The Network Origins of Economic Growth

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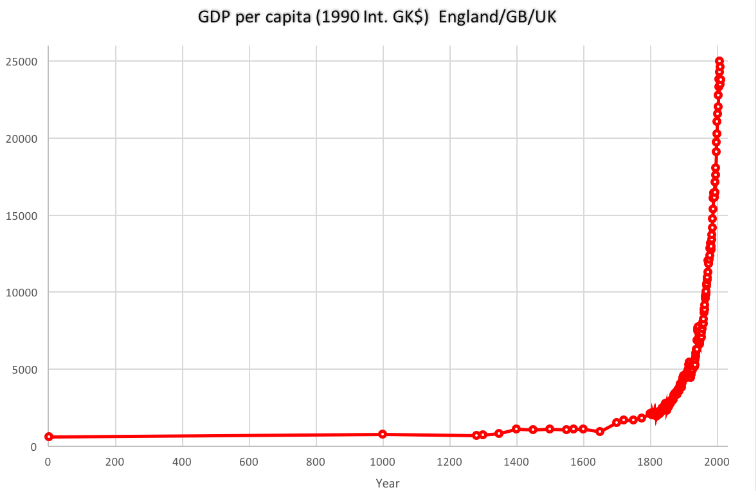
Southern Economics Association
November 18, 2017

THE Graph



Source: The Maddison-Project, http://www.ggdc.net/maddison/maddison-project/home.htm, 2013 version.

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A change in values led to different social network structure that made modern growth possible

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- Challenge 2: Explain modern growth (escape from Malthusian trap)
- Challenge 3: Why NW Europe (England)?

Broad Explanations

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- Improvement of capital goods
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- Necessary vs. Sufficient conditions

Traditional Endogenous Growth Models

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- Necessary Micro-foundations: innovations build upon each other in discrete steps, trial & error, "ideas having sex"

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- Social networks as a function of values and ideas (innovations).

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   - Does this change match that shown by **?**?
   - Can a change in values explain transition from Malthusian growth to Modern growth?
2. Social networks limit or empower productivity growth
   - Innovation as a function of network structure
   - How ideas are *generated*
   - *How* ideas spread
   - What *type* of ideas spread

Values generate Networks

- Different social values generate particular types of network structures
- Examples:
  - Downward mobility in English primogeniture (**?**)
  - "Bureaucratic" Mandarin societies (Japan, China, Imperial Rome) (**???**)
  - Marriage Networks among nobility vs. peasants (**???**).
  - Commercial societies and medieval trade (**??**)

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  2. Open/flat: "open-access orders" (**?**)
     - Impersonal, impartial, rule of law permitting open access and competition among most citizens for political & economic resources
     - Random/small worlds network—any node connects to any other node stochastically

Intuition: Ideas spread through networks

Endogenous growth with TFP spillovers on a *network*.

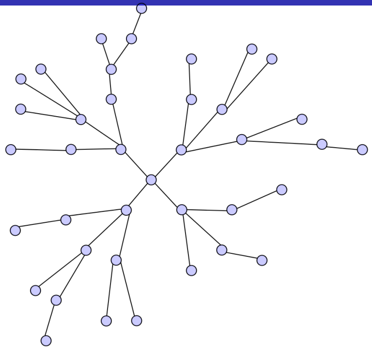
- Endogenous growth theories typically assume TFP growth spills over *instantaneously and uniformly*.
- (**?**): public goods aspect of ideas—nonrival and nonexcludable
- TFP growth should spill over through a *network of nodes.*
- Our claim: Network structure matters!

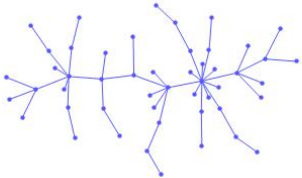
Intuition: Mechanism for TFP growth

Endogenous growth models commonly "assume innovation" ($\dot{A} \propto A$).

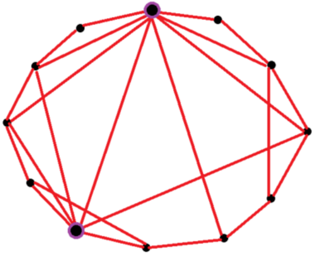
- $\dot{A} \not\propto A$, instead: $\Delta A \propto$ local network structure.
- As $g_N = \dot{N}/N = (\eta - \mu)$.
- Number of connections (edges) between N(t) members of the network is $\binom{N}{2} \propto N(t)^2 - N(t)$.
- This implies that for *some* networks, as N(t) grows large, growth rate of edges is *greater* than growth rate of population
- If $\Delta A \propto f(edges)$ then $g_A > g_N \Rightarrow g_y > 0$ in the steady state.

Some networks are more equal than others





1. Tree
2. Preferential Attachment (BA)
3. Small World (WS)



The Network Model

- The model consists of $N = \{n_t \in \mathbb{Z}_{++}\}$ arranged on an undirected graph $G = (N, E)$
- G is generated following on a fully connected Erdős-Renyi (ER) graph
- $N_i(E) = \{j : E_{ij} = 1\}$ is the set of 1^{st} -degree neighbors of agent i.

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3. Agents produce and consume production

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- Random agents are selected to "die," their edges are severed, capital stock of dead agents is distributed equally amongst those born
- New agents are "born" to the graph following ER rules, they inherit the dead's capital, and begin with the median population TFP.

The Network Model: Innovation

- Changes to TFP due to innovation are distributed exponentially

$$\phi_{t,i} \sim exp(\beta_{t,i}); E[\phi_{t,i}] = \beta_{t,i};$$

The average rate of innovation ($\beta_{t,i}$) is a function of the local network of the i^{th} agent, $N_i(E)$, specifically the clustering coefficient:

$$\beta_{t,i}(Cl_{t,i}) = D(Cl^{\gamma}_{t,i}) + \delta_{\phi}$$

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- $Cl_{t,i}$: clustering coefficient of the i^{th} agent: fraction of connected triples that include i (how many of my friends are also friends?)
- Exponential distribution and $\beta_{t,i}$ form give us useful properties:
  - $\frac{d\beta}{dCl} > 0$ and $\frac{d^2\beta}{dCl^2} < 0$
  - Clustering causes innovation to increase, but at a decreasing rate (due to the "echo chamber" effect)

The Network Model: Imitation

- Imitation ρ_i is given by an imitation probability $q_i(E)$ for each agent i
- Agents will imitate the productivity of their neighbor with the highest TFP

The Network Model: TFP evolution

Thus TFP evolves according to;

$$E[\Delta A_{t,i}] = \underbrace{D(CI_{t,i}^{\gamma}) + \delta_{\phi}}_{Innovation} + \underbrace{q_{t,i}\rho_{t,i}}_{Imitation}$$

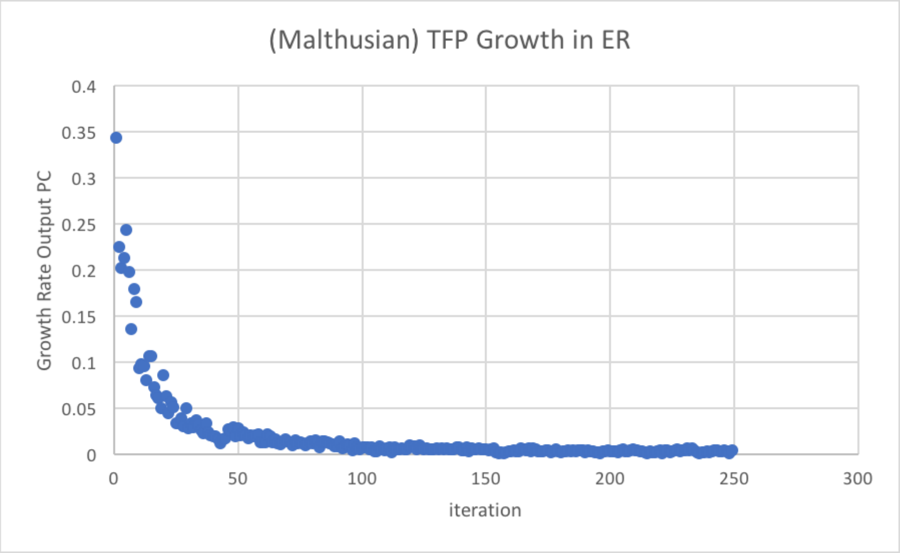
The Network Model: Production

- Every agent i, produces according to a production function

$$y_{t,i} = A_{t,i} k_{t,i}^{\alpha} l_{t,i}^{1-\alpha}$$

- All agents use 1 unit of labor and are endowed with random amount of capital, $k_{t=0,i} \sim U(0,1)$, and TFP, $A_{t=0,i} \sim U(0,1)$.
- There are no savings, $\Rightarrow K/L$ falls over time.
- TFP evolves through a stochastic innovation process, $\phi_{t,i}$, and a stochastic imitation, $\rho_{t,i}$ process.
- Thus, $E[A_{t,i}] = A_{t-1,i} + E[\phi_{t,i}] + E[\rho_{t,i}]$.

Preliminary Results



Current Limitations & Future Extensions

Immediate extensions (exogenous networks)

- "Solow" model with capital accumulation (exogenous saving rate capital accumulations)
- OLG or stochastic infinite horizons for agent lifespan
- Labor-Leisure tradeoff.
- Investment in Human Capital $\Rightarrow$ "natural" rate of innovation a function of HC.
- Make imitation success probabilistic

Further extensions (endogenous networks)

- Endogenize network generating algorithms (adaptive choice for connections).
- Endogenize growth and death rates.
- Redistributing capital upon death according to some wealth distribution

Other network structures: BA and WS

References I