News, Irreversible Investment and Time-Varying Uncertainty

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Empirical studies document that the volatility of output, investment and other macro variables of the US economy has exhibited a high degree of time variation. (Kim and Nelson, 1999; Stock and Watson, 2002;)

1. The “Great Moderation”

2. The recent financial crisis

Statistics $\Rightarrow$ stochastic volatility

Economics $\Rightarrow$ time-varying uncertainty
Existing literature

To study time-varying uncertainty, economists have started to relax the homoscedasticity assumption to stochastic processes.

1. Time-varying volatility of the exogenous shocks (Justiniano and Primiceri, 2008; Fernandez-villaverde et al., 2011)

2. Markov regime switching in the variance of the disturbance (Sims and Zha, 2006)

What explains the changing volatility? No expectation effect!
Objective

This paper studies the interaction among uncertainty, information flows and business fluctuations.

1. I propose time-varying uncertainty via a regime switching model in information assumes that the quality of signals about future economic fundamentals can change.

2. Irreversible investment interacts with financial market imperfection and imperfect information to amplify the effect of uncertainty.
“News” Driven Business Cycle
(Jaimovich and Sergio, 2009; Barsky and Sims, 2011)

“Uncertainty” Driven Business Cycle
(Bloom, 2009; Bloom et al., 2010)

⇒ Time-varying uncertainty stemming from changing information flow provides a synthesis.

Irreversible Investment Under Uncertainty
(Bernanke et al., 1983, Veracierto, 2002)

⇒ Uncertainty affects investment in a nonlinear way depends upon information flow.
More imprecise news — or foresight about future fundamentals reduce economic activity through a fall in investment triggered by higher uncertainty about future returns on capital.

The changing information flow induces stochastic volatility of the macro variables without posing additional assumption on the variance of exogenous shocks.

Macro variables respond to fundamentals in a nonlinear manner which depends crucially upon the level of uncertainty, the nonlinearity leads to asymmetric business cycle.
Households

\[
\max \sum_{t=0}^{\infty} \beta^t \left( \frac{(C_t - \gamma C_{t-1})^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\varphi}}{1+\varphi} \right) \\
(1)
\]

\[
C_t + I_t = W_t N_t + (1 - \tau_t^K) R_t K_{t-1} + Z_t \\
(2)
\]

We allow for a non-convex adjustment cost–partial irreversibility.

\[
I_t = Q_t(A_t)(K_t - (1 - \delta)K_{t-1}) \\
(3)
\]

\(Q_t\) is the indicator function

\[
Q_t = \begin{cases} 
1 & \text{if } A_t \geq A^* \\
q_t & \text{if } A_t < A^*
\end{cases} \\
(4)
\]
Firms

Firms are perfectly competitive, maximize the profits according to

$$\max Y_t - W_t N_t - R_t K_{t-1}$$  \hspace{1cm} (5)

The production function is,

$$Y_t = A_t K_t^{\alpha} N_{t-1}^{1-\alpha}$$  \hspace{1cm} (6)

The household and firms first order condition relates to irreversibility is:

$$\lambda_t q_t = \beta E_t \lambda_{t+1} [(1 - \tau_{t+1} K_t) \alpha \frac{Y_{t+1}}{K_t} + q_{t+1} (1 - \delta)]$$  \hspace{1cm} (7)
Information Structure

1. News shocks are important. (Schmitt-Grohe and Uribe, 2011)

2. News shocks have a limited role (Forni et al., 2011)

3. Uncertainty shocks are important. (Bloom et al., 2010)

4. The Livingston survey contains unemployment forecasts at a six-month horizon. The average absolute percentage forecast error is:
   - 3.3 percent in the first part of the sample (1961:IV-1982:IV)
   - only 1.5 percent in the second part of the sample (1983:I-2003:IV)

⇒ Quality of news signal varies overtime.
**Information Structure**

\[ a_t = \begin{cases} 
\rho a_{t-1} + \varepsilon_t & \text{for } S_t = 1 \\
\rho a_{t-1} + \phi_1\varepsilon_{t-1} + \phi_2\varepsilon_{t-2} + \cdots + \phi_j\varepsilon_{t-j} & \text{for } S_t = 2 
\end{cases} \]  

(8)

The agent knows technology evolve according to

\[
\begin{bmatrix}
p(S_t = 1|S_{t-1} = 1) & p(S_t = 2|S_{t-1} = 1) \\
p(S_t = 1|S_{t-1} = 2) & p(S_t = 2|S_{t-1} = 2)
\end{bmatrix} = \begin{bmatrix}
p_{11} & 1 - p_{11} \\
1 - p_{22} & p_{22}
\end{bmatrix} \]

(9)

Conditional on being in the regime without anticipated shock \((S_t = 1)\), Uncertainty in this regime can be represented by:

\[
E[A_{t+1} - E(A_{t+1}|\{\varepsilon_t, \varepsilon_{t-1}, \ldots, \varepsilon_{t-j}\})]^2 = (p_{11})^2 \sigma_\varepsilon^2
\]
Simple Model

inelastic labor, no habit formation

\[
\frac{q_t}{C_t} = \beta E_t \frac{1}{C_{t+1}} [(1 - \tau)\alpha A_{t+1} K_t^{\alpha - 1} + q_{t+1} (1 - \delta)] \tag{10}
\]

\[
C_t + q_t (K_t - (1 - \delta) K_{t-1}) = A_t K_t^\alpha \tag{11}
\]

log linearize

\[
E_t \hat{k}_{t+1} - \gamma_0 \hat{k}_t + \gamma_1 \hat{k}_{t-1} = \nu_0 E_t a_{t+1} - \nu_1 a_t - \eta E_t \hat{q}_{t+1} \tag{12}
\]
Simple Model

The equilibrium capital accumulation is:

\[
\hat{k}_t = \lambda_1 \hat{k}_{t-1} - \theta E_t \sum_{i=0}^{\infty} \theta^i (\nu_0 a_{t+1+i} - \nu_1 a_{t+i} - \eta \hat{q}_{t+1+i})
\]

\[
= \lambda_1 \hat{k}_{t-1} + \theta \nu_1 a_t - \theta (\nu_0 - \theta \nu_1) E_t \sum_{i=0}^{\infty} \theta^i a_{t+1+i} + \theta \eta E_t \sum_{i=0}^{\infty} \hat{q}_{t+1+i}
\]

\[\text{news channel} \quad \text{irreversible investment channel}\]
News Channel

\[ \hat{k}_t = \lambda_1 \hat{k}_{t-1} + \theta \nu_1 \hat{a}_t - \theta (\nu_0 - \theta \nu_1) E_t \sum_{i=0}^{\infty} \theta^i \hat{a}_{t+1+i} \]  

(13)

Suppose foresight period is \( q \).

1. Information set: \( \Omega_t = \{a_\ell, a_{\ell+1}, \ldots, a_{\ell+q}\}, \quad \ell \leq t \)

2. News arrival process:
   - perfect foresight: \( a_t = \varepsilon_{t-q} \)
   - correlated news: \( a_t = \phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2} + \cdots + \phi_q \varepsilon_{t-q}, \quad \sum_{i=1}^{q} \phi_i = 1 \)
News Channel

Suppose \( q = 2 \)

perfect foresight

\[
\hat{k}_t = \lambda_1 \hat{k}_{t-1} - \theta \nu_1 \varepsilon_{t-2} - \theta (\nu_0 - \theta \nu_1) \left( \varepsilon_{t-1} + \theta \varepsilon_t \right) 
\]

correlated news

\[
\hat{k}_t = \lambda_1 \hat{k}_{t-1} - \theta \nu_1 (\phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2}) - \theta (\nu_0 - \theta \nu_1) (\phi_1 \varepsilon_t + \phi_2 \varepsilon_{t-1} + \theta \phi_2 \varepsilon_t) 
\]

advantage of correlated news:
1. accommodates revisions in announcements
2. accounts for intensity of information flows
News Channel — First Moment Effect

\[ \hat{k}_t = \lambda_1 \hat{k}_{t-1} + \phi_2 \theta \nu_1 \varepsilon_{t-2} + (\phi_1 \theta \nu_1 - \phi_2 \theta (\nu_0 - \theta \nu_1)) \varepsilon_{t-1} - \theta (\nu_0 - \theta \nu_1)(\phi_1 + \theta \phi_2) \varepsilon_t \]
News Channel — Second Moment Effect

\[
\sigma^2(\hat{k}_t) = (\xi_1^2 + \xi_2^2 + \xi_3^2)\sigma^2_{\varepsilon}
\]
**Irreversible Investment Channel**

\[ \hat{k}_t = \lambda_1 \hat{k}_{t-1} + \theta \nu_1 \hat{a}_t + \theta \eta E_t \sum_{i=0}^{\infty} \hat{q}_{t+1+i} \]  

(14)

Consider two information flows with different information sets:

1. \( a_{t+1} = \varepsilon_t, \Omega_t^1 = \{k_{\ell-1}, a_{\ell+1}\}, \text{ for } \ell \leq t \)

   Given the restriction that \( E_t a_{t+i} = 0, \ E_t[\hat{q}_{t+1}|\Omega_t^1] = 0. \)

2. \( a_{t+1} = \varepsilon_{t+1}, \Omega_t^2 = \{k_{\ell-1}, a_{\ell}\}, \text{ for } \ell \leq t \)

Technology can only take two values \((\varepsilon_L, \varepsilon_H)\) with equal probability 0.5

\[ \hat{q}_{t+1} = \begin{cases} 
0 & \text{if } a_{t+1} = \varepsilon_H \geq a^* \\
-1 & \text{if } a_{t+1} = \varepsilon_L < a^* 
\end{cases} \]  

(15)

\[ E_t[\hat{q}_{t+1}|\Omega_t^2] = 0.5 \times 0 + 0.5 \times (-1) = -0.5 \]
First and Second Moment Effects

First Moment:

\[ \hat{k}_t = \lambda_1 \hat{k}_{t-1} + \theta \nu_1 \hat{a}_t + \theta \eta E_t \sum_{i=0}^{\infty} \hat{q}_{t+1+i} \]

\[ E_t[\hat{q}_{t+1}|\Omega_t^2] < E_t[\hat{q}_{t+1}|\Omega_t^1] \Rightarrow \hat{k}_t|\Omega_t^2 < \hat{k}_t|\Omega_t^1 \]

The equilibrium capital is lower under a smaller information set arising from higher uncertainty.

Second moment:

\[ \sigma^2(\hat{k}_t) = (\theta \nu_1)^2 \sigma_\varepsilon^2 + (\theta \eta)^2 \sigma_q^2 \]

\[ (\sigma_q^2)|\Omega_t^2 > (\sigma_q^2)|\Omega_t^1 \Rightarrow \sigma^2(\hat{k}_t|\Omega_t^2) > \sigma^2(\hat{k}_t|\Omega_t^1) \]

Higher uncertainty amplifies the variation of capital.
## Calibration

<table>
<thead>
<tr>
<th>parameters</th>
<th>values</th>
<th>notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>2</td>
<td>inverse of intertemporal elasticity of substitution</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>1</td>
<td>inverse of Frisch labor supply elasticity</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.36</td>
<td>capital share</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.025</td>
<td>depreciation rate</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.5</td>
<td>habit persistence for consumption</td>
</tr>
<tr>
<td>$\rho^A$</td>
<td>0.9</td>
<td>technology persistence</td>
</tr>
<tr>
<td>$\sigma^A$</td>
<td>0.0063</td>
<td>standard deviation of technology shock</td>
</tr>
<tr>
<td>$\phi_i$</td>
<td>0.25</td>
<td>weight on news, $i = 1, 2, 3, 4$</td>
</tr>
<tr>
<td>$q$</td>
<td>0.66</td>
<td>degree of irreversibility (Bloom, 2009)</td>
</tr>
</tbody>
</table>
Determinants of Technology Threshold

Top panel: percentage of investment rate in plant-level. Bottom panel: investment percentage deviation from trend in aggregate-level (by HP filter)
Investment and Financial Market Imperfection

1. Irreversible investment is not important in aggregate. (Dow and Olson, 1992; Veracierto, 2002;)

2. Investment rates have a low spread but a heavy right tail, due to the lack of disinvestment in firm-level data. (Barnett and Sakellaries, 1998; Bloom, 2009)

Irreversible investment constraint can still affect expectation even if no direct observations of negative investment in aggregate.
Investment and Financial Market Imperfection

In practice, expectation effect through irreversible constraint is strengthened due to financial market imperfection.

1. Adverse shocks to the economy may be amplified by worsening credit market conditions — financial accelerator. (Bernanke et al., 1996)

2. Financial frictions play a major role in shaping the uncertainty-investment nexus. (Gilchrist et al., 2010; Davig and Hakkio, 2010)

3. When shocks are persistent, financing and the irreversibility constraint interact and amplify each other. (Caggese, 2007)

4. Disaster outcomes that destroys a share of the capital stock, makes the return on capital very low following a disaster. (Gourio, 2010)
Determinants of Technology Threshold

\[ a^* = \mu_t a^T \]

\( \mu_t \): financial market indicator, \( a^T \): theoretical threshold that leads to zero investment, \( a^* \): threshold that leads to a “disaster” investment.
Foresight poses a challenge to econometric analysis since it generates an equilibrium with a non-fundamental moving average representation. (Leeper, Walker and Yang, 2011)

News about fundamental, unlike news about policies which can be observed by announcements or legislations, is absent of direct measurement.

With the inclusion of stock prices, consumer confidence and other leading indicators, it is helpful to predict the time path of TFP. (Barsky and Sims, 2009; Forni et al., 2011)

I calibrate persistence in News/No News regime using uncertainty index.
Determinants of Persistence in Regimes

Uncertain Index by Bloom, Floetotto, and Jaimovich (2010)

\[ x_t = \mu(S_t) + \rho^x x_{t-1} + \varepsilon_t \]  

\[ \mu(S_t) = \begin{cases} 
\mu_1 & \text{for } S_t = 1 \text{ (no news)} \\
\mu_2 & \text{for } S_t = 2 \text{ (news)} 
\end{cases} \quad \mu_1 > \mu_2 \]
Determinants of Persistence in Regimes

\[
\begin{bmatrix}
p_{11} & 1 - p_{11} \\
1 - p_{22} & p_{22}
\end{bmatrix}
= \begin{bmatrix}
0.7795 & 0.2205 \\
0.0632 & 0.9368
\end{bmatrix}
\]
**Decision Rules: News Channel**

- **Black solid line:** four periods smooth news, conditional on no news regime;
- **Blue dashed line:** four periods smooth news, conditional on news regime;
- **Red dotted line with triangle:** two periods smooth news, conditional on no news regime;
- **Green dotted line with circle:** two periods smooth news, conditional on news regime.
**Decision Rules: Irreversible Investment Channel**

- **Capital** \( k_t \)
- **Technology** \( A_t \)

- Black solid line: conditional on no news regime
- Blue dashed line: conditional on news regime
- Red dashed line with triangle: negative financial shock
- Green dashed line with circle: positive financial shock

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black solid line: conditional on no news regime; blue dashed line: conditional on news regime; red dashed line with triangle: negative financial shock; green dashed line with circle: positive financial shock.
First Moment Simulation

What’s the effect of an uncertainty shock?
First Moment Simulation

Hours

Consumption

Investment

Output

low $A^*$

high $A^*$
First Moment Simulation

1. Uncertainty shock can generate recession without technological regress.

2. Similar to Bloom (2009), Bloom, Floetotto and Jaimovich (2010), irreversible investment still plays the key role to generate business fluctuation.

3. Our model points out two sources of uncertainty changes:
   - how much information agents can receive about future fundamental
   - how bad is the financial market condition
How is the time-varying uncertainty due to interaction between news and irreversible investment contributes to generate stochastic volatility?
## Second Moment Simulation

<table>
<thead>
<tr>
<th>Data</th>
<th>Hours</th>
<th>Percentage</th>
<th>Standard Deviation</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972-1983</td>
<td>1.8224</td>
<td>1.2294</td>
<td>8.5154</td>
<td>3.4554</td>
</tr>
<tr>
<td>1984-2006</td>
<td>1.0407</td>
<td>0.6330</td>
<td>4.1111</td>
<td>1.5224</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model 1</th>
<th>Hours</th>
<th>Percentage</th>
<th>Standard Deviation</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972-2006</td>
<td>0.5238</td>
<td>0.9968</td>
<td>7.0537</td>
<td>1.8731</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model 2</th>
<th>Hours</th>
<th>Percentage</th>
<th>Standard Deviation</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972-1983</td>
<td>0.5073</td>
<td>0.9783</td>
<td>6.8195</td>
<td>1.8552</td>
</tr>
<tr>
<td>1984-2006</td>
<td>0.3250</td>
<td>0.6365</td>
<td>4.2567</td>
<td>1.1875</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Baseline Model</th>
<th>Hours</th>
<th>Percentage</th>
<th>Standard Deviation</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972-1983</td>
<td>1.0615</td>
<td>1.2080</td>
<td>10.8314</td>
<td>2.4070</td>
</tr>
<tr>
<td>1984-2006</td>
<td>0.6366</td>
<td>0.7727</td>
<td>6.6432</td>
<td>1.5147</td>
</tr>
</tbody>
</table>
### Second Moment Simulation

<table>
<thead>
<tr>
<th></th>
<th>Percentage Contribution to Difference in Volatility</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours</td>
<td>Consumption</td>
<td>Investment</td>
<td>Output</td>
</tr>
<tr>
<td><strong>News</strong></td>
<td>1972-1983</td>
<td>3%</td>
<td>2%</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>1984-2006</td>
<td>38%</td>
<td>36%</td>
<td>40%</td>
</tr>
<tr>
<td><strong>Irreversibility</strong></td>
<td>1972-1983</td>
<td>105%</td>
<td>23%</td>
<td>57%</td>
</tr>
<tr>
<td></td>
<td>1984-2006</td>
<td>59%</td>
<td>14%</td>
<td>34%</td>
</tr>
</tbody>
</table>
Second Moment Simulation

The second moment simulation provides a complementary explanation for the Great Moderation.

1. Good Luck
   (Stock and Watson, 2003; Justiniano and Primiceri, 2008)

2. Good Policy
   (Clarida, Gali and Gertler, 2000; Fernandez-Villaverda et al., 2010)

3. Information
Third and Fourth Moment Simulation

How the uncertainty effect contributes to the distribution of aggregate variables?
Third and Fourth Moment Simulation

An important feature of the data is the asymmetry distribution. (Neftci, 1984; Acemoglu and Scott, 1997)
### Third and Fourth Moment Simulation

<table>
<thead>
<tr>
<th></th>
<th>Hours</th>
<th>Consumption</th>
<th>Investment</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data</strong></td>
<td>-0.30</td>
<td>0.06</td>
<td>-0.39</td>
<td>-0.25</td>
</tr>
<tr>
<td>Skewness</td>
<td>2.49</td>
<td>2.65</td>
<td>3.45</td>
<td>3.09</td>
</tr>
<tr>
<td>Kurtosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No News Regime</strong></td>
<td>-0.50</td>
<td>-0.23</td>
<td>-0.60</td>
<td>-0.27</td>
</tr>
<tr>
<td>Skewness</td>
<td>3.82</td>
<td>2.76</td>
<td>3.62</td>
<td>3.06</td>
</tr>
<tr>
<td>Kurtosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>News Regime</strong></td>
<td>-0.53</td>
<td>-0.07</td>
<td>-0.53</td>
<td>-0.13</td>
</tr>
<tr>
<td>Skewness</td>
<td>3.76</td>
<td>2.56</td>
<td>3.50</td>
<td>2.95</td>
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<tr>
<td>Kurtosis</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Business Cycle Statistics

Theoretically, Veldkamp (2006) highlight the role of information, with learning process as the main driving force for asymmetry.

In this paper nonlinearity arises from irreversible investment, but information structure determines the degree of nonlinearity.
1. Uncertainty is determined by news channel and irreversible investment channel jointly.

2. Macro variables respond to fundamentals in a nonlinear manner.

3. Less news increases uncertainty and leads to drops in aggregate economic activity.

4. Less noisy news mitigate irreversible investment channel and strengthen news channel to decrease macro variable volatility, provides complementary explanation for great moderation.