# Building methodological Bridges

**Marco Raberto**[1]

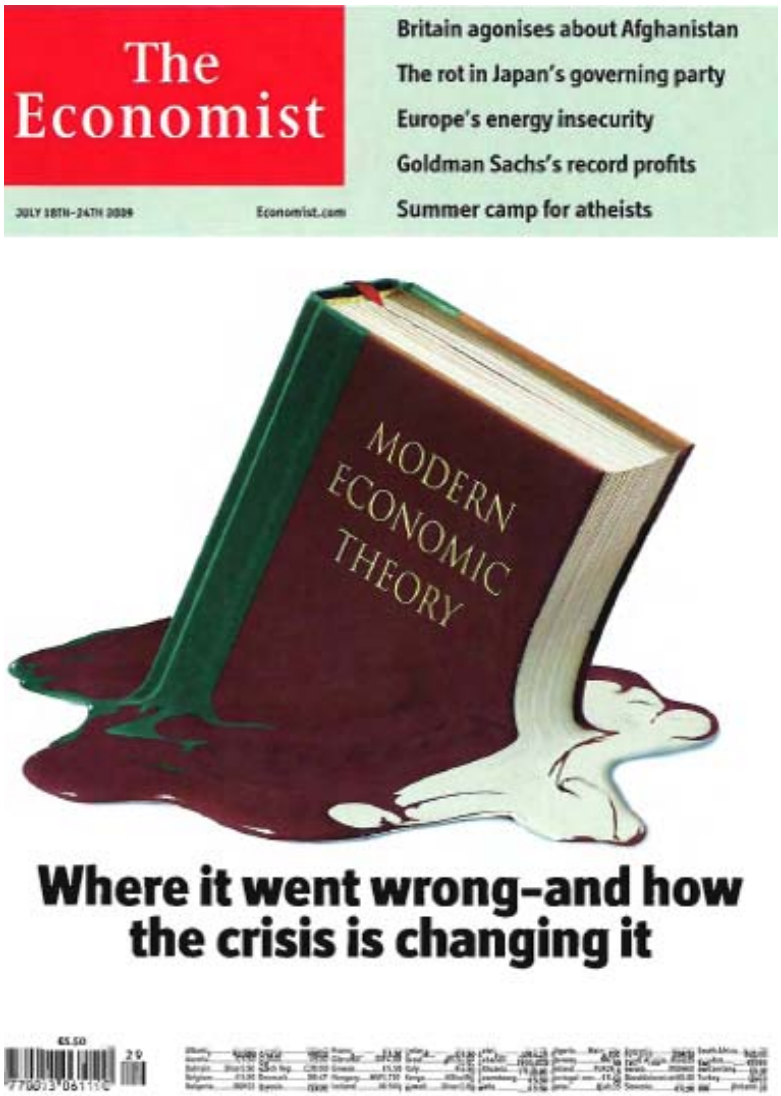
**Metamorphosis of Europe**
*Simulations of a new Global Political Economy?*
Chamber of Labour, Vienna, Austria

[1]DIME, University of Genova, Italy. Email: marco.raberto@unige.it

# Outline

- From economic crisis to crisis of economic theory
- Alternative interdisciplinary approaches:
  - Econophysics: statistical equilibrium
  - The agent-based computational economics (ACE) approach:
    - Eurace
    - Iceace
    - Symphony

# The economist, July 2009



# The current economic crisis as a crisis for economic theory

- The pre-crisis research agenda of macroeconomics:
  - improve the consensus among macroeconomists
  - further refine the DSGE model
  - assess and possibly remove the residual elements of "art" present in the conduct of economic policy

- "The whole intellectual edifice collapsed in the summer of last year". Alan Greenspan, testimony to House of Representatives Committee on Government Oversight and Reform, October 23rd 2008.

# The current economic crisis as a crisis for economic theory

- most macroeconomics of the past 30 years was "spectacularly useless at best, and positively harmful at worst"
- The current economic crisis as a crisis for economic theory Kirman, 2010; Colander et al., 2010; Stiglitz, 2011; Dosi 2011)
- Krugman (2011) on DSGE models:
  - they don't forecast the Great Recession
  - they don't even conceive the possibility of such a crisis
  - they don't provide any useful advice to policy makers

EUROPEAN CENTRAL BANK

EUROSYSTEM

**Reflections on the nature of monetary policy non-standard measures and finance theory**

**Speech by Jean-Claude Trichet, President of the ECB,**
**Opening address at the ECB Central Banking Conference**
**Frankfurt, 18 November 2010**

- "When the crisis came, the serious limitations of existing economic and financial models immediately became apparent. [...] **Macro models failed to predict the crisis** and seemed incapable of explaining what was happening to the economy in a convincing manner."
- "We need to deal better with **heterogeneity across agents and the interaction** among those heterogeneous agents. [...] **Agent-based modelling** dispenses with the optimisation assumption and allows for more complex interactions between agents. Such approaches are worthy of our attention."
- " we need to better **integrate the crucial role played by the financial system into our macroeconomic models** [... to account for the **pro-cyclical build up of leverage** and vulnerabilities]"
- "In this context, I would very much welcome inspiration from other disciplines: **physics, engineering, psychology, biology**."

# A statistical equilibrium model of competitive firms

- $X_t$: profit rates
- the dynamical evolution of profit rates could be interpreted as a diffusion process with drift:

$$dX_t = -\frac{D}{2b}\,\text{sign}(X_t - \mu)\,dt + \sqrt{D}\,dW_t \qquad D = \frac{2b^2}{\mu}$$

  - $-\text{sign}(X_t - \mu)$: central tendency of equalization of profit rates $\mu$;
  - $\sqrt{D}\,dW_t$: random and idiosyncraic factors affecting single firms
- The Laplace PDF is the stationary solution of the diffusion equation above!

# The ACE approach (I)

- The study of the economy by means of agent-based computational models is a relatively new field and dates back to the 90s.
- The increasing availability of cheap computing power made possible to undertake the computationally expensive experiments required to model the interactions of large numbers of bounded rational, heterogeneous agents.
- Simulating artificial economies on the computer is becoming a promising approach to the study of economic systems, able to overcome the limitations of mainstream analytical economic models (Nature vol 460, August 2009).

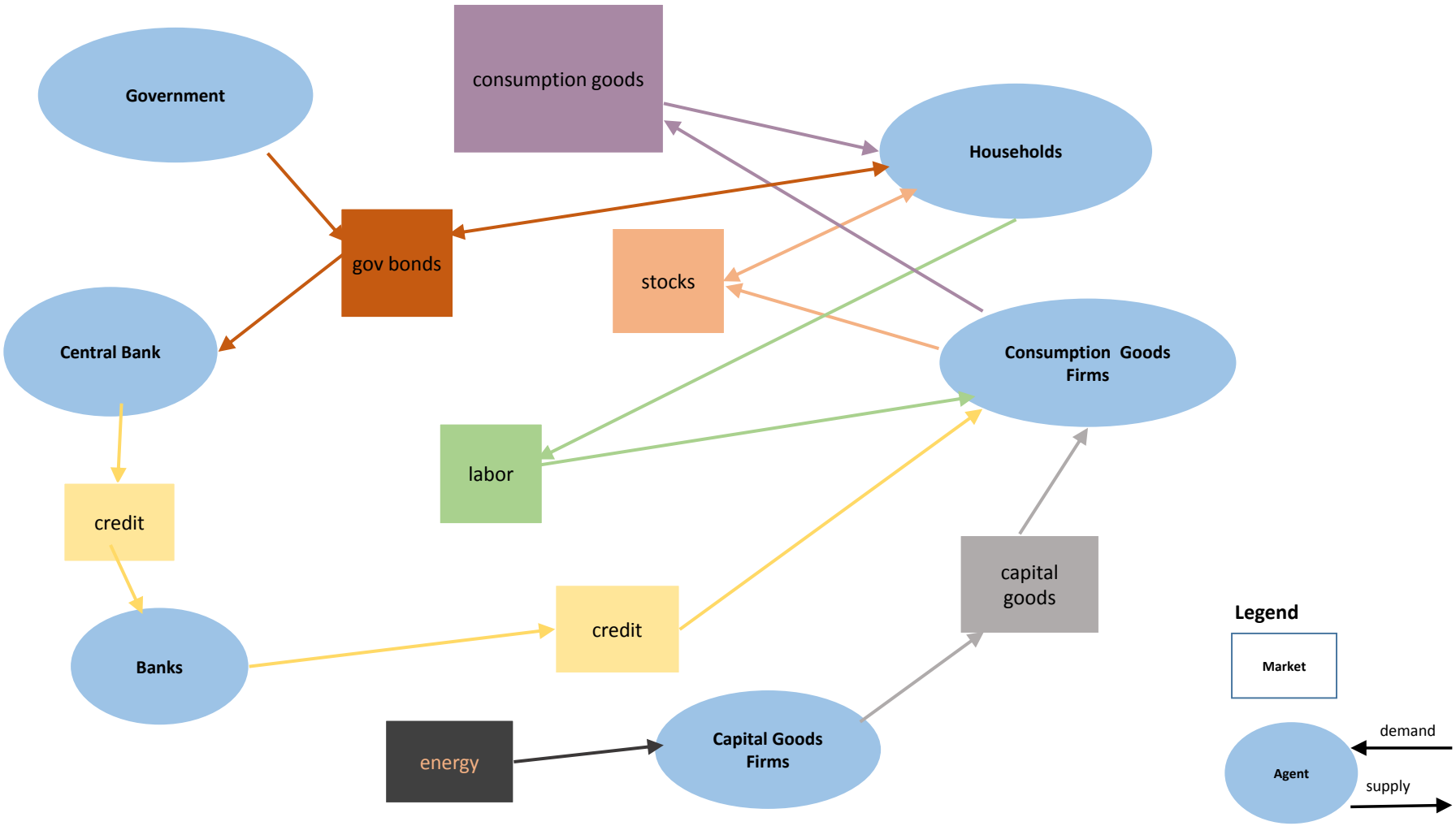
# The ACE approach (II)

- It allows the study of the emergent aggregate statistical regularities in the economy, which cannot be originated by the behaviour of a "typical" or "average" individual (Kirman J. Econ Perspectives 1992), but is the result of agents' behaviour and interaction.
- The agent-based methodology fully addresses the interaction and the coordination processes of heterogeneous economic agents by considering adapting and learning behaviours.
- In the credit markets, for example, it can take into account complex pattern of interactions like networks topologies, credit rationing, bankruptcy waves and cascade effects, which are important issues for the present state of the economy.

# The ACE approach for policy design

- An agent-based simulator is a powerful computational facility where to perform large-scale experiments on complex and realistic economic environments and to test different issues of policy design.
- It offers a realistic environment that is well suited for studying the out-of-equilibrium transitory dynamics of the economy caused by changes of policy parameters.

# Overview of the Eurace model (EU Project 2006-2009)



# Balance sheets of Eurace agents

| Agent | Assets | Liabilities |
|---|---|---|
| Household | Liquidity $\left( M^h \right)$<br>Equity shares<br>Gov bonds | Equity |
| CGP | Capital goods $(K^f)$<br>Inventories<br>Liquidity $\left( M^f \right)$ | Loans $\left( D^f = \sum_b \lambda_b^f \right)$<br>Equity $(E^f)$ |
| KGP | Liquidity $\left( M^f \right)$ | Equity |
| Bank | Loans $\left( \sum_f \lambda_b^f \right)$<br>Liquidity $\left( M^b \right)$ | Deposits (Liquidity of Hous, CGP and the KGP)<br>Standing facility with the CB<br>Equity |
| Government | Liquidity $\left( M^g \right)$ | Bonds<br>Equity |
| Central Bank | Standing facility with Banks<br>Gov bonds<br>Liquidity $\left( M^{CB} \right)$ | Outstanding fiat money<br>Deposits (Liquidity of Banks and the Gov)<br>Equity |

# Monetary aggregates and time invariants

- In the EURACE model we have a key monetary time invariant:

$$\left(\sum_h M^h + \sum_f M^f\right) + \sum_b E^b \quad + \quad M^g \quad + \text{ cum. energy costs}$$

private sector deposits + banks' equity + public sector deposits

$$=$$

$$\left(\text{initial value} + \sum_g n_g^{CB} p_g^*\right) + \left(\sum_b \sum_f \lambda_f^b\right) +$$

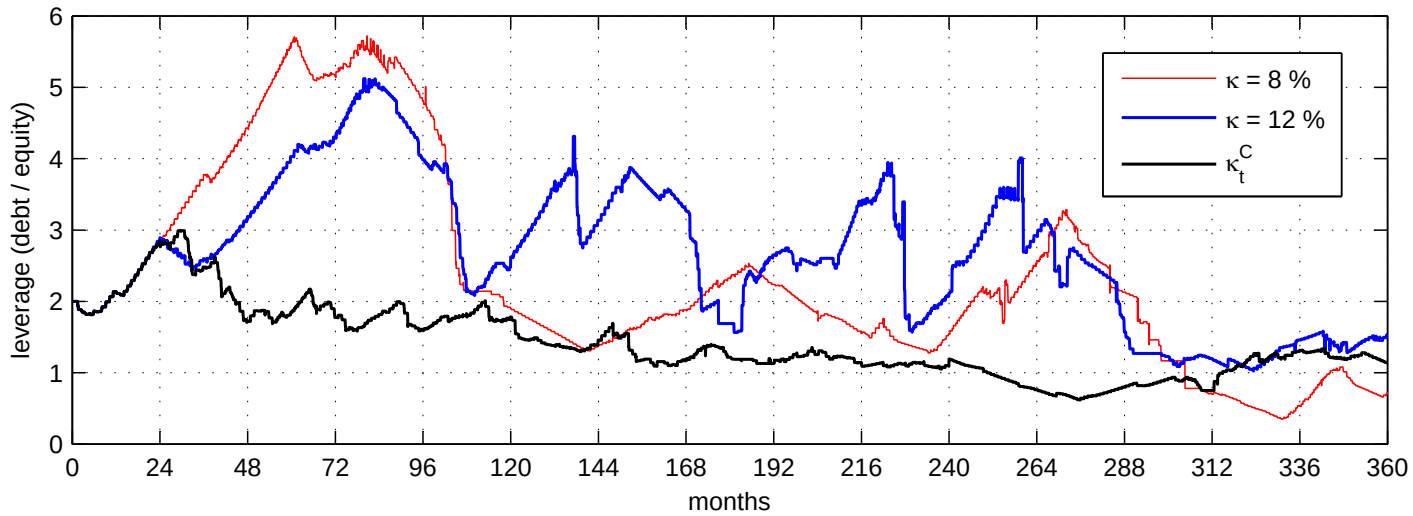
fiat money + credit money

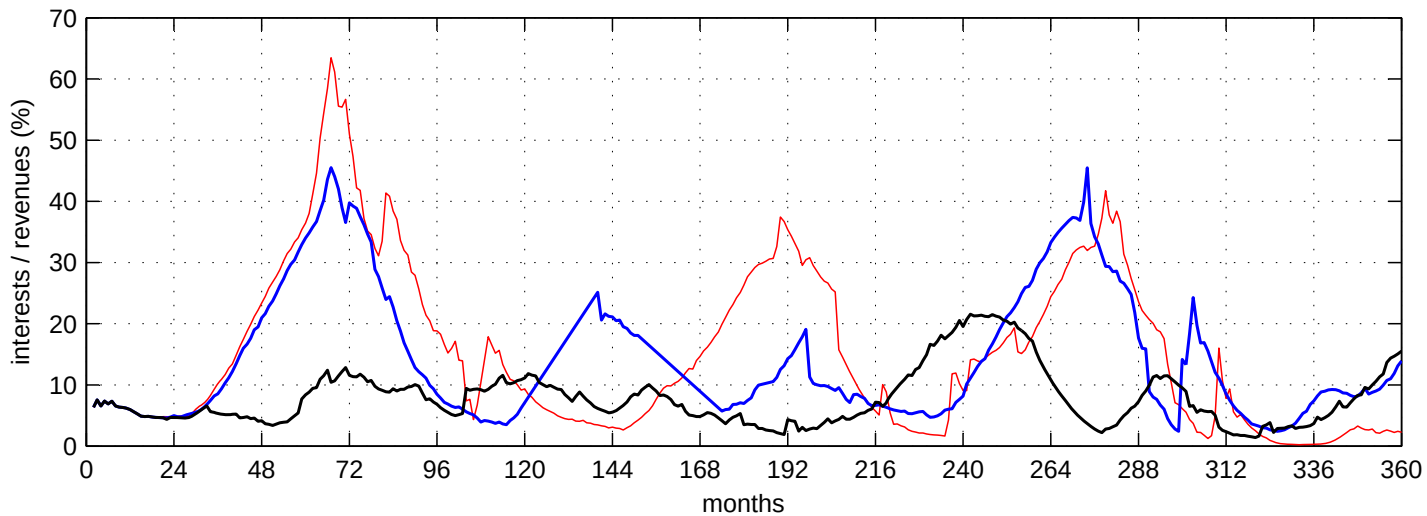
$p_g^*$ is the purchasing price of government bonds by the central bank (CB).

# Example of Eurace computational experiment

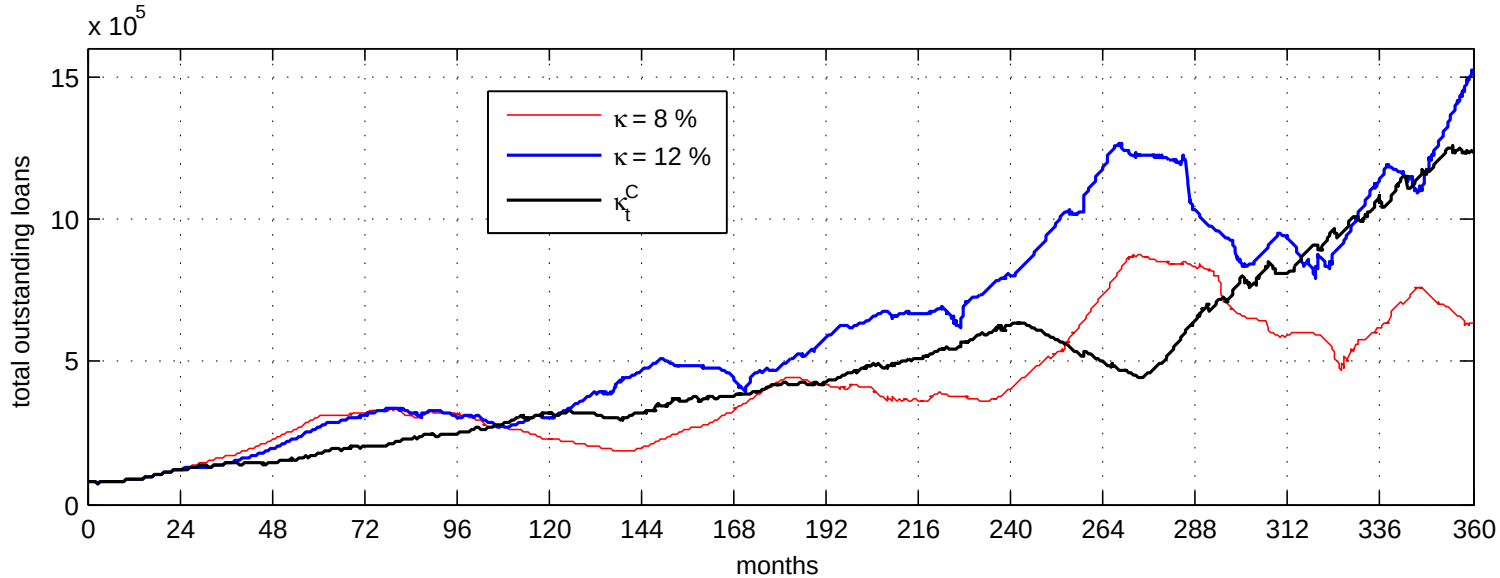
- Eurace is able to reproduce an endogenous credit-fueled boom-bust dynamics where excessive bank leverages, while benefitting in the short term, have destabilizing effects in the medium-long.
- We consider different values for the minimum capital requirements $\kappa$ of banks.
- We test the potential benefits of macro-prudential regulation, designing in the Eurace model a mechanism to encourage banks to build up and release capital buffers, according to the overall economic conditions of the economy.

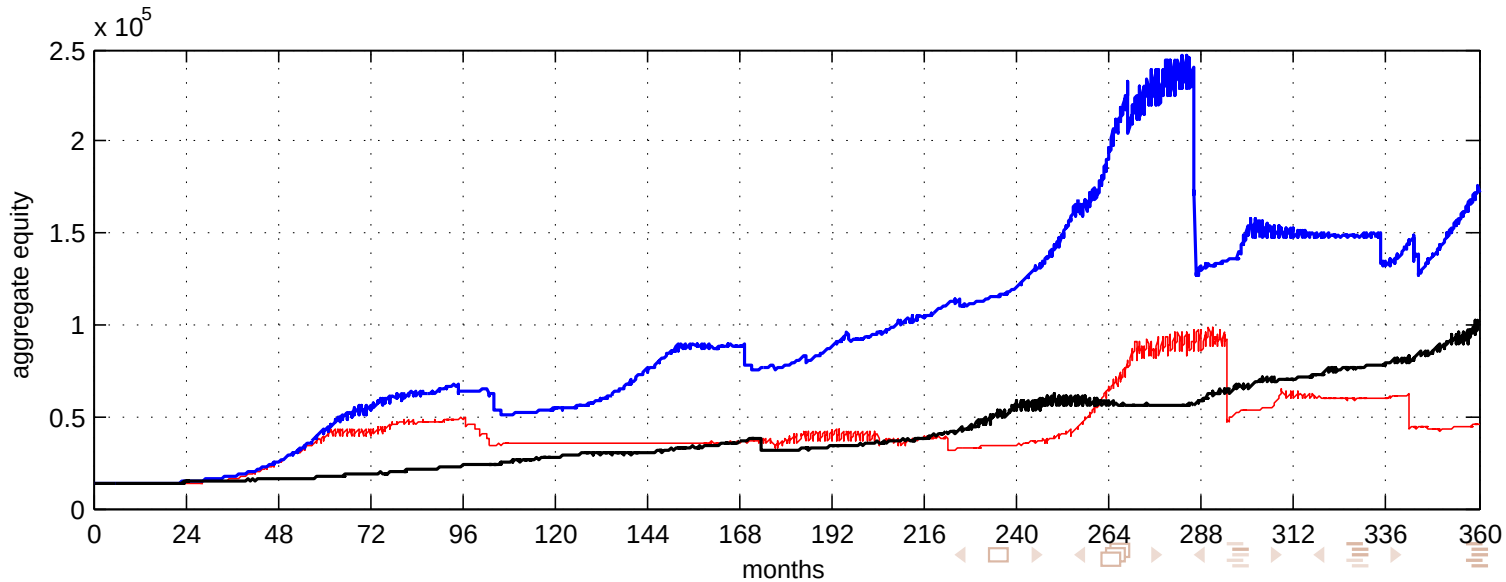
# Financial fragility indicators of firms



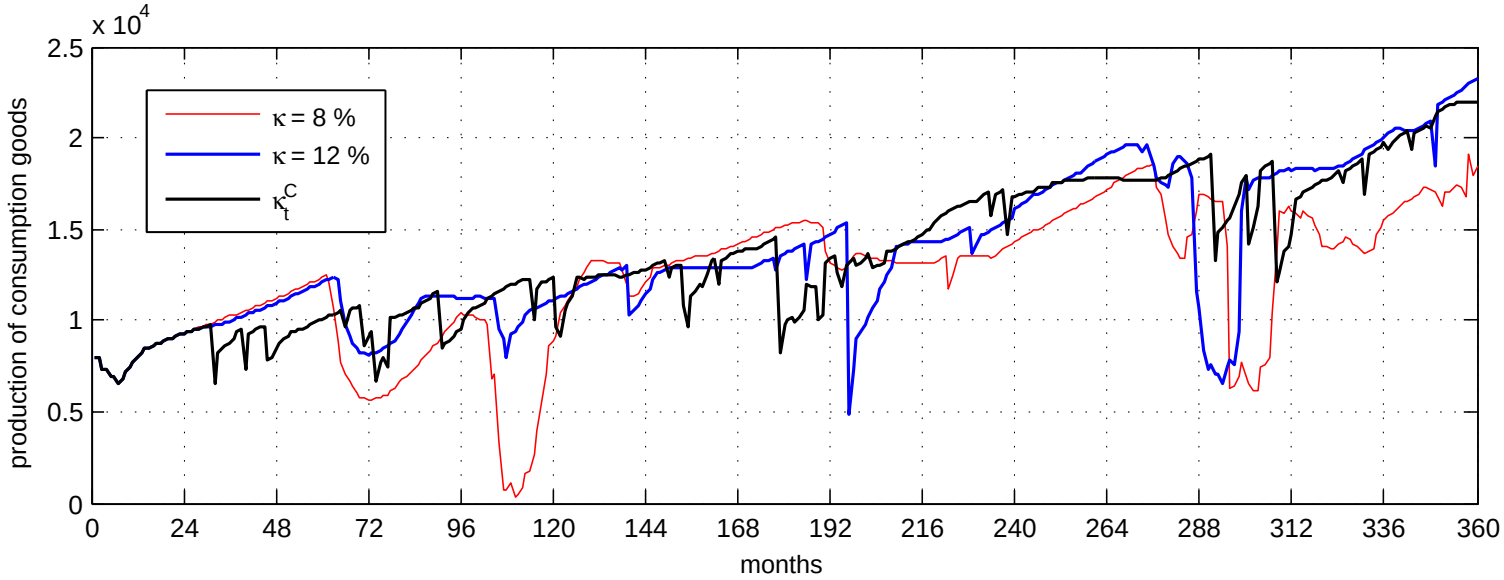



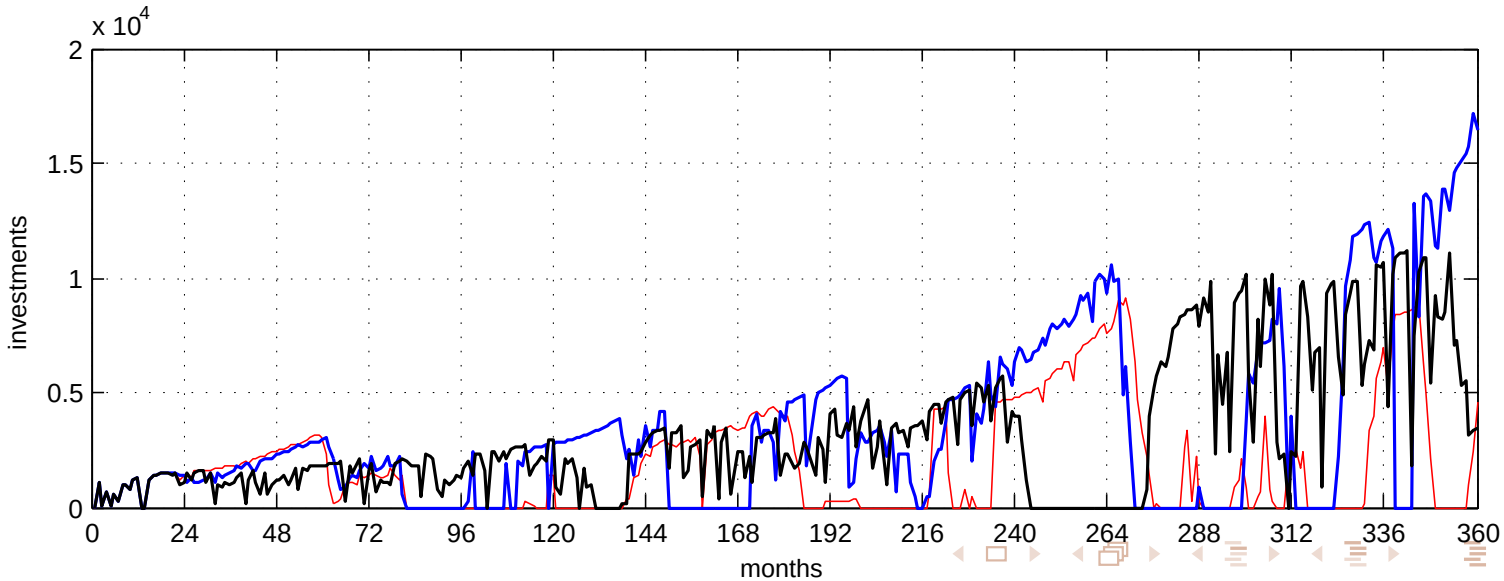
# Aggregate credit and aggregate banks' equity capital



# GDP components



# Comparison between the short run and the long run

| $\kappa$ (%) | cons. goods production | inv. goods production | unempl. rate (%) | banks' loans | firms' leverage |
|---|---|---|---|---|---|
| 8 | 9629 (25) | 1620 (14) | 2.84 (0.18) | 151393 (1042) | 3.21 (0.02) |
| 10 | 9530 (29) | 1530 (18) | 2.86 (0.18) | 143659 (1090) | 2.85 (0.02) |
| 12 | 9486 (27) | 1486 (14) | 2.88 (0.18) | 138126 (840) | 2.60 (0.01) |
| $\kappa_t^u$ | 9411 (40) | 1442 (24) | 2.95 (0.20) | 136749 (1246) | 2.58 (0.02) |
| $\kappa_t^c$ | 8518 (57) | 1069 (12) | 7.54 (0.57) | 121650 (512) | 2.23 (0.01) |

Table: Values averaged over 20 different random seeds in the first 5 years of simulation. $\kappa_t^u$ average value $= 11.54$, $\kappa_t^c$ average value $= 9.65$.

| $\kappa$ (%) | cons. goods production | inv. goods production | unempl. rate (%) | banks' loans | firms' leverage |
|---|---|---|---|---|---|
| 8 | 14296 (160) | 3650 (188) | 8.1 (0.5) | 720375 (25922) | 7.19 (0.85) |
| 10 | 14637 (126) | 3460 (154) | 7.6 (0.4) | 681196 (23748) | 6.74 (0.58) |
| 12 | 15081 (154) | 3729 (137) | 6.2 (0.4) | 722717 (25495) | 7.12 (1.26) |
| $\kappa_t^u$ | 15040 (157) | 3686 (131) | 5.5 (0.5) | 698161 (17714) | 6.76 (1.55) |
| $\kappa_t^c$ | 15419 (151) | 3901 (103) | 3.2 (0.4) | 590332 (10978) | 5.69 (3.31) |

Table: Values averaged over 20 different random seeds in the last 25 years of simulation. $\kappa_t^u$ average value $= 11.34$, $\kappa_t^c$ average value $= 9.61$.

# Iceace project

- Draws on the experience of EURACE
- Project title: '*Financial instability, credit rationing and business cycles in an agent-based model: the case of Iceland*'
- Three year project started in March 2011 funded by the Icelandic Center for Research (Rannis)
- Simpler model than Eurace but with the real estate sector.
- Identical results: credit-driven endogenous boom and bust
- Calibration on the Icelandic economy is going on

**http://iceace.github.io/home/**

# Main References

Cincotti, S., Raberto, M., and Teglio, A. (2010). Credit Money and Macroeconomic Instability in the Agent-based Model and Simulator Eurace. *Economics - The Open-Access, Open-Assessment E-Journal*, vol. 4 (26).

Teglio, A., Raberto, M., and Cincotti, S. (2012). The impact of banks' capital adequacy regulation on the economic system: an agent-based approach. *Advances in Complex Systems*, vol. 15.

Raberto, M., Teglio, A., and Cincotti, S. (2012). Debt, deleveraging and business cycles: An agent-based perspective. *Economics - The Open-Access, Open-Assessment E-Journal*, vol. 6 (27).

# The Future: EU Project SYMPHONY 2013-2016