The Aggregate Effects of Credit Market Frictions: Evidence from Firm-level Default Assessments

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Motivation

- Financial crisis has heightened interest in the **role of financial factors in shaping firm-level and aggregate economic performance**
- Key issue is whether **weak productivity growth** since global financial crisis can be attributed to financial factors
- To make progress on this, we need **specific data on how credit frictions affect firms**
- Need to take into account **firm heterogeneity**
- The UK is an interesting case given dependence on bank finance (especially SMEs)
  - **Unique data** on firm-level credit frictions
  - which we match with firm-level data on real side

Key Contributions

- Develop a theoretical model with **equilibrium default** to show that ex-ante default assessments matter for capital allocation
  - Unlike most models in the literature which assume away default
- Use default risk as a measure of firm-level credit frictions
- Estimate **firm-level default risk** using S&P's credit assessment model
  - This tool is widely used among lenders when making lending decisions
- Apply framework to a **unique data set** which matches firm-level default risk with encompassing data on real side of the economy
  - Entire non-financial sector (not just manufacturing)
  - Entire size distribution of firms
- Give a **quantitative assessment of output and productivity losses due to credit frictions** as measured by default risk

Key Results

- **Credit frictions depress output**: Average annual loss of $\approx 4.2\%$ over 2004-2012
- **Losses have been increasing since the crisis (persistent)**
- Frictions account for $\approx 18\%$ of the labor productivity gap at the end of 2012
- Losses are **driven primarily by lower aggregate capital**, **not misallocation of credit** across heterogeneous firms
- Findings mainly due to frictions on **SME credit markets**
- *Conservative* estimates: All effects double using expected output as benchmark instead of realized output

Literature

- **Macro-economic effects of financial frictions**
  - Midrigan & Xu (2014); Moll (2014); Asker et al (2014); Gilchrist et al (2013); Jeong and Townsend (2007); Amaral and Quintin (2010); Buera and Shin (2013); Moll (2014); Catherine et al (2018)
- **Causes of the productivity slowdown**
  - Gopinath et al (2017); Syverson (2017); Gordon (2016); Brynjolfsson et al (2017); Bloom et al (2017); Besley and Van Reenen (2014); LSE Growth Commission; Haskel & Westlake (2017)
- **Impact of Great Recession via credit frictions**
  - Chodorow-Reich (2014); Huber (2017); Greenstone et al (2014); Bentolila et al (2015); Schivardi et al (2018)
- **Misallocation literature**
  - Restuccia & Rogerson (2008); Hsieh & Klenow (2009, 2014); Bartelsman et al (2013); Asker et al (2014); Hopenhayn (2012,2014); Baqaee and Fahri (2017)

Roadmap

- Theoretical framework
- Data and measurement issues
- Core results
  - Micro-economic validation of our measure of credit frictions
  - Macro-economic implications
  - SMEs versus large firms
  - Misallocation versus scale effects
- Comparison with conventional approach to measurement of credit frictions

Theoretical framework: Firm-level decisions

- Start with **general framework**, then model **specific credit frictions**
- Production for firm n at time t: $Y_{nt} = \theta_{nt} \left(L_{nt}^{1-\alpha} K_{nt}^{\alpha} \right)^{\eta}$ with $\eta < 1$
- Firms maximize profits:

$$\Pi_{nt} = Y_{nt} - \left(\frac{w_t}{\tau_{nt}^{L}} \right) L_{nt} - \left(\frac{\rho_t}{\tau_{nt}^{K}} \right) K_{nt} \tag{1}$$

- FOCs for L and K imply

$$Y_{nt} = \theta_{nt}^{\frac{1}{1-\eta}} \psi\left(w_t, \rho_t\right) \tau_{nt} \tag{2}$$

- where distortions are:

$$\tau_{nt} \equiv \left(\tau_{nt}^{L} \right)^{\frac{(1-\alpha)\eta}{1-\eta}} \left(\tau_{nt}^{K} \right)^{\frac{\alpha\eta}{1-\eta}} \tag{3}$$

- Frictionless world: $\tau_{nt}^{L} = \tau_{nt}^{K} = 1$ for all firms $\rightarrow$ output solely determined by θ_{nt}, α and η, and macro factor prices w_t and ρ_t

Monopolistic competition

Theoretical framework: Aggregate implications

$$\textbf{Aggregate output} = Y_t = \psi(w_t, \rho_t)\hat{\theta}_t^{\frac{1}{1-\eta}}\Theta_t \tag{4}$$

- where $\hat{\theta}_t = \left(\sum_{n=1}^{N} \theta_{nt}^{\frac{1}{1-\eta}}\right)^{1-\eta}$ is aggregate fundamental *TFP*

$$\textbf{Credit market efficiency} = \boldsymbol{\Theta_t} = \sum_{\boldsymbol{n=1}}^{\boldsymbol{N}} \boldsymbol{\omega_{nt}\tau_{nt}} \tag{5}$$

- $\omega_{nt} = \left(\frac{\theta_{nt}}{\hat{\theta}_t}\right)^{\frac{1}{1-\eta}}$ are productivity weights s.t. $\sum_{n=1}^{N} \omega_{nt} = 1$

Equilibrium wage

Output and labor productivity losses

- **Efficient benchmark = no credit frictions = no default =** $\tau_{nt}^{K} = 1$
- Deviation of actual output from benchmark is given by

$$\textbf{Output loss} = \mathbf{1} - \boldsymbol{\Theta}_{\boldsymbol{t}}^{\frac{\mathbf{1}-\boldsymbol{\eta}}{\mathbf{1}-\boldsymbol{\alpha\eta}}} \tag{6}$$

- Change in labor productivity (= wage) that can be explained by changes in credit frictions is given by

$$\textbf{Productivity change} = \frac{1-\eta}{1-\alpha\eta}\left[\ln\Theta_t - \ln\Theta_{t-1}\right] \tag{7}$$

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Key measurement challenges

- How do we **measure credit frictions** (τ_{nt}^{K})?
- How do we **measure relative fundamental productivity** (ω_{nt})?

Measurement of credit frictions (τ_{nt}^K)

- Simple model of equilibrium credit contracts with moral hazard (unobserved costly managerial effort) to micro-found a measurable proxy for τ_{nt}^K
- Model implies that **repayment probability** is a sufficient statistic for capital allocation

$$\boldsymbol{\tau_{nt}^K = \phi_{nt} = \textbf{repayment probability of firm } n \textbf{ at time } t}$$

Equilibrium credit contracts

Measurement of relative productivity at the firm level

- Use theory as a guide (*instead of* TFP estimation with capital stock estimates)

$$\textbf{Relative productivity} = \omega_{nt} = \frac{\gamma_{nt}\Theta_t}{\phi_{nt}^{\frac{\alpha\eta}{1-\eta}}} \tag{8}$$

- where γ_{nt} is the firm's employment share in its industry
- **In the absence of distortions,** $\omega_{nt} = \gamma_{nt}$; i.e. relative $TFP =$ relative size
- If observe frictions (ϕ_{nt} and Θ_t): can purge distorted employment shares
- We also have

$$\sum_{n=1}^{N} \omega_{nt} = 1 \tag{9}$$

- Given data on repayment probabilities and employment shares, solve (8)-(9) for Θ_t and ω_{nt}

Data set

- Unique data set which matches
  - A **time-varying firm-specific measure of credit frictions** (repayment probability) with
  - UK Census Bureau (ONS) **administrative panel data** on employment, value added, investment, wage bill etc.

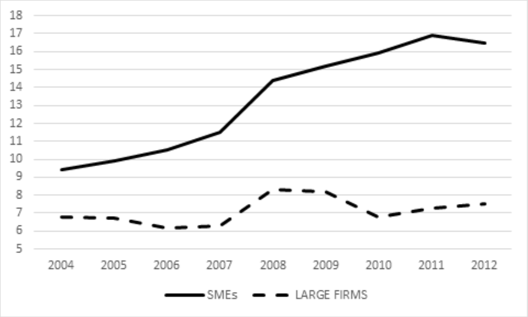
- **Estimate repayment probabilities using credit scoring model** (S&P's)
  - **Inputs**: all public & private company accounts from BvD Orbis, industry & macro factors
  - **Output**: risk score (aaa, bbb, etc.)
  - Match risk score to **historical default rates** to capture historical information set of lenders

Data set

- Data set covers **entire non-financial sector**
  - Not just manufacturing
  - Entire size distribution of firms
  - Public and private firms

Sample size | Productivity developments | Sample representativeness

Default probabilities



Aggregate probability of default at the 1-year horizon (in %)

- Probability of default **systematically larger for SMEs**
- **Significant increase after 2007** for both types of firms
- Remains higher than pre-crisis, dramatically so for SMEs
- Clear **size heterogeneity** highlights **need for sample that covers entire size distribution**

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Validation of repayment probability as a proxy for credit frictions (Table 2)

- Repayment probabilities affect firm behavior as suggested by the theory
- OLS with **year and firm fixed effects** (i.e. controlling for unobserved firm heterogeneity)

	(1)	(2)	(3)	(4)	(5)
	Log(employment)	Log(value added)	Log(capital stock)	Log(investment)	Log(investment/labor ratio)
Repayment probability	0.104*** (0.025)	0.608*** (0.045)	0.087*** (0.021)	**0.913***** (0.095)	0.820*** (0.094)
Observations	61,168	61,168	61,168	61,168	61,168

- **Non-trivial coefficients**: e.g. 10pp increase in repayment probability associated with a 9% increase in investment

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Aggregate implications: core results (Table 3)

	Credit market efficiency	Percentage loss of output
2004	0.907	3.19
2005	0.903	3.33
2006	0.905	3.27
2007	0.903	3.35
2008	0.875	4.36
2009	0.865	4.73
2010	0.864	4.77
2011	0.854	5.13
2012	0.849	5.32
Average	0.881	4.16

- 4.2% average output loss per annum in 2004-2012
- **Persistent increase in losses from 2007 onwards**
- Larger losses and deterioration for SMEs (4.9% versus 2.8%)

SMEs versus large firms

Scale effects or misallocation?

- **Output losses can be decomposed into two parts**
- **Scale effect**: impact of credit frictions on output through the aggregate stock of capital and labor inputs, holding the joint distribution of frictions and productivity constant
- **Misallocation effect**: impact of credit frictions on output holding both the aggregate stock of capital and labor fixed (depresses aggregate TFP)
  - Captures **how frictions vary with the relative fundamental productivity** of firms
  - Efficiency = channeling inputs to most productive firms

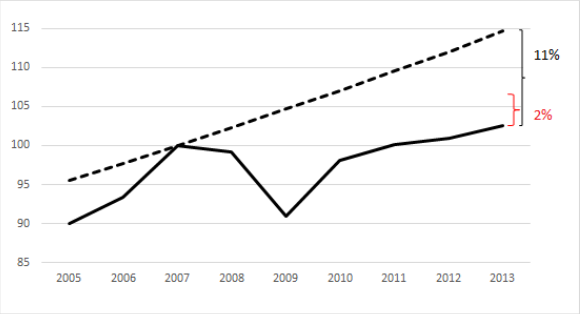
Technical details

Aggregate implications: scale and misallocation (Table 3)

	Overall percentage loss of output	Percentage loss of output due to scale effects	Percentage loss of output due to misallocation
2004	3.19	3.08	0.11
2005	3.33	3.22	0.11
2006	3.27	3.16	0.11
2007	3.35	3.24	0.11
2008	4.36	4.21	0.15
2009	4.73	4.54	0.19
2010	4.77	4.58	0.19
2011	5.13	4.90	0.23
2012	5.32	5.09	0.23
Average	4.16	4.00	0.16

- **Scale effect is main driver of output losses**
- Increase in misallocation losses since 2008 but relatively small
- Small misallocation effects in line with e.g. Midrigan & Xu (2014), Schivardi et al (2018) for other countries

How much of the productivity gap can we explain?



Real GVA per worker - actual versus trend, 2007=100

- Had default risks remained as in 2007, output would have been ≈ 2% higher in 2012
- **Almost one-fifth of the gap between actual and trend productivity by end 2012**

Robustness checks

- **Results on credit frictions are robust to:**
- Using Solow residuals to measure relative productivity (ω_{nt})
- Using alternative values of output-capital elasticity (α)
  - Losses increase as α gets bigger (capital more important in production)
- Using alternative values of parametrization of returns to scale (η)
  - Losses increase as we get closer to CRS
- Including labor market frictions
- Expected output benchmark (estimates of output losses roughly double in magnitude)

Labor market frictions | Expected versus realized output losses

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Comparison with conventional approach

- **Conventional measure of credit market distortions**
- Recover **implicit "wedge"** indirectly from data on capital and output

$$\tau^K_{nt} = \frac{\rho_t K_{nt}}{\alpha \eta Y_{nt}}$$

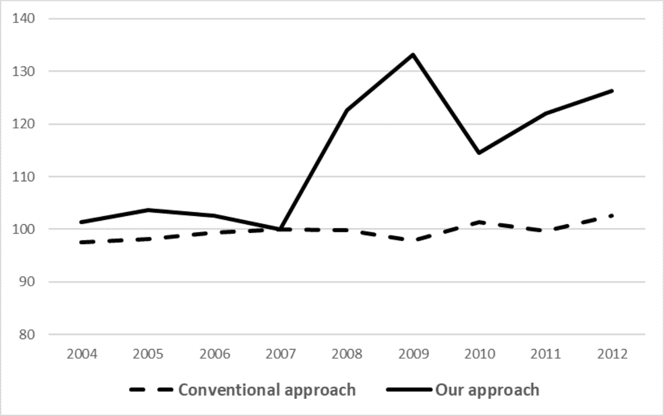
- **Pros**
  - Wider range of distortions, e.g. adjustment costs, capital taxes and subsidies
  - Measurement error in default risk: lenders could use other unobservable information
- **Cons**
  - All of the **measurement error** in capital is now attributed to factor market distortions
    - Measurement error is a very serious problem, e.g. Rotemberg and White (2017)
  - Impossible to relate the numbers to specific frictions: **"black box"**

Comparison with conventional approach for the manufacturing sector

- **Much larger losses** (44%), but scale effects still dominate
- The 2 measures are positively and significantly correlated
- **Default risk is only about 16% of total distortions**
- Capital distortions appear to be getting worse over time

Comparison with conventional approach for the manufacturing sector

- The impact of the **financial crisis** is **much more visible** if we follow our direct measurement approach



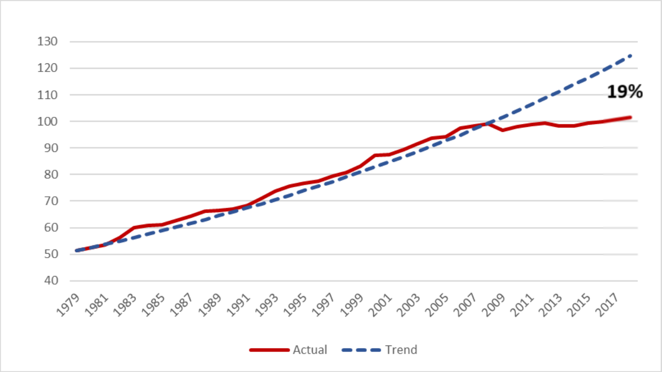
Percentage loss of output: index 2007=100

Conclusions

- Develop a novel **tractable model with default risk as a specific measure of credit frictions**
- Apply framework to a **unique data set** which matches firm-level default risk with encompassing data on real side of the economy to **quantify magnitude of output losses due to credit frictions**
- **Findings**
  - Credit frictions depress output
  - Losses from credit frictions have been increasing since financial crisis
  - Negative misallocation effects of credit frictions on output smaller than scale effects
- **Future work**
  - Extend time series dimension (productivity gap today is 19%)
  - Understanding other factors depressing productivity - e.g. demand
  - Implementing method on other countries

UK productivity slowdown

- **19% gap** between trend and actual labor productivity at end 2017

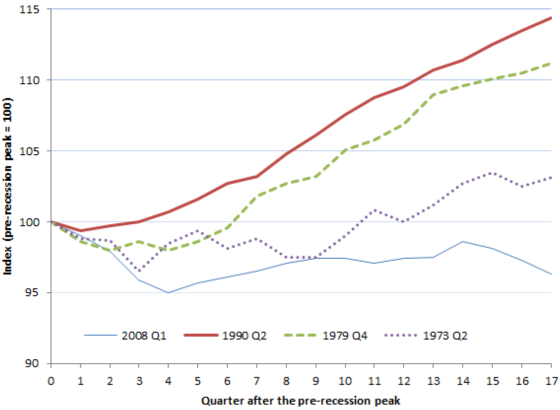


GDP/hour Q4 2007=100, trend=2.3% p.a.(Q1 1979-Q2 2008 average) Note: Q2 2008=start of recession. Source: ONS

Historical comparison International comparison

UK productivity slowdown: historical perspective

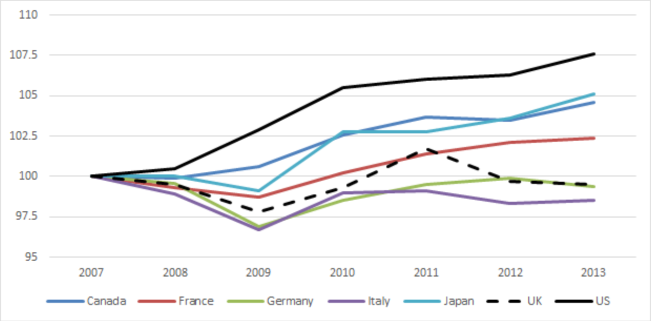
- Slowdown stands out in historical perspective



Output per worker, 2008-09 recession and previous three UK recessions. Pre-recession peak=100. Source: ONS

UK productivity slowdown: international perspective

- Slowdown stands out in international comparisons



GDP/hour, 2007=100. Source: OECD and ONS

UK productivity puzzle

Theoretical framework: Firm-level decisions

- This is a "Lucas span of control model" where profits are a return to ownership of technological/managerial capital θ
- The model could also be interpreted as a model with monopolistic competition where

$$\eta = 1 - \frac{1}{\varepsilon}$$

- and ε is the elasticity of demand
- $\eta = \frac{3}{4}$ corresponds to $\varepsilon = 4$

Firm decisions

Theoretical framework: Aggregate implications

- ρ_t is determined in global capital markets
- Exogenously fixed aggregate labor supply L
- Equilibrium wage is

$$w_t = \frac{(1-\alpha)\eta\psi(w_t,\rho_t)\hat{\theta}_t^{t\,\frac{1}{1-\eta}}\Theta_t}{L}$$

Aggregate implications

Capital shallowing or misallocation?

$$Y_t = TFP_t \times SCALE_t$$

$$TFP_t \equiv \hat{\theta}_t \Theta_t^T$$

$$SCALE_t \equiv \hat{\theta}_t^{\frac{\eta}{1-\eta}} \psi(w_t, \rho_t) \Theta_t^S$$

$$\Theta_t = \Theta_t^S \Theta_t^T$$

$$\Theta_t^T = \frac{\sum_{n=1}^N \omega_{nt} \tau_{nt}}{\left(\sum_{n=1}^N \omega_{nt} \tau_{nt} \tau_{nt}^L\right)^{(1-\alpha)\eta} \left(\sum_{n=1}^N \omega_{nt} \tau_{nt} \tau_{nt}^K\right)^{\alpha\eta}}$$

$$\Theta_t^S = \left(\sum_{n=1}^N \omega_{nt} \tau_{nt} \tau_{nt}^L\right)^{(1-\alpha)\eta} \left(\sum_{n=1}^N \omega_{nt} \tau_{nt} \tau_{nt}^K\right)^{\alpha\eta}$$

Misallocation

Capital shallowing or misallocation?

$$TFP_t \equiv \hat{\theta}_t \Theta_t^T$$

- Aggregate TFP is the product of "fundamental TFP" and aggregate frictions
- The misallocation component Θ_t^T captures the effect of credit frictions on TFP

Misallocation

Measurement of credit frictions

- **Firms**
- Risk neutral
- Heterogeneous productivities θ_n (TFP or demand shocks) and collateral A_n
- Produce using labor L_n and capital K_n
- Borrow B_n from banks and $K_n = A_n + B_n$
- Output is stochastic - Production takes place or fails (0)
- Manager exerts costly effort which determines the probability of success ϕ_n
- Effort is not observed by lenders

Solution overview

Measurement of credit frictions

- **Lenders**
- Risk neutral
- Compete and offer credit terms $\{B_n, R_n\}$ tailored to a firm's characteristics $\{\theta_n, A_n\}$
- Access funds at cost $\rho > 1$
- Seize firm's collateral A_n if output is 0
- **Lending contracts - timeline**
  1. Nature assigns each firm to a bank
  2. Banks offer credit contracts $\{B_n, R_n\}$ given firm's outside option $U(\theta_n, A_n)$ (assume exogenous and binding for now)
  3. Manager chooses effort to maximize expected profits
  4. Default occurs with probability $(1 - \phi_n)$ in which case firm loses A_n
  5. If there is no default, firm makes labor hiring decisions, produces, and repays R_n

Solution overview

- **Optimal repayment probability (stage 3)**
- Choice of default probability maximizes firm's expected profits given any credit contract $\{R_n, B_n\}$ offered
- First order condition for incentive compatible effort implies

$$\phi_n = f\left(\Pi\left(\theta_n, w, A_n + B_n\right) - R_n + A_n\right)$$

- ϕ_n increases in profit and collateral but decreases in interest payment

Solution overview

Measurement of credit frictions

- **Optimal lending contracts (stage 2)**
- Credit contract maximizes bank's expected profits s.t. IC effort
- Focus on case where firm's outside option binds (pins down R_n)
- Maximise bank's profit function with respect to B_n yields

$$\Pi_K\left(\theta_n, w, A_n, B_n^*\right) = \frac{\rho}{\phi_n^*\left(A_n, \theta_n\right)}$$

- MPK $=$ Lender's risk-adjusted cost of funds
- Lower default risk means more capital, all else equal
- Model yields a simple micro-foundation for credit frictions: $\tau_{nt}^K = \phi$

Solution overview

Measurement of credit frictions

- **Outside option (stage 1)**
- Suppose there is a switching cost, κ, from moving to another bank
- Define the outside option which generates zero profits for a competing bank as $\tilde{U}(A_n, \theta_n)$
- This is the best possible terms that another bank would offer
- Equilibrium outside option is

$$U(\theta, A) = \tilde{U}(A, \theta) - \kappa$$

Solution overview

Measurement of credit frictions

- Equilibrium repayment probability ϕ_{nt} can fall because of
  - Factors affecting profit function, e.g. more challenging business conditions
  - Balance sheet deterioration, e.g. a fall in collateral value
  - Higher switching costs as lenders are less keen for new business

Solution overview

Sample size

	IDBR market sector	ABI/ABS market sector	calibration sample
2004	1,322,081	38,670	26,155
2005	1,372,463	37,762	25,358
2006	1,409,765	31,804	21,989
2007	1,456,998	35,361	24,363
2008	1,543,660	38,333	23,614
2009	1,479,105	36,872	23,283
2010	1,458,805	36,919	23,010
2011	1,501,878	36,378	24,048
2012	1,502,333	36,513	24,720

Data and measurement issues

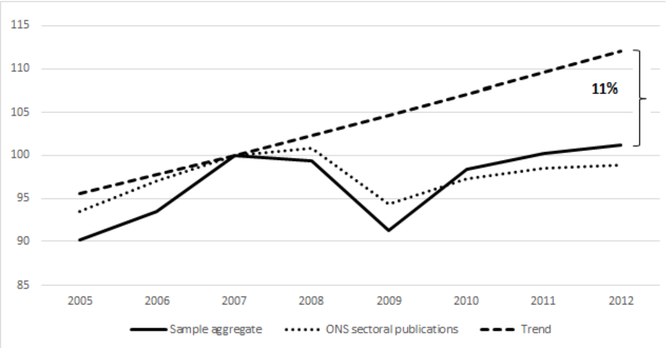
UK annual labor productivity growth

- Annual labor productivity growth (in %) by firm size and sector
- Labor productivity = real GVA per employee

	All firms	SMEs	Large firms	Manufacturing	Non-manufacturing
2005	4.80	7.10	2.60	4.10	5.64
2006	3.70	5.60	1.80	1.43	4.54
2007	6.90	5.60	8.00	15.25	4.88
2008	-0.60	-0.40	-0.90	2.35	-0.93
2009	-8.10	-8.60	-7.80	-5.20	-8.68
2010	7.70	8.50	7.10	7.95	7.93
2011	2.00	1.00	3.00	6.96	0.69
2012	0.90	1.80	0.00	-3.12	2.56

Data and measurement issues

Sample is representative of aggregate developments



Labor productivity in the “market sector” (2007=100)

Data and measurement issues

SMEs versus large firms

	Percentage loss of output for SMEs	Percentage loss of output for large firms
2004	3.62	2.34
2005	3.87	2.33
2006	3.89	2.24
2007	4.03	2.26
2008	**5.10**	3.05
2009	**5.66**	3.12
2010	**5.74**	2.98
2011	**6.08**	3.19
2012	**6.31**	3.23
Average	**4.92**	2.75

- **Higher output losses among SMEs**
- Aggregate deterioration driven by SMEs
- Scale effects dominate for both size categories

Core results

Measuring labor market frictions

- No direct measure of τ_{nt}^{L}
- Recover **implicit "wedge"** from data on GVA and the wage bill

$$\tau_{nt}^{L} = \frac{w_t L_{nt}}{(1-\alpha)\eta Y_{nt}}$$

- But irrelevant to our counterfactual of no credit market distortions, i.e. $\tau_{nt}^{K} = 1$ for all firms
- We perform the counterfactuals with and without labor market distortions as robustness check

Robustness checks

Alternative benchmark: expected output

- Baseline estimates are *conservative*
- Firms may exit when they default
- Expected output losses $>$ realized output losses
- **Expected output benchmark implies that the estimates of output losses roughly double in magnitude**
- Average annual expected output loss $\approx$ 9% and almost 40% of productivity gap due to credit frictions

Robustness checks

Demand shocks

$$Y_t = \psi(w_t, \rho_t)\hat{\theta}_t^{\frac{1}{1-\eta}}\Theta_t$$

- **Two channels through which demand shocks affect output**
  - **Direct effect** through fundamental productivity (quality/demand differences) $\hat{\theta}_t$ (present in frictionless world)
  - **Indirect effect through credit frictions**: $\psi(w_t, \rho_t)\Theta_t$
- Demand, supply, asset price shocks all filter through changes in default risk
- Capture the impact of any shock as it filters through credit frictions (separate from direct effects)
- Use average employment shares to retrieve relative productivity weights
  - Fix a firm's productivity/demand conditions when considering changes in default risk
  - Minimize possibility that estimates encapsulate shocks *unless* those shocks filter through credit frictions

Link to concept of TFPR

- Link between TFPR and credit and labor market frictions

$$TFPR_{nt} = \frac{Y_{nt}}{K_{nt}^{\alpha} L_{nt}^{1-\alpha}} = \frac{1}{\left(\frac{\alpha \eta \tau_{nt}^{K}}{\rho_t}\right)^{\alpha} \left(\frac{(1-\alpha)\eta \tau_{nt}^{L}}{w_t}\right)^{1-\alpha}}$$

- In frictionless world, $\tau_{nt}^{K} = \tau_{nt}^{L} = 1$ and $TFPR$ is equalized across firms