Coordinating Business Cycles

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Motivation

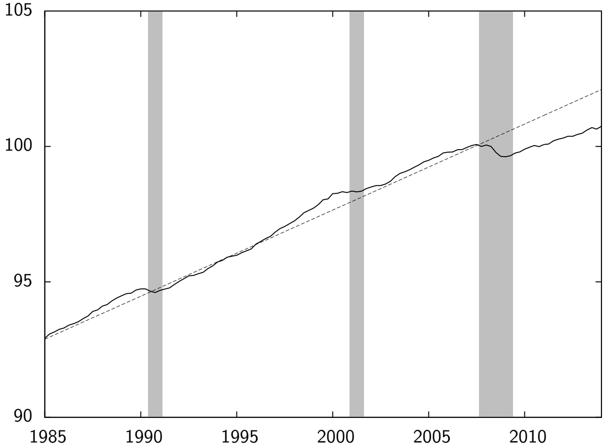

Figure : US real GDP (log) and linear trend (2007Q4 = 100)

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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Model Structure

- Standard neoclassical model with:
  - Monopolistic competition
    - Aggregate demand externality provides a motive to coordinate
  - Non-convex capacity choice ▸ Evidence
    - 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

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

under the budget constraints

$$P_t \left(C_t + K_{t+1} - (1-\delta) K_t \right) \leqslant W_t L_t + R_t K_t + \Pi_t$$

Production

- 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

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

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 θ follows an AR(1)

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

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

$$A_h(\theta_t) \equiv \omega A e^{\theta_t} > A e^{\theta_t} \equiv A_l(\theta_t)$$

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

$$m_t\left(\theta^t\right) \equiv \begin{cases} 1 & \text{if } \Pi_{ht} - f > \Pi_{lt} \\ \in (0,1) & \text{if } \Pi_{ht} - f = \Pi_{lt} \\ 0 & \text{if } \Pi_{ht} - f < \Pi_{lt} \end{cases}$$

Characterization

- The intermediate producer faces a simple static problem
- Producers face a positive aggregate demand externality

$$\Pi_{jt} = P_t Y_t^{\frac{1}{\sigma}} Y_{jt}^{\frac{\sigma-1}{\sigma}} - W_t L_{jt} - R_t K_{jt}$$

where σ determines the strength of externality

- In partial equilibrium, the capacity choice collapses to

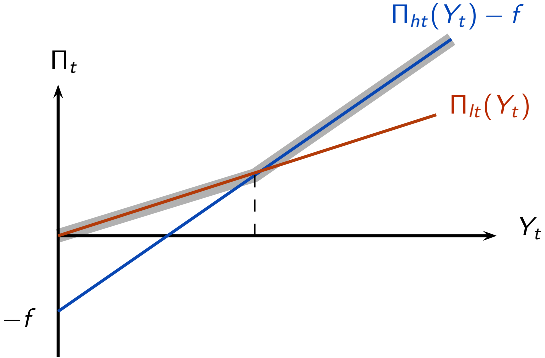
$$\Pi = \max \left[\frac{1}{\sigma} \frac{Y_t}{P_{ht}^{\sigma-1}} - f, \frac{1}{\sigma} \frac{Y_t}{P_{lt}^{\sigma-1}} \right]$$

with the cost of a marginal unit of output

$$P_{jt} = \frac{\sigma}{\sigma-1} MC_{jt} \quad \text{and} \quad MC_{jt} \equiv \frac{1}{A_{jt}(\theta)} \left(\frac{R_t}{\alpha} \right)^{\alpha} \left(\frac{W_t}{1-\alpha} \right)^{1-\alpha}$$

Characterization

- 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)

Static Equilibrium

- 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:

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

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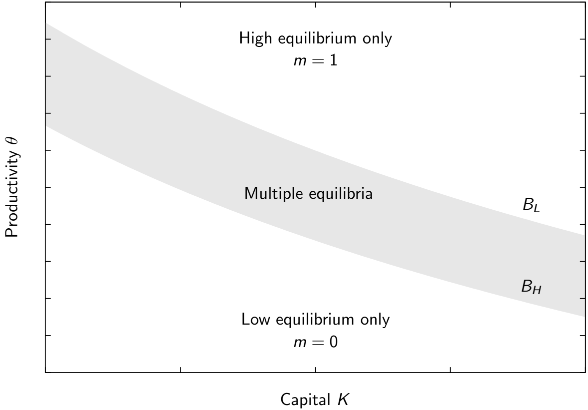
Static Equilibrium: Multiplicity

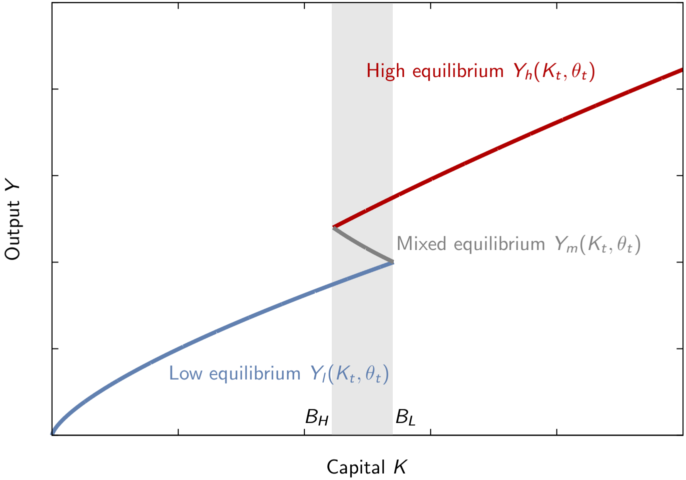
Proposition 1

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* $B_H \leqslant e^{\theta} K^{\alpha} \leqslant B_L$*.*



▸ Intuition

Static Equilibrium: Multiplicity



Multiplicity vs. Uniqueness

Static Equilibrium: Efficiency

Is the static equilibrium efficient?

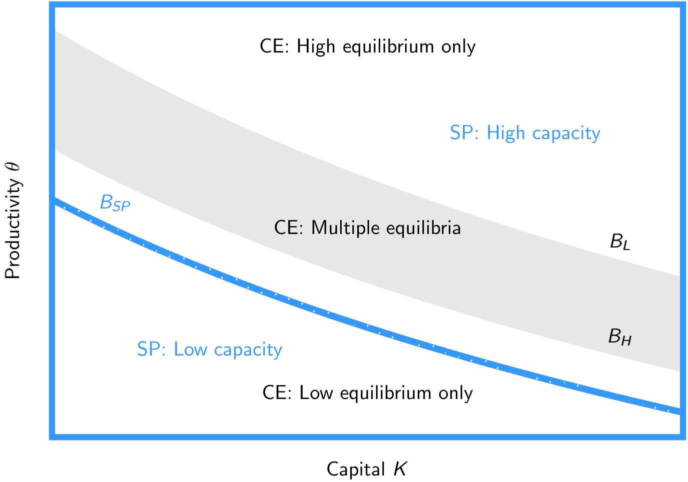
Proposition 2

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

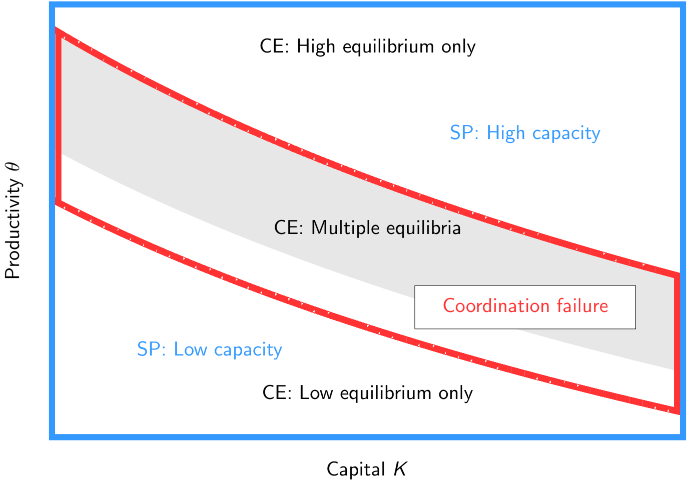
- *For $e^{\theta} K^{\alpha} \leqslant B_{SP}$, the planner chooses $m = 0$,*
- *For $e^{\theta} K^{\alpha} \geqslant B_{SP}$, the planner chooses $m = 1$.*

In addition, for σ low enough, $B_{SP} < B_H$.

Static Equilibrium: Efficiency



Static Equilibrium: Coordination Failure



II. Model: Incomplete Information Case

Model: Incomplete Information

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

▸ Capacity choice

Proposition 3

For γ_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 $v_j \geqslant \hat{v}(K, \theta_{-1})$. In addition, $\hat{v}$ is decreasing in its arguments.

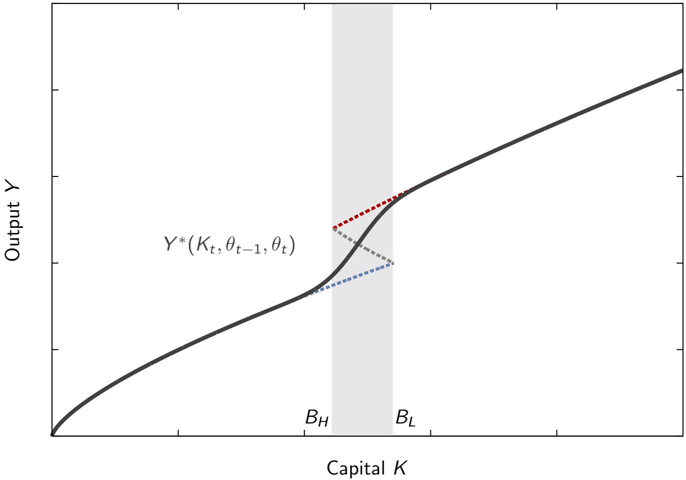
- **Remark:** the number of firms choosing high capacity is

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

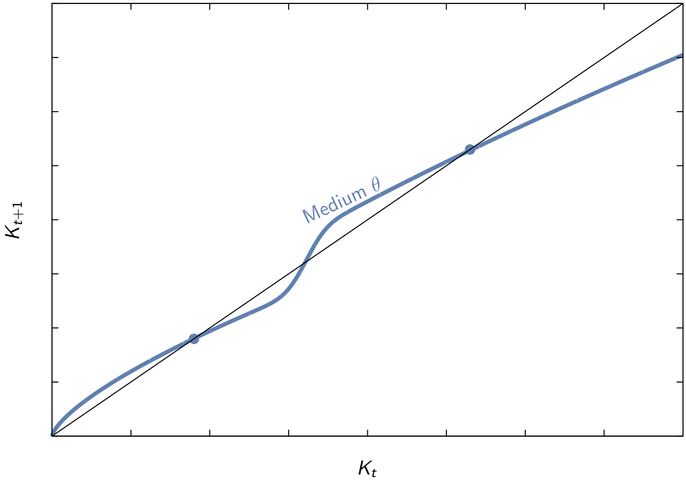
where Φ is the CDF of a standard normal

Details

Uniqueness of Static Game



Dynamics: Multiple Steady States



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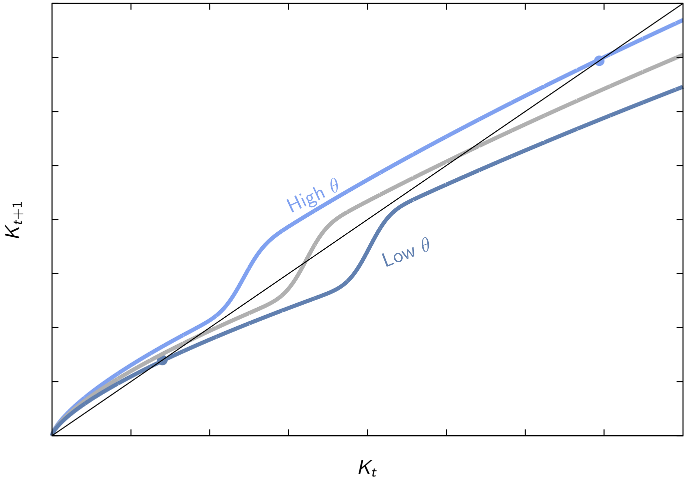
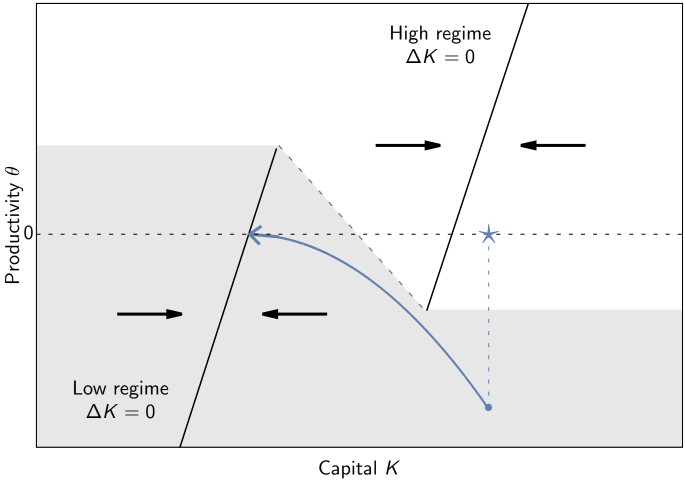


Dynamics: Phase Diagram



III. Quantitative Evaluation

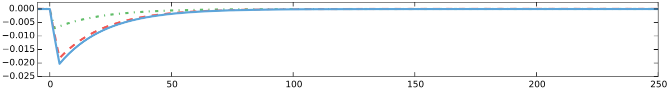
Quantitative Exercise

- The model is calibrated in a standard way ▸ Calibration
- We then evaluate the model on the following dimensions:
  - Business cycle moments: similar performance to standard RBC model ▸ RBC moments
  - Skewness: outperforms standard models due to existence of large recessions (fat left tail) ▸ Skewness
  - Impulse responses: secular stagnation, 2007-2009 recession?

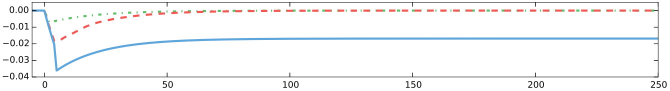
Impulse Responses

- The model dynamics display strong non-linearities
- We hit the economy with negative θ 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

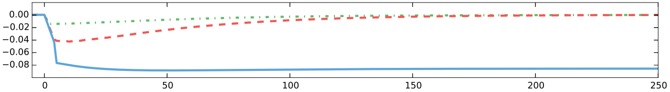
(a) θ



(b) Endogenous TFP

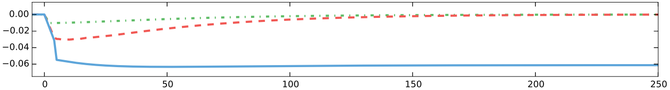


(c) Output

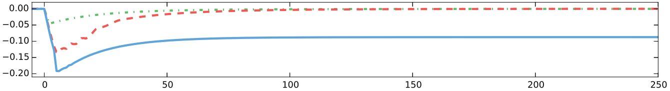


Impulse Responses

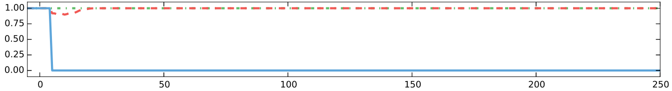
(d) Labor



(e) Investment



(f) Capacity m



2007-2009 Recession

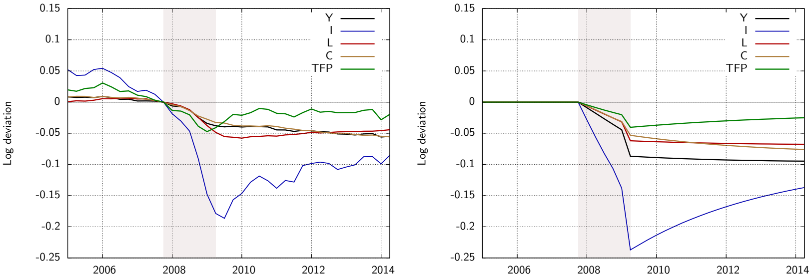


Figure : US series centered on 2007Q4 (left) vs model (right)

▸ TFP

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 ▸ Crowding
    - 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 ▸ Welfare
    - Possibly large multipliers without nominal rigidities ▸ Multiplier
- Optimal policy:
  - A mix of constant input and profit subsidy implements the constrained efficient allocation ▸ Optimal Policy

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:

$$C_t(Y) = 23.3 w_t Y - 7.78^{**} Y^2 + 0.000307^{*} Y^3 + \ldots$$

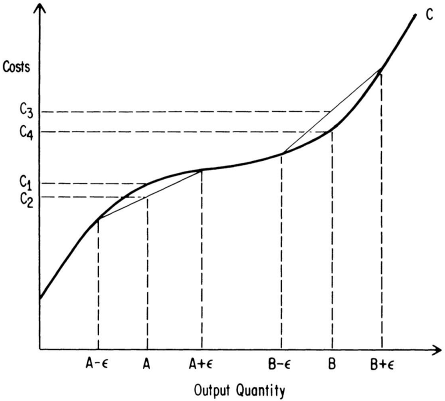


Figure : Non-convex cost curve (Ramey, 1991)

Model

Static Equilibrium: Multiplicity

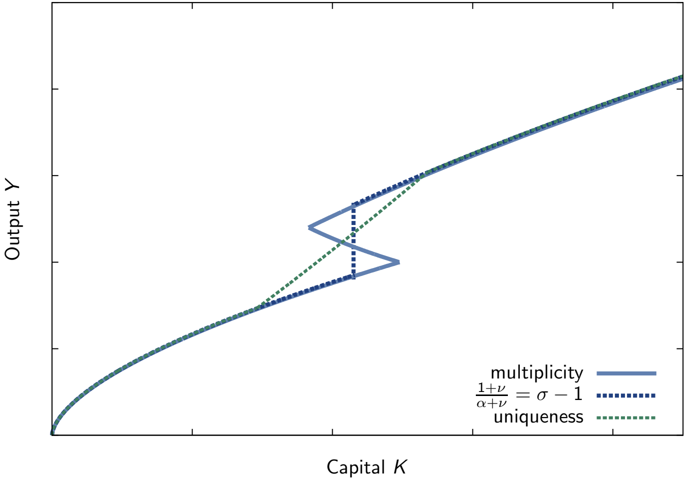
- Condition for multiplicity is

$$\frac{1+\nu}{\alpha+\nu} > \sigma - 1$$

- This condition is more likely to be satisfied if
  - σ is small: high complementarity through demand,
  - ν is small: low input competition (sufficiently flexible labor),
  - α is small: production is intensive in the flexible factor (labor).

Return

Static Equilibrium: Multiplicity vs. Uniqueness



◂ Multiplicity

Model: Incomplete Information

- Firms now solve the following problem:

$$u_j^* = \underset{u_j \in \{u_h, u_l\}}{\text{argmax}} \Big\{ \mathbb{E}\left[U_c\left(C, L\right)\left(\Pi_h\left(K, \theta, m\right) - f\right) \mid \theta_{-1}, v_j\right], \\ \mathbb{E}\left[U_c\left(C, L\right)\Pi_l\left(K, \theta, m\right) \mid \theta_{-1}, v_j\right] \Big\}$$

where

- Expectation term over θ and m
- m is now uncertain and firms must guess what others will choose!

Return

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 θ (γ_θ low),
  2. High precision in private signals (γ_v high)
     - Ensure that beliefs about fundamental (in γ_v) dominates feedback from others (in $\sqrt{\gamma_v}$)

Return

Parametrization

Standard parameters:

Parameter	Value	Source/Target
Time period	one quarter	
Capital share	$\alpha = 0.3$	Labor share 0.7
Discount factor	$\beta = 0.95^{1/4}$	0.95 annual
Depreciation rate	$\delta = 1 - 0.9^{1/4}$	10% annual
Elasticity of substitution	$\sigma = 3$	Hsieh and Klenow (2014)
Risk aversion	$\gamma = 1$	log utility
Elasticity of labor supply	$\nu = 0.4$	Jaimovich and Rebelo (2009)
Persistence θ process	$\rho_\theta = 0.95$	Cooley and Prescott (1985)
Stdev of θ	$\sigma_\theta = 0.006$	Stdev output

Parametrization

Three parameters remain: γ_v, ω and f

- Precision of private information γ_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$\leqslant$-4%),
  - Set $f = 0.019$ of GDP

Return

Business Cycle Moments

Correlation with output

Correlation with output	Output	Investment	Hours	Consumption
Data	1.00	0.87	0.86	0.94
Full model	1.00	0.89	1.00	0.99
RBC ($f = 0, \sigma \to \infty$)	1.00	0.96	1.00	0.99

Table : Correlation with output

- Again, similar performance to a standard RBC model

Return

Skewness

- The model does well for skewness and asymmetry of business cycles:

Skewness	Output	Investment	Hours	Consumption
Data	-0.59	-0.31	-0.35	-0.44
Full model	-0.16	-0.14	-0.16	-0.14
RBC ($f = 0, \sigma \to \infty$)	0.00	-0.01	0.00	0.01

Table : Skewness

Return

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

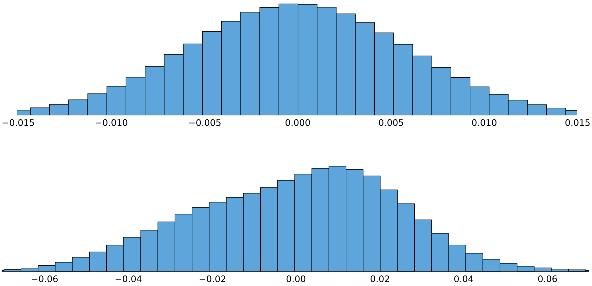


Figure : Ergodic distribution of θ (top) vs. output (bottom)

Skewness and Fat Tail

- Histogram of output in the data:

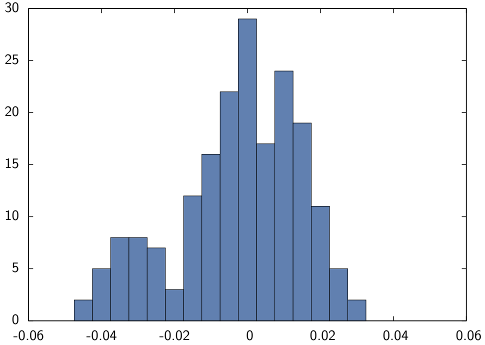


Figure : Distribution of log real GDP (1967-2014, linear trend)

Return

Business Cycle Moments

Standard deviations

Stddev Rel. to Output	Output	Investment	Hours	Consumption
Data	1.00	3.27	1.46	0.94
Full model	1.00	2.06	0.72	0.88
RBC ($f = 0, \sigma \to \infty$)	1.00	1.72	0.71	0.84

Table : Standard deviation relative to that of Output

- The full model behaves similarly to a standard RBC model

Return

Solution of the Model

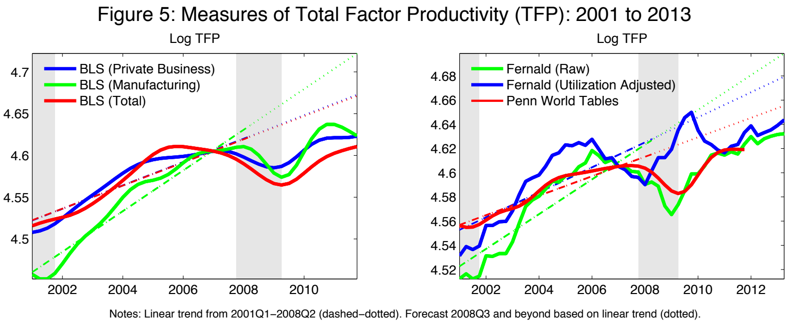
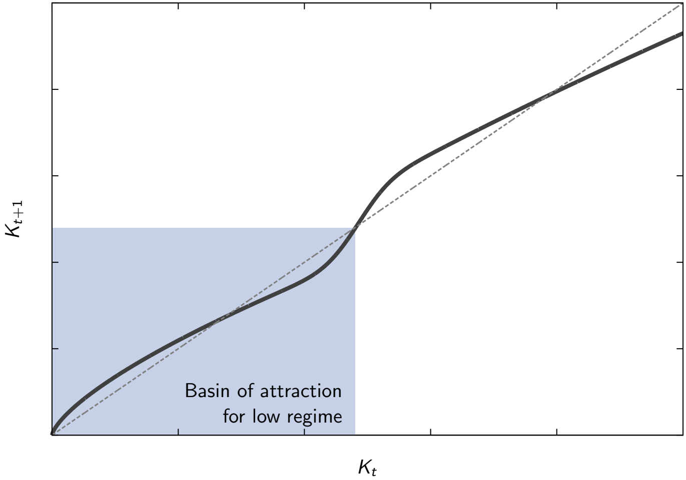


Figure : Various measures of TFP (*source:* Christiano, Eichenbaum and Trabandt, 2014)

Return

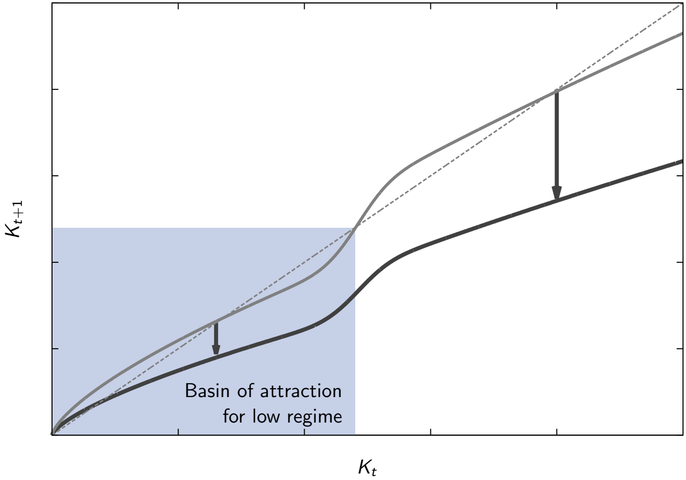
Fiscal Policy: Crowding Out

- Crowding out:



Fiscal Policy: Crowding Out

- Crowding out: decline in investment



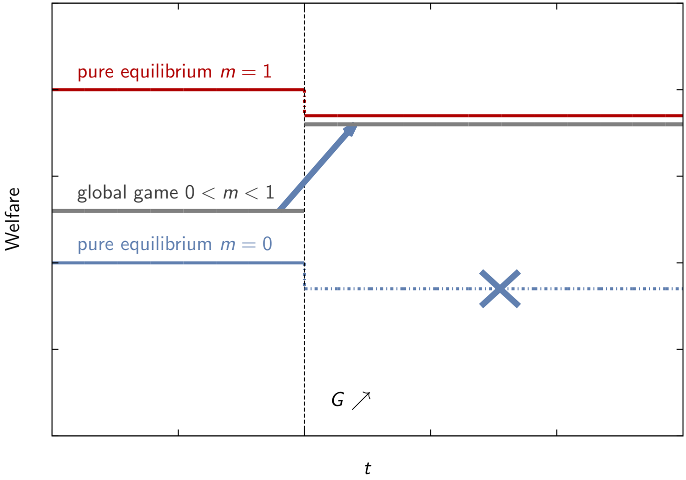
Fiscal Policy: Crowding Out

- 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 γ_v large, firms' choice of m unaffected by G,
  - Government spending is *always* welfare reducing

Return

Fiscal Policy: Wealth Effect

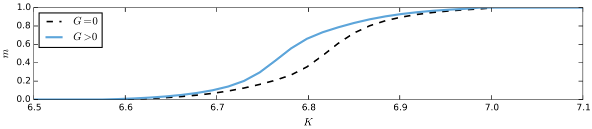
- How can a negative wealth effect be welfare improving?



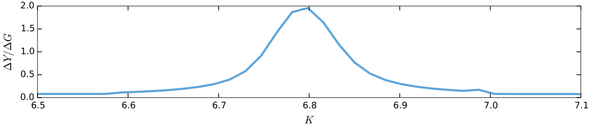
Return

Fiscal Policy

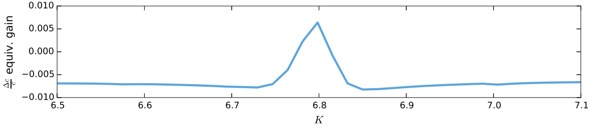
(a) Impact of G on capacity choice m



(b) Fiscal multiplier



(c) Welfare gains in consumption equivalent



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Optimal Policy

- We study a constrained planner with same information as outside observer:
  - At the beginning of period, only knows θ_{-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

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

$$m(\theta) = \int \sqrt{\gamma_v} \phi \left(\sqrt{\gamma_v} (v - \theta) \right) z(v) \, dv$$

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

Constrained Planner Problem

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

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Calibration Government Spending

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

Parameter	Value	Source/Target
Time period	one quarter	
Capital share	$\alpha = 0.3$	Labor share 0.7
Discount factor	$\beta = 0.95^{1/4}$	0.95 annual
Depreciation rate	$\delta = 1 - 0.9^{1/4}$	10% annual
Elasticity of substitution	$\sigma = 3$	Hsieh and Klenow (2014)
Risk aversion	$\gamma = 1$	log utility
Elasticity of labor supply	$\nu = 0.4$	Jaimovich and Rebelo (2009)
Persistence θ process	$\rho_\theta = 0.95$	Cooley and Prescott (1985)
Stdev of θ	$\sigma_\theta = 0.006$	Stdev output
Fixed cost	$f = 0.01485$	
High capacity	$\omega = 1.017$	
Government spending	$G = 0.00665$	0.5% of steady-state output

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