Firm Dispersion and Business Cycles: Estimating Aggregate Shocks using Panel Data

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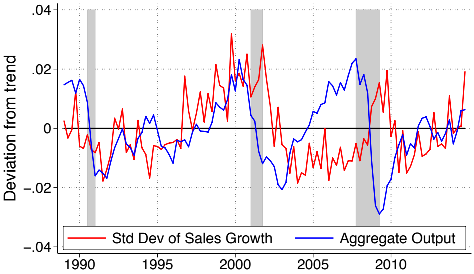
Introduction

- Recent focus in business cycle literature on learning from micro-data.
- In particular, firm distribution becomes more "spread out" in recessions.
  - Std. dev. of sales growth across firms is *countercyclical*.



Aggregate Output is Real GDP, taken from BEA National Income and Product Accounts, logged and detrended using a one-sided Hodrick-Prescott filter. *Std Dev of sales growth* is the cross-sectional standard deviation of the percentage change in quarterly sales across firms, using listed US firms in Compustat, with a cubic trend removed.

IQR Industry effects

Motivation and approach

Question: is increased dispersion a *cause* or an *effect* of cycle?

Our approach:

- Model of heterogeneous firms with aggregate shocks
  - Standard macro shocks
    - productivity
    - discount factor
    - labor supply
  - Uncertainty shock
    - direct shock to firm dispersion
- Estimate the model using
  - aggregate time series
    - output, consumption, hours worked
  - time series of firm dispersion
    - std. dev. sales growth over time, constructed from panel data
- Obtain estimates for
  - contribution of uncertainty shock to aggregates **(cause)**
  - contribution of macro shocks to dispersion **(effect)**

Results preview

- Q: Is firm dispersion a cause or effect of the business cycle?
- A: Neither!
- Estimation results show that
  - almost all fluctuation in aggregates is due to macro shocks
  - almost all fluctuation in dispersion is due to uncertainty shock
- Uncertainty shocks *can* generate recessions but don't.

DSGE overview

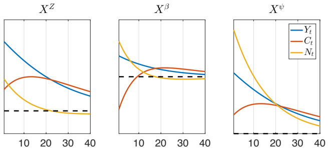
Model

$$
\begin{aligned}
u(C_t) &= X_t^{\beta} \beta R_t u(C_{t+1}) \\
-X_t^{\psi} v(N_t) &= u(C_t) \\
Y_t &= X_t^Z N_t^{\nu} K_t^{1-\nu} \\
Y_t &= C_t + (K_{t+1} - (1-\delta) K_t)
\end{aligned}
$$

$+$ **Parameters**

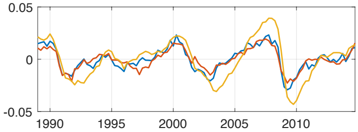
$$\theta = (u, v, \beta, \nu, \delta)$$

$\Rightarrow$ **Impulse responses**



Impulse responses

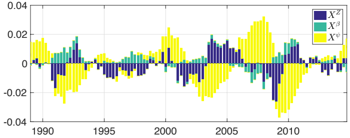
$+$ **Data**



$\Rightarrow$ **Likelihood**

$$\mathcal{P}(\text{data}|\theta)$$

$+$ **Shock decomposition**



Model: environment

- Discrete time, infinite horizon.
- **Household**
  - supplies labor N_t^s at competitive wage W_t
  - consumes consumption good C_t
  - receives dividends Π_t from firms.
- **Firms** Continuum of firms, each with state $(k_{it}, z_{it}, \xi_{it})$
  - hire labor n_{it} at competitive wage W_t,
  - produce using labor n_{it} and pre-installed capital stock k_{it}
    - decreasing returns to scale production function

$$y_{it} = X_t^Z z_{it} \left(n_{it}^{\nu} k_{it}^{1-\nu} \right)^{\kappa}, \qquad \kappa < 1$$

  - choose whether to adjust capital or not
    - pay $\xi_{it} \sim F\left(\bar{\xi}\right)$ to adjust
    - if adjusting, choose next period's capital stock $k_{i,t+1}$
  - pay out dividends π_{it}

Firm problem (adjust or not)

- The firm's state is $(k, z, \xi; \mathbf{S})$.
- Let $v(k, z, \xi; \mathbf{S})$ be the discounted present value of the firm.
- Each period, the firm chooses whether to adjust or not:

$$v\left(k, z, \xi; \mathbf{S}\right) = \max\left\{-\xi W\left(\mathbf{S}\right) + v^{\text{adj}}\left(k, z; \mathbf{S}\right), v^{\text{stay}}\left(k, z; \mathbf{S}\right)\right\}$$

- Gives threshold rule $\xi^*\left(k, z; \mathbf{S}\right)$.

Firm problem (continued)

Value of adjusting:

$$v^{\text{adj}}\Big(k, z; \mathbf{S}\Big) = \max_{d,k' \geq 0,n} d + \mathbb{E}\left[M\left(\mathbf{S}, \mathbf{S}'\right) v\left(k', z', \xi'; \mathbf{S}'\right)\right]$$

subject to

$$d = X^Z z \left(n^\nu k^{1-\nu}\right)^\kappa - W\left(\mathbf{S}\right) n - \left(k' - \left(1-\delta\right) k\right)$$

$$\log z' = \rho_z \log z + \varepsilon'_z, \qquad \varepsilon'_z \sim \mathcal{N}\left(-\frac{1}{2}\frac{\left(X^\sigma \sigma_z\right)^2}{1+\rho_z}, \left(X^\sigma \sigma_z\right)^2\right)$$

$$\mathbf{S}' \sim H\Big(\mathbf{S}, \mathbf{S}'\Big)$$

Value of not adjusting:

v^{stay} same as v^{adj} but $\frac{k' - (1-\delta)k}{k} \in [-b, b]$

Household problem

Let $\mathbf{W}(\mathbf{S})$ be the household's expected present discounted value:

$$\begin{aligned} \mathbf{W}(\mathbf{S}) &= \max_{C,N,A'} u(C-H) - X^{\psi} v(N) + \beta X^{\beta} \mathbb{E}\left[\mathbf{W}(\mathbf{S}') \,|\mathbf{S}\right] \\ C + Q(\mathbf{S}) A' &= W(\mathbf{S}) N + (Q(\mathbf{S}) + \Pi(\mathbf{S})) A \end{aligned}$$

Optimality conditions:

- stochastic discount factor

$$M(\mathbf{S}, \mathbf{S}') = \beta X^{\beta}(\mathbf{S}) \frac{u'(C(\mathbf{S}') - H(\mathbf{S}'))}{u'(C(\mathbf{S}) - H(\mathbf{S}))}$$

- labor supply

$$W(\mathbf{S}) = X^{\psi}(\mathbf{S}) \frac{v'(N(\mathbf{S}))}{u'(C(\mathbf{S}) - H(\mathbf{S}))}$$

Aggregate state

- The aggregate state is the distribution of firms and the aggregate shocks:

$$\mathbf{S} = \left(\mu\left(k, z, \xi\right), X^{Z}, X^{\beta}, X^{\psi}, X^{\sigma}\right)$$

  where the aggregate shocks are:
  - X^{Z}, a shock to aggregate TFP,
  - X^{β}, a shock to the household's discount factor,
  - X^{ψ}, a shock to the household disutility of labor,
  - X^{σ}, an uncertainty shock.
- Aggregate shocks follow AR(1) processes
  - in logs for (Z, β, ψ):

$$\log X^{j}_{t+1} = \rho^{j} \log X^{j}_{t} + \sigma^{j} \epsilon_{t}, \qquad \epsilon \sim \mathcal{N}\left(0, (\sigma^{j})^{2}\right),$$

  - in levels for σ:

$$X^{\sigma}_{t+1} = \rho^{\sigma} X^{\sigma}_{t} + \sigma^{\sigma} \epsilon_{t}, \qquad \epsilon \sim \mathcal{N}\left(0, (\sigma^{\sigma})^{2}\right).$$

Equilibrium

An equilibrium of this model consists of

- firms' value function $v(k, z, \xi; \mathbf{S})$,
- firms' policy functions $k'(k, z, \xi; \mathbf{S})$, $n(k, z, \xi; \mathbf{S})$ and $\xi^*(k, z; \mathbf{S})$,
- households' policies $C(\mathbf{S})$, $N(\mathbf{S})$ and associated discount factor $M(\mathbf{S}, \mathbf{S'})$,
- a wage $W(\mathbf{S})$,
- a law of motion for the distribution of firms $\Gamma(\mu, \mu'; \mathbf{S})$,

such that

1. the firms' policies are optimal,
2. the households' policies are optimal,
3. the labor market clears,

$$N(\mathbf{S}) = \int n(k, z, \xi; \mathbf{S})\, d\mu(k, z, \xi; \mathbf{S})$$

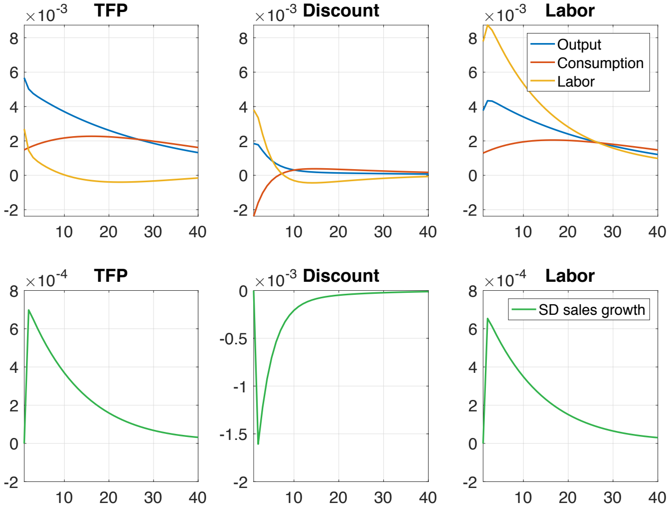
4. the law of motion of the distribution is consistent with the firm's policies.

Solution method

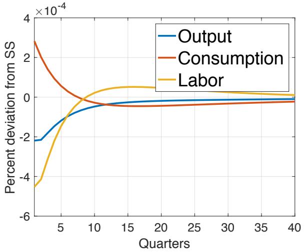
Solve numerically using a computer. 4 steps:

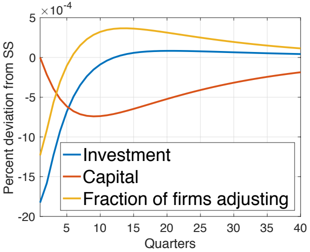
1. Solve for "steady state", i.e. eqbm without aggregate shocks.
   - A fixed-point problem in the wage W.
2. Construct discrete approximations of eqbm objects and conditions.
3. Take first-order Taylor approximation of discretized eqbm conditions.
   - Expand around steady state from Step 1.
4. Solve resulting first-order difference equation using linear algebra.

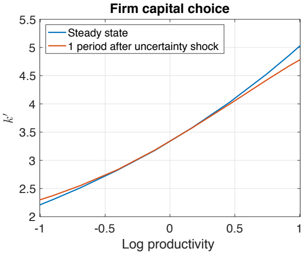
Impulse response functions



Uncertainty shock







Estimation

1. Fix some parameters externally:

$$\theta_1 = (\beta, \sigma, \eta, \delta, \nu)$$

2. Estimate steady-state parameters using simulated method of moments:

$$\theta_2 = (\bar{\xi}, \rho_z, \sigma_z, \kappa)$$

   - to match moments of long-run firm distribution (Compustat)

3. Estimate shock process parameters using Bayesian methods:

$$\theta_3 = \left\{\rho^j, \sigma^j\right\}_{j \in \{Z, \psi, \beta, \sigma\}}$$

   using as observable time series

   - Aggregate output, consumption and hours worked (NIPA)
   - Cross-sectional time series of SD sales growth (Compustat)

Data: cross-sectional

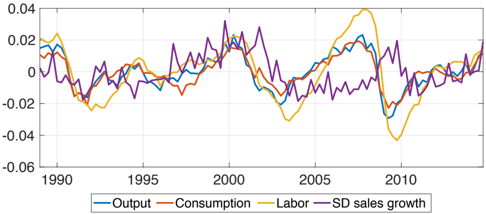
- **Compustat**: quarterly accounting data for publicy listed firms.
- **Sample selection**
  - US firms, 1989q1 to 2014q4
  - We drop from the sample
    - quarters in which a firm is involved in M&A
    - financial firms and utilities
    - each firm's first and last quarter
  - Resulting sample: 360,591 firm-quarter observations
- **Variable definitions**

$$\text{sales growth}_{it} = \frac{\text{sales}_{it} - \text{sales}_{i,t-1}}{\frac{1}{2}\left(\text{sales}_{it} + \text{sales}_{i,t-1}\right)}, \qquad \text{investment rate}_{it} = \frac{\text{ppe}_{it} - \text{ppe}_{i,t-1}}{\frac{1}{2}\left(\text{ppe}_{it} + \text{ppe}_{i,t-1}\right)}$$

$$\text{inaction rate}_t = \frac{1}{N_t}\sum_{i=1}^{N_t} \mathbf{1}\{|\text{investment rate}_{it}| > 0.01\}$$

Data: time series

- **Aggregate time series**
  - Source: National Income and Product Accounts (BEA)
  - Variables
    - Output Y_t: Real Gross Domestic Product
    - Consumption C_t: Real Personal Consumption Expenditures
    - Labor N_t: Index of Aggregate Weekly Hours
  - Logged and detrended using a one-sided HP-filter.
- **Cross-sectional time series:**
  - SD sales growth from Compustat.
  - Detrended using cubic time trend.



Estimation (1)

(1) Fix some parameters **externally**:

$$u(C-H) = \frac{(C-H)^{1-\sigma}}{1-\sigma}, \quad v(N) = \frac{N^{1+\eta}}{1+\eta}$$

Parameter		Value
Discount factor	β	0.99
Curvature of utility function	σ	1
Inverse Frisch elasticity	η	2
Depreciation rate	δ	0.03
Labor elasticity of output	ν	0.65

(2) Estimate steady-state parameters using **SMM**:

Parameter		Value	Target	Data	Model
Adjustment costs	$\bar{\xi}$	3.7×10^{-4}	Investment inaction rate	0.263	0.270
Decreasing RTS	κ	0.744	Dividends / output	0.070	0.073
Persistence idio. prod.	ρ_z	0.311	SD sales growth	0.285	0.243
Avg SD idio. prod.	$\bar{\sigma}_z$	0.320	SD investment rates	0.154	0.181

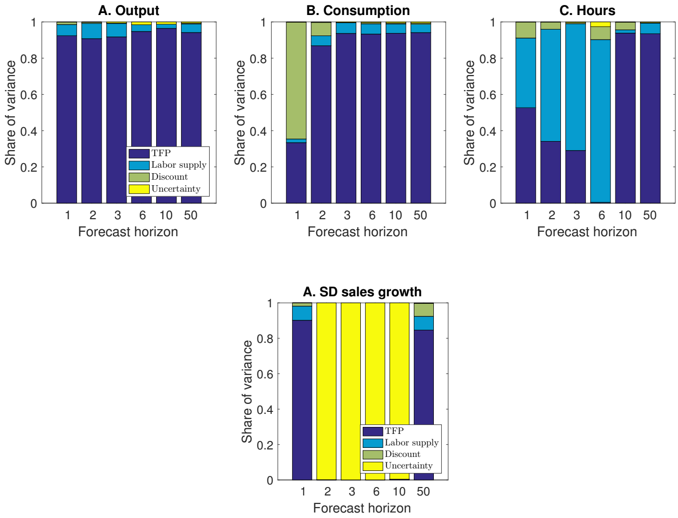
Results: priors and posteriors

(3) Estimate shock process parameters using **Bayesian methods**:

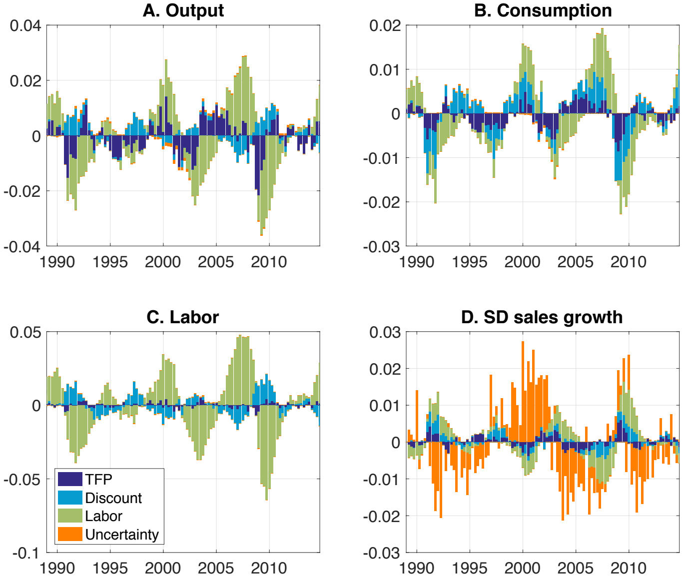
		Prior			Posterior	
Parameter name		**Type**	**Mean**	**SD**	**Mode**	**SD**
Autocorrelation, TFP shock	ρ^Z	Beta	0.600	0.260	0.983	0.015
Autocorrelation, discount shock	ρ^β	Beta	0.600	0.260	0.739	0.054
Autocorrelation, labor supply shock	ρ^ψ	Beta	0.600	0.260	0.986	0.006
Autocorrelation, uncertainty shock	ρ^σ	Beta	0.600	0.260	0.775	0.257
Standard deviation, TFP shock	σ^Z	Exp	0.100	0.100	0.012	0.001
Standard deviation, discount shock	σ^β	Exp	0.100	0.100	0.002	0.001
Standard deviation, labor supply shock	σ^ψ	Exp	0.100	0.100	0.012	0.001
Standard deviation, uncertainty shock	σ^σ	Exp	0.100	0.100	0.002	0.005

Posterior mode and SD are computed by drawing a sample of 10^6 points from the posterior distribution using the Metropolis-Hastings algorithm. We verify that Gelman's $\sqrt{\hat{R}}$ statistic is less than 1.05 for each parameter separately.

Results: FEVDs

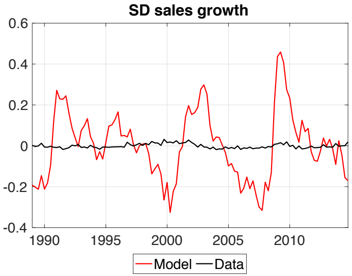


Results: shock decomposition



Uncertainty-driven business cycles

- Compute uncertainty shock series that matches output fluctuations.
- Counterfactual implications for SD sales growth:



Conclusion

- **Contribution**
  - We build a macro model consistent with micro evidence on dispersion.
  - We estimate the model on time series of aggregates and cross-sectional dispersion.
- **Findings**
  - Macro shocks alone not sufficient to explain fluctuations in dispersion.
  - Uncertainty shocks alone not sufficient to explain fluctuations in aggregates.
- **Future work**
  - Bayesian estimation of full parameter vector.
    - Computational speed is a barrier.
  - More comprehensive data.
  - A better model?

Literature

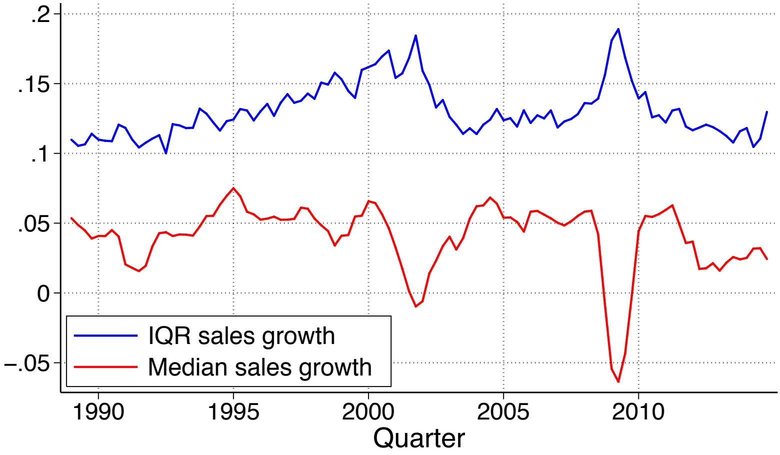
1. **Firm dispersion and uncertainty**
   Bloom (2007), Bloom, Floetteto, Jaimovich, Saporta-Eksten and Terry (2014), Bachmann and Bayer (2014), Schaal (2012), Jurado, Ludgvigson and Ng (2015), Vavra (2014), Christiano, Motto, Rosagno (2014), Gilchrist, Sim and Zakrajsek (2014), Berger, Dew-Becker and Giglio (2016), Bachmann and Moscarini (2012)

2. **Estimated macro models**
   Sargent (1989), Ingram, Kocherlakota and Savin (1994), Ireland (2004), Smets and Wouters (2007), Christiano, Eichenbaum and Evans (2001), Justiniano, Primiceri and Tambalotti (2011), Jermann and Quadrini (2012)

3. **Heterogeneous agent macro models**
   Hopenhayhn (1992), Khan and Thomas (2008), Khan, Senga and Thomas (2014), Clementi and Palazzo (2016), Winberry (2016), Gomes (2001), Gomes and Schmid (2010), Eisfeldt and Muir (2016)

4. **Linearizing heterogeneous agent models**
   Reiter (2009), Reiter (2010), McKay and Reis (2010), Winberry (2016), Ahn, Kaplan, Moll, Winberry and Wolf (2016)

Sales growth interquartile range



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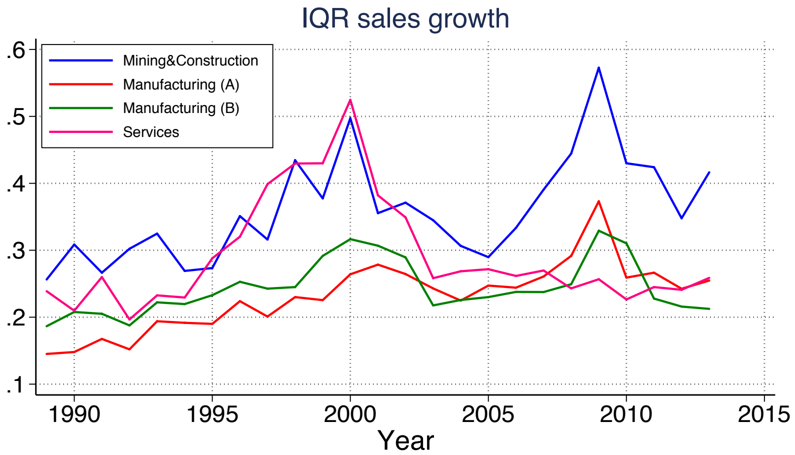
Sales growth dispersion by industry



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