Credit Market in an Agent-Based Model of Endogenous Growth with Locally Interacting Agents

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INET Workshop "Interlinkages and systemic risk"

Finance, Growth, and Business Cycles

- **Finance and growth**
  - is there any causal nexus between finance and growth?
  - J. Schumpeter (1912): Finance can promote economic growth
  - J. Robinson (1952): "Where enterprise leads, finance follows"
  - recent debate on the link between finance and long-run growth (Levine, 2005)

- **Finance and business cycles**
  - the recent financial crisis and the ensuing Great Recession showed how financial markets can heavily impact on macroeconomic volatility
  - financial frictions can cause macroeconomic instability via non-linear amplification effects (Brunnermeier et al., 2012)

Aims of the paper

1. Developing an agent-based model (ABM) to study in a single framework the relationships between credit, output volatility and long-run growth
2. Investigating how different credit market structures affect macroeconomic performance
3. Exploring how bank attitude towards risk affects short-run fluctuations and long-run output growth

Why Agent-Based Modelling (ABM)?

- **Best tool to study complex system dynamics**
- **Capturing relevant features of innovation and finance:**
  - "strong" Knightian uncertainty and imperfect information
    $\Longrightarrow$ boundedly rational agents
  - credit relationships and default risk
    $\Longrightarrow$ heterogenous, interacting agents
  - the risky, trial-and-error nature of innovation
    $\Longrightarrow$ local exploration on a lattice
- **Policy design:**
  - the flexibility and modularity of ABM allow to easily implement different scenarios
  - autarchy vs. big universal bank vs. small local banks

Finance & growth: evidence

1. Financial development does exert a positive impact on growth (e.g. Aghion & Howitt, 2009)
2. Non-linear effects:
   - income (e.g. Rousseau & Watchel, 2011)
   - level of financial development (e.g. Arcand et al., 2011)
   - inflation (e.g. Rousseau & Watchel, 2002)
   - intermediation vs. non-intermediation activity (e.g. Beck et al., 2012)
   - productivity frontier (e.g. Aghion et al., 2005)
3. Credit booms may be associated either with financial deepening or with financial crises (e.g. Dell'Ariccia et al., 2012)
4. Volatility and growth through financial development (e.g. Aghion et al., 2005)

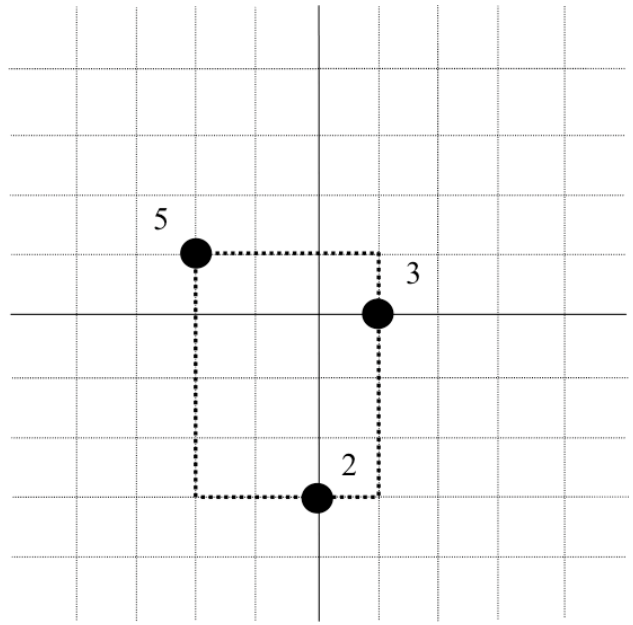
Finance & growth: channels

How does finance lead to higher economic growth?

1. Financial systems (FS) produce ex-ante information about investment projects and allocate capital (e.g. Greenwood & Jovanovic, 1990)
2. FS monitor investment and implement corporate governance (e.g. Bencivenga & Smith, 1993)
3. FS facilitate risk diversification (e.g. Acemoglu & Zilibotti, 1997)
4. FS pool savings (e.g. Acemoglu & Zilibotti, 1997)
5. FS facilitate the exchange of goods and services (e.g. Greenwood & Smith, 1996)

The "Island Model" (Fagiolo and Dosi, 2003)

- Technological space:
  - Discrete, infinite set of **technologies** (islands)
  - Technologies located in 2-dim lattice, each node can be an "island" with prob π (i.i.d.)
  - each island j has a **productivity coefficient** s_j increasing with its distance from O



- N **firms**
  - At $t = 0$ all placed on initially known island
  - On each island there can be many firms, each firms can only master 1 technology at a given t

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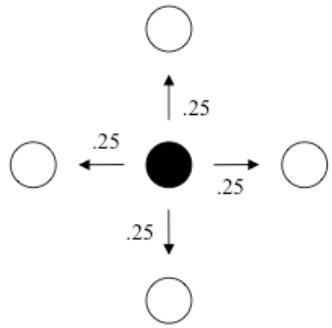
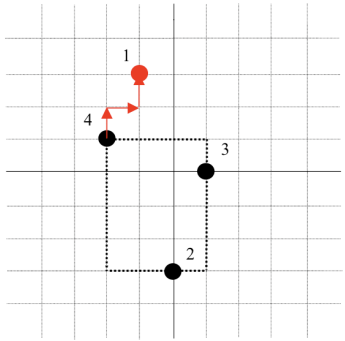
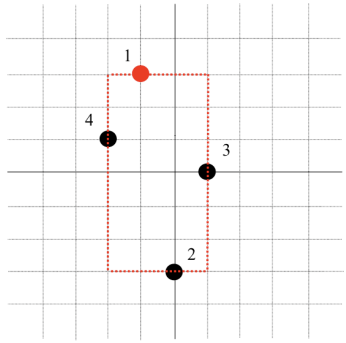
- **Explorers**. Leave island traveling at random until they find a new island. Productivity of new island depends on luck and increases with knowledge of innovator.
- **Imitators**. Signals about productivity are spread from each populated island. Miners can decide to imitate another island if they find it more productive (in probability). Imitation takes time.







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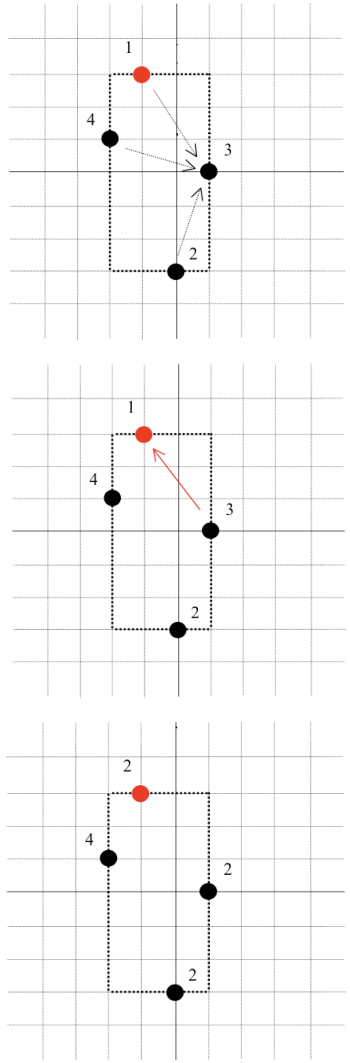

Beyond the Basic Model

- **Exploration and imitation are now costly**
  - autarchy: There are no banks, agents use their own savings to finance exploration and imitation activities
  - credit: Agents deposit savings in the banks, and borrow from them if deposits are not enough

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- **Consumption and saving**
  - agents consume a fraction c of their own current output and deposit remaining part (saving) in the banks
  - if agents decide to sail (explore/imitate), they pay a per-period cost equal to their current consumption
  - if deposits cannot cover imitation cost or expected exploration cost, agents must apply for a loan to the bank
  - agents pay interest rates that depend on project riskiness

Credit

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- Maximum amount of credit provided by banks to each agent is proportional to agents' collateral (current production) via a **loan-to-value** micro parameter γ
- Banks allocate credit using a pecking-order rule

Scenarios

- **Credit-market structure**
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  2) risk-lover banks: finance first explorers then imitators
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- **Production and innovation**
  1) returns-to-scale regimes (α): $\downarrow$ vs $\leftrightarrow$ vs $\uparrow$
  2) willingness to explore (ϵ): low vs high

Bankruptcies

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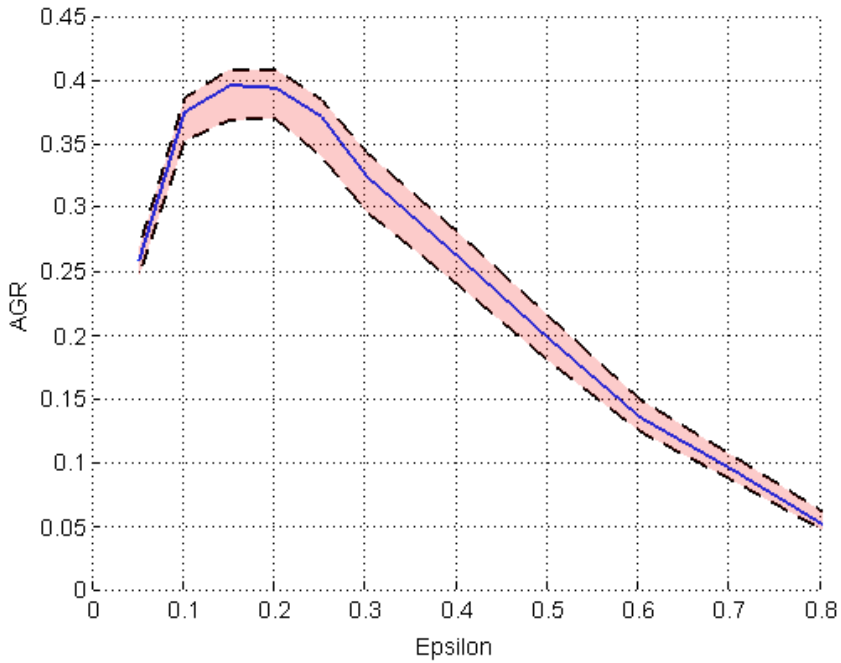
- **Banks**
  - when equity becomes negative, the bank goes bankrupt
  - residual resources are split among miners proportionally to their savings

The Trade-Off between Exploitation and Exploration

The credit-augmented model reproduces most of the features of the basic model. EX: the exploration-exploitation trade-off



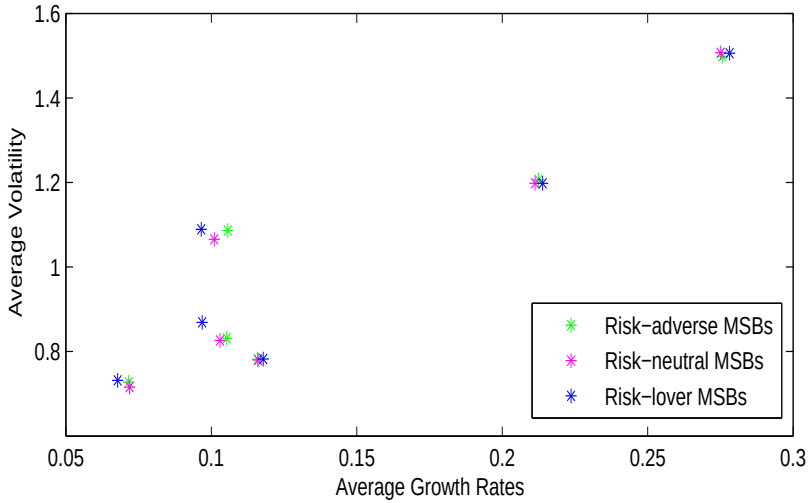
Many small banks (MSBs) scenario with risk-neutral banks

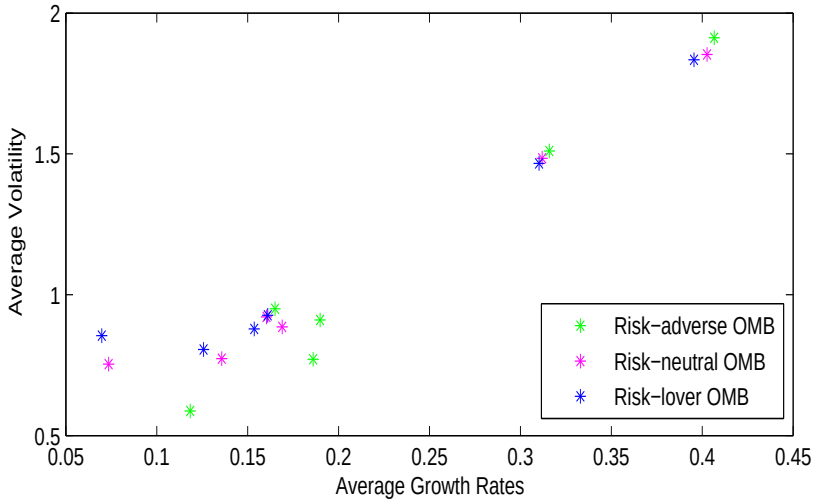
Does Finance Promote Long-Run Economic Growth?

Credit is beneficial to growth when agent willingness to explore is sufficiently high and returns to scale are not too low

(α, ϵ)	$agr_{many} - agr_{aut}$	$agr_1 - agr_{aut}$	$sd_{many} - sd_{aut}$	$sd_1 - sd_{aut}$
(1.5,0.1)	-0.0077^{**}	-0.0062^{**}	0.0414	0.1622^{**}
(1.5,0.4)	-0.0091^{**}	0.2610^{**}	0.0377^{**}	0.1209^{**}
(2,0.1)	0.0058^{**}	-0.0540^{**}	0.1092^{**}	0.2499^{**}
(2,0.4)	0.0242^{**}	0.2859^{**}	0.1049^{**}	0.2253^{**}
(2.5,0.1)	0.0002	-0.1458^{**}	0.1310^{**}	0.2673^{**}
(2.5,0.4)	0.0324^{**}	0.4729^{**}	0.1165^{**}	0.2969^{**}

Does Higher Long-Run Growth Imply Higher Volatility?





- Full sample size: positive correlation between growth and volatility (left)
- 50-period rolling window: volatility decreases over time in the OMB scenario, but not in the MSB one

Does Credit-Market Structure Affect Growth?

Credit-market concentration impacts positively on growth and reduces volatility especially when propensity to explore is high

Par	**Adverse Banks**		**Neutral Banks**		**Risky Banks**	
(α, ϵ)	$agr_1 - agr_{many}$	$sd_1 - sd_{many}$	$agr_1 - agr_{many}$	$sd_1 - sd_{many}$	$agr_1 - agr_{many}$	$sd_1 - sd_{many}$
(1.5,0.1)	0.0491^{**}	0.1684^{**}	0.0432^{**}	0.1448^{**}	0.0443^{**}	0.1410^{**}
(1.5,0.4)	0.0468^{**}	-0.1401^{**}	0.0019^{*}	0.1228^{**}	0.0015	0.0374^{**}
(2,0.1)	0.1034^{**}	0.3039^{**}	0.0964^{**}	0.2682^{**}	0.1007^{**}	0.2858^{**}
(2,0.4)	0.0806^{**}	-0.0606^{**}	0.0288^{**}	-0.0636^{**}	0.0327^{**}	-0.0529^{**}
(2.5,0.1)	0.1309^{**}	0.4131^{**}	0.1173^{**}	0.3287^{**}	0.1275^{**}	0.3464^{**}
(2.5,0.4)	0.0841^{**}	-0.1760^{**}	0.0570^{**}	-0.2108^{**}	0.0679^{**}	-0.1801^{**}

Does Banks' Attitude Towards Risk Affect Growth?

- Monopolistic bank: growth is always higher if the bank is risk-adverse
- Many small banks: growth is higher whenever banks are risk-adverse AND propensity to innovate is high

Par	**Many Small Banks**		**One Monopolistic Bank**	
(α, ϵ)	$agr_{lover} - agr_{adverse}$	$sd_{lover} - sd_{adverse}$	$agr_{lover} - agr_{adverse}$	$sd_{lover} - sd_{adverse}$
(1.5,0.1)	0.0019	0.0004	-0.0040^{**}	-0.0230^{**}
(1.5,0.4)	-0.0038^{**}	0.0042	-0.0486^{**}	0.2672^{**}
(2,0.1)	0.0014	-0.0081	-0.0057^{*}	-0.0438^{**}
(2,0.4)	-0.0084^{**}	0.0377^{**}	-0.0603^{**}	0.0346^{**}
(2.5,0.1)	0.0025	0.0068	-0.0111^{*}	-0.0776^{**}
(2.5,0.4)	-0.0091^{**}	0.0030	-0.0362^{**}	-0.0318^{**}

Sensitivity (Regression-Based) Analysis

- **So far**: Scenario analysis where only few parameters change simultaneously

Sensitivity (Regression-Based) Analysis

- **So far**: Scenario analysis where only few parameters change simultaneously
- **Now**: Randomly changing (almost) all parameters and evaluate partial-correlation impacts on dependent variables
- **Methodology:**
  - for any given credit-market structure and bank propensity to risk (6 scenarios), simulate the model 1000 times drawing uniformly at random all other parameters within given ranges
  - regress dependent variable against parameters using cross-section OLS
  - dependent variables: (i) average growth rate; (ii) output volatility; (iii) exploration ratio; (iv) bank loan-to-assets ratio (v) project failure ratio

Sensitivity (Regression-Based) Analysis: Results

- **Goodness-of-fit very high**

Sensitivity (Regression-Based) Analysis: Results

- **Goodness-of-fit very high**
- **Coefficients:**
  - Loan-to-value ratio: + growth rate and loan ratio; − output volatility, exploration ratio and project failure ratio
  - Returns-to-scale: + growth rate, output volatility and failure ratio; − loan ratio
  - Willingness-to-explore: − growth rate and output volatility; + exploration, loan and failure ratios
  - Credit multiplier parameter significantly affects different dependent variables according to banks' risk attitude in OMB scenarios
  - Interest-rate spread affects loan and failure ratios when OMB is risk-adverse

Summing up....

- **Results**
  - credit improves the performance of the economy
  - presence of banks increases long-run economic growth but also output volatility
  - in economies with a higher propensity to innovate, a more-concentrated and more risk-averse banking sector allows to attain higher and more stable economic growth

- **Sensitivity Analysis**
  - preliminary regression results show the importance of technological and loan-to-value parameters
  - further econometric analyses needed: quantile regressions and non-linear effects
  - empirical calibration can be employed to shrink the parameter space

On Our Agenda...

- Introducing Basel-like capital requirements to determine banks' supply of credit
- Allowing for bank heterogeneity in their pecking order rules
- Introducing time lags for the creation of a new bank after bankruptcy episodes
- Introducing bank bankruptcy costs (e.g. Greenwald and Stiglitz, 1993)

Parameters

N= 100	number of agents
T=1000	length of simulations
α= 1.5, 2, 2.5	returns to scale
ϵ= 0.1, 0.4	willingness to explore
ρ= 0.01	degree of local interactions
φ= 0.4	degree of knowledge accumulation
λ=5	likelihood of radical innovation
π= 0.4	technological opportunities
s= 0.3	propensity to save
γ=2	loan-to-value ratio
$\chi = 0.3$	precautionary reserves coefficient
$\mu = 0.01$; $\nu = 0.05$	imitators and explorers interest rates