Expectation Formation, Fiscal Policies and Macroeconomic Performance when Agents are Heterogeneous and the World is Changing

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Motivations

- Rational expectations vs. the “wilderness” of bounded rationality
- Rational expectations not suited for complex, evolving systems, if suited at all

Uncertainty

- Knight (1921) :

  The probability of events, the distribution of outcomes and even the exhaustive list of events are not known

- Keynes (1937):

  “We simply do not know.”

  - Multiple equilibria and coordination failures
  - Decisions driven by animal spirits
  - Response to uncertainty involves imitation, “beauty contest” and robust heuristics

(Relatedly) Unpredictability

- Endogenous shocks, radical changes in policies, deep downturns (Stiglitz, 2011, 2014)
- Structural breaks in the underlying distributions, outliers (Hendry and Mizon, 2014)
- Micro $\neq$ Macro :
  - Positive comovement across agents,
  - Synchronising decisions (e.g. investment spikes);
  - Propagation effects (Cooper and Haltiwanger, 1993),
  - Imitation and contagion,
  - Non-linearities in the aggregate system dynamics

From Rational to Rule-Based Adaptive Expectations and/or behaviours

- **Evidence and interpretations:**
  - Learning and procedural uncertainty
    (Dosi and Egidi 1991; Dosi et al. 2001)
  - Routines
    (Cyert and March 1963; Nelson and Winter 1982; Heiner 1983; Cohen et al. 1996)
  - Heuristics
    (Gigerenzer, 1999, 2007; Gigerenzer and Brighton, 2009)
  - Imperfect information
    (Greenwald and Stiglitz, 1986; Caroll, 2003; Coibion and Gorodnichenko, 2012)
  - Extrapolation and persistence
    (Caroll, 2003; Fuhrer, 2015; Gennaioli et al., 2015)
  - Heterogeneity in beliefs
    (Coibion et al., 2015)

From Rational to Rule-Based Adaptive Expectations and/or behaviours

- **Experiments:**
  - Decision biases
    (Tversky and Kahneman, 1974; Schweitzer and Cachon, 2000; Colasante et al., 2015)
  - Adaptive rules
    (Broder, 2003; Colasante et al., 2015)
  - Heterogeneity and switching
    (Hommes, 2011; Anufriev and Hommes, 2012; Assenza et al. 2014)
  - Organizational routines
    (Cohen and Bacdayan 1994)

What We Do

1. Introduce heterogeneous, adaptive expectation rules in the K+S family of models
   (Dosi et al. 2010, 2013, 2015)

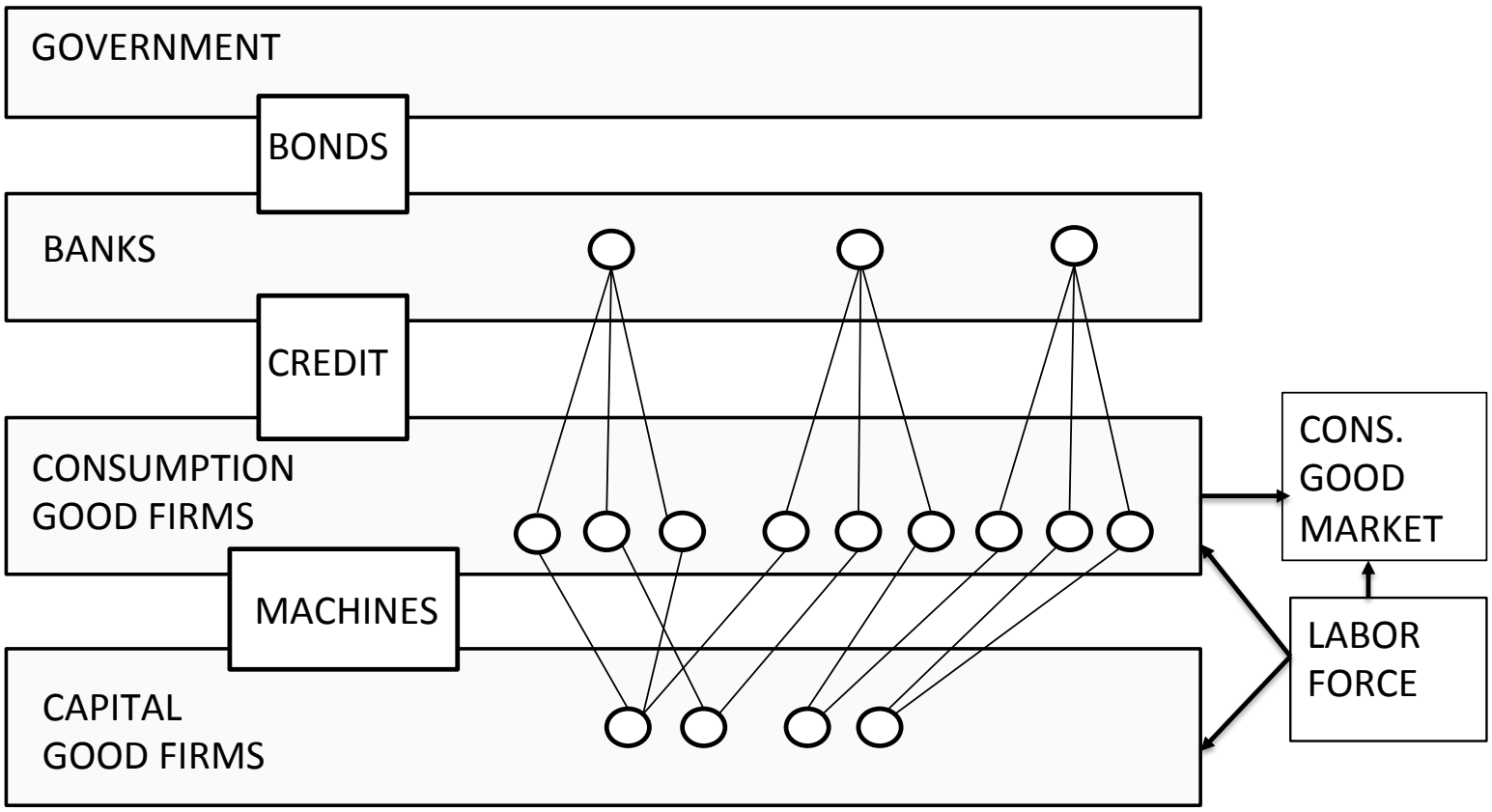
2. Analyze system dynamics under different expectational regimes, providing agents with a better informational and computational toolkit (i.e. “mimicking” rational behaviour)

3. Analyze the impact of different fiscal policies under alternative expectation setups

A Bird's Eye View of the Main Results

- The macroeconomic results generated by the K+S model are robust to more sophisticated expectation heuristics
- Fiscal austerity policies depress the short- and long-run performance of the economy for any given expectation rule
- **Results do not improve when agents are "more rational"**
  - Why? They cannot account for structural breaks and uncertainty in their decision mechanisms
  - On the contrary, more rationality might worsen both individual and collective performance

Model Structure



The Sequence of Microeconomic Decisions

1. Banks fix the maximum credit supply
2. Capital-good firms perform R&D, innovate and imitate
3. Consumption-good firms fix production and investment, based on expected demand
4. Firms ask for credit if needed, machines are paid
5. Production begins and firms hire workers
6. The consumption-good market opens
7. Firms repay their debt, bank profits and equity are computed accordingly
8. Firm entry and exit
9. Machines are delivered to consumption-good firms

Technical Change and Capital-Good Firms

- Capital-good firms search for better machines and for more efficient production techniques
- They invest in R&D investment a fraction of past sales, and allocate R&D funds between innovation and imitation
- They fix prices applying a mark-up on unit cost of production and send a “brochure” with the price and the productivity of their machines to consumption-good firms

Investment and Consumption-Good Firms

- **Expansion investment**
  - demand expectations (D^e) determine the desired level of production (Q^d) and the desired capital stock (K^d)
  - firm invests (EI) if the desired capital stock is higher than the current capital stock (K):

$$EI = K^d - K$$

- **Replacement investment**

Demand Expectations Rules

adapted from Anufriev and Hommes (2012)

E1. Naïve expectations (NA) (Baseline)

$$D^e_{1,j}(t) = D_j(t-1)$$

E2. Adaptive expectations (ADA)

$$D^e_{2,j}(t) = D^e_j(t-1) + w_{ada}(D_j(t-1) - D^e_j(t-1)), \qquad w_{ada} = 0.65$$

E3. Weak trend rule (WTR)

$$D^e_{3,j}(t) = D_j(t-1) + w_{wtr}(D_j(t-1) - D_j(t-2)), \qquad w_{wtr} = 0.4$$

E4. Strong trend rule (STR)

$$D^e_{4,j}(t) = D_j(t-1) + w_{str}(D_j(t-1) - D_j(t-2)), \qquad w_{str} = 1.3$$

E5. Anchor and adjustment (LAA)

$$D^e_{5,j}(t) = [1 + w_{laa}\Delta GDP(t-1) + (1 - w_{laa})\Delta D_j(t-1)]\, D_j(t-1) \qquad w_{laa} = 0.5$$

Heterogeneous Expectation Rules

Performance evaluation:

- portfolio of 5 expectation rules (E1-5)
- agents can switch among different expectation rules according to their past performance $U_{h,j}(t)$

$$U_{h,j}(t) = -\left(\frac{D_j(t-1) - D^e_{h,j}(t-1)}{D^e_{h,j}(t-1)}\right)^2 + \eta U_{h,j}(t-1)$$

$0 \leq \eta \leq 1$ represents the memory

Heterogeneous Expectation Rules

Switching:

- probabilistic choice (initialization as Uniform distribution)
- probability of heuristic $n_{h,j}(t)$ updated in each period:

$$n_{h,j}(t) = \delta n_{h,j}(t-1) + (1-\delta)\frac{\exp(\beta U_{h,j}(t))}{Z_j(t)}$$

  δ captures the persistence; β captures the intensity of choice; $Z_j(t) = \sum_{h=1}^{H} \exp(\beta U_{h,j}(t))$ normalization factor

- expectation of entering firms: probabilities proportional to diffusion of the heuristic in the economy

Consumption-Good Market

- **Supply:**
  - imperfect competition: prices (p_j) $\Rightarrow$ variable mark-up (mi_j) on unit cost of production (c_j)
  - firms first produce and then try to sell their production (inventories)
- **Demand:** workers' consumption
- **Market dynamics:**
  - market shares evolve according to a replicator dynamics
  - firm competitiveness depends on price and unfilled demand

The Banking Sector

- **Credit demand:** firms' desired production and investment - available liquidities
- **Credit supply:** Basel capital adequacy + endogenous buffer
- **Credit allocation:** pecking-order base; possible rationing
- **Bank failure:** negative net worth due to accumulated bad debt (firms default when exit)
- **Bail-out:** Government steps in, negative effect on public budget

Labor Market

- Exogenous labor supply
- Wage dynamics determined by avg. productivity, inflation and unemployment

$$\frac{\Delta w(t)}{w(t-1)} = \pi^T + \psi_1 * (\pi_t - \pi^T) + \psi_2 * \frac{\Delta \overline{AB}(t)}{\overline{AB}(t-1)} - \psi_3 * \frac{\Delta U(t)}{U(t-1)}$$

- Involuntary unemployment + possibility of labor rationing

Closing the Model: The Macro Framework

- **Fiscal policy and the public budget:**
  - constant tax and unemployment-subsidy rate
  - the public deficit in each period is:

$$Def_t = BankBailout_t - Tax_t + G_t + r_{B,t} Debt_t$$

  - it may be subject to a fiscal rule: $Def_t / GDP_t \leqslant 3\%$

- **Monetary policy:**
  - "conservative" Taylor rule tackling the inflation gap:

$$r_t = r^T + \gamma_\pi * (\pi_t - \pi^T) + \gamma_U * (U^T - U(t)), \qquad \gamma_\pi > 1, \gamma_U = 0$$

- **Employment, consumption, investment, inventories and GDP are obtained by aggregating micro quantities**

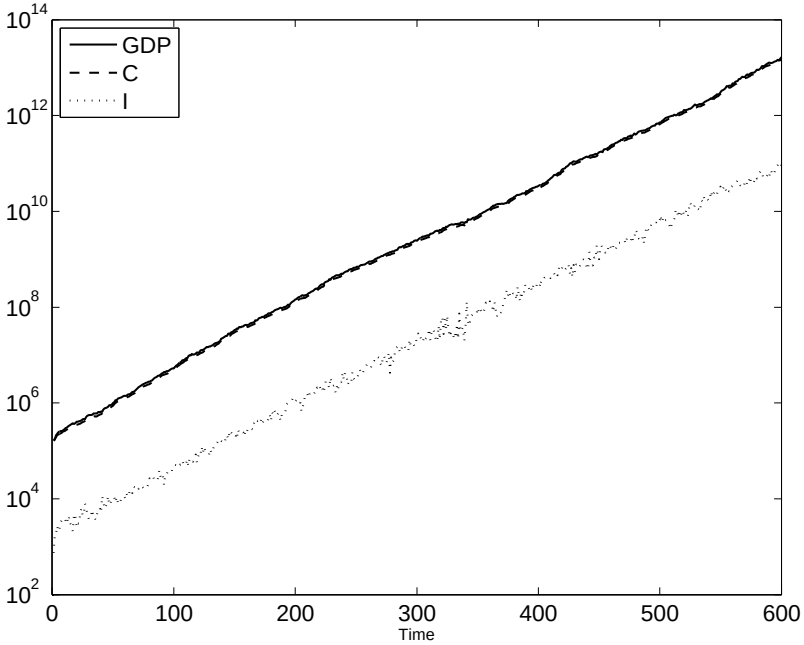
Validating the K+S Model

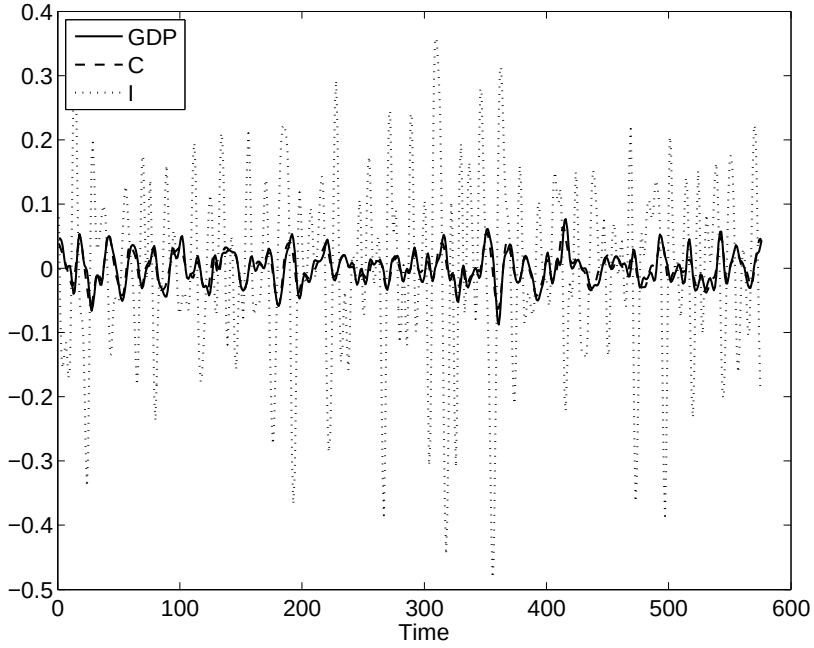
- ABMs are much more complex than standard, e.g. RBC, macroeconomic models
- The model should match an ensemble of macroeconomic stylized facts, including those addressed by standard models
- The model should also be able to match the largest possible number of microeconomic stylized facts (standard macroeconomic models are not usually able to match any microeconomic stylized fact)

Stylized Facts Replicated by the K+S model

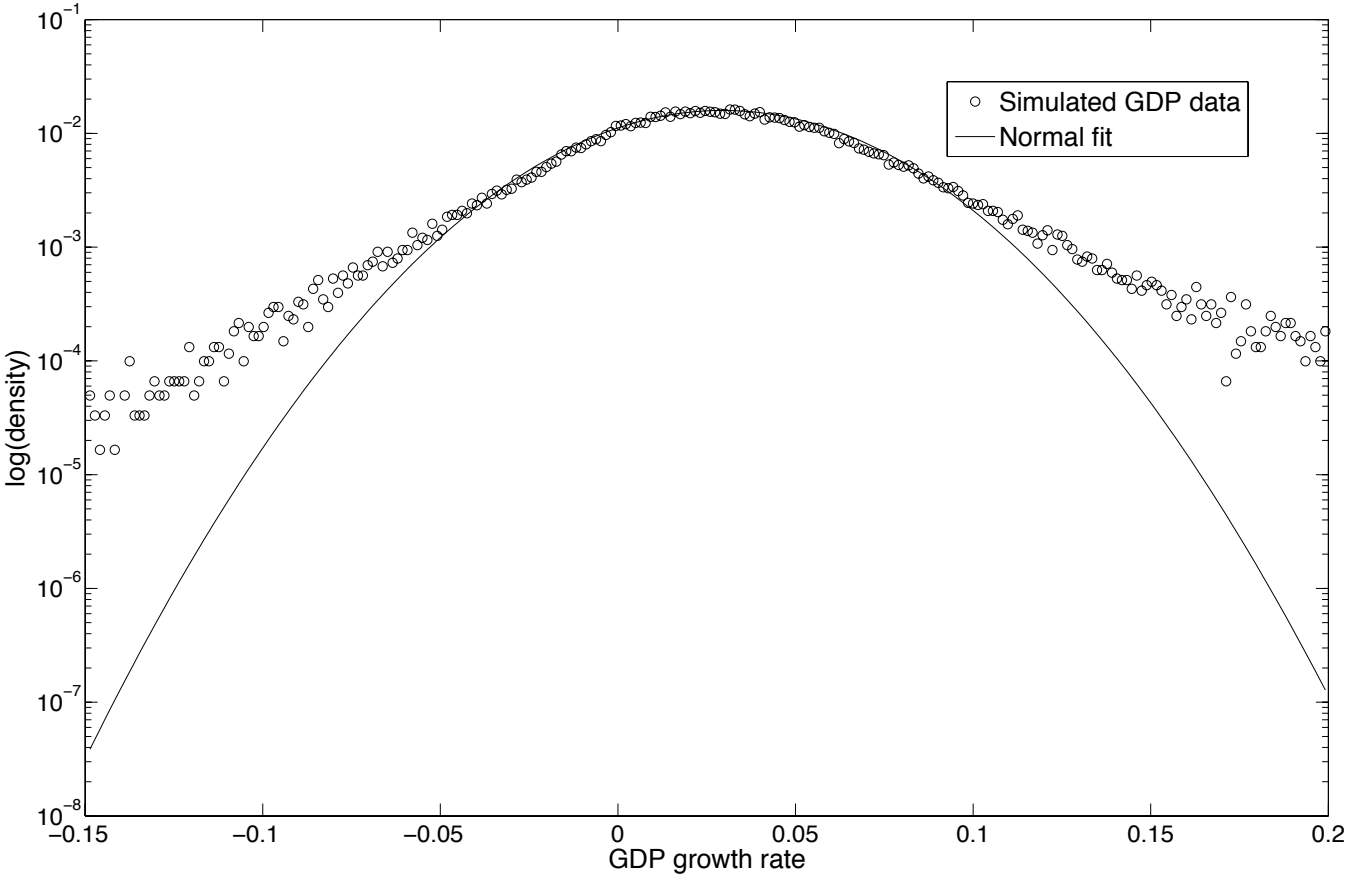
Stylized facts	**Empirical studies**
Macroeconomic stylized facts	
Endogenous self-sustained growth with persistent fluctuations	Kuznets and Murphy (1966); Stock and Watson (1999)
Fat-tailed GDP growth-rate distribution	Fagiolo et al (2008)
Recession duration exponentially distributed	Ausloos et al (2004); Wright (2005)
Cross-correlations of macro variables	Stock and Watson (1999)
Microeconomic stylized facts	
Firm (log) size distribution is right-skewed	Dosi (2007)
Fat-tailed firm growth-rate distribution	Bottazzi and Secchi (2003, 2006)
Productivity heterogeneity across firms	Bartelsman and Doms (2000)
Lumpy investment rates at firm-level	Doms and Dunne (1998)
Firm bankruptcies are counter-cyclical	Jaimovich and Floetotto (2008)
Firm bad-debt distribution fits a power-law	Di Guilmi et al (2004)

Endogenous growth and fluctuations

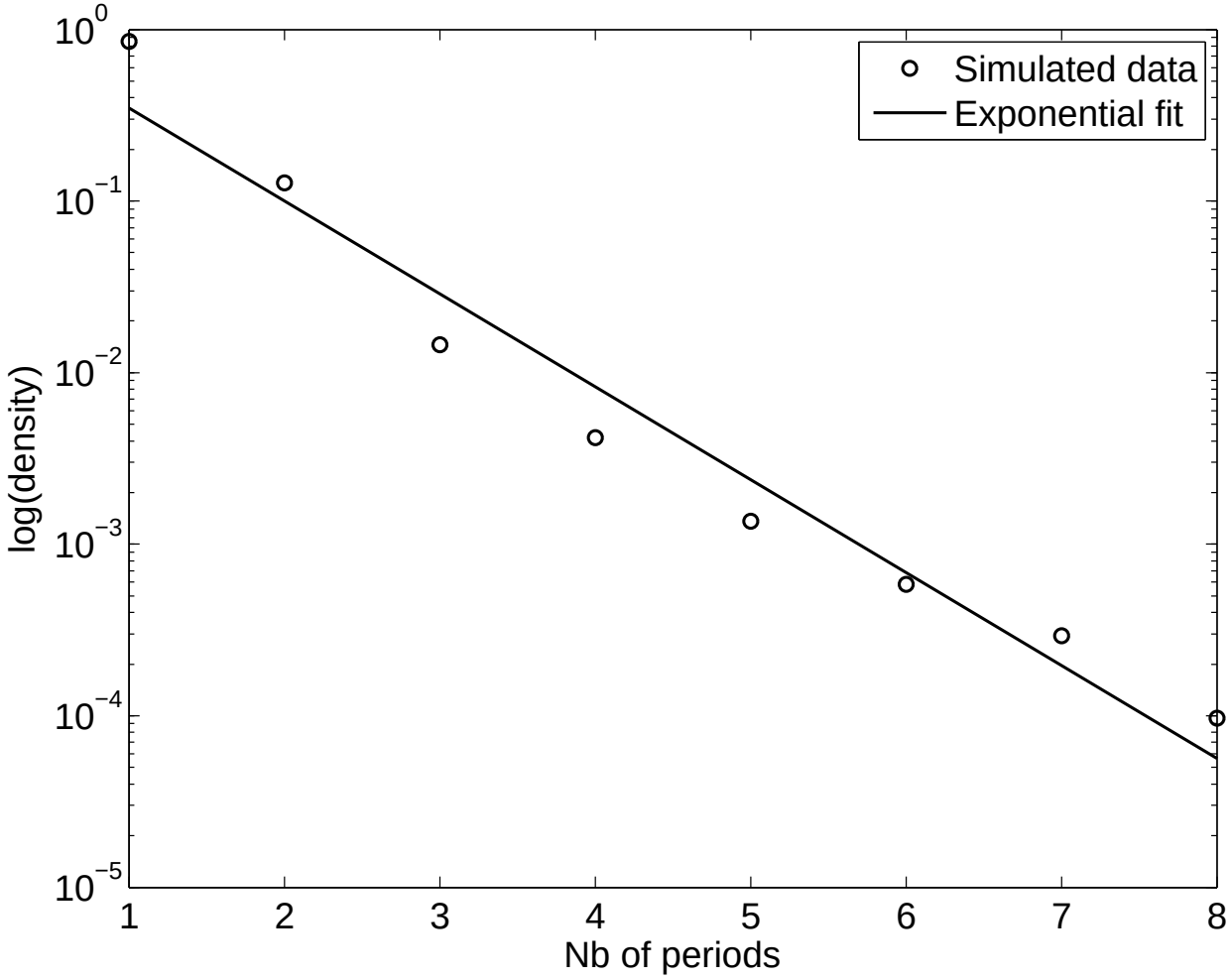




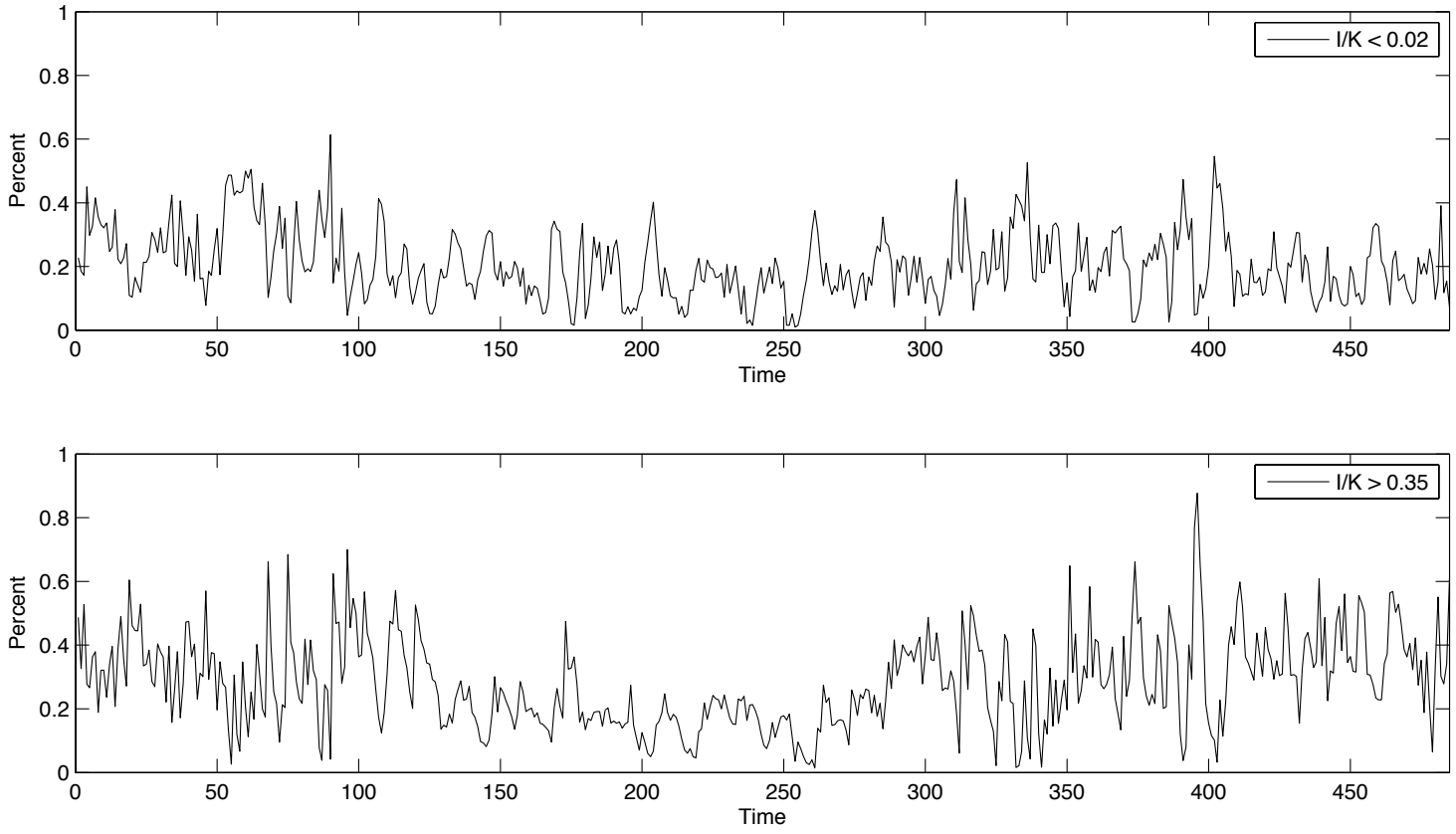
Emergent Deep Recessions and Fat-Tailed Distributions of GDP



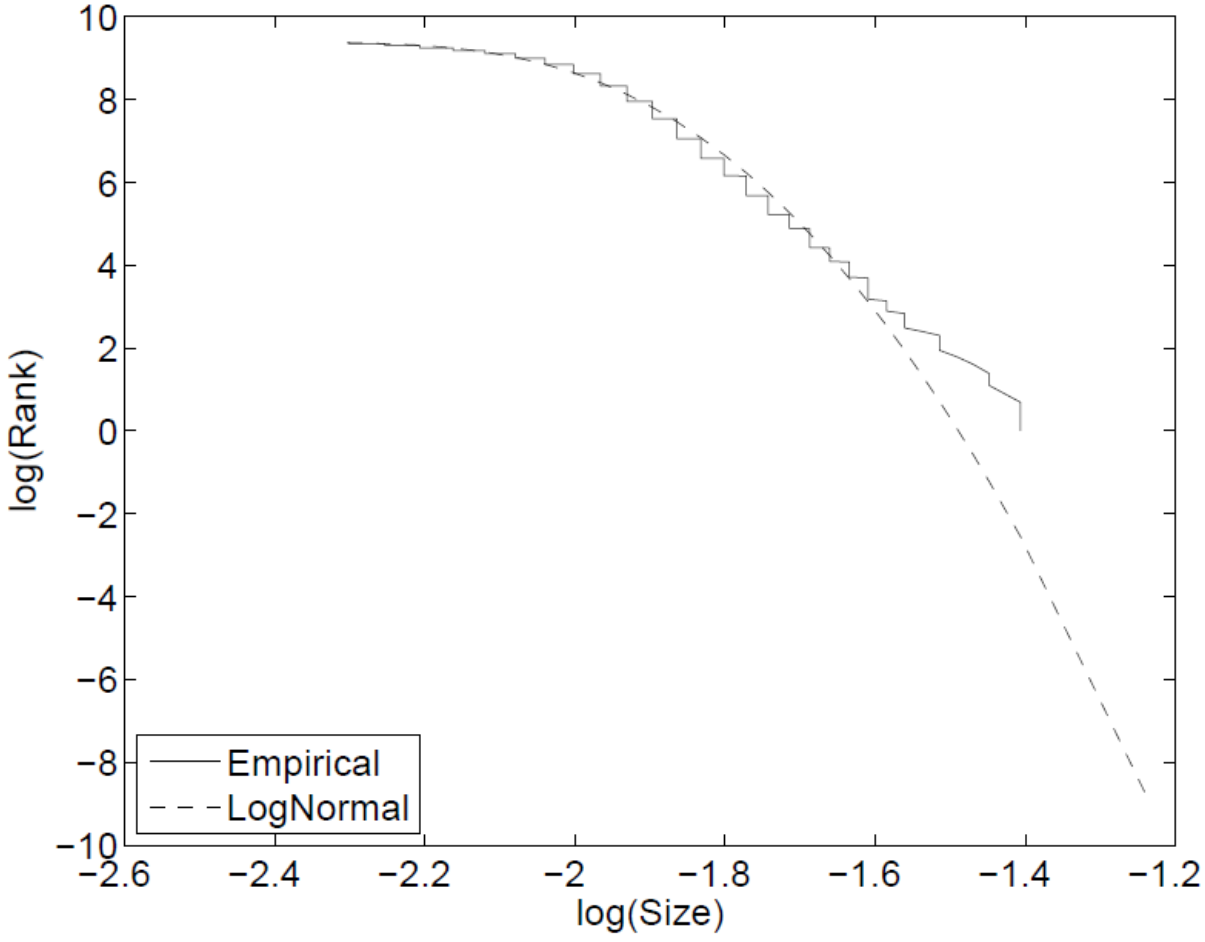
Recession duration exponentially distributed



Investment Lumpiness



Firm size distribution



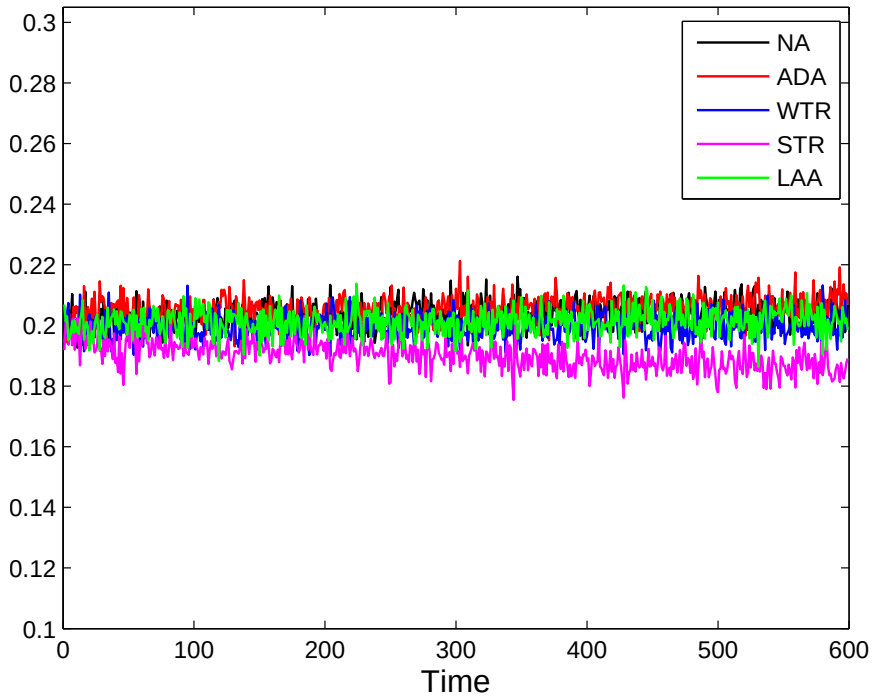
Expectation Rules and Macroeconomic Dynamics

1. Analyze system dynamics under different expectational regimes and policies

2. Providing agents with a better informational and computational toolkit (i.e. “mimicking” rational behaviour)

Heterogeneous Expectations Dynamics (SWITCH)

Figure : Average share of each heuristic over time (average over 50 simulations).



- An ecology of coexisting rules

Expectation Rules and Macroeconomic Dynamics

Table : Ratio with respect to the baseline (myopic expectations: NA).
*: sig.diff. wrt. baseline at 1% (**) and 5% level (*).

Expectation rules	Avg. GDP growth	GDP volatility	Unempl. rate	Likelihood of crises
ADA	1.00	0.86**	1.30	0.61**
WTR	1.01	1.06	0.69*	1.05
STR	0.97**	2.88**	2.34**	3.08**
LAA	1.00	1.56**	0.89	1.78**
SWITCH	1.01	0.96	0.55**	0.79

- More sophisticated expectations rules do not significantly affect the performance of the economy (in line with Dosi et al. 2006)
- Only exception is the strong trend rule, with very strong positive feedbacks

The Impact of a Fiscal Austerity Rule

Within Expectation Scenario

Expectation rules	Avg. GDP growth	GDP vol.	Unempl. rate	Likelyhood of crises	Freq. debt crises across sim.
NA	0.67**	8.94**	3.69**	1.42**	0.30
ADA	0.03**	25.52**	5.47**	3.18**	0.66
WTR	0.82**	6.27**	4.08**	1.52**	0.22
STR	0.85**	4.47**	2.83**	1.16**	0.52
LAA	0.95**	3.89**	3.20**	1.34**	0.12
SWITCH	0.92**	4.92**	3.78**	1.62**	0.12

- Austerity rules harm the economy in all expectation scenarios
- Austerity is always self-defeating leading to sovereign debt crises
- Worst case is ADA: agents adapt to austerity!

Getting closer to “rational expectations”

Changes to the adaptive expectations (ADA) rule

- In the initial ADA rule, all agents use the same parameter

$$D^e_{2,j}(t) = D^e_j(t-1) + w_{ada}(D_j(t-1) - D^e_j(t-1)), \quad w_{ada} = 0.65$$

- Instead, we allow agents to learn their parameter endogenously through **OLS learning**
  - Firms estimate their own parameter
  - They apply a linear model to their past data
  - Feedback rule from firm performance to behaviour

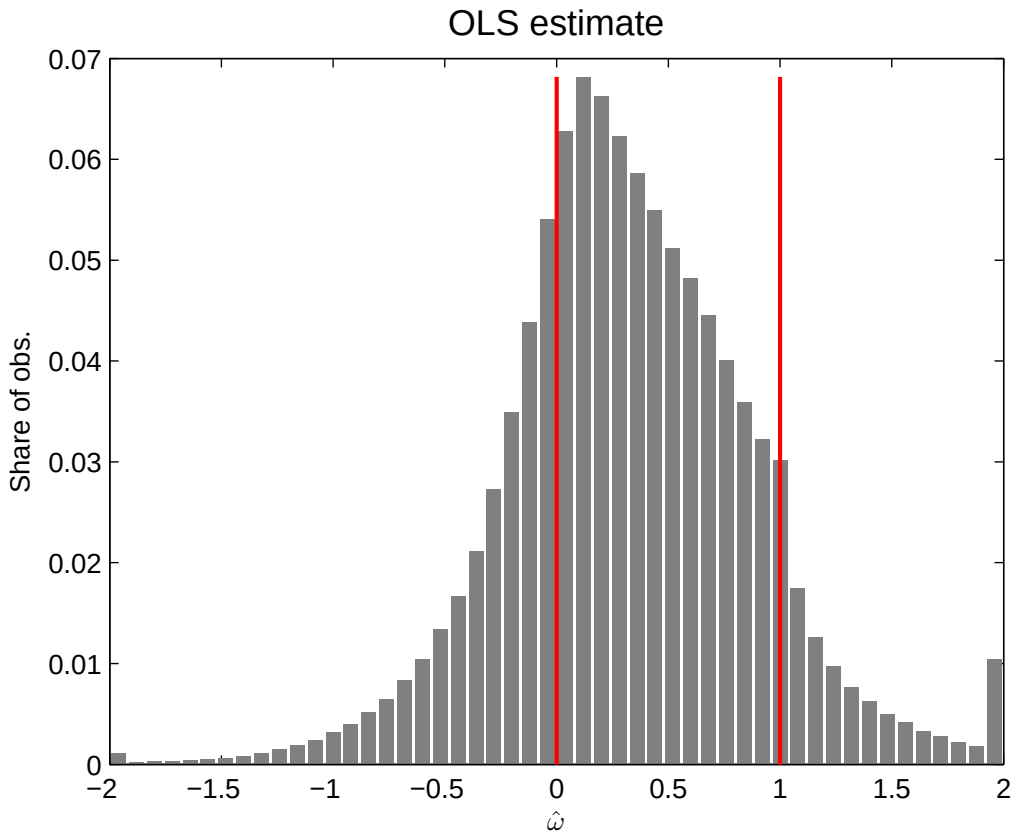
OLS learning

At any point in time, two types of agents co-evolve:

- **Heuristics-guided firms**
  - Firms without enough data to perform OLS learning (soon after entry)
  - They use the homogeneous parameter w_{ada}
- **Sophisticated firms**
  - They use OLS estimation to define $\hat{w}_{ada,j,t}$

Their relative share depends on the minimum number of observations to do OLS.

OLS learning outcomes



- For a non-negligible part of the agents, learning yields overshooting

OLS learning results

Expectation rules	GDP growth	GDP volatility	Unempl. rate	Likelihood of crises	Debt/GDP
Ratios wrt. NA					
ADA	1.00	0.86**	1.30**	0.61**	1.84
ADA + OLS	0.96**	1.24**	4.55**	1.62**	19.87**
Ratio wrt. ADA					
ADA + OLS	0.97**	1.45**	3.49**	2.66**	10.80**

- Other things being equal, OLS learning is destabilizing
- **Why?**

Expectation rules and forecast errors

Expectation rule	Forecast errors	
	Mean	Std. dev.
Without OLS learning		
NA	0.02	0.50
ADA	0.03	0.30
ADA + OLS learning		
Average (all agents)	0.42	3.13
Heuristic agents	0.10	0.27
Sophisticated agents	0.52	3.56

With OLS learning:

- Lower ability to forecast demand
- Higher dispersion in the errors
- Large difference in performance across types of agents

What drives the results?

Is sophisticated agents' lower performance due to:

1. An insufficient number of observations?

   $\rightarrow$ Are errors reduced when agents use more observations?

2. The noise created by the heuristic agents?

   $\rightarrow$ Does macroeconomic performance deteriorate when more heuristic agents are present?

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   No! They increase!

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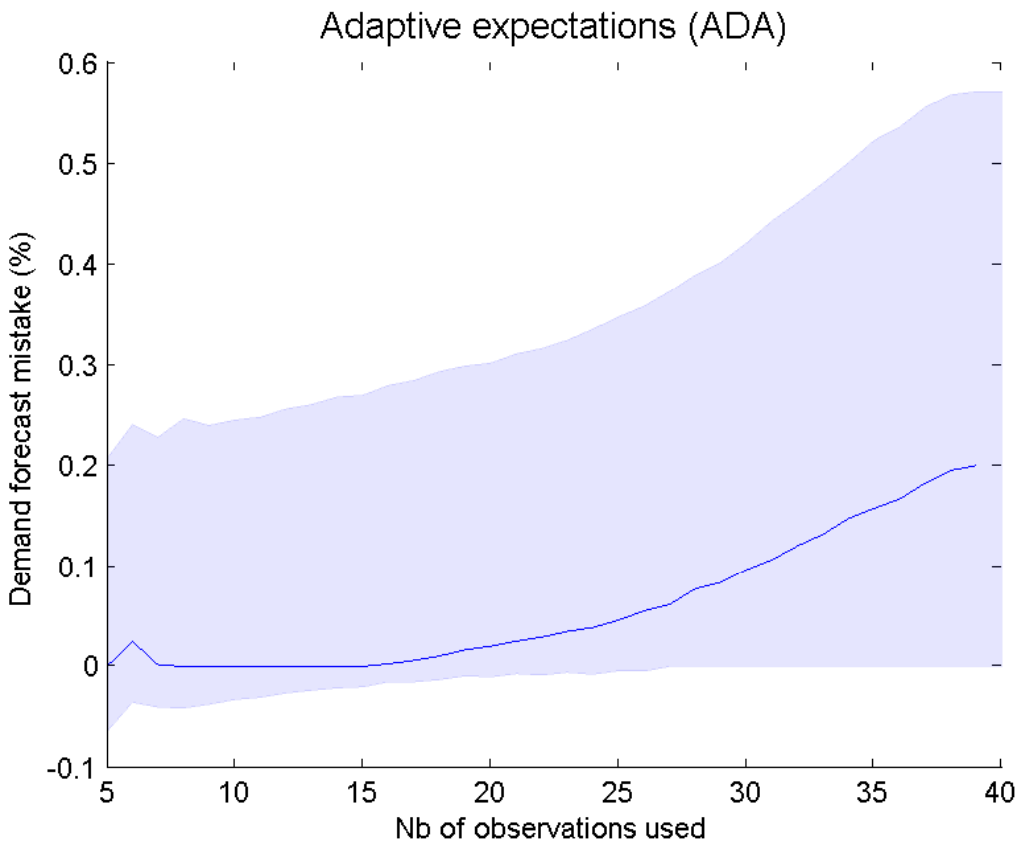
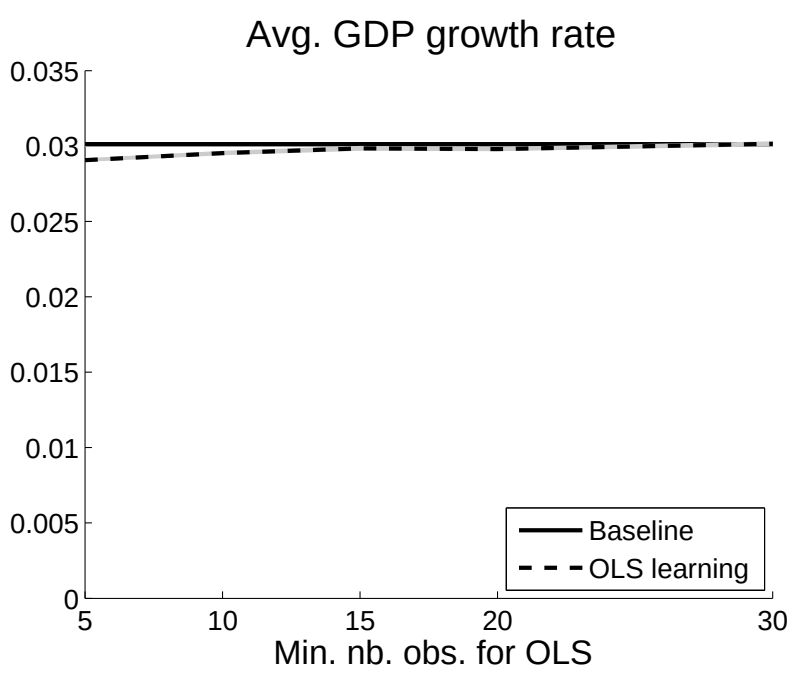
Are errors reduced when agents use more observations?

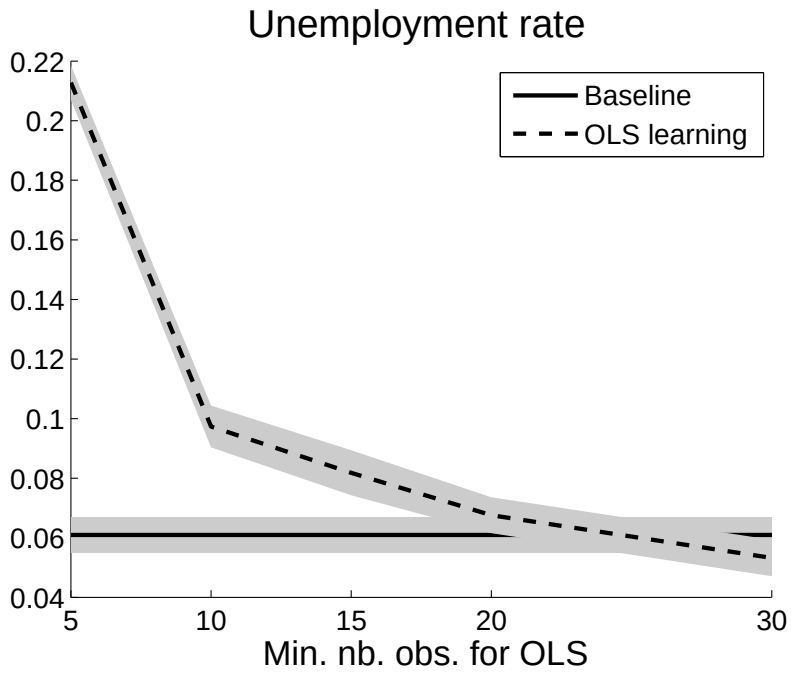


No! They increase!

Why? Better fit, but worse prediction

Does macroeconomic performance deteriorate when more heuristic agents are present?





No, it improves!

Why? Both types of agents make smaller mistakes

The stabilizing role of heuristics

- **A large share of agents performing OLS learning is destabilizing**
  - Bending a complex, non-linear world into a linear framework
  - More information deteriorates the quality of the forecast (cf. Geanokoplos 1992)
  - Following the Box-Jenkins approach, more sophisticated models fit better the data but are worst predictors
- Relative stability is recovered when there is a sufficient fraction of heuristic-guided agents
- Preliminary findings using the trend rules confirm these results

Concluding Remarks

Macroeconomic dynamics not significantly altered by changes in the expectation model
(in line with Dosi et al. 2006)

- Only indirect effect of demand expectations interacting with firms' heterogeneous productivity and financial conditions
- Austerity policies considerably harm macroeconomic performance (cf. Dosi et al. 2015), irrespectively of the sophistication of expectation-formation rules

Concluding Remarks

Making agents "more rational" is counterproductive in an economy modelled as a complex evolving system

- When the world is changing and the dynamic is perfectly unknown, trying to fine-tune behaviours upon less than perfect models of the world worsens forecasting performance of the individual agents and the economic performance of the aggregate system.
- If agents do not know the data-generating process of the world, heuristics are better!

Next Steps

- Improving the assessment of fiscal policies under different expectation scenarios: computing fiscal multipliers