The Econometrics of Agent-Based Macromodels:

Assessing the Source of Business Cycles Employing an Evolutionary, Agent-Based Model

Andrea Roventini[1,2]

andrea.roventini@univr.it
http://dse.univr.it/

[1]Sant'Anna School of Advanced Studies, Pisa (Italy)

[2]University of Verona, Verona (Italy)

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Motivations

Agent-Based Models and Econometrics

- **Agent-based models (ABMs) seem to be a promising way to develop an alternative microfounded macroeconomics**
  - descriptive purposes: replication and explanation of micro and macro stylized facts
  - normative purposes: policy implications
- **What is the relationships between ABMs and econometrics and empirical validation in general?**
  - useful references: Fagiolo et al, Computational Economics, 2007; Delli Gatti et al 2010

Motivations

Explaining the Source of Business Cycles

- **Endogenous vs. exogenous theories of business cycles**
  - exogenous theories are dominant, but ...
  - Zarnowitz (1985) “purely stochastic explanation (of business cycles) have no theoretical content”
  - Irving Fisher (1925), business fluctuations cannot be considered like “the cycles superstitious gamblers believe at casinos”
- **Heterogenous vs. aggregate sources of shocks**
- **Propagation mechanisms and the role of microeconomic interaction between agents**
- **Contributing to this debate assessing the empirical performance of the Keynes+Schumpeter (K+S) model (Dosi, Fagiolo and Roventini, JEDC, forthcoming)**

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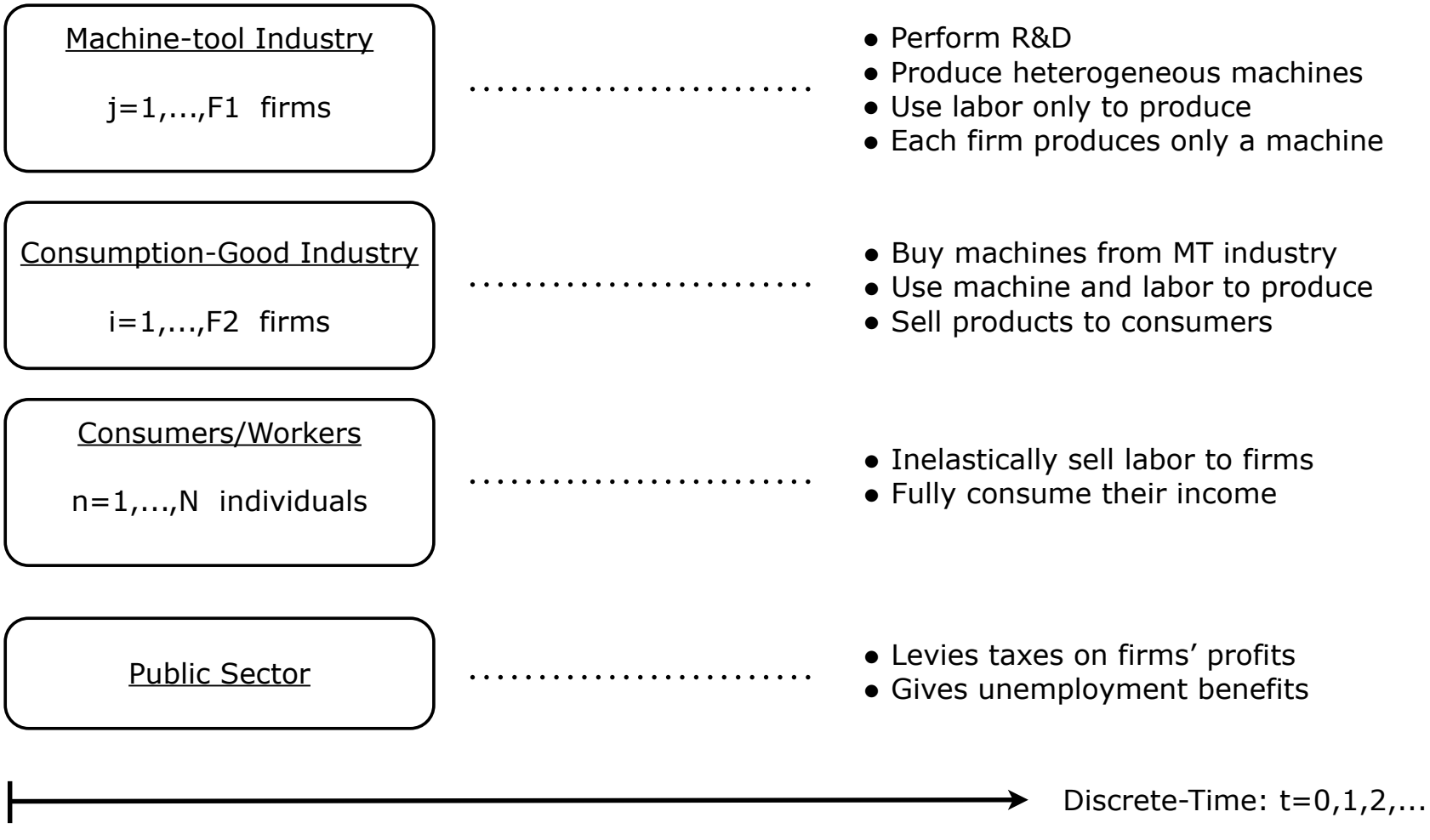
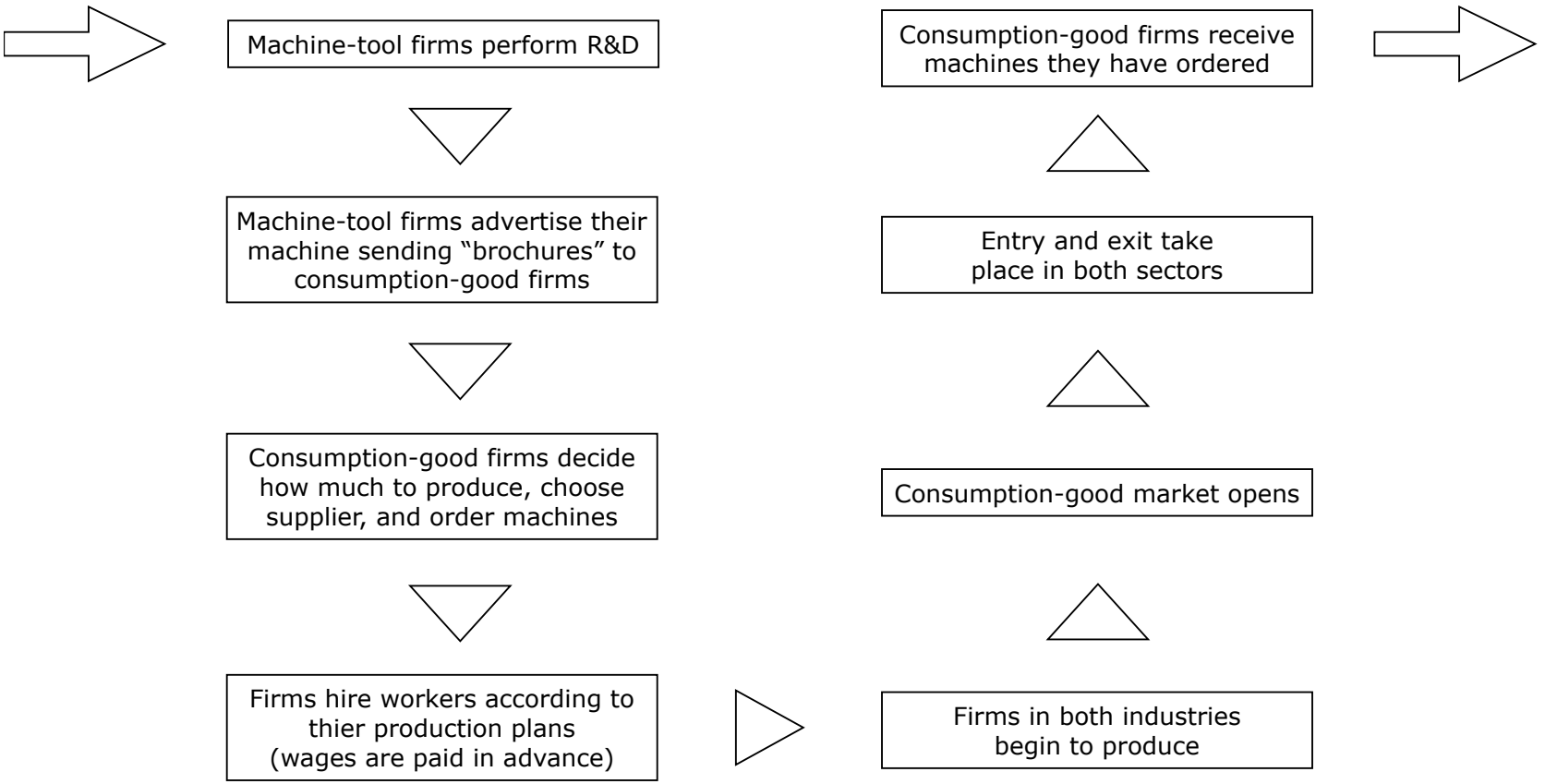
Structure of the K+S Model



What Happens in a Generic Time Step?



Simulation Strategy

1. Choose initial conditions and systems parameters
2. Generate a simulation run for $t = 1, \ldots, T$
3. Analyze qualitative and quantitative results
4. Redo Steps 1-3 performing a Monte Carlo exercise to
   - Wash away across-simulations variability introduced by stochastic components
     - Negligible across-simulations stochastic variability
     - Limited number of replications as robust proxy for time-series behavior
   - Study how different initial conditions and system parameters affect the statistics of interest
     - Initial conditions do not dramatically affect results
     - Focus on sensitivity analysis of system parameters
5. Replication of stylized facts (output validation) as a pre-requisite for policy analysis (“what happens if”)

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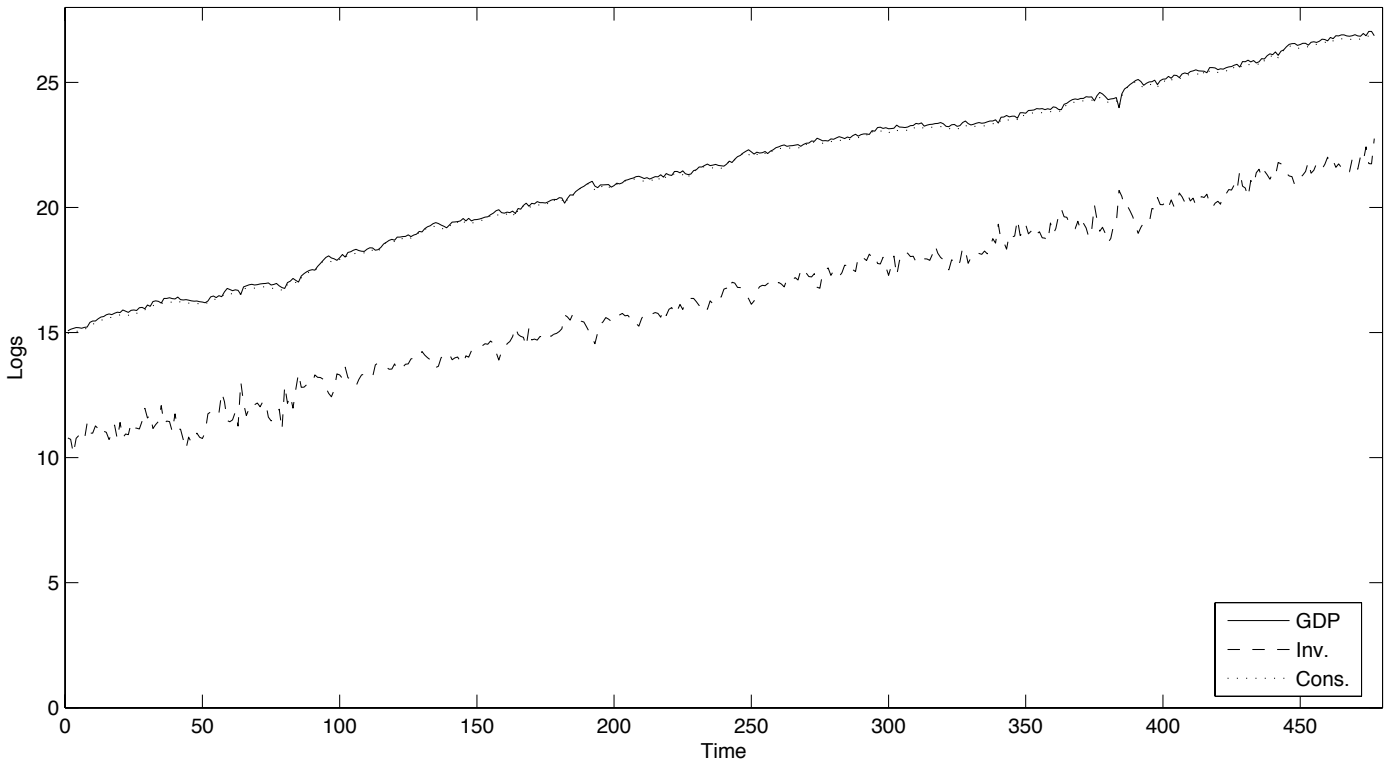
Validating the K+S Model

- **ABMs are much more complex than standard, e.g. RBC, macroeconomic models**
- **The model should then be able at least to match the same macroeconomic stylized facts of standard models**
- **The model should also be able to match the largest number of microeconomic stylized facts**
- **This is relevant because standard macroeconomic models are not usually able to match any microeconomic stylized fact**

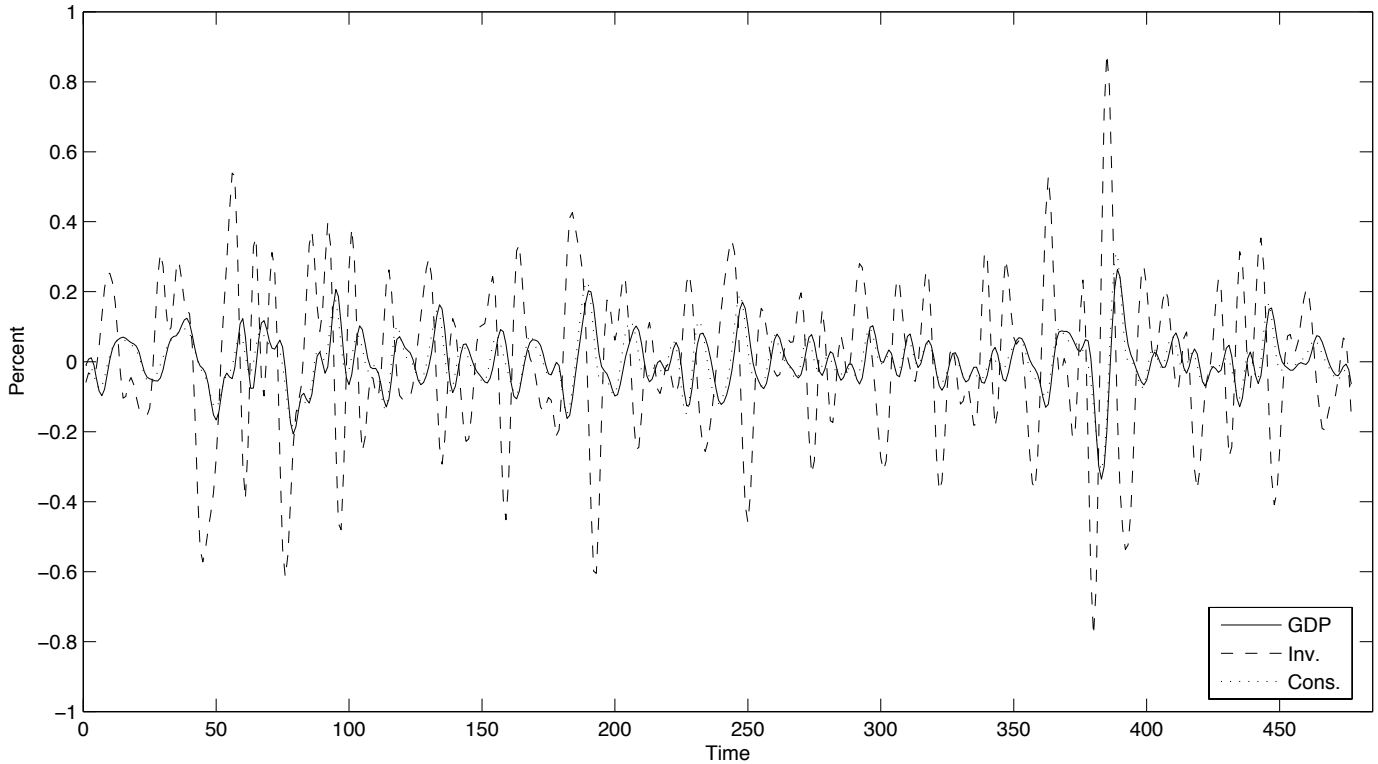
Macroeconomic Stylized Facts

- **The K+S model is able to account for a rich ensemble of macro stylized facts**
  1) endogenous growth with endogenous business cycles
  2) investment more volatile than GDP; consumption less volatile than GDP
  3) relative standard deviations of employment, unemployment rate, real wage and inflation in line with the empirical evidence
  4) consumption, net investment and change in inventories procyclical and coincident variables
  5) procyclical employment; countercyclical unemployment
  6) procyclical productivity
  7) countercyclical prices; procyclical inflation
  8) countercyclical mark-ups
  9) total credit procyclical and coincident
  10) bankruptcy rates procyclical and lagging
  11) quasi-Laplace fat-tailed distributions (see Fagiolo, Napoletano and Roventini, 2008, J. of Appl. Econometrics)
  12) output and consumption appear to be cointegrated

GDP, Consumption, Investment (logs)



Bandpassfiltered GDP, Consumption, and Investment



GDP, Consumption and Investment Statistics

	Output	**Consumption**	**Investment**
Avg. growth rate	0.0254	0.0252	0.0275
	(0.0002)	(0.0002)	(0.0004)
Dickey-Fuller test (logs)	6.7714	9.4807	0.2106
Dickey-Fuller test (Bpf)	-6.2564^*	-5.8910^*	-6.8640^*
Std. Dev. (Bpf)	0.0809	0.0679	0.4685
	(0.0007)	(0.0005)	(0.0266)

Table: Monte Carlo simulation standard errors in parentheses. Asterisks (*): Significant at 95% level

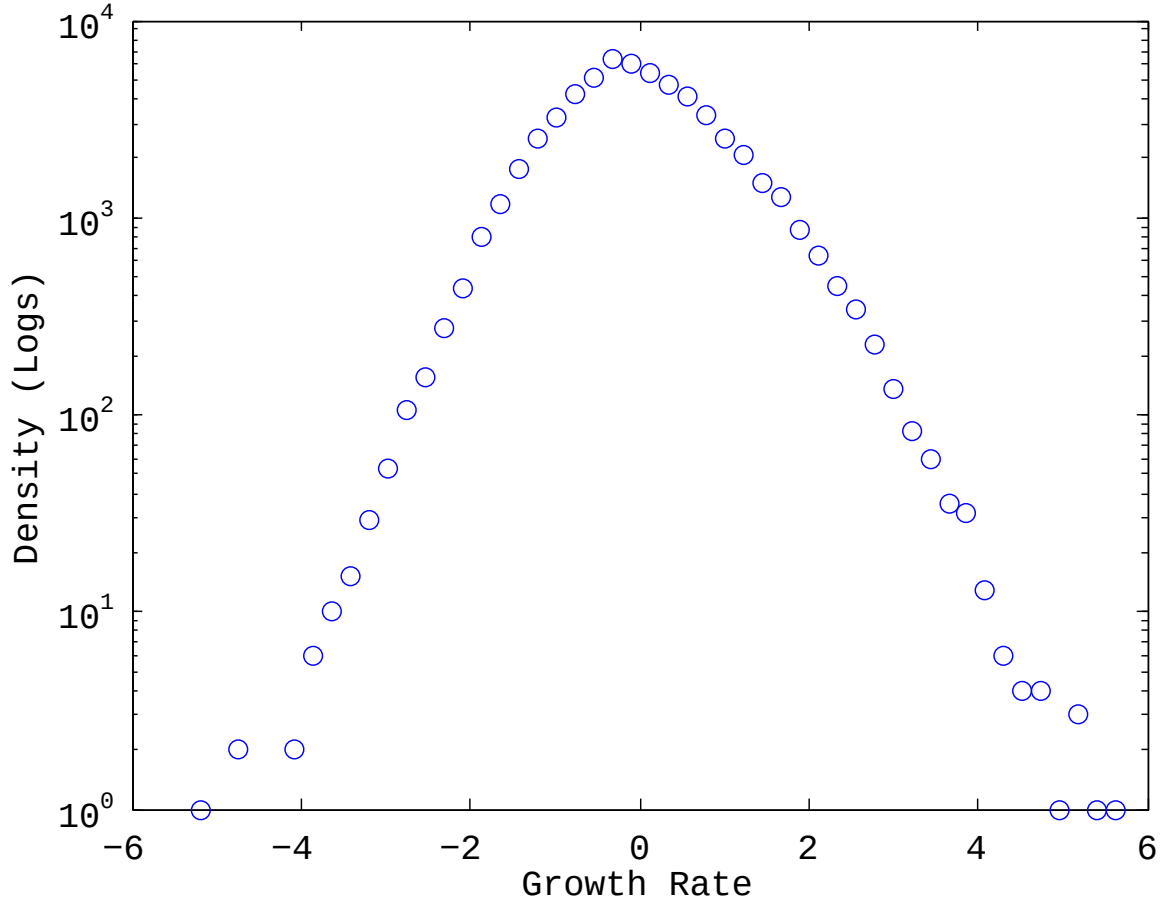
Relative Standard Deviations

Series (x)	$\sigma(x)/\sigma(y)$
Output	1
Consumption	0.8389
Investment	5.7880
Employment	0.8044
Unemployment rate	0.6654
Real wage	0.5318
Inflation	0.1907

Correlation Structure

Series	**Output (bpf 6,32,12)**						
bpf 6,32,12	**t-3**	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**
Output	0.177	0.548	0.870	1	0.870	0.548	0.177
Consumption	0.098	0.426	0.756	0.953	0.925	0.685	0.339
Investment	-0.312	-0.265	-0.086	0.184	0.447	0.595	0.576
Net Investment	0.039	0.219	0.401	0.511	0.504	0.385	0.210
Ch. in Invent.	0.118	0.235	0.295	0.257	0.133	-0.020	-0.132
Employment	-0.190	0.080	0.408	0.669	0.756	0.645	0.407
Unempl. Rate	0.208	-0.060	-0.392	-0.6601	-0.755	-0.649	-0.411
Productivity	0.308	0.532	0.711	0.767	0.666	0.438	0.166
Price	0.318	0.270	0.092	-0.164	-0.395	-0.507	-0.469
Inflation	0.084	0.311	0.446	0.402	0.197	-0.063	-0.248
Mark-up	0.160	0.041	-0.099	-0.204	-0.236	-0.197	-0.123

GDP Growth-Rate Distribution



Output and Consumption Cointegration

- **Empirical evidence suggests that output and consumption are cointegrated (e.g. Greene, 2007)**
- **We test for cointegration on the artificial series generated by the model**
- **Results**
  - according to the Engle-Granger methodology, output and consumption are cointegrated
  - the Johansen methodology delivers more mixed results

Microeconomic Stylized Facts

- **The K+S model is able to account for a rich ensemble of micro (firm-level) cross-section stylized facts (Dosi, 2007)**
  1) productivity dispersion among firms is large
  2) inter-firm productivity differentials are persistent over time
  3) firm size distributions are right skewed (and even more skewed than log-normal distributions)
  4) firms growth rates can be proxied by fat-tailed quasi-Laplace densities
  5) investment lumpiness (coexistence of firms investing a lot and investing almost-zero, see Gourio & Kashyap, J. Mon. Econ., 2007)
  6) bankruptcy rates can be proxied by power-law densities (see Fujiwara, 2004, Di Guilmi et al. 2003)

Firms' Productivity Moments

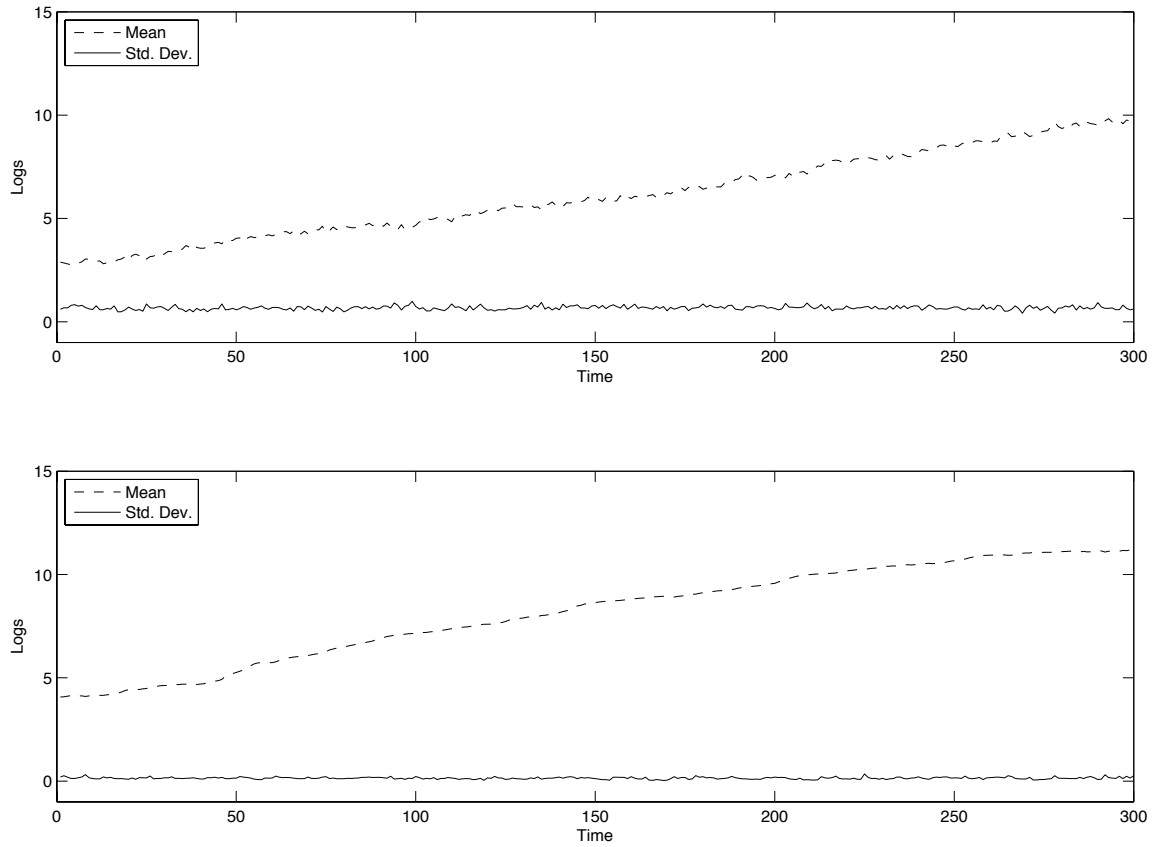


Figure: 1st panel: capital-good firms; 2nd panel: consumption-good firms

Persistence of Productivity Differentials

Industry	**t-1**	**t-2**
Capital-good	0.5433	0.3700
	(0.1821)	(0.2140)
Consumption-good	0.5974	0.3465
	(0.2407)	(0.2535)

Table: *Standard deviations in parentheses*

Firm Size Distributions: Are Distributions Log-Normal?

Industry	**Jarque-Bera**		**Lilliefors**		**Anderson-Darling**	
	stat.	p-value	stat.	p-value	stat.	p-value
Capital-good	20.7982	0	0.0464	0	4.4282	0
Consumption-good	3129.7817	0	0.0670	0	191.0805	0

Table: Size distribution are even more skewed than log-normal distribution in line with the empirical evidence

Growth-Rate Distributions: Subbotin Estimation

Series	Subbotin Parameters			
	b	std. dev.	a	std. dev.
Capital-good firms	0.5285	0.0024	0.4410	0.0189
Consumption-good firms	0.4249	0.0051	0.0289	0.0037
Output	1.4673	0.0122	0.0775	0.0004

Investment Lumpiness

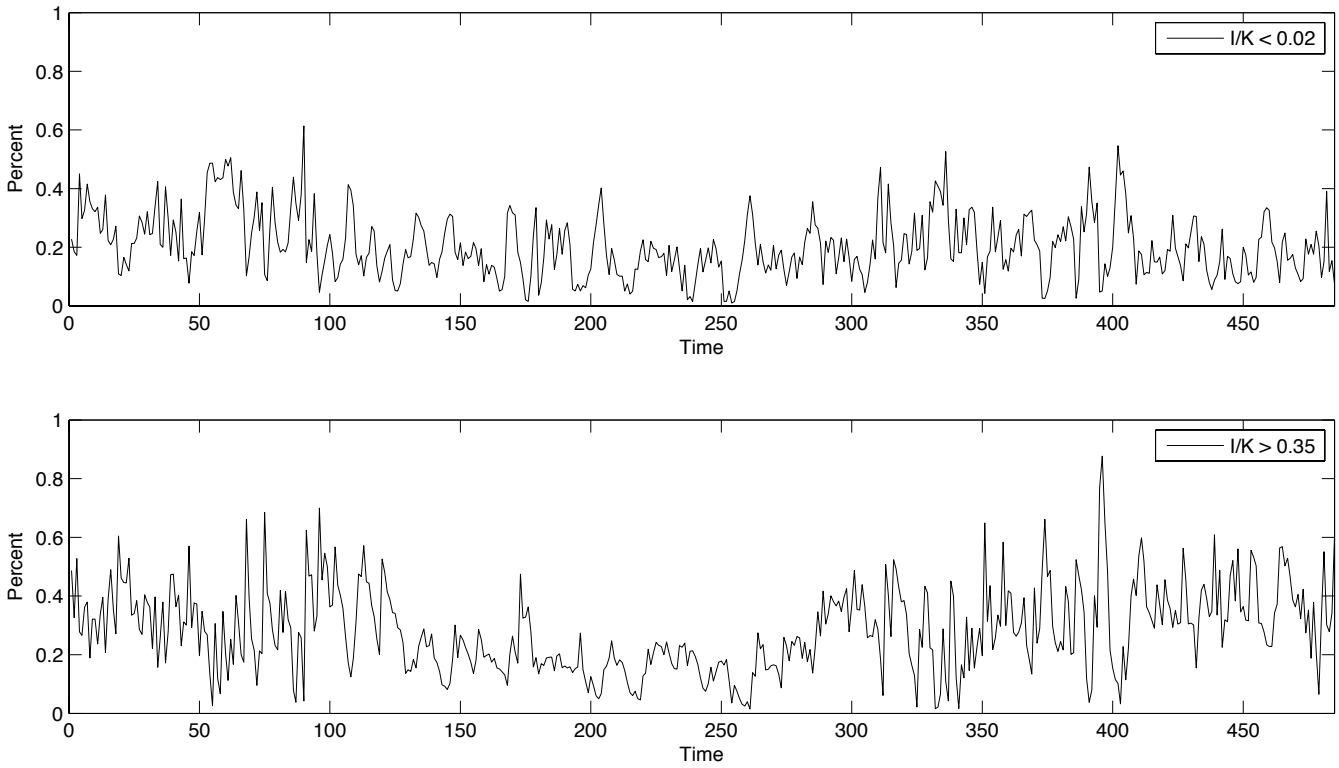


Figure: 1st panel: share of firms with (near) zero investment;
2nd panel: share of firms with investment spikes

Firms' Bankruptcy Rate Distribution

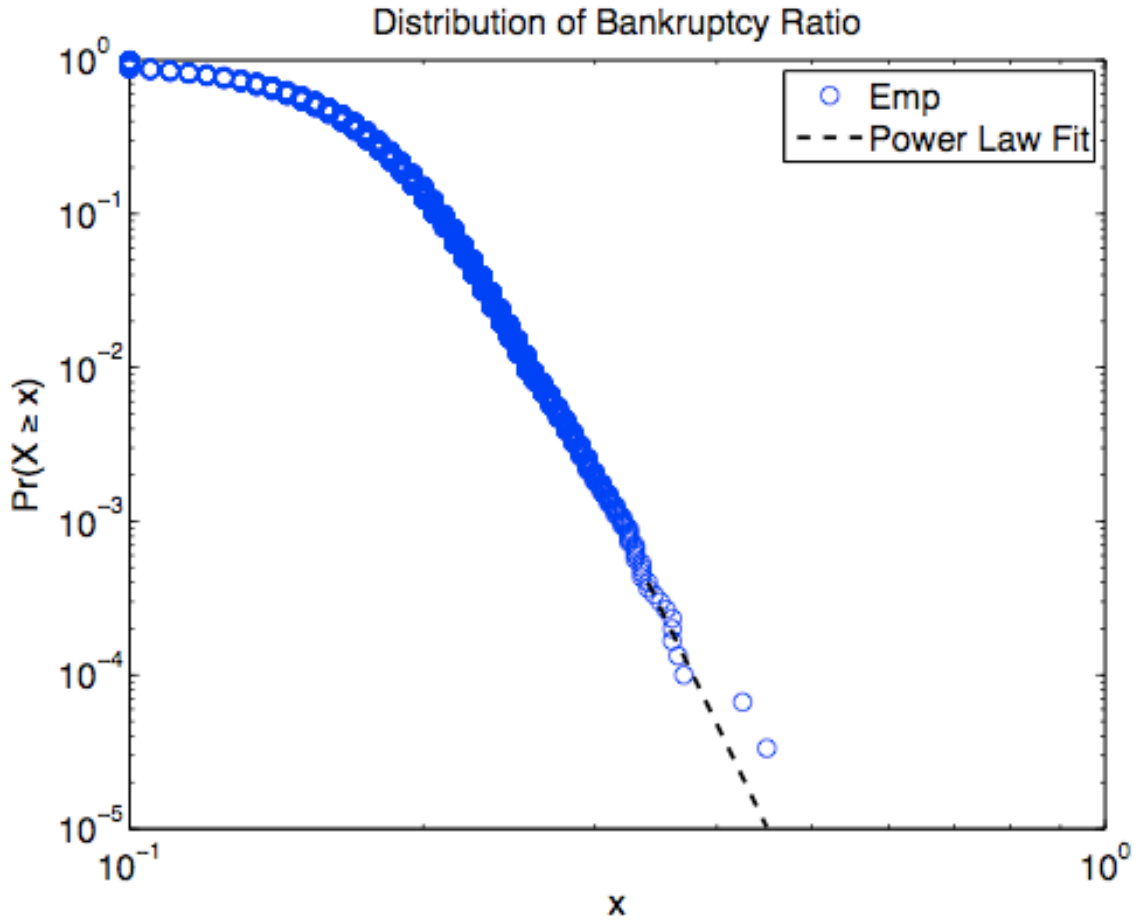


Figure: empirical distribution of bankruptcy rates together with power-law fit

Explaining Business Cycle Dynamics

- **The K+S model endogenously generate business cycles**
- **What's their source?**
  - investment instability as in genuine Keynesian theory of fluctuations
  - micro interactions between heterogenous firms lead to coordination failures and give rise to business cycles
- **What does the model tell in the Frisch-Slutstky framework?**
- **Let us consider the Blanchard-Quah (BQ) decomposition**

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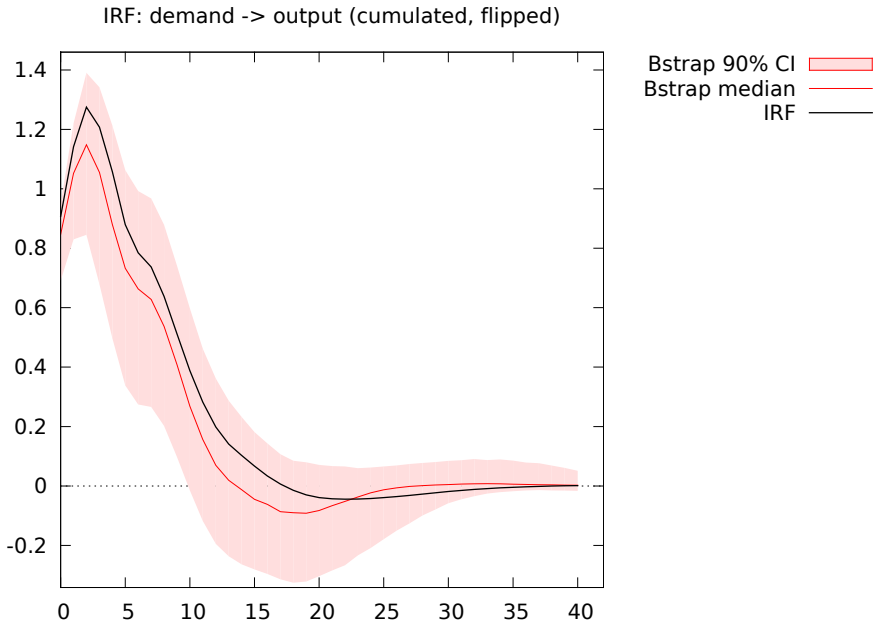
The Blanchard and Quah (1989) Identification Strategy

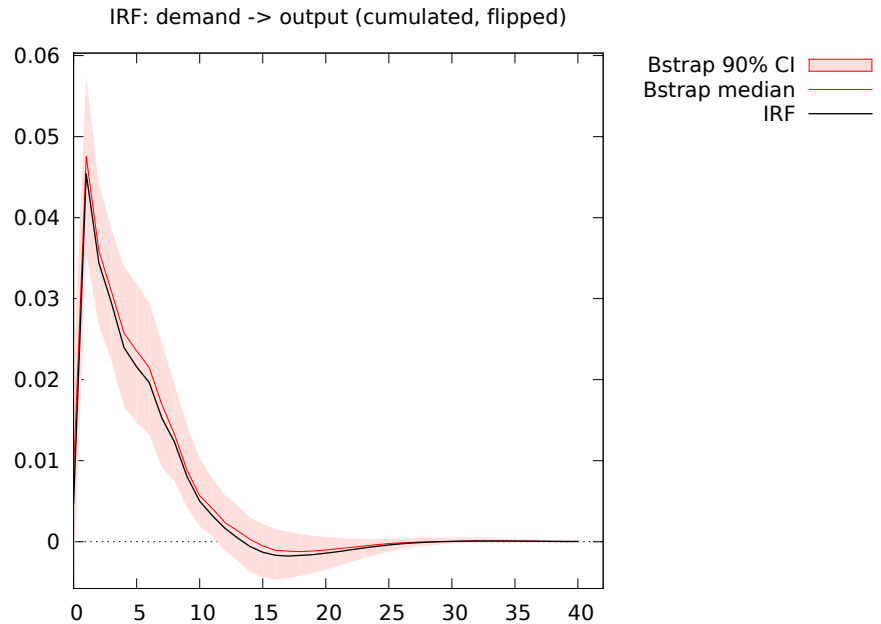
- **Consider a VAR with output and unemployment**
- **Two sources of shocks: supply and demand**
- **Assumptions:**
  - supply shocks have permanent effects on output
  - demand shocks have temporary effects on output
  - both shocks have transitory effects on unemployment
- **These assumptions allow to identify the VAR and to compute the impulse response functions (IRF)**
- **We can then compare the empirically observed IRF with the ones generated by our model**

Demand Shocks and Output Dynamics

Blanchard-Quah (BQ) vs. Model-Generated (MG) Impulse Response Functions (IRF)



BQ IRF



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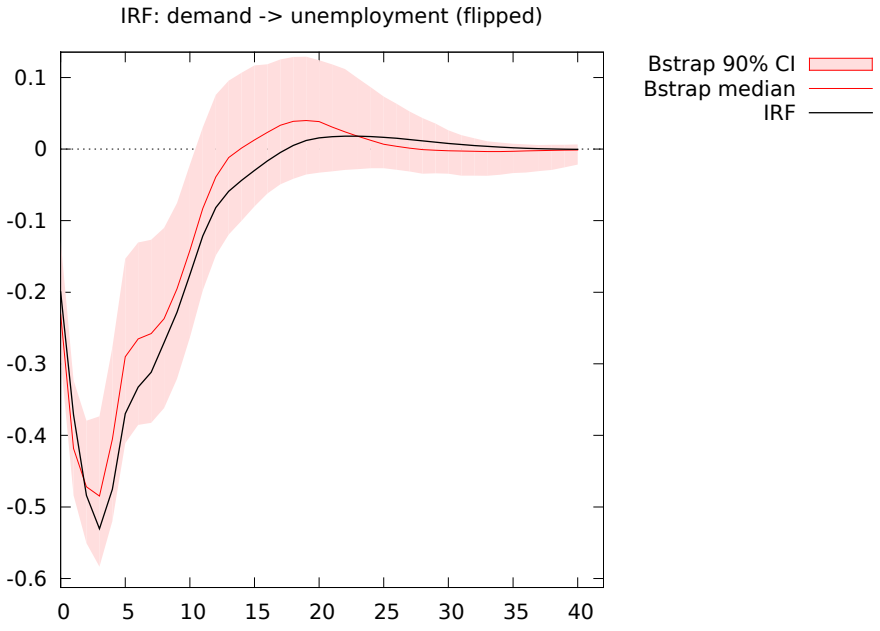

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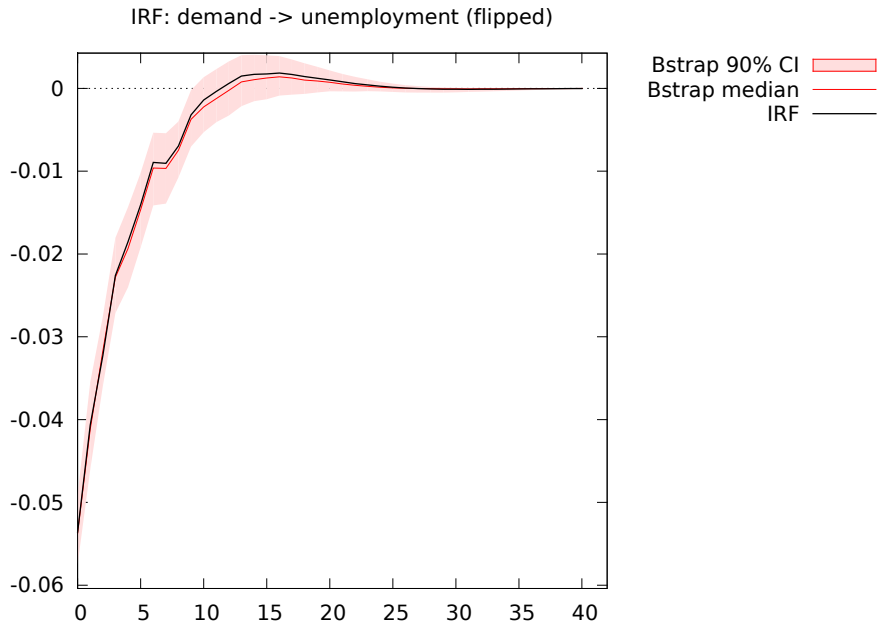

MG IRF

Supply Shocks and Output Dynamics

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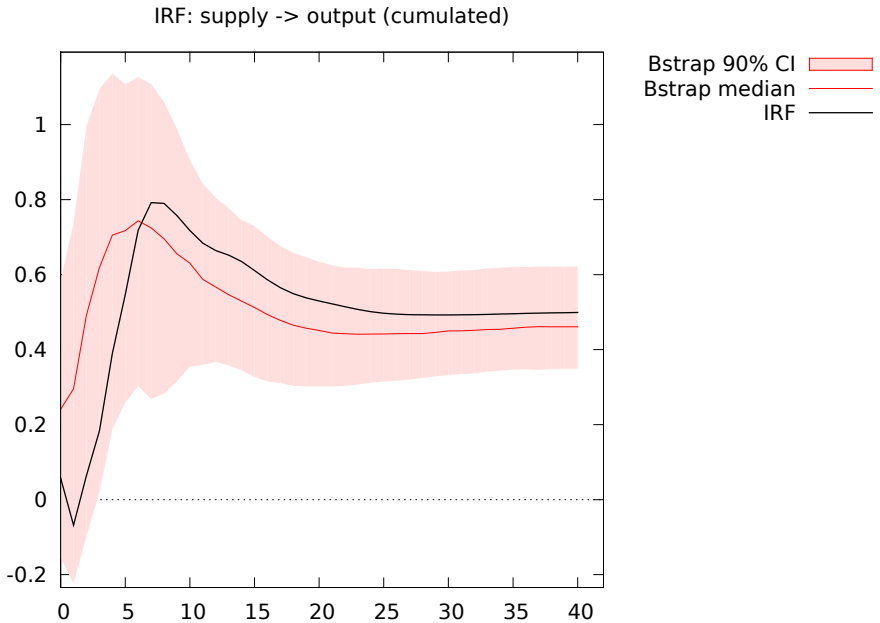
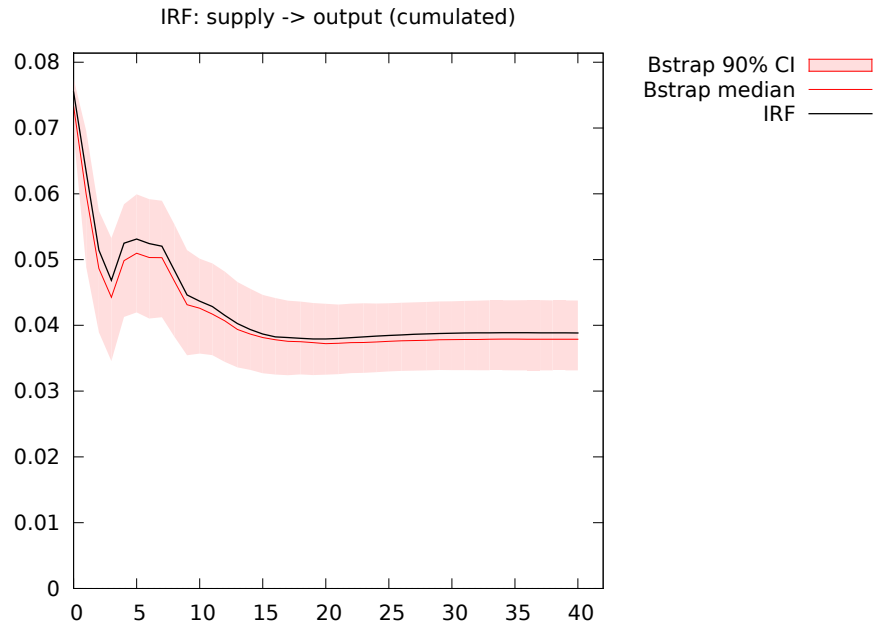


BQ IRF



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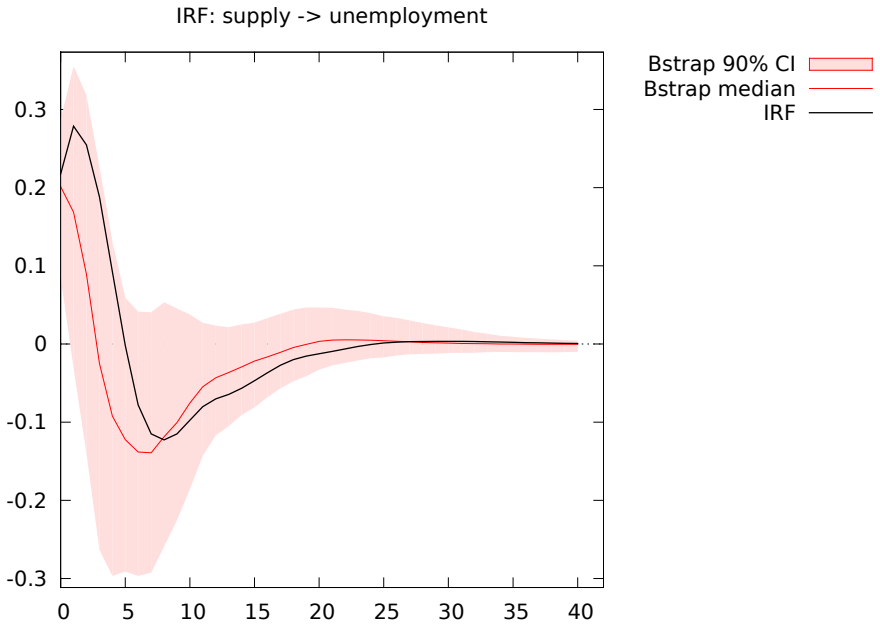

BQ IRF

MG IRF

Explaining Busines Cycles: The K+S vs. RBC Models

- **The K+S model builds an artificial world and therefore its "true structure" is known to the analyst**
- **The K+S and RBC models produce the same IRFs, but**
  - by construction, the K+S model has no aggregate supply shocks
  - indeed business cycles endogenously stem from demand instability grounded on micro interactions between heterogenous firms

Understanding the Source of Business Cycles

- **Does the Blanchard-Quah methodology let the data speak freely?**
- **Very strong identification and misleading assumptions underlying the IRFs:**
  - aggregate, exogenous shocks
  - only supply shocks have permanent effects
- **The K+S model almost matches the IRFs even with multiple persistent demand shocks**
- **Are the IRFs generated applying the BQ methodology useful to discern between alternative business-cycle theories?**
- **Exercises in ABM time series suggest that they lead in the wrong direction**

What Are the Ways Forward?

- **The importance of the underlying statistical model**
- **The general-to-specific LSE approach**
- **Cointegrated VAR**
- **Which identification strategies, if any, in an ABM world?**