Economic inequalities spatial patterns in a sustainable world: a complex systems approach

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May 11, 2012

with help from Bin XU, Adrian Carro Patino and Itzhak Royi.

Geographical patterns of economic activity

Geographical economics is concerned with geographical patterns of economic activity.

Economists have tried to explain the origin of industrial regions: what are the reasons for the strong disparities between world economic regions?

They proposed various *equilibrium* models based on increasing returns or variety of possible activities.

A physicist view: growth and *non-equilibirum* dynamics explain these large differences as spatial instabilities: Patterns, Dissipative structures.

Empirical evidence:

Paul Bairoch (1930-1999), published "Victoires et Déboires" in 1997 about the history of the Industrial Revolution. He noted that disparities in economic activity were strongly increased by the Industrial Revolution. Economic activities are nowadays strongly concentrated in Industrial regions.

A basi dynamics for economic disparities:

The "rich get richer" principle $\Longrightarrow$ scale free distributions and spatial inequalities.

Geographical patterns of economic activity

Plan

- 1 The simplest model of evolutionary economics, the AK model is equivalent to Shnerb etal AB model which gives rise to patterns.

- If we accept the idea that the Industrial revolution and the Cornucopian Economy that followed during a couple of centuries are a transient stage in the history of Mankind, what will the future look like after the transition to a sustainable and stationary economy, especially in terms of geographical disparities? A strongly contrasted world with economically active regions as nowadays? Or a more equitable repartition of wealth and economic activity?

  We here demonstrate how computations can reduce the set of possible scenarios.
  - 2 A passive agent model (diffusion of economic factors)
  - 3 A bounded rationality model, based on a delocalized market for energy

The AK = AB model

"The importance of being discrete: Life always wins on the surface" Nadav M. Shnerb, Yoram Louzoun, Eldad Bettelheim, and Sorin Solomon, PNAS, (2000), 97, pp. 10322-10324

Based on auto-catalytic process: $K + A \Longrightarrow 2K + A$ where A is technology and K capital.

$$\dot{K} = \lambda A.K - \mu K - D_K \Delta K \tag{1}$$

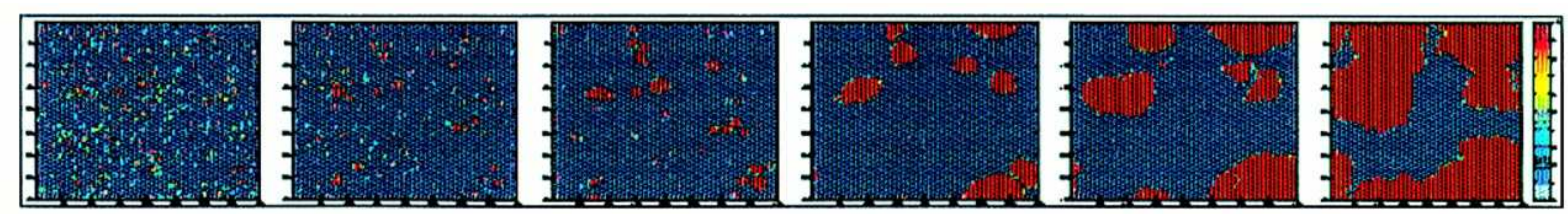
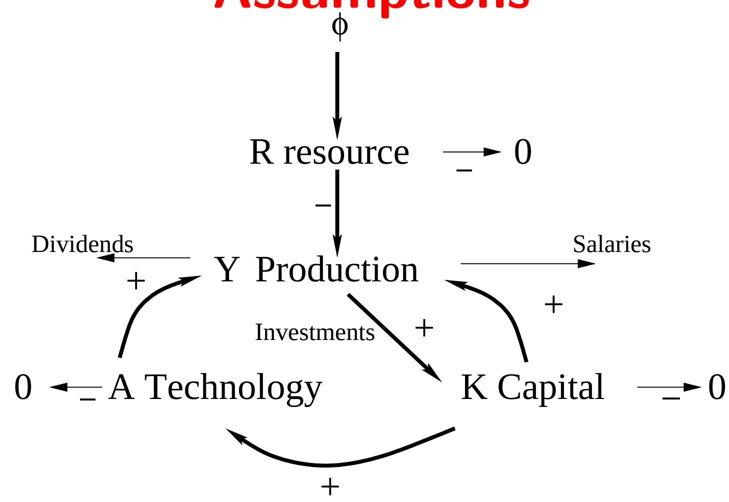


Figure 1: Evolution of local Capital color coded (dark blue=0, red ≥ 10)

Auto-catalysis, noise and diffusion lead to spatial patterns.

Although AK models are familiar to evolutionary economists, they are not used in geographical economics.

Assumptions



$$\dot{A} = \mu \frac{K}{K + K_1} - \delta_A A \quad (2)$$

$$\dot{K} = \rho \frac{AKC}{K + C} - \delta_K K \quad (3)$$

$$\dot{R} = \phi - C - \delta_R R \quad (4)$$

$$C = \inf(R, K(\sqrt{\frac{\rho A}{p}} - 1)) \quad (5)$$

Capital K investment drives Technical progress A limited by physical constraints.
Production function: constant return to scale, no perfect substitution: development limited by the availability of energy C.
A constant flux ϕ of resource R is available.
Production uses optimally resource, C, taking into account its price p.

Spatial simulations: the reaction-diffusion model

Discretise space: square lattice.

Each cell obeys a reaction dynamics (eq. 1-3) and and passive diffusion across cell boundaries. (Large transportation costs for energy)

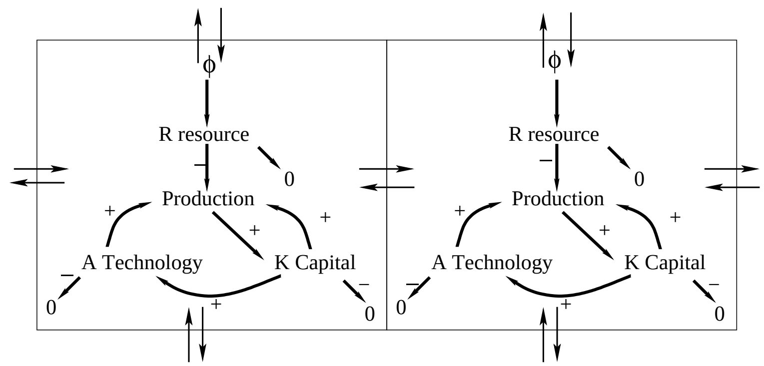


Figure 2: Reaction-diffusion dynamics in 2 cells.

Simulation results: no spatial structure, narrow distributions of variables A, K, R, P. Dynamical behaviour quasi-identical to a sum of independant cells obeying eq. 1-3.

Interpretation: quantities appearing in the positive loops reach saturation; no more auto-catalysis, the role of positive loops is negligible.

Spatial simulations: the market model

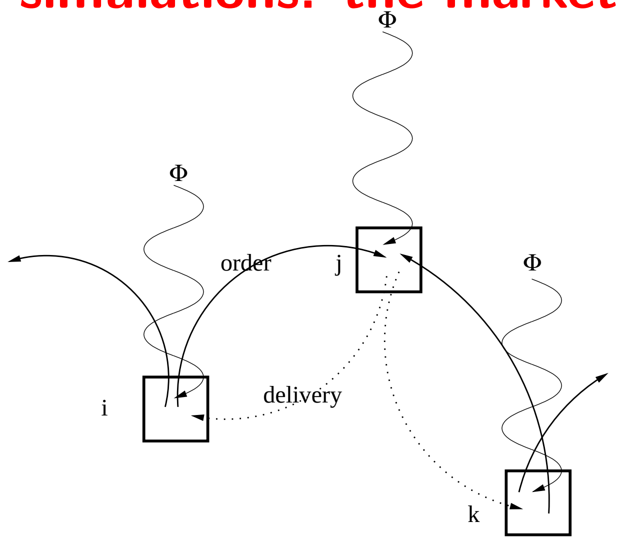


Figure 3: Market. All cells receive a constant energy flux Φ. Cells i and k order energy to cell k according to a logit function . Cell j delivers to cell i and k, according to availability.

$$\hat{\Pi} = \sum_j \rho \frac{A_j K_j C_j}{K_j + \sum_j C_j} - (p_0 + t_c d_{ij}).C_j - \frac{1}{\beta} \sum_j C_j log(C_j) \tag{6}$$

$\frac{1}{\beta}$ cost of information, t_c transportation cost and the last term is the entropy of the distribution.

$$f(d_{ij}) = \frac{exp(-\beta t_c d_{ij})}{\sum_j exp(-\beta t_c d_{ij})} \tag{7}$$

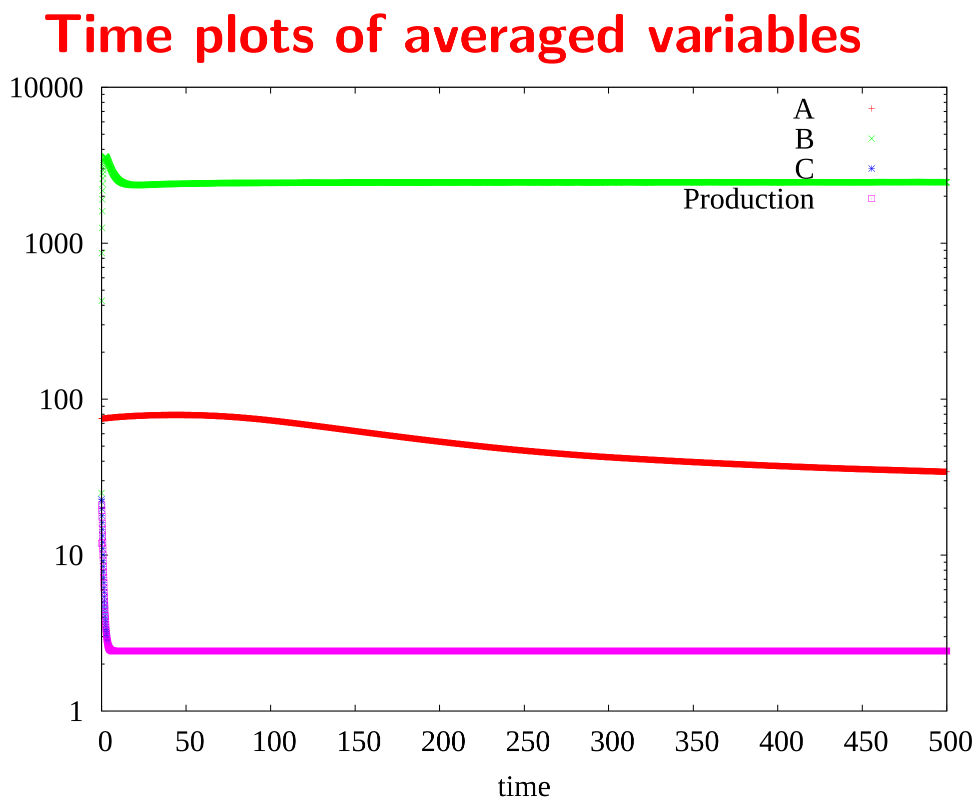


Figure 4: Time variation of average Technical knowledge A, Capital K, resource R and production observed for a 50x50 lattice. $exp(\beta t_c) = 2$. Levels equivalent to homogeneous ODE model except for the decrease of Technical knowledge.

Patterns

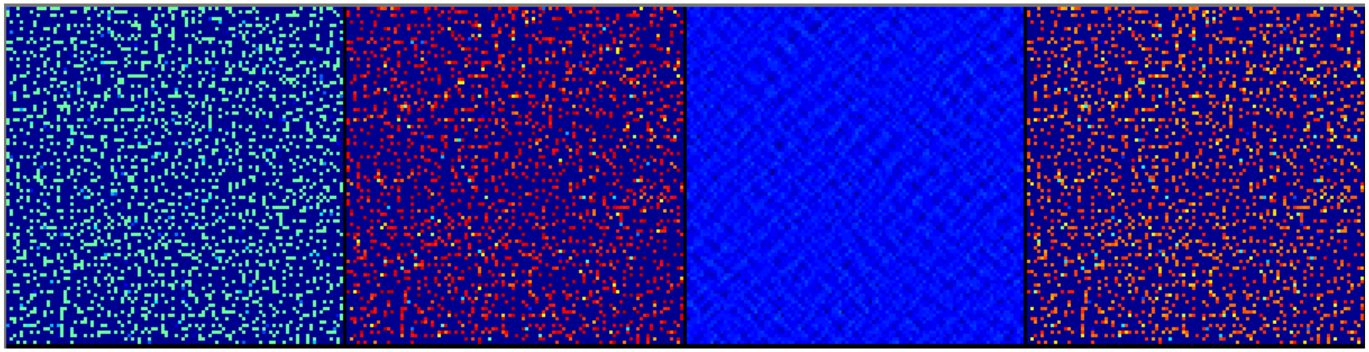


Figure 5: Local magnitude of Technical knowledge A, Capital K, resource R and Y Production. Logarithmic color scale, dark blue=1, brown 160 000

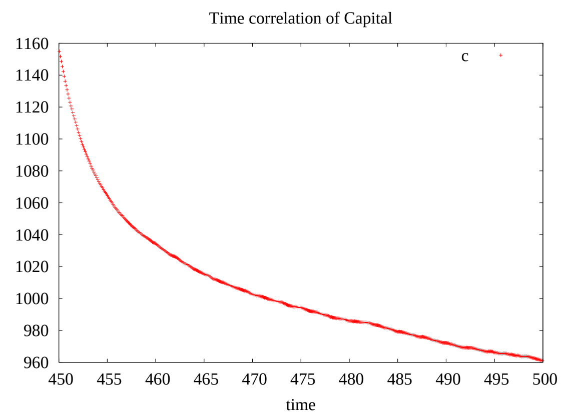


Figure 6: Time correlation of capital

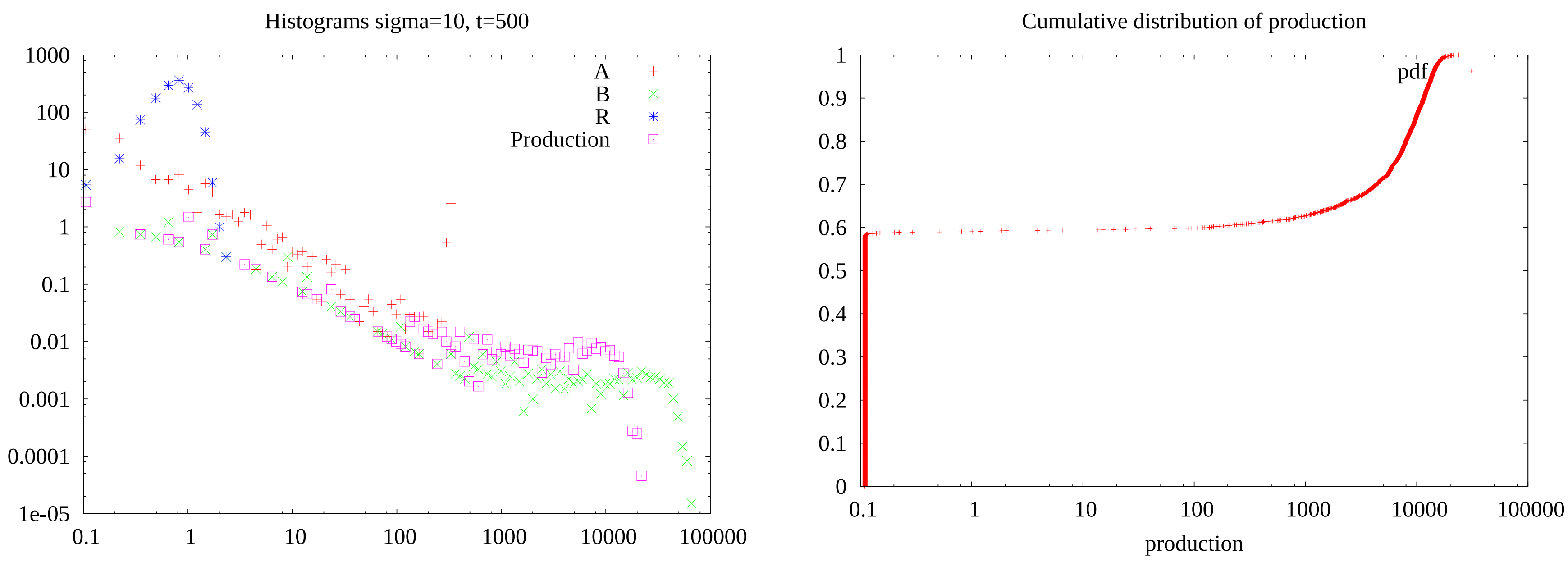


Figure 7: Distributions of Technical coefficient A Capital K, Resource R and Production. Right Cumulative distribution of production

Technical coefficient A, Capital K and Production P obey bimodal distribution with wide peaks for larger values.

Conclusions

Hypotheses:

1. Limitation on resource influx and technological coefficients;
2. Limited substitution of production factors.

Simulation results:

- Local resource diffusion yield disordered patterns with little contrast between regions.
- Non-local resource markets yields concentration of activities in industrial regions much more active than their surroundings.

- Local resource use goes with high transportation costs for the resource: wind mills and photo-voltaic cells generate electricity which transportation is more costly than oil, gas or uranium, because of losses and difficulties in storage.
- If nuclear energy is made available from fast breeders, we will again be in a low transportation cost situation with little limit on the resource and we might expect a strong concentration of economic activities. Other technologies such as high T_c super-conductor technology might also favor low transportation costs.