A New Look at Uncertainty Shocks: Imperfect Information and Misallocation

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June, 2014
The 2007-09 recession is characterized by

1. **[Micro fact]** a rise in micro level volatility
   - firm level productivity, sales growth rates
     - TFP-based measure

2. **[Macro fact]** a large and persistent recession
   - 18 months recession
     - recessions

I proposes a theory that reconciles the micro fact with the macro one

- uncertainty shocks
- imperfect information / Bayesian learning
1 Empirical data on micro uncertainty
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2. **Build a heterogeneous firm model with Bayesian learning**
Outline

1. **Empirical data on micro uncertainty**
   - Level of uncertainty is heterogeneous among firms
   - Level of uncertainty is time-varying

2. **Build a heterogeneous firm model with Bayesian learning**
   - Account for heterogeneous uncertainty at micro level
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2 Build a heterogeneous firm model with Bayesian learning
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   - Uncertainty shocks drive countercyclical uncertainty
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3. **Important implications for aggregate dynamics**
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3. **Important implications for aggregate dynamics**
   - Rapid drop and slow recovery, following uncertainty shocks
Heterogeneous uncertainty

- The conditional variance of idiosyncratic shocks is heterogeneous.
- The more informed, the smaller the conditional variance.

The model reconciles the micro fact with the macro one.

- The variance of plant level productivity growth rates is countercyclical.
- The model reproduces a rapid drop and slow recovery in recessions.
  - GDP falls by 80% and investment falls by 74% relative to the data. (output -4.5%, investment -14.2%, measured TFP -2.6%)
Related papers

**Micro level volatility and business cycles**
- Bloom (2009); Bloom et al. (2012); Bachman, Elstner and Sims (2013); Gilchrist, Sim, and Zakrajsek (2010); Arellano, Bai, and Kehoe (2012); Christiano, Motto, and Rostagno (2010); Vavra (2013); Schaal (2013); Takahashi (2013); Oh (2013)

**Information friction and misallocation**
- David, Hopenhayn and Venkateswaran (2013); Jovanovic (2013)

**Bayesian learning**
- Jovanovic (1982); Alti (2003); Timoshenko (2013)
Micro uncertainty measure

**Empirical strategy to measure heterogeneous uncertainty**
- Hard to elicit subjective probability distribution
- Instead, through the lens of investors and analysts’ forecasts

**Institutional Brokers’ Estimate System (IBES)**
- Firm level data on earning forecasts (EPS) by market participants
- Highest, lowest, mean, median and standard deviation are available
- 13,114 analysts from 846 contributors (brokers)
- US 1,345 firms, more than 20 EPS forecasts can be obtained

**Cross-sectional dispersion of EPS forecasts**
Heterogeneous uncertainty

Cross-sectional dispersion of EPS forecasts

Source: Institutional Brokers' Estimate System.
Cyclicality of uncertainty: EPS based

Correlation with GDP growth: -0.464

Source: Institutional Brokers' Estimate System.
TFP-based uncertainty measure

Census of Manufactures (CM) and Annual Survey of Manufactures (ASM)

- 300,000 to 400,000 establishments per survey (CM, every five years ending 2 and 7)
- 50,000 to 75,000 establishments per survey (ASM, every year)

Sample selection

- 15,673 establishments
  - between 1972 and 2009
  - appearing in more than 25 years

Cross-sectional dispersion of TFP shocks

- \( \log(z_{j,t}) = \rho \log(z_{j,t-1}) + \mu_j + \lambda_t + e_{j,t} \) (TFP shocks)
Cyclicality of uncertainty: TFP based

Correlation with GDP growth: -0.467
### Statistics of uncertainty measures

<table>
<thead>
<tr>
<th></th>
<th>EPS-based</th>
<th>TFP-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation</td>
<td>0.08</td>
<td>0.52</td>
</tr>
<tr>
<td>Skewness</td>
<td>1.47</td>
<td>-0.34</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>5.21</td>
<td>3.53</td>
</tr>
<tr>
<td>First order autocorrelation</td>
<td>0.70</td>
<td>0.69</td>
</tr>
<tr>
<td>Correlation with EPS-based</td>
<td>1.00</td>
<td>0.69</td>
</tr>
<tr>
<td>Correlation with TFP-based</td>
<td>0.69</td>
<td>1.00</td>
</tr>
<tr>
<td>Correlation with GDP growth rate</td>
<td>-0.464</td>
<td>-0.467</td>
</tr>
</tbody>
</table>

1. EPS-based and TFP-based are correlate each other
2. both measures are persistent and countercyclical
Summary of empirical facts

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   - Heterogeneity in conditional variance of idiosyncratic shocks
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3. Correlation with TFP-based uncertainty measure
Model

I develop a heterogeneous firm model with Bayesian learning.

- Idiosyncratic productivity has two components, not separately observed.
I develop a heterogeneous firm model with Bayesian learning.

- Idiosyncratic productivity has two components, not separately observed.
  - base component

1. Base component is persistent and changes infrequently.
2. Temporary component
3. Information shocks (heterogeneous uncertainty)
4. The arrival probability of information shocks is stochastic.
   - Uncertainty shocks (countercyclical productivity dispersion)
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  - lose information and restart learning
    - (information shocks: heterogeneous uncertainty)
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  1. base component
  2. temporary component

- Base component is persistent and changes infrequently.
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    (information shocks: heterogeneous uncertainty)

- The arrival probability of information shocks is stochastic.
  (uncertainty shocks: countercyclical productivity dispersion)
Overview of production

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

- aggregate TFP: \( z \in \{z_1, ..., z_{N_e}\} \) with: \( \Pr (z' = z_m \mid z = z_l) \equiv \pi_{lm} \)

- idiosyncratic TFP: \( \varepsilon = \theta + a \)
  - base component \( \theta \): with probability \( \pi \), the current level is lost and newly drawn
  - transitory component: \( a \): firms draw a new level every period

- capital stock: \( k \)

- labor from households (real wage \( \omega \)): \( n \)
Overview of learning

Firms learn their permanent component gradually (DeGroot (2004))

- $\varepsilon$ is observed, but $\theta$ and $a$ are not observed: $\varepsilon = \theta + a$

- A firm with $(\bar{\varepsilon}, t)$ infers the posterior distribution: $\theta \sim N(A, B)$

  - $\bar{\varepsilon} = \sum_{i=1}^{t} \varepsilon_i / t$ (mean of the previously observed idiosyncratic shocks)
  - $t$ (the number of the observations)

\[
A = \frac{\sigma_a^2}{\sigma_a^2 + t\sigma_\theta^2} \bar{\theta} + \frac{t\sigma_\theta^2}{\sigma_a^2 + t\sigma_\theta^2} \bar{\varepsilon} \tag{1}
\]

\[
B = \frac{\sigma_a^2 \sigma_\theta^2}{\sigma_a^2 + t\sigma_\theta^2} \tag{2}
\]
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

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

subject to : \( \bar{\varepsilon}' = \frac{t\bar{\varepsilon} + \varepsilon'}{t + 1} \)
Micro implications

Countercyclical variance of plant level productivity growth rates

- this is because many firms change productivity.
- this is not because all firms face the higher volatility of idiosyncratic shocks.

Heterogeneous uncertainty

- informed and uninformed firms coexist.
  - informed: the conditional variance of idiosyncratic productivity is low.
  - uninformed: the conditional variance of idiosyncratic productivity is high.
- the population shares of each type of firms are time-varying.
Heterogeneous uncertainty

A three-firm example

- big line: the unconditional distribution of idiosyncratic productivity: \( \theta \)
- small line: the conditional distribution for each firm
  - grey line: informed
  - blue line: well-informed
  - orange line: uninformed

Pre-recession

Recession
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 lost makes firms cautious.
  - the cautiousness is muted when the shock ends.

- 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 are compounded.

- after recessions
  - distributional effects dominate precautionary ones.
Calibration

\[ u(C, L) = \log C + \eta L \]
\[ \varepsilon = \theta + a \quad \theta \sim N(\bar{\theta}, \sigma^2_{\theta}) \]
\[ y = z\varepsilon(k^\alpha n^{1-\alpha})^\nu \]
\[ a \sim N(0, \sigma^2_a) \]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Targets</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital share of income: ( \alpha )</td>
<td>0.335</td>
<td>Capital share of income</td>
<td>0.335</td>
<td>0.335</td>
</tr>
<tr>
<td>Returns to scale: ( \nu )</td>
<td>0.80</td>
<td>Aggregate K/Y</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Depreciation rate: ( \delta )</td>
<td>0.079</td>
<td>Aggregate I/K</td>
<td>0.079</td>
<td>0.079</td>
</tr>
<tr>
<td>Discount factor: ( \beta )</td>
<td>0.04</td>
<td>Real interest rate</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Leisure preference: ( \eta )</td>
<td>2.0</td>
<td>Hours worked</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>Mean of persistent component of TFP: ( \bar{\theta} )</td>
<td>1.38</td>
<td>Micro level mean of i/k</td>
<td>0.122</td>
<td>0.118</td>
</tr>
<tr>
<td>Variance of temporarily component of TFP: ( \sigma_a )</td>
<td>0.15</td>
<td>Micro level standard deviation of i/k</td>
<td>0.337</td>
<td>0.368</td>
</tr>
<tr>
<td>Variance of persistent component of TFP: ( \sigma_\theta )</td>
<td>0.33</td>
<td>Micro level serial correlation of i/k</td>
<td>0.058</td>
<td>0.007</td>
</tr>
<tr>
<td>Mean of aggregate TFP in non-recessions: ( z_H )</td>
<td>1.00</td>
<td>Micro level mean of TFP shocks in non-recessions</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Mean of aggregate TFP in recessions: ( z_L )</td>
<td>0.98</td>
<td>Micro level mean of TFP shocks in recessions</td>
<td>-0.166</td>
<td>-0.110</td>
</tr>
<tr>
<td>Probability of a new TFP draw in non-recessions: ( \pi_L )</td>
<td>0.15</td>
<td>Micro level variance of TFP shocks in non-recessions</td>
<td>0.243</td>
<td>0.234</td>
</tr>
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</table>
Distribution of TFP shocks

Level and cyclicality: the mean and variance of establishment-level TFP shocks

<table>
<thead>
<tr>
<th></th>
<th>mean non-recession (recession)</th>
<th>standard deviation non-recession (recession)</th>
</tr>
</thead>
<tbody>
<tr>
<td>data model</td>
<td>0.00 (−0.166)</td>
<td>0.243 (0.349)</td>
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Simulation results

- An example of one firm over 50 periods
The Great Recession simulation

1. **2nd moment shock**: $\pi$ (from 0.15 to 0.55)
2. **1st moment shock**: $z$ (from 1.00 to 0.98)

Peak-to-trough declines: U.S. 2007 recession and model:

<table>
<thead>
<tr>
<th></th>
<th>GDP</th>
<th>$I$</th>
<th>$N$</th>
<th>$C$</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>data</td>
<td>5.59</td>
<td>18.98</td>
<td>6.03</td>
<td>4.08</td>
<td>2.18</td>
</tr>
<tr>
<td>model (1st moment shock + 2nd moment shock)</td>
<td>4.48</td>
<td>14.14</td>
<td>2.27</td>
<td>2.72</td>
<td>2.60</td>
</tr>
<tr>
<td>model (2nd moment shock)</td>
<td>2.61</td>
<td>8.37</td>
<td>1.25</td>
<td>1.38</td>
<td>1.39</td>
</tr>
</tbody>
</table>
Recent recession simulation
perfect foresight transitions

Tatsuro Senga (Ohio State)
Role of imperfect information
perfect foresight transitions

Output

Consumption

Labor

Investment

TFP

Uncertainty shock

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At the start of the recession

Average investment in each cohort and firm distribution

Impacts of uncertainty shocks are compounded

- precautionary effects at period 1 [▲6.2% in investment]
- distributional effects at period 2 [▲8.2% 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

Informed and uninformed firms coexist, implying heterogeneous uncertainty.

- the more informed, the smaller the conditional variance.

Many firms change productivities, lose information and restart learning in periods with uncertainty shocks.

- time-varying population share of informed and uninformed firms

Implications:

1. Uncertainty shocks drive countercyclical variance of plant level productivity growth rates.

2. The population share of uninformed firms increases sharply in recessions, however this does not decrease immediately after recessions.

3. Quick drop and slow rebound, following uncertainty shocks.
Comparison of postwar recessions

Cumulative decline of Real GDP

![Cumulative decline of Real GDP graph](image)

Source: Federal Reserve Bank of Minneapolis.