Firm Heterogeneity, Credit Shocks and Business Cycles

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Business Cycles and Heterogeneity

Quantitative analysis challenged by the (US) Great Recession.

inconsistent with the canonical model of Kydland and Prescott 1982

Heterogeneous agent models offer insights into large recessions.

Households (amplify changes in aggregate consumption)

Krueger, Mitman and Perri (2015)

Kim (2016)

Khan (2017)

Glover, Heathcote, Krueger and Rios-Rull (2015)

Guerrieri and Lorenzoni (2015)

Heterogeneous Firms

Uncertainty

Bloom et. al (forthcoming)

Senga (2016)

Credit Shocks

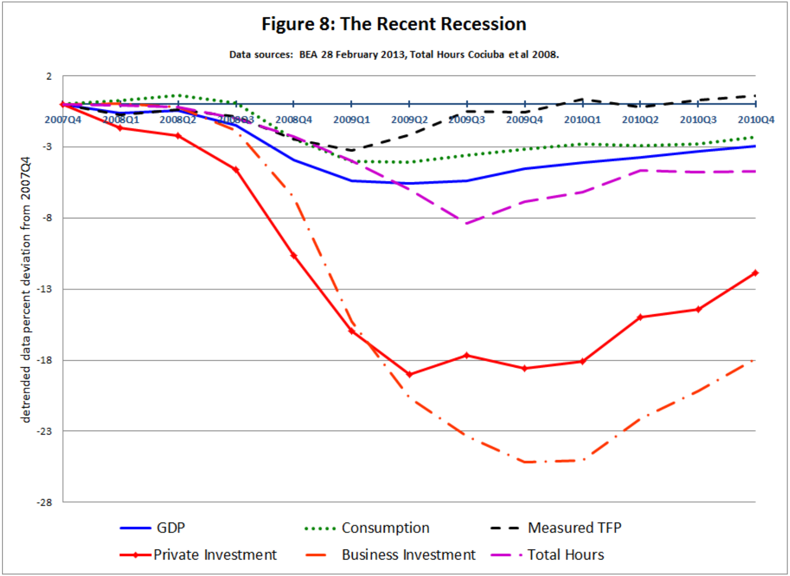
Khan and Thomas (2013)

Buera, Fattal Jaef and Shin (2015)

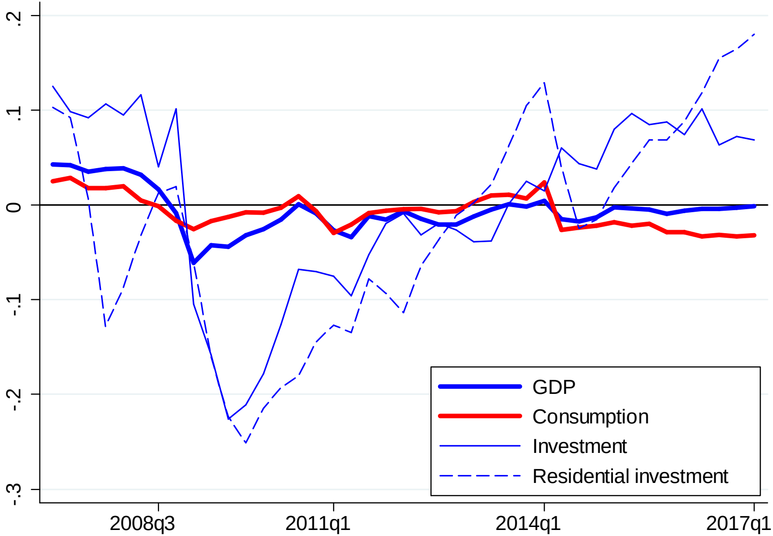
Jo (2017)

Khan, Senga and Thomas (2017).

The Great Recession in the United States



Japanese Business Cycle



Credit Shocks and Heterogeneity in Firms

- TFP fell relatively little compared to GDP and Investment.
- Credit shocks are better able to explain the recession.
- Heterogeneity is essential, average firm does not need to borrow.
- Quantitative importance depends on distribution of cash and debt.
  - borrowing by itself does not imply vulnerability to credit
  - firm data needed to further evaluate the mechanism

crisis evidence

Khan and Thomas (2013) 'Credit Shocks and Aggregate Fluctuations in an Economy with Production Heterogeneity' Journal of Political Economy. Vol. 121, No. 6.

Overview of Results

Collateral constraints drive a firm life-cycle in the model.

- Younger, smaller firms are more leveraged.
- Growing gradually, they maintain leverage in a narrow range.
- Eventually, firms reduce debt. Some accumulate financial savings.

Credit shocks can cause large, lasting recessions.

- Gradual unraveling of TFP (increasing capital misallocation)
- Large declines in GDP and investment (future TFP effect)
- Smaller, more leveraged firms disproportionately affected (▸ BED figure)

Model

- firm production: $y = z\varepsilon F(k, n)$
  - z aggregate shock and ε firm-level shock
  - labor from households (real wage ω)
  - one-period debt with face value $b' \in R$ (relative price q^{-1})

- firm entering period identified by (k, b, ε)
  - chooses n, repays b, chooses k', b', and D
  - survival probability: $1 - \pi_d$ (known before investment)

- 2 frictions influencing choices of k', b', and D
  - specificity of capital: $\theta_k \in (0, 1)$ from each unit uninstalled
  - collateralized debt limit: $b' \leq \theta_b [\theta_k k]$
  - $\theta_b \in \{\theta_1, ..., \theta_{N_\theta}\}$ with $\Pr(\theta_b' = \theta(m) \mid \theta_b = \theta(l)) \equiv \pi_{lm}^{\theta_b}$

Model

Households and Dynamic Stochastic General Equilibrium

equilibrium decision rules

$$C = C(s, \mu), \;\; N = N(s, \mu)$$

real wage

$$\omega(s, \mu) = D_2 u(C, 1 - N) / D_1 u(C, 1 - N)$$

risk free real interest rate

$$q\,(s, \mu) = \beta \sum \pi^s_{lm} D_1 u(C'_m, 1 - N'_m) / D_1 u(C, 1 - N)$$

stochastic discount factor

$$d_m\,(s, \mu) = \beta D_1 u(C'_m, 1 - N'_m) / D_1 u(C, 1 - N)$$

(S,s) decision rules of unconstrained firms

$$k_u^*(\varepsilon; s, \mu) = \arg\max_{k'} \left[-pk' + \beta \sum \sum \pi_{lm}^s \pi_{ij} W_0(k', 0, \varepsilon_j; s_m, \mu') \right]$$

$$k_d^*(\varepsilon; s, \mu) = \arg\max_{k'} \left[-p\theta_k k' + \beta \sum \sum \pi_{lm}^s \pi_{ij} W_0(k', 0, \varepsilon_j; s_m, \mu') \right]$$

$$K^w(k, \varepsilon; s, \mu) = \begin{cases} k_u^*(\varepsilon; s, \mu) & \text{if } k < \frac{k_u^*(\varepsilon; s, \mu)}{1-\delta} \\ (1-\delta)k & \text{if } k \in \left[\frac{k_u^*(\varepsilon; s, \mu)}{1-\delta}, \frac{k_d^*(\varepsilon; s, \mu)}{1-\delta} \right] \\ k_d^*(\varepsilon; s, \mu) & \text{if } k > \frac{k_d^*(\varepsilon; s, \mu)}{1-\delta} \end{cases}$$

Investment behaviour of any firm unaffected by borrowing conditions

▸ firm value

Analysis

- Firms distinguished by whether $b' \leq \theta_b \theta_k k$ will ever bind

- *unconstrained firm*
  - shadow value of dividends and retained earnings are equal
  - w.l.o.g. ignore b in determining $k' = K^w(k, \varepsilon; s, \mu)$
  - Compute a minimum savings policy, $B^w(k', \varepsilon; s, \mu)$.
    This, alongside k', yields $D^w(k, b, \varepsilon; s, \mu)$.

- *constrained firm*: binding constraint in some future state(s)
  - shadow value of retained earnings exceeds that of dividends
  - implication: $D = 0$, $K^c(k, b, \varepsilon; s, \mu)$ implies $B^c(k, b, \varepsilon; s, \mu)$

Minimum Savings Policies

A financially unconstrained firm must follow a policy that ensures it is never subject to borrowing limits.

$B^w\left(k, \varepsilon; \cdot\right)$ is the minimum savings to be unconstrained

$$B^w\left(k, \varepsilon_i; s_l, \mu\right) \equiv \min_{\{\varepsilon_j | \pi_{ij}>0 \text{ and } s_m | \pi^s_{lm}>0\}} \widetilde{B}\left(K^w\left(k, \varepsilon; \cdot\right), \varepsilon_j; s_m, \mu'\right)$$

$$\widetilde{B}(k, \varepsilon; \cdot) \equiv D^w(k, 0, \varepsilon; \cdot) + q \min\left\{B^w\left(k, \varepsilon_i; \cdot\right), \theta_b \theta_k k\right\}$$

Payments $D^w \geq 0$ to shareholders.

$$D^w(k, b, \varepsilon) \equiv z\varepsilon F(k, N(k, \varepsilon)) - \omega N(k, \varepsilon) - b - \mathcal{J}\left(\cdot\right)\left[K^w\left(k, \varepsilon\right) - (1 - \delta) k\right]$$

A Summary of Firm Dynamics

- Unconstrained firms' capital policies do not depend on their financial savings or debt.
- A minimum savings policy preserves this independence
- Constrained firms cannot adopt both the capital and minimum savings decisions of unconstrained firms.
- Their capital choices are functions of their debt.
- They may not have binding borrowing constraints.

Calibration

Functional forms and aggregate data

$$u(C, L) = \log C + \varphi L \qquad z\varepsilon F(k, n) = z\varepsilon k^{\alpha} n^{\nu} \qquad k_0 = \chi \int k\widetilde{\mu}(d[k \times b \times \varepsilon])$$

$$\log \varepsilon' = \rho_{\varepsilon} \log \varepsilon + \eta'_{\varepsilon} \qquad b_0 = 0$$

β : real rate $= 0.04$

ν : labor share $= 0.60$

δ : investment/capital $= 0.07$

α : capital/output $= 2.3$

φ : hours worked $= 0.33$

θ_b : debt/assets $= 0.372$ (54Q1-06Q4)

π_d : exit rate of firms $= 0.10$

χ : new/typical firm size $= 0.10$

Calibration

Firm data

LRD

lumpy invest rate $= 0.186$

$\sigma(i/k) = 0.337$

$corr(i/k, i/k_{-1}) = 0.058$

parameters

$\theta_k = 0.954$

$\rho_\varepsilon = 0.659$

$\sigma_{\eta_\varepsilon} = 0.118$

- mean investment rate is 0.12 in data and 0.11 in model.

COMPUSTAT (1954-2011 averages)

corr(size,leverage) $= 0.022$

$\sigma(\text{cash/size}) = 0.16$

parameters

$\omega_e = 0.291$

$\alpha_e = 0.225$

- Aggregate cash to assets ratio was 0.10 in 2006 and 0.12 in model (Bates, Kahle & Stulz 2009).

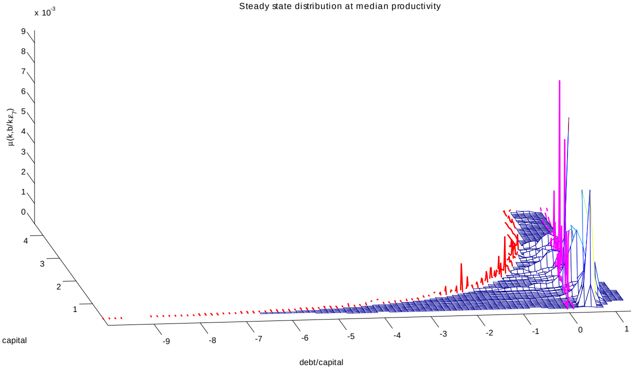
Credit Shocks

We assume θ_b follows an independent 2-state Markov Chain with $\theta_b \in \{1.38, \theta_l\}$ and transition probabilities,

$$\left| \begin{array}{cc} p_0 & 1 - p_0 \\ 1 - p_1 & p_1 \end{array} \right| .$$

- Reinhart and Rogoff (2009) report that the average number of banking crisis over 1945-2008 across advanced economics was 1.4.
- There have been 2 in the U.S. Financial crisis are rare events.
- Across advanced economies, 7 percent of time was spent in crisis.
- We choose $p_0 = 0.97648$ and $1 - p_1 = 0.3125$ to imply 7 percent of time spent in crisis and an average duration of 3.2 years.
- We set $\theta_l = 0.5$ to imply a 25 percent reduction in debt.

Steady state distribution for median productivity



- new firm k: 0.15
- avg constrained k: 1.8
- avg unconstrained k: 2.0
- constrained firms: 61% / with binding constraint: 24%
- avg no constraint k: 1.54

▸ business cycles

Credit crisis with recovery in date 5

Peak-to-Trough Percent Changes

	GDP	I	N	C	TFP
data	-5.6	-19.0	-6.0	-4.1	-2.2
credit shock	-4.4	-21.8	-3.4	-1.0	-1.3

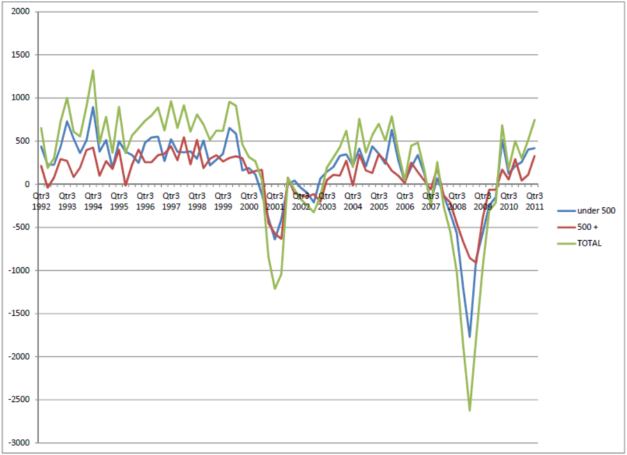
A credit shock delivers the observed decline in GDP and

1. reproduces the disproportionate fall in investment
2. is close to the change in measured TFP (07Q4 - 09Q1 change was -2.71)
3. change in loans of -26.1 percent (data: -48 to -19 percent ▸ crisis evidence).

A TFP-shock will not explain GDP or investment and yields only a 4.1 percent (delayed) decline in debt.

	GDP	I	N	C	TFP
one s.d. TFP shock	-3.8	-14.6	-2.2	-0.85	-2.6

Evidence of disproportionate effect on small firms



net employment change in 1000s

overview results

Risky lending and and loan rate schedules

one period non-contingent debt

The collateral constraint is ad hoc, proxying for richer financial frictions.

$$q\left(k', b', \varepsilon_i; s_l, \mu\right) b' = \sum_{m=1}^{N_s} \pi^s_{lm} d_m\left(s_l, \mu\right) \sum_{j=1}^{N_\varepsilon} \pi^\varepsilon_{ij} \Big[\chi\left(x'_{jm}, \varepsilon_j; s_m, \mu'\right) b' + \Big(1 - \chi\left(x'_{jm}, \varepsilon_j; s_m, \mu'\right)\Big) \min\Big\{b', \rho\left(1-\delta\right) k'\Big\} \Big]$$

Endogenous collateral constraints as default risk constrains borrowing

An extensive margin amplifies the effect of credit shocks *depending on the distribution of leverage* (importance of firm level data)

Khan, Thomas and Senga (2017) 'Default Risk and Aggregate Fluctuations in an Economy with Production Heterogeneity'

Growth Shocks with Entry and Exit

Changes in the Distribution of firms with an extensive margin

- Shocks to TFP growth rates
  - lost decades amplified by fall in business formation
- Default risk does not imply enough credit spread.
- Introduce a general equilibrium countercyclical stochastic discount factor (Epstein and Zin).
- Reproduce the size and age distribution of firms.
- Explore the long-run effects of a persistent reduction in entry.
- How do entry and exit respond to credit shocks?

Concluding remarks

- Quantitative business cycle analysis is converging with policy makers' views.
- We now have models where a shock to credit markets can cause a large and protracted recession.
- The result is a disproportionate response in investment and output, and a small fall in TFP, consistent with the recent US recession.
- Future work needs to use firm-level data to better measure the quantitative significance of the model.
- What is the distribution of firms over productivity, capital and financial assets?

Related work

- Business cycle propagation through financial frictions

  Kiyotaki and Moore (1997)

- Emphasis on financial shocks
  - Jermann & Quadrini (2009): DSGE financial frictions model with credit shocks

- Emphasis on firm-level heterogeneity
  - Arellano, Bai & Kehoe (2010): Aggregate effects of shocks to firm-level risk

overview

Evidence

- Chari, Christiano and Kehoe (2008): stock of commercial and industrial loans across regulated banks rose in 2008Q3
- Koepke and Thomson (2011): over 2008Q4-2009Q4, it fell 18.7 percent
- Ivashina and Scharfstein (2009):2007-08, syndicated lending fell sharply
  - far larger market than lending by regulated banks
  - investment loans fell 48 percent
- Almeida, Campello, Laranjeira and Weisbenner (2009)
  - investment fell by one-third among firms with substantial debt maturing over the year following August 2007
  - no investment decline among otherwise similar firms

peak to trough, overview

Expected value of a firm

$$v_0\left(k,b,\varepsilon_i;s_l,\mu\right)=(1-\pi_d)v\left(k,b,\varepsilon_i;s_l,\mu\right)$$
$$+\pi_d\max_n\Big[z_l\varepsilon_iF\left(k,n\right)-\omega\left(s_l,\mu\right)n+\theta_k\left(1-\delta\right)k-b\Big]$$

$$v\left(k,b,\varepsilon_i;s_l,\mu\right)=\max\Big\{v^u\left(k,b,\varepsilon_i;s_l,\mu\right),\ v^d\left(k,b,\varepsilon_i;s_l,\mu\right)\Big\}$$

given (s_l,μ) and $\mu'=\Gamma(s_l,\mu)$ *with* $s_l=(z_l,\theta_b)$

▸ decision rules

Upward capital adjustment

$$v^u\left(k, b, \varepsilon_i; s_l, \mu\right) =$$

$$\max_{n,k',b',D}\Big[D + \sum_{m=1}^{N_s} \pi^s_{lm} d_m\left(s_l, \mu\right) \sum_{j=1}^{N_\varepsilon} \pi_{ij} v_0\left(k', b', \varepsilon_j; s_m, \mu'\right)\Big]$$

subject to:

$$k' \geq (1-\delta)\,k \quad \text{and} \quad b' \leq \theta_b \theta_k k$$

$$0 \leq D \leq z_l \varepsilon_i F\left(k, n\right) - \omega\left(s_l, \mu\right) n + q\left(s_l, \mu\right) b' - \left[k' - (1-\delta)\,k\right] - b$$

Downward capital adjustment

$$v^d\left(k, b, \varepsilon_i; s_l, \mu\right) =$$

$$\max_{n,k',b',D}\left[D + \sum_{m=1}^{N_s} \pi^s_{lm} d_m\left(s_l, \mu\right) \sum_{j=1}^{N_\varepsilon} \pi_{ij} v_0\left(k', b', \varepsilon_j; s_m, \mu'\right)\right]$$

subject to:

$$k' \leq (1-\delta)\,k \quad \text{and} \quad b' \leq \theta_b \theta_k k$$

$$0 \leq D \leq z_l \varepsilon_i F\left(k, n\right) - \omega\left(s_l, \mu\right) n + q\left(s_l, \mu\right) b' - \theta_k\left[k' - (1-\delta)\,k\right] - b$$

decision rules

Firms without borrowing constraints

- We introduce a second type of firm without borrowing constraints.
- Optimally choose the capital policies of unconstrained firms.
- Indifferent to financial savings, we assign them debt policies

$$b' = \alpha_e \left(k'\right)^2 .$$

- The fraction of firms without borrowing constraints is ω_e.
- Second type of firms increases the correlation between size and leverage from -0.22.

Real Shocks

- Changes in the distribution of production drive differences between measured aggregate total factor productivity and its exogenous component.
- These differences arise from credit shocks.
- We measure a log-normal technology shocks process (1954-2012)

$$\log z' = \rho_z \log z + \eta_z' \text{ with } \eta_z \sim N\left(0, \sigma_{\eta_z}^2\right),$$

where $\rho_z = 0.9092$ and $\sigma_{\eta_z} = 0.0145$.

We use the Rouwenhorst algorithm to create 3-state Markov Chain.

Business cycles with real and financial frictions

full economy

$x =$	Y	C	I	N	K	r
mean(x)	0.578	0.485	0.094	0.333	1.323	0.042
σ_x/σ_Y	2.089	0.512	4.326	0.639	0.542	0.455
$corr(x, Y)$	1.000	0.833	0.931	0.897	0.105	0.670

eliminating credit shocks

$x =$	Y	C	I	N	K	r
mean(x)	0.583	0.488	0.096	0.334	1.354	0.042
σ_x/σ_Y	(1.997)	0.503	3.859	0.562	0.485	0.453
$corr(x, Y)$	1.000	0.931	0.967	0.945	0.074	0.671

- Business cycles are relatively unaffected by credit shocks.
- The model economy with real and financial frictions looks like a equilibrium business cycle model without heterogeneity.

steady state