time clustering**: yes, yes, yes, yes

\[
\Delta \log k_{it+1} = \beta y_{it-1} e_t^m + \alpha_i + \alpha_{st} + \Gamma' Z_{it-1} + \varepsilon_{it}
\]

- Monetary expansion has positive sign ($-\varepsilon_t^m$)
- Standardize leverage and distance to default over all firms and quarters
## Low-Risk Firms More Responsive

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>leverage × shock</td>
<td>-0.66**</td>
<td>-0.52**</td>
<td></td>
<td>-0.50*</td>
<td>-0.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.27)</td>
<td>(0.25)</td>
<td></td>
<td>(0.25)</td>
<td>(0.39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1{cr_{jt} ≥ A}</td>
<td></td>
<td></td>
<td>2.69**</td>
<td></td>
<td>2.41**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.16)</td>
<td></td>
<td>(1.19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dd × shock</td>
<td></td>
<td></td>
<td>1.06**</td>
<td></td>
<td></td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.45)</td>
<td></td>
<td></td>
<td>(0.44)</td>
<td></td>
</tr>
<tr>
<td>ffr shock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observations</th>
<th>239259</th>
<th>239259</th>
<th>239259</th>
<th>151433</th>
<th>239259</th>
<th>151433</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>0.108</td>
<td>0.119</td>
<td>0.116</td>
<td>0.137</td>
<td>0.119</td>
<td>0.139</td>
</tr>
</tbody>
</table>

| Firm controls   | no    | yes   | yes   | yes    | yes   | yes    | yes   |
| Time sector FE  | yes   | yes   | yes   | yes    | yes   | yes    | yes   |
| Time clustering | yes   | yes   | yes   | yes    | yes   | yes    | yes   |

\[
\Delta \log k_{it+1} = \beta y_{it-1} \varepsilon^m_t + \alpha_i + \alpha_{st} + \Gamma' Z_{it-1} + \varepsilon_{it}
\]

- Monetary expansion has positive sign ($-\varepsilon^m_t$)
- Standardize leverage and distance to default over all firms and quarters
## Low-Risk Firms More Responsive

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>leverage × shock</td>
<td>-0.66**</td>
<td>-0.52**</td>
<td></td>
<td>-0.50*</td>
<td>-0.47</td>
<td>-0.24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.27)</td>
<td>(0.25)</td>
<td></td>
<td>(0.25)</td>
<td>(0.39)</td>
<td>(0.38)</td>
<td></td>
</tr>
<tr>
<td>(1 {c_{ijt} \geq A})</td>
<td></td>
<td></td>
<td>2.69**</td>
<td></td>
<td>2.41**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.16)</td>
<td></td>
<td>(1.19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dd × shock</td>
<td></td>
<td></td>
<td></td>
<td>1.06**</td>
<td></td>
<td>0.70</td>
<td>1.07**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.45)</td>
<td></td>
<td>(0.44)</td>
<td>(0.52)</td>
</tr>
<tr>
<td>ffr shock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.63**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.72)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>239259</th>
<th>239259</th>
<th>239259</th>
<th>151433</th>
<th>239259</th>
<th>151433</th>
<th>151433</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.108</td>
<td>0.119</td>
<td>0.116</td>
<td>0.137</td>
<td>0.119</td>
<td>0.139</td>
<td>0.126</td>
</tr>
<tr>
<td>Firm controls</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Time sector FE</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Time clustering</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

\[
\Delta \log k_{it+1} = \beta y_{it-1} \varepsilon_t^m + \alpha_i + \alpha_{st} + \Gamma' Z_{it-1} + \varepsilon_{it}
\]

- Monetary expansion has positive sign \(-\varepsilon_t^m\)
- Standardize leverage and distance to default over all firms and quarters
Results Hold Using Only Within-Firm Variation

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>leverage × ffr shock</td>
<td>-0.81**</td>
<td>-0.68**</td>
<td>-0.33</td>
<td>-0.21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.31)</td>
<td>(0.28)</td>
<td>(0.37)</td>
<td>(0.38)</td>
<td></td>
</tr>
<tr>
<td>dd × ffr shock</td>
<td></td>
<td></td>
<td>1.10***</td>
<td>0.89**</td>
<td>1.12**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.39)</td>
<td>(0.38)</td>
<td>(0.47)</td>
</tr>
<tr>
<td>ffr shock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.64**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.77)</td>
</tr>
</tbody>
</table>

| Observations     | 219702 | 219702 | 151433 | 151433 | 151433 |
| R²                | 0.113  | 0.124  | 0.137  | 0.139  | 0.126  |
| Firm controls     | no     | yes    | yes    | yes    | yes    |
| Time sector FE    | yes    | yes    | yes    | yes    | no     |
| Time clustering   | yes    | yes    | yes    | yes    | yes    |

\[ \Delta \log k_{it+1} = \beta (y_{it-1} - E_i [y_{it}]) \varepsilon_t^m + \alpha_i + \alpha_{st} + \Gamma_1 Z_{it-1} + \Gamma_2 (y_{it-1} - E_i [y_{it}]) Y_{t-1} + \varepsilon_{it} \]

- Monetary expansion has positive sign \((-\varepsilon_t^m)\)
- Standardize demeaned leverage and distance to default over all firms and quarters
Dynamics of Differences Across Firms

(a) Leverage

(b) Distance to Default

\[
\log k_{it+h+1} - \log k_{it} = \beta_h (y_{it-1} - E_i[y_{it}]) \epsilon_t^m + \alpha_{ih} \alpha_{stth} + \\
+ \Gamma_{1h} Z_{it-1} + \Gamma_{2h} (y_{it-1} - E_i[y_{it}]) Y_{t-1} + \epsilon_{ith}
\]
Heterogeneous Firm New Keynesian Model
Model Overview

1. **Investment block**
   - Heterogeneous firms invest s.t. default risk
   - Intermediary lends resources from household to firms

2. **New Keynesian block**
   - Retailers differentiate output s.t. sticky prices
   - Final good producer combines goods into final output
   - Monetary authority follows Taylor rule *(monetary shock)*
   - Capital good producer with adjustment costs

3. **Representative household**
   - Owns firms + labor-leisure choice
Heterogeneous Firms

Enter period with state variables $z_{jt}$, $\omega_{jt}$, $k_{jt}$, and $b_{jt}$
Heterogeneous Firms

Enter period with state variables $z_{jt}$, $\omega_{jt}$, $k_{jt}$, and $b_{jt}$

1. **Exogenous exit**: w/ i.i.d. prob $\pi_d$, forced to exit at end of period
Heterogeneous Firms

Enter period with state variables $z_{jt}$, $\omega_{jt}$, $k_{jt}$, and $b_{jt}$

1. **Exogenous exit**: w/ i.i.d. prob $\pi_d$, forced to exit at end of period

2. **Default decision**
   - If default, value = 0
   - If continue, repay debt $b_{jt}$ and pay operating cost $\xi$
Heterogeneous Firms

Enter period with state variables $z_{jt}$, $\omega_{jt}$, $k_{jt}$, and $b_{jt}$

1. **Exogenous exit**: w/ i.i.d. prob $\pi_d$, forced to exit at end of period

2. **Default decision**
   - If default, value = 0
   - If continue, repay debt $b_{jt}$ and pay operating cost $\xi$

3. **Production**: $y_{jt} = z_{jt}(\omega_{jt}k_{jt})^\theta n_{jt}^{\nu}$, $\theta + \nu < 1$ at price $p_t$
   - $\log z_{jt+1} = \rho \log z_{jt} + \varepsilon_{jt+1}^z$, $\varepsilon_{jt+1}^z \sim N(0, \sigma^2)$
   - $\log \omega_{jt} \sim N(-\sigma^2_{\omega}/2, \sigma^2_{\omega})$ i.i.d.
     - Undepreciated capital $(1 - \delta)\omega_{jt}k_{jt}$
Heterogeneous Firms

Enter period with state variables $z_{jt}$, $\omega_{jt}$, $k_{jt}$, and $b_{jt}$

1. **Exogenous exit**: w/ i.i.d. prob $\pi_d$, forced to exit at end of period

2. **Default decision**
   - If default, value = 0
   - If continue, repay debt $b_{jt}$ and pay operating cost $\xi$

3. **Production**: $y_{jt} = z_{jt}(\omega_{jt}k_{jt})^{\theta}n_{jt}^{\nu}$, $\theta + \nu < 1$ at price $p_t$
   - $\log z_{jt+1} = \rho \log z_{jt} + \varepsilon_{zt+1}^z$, $\varepsilon_{zt+1}^z \sim N(0, \sigma^2)$
   - $\log \omega_{jt} \sim N(-\sigma^2_\omega/2, \sigma^2_\omega)$ i.i.d.
     - Undepreciated capital $(1 - \delta)\omega_{jt}k_{jt}$

4. **Investment**: choose $q_{jt}k_{jt+1}$ and financing $b_{jt+1}$, $d_{jt}$
   - External finance $b_{jt+1}$ at price $Q_t(z_{jt}, k_{jt+1}, b_{jt+1})$
   - Internal finance subject to $d_{jt} \geq 0$
Financial Intermediary

- **Financial intermediary** lends from households to firms
  - No default: get $1/\Pi_{t+1}$ (nominal debt)
  - Default: get up to $\alpha q_{t+1} \omega_{jt+1} k_{jt+1}$ per unit of debt
Financial Intermediary

- **Financial intermediary** lends from households to firms
  - No default: get $1/\Pi_{t+1}$ (nominal debt)
  - Default: get up to $\alpha q_{t+1} \omega_{jt+1} k_{jt+1}$ per unit of debt

\[
Q_t(z,k', b') = \mathbb{E}_t[\Lambda_{t+1}((1 - \mathbb{1}\{\text{default}_{t+1}(z', \omega', \zeta', k', b')\})) \times \frac{1}{\Pi_{t+1}}] \\
\quad + \mathbb{1}\{\text{default}_{t+1}(z', \omega', \zeta', k', b')\} \times \min\{1, \alpha \frac{q_{t+1} \omega' k'}{b' / \Pi_{t+1}}\})
\]
An Equilibrium of this Model Satisfies

1. **Heterogeneous firms** choose investment \( k'_t(z, \omega, k, b) \), financing \( b'_t(z, \omega, k, b) \), and default decision

2. **Financial intermediaries** price default risk \( Q_t(z, k', b') \)

3. **Firm entry** with shifted initial distribution

4. **Retailers and final good producer** generate Phillips Curve

5. **Monetary authority** follows Taylor rule

6. **Capital good producer** generates capital price \( q_t \)

7. **Household** supplies labor \( N_t \) and generates SDF w/ \( \Lambda_{t+1} \)
Channels of Investment Response to Monetary Policy
Risk-Free Firms’ Response

\[ q_t = \frac{1}{R_t} \left( \mathbb{E}_t [\text{MRPK}_{t+1}(z', k')] + \frac{\text{Cov}_t(\text{MRPK}_{t+1}(z', k'), 1 + \lambda_{t+1}(z', k', b'))}{\mathbb{E}_t[1 + \lambda_{t+1}(z', k', b')]} \right) \]

\[ \text{MRPK}_{t+1}(z', k') = \frac{\partial}{\partial k'} \left( \max_{n'} p_{t+1} z' (\omega' k')^{\theta}(n')^{\nu} - w_{t+1} n' + q_{t+1}(1 - \delta)\omega' k' \right) \]
Risk-Free Firms’ Response: Discount Rate Falls

\[ q_t = \frac{1}{R_t} \left( \mathbb{E}_t \left[ \text{MRPK}_{t+1}(z', k') \right] + \frac{\text{Cov}_t(\text{MRPK}_{t+1}(z', k'), 1 + \lambda_{t+1}(z', k', b'))}{\mathbb{E}_t[1 + \lambda_{t+1}(z', k', b')]} \right) \]

\[ \text{MRPK}_{t+1}(z', k') = \frac{\partial}{\partial k'} \left( \max_{n'} \rho_{t+1} z'(\omega'k')^{\theta}(n')^{\nu} - w_{t+1}n' + q_{t+1}(1 - \delta)\omega'k' \right) \]
Risk-Free Firms’ Response: Future Revenue Rises

\[
q_t = \frac{1}{R_t} \left( \mathbb{E}_t \left[ \text{MRPK}_{t+1}(z', k') \right] + \frac{\text{Cov}_t(\text{MRPK}_{t+1}(z', k'), 1 + \lambda_{t+1}(z', k', b'))}{\mathbb{E}_t[1 + \lambda_{t+1}(z', k', b')]} \right)
\]

\[
\text{MRPK}_{t+1}(z', k') = \frac{\partial}{\partial k'} \left( \max_{n'} w_{t+1} z'(\omega'k')^{\theta}(n')^{\nu} - w_{t+1} n' + q_{t+1}(1 - \delta)\omega'k' \right)
\]
Risk-Free Firms’ Response: Price of Capital Rises

\[
q_t = \frac{1}{R_t} \left( \mathbb{E}_t [\text{MRPK}_{t+1}(z', k')] + \frac{\text{Cov}_t(\text{MRPK}_{t+1}(z', k'), 1 + \lambda_{t+1}(z', k', b'))}{\mathbb{E}_t[1 + \lambda_{t+1}(z', k', b')]} \right)
\]

\[
\text{MRPK}_{t+1}(z', k') = \frac{\partial}{\partial k'} \left( \max_{n'} \rho_{t+1} z'(\omega' k')^\theta (n')^\nu - w_{t+1} n' + q_{t+1}(1 - \delta) \omega' k' \right)
\]
Risky Firms’ Response

\[
\left(q_t - \epsilon_{R,k'} \frac{b'}{k'}\right) \frac{R_{t}^{sp}(z,k',b')}{1 - \epsilon_{R,b'}} = \frac{1}{R_t} \left( \mathbb{E}_t \left[ \text{MRPK}_{t+1}(z',k') \right] + \frac{\text{Cov}_t(\text{MRPK}_{t+1}(z',k'), 1 + \lambda_{t+1}(z',k',b'))}{\mathbb{E}_t[1 + \lambda_{t+1}(z',k',b')]} \right)
\]

\[
d = 0 \implies q_t k' = \max_n p_t z(\omega k)^\theta n^\nu - w_t n - b - \xi + q_t(1 - \delta)\omega k + \frac{1}{R_t(z,k',b')} b'
\]

\[
\text{MRPK}_{t+1}(z',k') = \frac{\partial}{\partial k'} \left( \max_{n'} p_{t+1} z'(\omega' k')^\theta (n')^\nu - w_{t+1} n' + q_{t+1}(1 - \delta)\omega' k' \right)
\]
\[
\left(q_t - \varepsilon_{R,k'} \frac{b'}{k'} \right) \frac{R_t^{SP}(z, k', b')}{1 - \varepsilon_{R,b'}} = \frac{1}{R_t} \left( \mathbb{E}_t [\text{MRPK}_{t+1}(z', k')] + \frac{\text{Cov}_t(\text{MRPK}_{t+1}(z', k'), 1 + \lambda_{t+1}(z', k', b'))}{\mathbb{E}_t[1 + \lambda_{t+1}(z', k', b')]} \right)
\]

\[
d = 0 \implies q_t k' = \max_n p_t z(\omega k)^{\theta} n^\nu - w_t n - b - \xi + q_t (1 - \delta) \omega k + \frac{1}{R_t(z, k', b')} b'
\]

\[
\text{MRPK}_{t+1}(z', k') = \frac{\partial}{\partial k'} \left( \max_{n'} p_{t+1} z'(\omega' k')^{\theta} (n')^\nu - w_{t+1} n' + q_{t+1} (1 - \delta) \omega' k' \right)
\]
Risky Firms’ Response: Cash Flow Rises

\[
\left( q_t - \varepsilon_{R,k'} \frac{b'}{k'} \right) \frac{R^S_t(z,k',b')}{1 - \varepsilon_{R,b'}} = \frac{1}{R_t} \left( \mathbb{E}_t \left[ \text{MRPK}_{t+1}(z', k') \right] + \frac{\text{Cov}_t(\text{MRPK}_{t+1}(z', k'), 1 + \lambda_{t+1}(z', k', b'))}{\mathbb{E}_t[1 + \lambda_{t+1}(z', k', b')]} \right)
\]

\[
d = 0 \implies q_t k' = \max_n p_t z(\omega k)\theta n' - w_t n - b - \xi + q_t (1 - \delta) \omega k + \frac{1}{R_t(z, k', b')} b'
\]

\[
\text{MRPK}_{t+1}(z', k') = \frac{\partial}{\partial k'} \left( \max_{n'} p_{t+1} z'(\omega' k')\theta (n')\nu - w_{t+1} n' + q_{t+1} (1 - \delta) \omega' k' \right)
\]
Risky Firms’ Response: Recovery Value Rises

\[
\left( q_t - \varepsilon_{R,k'} \right) \frac{b'}{k'} \frac{R_t^{sp}(z,k',b')} {1 - \varepsilon_{R,b'}} = \frac{1}{R_t} \left( \mathbb{E}_t \left[ \text{MRPK}_{t+1}(z',k') \right] + \frac{\text{Cov}_t(\text{MRPK}_{t+1}(z',k'), 1 + \lambda_{t+1}(z',k',b'))} {\mathbb{E}_t[1 + \lambda_{t+1}(z',k',b')]} \right)
\]

\[
d = 0 \implies q_t k' = \max_n \rho_t z(\omega k') \theta n' - w_t n - b - \xi + q_t (1 - \delta) \omega k + \frac{1}{R_t(z,k',b')} b'
\]

\[
R_t^{sp}(z,k',b') = \text{Prob} \left( \text{default}_{t+1}(z',k',b') \right) \left( 1 - \min\{1, \alpha \frac{q_{t+1} \omega' k'}{b' / \Pi_{t+1}} \} \right)
\]
Which Is More Responsive? Quantitative Question
Calibration
Overview of Calibration

- **Fix** subset of parameters to standard values

- **Choose** parameters governing idiosyncratic shocks, financial frictions, and lifecycle to match empirical targets
## Parameters to be Computed

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Idiosyncratic shock processes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho$</td>
<td>Persistence of TFP</td>
<td></td>
</tr>
<tr>
<td>$\sigma$</td>
<td>SD of innovations to TFP</td>
<td></td>
</tr>
<tr>
<td>$\sigma_\omega$</td>
<td>SD of capital quality</td>
<td></td>
</tr>
<tr>
<td><strong>Financial frictions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\xi$</td>
<td>Operating cost</td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Loan recovery rate</td>
<td></td>
</tr>
<tr>
<td><strong>Firm lifecycle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m$</td>
<td>Mean shift of entrants’ prod.</td>
<td></td>
</tr>
<tr>
<td>$s$</td>
<td>SD shift of entrants’ prod.</td>
<td></td>
</tr>
<tr>
<td>$k_0$</td>
<td>Initial capital</td>
<td></td>
</tr>
<tr>
<td>$\pi_d$</td>
<td>Exogeneous exit rate</td>
<td></td>
</tr>
</tbody>
</table>

Choose labor disutility $\Psi$ to ensure steady state employment = 0.6
## Empirical Targets

<table>
<thead>
<tr>
<th>Moment</th>
<th>Description</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment behavior (annual)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma \left( \frac{i}{k} \right)$</td>
<td>SD investment rate</td>
<td>33.7%</td>
<td></td>
</tr>
<tr>
<td><strong>Financial behavior (annual)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E[\text{default rate}]$</td>
<td>Mean default rate</td>
<td>3.00%</td>
<td></td>
</tr>
<tr>
<td>$E[\text{credit spread}]$</td>
<td>Mean credit spread</td>
<td>2.35%</td>
<td></td>
</tr>
<tr>
<td>$E[b/k]$</td>
<td>Mean gross leverage ratio</td>
<td>34.4%</td>
<td></td>
</tr>
<tr>
<td><strong>Firm Growth (annual)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E[n_1]/E[n]$</td>
<td>Rel. size of age 1 firms</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>$E[n_2]/E[n]$</td>
<td>Rel. size of age 2 firms</td>
<td>36%</td>
<td></td>
</tr>
<tr>
<td><strong>Firm Exit (annual)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E[\text{exit rate}]$</td>
<td>Mean exit rate</td>
<td>8.7%</td>
<td></td>
</tr>
<tr>
<td>$E[M_1]/E[M]$</td>
<td>Share of firms at age 1</td>
<td>10.5%</td>
<td></td>
</tr>
<tr>
<td>$E[M_2]/E[M]$</td>
<td>Share of firms at age 2</td>
<td>8.1%</td>
<td></td>
</tr>
</tbody>
</table>
Empirical Targets

<table>
<thead>
<tr>
<th>Moment</th>
<th>Description</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment behavior (annual)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma \left( \frac{i}{k} \right)$</td>
<td>SD investment rate</td>
<td>33.7%</td>
<td>31.8%</td>
</tr>
<tr>
<td><strong>Financial behavior (annual)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mathbb{E} [\text{default rate}]$</td>
<td>Mean default rate</td>
<td>3.00%</td>
<td>2.01%</td>
</tr>
<tr>
<td>$\mathbb{E} [\text{credit spread}]$</td>
<td>Mean credit spread</td>
<td>2.35%</td>
<td>2.54%</td>
</tr>
<tr>
<td>$\mathbb{E} [b/k]$</td>
<td>Mean gross leverage ratio</td>
<td>34.4%</td>
<td>33.6%</td>
</tr>
<tr>
<td><strong>Firm Growth (annual)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mathbb{E} [n_1]/\mathbb{E} [n]$</td>
<td>Rel. size of age 1 firms</td>
<td>28%</td>
<td>42%</td>
</tr>
<tr>
<td>$\mathbb{E} [n_2]/\mathbb{E} [n]$</td>
<td>Rel. size of age 2 firms</td>
<td>36%</td>
<td>66%</td>
</tr>
<tr>
<td><strong>Firm Exit (annual)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mathbb{E} [\text{exit rate}]$</td>
<td>Mean exit rate</td>
<td>8.7%</td>
<td>7.88%</td>
</tr>
<tr>
<td>$\mathbb{E} [M_1]/\mathbb{E} [M]$</td>
<td>Share of firms at age 1</td>
<td>10.5%</td>
<td>7.4%</td>
</tr>
<tr>
<td>$\mathbb{E} [M_2]/\mathbb{E} [M]$</td>
<td>Share of firms at age 2</td>
<td>8.1%</td>
<td>6.1%</td>
</tr>
</tbody>
</table>
## Parameters to be Computed

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Idiosyncratic shock processes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho$</td>
<td>Persistence of TFP</td>
<td>0.86</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>SD of innovations to TFP</td>
<td>0.03</td>
</tr>
<tr>
<td>$\sigma_\omega$</td>
<td>SD of capital quality</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Financial frictions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\xi$</td>
<td>Operating cost</td>
<td>0.02</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Loan recovery rate</td>
<td>0.91</td>
</tr>
<tr>
<td><strong>Firm lifecycle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m$</td>
<td>Mean shift of entrants’ prod.</td>
<td>2.92</td>
</tr>
<tr>
<td>$s$</td>
<td>SD shift of entrants’ prod</td>
<td>1.11</td>
</tr>
<tr>
<td>$k_0$</td>
<td>Initial capital</td>
<td>0.46</td>
</tr>
<tr>
<td>$\pi_d$</td>
<td>Exogeneous exit rate</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Choose labor disutility $\Psi$ to ensure steady state employment $\mu = 0.6$
Overview of Calibration

- **Fix** subset of parameters to standard values

- **Choose** parameters governing *idiosyncratic shocks*, *financial frictions*, and *lifecycle* to match empirical targets
Overview of Calibration

- **Fix** subset of parameters to standard values

- **Choose** parameters governing *idiosyncratic shocks, financial frictions*, and *lifecycle* to match empirical targets

- **Analyze** sources of financial heterogeneity
  1. Lifecycle dynamics
  2. Productivity shocks

- **Verify** model (roughly) matches untargetted statistics
  1. Lifecycle dynamics
  2. Distribution of investment and leverage
  3. Investment-cash flow sensitivity
Quantitative Analysis of Monetary Transmission Mechanism
Aggregate Monetary Transmission Mechanism

• Peak responses in line with VARs (CEE 2005)
• Not designed to generate hump-shaped responses
Heterogeneous Responses Consistent with Data

<table>
<thead>
<tr>
<th></th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>leverage × ffr shock</td>
<td>−1.193</td>
<td>−0.955</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.151</td>
<td>0.216</td>
</tr>
<tr>
<td>Time FE</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Firm controls</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

\[ \Delta \log k_{it+1} = \beta l_{it-1} e_t^m + \alpha_i + \alpha_{st} + \Gamma'Z_{it-1} + \varepsilon_{it} \]
Heterogeneous Responses Consistent with Data
Aggregate Effect Depends on Distribution of Risk

Back of the envelope calculation:

- Fix investment response across state space
- Vary initial distribution of cash on hand:

\[
\mu(z, x) = \omega \mu_{\text{normal}}(z, x) + (1 - \omega) \mu_{\text{bad}}(z, x)
\]

\[
\text{s.s.} + (\text{s.s., low prod.})
\]
Conclusion
Default risk *dampens* response of investment to monetary policy
Default risk dampens response of investment to monetary policy

1. **Which firms respond the most?**
   - Firms with low leverage and high credit ratings
   - Indicates default risk is key to micro response

2. **Implications for aggregate transmission?**
   - Low-risk firms drive aggregate response
   - Suggests that aggregate effect depends on distribution of default risk
Appendix
Constructing Investment

1. Start with firms’ reported level of plant, property, and equipment ($ppegtq$) as firms’ initial value of capital
2. Compute differences of net plant, property, and equipment ($ppentq$) to get net investment
3. Interpolate missing values when missing a single quarter in the data
4. Compute gross investment using depreciation rates of Fixed Asset tables from NIPA at the industry level
5. Trim the data: extreme values and short spells
Sectoral Controls

Sectors considered:
1. Agriculture, Forestry, And Fishing: $\text{sic} < 10$
2. Mining: $\text{sic} \in [10, 14]$
3. Construction: $\text{sic} \in [15, 17]$
4. Manufacturing: $\text{sic} \in [20, 39]$
5. Transportation, Communications, Electric, Gas, And Sanitary Services: $\text{sic} \in [40, 49]$
6. Wholesale Trade: $\text{sic} \in [50, 51]$
7. Retail Trade: $\text{sic} \in [52, 59]$
8. Services: $\text{sic} \in [70, 89]$

Sectors not considered:
1. Finance, Insurance, and Real Estate: $\text{sic} \in [60, 67]$
2. Public Administration: $\text{sic} \in [91, 97]$
Firm-Level Heterogeneity Variables

1. Leverage: Ratio of total debt \((d_{1c} + d_{1t})\) to total assets \((a_t)\).
2. Net leverage: Subtract current assets \((a_{ct})\) net of other current liabilities \((l_{ct})\) from debt liabilities to total assets.
   - Current assets consists of cash and other assets expected to be realized in cash within the next 12 months.
   - Current liabilities are those due within one year.
3. Real Sales Growth: log-differences in sales \((s_{a})\) deflated using CPI.
4. Size: Log of total assets.
• Firms exit due to exit shocks and default

• One new entrant for each exiting firm

  1. Draw productivity $z_{jt}$ from shifted distribution

     $$\log z_{jt} \sim N \left( -m \frac{\sigma}{\sqrt{1 - \rho^2}}, s^2 \frac{\sigma^2}{1 - \rho^2} \right)$$

  2. Draw capital quality $\omega_{jt}$ from ergodic distribution

  3. Endowed with $k_0$ units of capital and $b_0 = 0$ units of debt

     $\implies$ incumbent w/ initial state $(z_{jt}, \omega_{jt}, k_0, 0)$
Retailers and Final Good Producer

- Monopolistically competitive retailers
  - Technology: \( \tilde{y}_{it} = y_{it} \) \( \implies \) real marginal cost \( = p_t \)
  - Set price \( \tilde{p}_{it} \) s.t. quadratic cost \( - \frac{\varphi}{2} \left( \frac{\tilde{p}_{it}}{\tilde{p}_{it-1}} - 1 \right)^2 Y_t \)

- Perfectly competitive final good producer
  - Technology: \( Y_t = \left( \int \tilde{y}_{it}^\gamma \, di \right)^{\frac{\gamma}{\gamma-1}} \implies P_t = \left( \int \tilde{p}_{it}^{1-\gamma} \, di \right)^{\frac{1}{1-\gamma}} \)

- Implies New Keynesian Phillips Curve

\[
\pi_t = \frac{\gamma - 1}{\varphi} \log \frac{p_t}{p^*} + \beta E_t [\pi_{t+1}]
\]
• Monetary authority follows Taylor rule

\[ \log R_{t}^{\text{nom}} = \log \frac{1}{\beta} + \varphi_{\pi} \Pi_t + \varepsilon_{t}^{m} \]

• Capital good producer with technology

\[ K_{t+1} = \Phi \left( \frac{l_{t}}{K_{t}} \right) K_{t} + (1 - \delta)K_{t} \implies q_{t} = 1 / \Phi' \left( \frac{l_{t}}{K_{t}} \right) = \left( \frac{l_{t}/K_{t}}{\delta} \right)^{1/\phi} \]

• Representative household with preferences

\[ \mathbb{E}_{0} \sum_{t=0}^{\infty} \beta^{t} (\log C_{t} - \Psi N_{t}) \]

• Owns firms \implies \Lambda_{t+1} = \beta \frac{C_{t}}{C_{t+1}}

• Labor-leisure choice \implies w_{t}C_{t}^{-1} = \Psi

• Euler equation for bonds \implies 1 = \beta R_{t}^{\text{nom}} \mathbb{E}_{t} \left[ \frac{\Lambda_{t+1}}{\Pi_{t+1}} \right] \]
Model-Implicit Investment-Cash Flow Sensitivity

<table>
<thead>
<tr>
<th></th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>cash flow</td>
<td>1.08</td>
<td>0.18</td>
</tr>
<tr>
<td>Tobin’s q</td>
<td>0.15</td>
<td>0.008</td>
</tr>
</tbody>
</table>

\[
\frac{i_{it}}{k_{it}} = \alpha + \alpha_1 \frac{\pi_{it-1}}{k_{it}} + \alpha_2 q_{it} + \varepsilon_{it}
\]
## Fixed Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Household</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>Discount factor</td>
<td>0.99</td>
</tr>
<tr>
<td><strong>Firms</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\nu$</td>
<td>Labor coefficient</td>
<td>0.64</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Capital coefficient</td>
<td>0.21</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation</td>
<td>0.026</td>
</tr>
<tr>
<td><strong>New Keynesian Block</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\phi$</td>
<td>Aggregate capital AC</td>
<td>4</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Demand elasticity</td>
<td>10</td>
</tr>
<tr>
<td>$\varphi_{\pi}$</td>
<td>Taylor rule coefficient</td>
<td>1.25</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>Price adjustment cost</td>
<td>90</td>
</tr>
</tbody>
</table>
Two key sources of **financial heterogeneity**

1. Lifecycle dynamics
2. Productivity shocks
Firm Lifecycle Dynamics

- Young firms **riskier than average**
- But default risk spread out over large set of firms
• Firms growth more quickly than in data
  • Data features other sources of lifecycle dynamics
• Age-dependence of exit rates in line with data
## Investment and leverage heterogeneity

<table>
<thead>
<tr>
<th>Moment</th>
<th>Description</th>
<th>Data</th>
<th>Sel. Model</th>
<th>Full Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mathbb{E} \left[ \frac{i_k}{k} \right]$</td>
<td>Mean investment rate</td>
<td>12.2%</td>
<td>8.83%</td>
<td>20.6%</td>
</tr>
<tr>
<td>$\sigma \left( \frac{i_k}{k} \right)$</td>
<td>SD investment rate (calibrated)</td>
<td>33.7%</td>
<td>31.8%</td>
<td>38.5%</td>
</tr>
<tr>
<td>$\rho \left( \frac{i_k}{k}, \frac{i_{k-1}}{k-1} \right)$</td>
<td>Autocorr investment rate</td>
<td>0.058</td>
<td>-0.26</td>
<td>-0.26</td>
</tr>
<tr>
<td>$\sigma \left( \frac{b_k}{k} \right)$</td>
<td>SD leverage ratio</td>
<td>36.4%</td>
<td>76.4%</td>
<td>77.0%</td>
</tr>
<tr>
<td>$\rho \left( \frac{b_k}{k}, \frac{b_{k-1}}{k-1} \right)$</td>
<td>Autocorr leverage ratio</td>
<td>0.94</td>
<td>0.92</td>
<td>0.95</td>
</tr>
<tr>
<td>$\rho \left( \frac{i_k}{k}, \frac{b_k}{k} \right)$</td>
<td>Corr. of leverage and investment</td>
<td>-0.08</td>
<td>-0.16</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

## Measured investment-cash flow sensitivity

<table>
<thead>
<tr>
<th>Without cash flow</th>
<th>With cash flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
</tr>
<tr>
<td>Tobin’s q cash flow</td>
<td>0.01***</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.097</td>
</tr>
</tbody>
</table>