Coordinating Business Cycles

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Figure: US real GDP (log) and linear trend (2007Q4 = 100)
Motivation

- Postwar US business cycles:
  - Strong tendency to revert back to trend
  - 2007-09 recession: the economy seems to have fallen to a lower steady state

- We propose an explanation based on coordination failures
  - When complementarities are strong, can model the economy as a coordination game with multiple equilibria
    - Diamond (1982); Kiyotaki (1988); Benhabib and Farmer (1994);...
  - Hypothesis: the economy is trapped in a low output equilibrium as agents fail to coordinate on higher production/demand
Our Contribution

• We develop a model of coordination failures and business cycles
• We respond to two key challenges in this literature:
  ▶ Quantitative
    • Typical models are too stylized/unrealistic
      ⇒ Our model is a small deviation from standard neoclassical model with monopolistic competition
  ▶ Methodological
    • Equilibrium indeterminacy limits welfare/quantitative analysis
      ⇒ We adopt a global game approach to discipline equilibrium selection
• The model can be used as a benchmark for quantitative and policy analysis
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- We respond to two key challenges in this literature:
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  - **Methodological**
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      ⇒ We adopt a global game approach to discipline equilibrium selection
- The model can be used as a benchmark for quantitative and policy analysis
• Standard neoclassical model with:
  ▶ Monopolistic competition
    • Aggregate demand externality provides a motive to coordinate
  ▶ Non-convex capacity choice
    • Breaks concavity of firm’s problem, locally increasing returns
    • Large evidence for investment, labor but also shifts/production lines
    • We capture these non-convexities in the simplest way
      \[ u_t \in \{u_h > u_l\} \]

• Multiplicity?
  ▶ Multiplicity for relevant parameters under complete information,
  ▶ Uniqueness everywhere under incomplete information (global game)
Main Results

• Dynamics
  ▶ Multiple steady states in the multiplicity region
  ▶ Deep recessions: the economy can fall in a coordination trap where coordination on high steady state is difficult
  ▶ Quantitatively consistent with various features of the recovery from 2007-2009 recession

• Policy
  ▶ Fiscal policy in general welfare reducing as coordination problem magnifies crowding out
  ▶ But sometimes increases welfare by helping coordination close to a transition
  ▶ Optimal policy is a mix of input and profit subsidies
I. Model: Complete Information Case
• Infinitely-lived representative household that solves

$$\max_{C_t, L_t, K_{t+1}} \mathbb{E} \sum_{t=0}^{\infty} \beta^t \left[ \frac{1}{1-\gamma} \left( C_t - \frac{L_t^{1+\nu}}{1+\nu} \right)^{1-\gamma} \right], \gamma \geq 0, \nu \geq 0$$

under the budget constraints

$$P_t (C_t + K_{t+1} - (1-\delta) K_t) \leq W_t L_t + R_t K_t + \Pi_t$$
• Two types of goods:
  ▶ Final good used for consumption and investment
  ▶ Differentiated goods $j \in [0, 1]$ used in production of final good

• Competitive final good industry with representative firm

\[ Y_t = \left( \int_0^1 Y_{jt} \frac{\sigma - 1}{\sigma} dj \right)^{\frac{\sigma}{\sigma - 1}}, \sigma > 1 \]

yielding demand curve and price index

\[ Y_{jt} = \left( \frac{P_{jt}}{P_t} \right)^{-\sigma} Y_t \quad \text{and} \quad P_t = \left( \int_0^1 P_{jt}^{1-\sigma} dj \right)^{1/(1-\sigma)} \]

and we normalize $P_t = 1$
Intermediate Producers

- Unit continuum of intermediate goods producer under monopolistic competition

\[ Y_{jt} = Ae^\theta u_{jt} K_{jt}^\alpha L_{jt}^{1-\alpha} \]

- Aggregate productivity \( \theta \) follows an AR(1)

\[ \theta_t = \rho \theta_{t-1} + \varepsilon_t^\theta, \quad \varepsilon_t^\theta \sim \text{iid } \mathcal{N} (0, \gamma_{\theta}^{-1}) \]

- Capacity utilization \( u_{jt} \)
  - Binary decision \( u_{jt} \in \{1, \omega\} \) with \( \omega > 1 \)
  - Operating at high capacity \( \omega \) costs \( f \)
  - Acts as a TFP shifter:

\[ A_h (\theta_t) \equiv \omega Ae^\theta \quad > \quad Ae^\theta \equiv A_l (\theta_t) \]
Equilibrium Definition

**Definition**
An equilibrium is policies for the household \( \{C_t(\theta^t), K_{t+1}(\theta^t), L_t(\theta^t)\} \), policies for firms \( \{Y_{jt}(\theta^t), K_{jt}(\theta^t), L_{jt}(\theta^t)\} \), \( j \in \{h, l\} \), a measure \( m_t(\theta^t) \) of high capacity firms, prices \( \{R_t(\theta^t), W_t(\theta^t)\} \) such that

- Household and firms solve their problems, markets clear,
- Mass of firms with high capacity is consistent with firms’ decisions

\[
\begin{align*}
    m_t(\theta^t) &\equiv \begin{cases} 
    1 & \text{if } \Pi_{ht} - f > \Pi_{lt} \\
    \in (0, 1) & \text{if } \Pi_{ht} - f = \Pi_{lt} \\
    0 & \text{if } \Pi_{ht} - f < \Pi_{lt}
    \end{cases}
\end{align*}
\]
The intermediate producer faces a simple static problem

Producers face a positive aggregate demand externality

\[ \Pi_{jt} = P_t Y_t^{1/\sigma} Y_{jt}^{\sigma-1/\sigma} - W_t L_{jt} - R_t K_{jt} \]

where \( \sigma \) determines the strength of externality

In partial equilibrium, the capacity choice collapses to

\[ \Pi = \max \left[ \frac{1}{\sigma} \frac{Y_t}{P_{ht}^{\sigma-1}} - f, \frac{1}{\sigma} \frac{Y_t}{P_{lt}^{\sigma-1}} \right] \]

with the cost of a marginal unit of output

\[ P_{jt} = \frac{\sigma}{\sigma - 1} MC_{jt} \quad \text{and} \quad MC_{jt} \equiv \frac{1}{A_{jt}^t (\theta)} \left( \frac{R_t}{\alpha} \right)^{\alpha} \left( \frac{W_t}{1 - \alpha} \right)^{1-\alpha} \]
• Incentives to use high capacity increase with aggregate demand $Y_t$
Characterization

- Under GHH preferences,
  - Labor supply curve independent of $C$,
  - Production side of the economy can be solved independently of consumption-saving decision!

- We thus proceed in two steps:
  - First, study static equilibrium (production and capacity choice)
  - Then, return to the dynamic economy ($C$ and $K'$ decisions)
• Simple aggregate production function:

\[ Y_t = \overline{A}(\theta_t, m_t) K_t^\alpha L_t^{1-\alpha} \]

\[ L_t = \left[ (1 - \alpha) \frac{\sigma - 1}{\sigma} \overline{A}(\theta_t, m_t) K_t^\alpha \right]^{\frac{1}{\nu+\alpha}} \]

• Endogenous TFP:

\[ \overline{A}(\theta, m) = \left( mA_h(\theta)^{\sigma-1} + (1 - m) A_l(\theta)^{\sigma-1} \right)^{\frac{1}{\sigma-1}} \]
• Simple aggregate production function:

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Static Equilibrium

- Simple aggregate production function:
  \[ Y_t = \bar{A}(\theta_t, m_t) K_t^\alpha L_t^{1-\alpha} \]
  \[ L_t = \left[ (1 - \alpha) \frac{\sigma - 1}{\sigma} \bar{A}(\theta_t, m_t) K_t^\alpha \right]^{\frac{1}{\nu+\alpha}} \]

- Endogenous TFP:
  \[ \bar{A}(\theta, m) = \left( mA_h(\theta)^{\sigma-1} + (1 - m) A_l(\theta)^{\sigma-1} \right)^{\frac{1}{\sigma-1}} \]
Proposition 1

Suppose that \( \frac{1+\nu}{\alpha+\nu} > \sigma - 1 \), then there exists cutoffs \( B_H < B_L \) such that there are multiple static equilibria for \( B_H \leq e^\theta K^\alpha \leq B_L \).
Static Equilibrium: Multiplicity

High equilibrium $Y_h(K_t, \theta_t)$

Low equilibrium $Y_l(K_t, \theta_t)$

Mixed equilibrium $Y_m(K_t, \theta_t)$

Capital $K$

Output $Y$
Is the static equilibrium efficient?

**Proposition 2**

*For \(\frac{1+\nu}{\alpha+\nu} > \sigma - 1\), there exists a threshold \(B_{SP} < B_L\) such that*

- *For \(e^\theta K^\alpha \leq B_{SP}\), the planner chooses \(m = 0\),
- *For \(e^\theta K^\alpha \geq B_{SP}\), the planner chooses \(m = 1\).*

*In addition, for \(\sigma\) low enough, \(B_{SP} < B_H\).*
Static Equilibrium: Efficiency

CE: Multiple equilibria

CE: High equilibrium only

SP: High capacity

SP: Low capacity

CE: Low equilibrium only

Productivity $\theta$

Capital $K$
Static Equilibrium: Coordination Failure

- **CE:** High equilibrium only
- **CE:** Multiple equilibria
- **CE:** Low equilibrium only
- **SP:** High capacity
- **SP:** Low capacity
- **Coordination failure**
II. Model: Incomplete Information Case
Model: Incomplete Information

- Model remains the same, except:
  - Capacity choice is made under uncertainty about current $\theta_t$
- New timing:
  1. Beginning of period: $\theta_t = \rho \theta_{t-1} + \varepsilon_t^\theta$ is drawn
  2. Firm $j$ observes private signal $v_{jt} = \theta_t + \varepsilon_{jt}^\nu$ with $\varepsilon_{jt}^\nu \sim \text{iid } \mathcal{N}(0, \gamma_v^{-1})$
  3. Firms choose their capacity $u_j \in \{u_l, u_h\}$
  4. $\theta_t$ is observed, production takes place, $C_t$ and $K_{t+1}$ are chosen
Proposition 3

For $\gamma_v$ large and if

$$\frac{\sqrt{\gamma_v}}{\gamma_\theta} > \frac{1}{\sqrt{2\pi}} \frac{\omega^{\sigma-1} - 1}{\sigma - 1},$$

then the equilibrium of the static global game is unique and takes the form of a cutoff rule $\hat{v}(K, \theta_{-1}) \in \mathbb{R} \cup \{-\infty, \infty\}$ such that firm $j$ choose high capacity if and only if $v_j \geq \hat{v}(K, \theta_{-1})$. In addition, $\hat{v}$ is decreasing in its arguments.

- **Remark:** the number of firms choosing high capacity is

$$m \equiv 1 - \Phi(\sqrt{\gamma_v} (\hat{v}(K, \theta_{-1}) - \theta))$$

where $\Phi$ is the CDF of a standard normal
Uniqueness of Static Game

\[ Y^*(K_t, \theta_{t-1}, \theta_t) \]
Dynamics: Multiple Steady States

\[ K_{t+1} + K_t \text{ Medium } \theta \]

\[ K_t \]
Dynamics: Multiple Steady States

\[ K_{t+1} = f(K_t) \]

High \( \theta \)

Low \( \theta \)
Dynamics: Phase Diagram

- High regime: $\Delta K = 0$
- Low regime: $\Delta K = 0$

Productivity $\theta$

Capital $K$
III. Quantitative Evaluation
Quantitative Exercise

- The model is calibrated in a standard way
- We then evaluate the model on the following dimensions:
  - Business cycle moments: similar performance to standard RBC model
  - Skewness: outperforms standard models due to existence of large recessions (fat left tail)
  - Impulse responses: secular stagnation, 2007-2009 recession?
• The model dynamics display strong non-linearities
• We hit the economy with negative $\theta$ shocks:
  1. Small
  2. Medium and lasts 4 quarters
  3. Large and lasts 4 quarters
• Results:
  ▶ The response to small shock is similar to standard RBC model
  ▶ Strong amplification and propagation for larger shocks
  ▶ Large, long-lasting shocks can push the economy towards low steady state: coordination trap
Impulse Responses

(a) $\theta$

(b) Endogenous TFP

(c) Output
Impulse Responses

(d) Labor

(e) Investment

(f) Capacity $m$
Figure: US series centered on 2007Q4 (left) vs model (right)
IV. Policy Implications
Policy Implications

• The competitive economy suffers from two (related) inefficiencies:
  1. Monopoly distortions on the product market,
     • Correct this margin immediately with input subsidy $s_{kl}$ that offsets markup $1 - s_{kl} = \frac{\sigma - 1}{\sigma}$,
  2. Inefficient capacity choice due to aggregate demand externality.

• We analyze:
  ▶ Impact of fiscal policy
  ▶ Optimal policy and implementation
Policy: Summary of Results

- Fiscal policy:
  - Government spending is in general detrimental to coordination
    - Crowding out effect magnified by coordination problem
    - This effect dominates in most of the state space
  - But negative wealth effect can overturn this result
    - When preferences allow for wealth effect on labor supply, fiscal policy may be welfare improving by helping coordination
    - Possibly large multipliers without nominal rigidities

- Optimal policy:
  - A mix of constant input and profit subsidy implements the constrained efficient allocation
V. Conclusion
Conclusion

• We construct a dynamic stochastic general equilibrium model with coordination failures
  ▶ Provides a foundation for Keynesian-type effects without nominal rigidities

• The model generates:
  ▶ Deep recessions: secular stagnation?
  ▶ Fiscal policy can be welfare improving

• Future agenda:
  ▶ Quantitative side:
    • Understand the role of firm-level heterogeneity
    • Use micro-data to discipline the non-convexities
  ▶ Learning, optimal fiscal policy, etc.
Evidence of Non-Convexities

• Typical neoclassical model assumes convex cost functions
  ▶ Well-defined maximization problem with unique equilibrium
• However, large evidence of non-convexities in cost functions:
  ▶ Firms adjust output along various margins which differ in lumpiness/adjustment/variable costs
    • Cooper and Haltiwanger (2006): lumpy adjustments in labor and investment,
    • Bresnahan and Ramey (1994): lumpy changes in production at plant-level with plant shutdowns/restart,
    • Hall (1999): non-convexities in shift adjustments across Chrysler assembly plants.
Evidence of Non-Convexities

- Ramey (JPE 1991) estimates cost functions
  - Example food industry:
    \[ C_t(Y) = 23.3w_t Y - 7.78** Y^2 + 0.000307* Y^3 + \ldots \]

**Figure**: Non-convex cost curve (Ramey, 1991)
Static Equilibrium: Multiplicity

- Condition for multiplicity is

\[
\frac{1 + \nu}{\alpha + \nu} > \sigma - 1
\]

- This condition is more likely to be satisfied if
  - \( \sigma \) is small: high complementarity through demand,
  - \( \nu \) is small: low input competition (sufficiently flexible labor),
  - \( \alpha \) is small: production is intensive in the flexible factor (labor).
Static Equilibrium: Multiplicity vs. Uniqueness

\[ \frac{1+\nu}{\alpha+\nu} = \sigma - 1 \]
Model: Incomplete Information

- Firms now solve the following problem:

\[
    u_j^* = \arg\max_{u_j \in \{u_h, u_l\}} \left\{ \mathbb{E} \left[ U_c (C, L) (\Pi_h (K, \theta, m) - f) \mid \theta - 1, v_j \right], \right. \\
    \left. \mathbb{E} \left[ U_c (C, L) \Pi_l (K, \theta, m) \mid \theta - 1, v_j \right] \right\}
\]

where

- Expectation term over \( \theta \) and \( m \)
- \( m \) is now uncertain and firms must guess what others will choose!
Uniqueness of Static Game

- Condition for uniqueness

\[
\frac{\sqrt{\gamma_v}}{\gamma_\theta} > \frac{1}{\sqrt{2\pi}} \frac{\omega^{\sigma-1} - 1}{\sigma - 1}
\]

- This condition requires:
  1. Uncertainty in fundamental \( \theta \) (\( \gamma_\theta \) low),
  2. High precision in private signals (\( \gamma_v \) high)

- Ensure that beliefs about fundamental (in \( \gamma_v \)) dominates feedback from others (in \( \sqrt{\gamma_v} \))
### Parametrization

Standard parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
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<th>Source/Target</th>
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<tbody>
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<td>Time period</td>
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</tr>
<tr>
<td>Stdev of $\theta$</td>
<td>$\sigma_\theta = 0.006$</td>
<td>Stdev output</td>
</tr>
</tbody>
</table>
Three parameters remain: $\gamma_v$, $\omega$ and $f$

- **Precision of private information $\gamma_v$:**
  - Target dispersion in forecasts about GDP growth from SPF:
  - One quarter ahead: $\gamma_v = 124,232 \simeq 0.2\%$ stdev

- **Capacity utilization ratio $\omega = \frac{u_h}{u_l}$:**
  - Match pre-2008/post-2010 averages $\simeq 1.017$

- **Fixed cost $f$:**
  - Chosen to match the tail probability of large crises in SPF (growth $\leq -4\%$),
  - Set $f = 0.019$ of GDP
Business Cycle Moments

Correlation with output

<table>
<thead>
<tr>
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<th>Output</th>
<th>Investment</th>
<th>Hours</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>1.00</td>
<td>0.87</td>
<td>0.86</td>
<td>0.94</td>
</tr>
<tr>
<td>Full model</td>
<td>1.00</td>
<td>0.89</td>
<td>1.00</td>
<td>0.99</td>
</tr>
<tr>
<td>RBC ((f = 0, \sigma \to \infty))</td>
<td>1.00</td>
<td>0.96</td>
<td>1.00</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Table: Correlation with output

• Again, similar performance to a standard RBC model
The model does well for skewness and asymmetry of business cycles:

<table>
<thead>
<tr>
<th>Skewness</th>
<th>Output</th>
<th>Investment</th>
<th>Hours</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>-0.59</td>
<td>-0.31</td>
<td>-0.35</td>
<td>-0.44</td>
</tr>
<tr>
<td>Full model</td>
<td>-0.16</td>
<td>-0.14</td>
<td>-0.16</td>
<td>-0.14</td>
</tr>
<tr>
<td>RBC ((f = 0, \sigma \rightarrow \infty))</td>
<td>0.00</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table: Skewness
Skewness and Fat Tail

- The negative skewness is due to ability to generate deep recessions:

Figure: Ergodic distribution of $\theta$ (top) vs. output (bottom)
Skewness and Fat Tail

- Histogram of output in the data:

**Figure:** Distribution of log real GDP (1967-2014, linear trend)
### Business Cycle Moments

#### Standard deviations

<table>
<thead>
<tr>
<th>Stddev Rel. to Output</th>
<th>Output</th>
<th>Investment</th>
<th>Hours</th>
<th>Consumption</th>
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<tbody>
<tr>
<td><strong>Data</strong></td>
<td>1.00</td>
<td>3.27</td>
<td>1.46</td>
<td>0.94</td>
</tr>
<tr>
<td><strong>Full model</strong></td>
<td>1.00</td>
<td>2.06</td>
<td>0.72</td>
<td>0.88</td>
</tr>
<tr>
<td><strong>RBC ($f = 0, \sigma \to \infty$)</strong></td>
<td>1.00</td>
<td>1.72</td>
<td>0.71</td>
<td>0.84</td>
</tr>
</tbody>
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**Table**: Standard deviation relative to that of Output

- The full model behaves similarly to a standard RBC model
Figure 5: Measures of Total Factor Productivity (TFP): 2001 to 2013

Notes: Linear trend from 2001Q1–2008Q2 (dashed–dotted). Forecast 2008Q3 and beyond based on linear trend (dotted).

Figure: Various measures of TFP (source: Christiano, Eichenbaum and Trabandt, 2014)
Fiscal Policy: Crowding Out

- Crowding out:

\[ K_{t+1} \]

Basin of attraction for low regime

\[ K_t \]
Crowding out: decline in investment
• Coordination is **worsened** by crowding out:
  - Capital $K$ plays a crucial role for coordination,
  - By crowding out private investment, government spending makes coordination on high regime less likely in the future!
  - Large dynamic welfare losses

• **Result:** Under GHH preferences,
  - For $\gamma_v$ large, firms’ choice of $m$ unaffected by $G$,
  - Government spending is *always* welfare reducing
Fiscal Policy: Wealth Effect

- How can a negative wealth effect be welfare improving?

![Graph showing welfare levels for different equilibrium states](image-url)
Fiscal Policy

(a) Impact of $G$ on capacity choice $m$

(b) Fiscal multiplier

(c) Welfare gains in consumption equivalent
We study a constrained planner with same information as outside observer:

- At the beginning of period, only knows $\theta_{-1}$
- Does not observe firms’ private signals
Constrained Planner Problem

- The planner chooses a probability to choose high capacity $z(v_j)$ for all signals $v_j$

$$V(K, \theta_{-1}) = \max_{z, C, L, K'} \mathbb{E}_\theta \left[ \frac{1}{1-\gamma} \left( C - \frac{L^{1+\nu}}{1+\nu} \right)^{1-\gamma} + \beta V(K', \theta) \right]$$

subject to

$$C + K' = \overline{A}(\theta, m) K^\alpha L^{1-\alpha} + (1 - \delta) K - mf$$

$$m(\theta) = \int \sqrt{\gamma} \phi (\sqrt{\gamma} (v - \theta)) z(v) dv$$

$$\overline{A}(\theta, m) = \left( mA_h (\theta)^{\sigma-1} + (1 - m) A_l (\theta)^{\sigma-1} \right)^{\frac{1}{\sigma-1}}$$
Proposition 4

The competitive equilibrium with imperfect information is inefficient, but the efficient allocation can be implemented with:

1. An input subsidy \( 1 - s_{kl} = \frac{\sigma - 1}{\sigma} \) to correct for monopoly distortions,
2. A profit subsidy \( 1 + s_\pi = \frac{\sigma}{\sigma - 1} \) to induce the right capacity choice.

- Remark:
  - The profit subsidy is just enough to make firms internalize the impact of their capacity decision on others.
Calibration Government Spending

- Utility function: \( U(C, L) = \log C - (1 + \nu)^{-1} L^{1+\nu} \)

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<td>High capacity</td>
<td>( \omega = 1.017 )</td>
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<tr>
<td>Government spending</td>
<td>( G = 0.00665 )</td>
<td>0.5% of steady-state output</td>
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