Strapped for Cash: The Role of Financial Constraints for Innovating Firms and Aggregate Growth

Esther Ann Bøler, Imperial College & CEPR
Andreas Moxnes, BI Norwegian School of Business & CEPR
Karen Helene Ulltveit-Moe, Uni Oslo & CEPR

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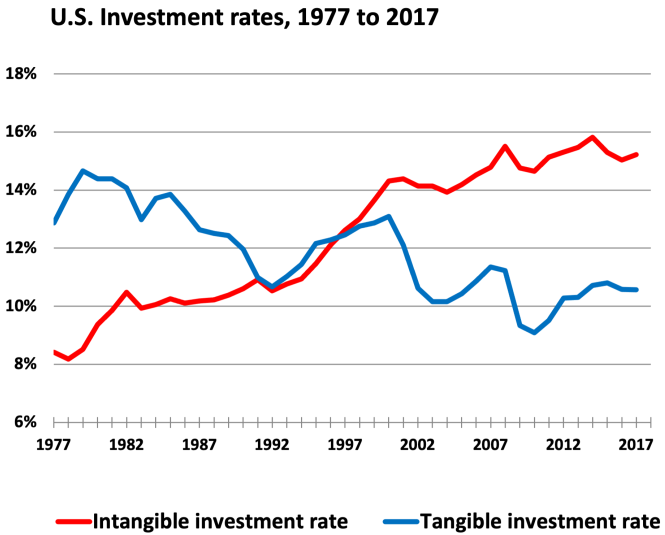
A technological revolution

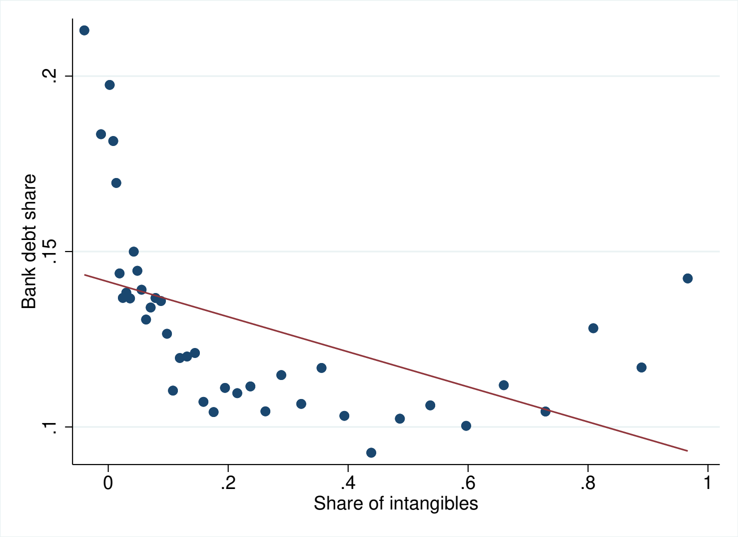


Source: intaninvest.net.

Motivation

- Developed economies now invest more in intangible than tangible capital (Corrado and Hulten, 2010)
- Bank debt important in the life-cycle of firms
  - Dominant source of financing for EU SMEs (ECB, 2019)
- Intangible-intensive firms credit constrained?
  - Our focus: Collateral hard to secure on the basis of intangible assets
  - Particularly salient for young firms

Strapped for cash?



Notes: Bank debt share is bank debt relative to sales. Share of intangibles is intangible assets relative to fixed assets. The figure shows a binned scatterplot after residualizing the x and y variables on NACE 2-digit fixed effects. Data from 2010.

This paper

- How do collateral constraints affect firms' financing and performance?
- What are the overall implications for growth and misallocation?
- Closing the gap between the firm-level effects of financial constraints and the aggregate effects of financial constraints and misallocation

This paper

- *Micro*:
  - Exploit a 2015 reform allowing firms to use *patents* as collateral
  - DiD comparing exposed firms to unexposed firms before/after reform
- *Macro*: Aggregate impact on labor productivity
  - Develop parsimonious quantitative framework. Two forces:
    - Capital deepening: Aggregate capital / labor ratio $\uparrow$
    - Misallocation: Direction & magnitude depends on distribution of initial credit constraints
  - Use DiD estimates for model quantification

Our contribution

- Exploit clean quasi-natural experiment to assess the impact of collateral constraints
  - Much of the previous literature is either theoretical (Long, 2002, Amable et al., 2010, Moll, 2014) or not able to address causality (Hall, 2019)
- Analyze aggregate effects in parsimonious quantitative framework
  - Avoid TFPR estimation commonly used in the misallocation literature
  - Allows for any distribution of initial & change in constraints.
  - Simple mapping between reduced form and model.
- Cover the universe of active firms, including young and small firms
  - Many previous papers have used data on publicly listed firms (Brown et al., 2009, Chava et al, 2017, Mann, 2018)
  - Unlisted firms for aggregate outcomes (Caglio et al, 2022)
- Address complementarity bank debt $\Longleftrightarrow$ equity funding

Outline

- Theoretical framework
- Data
- Micro: Reform details, testable predictions, empirical strategy, results
- Macro: Quantification, results
- Conclusions

Theoretical framework

Model, part I

- Simple monopolistic competition framework, in the spirit of Hsieh & Klenow (2009)
- Production function for firm i

$$Y_i = A_i K_i^{\alpha_s} L_i^{1-\alpha_s}$$

- Demand:
  - CES across firms within a sector s
  - Price index P_s & elasticity of substitution σ
  - Cobb-Douglas across sector with expenditure share θ_s Details
- The firm:
  - Maximizes profits
  - Takes wages w and interest rate r as given

Credit constraints

- *Credit constraints*: The total capital that the firm has is less than the amount it would want at the interest rate that it is currently paying (Banerjee & Duflo, 2014)

- Capital distortion $\tau_i \geq 1$. Firms will invest in capital until its MRPK equals $\tau_i R$ ▸ Graph

- For constrained firms with $\tau_i > 1$, compared to optimal situation with no financial constraints:
  - $MRPK_i$ is higher than optimal
  - Capital stock is lower than optimal

Factor demand

- Profits for firm i

$$\pi_i = p_i Y_i - wL_i - \tau_i r K_i$$

- Firm i's optimal price is a constant markup over marginal costs

$$p_i = \kappa \frac{\sigma}{\sigma - 1} \frac{(\tau_i r)^{\alpha} w^{1-\alpha}}{A_i}$$

- Firm i's demand for labor and capital:

$$K_i = D_s \frac{\alpha}{r} A_i^{\sigma-1} \tau_i^{\alpha(1-\sigma)-1}$$

$$L_i = D_s \frac{1-\alpha}{w} A_i^{\sigma-1} \tau_i^{\alpha(1-\sigma)}$$

where D_s is an industry-specific demand shifter

- These expressions guide our empirical analysis

Empirics

Data I

- Administrative firm register data from Statistics Norway
  - Covers all firms in all sectors
  - Key variables: firm age, number of employees

- Administrative firm-level accounting data from Statistics Norway
  - All joint-stock firms in all sectors
  - Key variables: Sales, employment, tangible/intangible capital
  - Intangible capital: R&D, patents, goodwill. Deferred taxes dropped

Data II

- Bank data from the Norwegian Tax Authority (Skatteetaten)
  - Yearly data on all loans given by financial institutions registered in Norway (firm-bank-year-loan)
  - Key variables: value of loan, interest paid
- Patent data from the Norwegian Patent Office
  - key variables: patent applications, status of patent
- Shareholder data by firm
  - # shareholders, and issue of new stock
- Link all datasets with a unique firm identifier
- Main analysis 2010-2018

Reduced form

The reform

- The use of collateral is regulated by law. Bill passed on 23 January 2015 to allow firms to use patents as collateral
- The reform was introduced to alleviate financial constraints for firms with primarily intangible rather than tangible assets
- Not part of a bigger tax reform. Effective as of 1st July 2015
- Norway late in the game: 38% of U.S. patenting firms had previously pledged patents as collateral in 2013 (Mann, 2018)

Testable hypotheses

- For constrained firms, reform leads to
  - Increase in capital stock (tangible or intangible)
  - More bank borrowing
- If borrowing $\uparrow$ but no change in firm outcomes, suggests that firm is substituting from other forms of financing to bank debt.

Empirics: Methodology

Diff-in-diff: Compare firms affected by the reform to other firms pre/post 2015:

$$y_{it} = \alpha_i + \beta P_i \times Post_t + \gamma X_{i0} \times \delta_t + \delta_{st} + \varepsilon_{it},$$

- $P_i = 1$ if firm i has ≥ 1 patent applications between 2010 and 2015
- α_i firm FE, δ_{st} industry-year FE (NACE 2-digit)
- $Post_t = 1$ if $t > 2015$

- X_{i0}: Log employment, log capital (fixed assets), share of intangibles, dummy for having received public funding
  - Measured at baseline and interacted with year dummies

Outcome variables

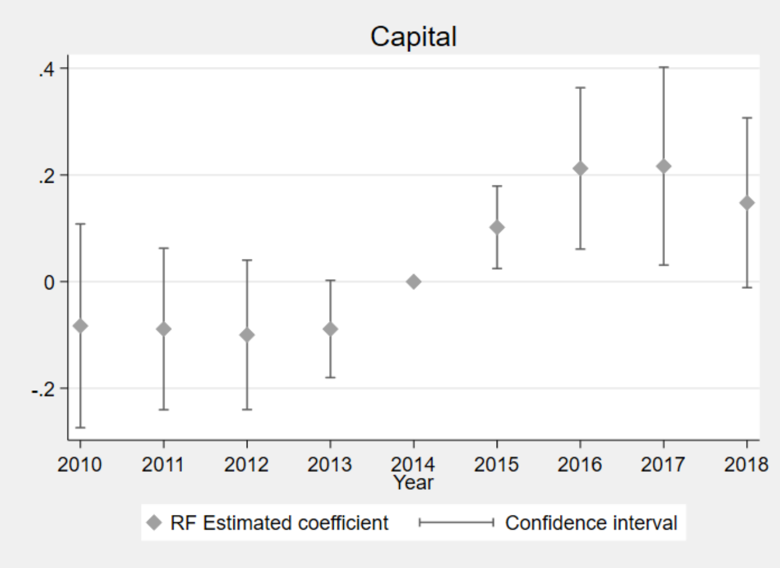
- Measures of firm performance:
  - Log employment
  - Capital
  - Log sales
  - MRPK (operating income divided by total fixed assets)
  - Intangible capital
- Measures of credit:
  - Bank loan dummy
  - Bank debt
  - Total bank debt relative to sales
  - Short term relative to total debt
  - Number of bank connections
  - Interest rate, $i_{it} = \frac{Interest_{it}}{(Debt_{it} + Debt_{it-1})/2}$
- Equity funding
  - new stocks
  - new investors

Results: Firm performance

	Log empl	Log sales	Capital	MRPK	Intangible capital
	(1)	(2)	(3)	(4)	(5)
$Post_t \times Pat_i$	0.089^{***}	0.022	0.223^{**}	-0.246^{***}	1.133^{***}
	(0.030)	(0.041)	(0.103)	(0.080)	(0.286)
Firm FE	Yes	Yes	Yes	Yes	Yes
Controls*year	Yes	Yes	Yes	Yes	Yes
Industry*year FE	Yes	Yes	Yes	Yes	Yes
Estimator	OLS	OLS	PPML	OLS	PPML
Observations	763,161	748,284	753,992	739,488	118,605

Standard errors in parenthesis are clustered on firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Capital refers to fixed assets. MRPK refers to operating income divided by total fixed assets. Controls include baseline levels of: log employment, log capital, share of intangibles and a dummy for public funding, all interacted with year dummies.

Pre-trends


Capital
.4
.2
0
-.2
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year
RF Estimated coefficient
Confidence interval

Results: Credit

	Bank loan	Bank debt	$\frac{Bank\ Debt}{Total\ Sales}$	$\frac{Short\ Debt}{Total\ Debt}$	No of Banks	Interest rate
	(1)	(2)	(3)	(4)	(5)	(6)
$Post_t \times Pat_i$	0.049***	0.594***	0.014**	−0.023**	0.146***	0.001
	(0.019)	(0.175)	(0.006)	(0.010)	(0.041)	(0.003)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls*year	Yes	Yes	Yes	Yes	Yes	Yes
Industry*year FE	Yes	Yes	Yes	Yes	Yes	Yes
Estimator	OLS	PPML	OLS	OLS	OLS	OLS
Observations	763,161	501,278	723,632	758,311	763,161	336,497

Standard errors in parenthesis are clustered on firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls include baseline levels of: log employment, log fixed assets, share of intangibles and a dummy for public funding, all interacted with year dummies.

Taking stock

- More capital & employment & intangible investments
- More bank borrowing
- Interest rate unchanged
- Suggests that on average, treated firms are indeed credit constrained

Robustness & further results

- Heterogeneity: young firms ▸ Link
- Continuous treatment, granted patents
- Pre-trends for credit ▸ Link
- Placebo exercise on pre-sample ▸ Link
- Equity funding ▸ Link
- Credit constraint measures from the Financial Conduct Authority (Finanstilsynet) ▸ Link

Quantitative framework

Quantitative framework

- Aggregate effects of relaxing the credit friction.
- Quantify change in aggregate output per worker. Mechanisms:
  - Capital deepening (aggregate K/L up)
  - Misallocation
- To answer this question, we need to go back to the model
- Consider initial $\longrightarrow$ counterfactual equilibrium with relative change $\hat{x} = x'/x$
  - "Exact hat algebra" approach by Dekle et al (2018)
- Baseline: Infinitely elastic capital supply, exogenous interest rate R

Comparative statics

Results:

- Change in firm-level capital stock

$$\hat{K}_i = \hat{\tau}_i^{\alpha_s(1-\sigma)-1} \hat{P}_s^{\sigma-1}$$

- Change in sector-level price index:

$$\hat{P}_s = \left[\sum_{i=1}^{M_s} \omega_i \hat{\tau}_i^{\alpha_s(1-\sigma)} \right]^{1/(1-\sigma)}$$

where ω_{si} is initial market shares, $\omega_{si} = sales_{si} / \sum_{i \in s} sales_{si}$

- $P_s \downarrow$ if one or more firms in the sector experiences reduced credit constraints

- Firms with $\hat{\tau}_i = 1$ will contract as they face more competition from firms with reduced credit constraints

Aggregate outcomes

- Follow Hsieh & Klenow (2009) and express industry output:

$$Y_s = TFP_s K_s^{\alpha_s} L_s^{1-\alpha_s}$$

- Change in industry labor productivity:

$$\frac{\hat{Y}_s}{\hat{L}_s} = T\hat{F}P_s \left(\frac{\hat{K}_s}{\hat{L}_s} \right)^{\alpha_s} = \frac{1}{\hat{P}_s}$$

- Two distinct sources of industry (and aggregate) labor productivity growth:
  - industry capital intensity increases (K_s/L_s goes up)
  - potentially reduced misallocation (if TFP_s goes up)

Two propositions

Proposition

The relative change in the credit friction is given by

$$\hat{\tau}_i = \left(\frac{\hat{K}_i}{\hat{P}_s^{\sigma-1}} \right)^{1/[\alpha_s(1-\sigma)-1]} .$$

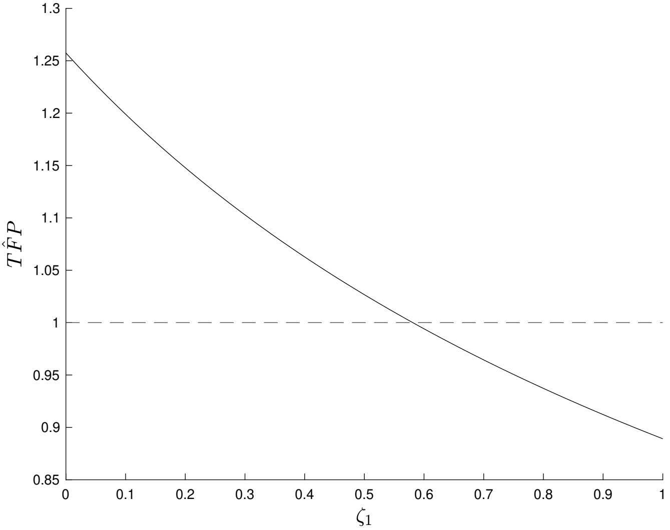
$\longrightarrow$ DiD estimate of within-industry capital growth identifies capital friction

Proposition

Consider a sector production function $Y_s = TFP_s K_s^{\alpha_s} L_s^{1-\alpha_s}$. *The relative change in industry-level TFP is*

$$\hat{TFP}_s = \frac{\left[\sum_{i=1}^{M_s} \omega_i \hat{\tau}_i^{\alpha_s(1-\sigma)} \right]^{1/(\sigma-1)}}{\left[\sum_{i=1}^{M_s} \zeta_i \hat{\tau}_i^{-1} \right]^{\alpha_s}},$$

where ζ_i *are initial capital shares,* $\zeta_i = K_i / \sum_{i=1}^{M_s} K_j$.



The figure shows $T\hat{F}P_s$ for different values of ζ_1. $\sigma = 5$, $\alpha = 0.5$, $\hat{\tau}_1 = 0.5$, $\hat{\tau}_2 = 1$, $\omega_1 = \omega_2 = 0.5$.

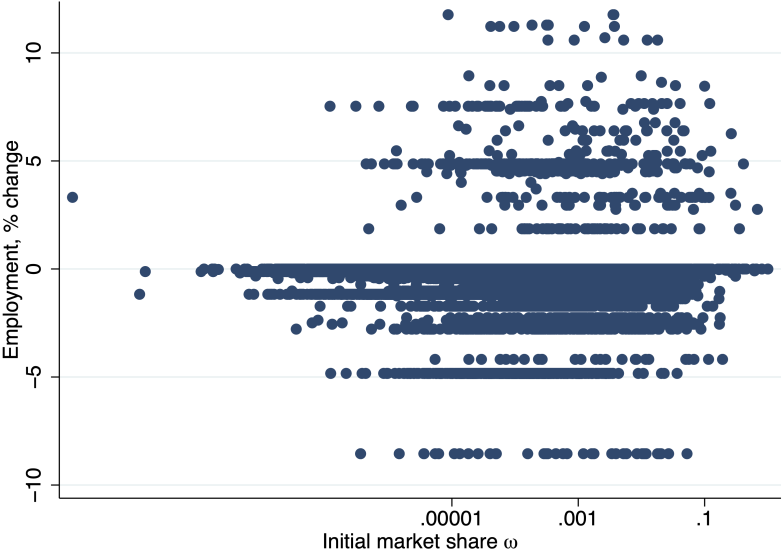
Quantification

Data requirements:

β	DiD estimate, ln $Capital_i$	0.22	
α_s	Capital share	0.30 (mean)	1 - (wage costs)/(total costs)
σ	Elasticity of substitution	4	Broda & Weinstein (2006)
ω_{si}	Sales shares	Firm level	Our data, 2014
ζ_i	Capital shares	Firm level	Our data, 2014

- No need to calculate TFPR (used to infer frictions in misallocation literature)

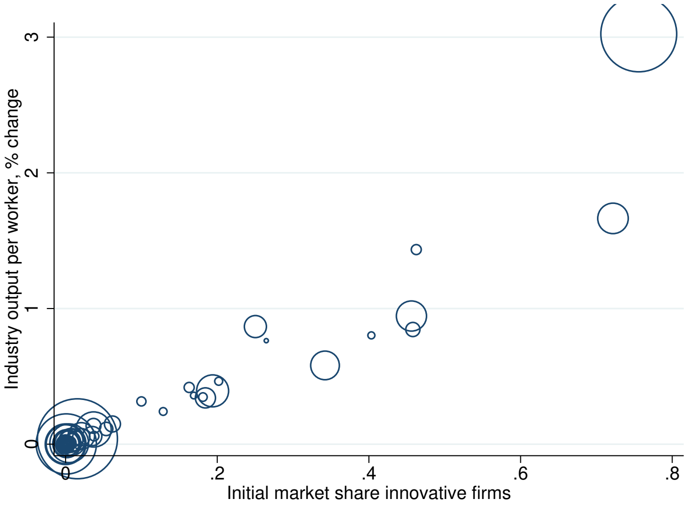
Results: Reallocation



Results: Reallocation

- Estimate $\hat{\tau}_i = 0.89$, implicit capital cost $\downarrow$ 11% for a treated firm, relative to a control firm
- No clear relationship between initial market share and subsequent growth
  - Both small and large firms affected by reform
- $6.7 \longrightarrow 7.0\%$ of aggregate employment $\approx$ 4000 workers reallocated from control to treated firms.

Results: Aggregate productivity growth



- Up to 3% increase in industry output per worker.
- Gains concentrated in sectors where treated firms have big market share.

Results: Misallocation

- Recall from theory: Industry output per worker $\uparrow$ because
  1. Capital deepening (aggregate K/L up)
  2. Ambigous effect on misallocation
     - Frictions reduced for firms with high initial τ: $T\hat{F}P_s \uparrow$
     - Frictions reduced for firms with low initial τ: $T\hat{F}P_s \downarrow$
     - Model tells us that we need both ω_i and ζ_i to sort this out.

- We find channel 1 is quantitatively dominant
  - Growth in Y_s/L_s order of magnitude larger than growth in TFP_s
  - $T\hat{F}P_s$ negative for some industries

- TFP losses from misallocation smaller than typical estimates in the literature (e.g., Midrigan and Xu, 2014)

Results: Aggregate impact

- Aggregate gains from relaxing the credit constraint:
  - According to the model: Increase in output per worker $1/\hat{P} = 1/\prod_s \hat{P_s^{\beta_s}} = 1.006$.
  - Equivalent to 0.62 billion USD
  - Same magnitude as total subsidies given by the main governmental agency for innovation and industrial policy in Norway (2021).

- Back-of-the-envelope calculation:
  - The total implicit cost of the collateral constraint is $RK\left(\tau - \tau'\right) = RK\tau'\left(1/\hat{\tau} - 1\right)$, where K is the intital aggregate capital stock for treated firms
  - Use the median bank interest rate in our sample $R = 0.07$, assume τ'=1 (credit friction is completely eliminated)
  - Total implicit cost = 0.73 billion USD

- Results from extension with fixed K: Link

Summary and conclusions

- The reform had a significant impact on firm's bank borrowing:
    - More likely to get bank loans, increased number of bank connections
    - No impact on the interest rate
- The reform had a significant impact on the real economy:
    - Increased capital stock, employment and intangibles
- Quantitative model suggests large improvements in output mostly due to capital deepening
    - Misallocation plays a smaller role
- Together, findings consistent with credit (collateral) constraints
    - Policies to increase the pledgeability of patents alleviate financial constraints on innovation

Thank you!

Model details

- Aggregate output is produced using a Cobb-Douglas production function:

$$Y = \prod_{s=1}^{S} Y_s^{\theta_s},$$

where Y_s is output from industry s and $\sum_{s=1}^{S} \theta_s = 1$

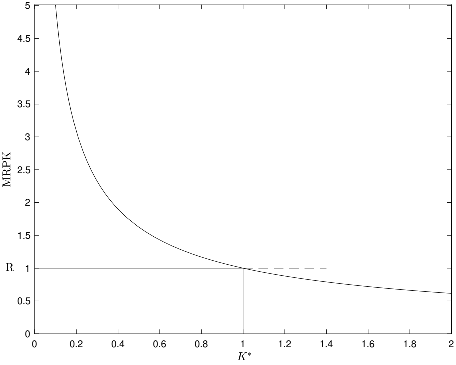
- Sectoral output is itself a CES aggregate of M_s firms producing differentiated products:

$$Y_s = \left(\sum_{i=1}^{M_s} Y_i^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)},$$

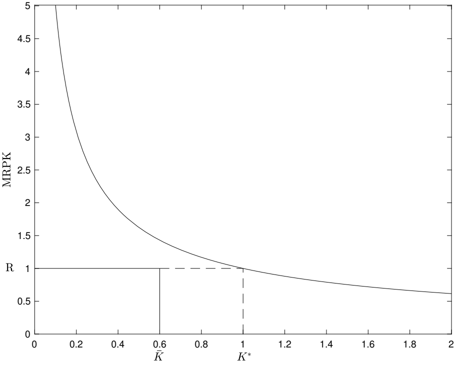
where σ is the elasticity of substitution across firms and Y_i is output of firm i

- P_s denotes the corresponding sector-level CES price index Back

Testable hypotheses



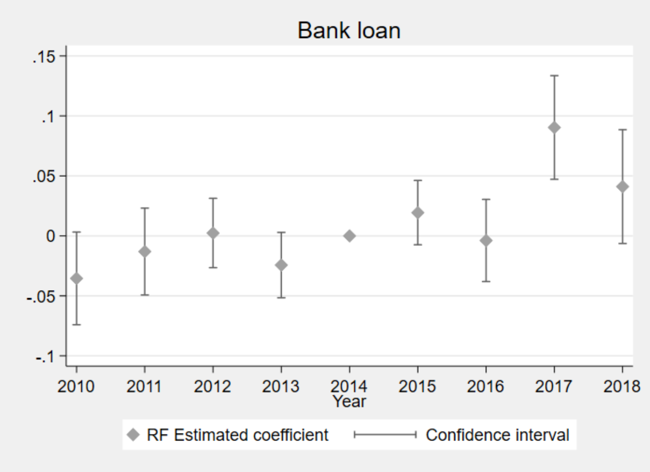
Unconstrained



Constrained

Back

Pre-trends for bank dummy



Back

Results: Credit and Young firms

	Bank loan	Bank debt	$\frac{Bank\ Debt}{Total\ Sales}$	$\frac{Short\ Debt}{Total\ Debt}$	No of Banks	Interest rate
	(1)	(2)	(3)	(4)	(5)	(6)
$Post_t \times P_i$	0.043^{**}	0.634^{***}	0.010	-0.009	0.145^{***}	0.001
	(0.020)	(0.180)	(0.06)	(0.010)	(0.044)	(0.003)
$Post_t \times P_i \times Young_i$	0.063	-0.858	0.032^{*}	-0.108^{***}	0.046	0.002
	(0.052)	(0.643)	(0.019)	(0.032)	(0.111)	(0.007)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls*year	Yes	Yes	Yes	Yes	Yes	Yes
Industry*year FE	Yes	Yes	Yes	Yes	Yes	Yes
Young*year FE	Yes	Yes	Yes	Yes	Yes	Yes
Estimator	OLS	PPML	OLS	OLS	OLS	OLS
Observations	763,161	501,278	723,632	758,311	763,161	336,497

Standard errors in parenthesis are clustered on firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls include baseline levels of: log employment, log fixed assets, share of intangibles and a dummy for public funding, all interacted with year dummies.

$Young_i = 1$ if a firm is 6 years or younger in 2015 Back

Results: Firm Performance and Young Firms

	Log empl	Log sales	Capital	MRPK	Intangible capital
	(1)	(2)	(3)	(4)	(5)
$Post_t \times Pat_i$	0.066^{**}	-0.003	0.207^{**}	-0.179^{**}	1.202^{***}
	(0.032)	(0.042)	(0.105)	(0.077)	(0.296)
$Post_t \times Pat_i \times Young_i$	0.216^{**}	0.287^{**}	0.426^{***}	-0.543	-0.784^{*}
	(0.085)	(0.140)	(0.131)	(0.341)	(0.442)
Firm FE	Yes	Yes	Yes	Yes	Yes
Controls*year	Yes	Yes	Yes	Yes	Yes
Industry*year FE	Yes	Yes	Yes	Yes	Yes
Young*year FE	Yes	Yes	Yes	Yes	Yes
Estimator	OLS	OLS	PPML	OLS	PPML
Observations	763,161	748,284	753,992	739,488	118,605

Standard errors in parenthesis are clustered on firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Capital refers to fixed assets. MRPK refers to operating income divided by total fixed assets. Controls include baseline levels of: log employment, log fixed assets, share of intangibles and a dummy for public funding, all interacted with year dummies.

$Young_i = 1$ if a firm is 6 years or younger in 2015 Back

Results: Credit – Constrained firms

	Bank loan	Bank debt	$\frac{Bank\ \ Debt}{Total\ \ Sales}$	$\frac{Short\ \ Debt}{Total\ \ Debt}$	No of Banks	Interest rate
	(1)	(2)	(3)	(4)	(5)	(6)
$Post_t \times Pat_i$	0.051	0.486**	0.020*	−0.015	0.122*	0.002
	(0.031)	(0.206)	(0.012)	(0.018)	(0.065)	(0.004)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls*year	Yes	Yes	Yes	Yes	Yes	Yes
Industry*year FE	Yes	Yes	Yes	Yes	Yes	Yes
Estimator	OLS	PPML	OLS	OLS	OLS	OLS
Observations	190,068	131,070	170,052	188,379	190,068	93,603

Standard errors in parenthesis are clustered on firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls include baseline levels of: log employment, log fixed assets, share of intangibles and a dummy for public funding, all interacted with year dummies.

Results: Firm Performance – Constrained firms

	Log empl	Log sales	Capital	MRPK	Intangible capital
	(1)	(2)	(3)	(4)	(5)
$Post_t \times Pat_i$	0.128^{**}	0.086	0.318^{**}	-0.451^{***}	0.991^{***}
	(0.054)	(0.081)	(0.162)	(0.188)	(0.381)
Firm FE	Yes	Yes	Yes	Yes	Yes
Controls*year	Yes	Yes	Yes	Yes	Yes
Industry*year FE	Yes	Yes	Yes	Yes	Yes
Estimator	OLS	OLS	PPML	OLS	PPML
Observations	190,068	182,611	187,172	177,322	31,239

Standard errors in parenthesis are clustered on firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls include baseline levels of: log employment, log fixed assets, share of intangibles and a dummy for public funding, all interacted with year dummies.

Back

Falsification test

	Bank loan	Bank debt	$\frac{Bank\ Debt}{Total\ Sales}$	Capital	MRPK	Intangible capital
	(1)	(2)	(3)	(4)	(5)	(6)
$Post2010 \times Pat10_i$	-0.007	0.112	0.005	-0.003	-0.126	-1.003^{**}
	(0.016)	(0.194)	(0.005)	(0.084)	(0.087)	(0.409)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls*year	Yes	Yes	Yes	Yes	Yes	Yes
Industry*year FE	Yes	Yes	Yes	Yes	Yes	Yes
Estimator	OLS	PPML	OLS	PPML	OLS	PPML
Observations	854,061	593,554	803,368	849,584	827,646	146,601

Standard errors in parenthesis are clustered on firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls include baseline levels of: log employment, log fixed assets, share of intangibles and a dummy for public funding, all interacted with year dummies.

Placebo on pre-sample period 2005-2015. Back

Equity

- Is equity a substitute or complement to debt?
- Outcome variables:
  - New stocks: net issue dummy $= 1$ if firm issues new stock.
  - Number of sharesholders

Results: Equity funding

	Equity issue dummy	Equity issue dummy	Log shareholders	Log shareholders
	(1)	(2)	(3)	(4)
$Post_t \times Pat_i$	-0.024^{**}	-0.047^{***}	-0.052	-0.078^{**}
	(0.010)	(0.011)	(0.035)	(0.037)
$Post_t \times Pat_i \times Young_i$		0.116^{***}		0.203^{*}
		(0.037)		(0.109)
Firm FE	Yes	Yes	Yes	Yes
Controls*year	Yes	Yes	Yes	Yes
Industry*year FE	Yes	Yes	Yes	Yes
Young firm*year FE	No	Yes	No	Yes
Observations	763,161	763,161	665,403	665,403

Standard errors in parenthesis are clustered on firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls include baseline levels of: log employment, log fixed assets, share of intangibles and a dummy for public funding, all interacted with year dummies.

Complementarities: Removing collateral constraint leads to issue of new stock. Back

How different are firms with intangibles?

	Firms w/ intangibles		Firms w/o intangibles	
	Mean	Median	Mean	Median
Age	8.48	8	9.54	10
Employees	23.39	2	14.03	5
Bank connections	0.63	0	0.91	1
Bank debt dummy	0.31	0	0.50	1
N	11,696		65,353	

How different are firms with patents?

	Firms w/ patents		Firms w/o patents	
	Mean	Median	Mean	Median
Age	10.10	11	9.37	10
Employees	125.73	15	14.25	4
Bank connections	1.13	1	0.86	1
Bank debt dummy	0.52	1	0.47	0
N	835		76,214	

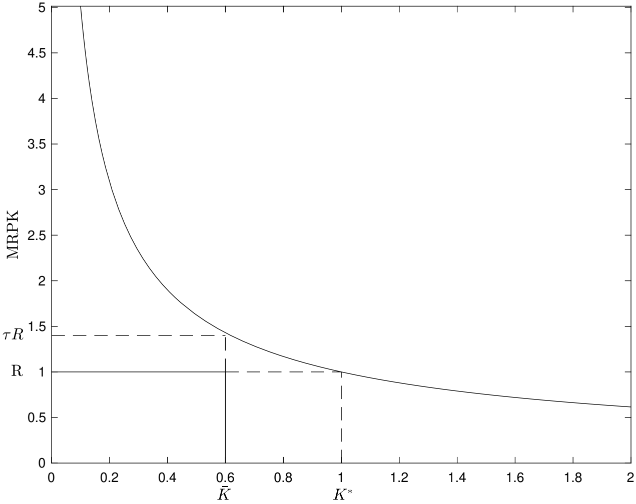
Patenting firms and bank debt

	Bank loan dummy	Bank loan dummy	Bank loan dummy	Bank loan dummy
	(1)	(2)	(3)	(4)
P_i	0.065**	-0.043	-0.041	0.017
	(0.030)	(0.031)	(0.031)	(0.034)
Log emp		0.079***	0.073***	0.063***
		(0.009)	(0.009)	(0.007)
Age			0.005***	0.003***
			(0.001)	(0.001)
Industry FE	No	No	No	Yes
Observations	84,063	84,063	84,063	84,063

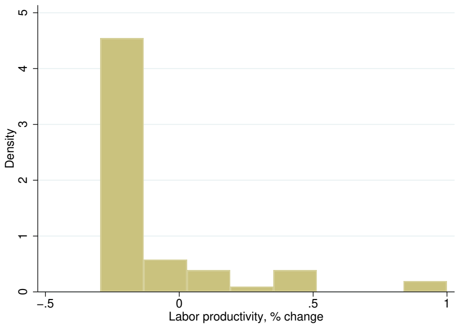
Data from 2013. Standard errors in parenthesis are clustered on industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

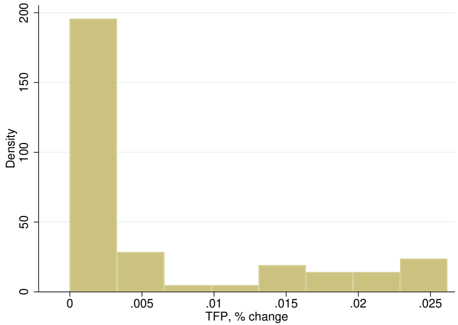
Back

Model: Friction vs constraint



Extension: Endogenous R





- Replace open economy assumption with endogenous R and fixed K.
- Some sectors lose as K is reallocated to other sectors.
- Aggregate growth is *only* due to misallocation
  1. across firms
  2. across sectors Back