Interacting prudential and monetary policies in an agent-based model

PKSG – 26th Annual Workshop

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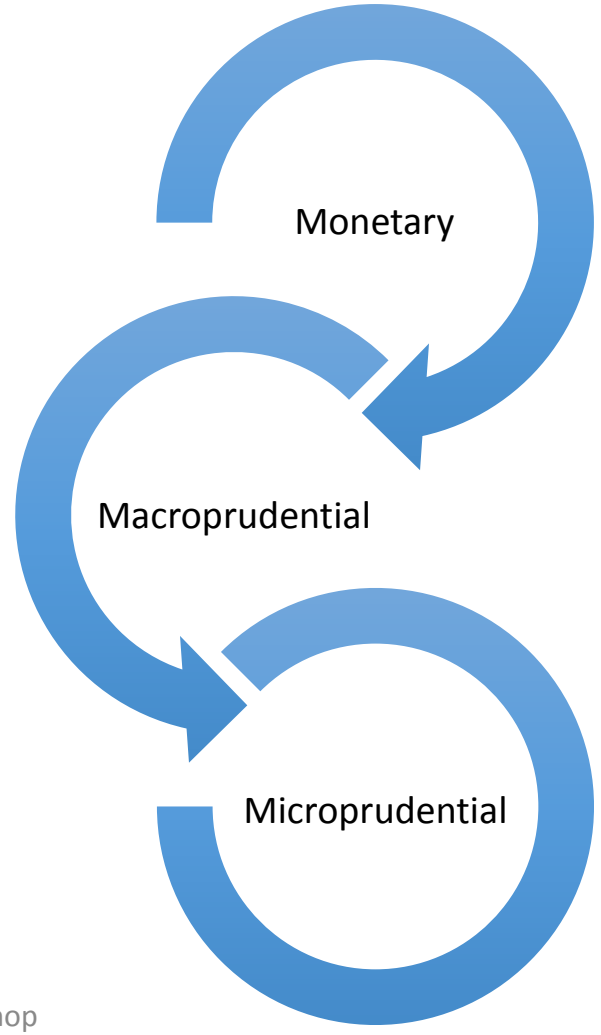
Holy trinity of Central Banking

From the One Bank Research Agenda by the BoE:

- Impacts on transmission mechanisms
- Co-ordination?
- Need for monetary policy reform?
- What is the appropriate macroprudential framework?



Overview

1. Motivation
2. Challenges to macroeconomic modelling
3. Combining agent-based and stock-flow consistent modelling
4. Model characteristics and dynamics
5. Policy experiments
6. Conclusion & next steps

Motivation: Monetary and (micro/macro) prudential policies

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- Monetary: policies to target price stability
  - interest rate setting, open market operations, forward guidance, communication
- Prudential: "…policies that focus on the interactions between financial institutions, markets, infrastructure and the business cycle."
  - Micro-prudential: requirements in terms of capital, liquidity and leverage (BCBS 2010 / Seoul G20 2010),
  - Macro-prudential: curbing procyclical credit growth & contraction, limit the transmission of shocks across the financial system
- "… having two separate sets of instruments may not necessarily prevent situations in which they interact, and may therefore have compounding or conflicting effects on the objectives they pursue."

(Beau, Clerc & Mojon 2012)

Towards an AB-SFC paradigm

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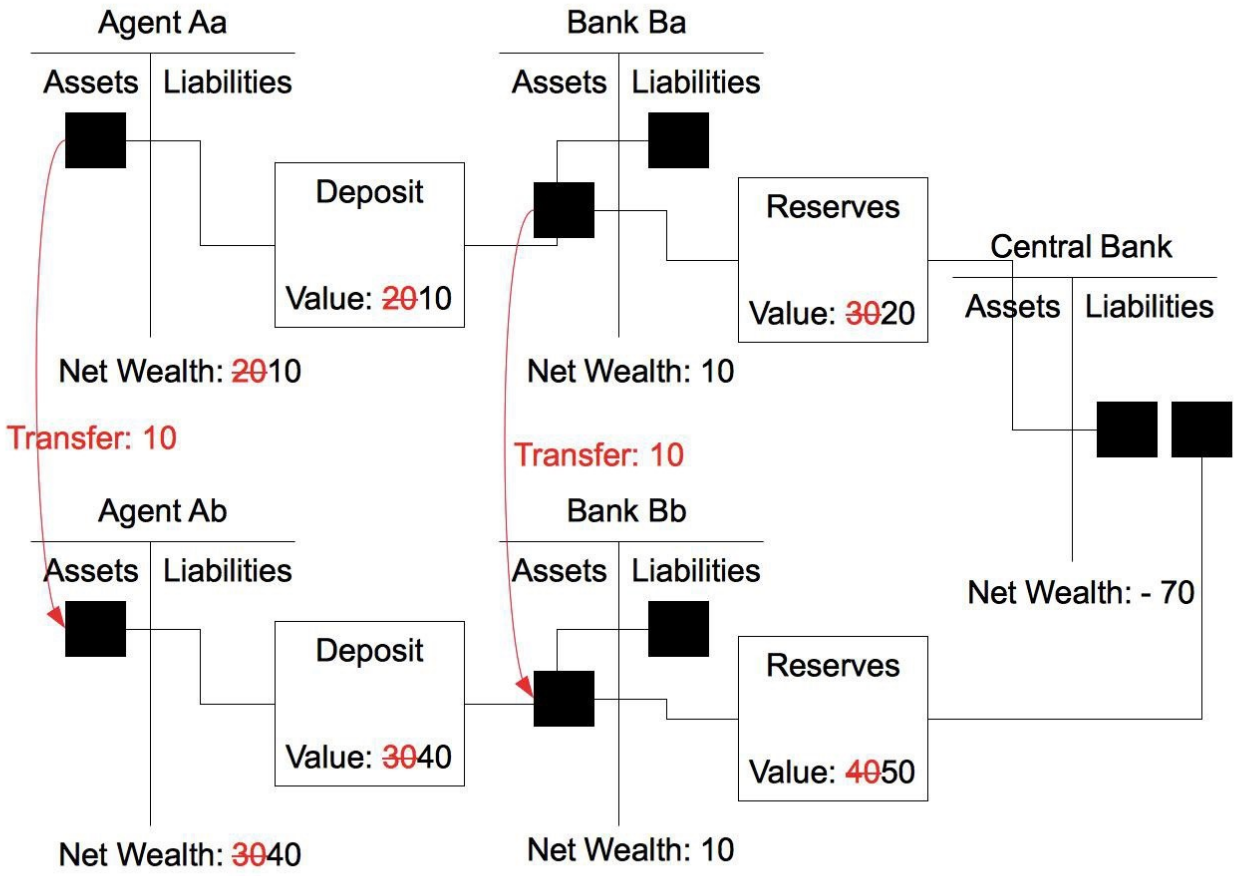
- A fully integrated and coherent representation of real and financial economies thanks to rigorous accounting rules of SFC models + local and disperse interaction and “emergence”.
- AB-SFC models fundamentally aims at adding a new complexity layer besides the one referring to the role of agents' interactions in shaping individual and aggregate behaviours:

✓ **in a monetary economy, agents are closely interrelated through a complex network linking their balance sheets**

Simple example



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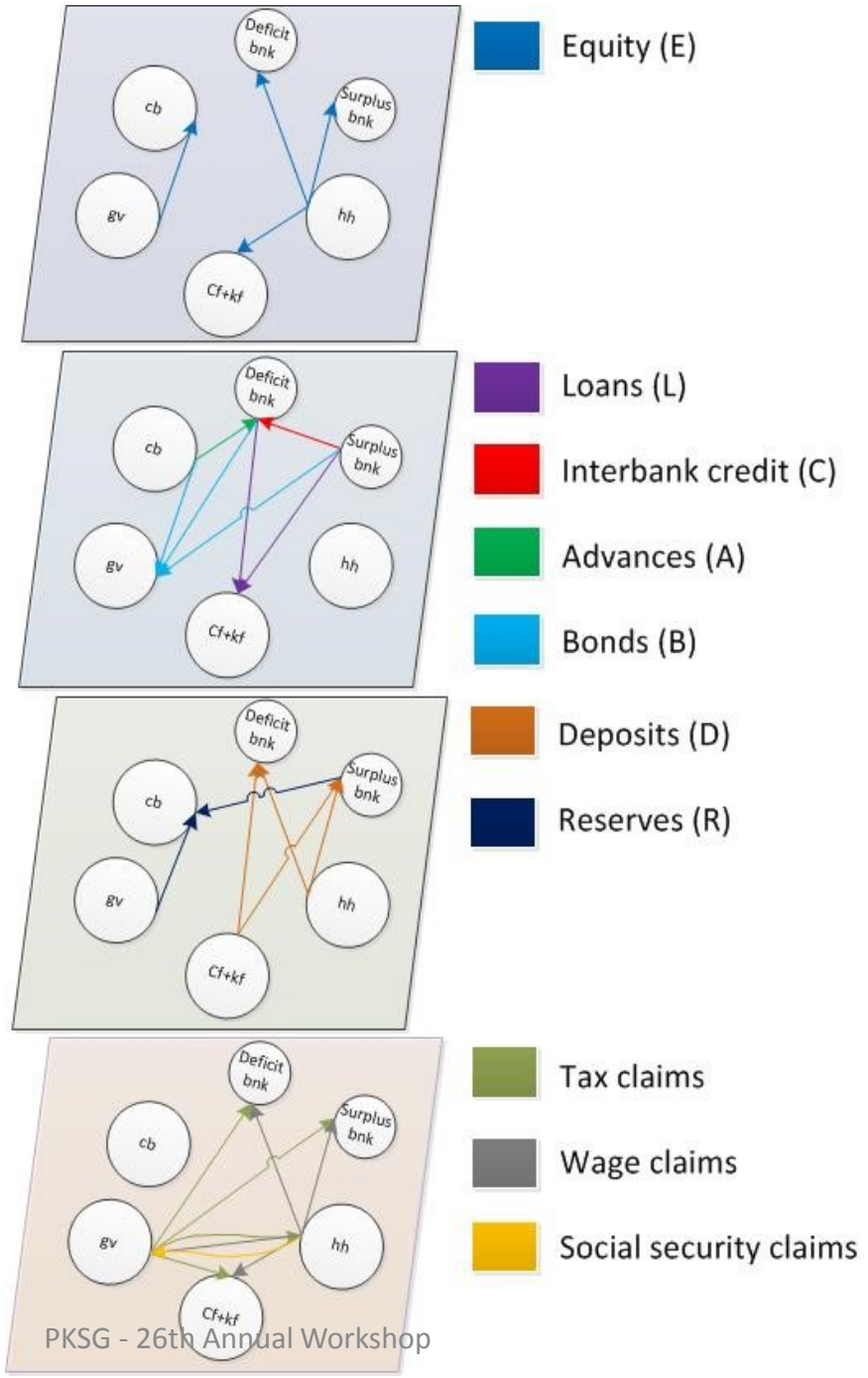
Interactions

1. Multi-layered contractual networks

… of property, debts and claims



AB dynamics

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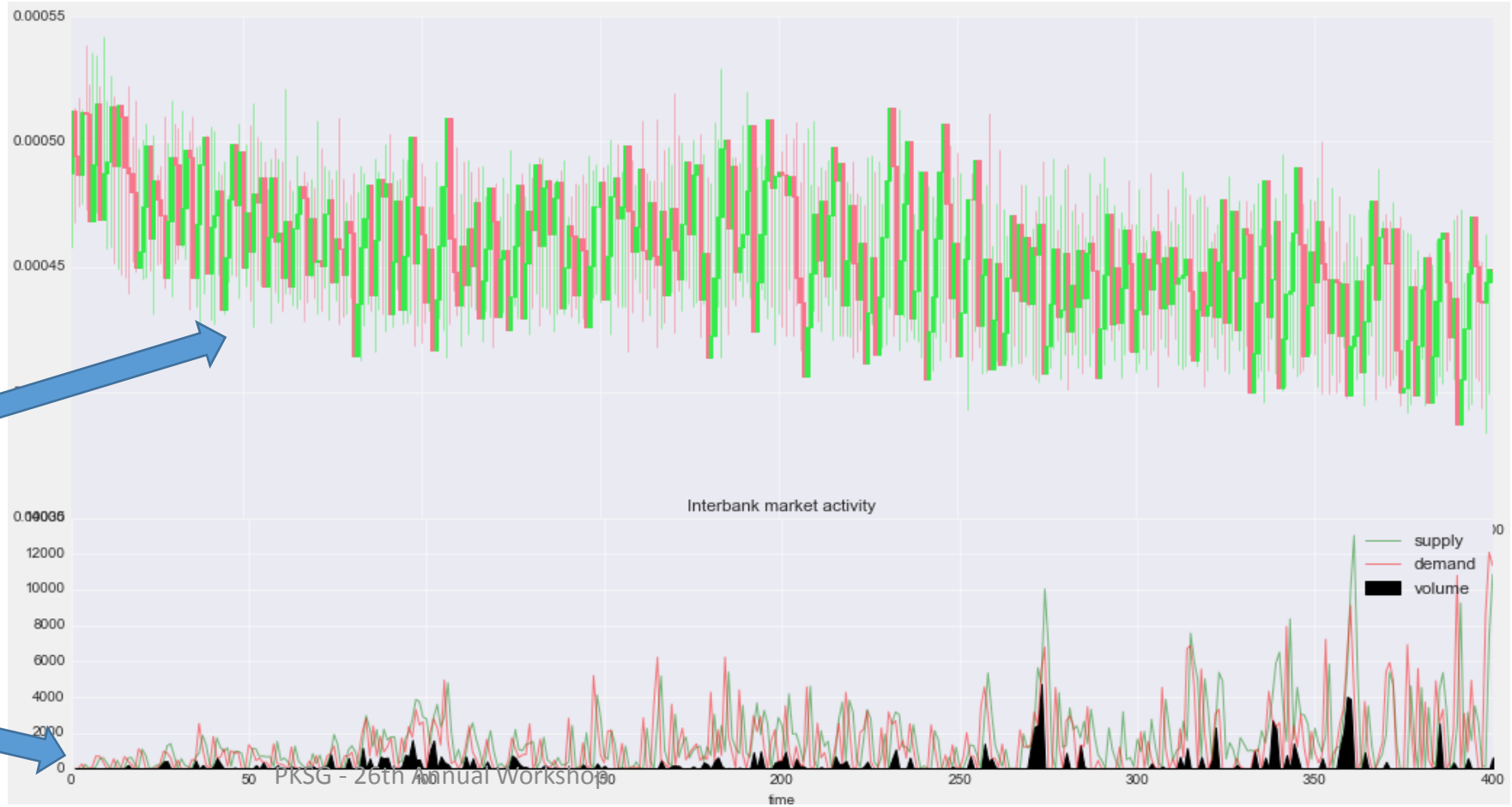
Interactions

1. Contractual networks
2. Markets

(…for cGoods, kGoods, labour, business loans, deposits, interbank loans)

⇒Different agents, different prices

⇒No market clearing assured



AB dynamics

Stochasticity: *every run is different*, due to

1. Interactions - e.g. probability for firms to change supplier:

$$\theta = \begin{cases} 1 - e^{\frac{\in p_\chi - p_{old}}{p_\chi}}, & if\ p_\chi > p_{pf} \\ 0 & otherwise \end{cases}$$

where ∈ = intensity of choice, p_χ the lowest observed supplier price, and p_{pf} the preferred supplier's price

AB dynamics

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Stochasticity: *every run is different*, due to

2. Decision rules - e.g. Wages and prices are backward-looking, with stochastic mark-up based on macroeconomic or microeconomic thresholds

$$\psi_{x,t}^{ulc} = \begin{cases} \psi_{x,t-1}^{ulc}(1+FN)\ if\ \frac{inv_{xt-1}}{inv_{x,t}^{d}} \leq \upsilon^{N} \\ \psi_{x,t-1}^{ulc}(1-FN)\ if\ \frac{inv_{xt-1}}{inv_{x,t}^{d}} > \upsilon^{N}. \end{cases}$$

where inv_{xt-1} is current inventory , $inv_{x,t}^{d}$ desired inventory, stochastic mark-up FN (Folded Normal Distribution)

AB dynamics

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Sensing – *what agents can see*

✓ Their own variables + derived variables (e.g. net present value), plus:

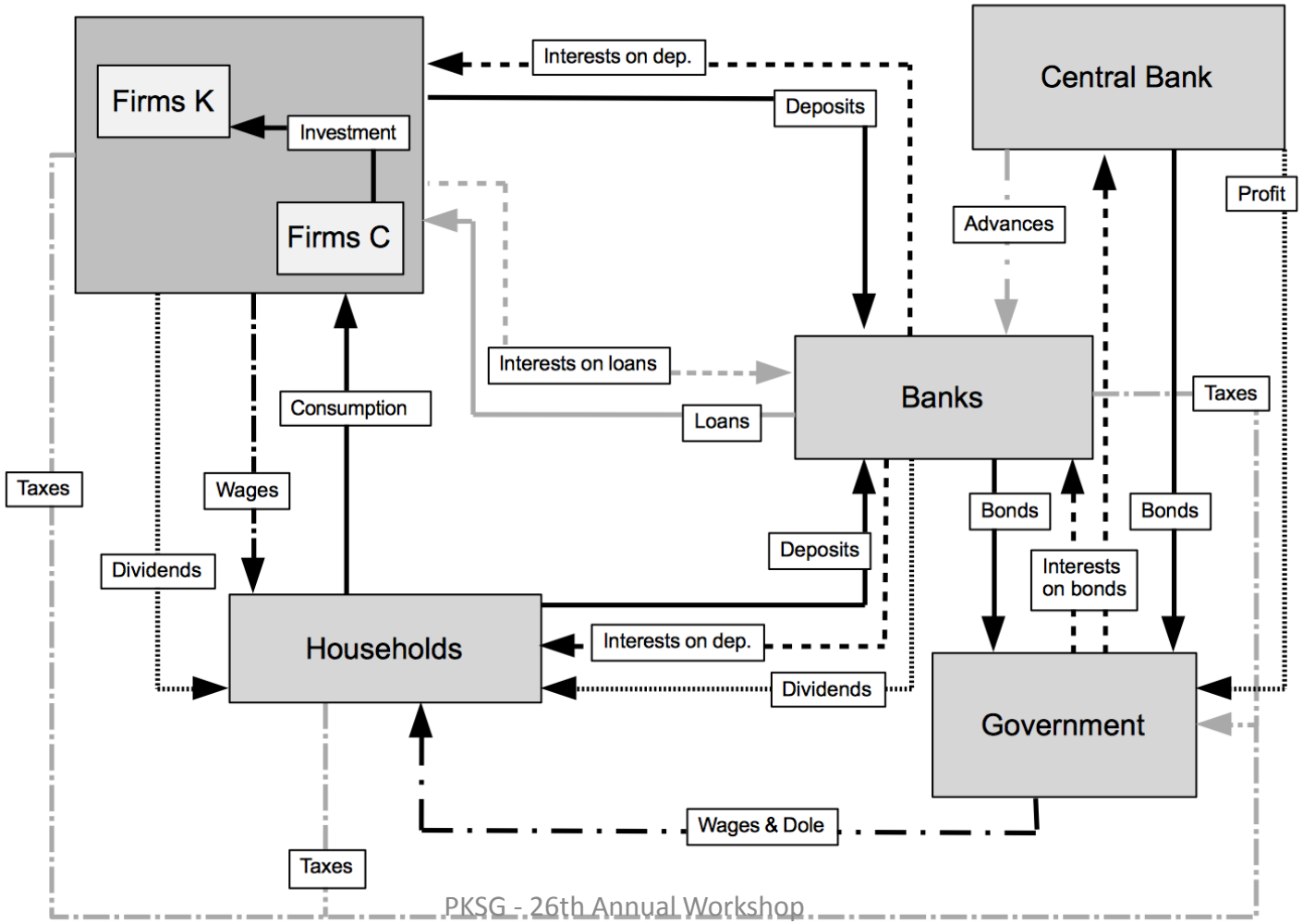
- For the Central Bank: banks' capital ratio, liquidity ratio, inflation, total credit, GDP
- For banks: customer operating cash flows
- For households: inflation, & unemployment

Model

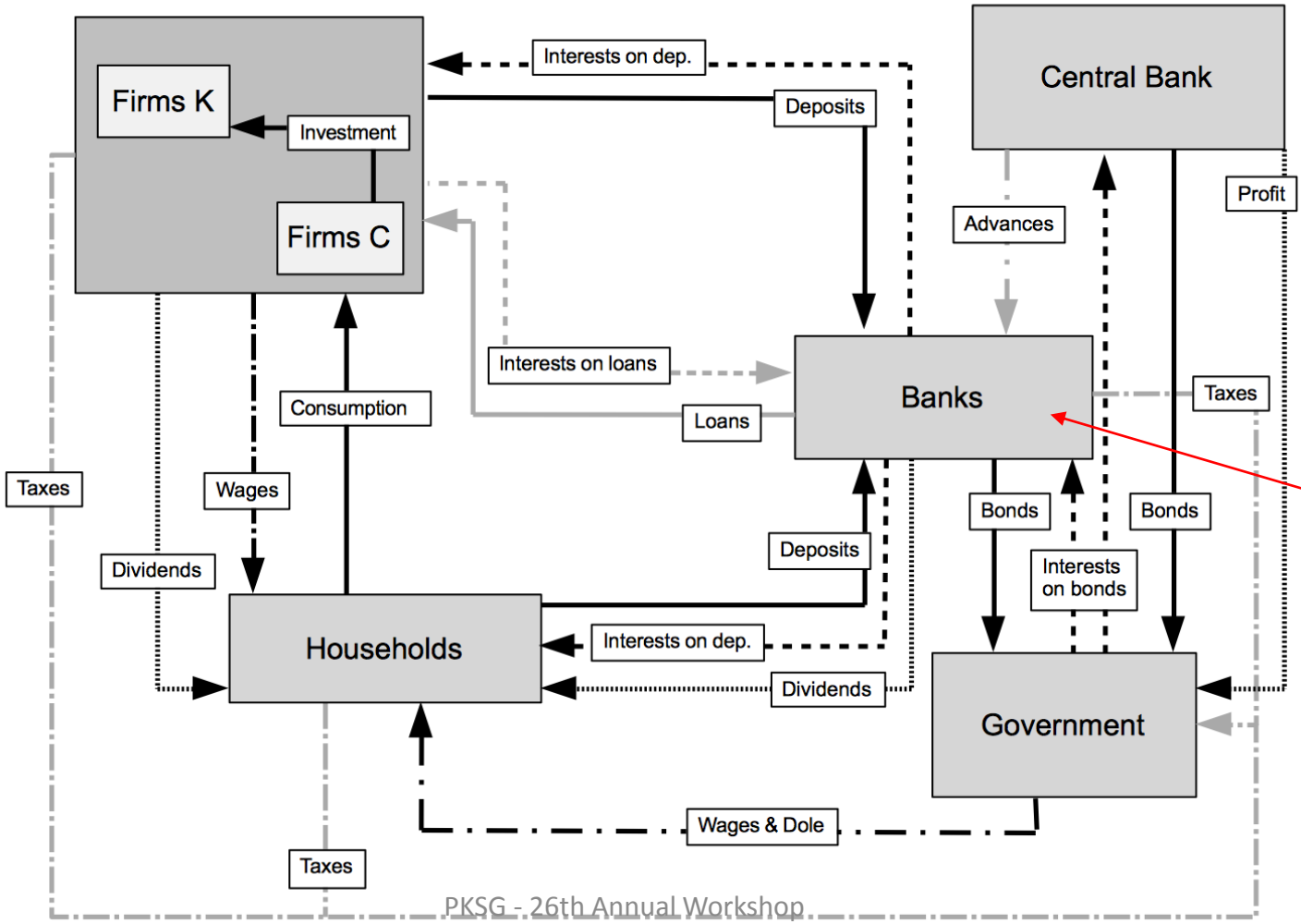
Based on Caiani et al. (2016)

- Six types of agents with 100+ state variables
- 8,000 Households, 100 cFirms, 20 kFirms, 10 banks, 1 Central Bank , 1 Government
- interaction on 6 markets and in 10 contractual networks
- described in 88 behavioural equations with 50 parameters

Flow diagram of Caiani et al. (2016)



Flow diagram of Caiani et al. (2016)



Interbank market

Decision rules
(bounded rationality, simple heuristics, incomplete sensing)

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The Central bank decides on interest rates, liquidity ratio, capital ratio

Banks decide on capital, liquidity, bond buing

Households decide on consumption, wages, saving

Firms decide on investment, lending, hiring, bond buying

Government decides on taxes, bond selling

Model characteristics

Key decision rules:

Inflation targeting (CB)

$$i^{r}_{cb,t} = \begin{cases} i^{r}_{cb,t-1} + \psi_{monetary} & if\ I_t > I^{*}_t \\ i^{r}_{cb,t-1} - \psi_{monetary} & if\ I_t < I^{*}_t \\ i^{r}_{cb,t-1} & otherwise, \end{cases} \qquad (7.4.2)$$

$$i^{A}_{cb,t} = i^{R}_{cb,t} + \psi_{R} \qquad (7.4.3)$$

Model characteristics

Key decision rules:

Countercyclical capital and liquidity buffers (CB)

$$CR_t^T = \begin{cases} CR_{t-1}^T + \psi_{prudential} & if \ \frac{L_t}{GDP_t} > \varphi_{prudential} \\ CR_{t-1}^T - \psi_{prudential} & if \ \frac{L_t}{GDP_t} < \varphi_{prudential} \\ CR_{t-1}^T & otherwise, \end{cases} \quad (7.4.4)$$

$$LR_t^T = \begin{cases} LR_{t-1}^T + \psi_{prudential} & if \ \frac{L_t}{GDP_t} > \varphi_{prudential} \\ LR_{t-1}^T - \psi_{prudential} & if \ \frac{L_t}{GDP_t} < \varphi_{prudential} \\ LR_{t-1}^T & otherwise, \end{cases} \quad (7.4.5)$$

Model characteristics

Key decision rules

Bank lending

- Interest on loans

$$i^{L}_{bnk,t} = \begin{cases} (\bar{i}^{L}_{bnk,t-1} + \Delta fuc^{e}_{x,t})(1+FN)\ if\ CR_{bt} < CR^{T}_{t} \\ (\bar{i}^{L}_{bnk,t-1} + \Delta fuc^{e}_{x,t})(1-FN)\ otherwise. \end{cases} \quad (7.3.3)$$

- Interest on deposits

$$i^{D}_{bt} = \begin{cases} i^{-d}_{bt-1}(1-FN)\ if\ \ LR_{bt} \geq LR_{t} \\ i^{-d}_{bt-1}(1+FN)\ otherwise. \end{cases} \quad (7.3.5)$$

- Dividends

$$div_{bnk,t} = \begin{cases} (1+\alpha^{d})(\rho_{b} * prof)\ if\ CR_{bt} > CR^{T}_{t} \\ \rho_{b} * prof, otherwise. \end{cases} \quad (7.3.10)$$

- Elastic supply and demand

Model characteristics

Key Decision rules

The interbank market

- Per-period interest on overnight loans
(subject to maximum CB advances rate)

$$i_{bt}^{ib} = (\vec{i}_{bt}^{l} - i_{bt}^{cb})/\overline{maturity},$$

- Supply/Demand interbank loans: actual - desired liquidity ratio

$$I_{bt}^{S} = \left(LR_{bt} - LR_{bt}^{d}\right) * D_{bt}$$

Model characteristics

Key decision rules

- Household consumption: income, inflation expectations, wealth

$$c^{D}_{hh,t} = \alpha^{y} \frac{y_{hh,t}}{I^{e}_{hh,t}} + \alpha^{q} \frac{q_{hh,t}}{I^{e}_{hh,t}}, \qquad (7.1.2)$$

- Wages: backward-looking, with unemployment threshold

$$w^{d}_{hh,t} = \begin{cases} w^{d}_{hh,t-1}(1 - FN) \; if \sum_{n=1}^{4} u_{hh,t-n} > \varphi_{u} \\ w^{d}_{hh,t-1}(1 + FN) \; if \; \sum_{n=1}^{4} u_{hh,t-n} \leq \varphi_{u} \; and \; U_{t} \leq \varphi_{U}, \end{cases} \qquad (7.1.1)$$

Model characteristics

Key decision rules

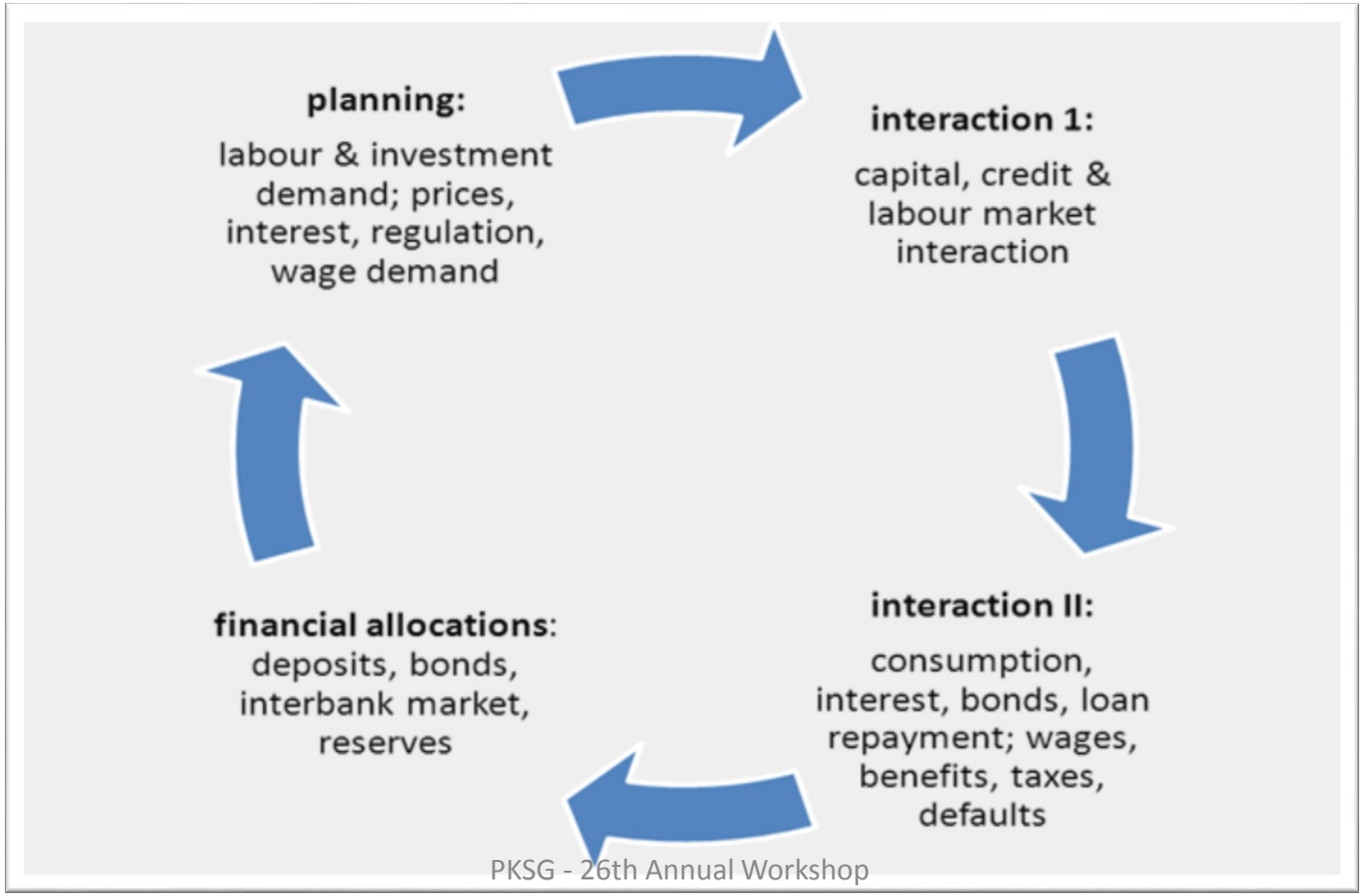
Firms

- Price: costs + mark-up, dependent on inventories

$$p_{x,t}^{N} = (1 + \psi_{x,t}^{ulc}) \frac{ulc_{xt}^{e} l_{xt}^{d}}{o_{xt}^{D}}, \qquad (7.2.3)$$

$$\psi_{x,t}^{ulc} = \begin{cases} \psi_{x,t-1}^{ulc}(1 + FN) \; if \; \frac{inv_{xt-1}}{inv_{x,t}^{d}} \leq \upsilon^{N} \\ \psi_{x,t-1}^{ulc}(1 - FN) \; if \; \frac{inv_{xt-1}}{inv_{x,t}^{d}} > \upsilon^{N}. \end{cases} \qquad (7.2.4)$$

Simulation Sequence

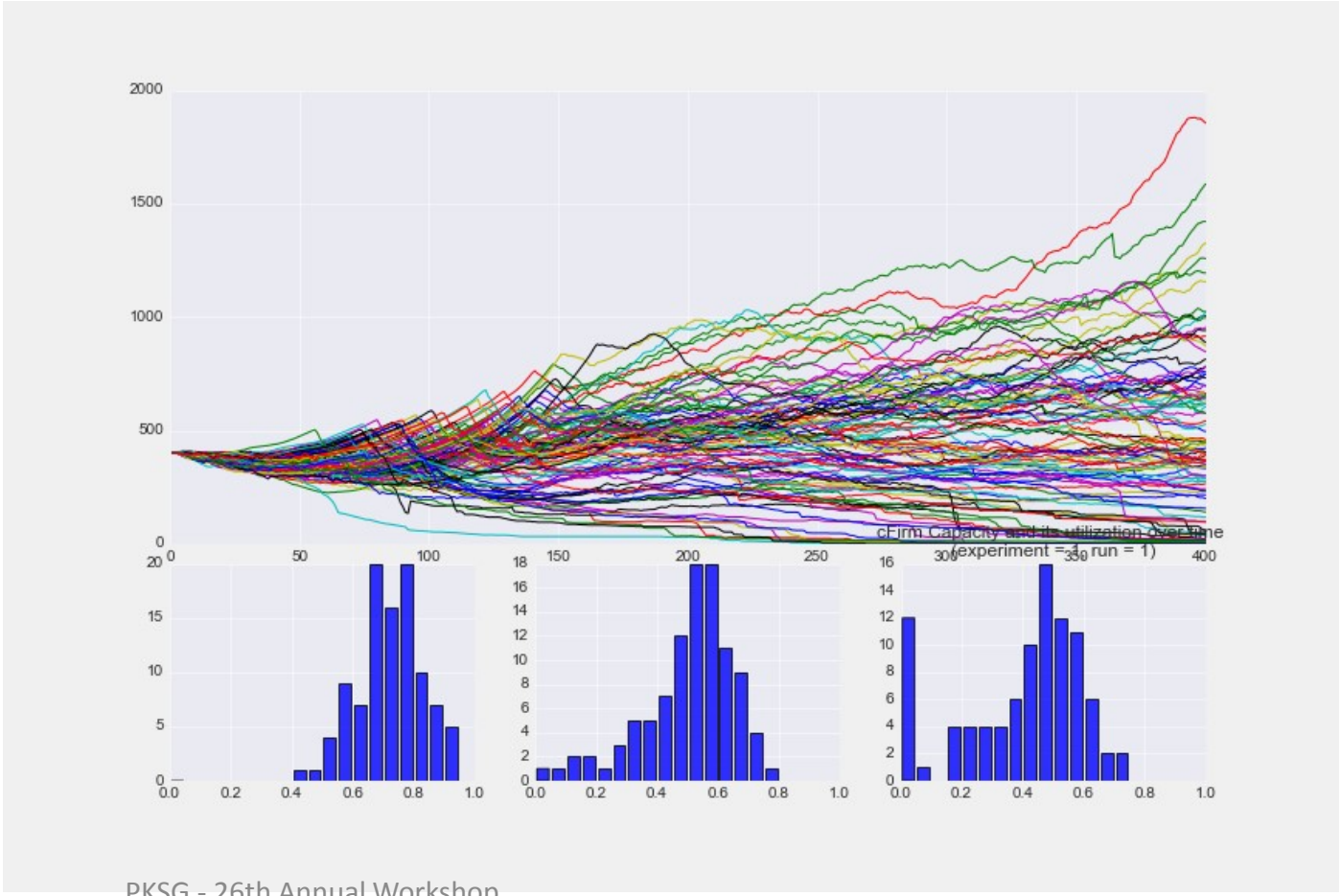


Simulation Sequence

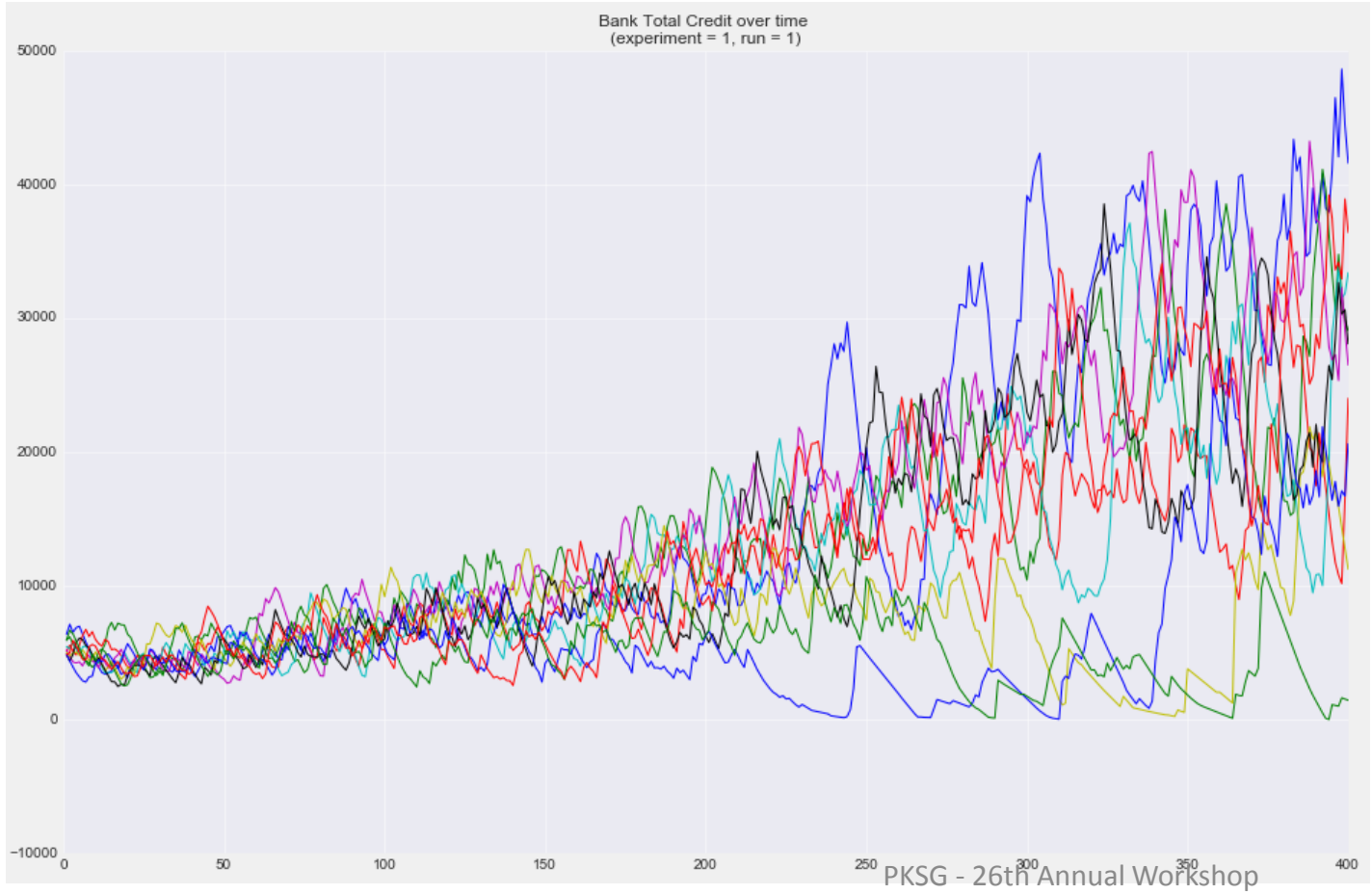
planning:

labour & investment demand; prices, interest, regulation, wage demand

Firms are heterogeneous and distributions shift over time

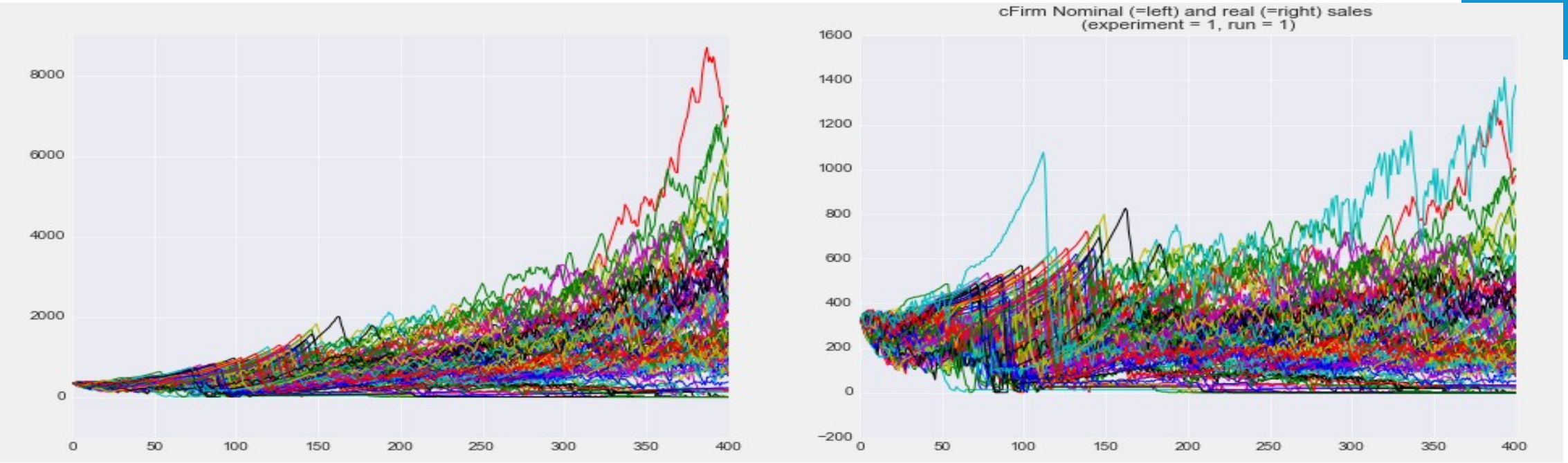


Simulation Sequence



Bank lending volumes differ widely over bank

Simulation Sequence

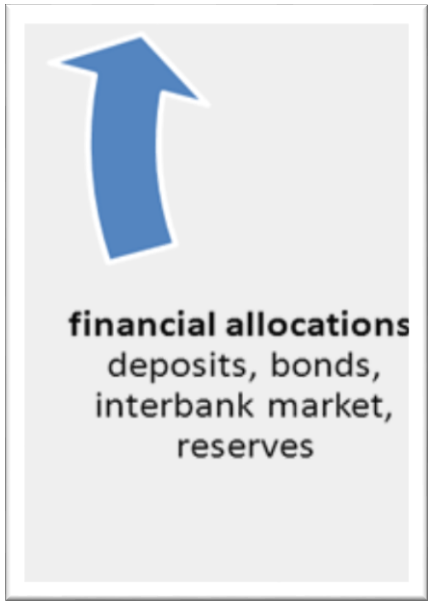


interaction II:

consumption, interest, bonds, loan repayment; wages, benefits, taxes, defaults

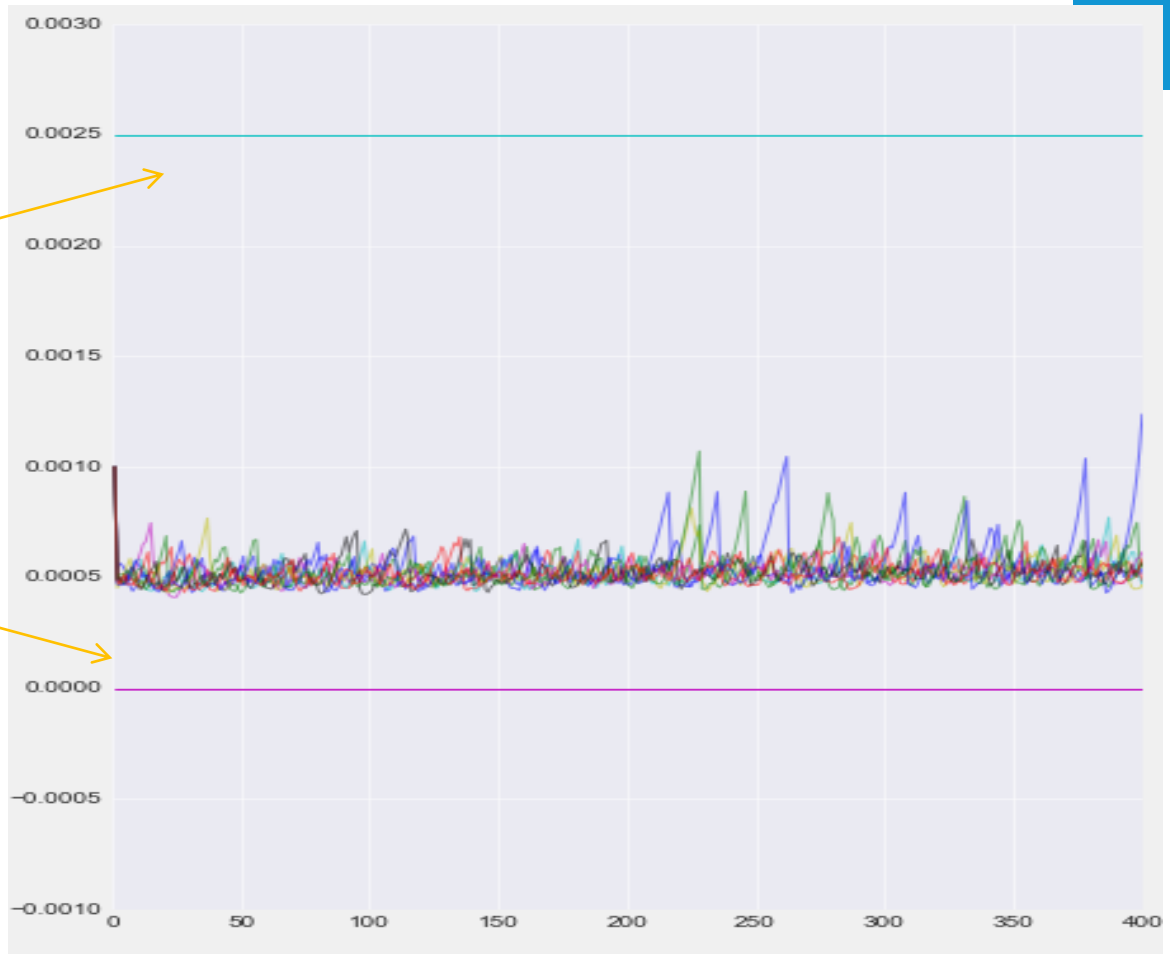
Simulation Sequence

This is where monetary/ prudential policy takes place



Advances rate

Bank rate



Interbank market and CB spread

Model characteristics and dynamics

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Model calibration and initialization

Agents' state variables: initially stock-flow consistent

All debtors have creditors

Model-wide variables: initially steady-state

inflation, GDP, wages, unemployment, interest

Parameters: realistic

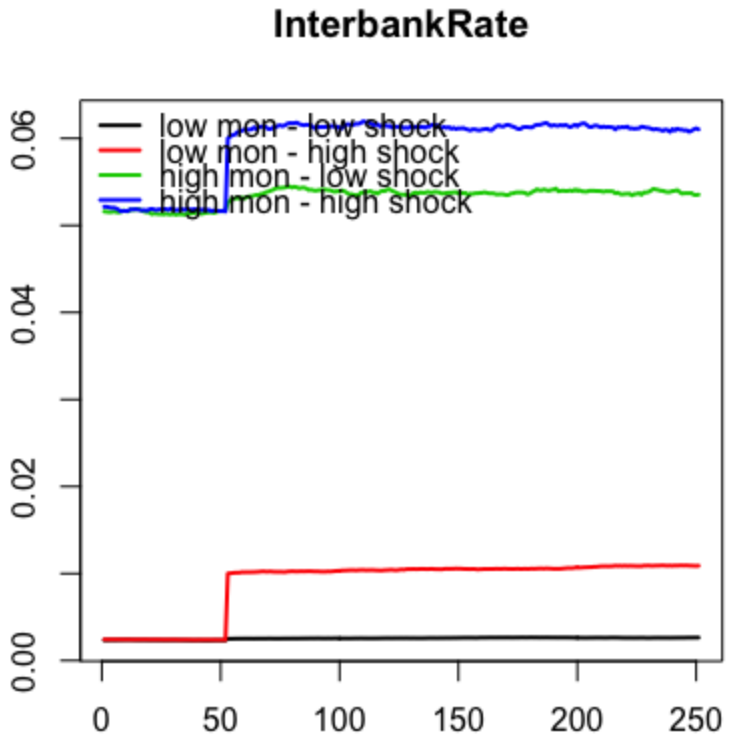
CB advances rate = .25, inflation target = 2%

Monetary policy

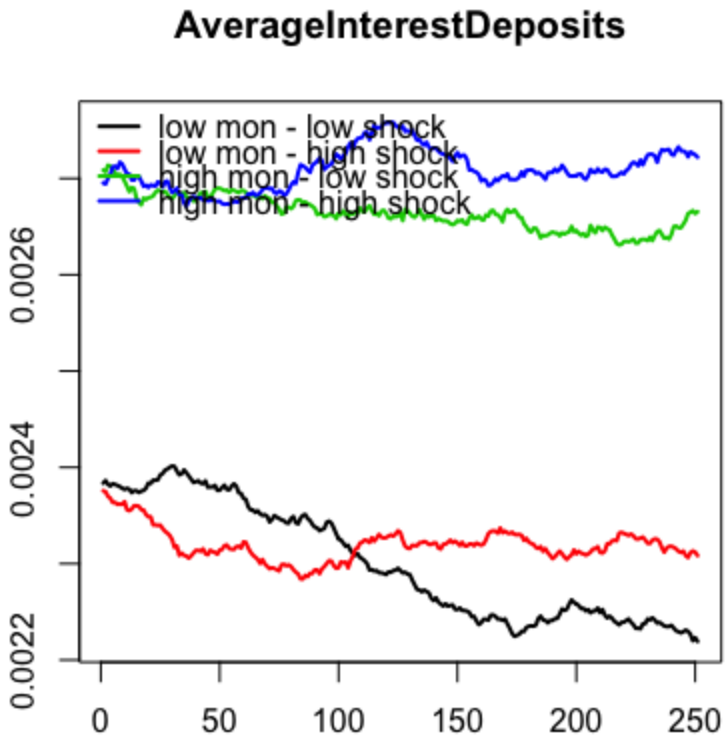
- Initially no impact
- Explicit transmission mechanism modelling
  - Interest rates
  - Prices and Wages
  - Investment and Consumption
- Arestis and Sawyer (2006)
  - “We find that the impact of changes in the rate of interest has a weak effect on inflation (of the order of 0.2–0.3% following a 1% change in the discount rate), while there are more substantial effects on real variables, especially on investment, which thereby affects the future capital stock”

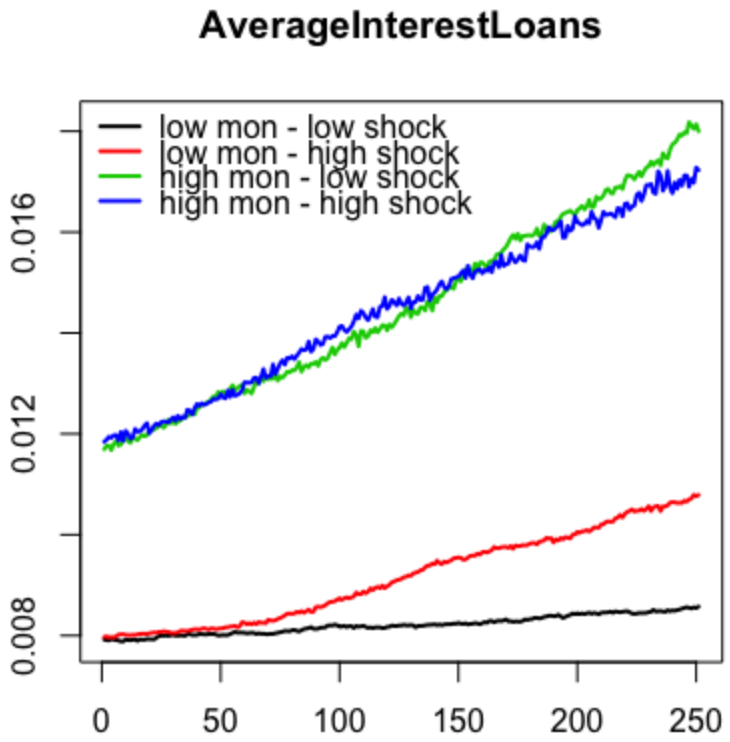
Monetary policies

- Fixed interest rates
  - Low and High
- Shock
  - Small and Large

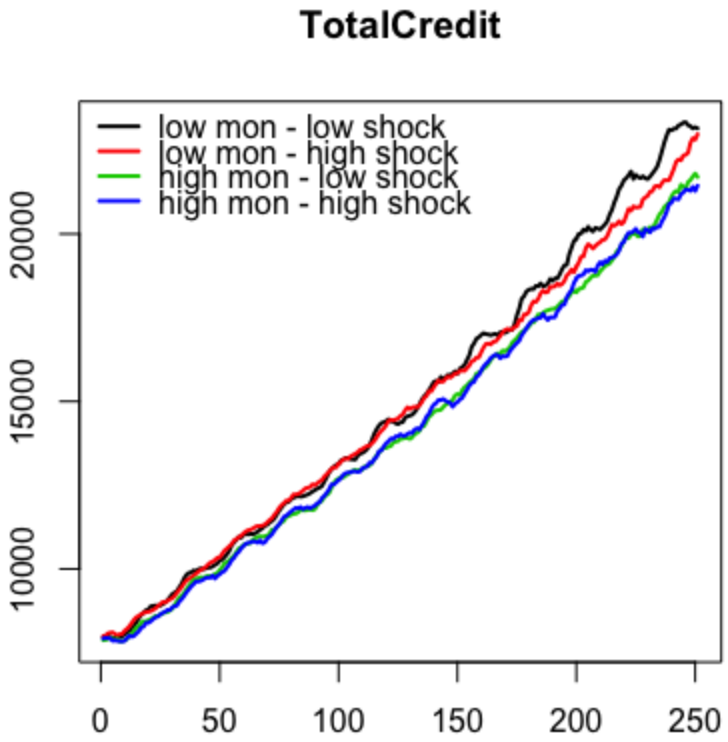


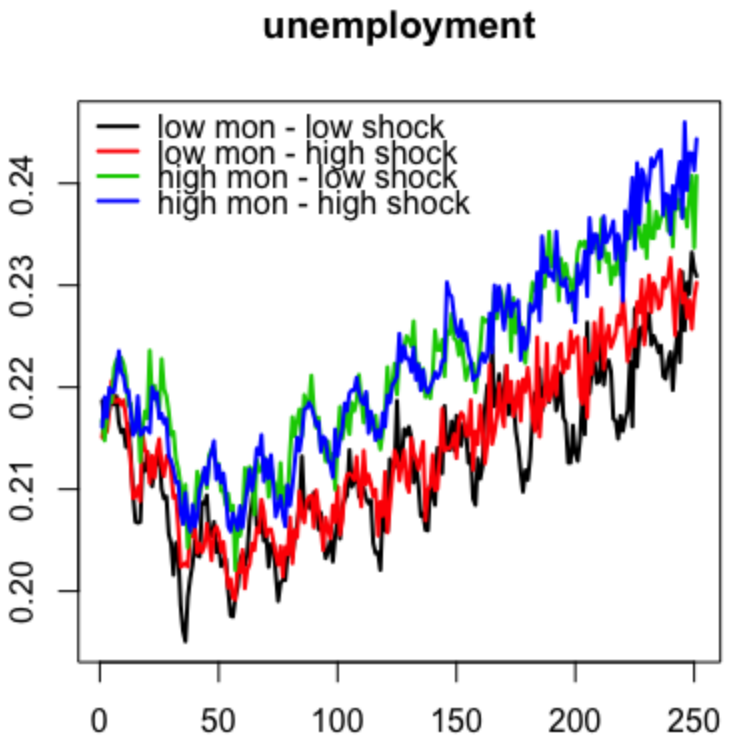
Impacts on interests rates



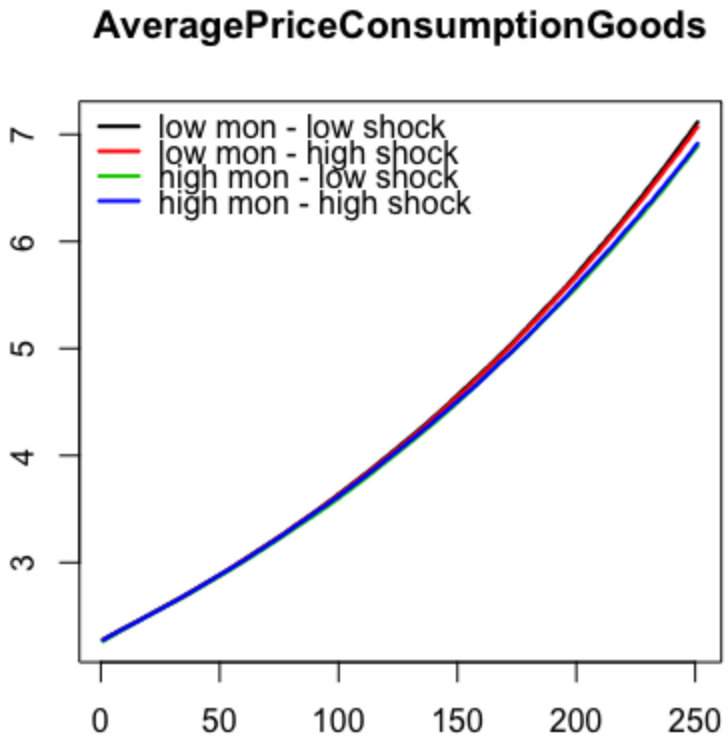


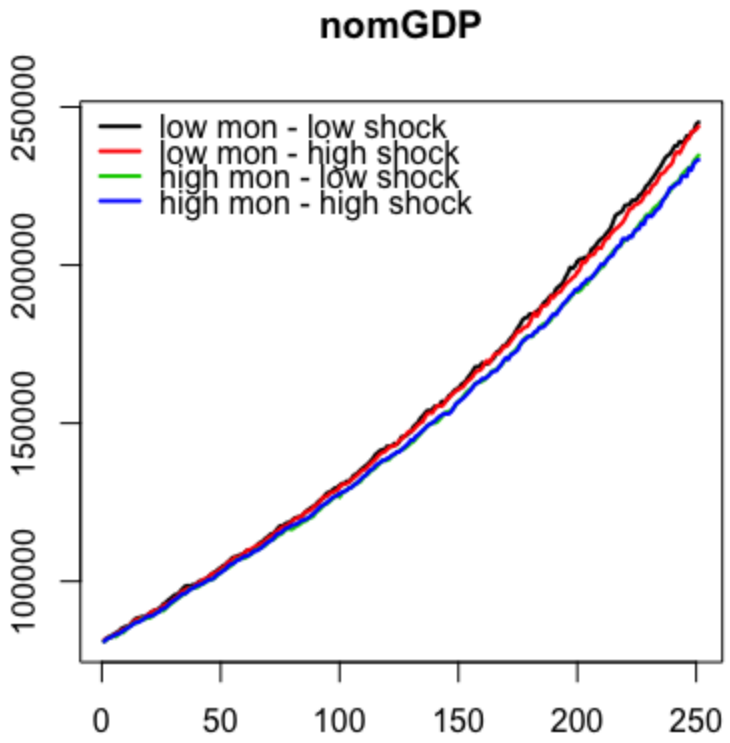
Credit and Unemployment





Prices and GDP





Summary Next steps

- Better model design
- More detailed study of model dynamics
- More rigorous model validation
- General sensitivity analysis
- More refined policy experiments

- Adding a housing market
- Adding proper labour market and income distribution

Thank you for listening

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Questions & feedback?

http://github.com/s120/jmab

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JMAB - Acknowledgments

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- University of Limerick, Ireland: Antoine Godin and Stephen Kinsella
- Outputs:
  - **Develop "tools"** to handle the heterogeneity of stocks and agents involved in real & financial transactions: (JMAB).
  - **Set "standards"** to build, calibrate, and validate models.
  - **Define a** (relatively) simple, general, flexible model to serve as **"benchmark"**.

Java Macroeconomic Agent-Based toolkit

- **Object Oriented Programming** leads to modularity, flexibility and re-usability.
- **Event Based Approach**: possibility of asynchronous decisions and different economic processes/interactions frequencies.
- **Explicit Balance Sheet Modelling**: Agents' Stock Matrices
  - Helps in ensuring the SFC
  - Flexible tool to store information and manage heterogeneity
  - Helps tracking multi-layered networks and balance sheets interdependencies
- **Automatic procedures to ensure** that **Copeland's quadruple entry** principle is respected.
- **Fully scalable view** of models' dynamics

From micro to meso to macro

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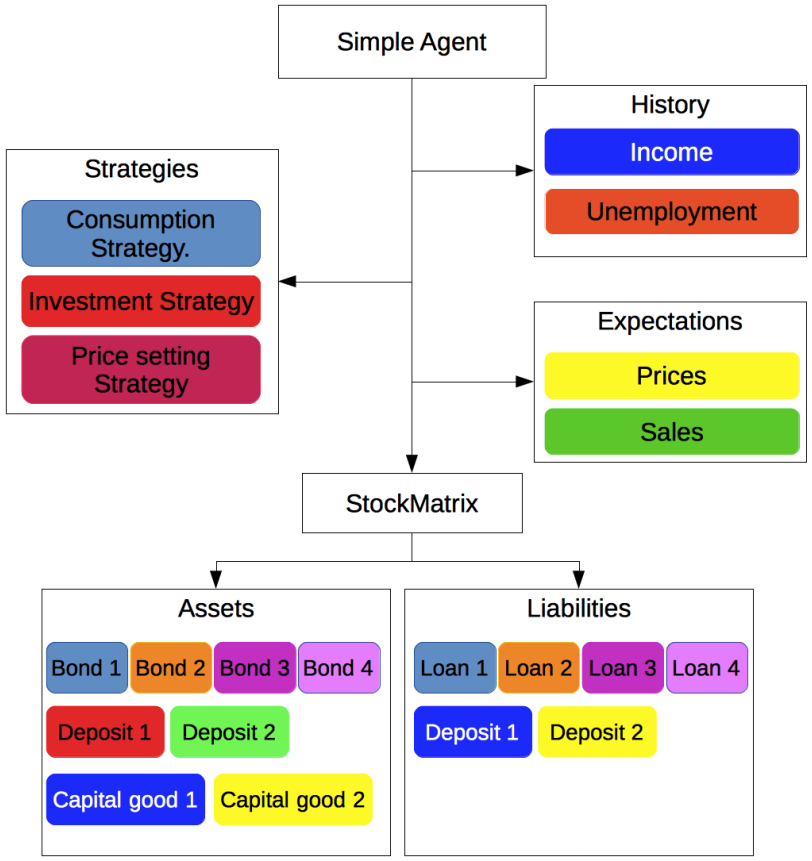
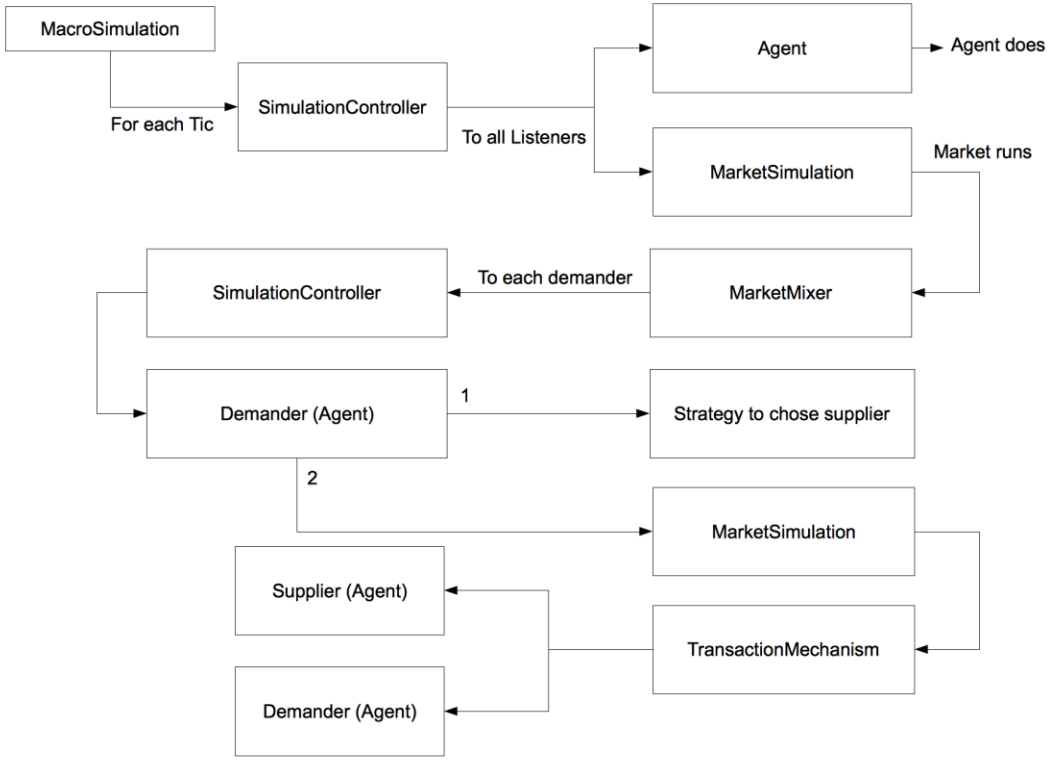
JMAB…

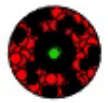
- provides a **comprehensive representation of the complex dynamic network linking agents' balance sheets** and its evolution through time as transactions between different agents occur. This allows:
  - network analysis
  - fragility analysis
- provides an **overall balance sheet and flows of funds representation** of the economy allowing for
  - more traditional analysis at the macroeconomic level
  - synthetic measures to assess the state of the economy and its future evolution

More concretely





Evolving credit network



t=2-3

- Green: banks
- Red: consumption firms
- Black: capital firms