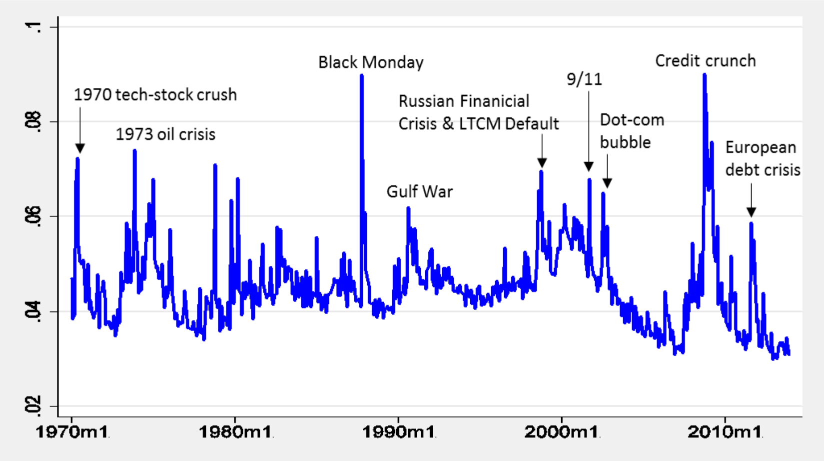
A New Look at Uncertainty Shocks: Imperfect Information and Misallocation

Tatsuro Senga
The Ohio State University

European Winter Meeting of the Econometric Society

15 December, 2014

Aggregated data: Monthly US stock market volatility



Uncertainty and recessions

Is uncertainty an important driver of business cycles?

Uncertainty has been blamed for recessions

- "*participants reported that uncertainty about the economic outlook was leading firms to defer spending projects until prospects for economic activity became clearer*." FOMC (2008)
- "*Uncertainty is largely behind the dramatic collapse in demand. Given the uncertainty, why build a new plant, or introduce a new product? Better to pause until the smoke clears*." Blanchard (2009)

This paper: New type of uncertainty shocks

Empirics: Panel data of firm-level uncertainty

- Earnings data (I/B/E/S): ex-ante forecasts & ex-post realizations
- Cross-sectional features & business cycle properties

Theory: Heterogeneous firm model with Bayesian learning

- the level of idiosyncratic productivity is unknown
  - a firm learns and updates its posterior
  - the posterior mean and variance are heterogeneous among firms

Main Results

Empirics: Firm-level uncertainty is heterogeneous and countercyclical

- Differences in the degree of uncertainty facing individual firms
- The average level of uncertainty across firms is countercyclical

Theory: The model economy exhibits quick drops and slow recoveries following uncertainty shocks

- Short-lived shocks create long-lived aggregate effects endogenously
- Neither real nor nominal rigidity required
- Uncertainty shocks explain 51% of the Great Recession

Outline

1. Empirics: Annual firm panel on after-tax return on capital (ROC)
2. Model
3. Calibration
4. Simulation

Measurement of uncertainty

Various measurements:

1. Volatility of stock returns
   (Leahy and Whited (1996))
2. Dispersion of productivity
   (levels: Kehrig (2012); growth rates: Bloom et al. (2014) and Bachmann and Bayer (2013))
3. Forecast disagreement & errors
   (Bachmann et al. (2013) and Bond et al. (2005))

Data: Overview

1. Institutional Brokers' Estimate System (I/B/E/S)
   I use both ex-ante analyst forecasts and ex-post realisations of EPS
   - a point forecast by an individual analyst for each firm at given date
   - street realisations
2. Compustat
   I use data on capital stock and other fundamentals

I merge two data sources to construct a panel of firms about return on capital

1. Cross-sectional moments
2. Forecast dispersions
3. Forecast errors

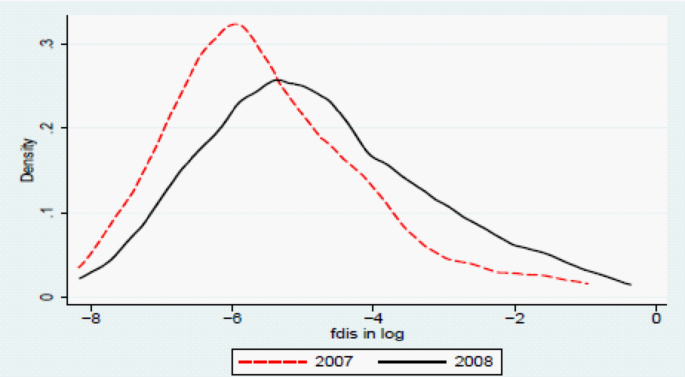
Data: Empirical moments

Table 1 - Basic Statistics of the Panel Dataset

	Mean	Standard deviation	Serial correlation	25%	Median	75%
Return on capital	0.19	0.51	0.29	0.06	0.12	0.23
Investment rate	0.15	0.42	0.04	0.08	0.12	0.18
Forecast dispersion	0.04	0.53	0.15	0.002	0.004	0.01
Forecast error	0.04	0.79	0.006	0.0004	0.003	0.02

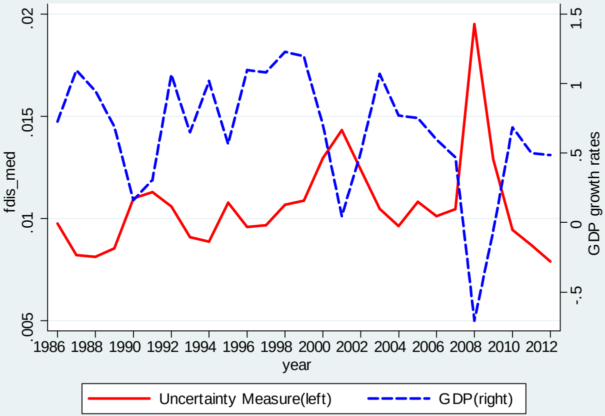
Notes: The table above shows the cross-sectional moments of the panel dataset. Return on capital is calculated as earnings (= Street earnings per share (EPS) multiplied by the number of outstanding shares) divided by capital stock (= the sum of Property, Plant, and Equipment and inventory). Investment rate is defined as capital expenditure divided by capital stock. Forecast dispersion is the cross-analyst standard deviation of return on capital forecasts normalized by the median value of forecasts. Forecast error is calculated as the gap between realised return on capital and the median value of forecasts. The panel dataset is constructed by merging data from both the IBES and Compustat, resulting in an unbalanced panel that contains firms appearing for at least 30 years between 1975 and 2012, consisting of 10,466 data with 302 firms.

Uncertainty: Earnings forecast dispersion



Notes: The figure plots the distribution of the uncertainty measure (log-transformed), calculated as the cross-analyst standard deviations of forecasts of return on capital normalized by the median forecast, for 2007 (dash, red) and 2008 (solid, black) respectively.

Uncertainty: Earnings forecast dispersion



Source: Institutional Brokers' Estimate System and Bureau of Economic Analysis.

Data: Measures of uncertainty

Table 2 - Correlation between Uncertainty Measures

	roc_mean	roc_sd	fdis_med	fdis_mean	fdis_sd	fdis_iqr	ferror_med	dis_BOS	sd_TFP	GDP
roc_mean	1.00									
roc_sd	0.69	1.00								
fdis_med	-0.47	0.17	1.00							
fdis_mean	-0.14	0.45	0.79	1.00						
fdis_sd	-0.05	0.40	0.60	0.91	1.00					
fdis_iqr	-0.13	0.48	0.86	0.88	0.67	1.00				
ferror_med	0.14	0.52	0.40	0.59	0.51	0.59	1.00			
dis_BOS	0.21	0.24	0.13	0.21	0.19	0.23	0.32	1.00		
sd_TFP	0.35	0.71	0.36	0.56	0.51	0.54	0.57	0.19	1.00	
GDP	-0.06	-0.51	-0.48	-0.43	-0.38	-0.48	-0.33	-0.33	-0.48	1.00

Notes: This table is the correlation matrix for various measures of uncertainty. Return on capital is calculated as earnings (= Street earnings per share (EPS) multiplied by the number of outstanding shares) divided by capital stock (= the sum of Property, Plant, and Equipment and inventory). Forecast dispersion is the cross-analysts standard deviation of earnings forecasts normalized by the median value of earning forecasts. roc_mean is calculated for each year as the cross-sectional mean of return on capital for the panel dataset and roc_sd is the cross-sectional standard deviation for the same data. Using the forecast dispersion data, for each year, fdis_med, fdis_mean,

Stylized facts about uncertainty

New measures of firm-level uncertainty constructed from forecasts dispersion among analysts

1. The degree of uncertainty facing individual firms is heterogeneous
   - standard deviation (0.53) and serial correlation (0.15)
2. The first as well as second moments of the measure are countercyclical
   - the correlation with GDP growth rates are negative
     mean (-0.48) and standard deviation (-0.38)
3. Positive correlation with other common measures:
   - TFP growth rates (0.56)

Outline

1. Empirics
2. Model: Heterogeneous firm model with Bayesian learning
3. Calibration
4. Simulation

Overview of production

Competitive firms producing homogenous good : $y = z\varepsilon(k^{\alpha}n^{1-\alpha})^{\nu}$

- Aggregate TFP: $z \in \{z_1, ..., z_{N_\varepsilon}\}$ with : $\Pr(z' = z_m \mid z = z_l) \equiv \pi^z_{lm}$
- Idiosyncratic TFP: $\varepsilon = \theta + a$, not separately observed
  - base component θ : reset randomly
    - with probability π, a new θ is drawn
    - with probability $1 - \pi$, the current θ is maintained
  - transitory component a : i.i.d.

Overview of learning

$y = z\varepsilon(k^{\alpha}n^{1-\alpha})^{\nu}, \qquad \varepsilon = \theta + a$

- ε is observed, but θ (persistent) and a (i.i.d.) are not separately observed
- a firm with $(\bar{\varepsilon}, t)$ updates the posterior distribution: $\theta \sim N(A, B)$
  1. $\bar{\varepsilon} = \sum_{i=1}^{t} \varepsilon_i / t$ (mean of the previously observed idiosyncratic shocks)
  2. t (the number of the observations)

$$A = \frac{\sigma_a^2}{\sigma_a^2 + t\sigma_\theta^2}\bar{\theta} + \frac{t\sigma_\theta^2}{\sigma_a^2 + t\sigma_\theta^2}\bar{\varepsilon} \qquad (1)$$

$$B = \frac{\sigma_a^2\sigma_\theta^2}{\sigma_a^2 + t\sigma_\theta^2} \qquad (2)$$

Two types of exogenous shocks

$y = z\varepsilon(k^{\alpha}n^{1-\alpha})^{\nu}, \qquad \varepsilon = \theta + a$

θ *changes with probability* π

- Uncertainty shocks π
  - two-state Markov process for the reset probability: $\pi \in \{\pi_L, \pi_H\}$
  - high reset probability
    - increases the dispersion of TFP growth rates across firms
    - pushes more firms into the early stage of learning
- Aggregate TFP shocks z

Firm problem

- Aggregate state involves nontrivial distribution of firms: $\mu = (\bar{\varepsilon}, t, \varepsilon, k)$
- Each firm takes the law of motion of aggregate states as given

$$\mu' = \Gamma(s, \mu) \text{ where } s = (z, \pi)$$

- Value of a firm

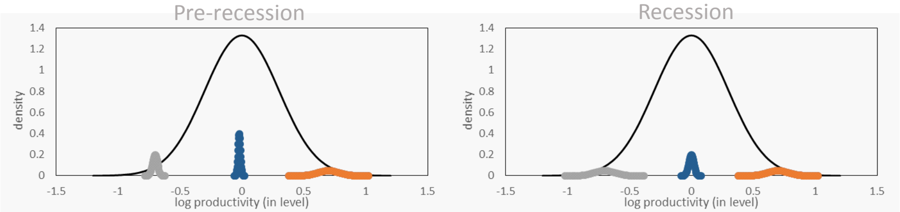
$$\begin{aligned} V(\bar{\varepsilon}, t, \varepsilon, k; s, \mu) &= \max_{n,k'} \Big[z\varepsilon (k^{\alpha} n^{1-\alpha})^{\nu} - \omega n + (1-\delta)k - k' \\ &\quad + (1-\pi) E_{s'|s} d\left(s', s, \mu\right) E_{\bar{\varepsilon}'|\bar{\varepsilon},t} V(\bar{\varepsilon}', t+1, \varepsilon', k'; s', \mu') \\ &\quad + \pi E_{s'|s} d\left(s', s, \mu\right) E_{\varepsilon'} V(\frac{\overline{\theta} + \varepsilon'}{2}, 2, \varepsilon', k'; s', \mu') \Big] \end{aligned}$$

$$\text{subject to} \quad : \quad \bar{\varepsilon}' = \frac{t\bar{\varepsilon} + \varepsilon'}{t+1}$$

Heterogeneous uncertainty

A three-firm example

- big line: the unconditional distribution of idiosyncratic productivity: θ
- small line: the conditional distribution for each firm
    1. grey line: informed
    2. blue line: well-informed
    3. orange line: uninformed

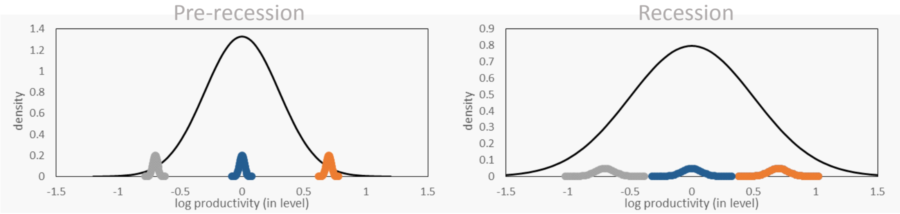


▸ homogeneous uncertainty ▸ micro implication

Bloom (2009)

Second moment shocks and non-convex adjustment costs

- real option effects ("wait-and-see"): a rapid drop and rebound
  - inaction regions expand in uncertain times
  - pent-up demand leads to a quick rebound
- Oi-Hartman-Abel effects: positive effects on target capital stock



Macro implications

Rapid drop and slow rebound

- precautionary effects
  - the high probability of information loss makes firms cautious.
  - this excess caution ends when the shock is off.
- distributional effects
  - the population share of uninformed firms increases sharply in recessions.
  - however, this does not decrease immediately after recessions end.

Quantitative results

- at the start of recessions
  - precautionary and distributional effects reinforce each other
    $\Rightarrow$ steep recessions
- after recessions
  - distributional effects dominate precautionary effects
    $\Rightarrow$ slow recoveries

Outline

1. Empirics
2. Model
3. Calibration
4. Simulation

Calibration: micro and macro parameters

$$u(C, L) = \log C + \eta L \qquad y = z\varepsilon(k^{\alpha} n^{1-\alpha})^{\nu}$$

- Aggregate moments for the U.S.

β : risk free real rate $= 0.04$
ν : labor share $= 0.60$
δ : investment/capital $= 0.07$

α : capital/output $= 2.5$
η : hours worked $= 0.33$

$$\varepsilon = \theta + a \qquad \theta \sim N(\bar{\theta}, \sigma_{\theta}^2) \qquad a \sim N(0, \sigma_a^2)$$

- The panel data

$\bar{\theta}$: return on capital (mean) $= 0.19$
σ_a^2 : return on capital (serial correlation) $= 0.29$
σ_{θ}^2 : investment rate (mean) $= 0.15$

Calibration: aggregate shocks

uncertainty shocks: $\pi \in \{\pi_L, \pi_H\}$ *with* $\begin{vmatrix} p_1 & 1-p_1 \\ 1-p_2 & p_2 \end{vmatrix}$

1. π_L $(= 0.15)$: mean of *fdis_med*
2. π_H $(= 0.32)$ $\Rightarrow$ 74% increase in *fdis_med*
3. p_1 $(= 0.86)$ and $p_2 (= 0.50)$ are estimated for the NBER business cycles patterns

aggregate TFP shocks: $\log z' = \rho_z \log z + \eta_z'$ *with* $\eta_z' \sim N(0, \sigma^2_{\eta_z})$

1. ρ_z $(= 0.85)$: Khan and Thomas (2013)
2. $\sigma^2_{\eta_z} (= 0.12)$: unconditional standard deviation of output

Outline

1. Empirics
2. Model
3. Calibration
4. Simulation ▸ solution

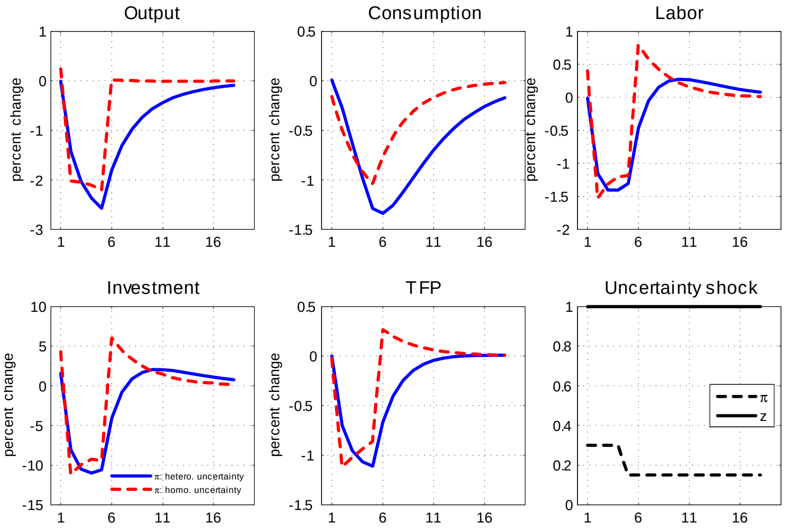
The Great Recession simulation

Table 5 - Peak-to-trough Drops for the Great Recession and Model

	GDP	Investment	TFP
data	5.59	18.98	2.18
model (uncertainty shock + aggregate productivity shock)	4.42	16.94	2.18
model (uncertainty shock)	2.57	10.99	1.11

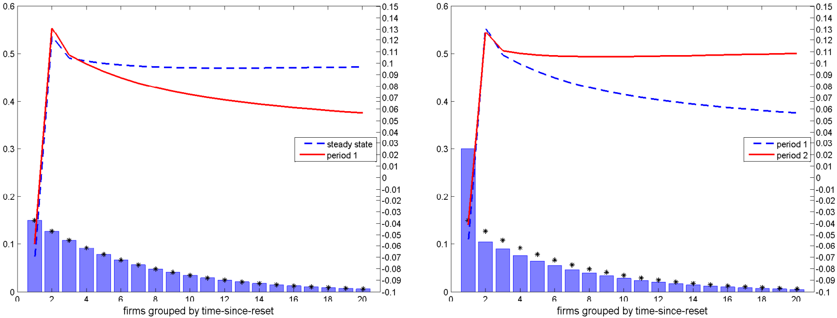
Notes: The peak-to-trough drops are calculated with log deviations from 07Q4 to 09Q2, detrended using the HP filter with parameter 1600. GDP and investment series are taken from BEA GDP Tables. Measured TFP is the Solow Residual series.

Role of imperfect information



At the start of the recession

Average investment in each cohort and firm distribution

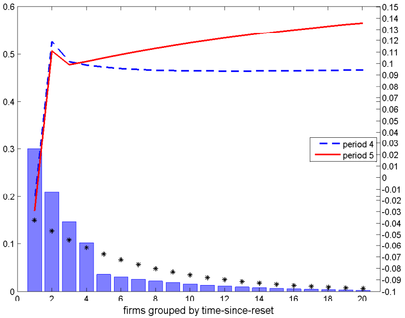


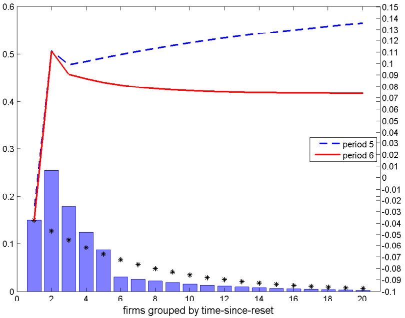
Impacts of uncertainty shocks are reinforced

- precautionary effects at period 1 [-12% in investment]
- distributional effects at period 2 [-5% in investment]

At the recovery stage from the recession

Average investment in each cohort and firm distribution





Pent-up investment demand is small

- few firms increase investment demand at period 5
- missing parts of the distribution is gradually filled up afterwards

Conclusion

Heterogeneous firm model with Bayesian learning at the firm level

Bayesian uncertainty model	Stochastic volatility model
belief & fundamental	fundamental
heterogeneous uncertainty	homogeneous uncertainty
no rigidity	non-convex adjustment costs

Implications:

1. The population share of uninformed firms increases sharply in recessions, however this does not decrease immediately after recessions.
2. Quick to lose confidence, however it takes time to restore confidence.
3. Quick drop and slow rebound, following uncertainty shocks.