

Extension I: Heterogeneous Agents in an Keynesian Agent-Based Model

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for labour market analysis

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- 1 Standard macroeconomic models: a comparative approach
 - The *IS* – *LM*-type models and the Lucas critique
 - DSGE modelling: main features & limits
- 2 Macroeconomic agent-based modelling: the economy as a complex adaptive system
 - The economy as a complex system
 - Agent-based models
- 3 Application: policy simulations within the JAMEL model
 - Conceptual description of the JAMEL model
 - Empirical validation
 - Labour mobility
 - Wage policies
- 4 Conclusions



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Macroeconometric models: main features

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	Keynesian models (e.g. $IS - LM$)
Microeconomic foundations	missing
Agents' behaviour	not modelled
Macroeconomic relationships	postulated and estimated
Source of fluctuations	exogenous shocks

Macroeconometric models & the Lucas critique

an example

A three-equation basic macroeconometric model:

→ a consumption function:

$$C_t = a_1 + a_2(Y_t - T_t) \quad (1)$$

→ an investment function:

$$I_t = b_1 - b_2 r_t \quad (2)$$

Macroeconometric models & the Lucas critique

an example

A three-equation basic macroeconometric model:

→ a consumption function:

$$C_t = a_1 + a_2(Y_t - T_t) + \epsilon_t \quad (1)$$

→ an investment function:

$$I_t = b_1 - b_2 r_t + \epsilon_t \quad (2)$$

Parameters to be estimated on empirical time series.

Macroeconometric models & the Lucas critique

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Policy variables to be shocked

Macroeconometric models & the Lucas critique

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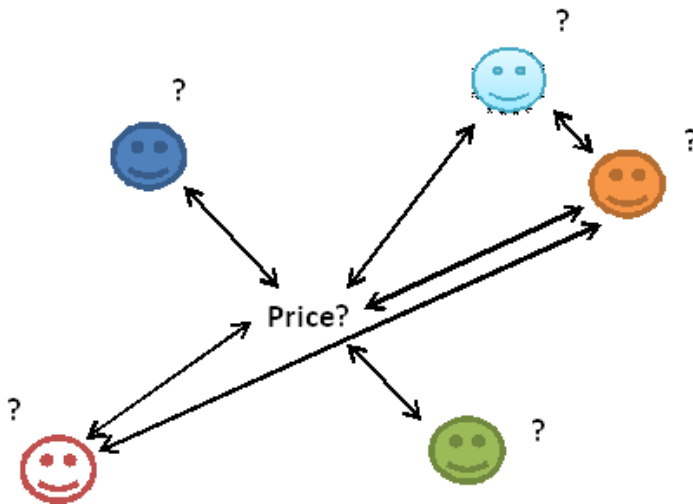
$$I_t = b_1 - b_2 r_t + \varepsilon_t \quad (2)$$

The Lucas critique:

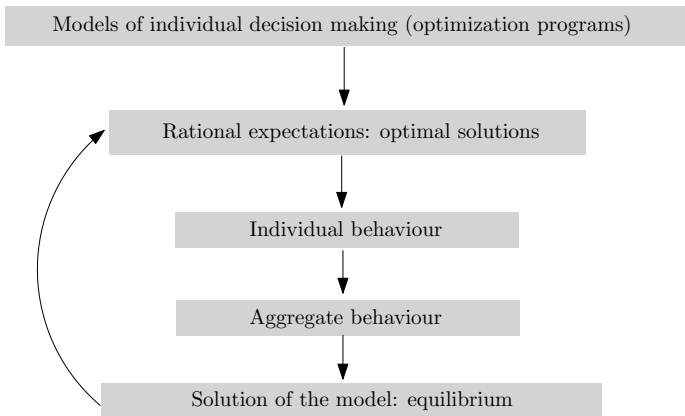
b_2 depends on the level of the policy instrument r ?

a_2 depends on the level of disposable income $Y_t - T_t$?

DSGE models: which behavioural model for microeconomic decisions?



DSGE models: the microeconomic paradigm of the *rational representative agent*



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DSGE models: main features in a nutshell

- Maximising agents with rational expectations.
- Representative agents
- Market clearing.
- Prevalence of an optimal equilibrium state.

► Skip the example



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Behaviour in a DSGE model: an example

The representative household chooses C and H to maximise his utility:

$$u(C_t, H_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{H_t^{1+\phi}}{1+\phi} \quad (3)$$

under a budget constraint:

$$P_t C_t + B_t \leq B_{t-1}(1 + i_{t-1}) + W_t H_t + \Pi_t, \quad t = 1, 2, \dots \quad (4)$$



Behaviour in a DSGE model: an example

The representative household chooses C and H to maximise his utility:

$$u(C_t, H_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{H_t^{1+\phi}}{1+\phi} \quad (5)$$

under a budget constraint:

$$P_t C_t + B_t \leq B_{t-1}(1 + i_{t-1}) + W_t H_t + \Pi_t, \quad t = 1, 2, \dots \quad (6)$$

Structural parameters, assumed to be policy-invariant.



Behaviour in a DSGE model: an example

The representative household chooses C and H to maximise his utility:

$$u(C_t, H_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{H_t^{1+\phi}}{1+\phi} \quad (7)$$

under a budget constraint:

$$P_t C_t + B_t \leq B_{t-1}(1 + i_{t-1}) + W_t H_t + \Pi_t, \quad t = 1, 2, \dots \quad (8)$$

Solutions give the consumption function:

$$1 + i_t = \beta^{-1} \left(\frac{C_t}{E_t(C_{t+1})} \right)^{-\sigma} \frac{E_t(P_{t+1})}{P_t} \quad (9)$$

and the labour supply function in the economy:

$$\frac{(H_t)^\phi}{(C_t)^{-\sigma}} = \frac{W_t}{P_t}$$

Comparative approach

	Keynesian models (e.g. $IS - LM$)	DSGE models
Microeconomic foundations	missing	representative agent
Agents' behaviour	not modelled	maximisation, rational expectations
Macroeconomic relationships	postulated and estimated	mapping with individual behaviour
Source of fluctuations	exogenous shocks	exogenous shocks

DSGE models: limits and interrogations

- Maximising agents with rational expectations.
→ Evidence in sociology, psychology, cognitive science, experimental economics ?



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DSGE models: limits and interrogations

- Maximising agents with rational expectations.
→ Evidence in sociology, psychology, cognitive science, experimental economics ?
- Representative agents
→ Coordination failures, interactions, heterogeneity ?
- Markets clearing.
- Prevalence of an optimal equilibrium state.
→ How to explain huge economic downturns as the one we are experiencing within a DSGE model ?



The crisis and the doubts of existing models

"[In] the face of crisis, we felt abandoned by conventional tools. The key lesson ... is the danger of relying on a single tool, methodology or paradigm.

The atomistic, optimising agents underlying existing models do not capture behavior during a crisis period. 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.

J.-C. Trichet, Governor of the ECB, 18/11/2010, Frankfurt, Germany

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Introduction: the concept of complex system

What do the following examples have in common ?

- the immune system of an individual,
- the evolution of species within an ecosystem,
- a megalopolis,
- the start-up industry,
- a financial market.



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Agent-based models: the economy as a complex adaptive system

Decentralized market economies are complex adaptive systems.

Large numbers of micro agents engage repeatedly in local interactions, giving rise to macro regularities, such as employment and growth rates, income distributions...

These macro regularities in turn feed back into the determination of local interactions. The result is an intricate system of interdependent feedback loops connecting micro behaviour, interaction patterns, and global regularities.

L. Tesfatsion, (2006)



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Agents-based models: Characteristics and advantages

- A *decentralized* economy: an artificial economy.



Agents-based models: Characteristics and advantages

- A *decentralized* economy: an artificial economy.
- *Procedural* rationality: simple behavioural rules/adjustments.
→ more experimental and empirical support than maximising behaviour.



Agents-based models: Characteristics and advantages

- *A decentralized* economy: an artificial economy.
- *Procedural* rationality: simple behavioural rules/adjustments.
→ more experimental and empirical support than maximising behaviour.
- *Heterogeneity*: agents, prices, quantities.



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Agents-based models: Characteristics and advantages

- A *decentralized* economy: an artificial economy.
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- *Heterogeneity*: agents, prices, quantities.
- Resolution by numeric simulation: no tractability conditions.
→ no aggregation issue, complex interactions schemes, flexibility.



Agents-based models: Characteristics and advantages

- A *decentralized* economy: an artificial economy.
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- Resolution by numeric simulation: no tractability conditions.
→ no aggregation issue, complex interactions schemes, flexibility.
- No equilibrium dynamics: non-market clearing, rationing, no maximisation of a welfare criterion.



Compared approach

	Keynesian models (e.g. $IS - LM$)	DSGE models	Agent-based macro models
Microeconomic foundations	missing	representative agent	interacting and heterogeneous agents
Agents' behaviour	not modelled	maximisation, rational expectations	procedural rationality, local information
Macroeconomic relationships	postulated and estimated	mapping with individual behaviour	emerging from individual and local interactions
Source of fluctuations	exogenous shocks	exogenous shocks	endogenous: coordination issues

Agent-based macroeconomics: what for ?

Such economic models should be able to provide an alternative tool to give insight into how government policies could affect the broad characteristics of economic performance, by quantitatively exploring how the economy is likely to react under different scenarios.

In principle it might even be possible to create an agent-based economic model capable of making useful forecasts of the real economy, although this is ambitious.

J.D. Farmer & D. Foley, *The Economy Needs Agent-Based Modelling* (2009)



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Agent-based modelling

How to build an agent-based model?

- 1 Creating individual agents (e.g. firms, households)
- 2 Defining their behaviour (e.g. savings/consumption behaviour, hiring behaviour)
- 3 Defining their interactions (e.g. unemployed households/firms' vacancies)
- 4 Defining aggregate data to save for each period (e.g. unemployment rate, production...)
- 5 Defining the initial conditions (e.g. initial endowment) and parameter values
- 6 Setting the number of periods to run the model.



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Agent-based modelling

How to use an agent-based model?

- ➊ Running the model to obtain an history of the system to analyse:
 - ▶ either instantaneously (through the graphical interface)
 - ▶ or statistically (at the end of the run)
- ➋ If stochastic elements, repeating several times the history.
- ➌ **Comparing histories with different parameters or policies**
→ **policy evaluation.**



Contributions to macro agent-based modelling (1)

- **Emergence of coordination:**

Howitt & Clower (JEBO, 2000), Lengnick (2013, JEBO)

- **Emergence of business cycles and empirical exercise:**

Gaffeo et al. (EEJ, 2008), Mandel et al. (Lagom Generic model, 2010), Dosi et al. (JEDC, 2010)

- **Monetary policy, macro-prudential framework and credit market disruptions:**

Raberto et al. (2007, 2008, in proceedings), Oeffner (2008, PhD thesis), Seppecher (2009, RE), Salle et al. (EM, 2013)

- **Income distribution and wage policies:**

Seppecher (2012, MD), Dosi et al. (2013, JEDC).



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Contributions to macro agent-based modelling (2)

- **Large-scaled European projects for policy evaluation:**
 - ▶ EURACE (Deissenberg et al. (AMC 2008), Raberto et al. (CE, 2010), Dawid et al. (2008, JEE).
 - ▶ CRISIS (Delli Gatti et al. (2010, JEDC)).
 - ▶ RASTANEWS.

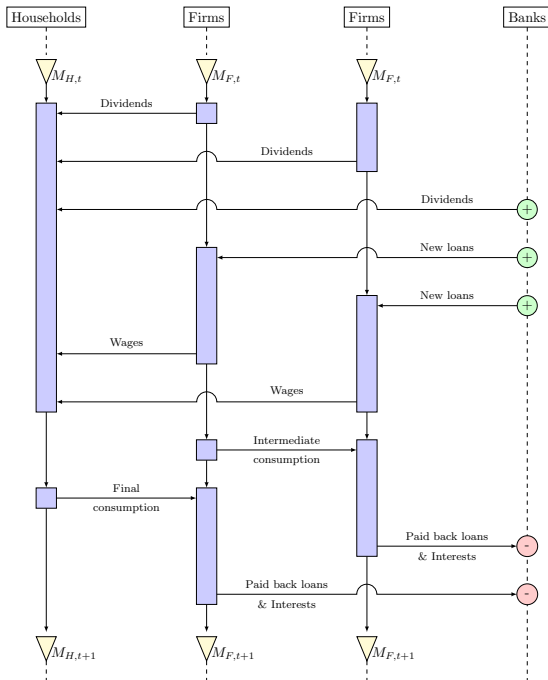


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Behavioural rules

Households

- Saving/consumption trade-off
- Reservation wage



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Firms

- Production plan (quantities, prices, raw materials)
- Wage offers
- Financing strategies: credit or cash-flow, payment of dividends.



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- Credits to firms
- Payment of dividends



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Firm creation and capital mobility



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Households

On the labour market, each unemployed household:

- consults a limited number of vacancies,
- holds the higher wage offer w ,
- if higher than his reservation wage, accepts the job,
- after a certain time of unemployment, resigns to lower his reservation wage.

On the goods market, each household:

- consults a limited number of bids,
- chooses the most interesting,
- spends a fraction of his income,
- saves the other share (\approx buffer-stock) rule.



Firms

Decision-making

- Update the quantity of goods to produce, observing the level of her inventory stock.
- Update her price, observing the level of her inventory stock.
- Update her offered wage, observing the level of vacancies.
- Determine her external financing need (bank loan).

Production

- Firms hire and fire households.
- The production is offered on the goods market.
- Pay back interests to the bank.
- If profits are positive, dividends are paid to owners.



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The bank

Credits:

- *As a first step*, all demand for credit by firms are satisfied.
- Interest payment feeds the capital of the bank.
- The surplus is paid to owners as dividends.

Bankruptcies:

- Firms unable to pay off the initial loan are downgraded to doubtful.
- Firms unable to pay off doubtful debt go bankrupt.
- The bank absorbs the default debt on its capital.
- If the capital is not sufficient, the bank goes bankrupt and the simulation breaks off (systemic crisis).



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Bankruptcies, firm creations and capital mobility

Each time a firm goes bankrupt:

- A new one is created within the following months.
- The new entrepreneur is a randomly selected household.
- He chooses the sector where to create the new firm according to a decentralized procedure.

Firm creation procedure:

- The entrepreneur randomly selects a subset of firms (both sectors together),
- looks at the most profitable firm among the subset, and
- creates the new firm in the corresponding sector



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Illustration: performing simulations

Baseline simulation

SIMULATION 1: baseline simulation for empirical validation.



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Empirical validation

Macro regularities

- Short-run fluctuations: "roller-coaster" ▶ Figure1
- Pro- and contra-cyclical patterns ▶ Figure2
- Beveridge and Phillips Curves ▶ Figure3
- Output autocorrelation ▶ Figure4
- Productivity shocks ▶ Figures5



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Empirical validation

Macro regularities

- Short-run fluctuations: "roller-coaster" ▶ Figure1
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Micro regularities

- Non-normal credit and profits distribution (power-law and right-skewed) ▶ Table1
- Realistic order of magnitude of entrant vs. incumbents firms
▶ Table2
- Bankrupt firms tend to be smaller and younger than average ▶ Figure5



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Illustration: performing simulations

Labour market simulation

SIMULATION 2: dampening labour mobility between the two sectors.



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Illustration: performing simulations

Labour market simulation

SIMULATION 3: increasing nominal wage downward flexibility.

Seppecher, Pascal, 2012, Flexibility of Wages and Macroeconomic Instability in an Agent-Based Computational Model with Endogenous Money, *Macroeconomic Dynamics*, vol. 16(S2), pages 284-297.



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Illustration: performing simulations

Labour market simulation

SIMULATION 4: implementing a minimum wage requirement.

Seppecher, Pascal, 2012, Flexibility of Wages and Macroeconomic Instability in an Agent-Based Computational Model with Endogenous Money, *Macroeconomic Dynamics*, vol. 16(S2), pages 284-297.



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Conclusions

Coordination does emerge in a fully decentralized economy.

Simplicity of assumptions vs. realism of emergent dynamics.

A powerful and interactive policy simulation tool.

Dynamics of capital accumulation, innovation et productivity improvements.

Simulations and results available on line at:

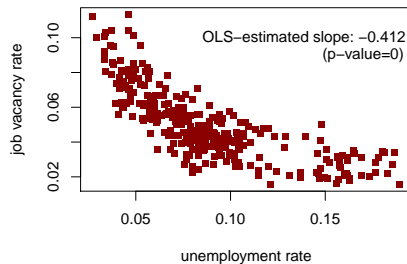
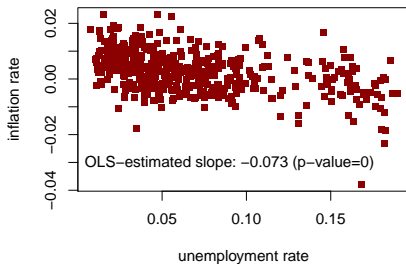
<http://p.seppecher.free.fr/jamel/>

Thank you very much for your attention

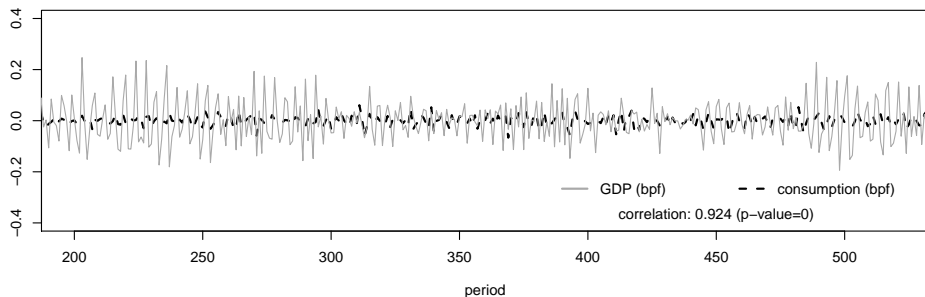


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Downward-sloping Phillips and Beveridge curves

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Dynamics of consumption and output

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Cyclical patterns

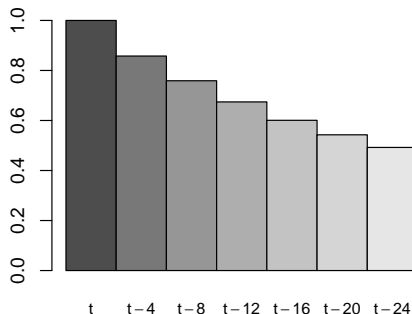


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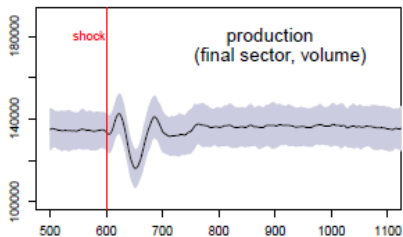
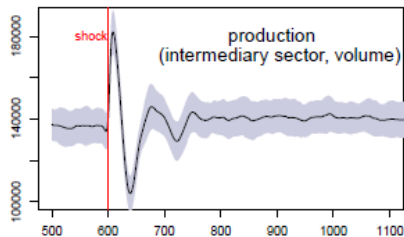
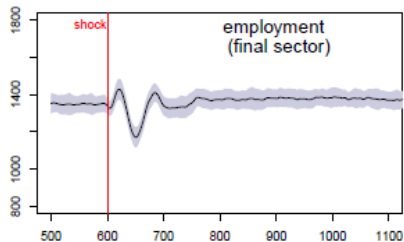
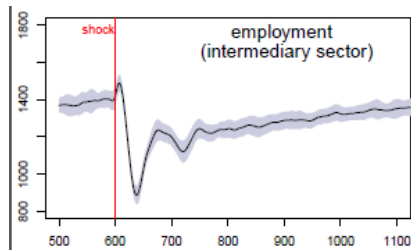


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Output autocorrelation

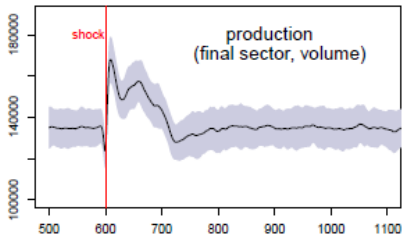
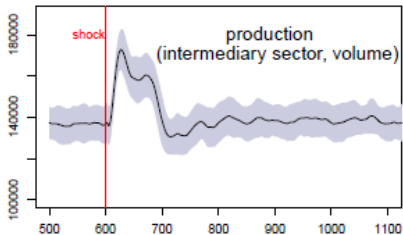
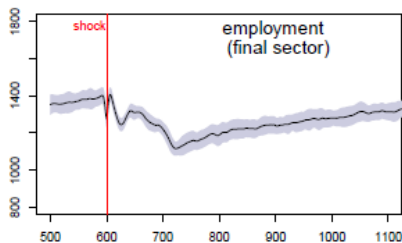
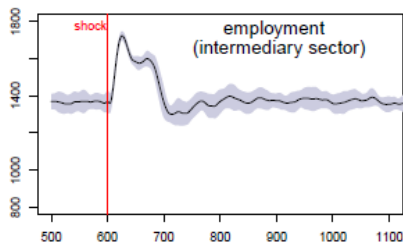
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Productivity shock in the intermediary sector

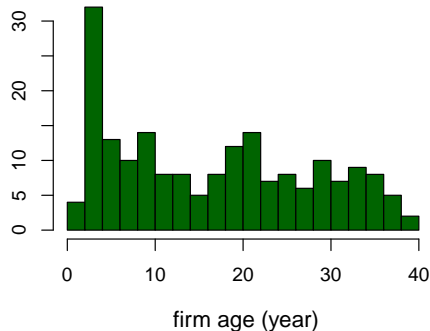
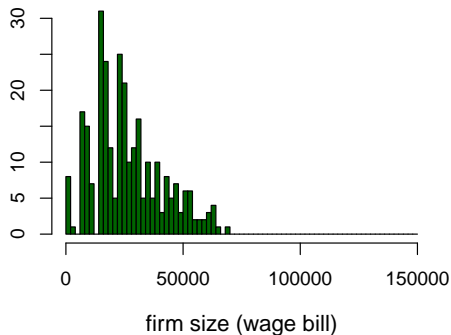


Productivity shock in the final sector

Impact on employment

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Age and size of bankrupt firms

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Entrant vs. incumbent firms

	Production ratio <u>entrants</u> total	Workforce ratio <u>entrants</u> total	Wage bill ratio <u>entrants</u> average incumbents	Size ratio (capital) <u>entrants</u> average incumbents
within the first 12 months	0.0146 (0.01)	0.016 (0.006)	0.992 (0.273)	0.092 (0.042)
within the first 24 months	0.034 (0.014)	0.03 (0.01)	1.085 (0.206)	0.283 (0.091)
Baldwin & Rafiquzzaman (1999)	0.0175-0.02	0.05	0.7-0.75	[0.25, 0.48]
Bartelsman et al. (2003)				[0.15 CA, 0.62 FIN]

Table: Estimations over 30 runs.

Profits and credit distribution

	Estimated shape parameter	skewness	p-value of the Shapiro normality test
firms' credits	1.47	0.762	0
	(0.126)	(0.106)	(0)
firms' profits	1.21	2.028	0
	(0.311)	(0.249)	(0)

Table: Estimations over 30 runs.

- Gaffeo et al. (2003, Physica A): 1.1 (G7 countries, 1990's)
- Ramsden et al. (2000): [0.65NE, 1.4HU] – 1.25 (US)

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