ETIC 2003

Evolutionary Modeling of Technical Change and Economic Dynamics

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Evolutionary Modeling and Econometric Analysis

Giorgio Fagiolo

Sant'Anna School of Advanced Studies
Laboratory of Economics and Management
Pisa, Italy

Summary (1/2)

- Theoretical Modeling and Econometrics
  - The Role of Assumptions and Testable Implications in Socio-Economic Analysis

- The "Evolutionary Paradigm" as a *natural* framework to deliver testable implications and "explain" real-world phenomena

- A first important distinction: "Reproducing" vs. "Forecasting"
  - Focus on: Explaining Past and Present Stylized Facts

    vs.

  - Generating (out-of- sample) Predictions and Policy Implications (... concluding remarks ...)

- A second important distinction: The "Origins" of Empirical Analyses
  - Testing implications derived from an underlying theoretical model
  - "Theory-free" (econometric-based) explorations of data
    - Can a "theory-free" analysis really exist?

- Econometric-based analyses
  - Econometric Modeling in presence of Evolutionary Change
    - Ex. 1: Functional (Parametric) Approach
  - A more "agnostic" approach
    - Ex. 2: Discovering stylized facts in applied IO
    - From basic beliefs about how the economy works to feedbacks to theory...

Summary (2/2)

- Different types of theory-driven testable implications:

  - “Light” (Qualitative) implications
    - Ex. 3: Can one explain a given observed phenomenon?
      - An Evolutionary Model of Cooperation

  - Testing for quantitative implications
    - Does the model replicate existing stylized facts (i.e. statistical properties)?
    - How many simultaneously?
    - Is the model able to provide “fresh”, robust, new implications?

    - Ex. 4: An “Analytically Solvable” Model
      - A Model of Industrial Clustering
    - Ex. 5: A “Computer-Simulated” Model
      - A Model of Endogenous Growth

- Conclusions: Remarks on...
  - Heterogeneity of approaches
  - Predictions and policy implications

- "Neoclassical" Economics: Too many "as ifs"?
  - Anything goes as long as the model delivers empirically testable implications and econometric tests do no reject them...
  - Two classes of theoretical models:
    - Delivering void or tautological empirical contents
      - ❖ Example: Game Theory
    - Equilibrium-based micro and macro models
      - ➢ Full rationality and perfect foresight
      - ➢ Static framework to explain dynamic phenomena
      - ➢ Delivering (static) equilibrium relationships btw variables
        - ❖ Examples:
          - Law of demand/supply
          - Steady-State (Optimal) Growth Rates
        - ❖ Each observation as an equilibrium?
        - ❖ Subsequent observations as transitions btw equilibria?
  - Econometric Analyses: Commitment to Stationarity
    - Testing parametric formulations derived from some equilibrium-based model (e.g. Barro and Sala-y-Martin regression-like analysis of growth convergence)
    - Even co-integrated VAR models cannot take into account "inherent non-stationarity due to innovative human behavior" (Doornik and Hendry, 1994, p.295)
- In the words of Richard Day:

  " Can one do good science by using models based on assumptions which are *clearly* at odds with any empirical evidence about micro behavior? "

The "Evolutionary Paradigm" and Econometrics (1/2)

- "Evolutionary" or "CES + Selection" Paradigm
  - Economy as a complex, evolving (dynamic), system
  - Agents cannot be computationally unbounded and fully rational
  - Agents are heterogeneous in almost all dimensions
  - Interactions structures evolve endogenously
  - (Possibly) some selective pressure
  - Open-Ended Search Spaces: Endogenous Novelty
  - The economy is by definition "out-of-equilibrium" at any time

- How Do Outcomes of a Standard "Evolutionary Model" look like?
  - ❖ Example
    - *N* Agents, *K* individual micro-characteristics (variables)
    - Dynamics in discrete time: $t = 0, 1, 2, ...$
    - Vector of system (micro and macro) parameters $\underline{\boldsymbol{\theta}}$
    - K-dim vector of individual (micro) variables: $\underline{\boldsymbol{x}}_{\boldsymbol{i}}(\boldsymbol{t};\ \boldsymbol{\theta})$
    - K-dim vector of macro variables $\underline{\boldsymbol{X}}(\boldsymbol{t};\ \boldsymbol{\theta})$ obtained as aggregation of $\underline{\boldsymbol{x}}_{\boldsymbol{i}}(\boldsymbol{t};\ \boldsymbol{\theta})$ over agents
    - Heterogeneity, bounded rationality, innovation, uncertainty, etc. imply that $\underline{\boldsymbol{x}}_{\boldsymbol{i}}$ and thus $\underline{\boldsymbol{X}}$ can be described by some (typically very complicated) stochastic process
    - Macro Outcome: Given any $\underline{\boldsymbol{\theta}}$, we (hope to) deliver a prediction about the *K*-dim distribution describing at each *t* the probability of finding $\underline{\boldsymbol{X}}$ in a neighborhood of some admissible point $\underline{X}$

The "Evolutionary Paradigm" and Econometrics (2/2)

- Two classes of outcomes (given system parameters $\underline{\boldsymbol{\theta}}$):
    - o If the model is analytically solvable:
        - Theoretical time-*t* distributions: $\pi_t(\underline{X} \mid \underline{\boldsymbol{\theta}})$
        - Kernel or transition matrices: $\Pi(\underline{X}_t \mid L^{(n)}\underline{X}_t ; \underline{\boldsymbol{\theta}})$
        - Probability of trajectories: $p(\underline{X}_t, t \geq 0 \mid \underline{\boldsymbol{\theta}})$
    - o If the model is NOT analytically solvable:
        - Any simulated run: *K* (Macro) Time-Series
        - Across *M* independent runs: *M* replications for any t.s.

- In general:
    - o At each time-tick our models deliver some (theoretical or frequency) distribution for $\underline{X}$ (or some statistics thereof)
    - o "Evolutionary-inspired" models provide the DGP which we think our real-world data being a realization of

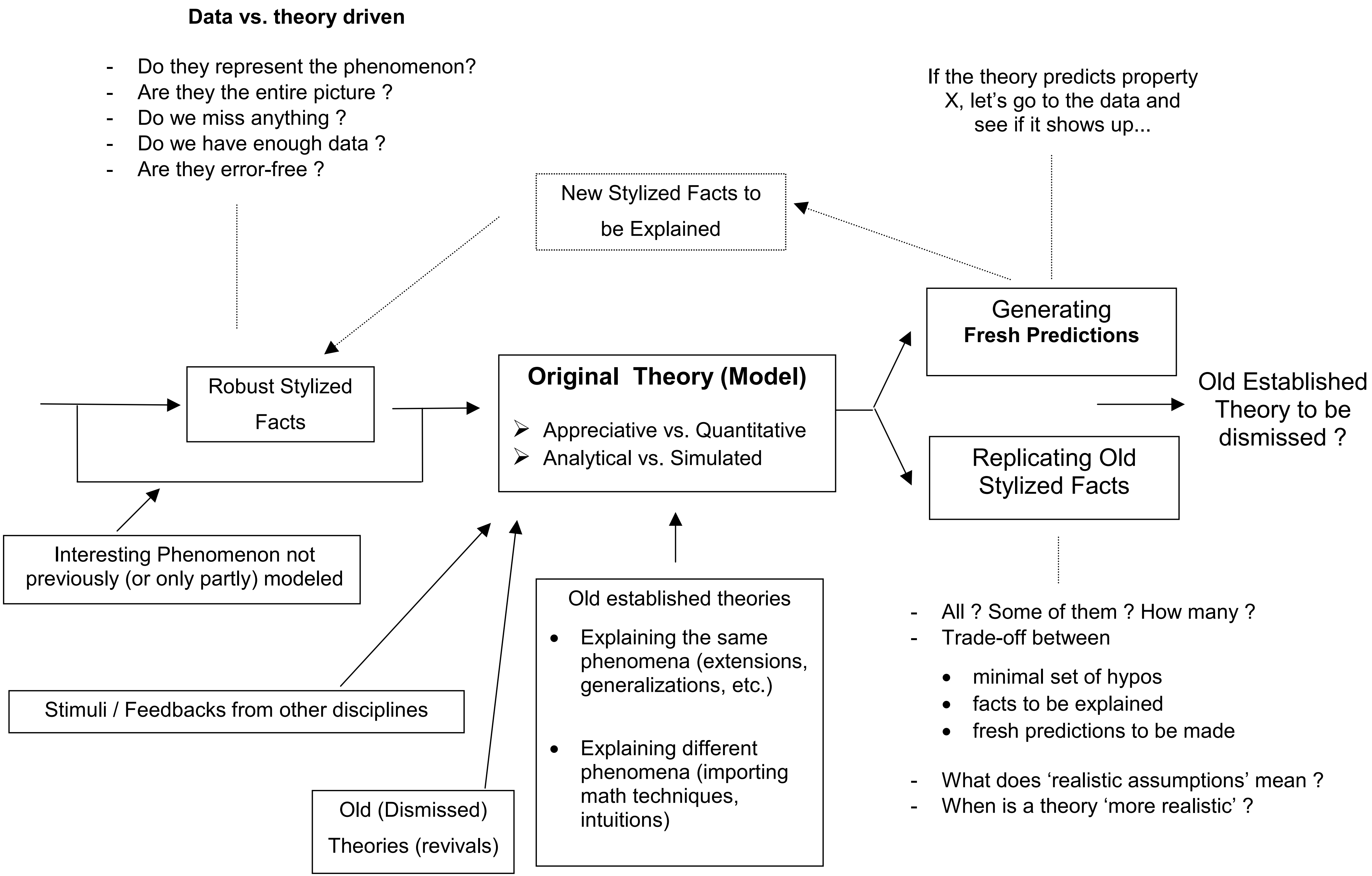
- Evolutionary (but also ACE, ECS, etc.) framework as a *natural* framework to deliver testable implications and "explain" real-world phenomena
    - o No interpretative commitment to equilibrium
    - o Allowing endogenously for structural change
    - o Avoiding assumptions which are "too far away" from empirical evidence on individual behavior and the microeconomics

Econometrics- vs. Theory-based Analyses

- Theory-free explorations of data
    - Are not explicitly derived from an underlying theoretical model
    - Start from analysis of data using parametric or (better) non-parametric descriptive or inferential tools
    - Can a “theory-free” analysis really exist?
        - (Almost) All econometric-based analyses are driven by:
            - Some underlying (theoretical) beliefs about how the economy should look like and work
            - Possibly some underlying explicit or implicit set of theories

- Implications derived from an underlying theoretical model
    - In sample:
        - Is the model able to replicate existing facts (and if yes, how many at the same time)?
        - Can the model generate fresh, new, facts?
    - Out-of-sample:
        - How does the model behave in forecasting exercises?
        - How reliable is the model to predict if and how (old and new) stylized facts would change in the future?
        - Is the model sufficiently robust to address policy implications?

➢ In what follows: How do these two approaches can be (and have been) addressed within an evolutionary framework?


Data vs. theory driven
- Do they represent the phenomenon?
- Are they the entire picture ?
- Do we miss anything ?
- Do we have enough data ?
- Are they error-free ?
If the theory predicts property X, let's go to the data and see if it shows up...
New Stylized Facts to be Explained
Robust Stylized Facts
Original Theory (Model)
Appreciative vs. Quantitative
Analytical vs. Simulated
Generating Fresh Predictions
Replicating Old Stylized Facts
Old Established Theory to be dismissed ?
Interesting Phenomenon not previously (or only partly) modeled
Stimuli / Feedbacks from other disciplines
Old (Dismissed) Theories (revivals)
Old established theories
Explaining the same phenomena (extensions, generalizations, etc.)
Explaining different phenomena (importing math techniques, intuitions)
- All ? Some of them ? How many ?
- Trade-off between
minimal set of hypos
facts to be explained
fresh predictions to be made
- What does 'realistic assumptions' mean ?
- When is a theory 'more realistic' ?

- Example #1: A “Functional” Approach (Foster and Wild, 1999)
  - Arguing that standard co-integrated VAR approach cannot deal with “truly endogenous, structural, change” because it always needs to resort to a “long-run equilibrium story”...
  - Econometric methodology should be built upon a “theory of historical process” focusing on:
    - Self-organization in dissipative systems
    - Structure building resulting in increasing organization and complexity
    - Irreversibility
  - Modeling time-series by alternative (non-linear) functional forms capturing (some) stylized facts in diffusion:

$$\Delta \log(x_t) = \alpha\, x_{t-1} \left[1 - \{\beta_1(\bullet)\, x_{t-1} - \beta_2(\bullet)\}\right] + [\text{exogenous}] + [\text{lags}] + \varepsilon_t$$

α = velocity of diffusion

$\beta_1(\bullet)$ = capacity limit

$\beta_2(\bullet)$ = niche competition term

- Why are these approaches still unsatisfactory?
  - They impose too much structure on the data
  - We are back to a top-down approach where some idea of “equilibrium” still exists (e.g. capacity limit and saturation)
  - Need to resort to less demanding approaches and to “more agnostic” explorations of data

- Analysis driven only by general beliefs about how the economy should work and look like (e.g. non-equilibrium, bounded-rationality)
- Example #2: Firm Growth and Gibrat-Law (Bottazzi *et al.*, 2002)
  - Standard stylized fact of firm growth

$$\Delta \log[S_{i,t}] = \alpha + \beta \log[S_{i,t-1}] + \varepsilon_t$$

α = industry-wide drift

ε_t = i.i.d. uncorrelated shocks

Gibrat Law (weak): $\beta = 0$

Gibrat Law (strong): Growth Shocks ~ LogNormal

- General strategy:
  - Exploring statistical properties of empirical distributions such as:
    - (labor) firm growth rates and variances
    - autocorrelation in growth dynamics
    - (labor) productivities

    and their (possible) across-sector differences
  - Studying "what data can tell us" so as to generate "stylized facts" to be interpreted and explained by theoretical models
  - Examples:
    - Persistent departures from log-normality in growth shocks and fat-tails
    - Lack of autocorrelation in growth dynamics despite firm heterogeneity in both production efficiency and in their growth shocks

- Evolutionary-based models delivering "light" but possibly not directly testable implications
- Ex. 3 (Axelrod, 1984): Evolutionary modeling of cooperation among boundedly rational agents
  - Decentralized Society, $I = \{1, 2, ..., N\}$ agents
  - Two pure strategies: {C, D}
  - Symmetric 2×2 PD game G with p.o. π_{hk} , $h,k \in \{C, D\}$
  - Discrete time: $t = \{ 0, 1, 2, ... \}$
  - Each agent only interacts (i.e. plays G) with all $j \in V_i \subset I$
  - State of the system: $\{a_{i,t}\}_{i \in I}$, where $a_{i,t} \in \{C, D\}$
  - At each time period:
    - An agent (say i) drawn at random ;
    - Plays G against all $j \in V_i$;
    - Update current strategy according to:

$$a_{i,t+1} \in \arg\max_{a=C,D} \sum_{j \in V_i} \pi(a; a_{j,t})$$

    - Change optimal strategy with some prob. $\varepsilon > 0$
- Some qualitative results:
  - Given a large family of interaction structures (i.e. graphs describing who interacts with whom), cooperation can be sustained over time to a large degree
  - This contrasts with "qualitative" predictions of rational-based models in game-theory because cooperation is a (strictly) dominated strategy.
  - However, this is what we can observe sometimes in reality!

Theory-driven testable implications (2/2)

- Testing for quantitative implications derived from theoretical models:
    - Does the model replicate existing stylized facts (and how many simultaneously)?
    - Is the model able to provide “fresh”, robust, new implications?
- Example #4 (Bottazzi, Fagiolo and Dosi, 2002)
    - A model of industrial clustering
    - Reproducing existing stylized fact
        - Skewed (statistically similar) distributions for the number of locations hosting at any time a given number of firms
    - Generating fresh implications
        - Agglomeration economies statistically differ across sectors
        - Mapping learning and technological accumulation patterns into meaningfully different strengths of agglomeration economies
- Example #5 (Fagiolo and Dosi, 2001)
    - A model of endogenous growth with spatially located firms
    - Reproducing existing stylized facts
        - Statistical properties of log(GNP) time-series
        - Evidence on size- (scale-) effects
    - Generating implications (to be tested...)
        - Relationships between “engines of growth” and growth rates averages and volatility
        - Predictions about the “exploration-exploitation” trade-off

The 'Industry Clustering' Model

- One Industry
- $i = 1, 2, \ldots$ firms
- $j=1, \ldots, M$ spatial locations (production sites)
- Discrete time: $t = 0, 1, 2, \ldots$
- Each location j is characterized by:
  - Geographical Benefit: $a_j > 0$
  - Agglomeration Strength: $b_j > 0$
- Initial Configuration (t=0):
  - N firms (incumbent) in the industry
  - System is characterized by the occupancy vector:

$$\underline{n}^0 = (n_1^0, n_2^0, \ldots , n_M^0), \quad \Sigma_h n_h^0 = N$$

- Dynamics (t>0):
  - One firm exits the industry (at random)
  - A firm enters and chooses location j with probability:

$$a_j + b_j\, n_j^t \quad \text{if} \quad \text{firm exits from } j' \neq j$$

$$a_j + b_j\, (n_j^t - 1) \quad \text{if} \quad \text{firm exits from } j' \equiv j$$

  - State of the System: $\underline{n}^t = (n_1^t, n_2^t, \ldots , n_M^t)$
  - Entry Rate = Exit Rate → $\Sigma_h n_h^t = N$

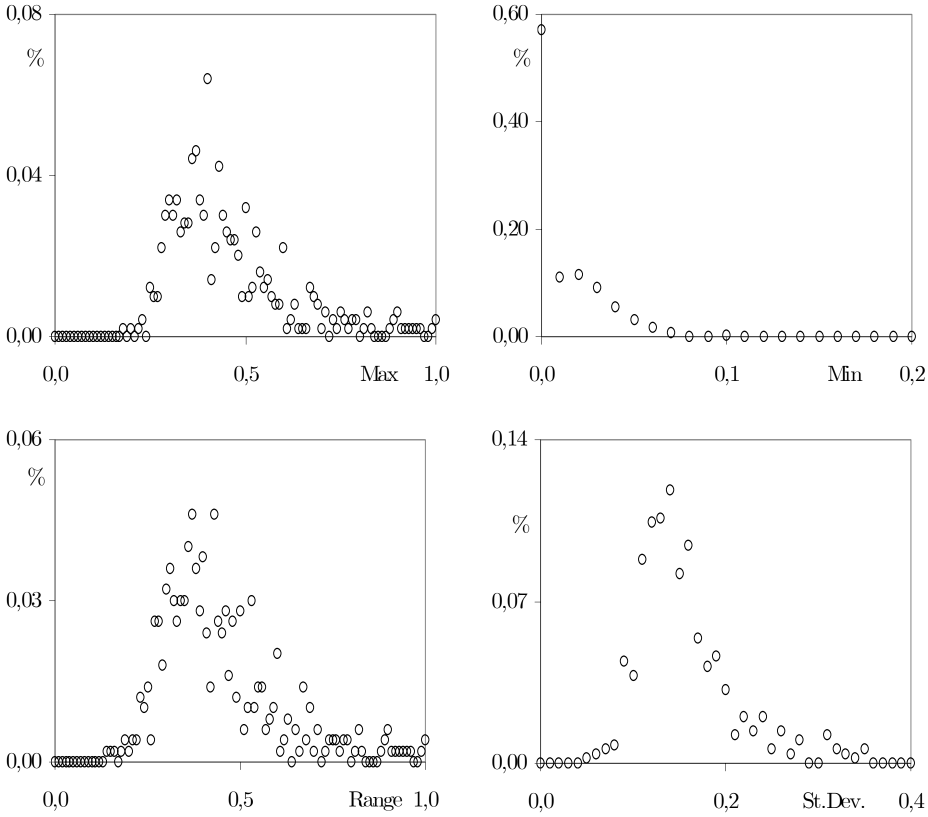


Figure 1: Frequency distributions of MAX (Top-Left), MIN (Top-Right), RANGE (Bottom-Left) and STANDARD DEVIATION (Bottom-Right) statistics computed on the distribution of Italian manufacturing business units (BUs) belonging to different industrial sectors (2-digit disaggregation) present in each geographical location in 1996. For each statistics S, a circle corresponding to a value s on the x-axis represents the % of all locations for which the statistics S (computed on the frequency distribution of firms belonging to each industrial sector present in that location) is equal to s. Locations are defined in terms of Local Systems of Labor Mobility (cf. footnote 6). Source: Our elaborations on ISTAT, Censimento Intermedio dell'Industria e dei Servizi.

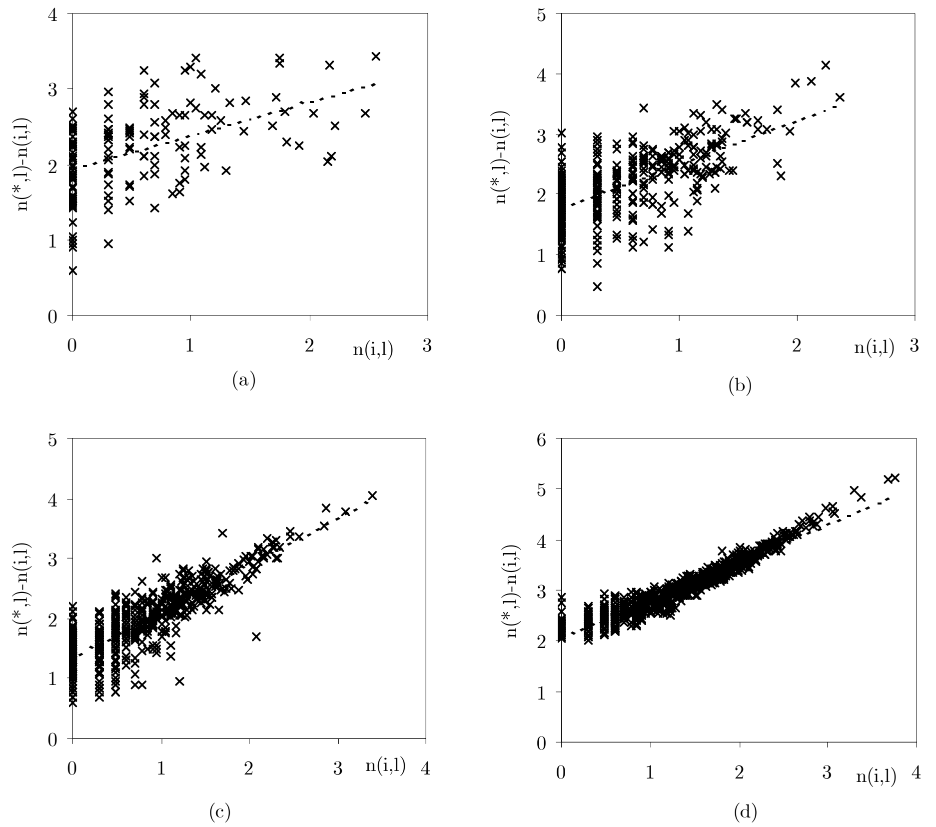


Figure 2: Number of business units belonging to sector l located in a given Local System of Labor Mobility ($n_{i,l}$) vs. the total number of BUs belonging to all sectors but l ($n_{i,\cdot} - n_{i,l}$). Panels: a) Leather products; b) Transport equipment; c) Electronics; d) Financial Intermediation. All variables are in log scale. Estimated Slopes of Linear Regressions (significance of t-test $\widehat{\beta} = 0$ in brackets): (a) $\widehat{\beta}$ =0.443 (0.0001); (b) $\widehat{\beta}$ =0.798 (0.0002); (c) $\widehat{\beta}$ =0.727 (0.0001); $\widehat{\beta}$ =0.746 (0.0000). Source: Our elaborations on ISTAT, Censimento Intermedio dell'Industria e dei Servizi, 1996.

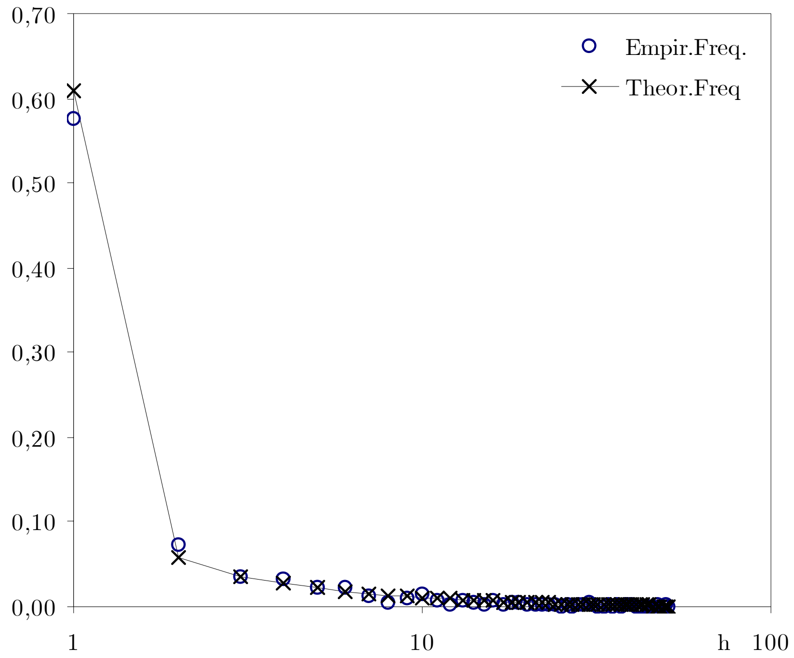


Figure 3: **Leather Products**. Observed vs. Theoretical Frequencies of BUs (business units) in LSLM (Local System of Labor Mobility). Y-axis: Frequency of LSLM hosting h BUs. Source: Our elaborations on ISTAT, 1996 data.

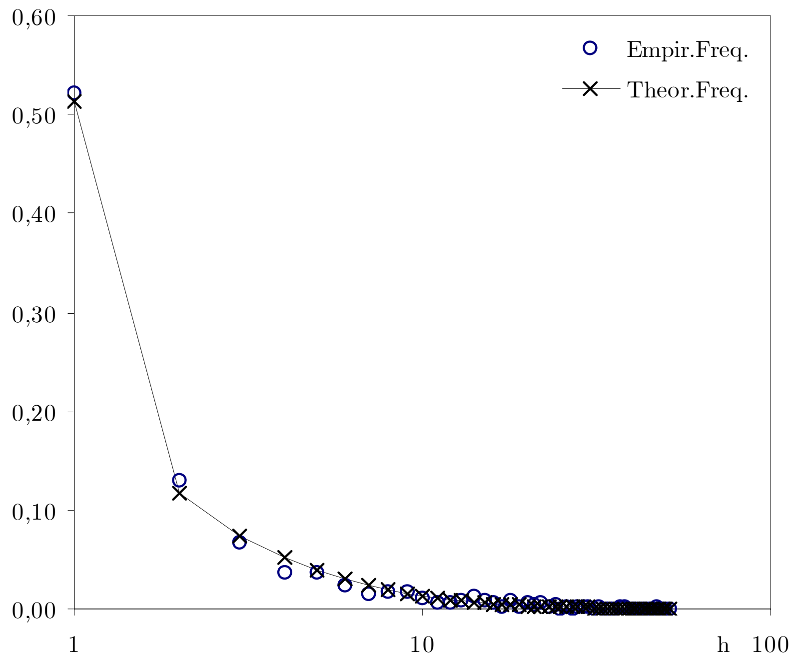


Figure 4: **Transport Equipment**. Observed vs. Theoretical Frequencies of BUs (business units) in LSLM (Local System of Labor Mobility). Y-axis: Frequency of LSLM hosting h BUs. Source: Our elaborations on ISTAT, 1996 data.

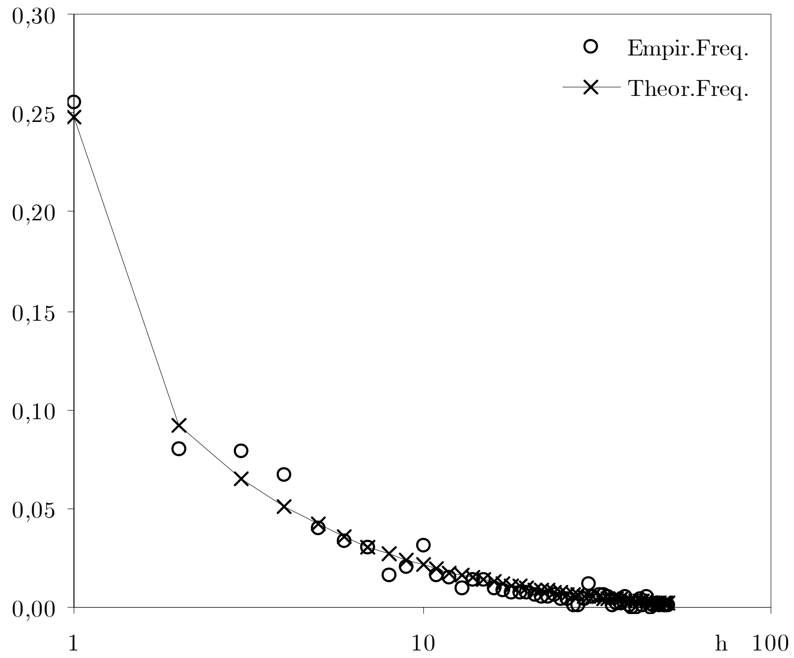


Figure 5: **Electronics**. Observed vs. Theoretical Frequencies of BUs (business units) in LSLM (Local System of Labor Mobility). Y-axis: Frequency of LSLM hosting h BUs. Source: Our elaborations on ISTAT, 1996 data.

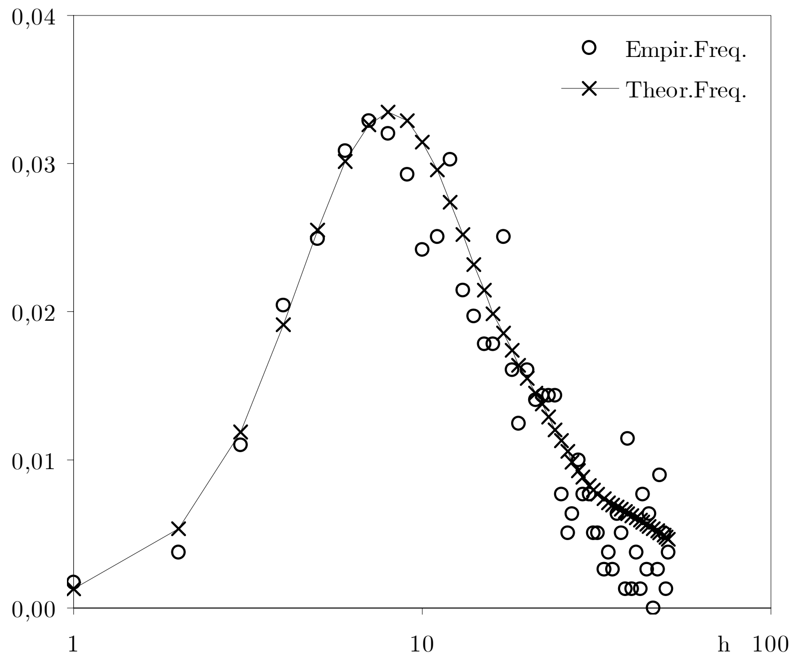


Figure 6: **Financial Intermediation**. Observed vs. Theoretical Frequencies of BUs (business units) in LSLM (Local System of Labor Mobility). Y-axis: Frequency of LSLM hosting h BUs. Source: Our elaborations on ISTAT, 1996 data.

Sector	ISIC Class	Pavitt's Group
Leather	D.19	Supplier Dominated (*SD*)
Transport Equipment	D.34, D.35	Scale Intensive (*SI*)
Electronics	D.30, D.31, D.32, D.33	Science Based (*SB*)
Financial Intermediation	J.65, J.66, J.67	Information Intensive (*II*)

Table 1

The Statistical Classification of the considered Sectors.

Sector (l)	γ_l^*	Confidence Intervals	$\chi^2(f_l, \psi_l(\gamma_l^*))$	Prob$\{\chi_D^2 > \chi^2(f_l, \psi_l(\gamma_l^*))\}$
Leather	0.0032	(0.0026, 0.0098)	52.6760	0.3709
Transport Equipment	0.0128	(0.0087, 0.0169)	58.7517	0.1855
Electronics	0.0376	(0.0301, 0.0462)	54.2862	0.3147
Financial Intermediation	0.7871	(0.7101, 0.8005)	44.1767	0.7051

Table 2

'Predicted' Agglomeration Parameters $\gamma_l^* = \arg\min_{\gamma_l \in G} \chi^2(f_l, \psi_l)$. Confidence Intervals for γ_l^* contain all γ_l s.t. the 5% Chi-Square test between $\psi_l(h; \gamma_l)$ and f_l is not rejected. Degrees of freedom: $D = 50$.

$\chi^2(\psi_l(\gamma_l^*), \psi_m(\gamma_m^*))$		m Leather	Transport	Electronics	Financial
l	Leather	$\square$	0.0523	0.0002	0.0001
	Transport	0.0523	$\square$	0.0000	0.0000
	Electronics	0.0002	0.0000	$\square$	0.0000
	Financial	0.0001	0.0000	0.0000	$\square$

Table 3

Tail probabilities for the Chi-Square test between $\psi_l(\gamma_l^*)$ ('predicted' distribution for sector l) and $\psi_m(\gamma_m^*)$ ('predicted' distribution for sector l). Degrees of freedom: $D = 50$.

$\chi^2(\psi_l(\gamma_l^*), \psi_m(\gamma_l^*))$		m Leather	Transport	Electronics	Financial
l	Leather	$\square$	0.9942	0.0621	0.0000
	Transport	0.9598	$\square$	0.0000	0.0000
	Electronics	0.0771	0.0000	$\square$	0.0000
	Financial	0.0001	0.0000	0.0000	$\square$

Table 4

Tail probabilities for the Chi-Square test between $\psi_l(\gamma_l^*)$ (distribution for sector l computed at the 'predicted' value for sector l) and $\psi_m(\gamma_l^*)$ (distribution for sector m computed at the 'predicted' value for sector l). Degrees of freedom: $D = 50$.

<table>
<tr><th><u>Sector</u></th><th><u>Agglomeration Economies</u></th><th><u>Why?</u></th></tr>
<tr><td>Scale Intensive</td><td rowspan="2">Higher</td><td>Hierarchical relations among firms
"Oligopolistic core"
Subcontracting networks</td></tr>
<tr><td>Supplier Dominated</td><td>Italian Districts
Inter-firm division of labor
Knowledge complementarities
District-specific institutional arrangements</td></tr>
<tr><td>Science-Based</td><td>Intermediate</td><td>Expected lower due to “Silicon Valley” effects
In Italy: Weaker</td></tr>
<tr><td>Info-Intensive</td><td>Lower</td><td>“Monopolistic competition” strategies of branch location near customers</td></tr>
</table>

The 'Island' Model

- N firms located in a 2-dim boundary-less lattice (technological space); distances in the lattice = technological differences

- A node (x,y) is a technology with probability $\pi \in (0,1)$; each technology has a productivity s(x,y)=|x|+|y|

- At time t=0 firms randomly distributed across existing technologies, all producing homogeneous good (GNP)

- Firms can be:
  - (a) Miners: Produce $q_{i,t} = s(x,y) \cdot [m_t(x,y)]^{\alpha-1}$
  - (b) Explorers: Random R&D (i.e. explore at random one of the four adjacent nodes with probability 1/4)
  - (c) Imitators: Adopt one of the existing technologies

- Miners → Explorers: With probability $\varepsilon \in [0,1]$

- Explorers → Miners:
  - With probability $\pi \in [0,1]$
  - Innovation occurs
  - Productivity of New Island in (x',y')

$$s(x', y') = (1 + W)(| x' | + | y' | + \varphi q_{i,\tau})$$

$W \sim$ Poisson(λ), $\varphi \in [0,1]$

- Miners → Imitators: - Adopt j' with prob. $\propto$

$$Q_t(x_{j'}, y_{j'}) \cdot Exp\{- \rho[| x_j - x_{j'} | + | y_j - y_{j'} |]\}$$

$\rho > 0$

- Imitators → Miners: - After $d(j,j') = |x_j - x_{j'}| + |y_j - y_{j'}|$ periods

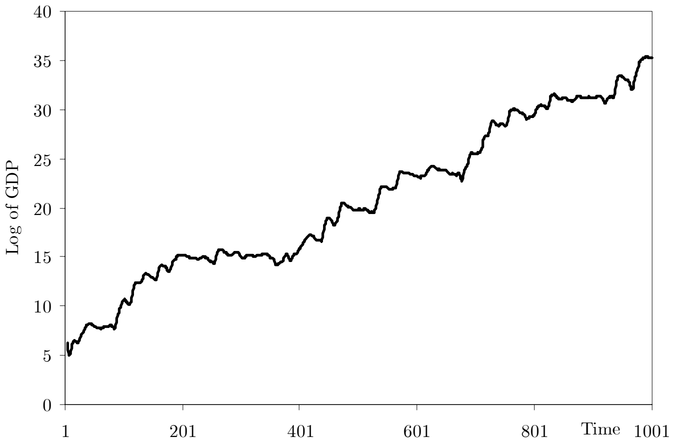


Figure 3: Patterns of Exponential Growth in an Open-Ended Economy with Exploration. Par. Setup: $N = 100$, $\pi = 0.1$, $\rho = 0.1$, $\alpha = 1.5$, $\varepsilon = 0.1$, $\lambda = 1$, $\varphi = 0.5$, $T = 1000$.

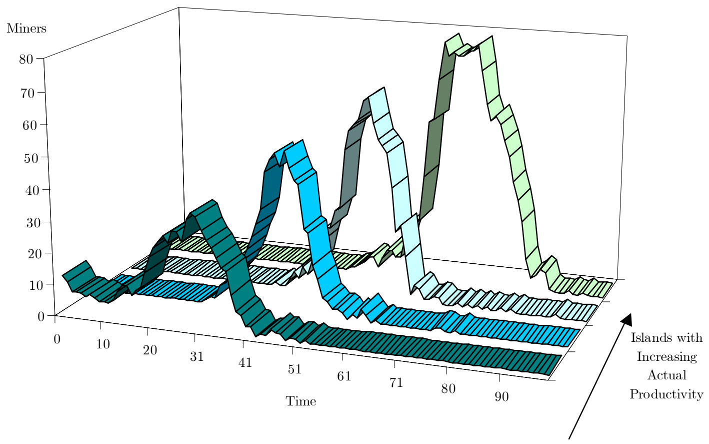


Figure 4b: Diffusion of technological innovations. An example of overlapping S-shaped patterns of adoption. Par. Setup: $N = 100$, $\pi = 0.1$, $\rho = 0.1$, $\alpha = 1.5$, $\varepsilon = 0.1$, $\lambda = 1$, $\varphi = 0.5$, $T = 1000$.

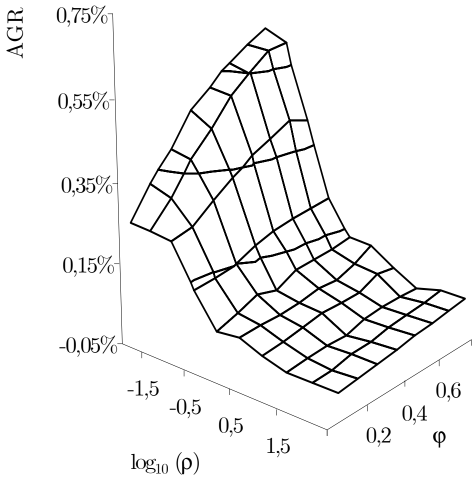


Figure 5b: Mean of Montecarlo AGR distributions as a function of $(\rho,\, \varphi)$. High opportunity regime: $\lambda = 5$, $\pi = 0.4$. Par. Setup: $N = 100$, $\alpha = 1.5$, $\varepsilon = 0.1$, $T = 1000$, $M = 10000$.

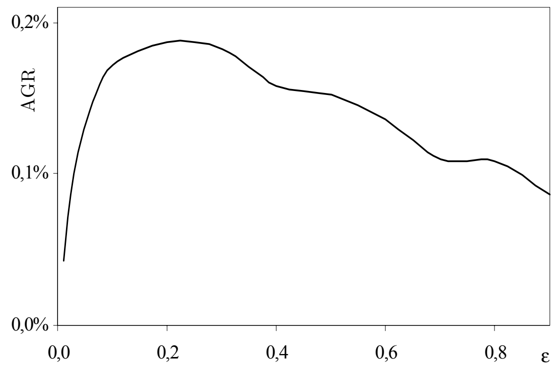


Figure 6d: Mean of Montecarlo AGR Distributions as a function of the willingness to explore ϵ. Technological Regime: $\lambda = 5$, $\pi = 0.4$, $\rho = \infty$, $\varphi = 0.5$. Other parameters: $\alpha = 1.4$, $N = 100$, $M = 10000$.

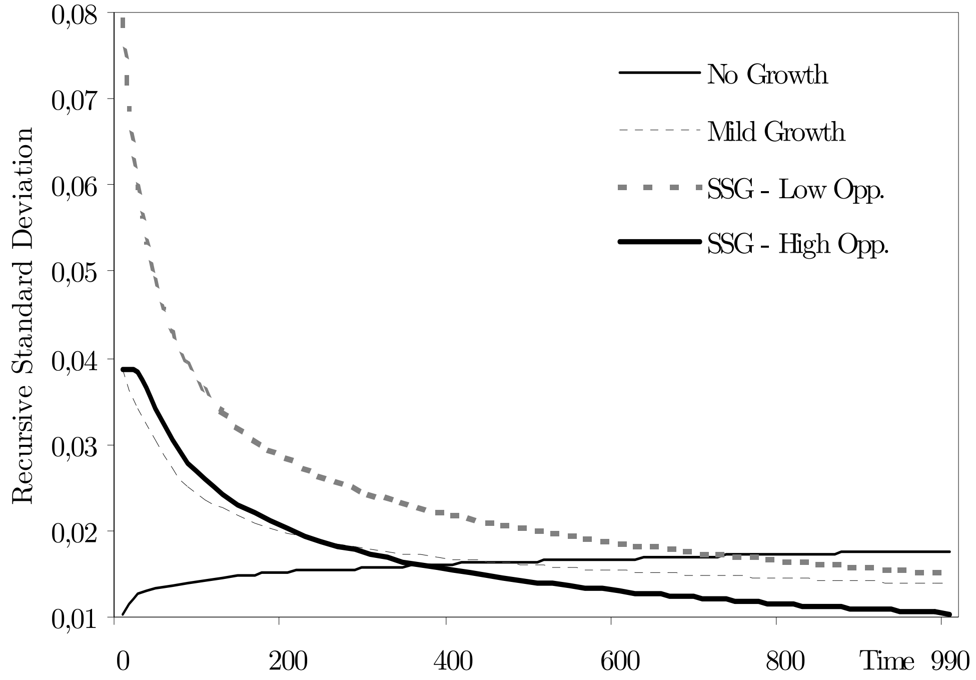


Figure 9b: Time evolution of GDP time-series growth rates (GRTS) volatility in four paradigmatic growth regimes. Y-Axis: Montecarlo Mean of recursive standard deviations of GRTS (within simulations).

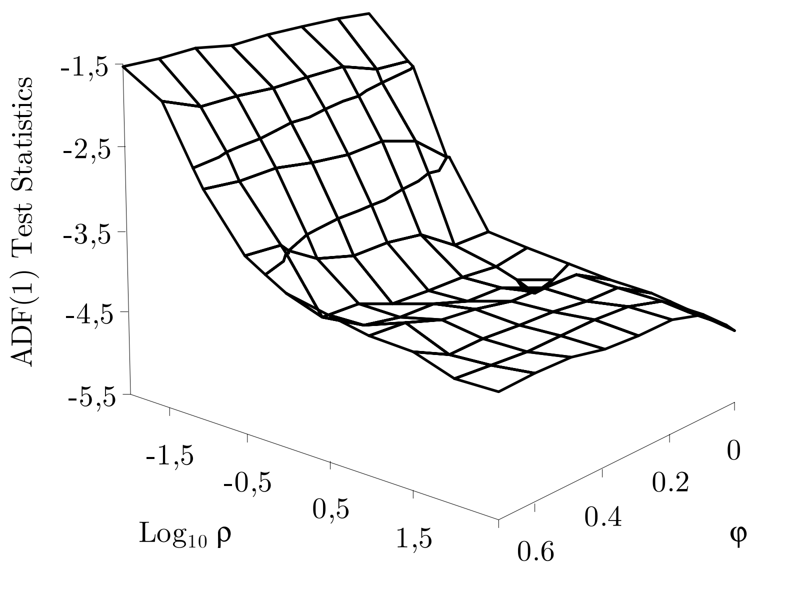


Figure 10a: A Montecarlo study of thresholds in the emergence of unit-roots in log(GDP) time-series. Mean of Montecarlo ADF(1) test statistics distribution in a high opportunity regime ($\lambda = 5$, $\pi = 0.4$). Critical values: -3.441 (5%); -4.022 (1%). Par. Setup: $\epsilon = 0.1$, $\alpha = 1.5$, $N = 100$, $T = 1500$, $M = 10000$.

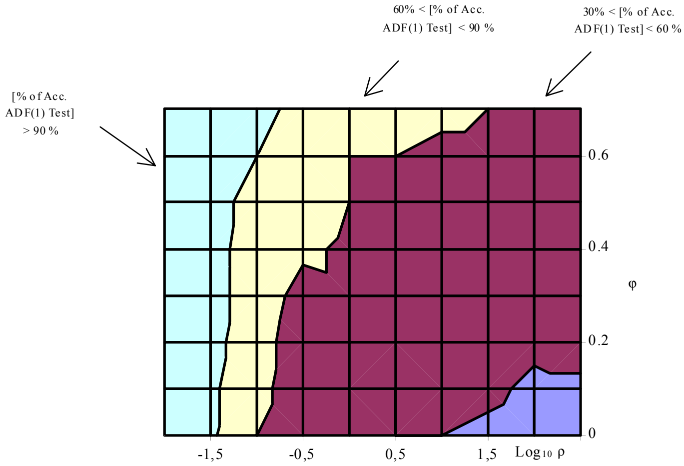


Figure 10b: A Montecarlo study of thresholds in the emergence of unit-roots in log(GDP) time-series. Frequency of acceptance of the 5%-ADF(1) test in a high opportunity regime ($\lambda = 5$, $\pi = 0.4$). Par. Setup: $\epsilon = 0.1$, $\alpha = 1.5$, $N = 100$, $T = 1500$, $M = 10000$.

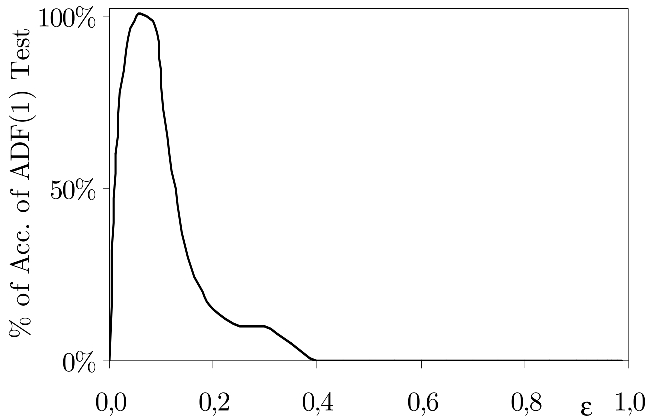


Figure 10c: A Montecarlo study of thresholds in the emergence of unit-roots in log(GDP) time-series. Frequency of acceptance of the 5%-ADF(1) test as a function of ϵ in a high opportunity, no info diffusion regime with low path dependency ($\lambda = 5$, $\pi = 0.4$, $\rho = \infty$, $\varphi = 0.1$). Par. Setup: $\alpha = 1.5$, $N = 100$, $T = 1500$, $M = 10000$.

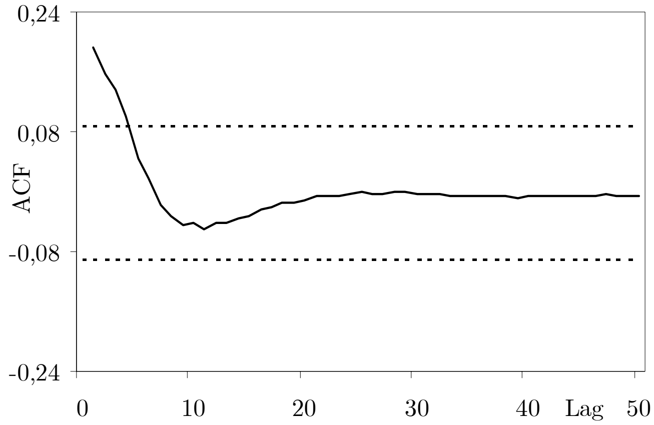


Figure 11a: A Montecarlo study of growth rates time-series autocorrelation structure. Mean of MC autocorrelation function. Technological regime: high opportunities ($\lambda = 5$, $\pi = 0.4$), global info diffusion ($\rho = 0$) and high path-dependency ($\varphi = 0.5$). Dotted lines: 95% Bartlett bands. Parameter setup: $\alpha = 0.1$, $\epsilon = 0.1$, $N = 100$, $M = 10000$, $T = 1500$.

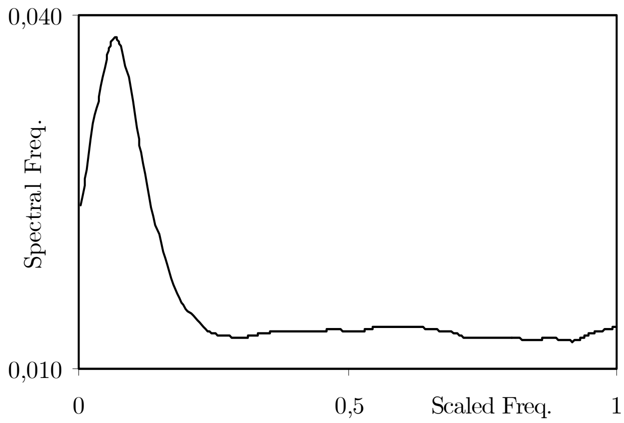


Figure 11b: A Montecarlo study of growth rates time-series autocorrelation structure. MC estimate of log(GDP) growth rates spectral density. Technological regime: high opportunities ($\lambda = 5$, $\pi = 0.4$), global info diffusion ($\rho = 0$) and high path-dependency ($\varphi = 0.5$). Frequencies are scaled so as to map the unit interval. Spectra computed by smoothing the periodogram using a Bartlett window with width=50. Parameter setup: $\alpha = 0.1$, $\epsilon = 0.1$, $N = 100$, $M = 10000$, $T = 1500$.

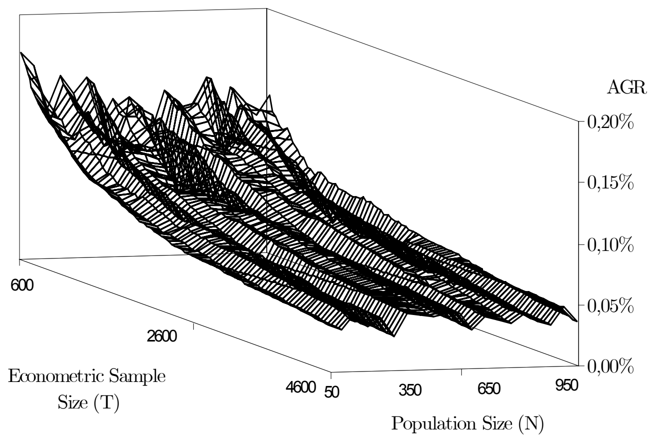


Figure 12: Mean of Montecarlo AGR distributions as a function of econometric sample size (T) and population size (N). Par. Setup: $\lambda = 1$, $\pi = 0.1$, $\alpha = 1.5$, $\varepsilon = 0.1, \rho = 0.01$, $\varphi = 0.5$, $M = 10000$.

Concluding Remarks (1/2)

- Link between evolutionary modeling and econometrics
    - Implications about “out-of-equilibrium” multi-dimensional distributions of interesting micro and macro variables
        - Departures from predicted shape/parameters
        - Recovering empirical distributions and other statistical properties
    - How do these distributions change in time?
        - Estimating transition matrices / kernel
        - Example: Firm Growth Rates
    - Well-established tools; room for developing new econometric tools

- Evolutionary Paradigm: Too much heterogeneity?
    - Almost all “evolutionary” inspired models almost not comparable to each other (assumptions, analysis, implications)
    - A lot of overlap between “evolutionary” paradigm and other similar theoretical approaches (CES, ACE, etc.)
    - Still poor agreement on:
        - Class of assumptions employed (innovation, imitation, etc.)
        - Types and “depth” of simulation exercises
        - Econometrics to be employed
    - Variety often implies richness
    - Need for established “routines”
    - Still hard to categorize (or classify) attempts in using econometrics together with non standard approaches!

Concluding Remarks (2/2)

- What about predictions and policy implications
  - Types of testable implications
    - Generating stylized facts from a-theoretical exercises
    - Theoretical models implying only weak qualitative implications about micro-macro relationship
    - Reproducing stylized facts (statistical properties, distributions, etc.) implied by simulated models
    - Generating new implications to be tested
  - What about using "evolutionary" models to make out-of-sample predictions and address policy implications?
    - Need for "deep" analyses of the parameter space when the latter is too large
    - Need for reduced-form models (smaller parameter spaces)
    - Clear interpretation of parameters in terms of real-world proxies
    - Treatment of time (exogenous ticks, event-driven ticks)
    - Aggregation problems: When does a stylized fact is really an emergent property or it is a mere aggregation effect?
    - Testing a well-established class of models:
      - Across-time
      - Across countries, industries, etc.
      - Against structural changes and other exogenous events
- Still, much work to be done...
  - Reproducing stylized facts in Dosi *et al.* (1994)
  - Using models for policy implications
  - Exploiting practitioners' dissatisfaction with standard equilibrium models...

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