Credit Supply and Productivity Growth

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Bank of Italy, Stanford University
TFP is authors' elaboration on country-level “multifactor productivity” built by OECD. Values in 1985 (or first available year) are normalized to 1. Each country is given equal weight. Countries are: AUS, AUT, BEL, CAN, CHE, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN, KOR, NLD, NZL, PRT, SWE and USA.
Detrended growth rates for a large sample of Italian corporations (CADS). TFP = $\log VA - \frac{1}{3} \cdot \log K - \frac{2}{3} \cdot \log L$ where VA is value added, $K$ is the capital stock and $L$ total wage bill. Labor productivity is value added per employee (winsorized at 98% before taking averaging at yearly level). No adjustment for entry/exit.
Finance → Productivity

- **no effect?** finance is useful only to purchase inputs

- **negative?**
  - “necessity mother of invention”: Field (2003)
  - scarcity and project selection: Ates and Saffie, (2016)
  - corporate governance and career concern: Jensen (1986) and Bernstein (2015)

- **positive?**
  - e.g. Benfratello et al (2008), anecdotal evidence
This Paper

Q: credit supply $\rightarrow$ TFP? How?

- builds a dataset
  - full pictures of access to credit + loan level info + input/output
  - several productivity-enhancing activities

- identifies firm-idiosyncratic credit shocks relying on stickiness of lending relations (e.g. Khwaja & Mian 2008, Chodorow-Reich 2014, Amiti & Weinstein 2017) - 2 strategies
  1. lenders change credit to the same borrower $\rightarrow$ supply variation
  2. natural experiment: 2007/08 freeze of interbank market

- estimates firm-level productivity
  - heterogeneous credit shocks
Results

1. ↓ 1% cred supply ⇒ ↓ 0.1% (0.02%) VA (revenues) productivity growth
   - magnitude: ↓ 12% (2007-2009) ⇒ ≈ \(\frac{1}{4}\) of the observed decrease in TFP

2. credit necessary for productivity-enhancing strategies
   - effect on productivity is persistent
   - ↑ cred supply ⇒ ↑ IT adoption, Innovation, and Management Practices, Export

3. negative shocks more important than positive ones
   - ⇒ volatility is bad
Literature


- effects on firm ability to use these inputs, why and for how long?


- improve on: data, identification, estimation and channels


- allocation vs direct effect on productivity


- identification of idiosyncratic shocks
Outline

1. Credit supply shocks
2. Production function estimation
3. Does credit supply affect TFP?
4. Freeze of interbank market
5. Productivity-enhancing activities
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Data

Credit Register: all credit relations in country
- report credit instruments, we use total
- focus on credit granted, yearly
- sample
  - years: 1997-2013
  - 1k banks
  - 500k firms per year
  - 1.3k borrowers per bank per year

Balance-Sheets and Income Statement from CADS:
- large sample of small and large Italian firms in manufacturing, construction, and private services
- capital series reconstructed with perpetual inventory methodology
- sector-level deflators from National Accounts
  - ⇒ output is revenues or value added, not quantity (Foster, Haltiwanger, and Syverson, 2008)
Bank A total credit + 3
Bank B total credit + 2

Because of different borrowers demand or lender supply?
Focusing on the common borrower we can figure out Bank B is expanding supply more than Bank A.
Credit Supply: an Empirical Framework

Assume, as a starting point:

\[
\frac{C_{i,b,t}}{C_{i,b,t-1}} = \frac{C(J_t, D_{i,t}, \Phi_{b,t}, X_{i,b,t})}{C(J_{t-1}, D_{i,t-1}, \Phi_{b,t-1}, X_{i,b,t-1})}
\]

- \(J_t\) economy-wide shocks (e.g. business cycle)
- \(D_{i,t}\) firm-specific factors (e.g. productivity or demand)
- \(\Phi_{b,t}\) bank supply factors (e.g. cost of funds)
- \(X_{i,b,t}\) match-specific factor (e.g. strength of relation)

Log-linearizing:

\[
\Delta c_{i,b,t} = j_t + d_{i,t} + \phi_{b,t} + \varepsilon_{i,b,t}
\]

Are OLS results \(\phi_{b,t}\) good estimate of supply shock (i.e. changes in \(\Phi_{b,t-1}\))?
- condition on demand \(d_{i,t}\)
Extensions

(1) substitution/complementarity with other lenders?

$$\Delta c_{i,b,t} = j_t + d_{i,t} + \phi_{b,t} + \gamma_t \cdot \phi_{b',t} + \varepsilon_{i,b,t}$$

(2) match-specific shocks?

$$\Delta c_{i,b,t} = j_t + d_{i,t} + \phi_{b,t} + \gamma_t \cdot O_{i,b,t-1} + \varepsilon_{i,b,t}$$

Solution: alternative specifications

- $b'$ is the main lender of $i$ at time $t - 1$
- $O_{i,b,t-1}$ is a (large) set of match specific observables

Results equal to the baseline
firm-level credit supply shocks:

$$\phi_{i,t} = \sum_b w_{i,b,t-1} \cdot \phi_{b,t}$$

$$w_{ib,t-1} = \frac{C_{ib,t-1}}{C_{i,t-1}}$$: borrower-lender relations mitigate asymmetric info & limited commitment

- valuables, costly to establish and sticky
- changes in lenders’ credit supply affects financing ability of connected borrowers
Credit supply shock = supply shock of Bank A

Credit supply shock = supply shock of Bank B
Credit supply shock = 0.5 × shock of Bank A + 0.5 × shock of Bank A
Credit applications with unconnected lenders

- ↑ credit supply → less need to apply for loans with new lenders
- ↑ credit demand → more loan applications

Results below validate our measure of credit supply shocks

- $PI = \text{credit applications with unconnected lenders}$

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>N. of $PI$</th>
<th>N. of $PI</th>
<th>Pr(N. of $PI &gt; 0$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>$\phi_{i,t}$</td>
<td>-0.537***</td>
<td>-0.458***</td>
<td>-0.0780***</td>
</tr>
<tr>
<td></td>
<td>(0.0796)</td>
<td>(0.113)</td>
<td>(0.0173)</td>
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<tr>
<td>Observations</td>
<td>656k</td>
<td>456k</td>
<td>656k</td>
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<tr>
<td>$R^2$</td>
<td>0.500</td>
<td>0.477</td>
<td>0.348</td>
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</table>
Credit supply $\rightarrow$ input & output growth

For each (log) input or output measure, we estimate:

$$\Delta x_{i,t} = \psi_i + \psi_{p,s,t} + \gamma \phi_{i,t} + \eta_{i,t}$$

one observation is one firm $i$ for one year $t$ (unbalanced panel)
Credit supply → input & output growth

For each (log) input or output measure, we estimate:

$$\Delta x_{i,t} = \psi_i + \psi_{p,s,t} + \gamma \phi_{i,t} + \eta_{i,t}$$

<table>
<thead>
<tr>
<th>VARIABLES (in delta Log)</th>
<th>Credit</th>
<th>VA</th>
<th>Revenues</th>
<th>Capital</th>
<th>Wagebill</th>
<th>Employees</th>
<th>Intermediates</th>
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<tr>
<td></td>
<td>(1)</td>
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<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
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<td>(7)</td>
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<td>All Industries</td>
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<tr>
<td>$\phi_{i,t}$</td>
<td>0.949***</td>
<td>0.123***</td>
<td>0.0474***</td>
<td>0.0619***</td>
<td>0.0154*</td>
<td>0.00608</td>
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<td>(0.00926)</td>
<td>(0.00889)</td>
<td>(0.0114)</td>
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<tr>
<td>$R^2$</td>
<td>0.239</td>
<td>0.224</td>
<td>0.302</td>
<td>0.259</td>
<td>0.324</td>
<td>0.319</td>
<td>0.302</td>
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<td>Manufacturing</td>
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<tr>
<td>$\phi_{i,t}$</td>
<td>0.966***</td>
<td>0.134***</td>
<td>0.0436***</td>
<td>0.0610***</td>
<td>0.00388</td>
<td>-0.00892</td>
<td>0.00716</td>
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<td>(0.0253)</td>
<td>(0.0201)</td>
<td>(0.0143)</td>
<td>(0.0169)</td>
<td>(0.0116)</td>
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<td>$R^2$</td>
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<td>0.241</td>
<td>0.309</td>
<td>0.253</td>
<td>0.326</td>
<td>0.317</td>
<td>0.308</td>
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</table>

“Naive” credit regression
1. Credit supply shocks
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Production with heterogeneous credit constraints

Estimate production function to back out $\omega_{i,t}$

$$Y_{i,t} = \exp\{\omega_{i,t} + f(l_{i,t}, k_{i,t}, m_{i,t}, \beta)\}$$

to estimate $\beta$ we augment classical control function approach


with

1. set of credit constraints

$$B_{i,t} \leq K_{i,t-1} \cdot \Gamma_t (B_{i,t-1}, \phi_{i,t}, \omega_{i,t})$$
$$M_{i,t} \leq K_{i,t-1} \cdot \Gamma_t^M (B_{i,t-1}, \phi_{i,t}, \omega_{i,t})$$

2. modified Markovian law of motion

$$E [\omega_{i,t}|I_{t-1}] = E [\omega_{i,t} | \omega_{t-1}, \phi_{i,t-1}]$$

More details
Off-the-shelf methods
Results

- \( f(\cdot, \beta) \) either Cobb Douglas or Trans-Log

CD:
- value added: average \( \beta_k \approx 0.20 \) and \( \beta_l \approx 0.66 \)
- net revenues: average \( \beta_k \approx 0.09 \), \( \beta_l \approx 0.16 \) and \( \beta_m \approx 0.82 \)

back out productivity as residual:

\[
\omega_{i,t} = y_{i,t} - f(k_{i,t}, l_{i,t}, m_{i,t}, \beta)
\]

\( \omega_{i,t} \) summarize: product quality, entrepreneur’s skills, unobserved input quality, luck etc..
Outline

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Credit supply $\rightarrow$ productivity growth

Estimate the effect of credit supply shocks on TFP growth

$$\Delta \omega_{i,t} = \psi_i + \psi_{p,s,t} + \gamma \phi_{i,t} + \eta_{i,t}$$

one observation is one firm $i$ for one year $t$ (unbalanced panel)

- alternatively: “Raw” correlation
Credit supply \( \rightarrow \) productivity growth

\[
\Delta \omega_{i,t} = \psi_i + \psi_{p,s,t} + \gamma \phi_{i,t} + \eta_{i,t}
\]

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>( \Delta \omega_{i,t} ) (1)</th>
<th>( \Delta \omega_{i,t} ) (2)</th>
<th>( \Delta \omega_{i,t} ) (3)</th>
<th>( \Delta \omega_{i,t} ) (4)</th>
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</thead>
<tbody>
<tr>
<td>Functional Form</td>
<td>Cobb-Douglas</td>
<td>Trans-Log</td>
<td>Cobb-Douglas</td>
<td>Trans-Log</td>
</tr>
<tr>
<td>Output Measure</td>
<td>Value Added</td>
<td>Value Added</td>
<td>Net Revenues</td>
<td>Net Revenues</td>
</tr>
</tbody>
</table>

**All industries**

<table>
<thead>
<tr>
<th>( \phi_{i,t} )</th>
<th>0.0946***</th>
<th>0.109***</th>
<th>0.0190***</th>
<th>0.0259***</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(0.0155)</td>
<td>(0.0160)</td>
<td>(0.00477)</td>
<td>(0.00491)</td>
</tr>
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<td>Observations</td>
<td>656,960</td>
<td>656,960</td>
<td>656,960</td>
<td>656,960</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.172</td>
<td>0.185</td>
<td>0.178</td>
<td>0.195</td>
</tr>
</tbody>
</table>

**Manufacturing**

<table>
<thead>
<tr>
<th>( \phi_{i,t} )</th>
<th>0.115***</th>
<th>0.121***</th>
<th>0.0303***</th>
<th>0.0323***</th>
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<tr>
<td></td>
<td>(0.0178)</td>
<td>(0.0186)</td>
<td>(0.00595)</td>
<td>(0.00649)</td>
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<tr>
<td>Observations</td>
<td>347,990</td>
<td>347,990</td>
<td>347,990</td>
<td>347,990</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.186</td>
<td>0.200</td>
<td>0.144</td>
<td>0.180</td>
</tr>
</tbody>
</table>
Magnitudes

- credit supply ↑ 1% increase ⇒
  - VA productivity ↑ 0.1 - 0.13%
  - revenue productivity ↑ 0.02 - 0.03%

2007 to 2009: credit growth down by 12%, rev prod. down by 1% and VA prod down by 8.8%

⇒ if credit crunch is totally supply driven, can explain between 12% and 30% of drop in productivity

Effect stronger in manufacturing

Bootstrap
Estimated effect is remarkably robust

Results are unaffected by

- inclusion of firm-level controls
- exclusion of “significant” borrowers
- using 4 vs 2 digits industry classification (Ateco 2007)
- allowing for endogenous exit (Olley and Pakes, 1996)
- alternative credit supply shocks (lending relations controls)
- using “traditional” production function estimation techniques
- using “split sample” procedure to compute credit supply shocks (sample biases or mechanical correlation)

Results stable across different Fixed-Effects structures

- test for correlated unobservables
- bounding sets (Oster, 2016)
Persistency and Pre-trend

\[ \omega_{i,t} = \psi_i + \psi_{p,s,t} + \sum_{j=3}^{-3} \gamma_j \phi_{i,t-j} + \eta_{i,t} \]

No significant pre-trend, levels remain persistently higher after shock.
Negative vs positive shocks

Re-estimate

\[ \omega_{i,t} = \psi_i + \psi_{p,s,t} + \sum_{j=3}^{-3} \gamma_j \phi_{i,t-j} + \eta_{i,t} \]

- including only obs with positive or negative \( \phi_{i,t} \)
- substitute \( \phi_{i,t} \) with its absolute value

![Graph showing negative and positive shocks with values around 0]
Shape of credit - prod relation (quintiles)

Divide $\phi_{i,t}$ in quintiles (omit the lowest) and estimate

$$\omega_{i,t} = \psi_i + \psi_{p,s,t} + \sum_{q=1}^{5} \gamma_q \cdot 1(\phi_{i,t} \in q) + \eta_{i,t}$$
<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heterogeneity Dimension</td>
<td>Big (Assets) (1)</td>
<td>Big (Workforce) (2)</td>
<td>Few Lenders (3)</td>
<td>High Sectoral Leverage (4)</td>
<td>High Sectoral R-Z index (5)</td>
</tr>
<tr>
<td>All Industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\phi_{i,t}$</td>
<td>0.0251*** (0.00507)</td>
<td>0.0240*** (0.00527)</td>
<td>-0.0143 (0.0168)</td>
<td>0.00872 (0.00736)</td>
<td>0.0211*** (0.00697)</td>
</tr>
<tr>
<td>Interaction</td>
<td>-0.00562 (0.0103)</td>
<td>-0.00489 (0.00890)</td>
<td>0.0348** (0.0169)</td>
<td>0.0168* (0.00935)</td>
<td>0.00350 (0.00901)</td>
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<td>Observations</td>
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<td>600k</td>
<td>656k</td>
<td>656k</td>
<td>656k</td>
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<tr>
<td>R-squared</td>
<td>0.177</td>
<td>0.177</td>
<td>0.178</td>
<td>0.178</td>
<td>0.178</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$\phi_{i,t}$</td>
<td>0.0429*** (0.00706)</td>
<td>0.0426*** (0.00729)</td>
<td>-0.0128 (0.0229)</td>
<td>0.0105 (0.0105)</td>
<td>0.0235*** (0.00688)</td>
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<tr>
<td>Interaction</td>
<td>-0.0345*** (0.0122)</td>
<td>-0.0334*** (0.0112)</td>
<td>0.0445* (0.0232)</td>
<td>0.0309** (0.0128)</td>
<td>0.0238* (0.0129)</td>
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<td>Observations</td>
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<td>321k</td>
<td>347k</td>
<td>347k</td>
<td>347k</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.143</td>
<td>0.143</td>
<td>0.144</td>
<td>0.144</td>
<td>0.144</td>
</tr>
</tbody>
</table>
Outline

1. Credit supply shocks
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Alternative empirical design:
• shock affecting Bank A differently than Bank B
the Interbank Shock


▶ banks could not compensate with other sources of finance ⇒ credit to real economy significantly reduced.
  ▶ Cingano et al. (2015) show it affected investment
  ▶ Italian banks not directly exposed to ABS or Lehman-issued liabilities

pre-crisis (2006) exposure to ITBK as an exogenous shock to credit supply

▶ $\overline{ITBK}_{i,2006} = 2006$ weighted average “interbank liabilities-to-assets ratio” of firm’s $i$ lenders
For $t = 2007, 2008, 2009$ we estimate:

$$\Delta \omega_{i,t} = \psi_{p,s,t} + \gamma ITBK_{i,2006} + \eta_{i,t}$$

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>$\Delta \omega_{i,t}$</th>
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<th>$\Delta \omega_{i,t}$</th>
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<tr>
<td>Functional Form</td>
<td>Cobb-Douglas Value Added</td>
<td>Trans-Log Value Added</td>
<td>Cobb-Douglas Net Revenues</td>
<td>Trans-Log Net Revenues</td>
</tr>
<tr>
<td>Output Measure</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>All Industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ITBK_{i,2006}$</td>
<td>-0.0477**</td>
<td>-0.0574**</td>
<td>-0.0172**</td>
<td>-0.0222***</td>
</tr>
<tr>
<td></td>
<td>(0.0239)</td>
<td>(0.0257)</td>
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<td>(0.00781)</td>
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<td>110k</td>
<td>110k</td>
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<tr>
<td>$R^2$</td>
<td>0.112</td>
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<td>Manufacturing</td>
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<tr>
<td>$ITBK_{i,2006}$</td>
<td>-0.0802**</td>
<td>-0.106***</td>
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<tr>
<td>$R^2$</td>
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<td>0.143</td>
<td>0.086</td>
<td>0.113</td>
</tr>
</tbody>
</table>
Interbank Robustness

**Pre-trend:** for \( t = 2006, 2005, 2004 \) we estimate:

\[
\Delta \omega_{i,t} = \psi_{p,s,t} + \gamma ITBK_{i,2006} + \eta_{i,t}
\]

**Placebo:** for \( t = 2003, 2004, 2005 \) we estimate:

\[
\Delta \omega_{i,t} = \psi_{p,s,t} + \gamma ITBK_{i,2002} + \eta_{i,t}
\]

**Sensitivity to business cycle:** for \( t < 2006 \) we estimate:

\[
\Delta y_{i,t} = \psi_i + \alpha_i \cdot GDPgr_t + \eta_{i,t}
\]
\[
\alpha_i = \psi + \gamma \cdot ITBK_{i,2006} + \eta_i
\]

**Bootstrap:**
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Productivity-Enhancing Activities: Theory

Why should productivity improvements be stimulated by credit supply?

- fixed costs (Midrigan and Xu, 2014)
- intangibles are more sensitive to financial constraints (Garcia-Macia, 2017)
- productivity improvement more appealing for firms that can rapidly expand production
Survey conducted from ’84 on panel of firms

- mostly > 50 employees
- neither questions nor respondents are fixed over time

Variables:

1. IT-intensity of capital stock:
   - number of PCs used by the firm available for years 1999, 2000, 2001
   - PCs purchase enters into capital stock \( \rightarrow IT_{i,t} = \log \left( \frac{PCs}{K} \right)_{i,t} \)

2. exporter vs non-exporter: \( Expt_{i,t} \)

3. positive versus zero R&D investment: \( R&D_{i,t} \)

4. \( FinCon_{2010} \) equal to one iff difficulties to get external funds is thought to be “somehow important” or “very important” as obstacle to innovation in 2010
Patent and Management Practices

Patents
- patent applications registered at EPO by all Italian firms
- matched to fiscal codes by the Italian Chamber of Commerce
- priority dates: 1999-2012

World Management Survey
- phone interview to score management practices
- 1-5 score
- Bloom et al. 2007, 2012
## Results

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>PCs per unit of Capital</th>
<th>R&amp;D</th>
<th>Export</th>
<th>FinCon\textsubscript{2010}</th>
<th>No. of Patents (t+1)</th>
<th>Management Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>$\phi_{i,t}$</td>
<td>0.808*** (0.289)</td>
<td>0.238* (0.128)</td>
<td>0.152* (0.085)</td>
<td>-1.629*** (0.594)</td>
<td>0.0418** (0.0197)</td>
<td>2.166* (1.116)</td>
</tr>
<tr>
<td>Obs</td>
<td>3k</td>
<td>6k</td>
<td>13k</td>
<td>506</td>
<td>517k</td>
<td>183</td>
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<tr>
<td>$R^2$</td>
<td>0.968</td>
<td>0.759</td>
<td>0.843</td>
<td>0.421</td>
<td>0.757</td>
<td>0.020</td>
</tr>
<tr>
<td>Model</td>
<td>Panel</td>
<td>Panel</td>
<td>Panel</td>
<td>Cross Section</td>
<td>Panel</td>
<td>Cross Section</td>
</tr>
</tbody>
</table>

- **More on management**
Bandiera et al (2014) study use of time of 94 CEO of top 600 Italian companies

- finance is one of the most time consuming tasks

A new hypothesis

- managers/entrepreneurs have to divide their time between looking for funds and improving productivity
- firms connected to contracting lenders need to exert more effort in creating new lending relations, damaging productivity improvements

We show that indeed effort to connect with new lenders decrease with credit supply

- leave more direct investigation of this theory to future research
In this paper we

- exploit banks-firms connections to measure firm-specific shocks to credit supply
- estimate a simple model of production with heterogeneous credit frictions
- show that credit supply foster persistent growth in firm TFP
  - suggesting credit crunch had a role in productivity slowdown
- document that productivity-enhancing activities are stimulated by credit availability
Thank You
Who needs credit?

Credit intensity = credit granted / revenues

- average is 43 (34) cents of credit per euro of revenues for manufacturers (non-manufacturers)

is higher in industries with:

- higher capital/labor ratio
- low liquidity

Credit intensity and capital use - industries

Credit intensity and liquidity - industries
Who needs credit?

Share of companies exporting and doing R&D (survey data):
- credit intensity positively correlated with export
- no statistically significant relation with R&D
Total Factor Productivity Growth (avg. yearly %)

- France
- Germany
- Italy
- United Kingdom


Conceptual Framework

Firm $i$ use (log) input $x_i$ to produce (log) output $y_i$

$$y_i = \omega_i + f(x_i)$$

Firm need to get credit from bank $b$ to finance purchase of $x$.

Let

- $S_b$ factor of bank supply (e.g. cost of funds)
- interest rate be $r(S_b)$
- max amount of credit $b$ can give to $i$ $C(S_b)$

consequently

$$\Rightarrow x_i = \mathcal{X}(\omega_i, S_b)$$
Conceptual Framework - cont’d

What are the effect of a change in $S_b$?

If no effect on productivity, then

\[
\frac{\partial y}{\partial S} = \frac{\partial x}{\partial S} \cdot \frac{\partial f}{\partial x}
\]

If the equation does not hold $\Rightarrow$

\[
\frac{\partial \omega}{\partial S} \neq 0
\]

two problems

- how to identify $\frac{\partial y}{\partial S}$ and $\frac{\partial x}{\partial S}$?
  - stickiness of lending relations and a natural experiment
- how to estimate $\frac{\partial f}{\partial x}$?
  - model of production with heterogeneous credit frictions

▶ Back
  ▶ provide an important extension (heterogeneous credit constraints)

Roots of productivity heterogeneity: e.g. Syverson (2011)
  ▶ partly due to heterogeneous access to credit

Credit constraints in Developing countries: e.g. Banerjee et al (2012), McKenzie Woodruff (2008)
  ▶ formal and established firms with access to banking

CEO use of time and span of control: e.g. Lucas (1978), Bandiera et al (2011)
  ▶ entrepreneurs’ time and productivity effects of lending relations
Production function estimation

Problems with off-the-shelf methods:

1. firm might be constrained → can’t use unconstrained FOC (e.g. cost share)
2. credit shocks might affect both inputs and productivity → can’t use regressions or control function approach
   ▶ e.g. common Markovian assumption fails

\[ E[\omega_{i,t}|\mathcal{I}_{t-1}] \neq E[\omega_{i,t}|\omega_{t-1}] \]
What is credit used for?

We don’t know, but can look at correlations by estimating:

\[ \Delta x_{i,t} = a_t + b_x \cdot \Delta cred_{i,t} + \eta_{i,t} \]

where \( x \) is a (log) input.

<table>
<thead>
<tr>
<th>VARIABLES (in delta log)</th>
<th>VA</th>
<th>Revenues</th>
<th>Wagebill</th>
<th>Capital</th>
<th>Intermediates</th>
<th>Employees</th>
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<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>( \Delta cred_{i,t} )</td>
<td>0.135***</td>
<td>0.146***</td>
<td>0.117***</td>
<td>0.152***</td>
<td>0.157***</td>
<td>0.102***</td>
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<tr>
<td></td>
<td>(0.00186)</td>
<td>(0.00144)</td>
<td>(0.00113)</td>
<td>(0.00145)</td>
<td>(0.00148)</td>
<td>(0.00106)</td>
</tr>
<tr>
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<td>581k</td>
<td>581k</td>
<td>581k</td>
<td>581k</td>
<td>581k</td>
<td>581k</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.015</td>
<td>0.038</td>
<td>0.042</td>
<td>0.037</td>
<td>0.039</td>
<td>0.037</td>
</tr>
</tbody>
</table>
Credit supply and productivity growth

“Raw” correlation

- higher values of $\phi_{i,t}$ are associated with higher mean productivity growth

![Graph showing mean productivity growth across quintiles of credit supply shock.](image)
Industry × year correlation

Credit supply shocks and average revenue productivity growth at industry × year level

- significant positive relations (1% confidence)
Separate “structural productivity” vs “measurement error”

\[ \omega_{i,t} = \tilde{\omega}_{i,t} + \epsilon_{i,t} \]

**FOC for intermediates:**

\[ \frac{\partial \exp\{ f (l_{i,t}, k_{i,t}, m^{unc}, \beta) + \tilde{\omega}_{i,t} \}}{\partial m} = P_{p,t}^M \]

**constraint**

\[ m_{i,t} \leq m_{i,t}^{max} = \log \frac{1}{P_{p,t}^M} K_{i,t-1} \cdot \Gamma (B_{i,t-1}, \phi_{i,t}, \tilde{\omega}_{i,t}) \]
First Stage

\[ m_{i,t} = \min \{ m_{i,t}^{\max}, m_{i,t}^{\unc} \} := m(x_{i,t}, \tilde{\omega}_{i,t}, \phi_{i,t}) \]

- \( x_{i,t} \) includes few firm-level observables (e.g. inputs, past debt, input prices)

under standard assumptions we can “invert” the “structural error”:

\[ \exists h(\cdot) \text{ s.t. } \tilde{\omega}_{i,t} = h(x_{i,t}, m_{i,t}, \phi_{i,t}) \]

\[ \Rightarrow y_{i,t} = h(x_{i,t}, m_{i,t}, \phi_{i,t}) + f(l_{i,t}, k_{i,t}, m_{i,t}, \beta_{s}) + \epsilon_{i,t} \]

\[ = \Psi(x_{i,t}, m_{i,t}, \phi_{i,t}) + \epsilon_{i,t} \]

- estimate \( \Psi(\cdot) = E[y_{i,t} | x_{i,t}, m_{i,t}, \phi_{i,t}] \)
The law-of-motion for productivity can be written as

\[ E [\omega_i, t | \mathcal{I}_{t-1}] = E_t [\omega_i, t | \omega_{t-1}, \phi_{i, t-1}] = g_t (\omega_{t-1}, \phi_{i, t-1}) \]

for an unknown \( g_t (\cdot) \)

Define \( \zeta_{i, t} := \tilde{\omega}_{i, t} - E [\tilde{\omega}_{i, t} | \mathcal{I}_{t-1}] \). Moment conditions

\[ E [\zeta_{i, t} | \mathcal{I}_{t-1}] = E [\zeta_{i, t} | z_{i, t-1}] = E [\Psi_i, t - f (l_i, t, k_i, t, m_i, t, \beta) - g_t (\Psi_{i, t-1} - f (l_{i, t-1}, k_{i, t-1}, m_{i, t-1}, \beta), \phi_{i, t-1}) | z_{i, t-1}] = 0 \]

allow estimation of the parameter of interests \( \beta \)
Bootstrapped distribution

$$\Delta \omega_{i,t} = \psi_i + \psi_{p,s,t} + \gamma \phi_{i,t} + \eta_{i,t}$$
### Robustness - CD Revenues

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
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<tr>
<td>Model</td>
<td>Baseline</td>
<td>Firm Controls</td>
<td>Significant Borrowers</td>
<td>Alternative FEs structure</td>
<td>Match Controls</td>
<td>4 Digits Sector</td>
<td>Endogenous Exit</td>
<td>Cost Share</td>
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<td>(2)</td>
<td>(3)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
<td>(9)</td>
</tr>
<tr>
<td>$\phi_{i,t}$</td>
<td>0.0190***</td>
<td>0.0231***</td>
<td>0.0182***</td>
<td>0.0171***</td>
<td>0.0234***</td>
<td>0.0278***</td>
<td>0.0166***</td>
<td>0.0256***</td>
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<tr>
<td></td>
<td>(0.00477)</td>
<td>(0.00504)</td>
<td>(0.00540)</td>
<td>(0.00471)</td>
<td>(0.00604)</td>
<td>(0.00585)</td>
<td>(0.00465)</td>
<td>(0.00736)</td>
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<tr>
<td>Observations</td>
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<td>542,103</td>
<td>521,741</td>
<td>656,960</td>
<td>656,960</td>
<td>587,873</td>
<td>656,960</td>
<td>545,162</td>
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<tr>
<td>R-squared</td>
<td>0.178</td>
<td>0.181</td>
<td>0.192</td>
<td>0.096</td>
<td>0.178</td>
<td>0.272</td>
<td>0.177</td>
<td>0.185</td>
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<td></td>
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</tr>
<tr>
<td>Manufacturing</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\phi_{i,t}$</td>
<td>0.0303***</td>
<td>0.0326***</td>
<td>0.0330***</td>
<td>0.0321***</td>
<td>0.0331***</td>
<td>0.0401***</td>
<td>0.0295***</td>
<td>0.0537***</td>
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<tr>
<td></td>
<td>(0.00595)</td>
<td>(0.00623)</td>
<td>(0.00698)</td>
<td>(0.00600)</td>
<td>(0.00739)</td>
<td>(0.00731)</td>
<td>(0.00639)</td>
<td>(0.0104)</td>
</tr>
<tr>
<td>Observations</td>
<td>347,990</td>
<td>293,617</td>
<td>280,346</td>
<td>347,990</td>
<td>347,990</td>
<td>309,887</td>
<td>347,990</td>
<td>291,071</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.144</td>
<td>0.149</td>
<td>0.150</td>
<td>0.071</td>
<td>0.144</td>
<td>0.259</td>
<td>0.166</td>
<td>0.161</td>
</tr>
</tbody>
</table>
Test for Correlated unobservables

Connected lenders and borrowers might be subject to correlated shocks

- e.g. borrower output market and lender lending markets might overlap

we compare

\[
\Delta \omega_{i,t} = \psi_i + \psi_{p,s,t} + \gamma \cdot \phi_{i,t} + \eta_{i,t}
\]

\[
\Delta \omega_{i,t} = \psi_i + \psi_p + \psi_s + \psi_t + \gamma \cdot \phi_{i,t} + \eta_{i,t}
\]

results

- coefficients very similar whether or not we include \( \psi_{p,s,t} \) to control for local demand or technology shocks

- \( R^2 \) more than double

conclusions

- if correlated unobservables are affecting the results, then they are not clustered at local or industry level

- lending is indeed clustered at local/industry level

⇒ correlated unobservables unlikely to play a major role
## CD Revenues - Fixed Effects

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Baseline</td>
<td>Alternative</td>
</tr>
<tr>
<td></td>
<td>FEs structure</td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5)</td>
</tr>
<tr>
<td>All Industries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\phi_{i,t}$</td>
<td>0.0190***</td>
<td>0.0171***</td>
</tr>
<tr>
<td></td>
<td>(0.00454)</td>
<td>(0.00435)</td>
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<tr>
<td></td>
<td>(0.00477)</td>
<td>(0.00471)</td>
</tr>
<tr>
<td>Observations</td>
<td>656k</td>
<td>656k</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.178</td>
<td>0.096</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\phi_{i,t}$</td>
<td>0.0303***</td>
<td>0.0321***</td>
</tr>
<tr>
<td></td>
<td>(0.00595)</td>
<td>(0.00600)</td>
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<tr>
<td></td>
<td>(0.00595)</td>
<td>(0.00600)</td>
</tr>
<tr>
<td>Observations</td>
<td>347k</td>
<td>347k</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.144</td>
<td>0.071</td>
</tr>
</tbody>
</table>
Bounding sets

Bounding sets following Oster (2016) (builds on Altonji et al, 2005)

- based on a “proportional selection” assumption
- they don’t contain the zero \( \Rightarrow \) unobservables cannot drive the effect of credit on productivity to zero

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>( \Delta \omega_{i,t} )</th>
<th>( \Delta \omega_{i,t} )</th>
<th>( \Delta \omega_{i,t} )</th>
<th>( \Delta \omega_{i,t} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fnct Form</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cobb-Douglas</td>
<td>Trans-Log</td>
<td>Cobb-Douglas</td>
<td>Trans-Log</td>
<td></td>
</tr>
<tr>
<td>Value Added</td>
<td>Value Added</td>
<td>Net Revenues</td>
<td>Net Revenues</td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td></td>
</tr>
<tr>
<td>All industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\phi_{i,t} \begin{cases} 
[0.043 ; 0.095] & \text{All industries} \\
[0.069 ; 0.115] & \text{Manufacturing}
\end{cases}
\]
\textbf{Interbank and Credit}

\[ t = 2007, 2008, 2009 \]

\begin{tabular}{lcccc}
\hline
\textbf{VARIABLES} & \textbf{(1)} & \textbf{(2)} & \textbf{(3)} & \textbf{(4)} \\
 & \( \phi_{i,t} \) & \text{Credit Granted} & \( \phi_{i,t} \) & \text{Credit Granted} \\
 & & (delta log) & & (delta log) \\
\hline
\( ITBK_{i,2006} \) & -0.137*** & -0.203*** & -0.160*** & -0.253*** \\
& (0.00624) & (0.0383) & (0.00900) & (0.0509) \\
Observations & 110k & 108k & 57k & 57k \\
\( R^2 \) & 0.187 & 0.093 & 0.194 & 0.089 \\
Sample & All & All & Manufacturing & Manufacturing \\
\hline
\end{tabular}
Simplest production function is Value Added Cobb-Douglas:
\[ va_{i,t} = \omega_{i,t} + \rho [(1 - \beta_k) \cdot l_{i,t} + \beta_k \cdot k_{i,t}] \]
we let \( \rho \) vary from 0.3 to 2 and \( \beta_k \) from 0.01 to 0.9

▶ then, for each \((\rho, \beta_k)\) calculate
\[ \Delta \omega_{i,t} = \Delta va_{i,t} - \rho [(1 - \beta_k) \cdot \Delta l_{i,t} + \beta_k \cdot \Delta k_{i,t}] \]

▶ finally, run
\[ \Delta \omega_{i,t} = \psi_{p,s,t} + \gamma \cdot INTBK_{i,2006} + \eta_{i,t}^{prod} \]
coefficient for $INTBK_{i,2006}$ as function of $(\rho, \beta_k)$

- coefficient is negative for any value of the parameter space
- banks more exposed to interbank shock experience lower productivity growth
z-stats for $INTBK_{i,2006}$ as function of $(\rho, \beta_k)$ (change sign)

- the z-stat is above 2 in almost all the parameter space
  - banks more exposed to interbank shock experience significantly lower productivity growth
Visualizing” the Credit Supply Shocks

Evolution of $\phi_{i,t}$ for a 1.5% random sample of manufacturers

- Right panel shows residualized values after taking out firm and sector-province-year FEs
- No clear pattern over time: $\phi_{i,t}$ makes sense only relatively
## Pre-Trend

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
<th>$\Delta \omega_{i,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional Form Output Measure</td>
<td>Cobb-Douglas Value Added (1)</td>
<td>Trans-Log Value Added (2)</td>
<td>Cobb-Douglas Net Revenues (3)</td>
<td>Trans-Log Net Revenues (4)</td>
</tr>
<tr>
<td>All Industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ITBK_{i,2006}$</td>
<td>0.000422</td>
<td>-0.0146</td>
<td>-0.00509</td>
<td>-0.00702</td>
</tr>
<tr>
<td></td>
<td>(0.0230)</td>
<td>(0.0247)</td>
<td>(0.00927)</td>
<td>(0.00793)</td>
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<tr>
<td>Observations</td>
<td>117,590</td>
<td>115,260</td>
<td>117,362</td>
<td>115,042</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.090</td>
<td>0.079</td>
<td>0.168</td>
<td>0.112</td>
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<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ITBK_{i,2006}$</td>
<td>0.00325</td>
<td>0.0203</td>
<td>-0.0134</td>
<td>-0.0169</td>
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<tr>
<td></td>
<td>(0.0307)</td>
<td>(0.0340)</td>
<td>(0.0100)</td>
<td>(0.0119)</td>
</tr>
<tr>
<td>Observations</td>
<td>58k</td>
<td>58k</td>
<td>58k</td>
<td>58k</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.086</td>
<td>0.090</td>
<td>0.081</td>
<td>0.108</td>
</tr>
<tr>
<td>VARIABLES</td>
<td>( \Delta \omega_{i,t} )</td>
<td>( \Delta \omega_{i,t} )</td>
<td>( \Delta \omega_{i,t} )</td>
<td>( \Delta \omega_{i,t} )</td>
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<td>-----------</td>
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<tr>
<td>Functional Form Output Measure</td>
<td>Cobb-Douglas Value Added</td>
<td>Trans-Log Value Added</td>
<td>Cobb-Douglas Net Revenues</td>
<td>Trans-Log Net Revenues</td>
</tr>
<tr>
<td>All Industries</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>( ITBK_{i,2002} )</td>
<td>-0.0190</td>
<td>-0.0379</td>
<td>0.00919</td>
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<tr>
<td></td>
<td>(0.0251)</td>
<td>(0.0266)</td>
<td>(0.0101)</td>
<td>(0.00832)</td>
</tr>
<tr>
<td>Observations</td>
<td>98k</td>
<td>97k</td>
<td>98k</td>
<td>97k</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.085</td>
<td>0.083</td>
<td>0.152</td>
<td>0.111</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( ITBK_{i,2002} )</td>
<td>0.0105</td>
<td>-0.00803</td>
<td>0.00118</td>
<td>0.00908</td>
</tr>
<tr>
<td></td>
<td>(0.0337)</td>
<td>(0.0372)</td>
<td>(0.0106)</td>
<td>(0.0122)</td>
</tr>
<tr>
<td>Observations</td>
<td>51k</td>
<td>51k</td>
<td>51k</td>
<td>51k</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.094</td>
<td>0.098</td>
<td>0.090</td>
<td>0.106</td>
</tr>
</tbody>
</table>
# Interbank and Sensitivity to the Business Cycle

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Sensitivity to business cycle (1)</th>
<th>Sensitivity to business cycle (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Industries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ITBK_{i,2006}$</td>
<td>0.0767 (0.108)</td>
<td>0.0604 (0.0377)</td>
</tr>
<tr>
<td>Observations</td>
<td>34,004</td>
<td>34,004</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.030</td>
<td>0.104</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ITBK_{i,2006}$</td>
<td>0.195 (0.225)</td>
<td>-0.0292 (0.0464)</td>
</tr>
<tr>
<td>Observations</td>
<td>17,759</td>
<td>17,759</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.026</td>
<td>0.091</td>
</tr>
</tbody>
</table>

| Type of output | Value Added | Revenues |
Bootsratp distribution - Interbank Shock
“Visualizing” productivity dynamics

Evolution of $\omega_{i,t}$ for a 1.5% random sample of manufacturers

- Right panel shows residualized values of the growth rate (after taking out FEs)
Histogram of $\Delta \omega_{i,t}$
Possible Mechanisms? Management Practices

$MS_{i,t}$ is management score (1-5 scale) from WMS

$$MS_{i,t} = \psi + \gamma \phi_{i,t} + \eta_{i,t}$$

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>management (1)</th>
<th>operations (2)</th>
<th>monitor (3)</th>
<th>target (4)</th>
<th>people (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi_{i,t}$</td>
<td>2.166* (1.116)</td>
<td>1.202 (1.665)</td>
<td>3.116** (1.375)</td>
<td>1.872 (1.425)</td>
<td>1.940 (1.256)</td>
</tr>
<tr>
<td>Observations</td>
<td>183</td>
<td>183</td>
<td>183</td>
<td>183</td>
<td>183</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.020</td>
<td>0.002</td>
<td>0.026</td>
<td>0.010</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Productivity definitions

Productivity is residual from (log) sales generating production function:

\[ \omega_{i,t} = y_{i,t} - f(l_{i,t}, k_{i,t}, m_{i,t}, \beta) \]

- this is referred “productivity” in several studies, e.g. Olley and Pakes 1996
- this is referred as \( tfpr^{rr} \) in work by Foster, Grim, Haltiwanger and Wolf (NBER WP 2017 and AER P&P 2016)
- this is proportional to the empirical measure of (log) \( TFPQ \) in Hsieh and Klenow 2009
Revenue vs Quantity

Quantity produced (supply) is

\[ Q_{i,t} = \exp\{\omega^q_{i,t} + \beta^q_l \cdot l_{i,t} + \beta^q_k \cdot k_{i,t} + \beta^q_m \cdot m_{i,t}\} \]

Quantity sold (demand) is:

\[ Q_{i,t} = \left( \frac{P_{i,t}}{P_t} \right)^{-\sigma} \exp\{\theta_{i,t}\} \]

Then, growth of sales productivity is

\[ \Delta \omega_{i,t} = \frac{1}{\sigma} \cdot \Delta \theta_{i,t} + \frac{\sigma - 1}{\sigma} \cdot \Delta \omega^q_{i,t} \]
Revenue vs Quantity - cont’d

\[ \Delta \theta_{i,t} = a_i + a_{p,s,t} + \gamma^\theta \cdot \phi_{i,t} + \epsilon_{i,t} \]

\[ \Delta \omega^q_{i,t} = b_i + b_{p,s,t} + \gamma^q \cdot \phi_{i,t} + \epsilon_{i,t} \]

Then

\[ \gamma = \left( \frac{1}{\sigma} \cdot \gamma^\theta + \frac{\sigma - 1}{\sigma} \cdot \gamma^q \right) \]

and

\[ \frac{\partial \gamma}{\partial \sigma} > 0 \iff \gamma^q > \gamma^\theta \]