The Innovation Process of Firms and Distribution Pattern of Resource Firms Gained from Innovation: An Agent-Based Model Simulation

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Brief Introduction and Research Question

From the previous study, knowledge creation and spreading are embedding in the network of social interaction. Recently, some papers focus on simulating the role and interactions among firms in the innovation context (Paier et al. 2017; Ponsiglione, Quinto, and Zollo 2017). Their works have promoted research in the field of innovation simulation. This project tries to build a NetLogo model to answer these questions: how do the firms interact to create and utilize new knowledge to gain profit? What kind of resource distribution pattern comes into being after a long-time simulation?

To answer these questions, the core of this model was based on a conceptual framework, from Manfred Paier and his colleagues' paper (Paier et al. 2017), which is related to how the firms search and make a decision to select another firm to cooperate with and create new technologies. They use Austrian biotechnology-related patent data as empirical data to adapt the model to the real world. Nevertheless, our model only uses random data without importing any specific patent data. For other parts of this model, such as visualisation, they were based on Franz Wohlgezogen's Innovation Ecosystem model, which could be downloaded from the link shown in the Appendix.

ODD Description

This paper uses ODD description to illustrate the model in details.

Purpose

This model simulates the process of innovation made by firms. These innovations are regarded as the technologies the firms achieve by exploring, learning, cooperating and creating. We assumed that these technologies are the core for firms to invent patents.

Moreover, these patents belong to a kind of capital that could be transformed into the firms' resources for paying the costs and further innovation activities.

Entities, State Variables and Scales

The objects in this model are firms. The firms exist in a non-boundary, smooth space, and the space is a 33*33 square. The firms could search for and make friends randomly within a dynamic radius, provided that the friends meet some requirements. These requirements are the core of this model, which will be illustrated in details.

The firms mainly contain these variables: resources volume they own, firm age, technology field they stay, subfield of technology they belong to, the expertise level of the firms, target technology field, target subfield, target level of expertise, research target, research strategy, and the number of cases that successfully create patents in two scenarios: cooperation and spill-over.

The model runs for 5000 steps. Each time step is a quarter of a year.

Process Overview and Scheduling

The model will be executed by the following procedures every time step sequentially:

Record the age of firms and executing the death

The age of firms will be recorded. Each firm contains the same initial resource as start-up capital. If they exhaust all resources, they will die immediately.

Create the new firms

If the current number of firms is not up to the limit, creating the new firms will be executed. The location of firms, technologies they own, research target, and strategy will be randomly selected and assigned.

Research targets

In Paier's paper, a firm contains its knowledge endowment, which will be regarded as the kene (k_{ij}). And the firm a_i engages in research activities by using the research target it set. The research targets of firm ($\bar{k}_{ij}$) will be acquired by executing one of the following procedures: gridlock, conservative, incremental, and radical. The details of how these four kinds of procedures used will be illustrated in the main submodels part.

Research strategies

After the research target being determined, the firm will use one of the research strategies shown below to achieve the target with the partner: spill-over and cooperative research. The choice will be controlled by probability p. Moreover, successful criteria will determine whether the cooperation or spill-over will bring about innovation or not.

Output

The contribution of innovation (new patents) will be transformed into the resources that firms could use for paying for costs and research. The distribution of firms' resources is represented via the histogram.

Design Concepts

Structure: The basic structure of this model contains these parts: (1) specification of firms' research details: the firms' knowledge endowment and their strategies; (2) interaction process to find a partner and create new patents; (3) output: resources (or profits) gained from new patents.

Emergence: The model's primary output is the firm's resources distribution. The stable distribution reflects how large the resources gap exists among firms, which could emerge after a long-time simulation.

Adaptive behaviour: The key firm decision is whether they will cooperate with another firm or not. The decision is made by (1) confirming the number of interactions the potential partners already have; (2) the degree of similarity between the firm's research target and partners' knowledge endowment.

Interaction: This model contains two kinds of interactions. Free interactions (cooperative research): The firm a_i could search and find a similar partner (which holds an equal or similar knowledge endowment). The similarity of the desired partner will base on the firm's $\bar{k}_{ij}$ and partner's k_{ij}. Restrictive interactions (spill-over): The firm a_i must find a partner with the same technology area as firm a_i and partner should be more professional in teaching firm a_i to improve its expertise level.

Initialization

The number of 50 firms are initialized with random location, knowledge endowment, research target and research strategy. Other variables are specified in the model interface.

Input

All the data are generated automatically without any external data imported.

Main Submodels

a. Determine the target. The model assumes that all firms contain its own kene (k_{ij}). This is the current knowledge structure firm owns. k_{ij} contains a technology class T_m, subfield S and expertise level E, where m is the total number of technology classes and S & $E \in [1,10]$. The firm a_i also has its own research target ($\bar{k}_{ij}$). $\bar{k}_{ij}$ has same form with k_{ij} and is initialized. The firm a_i randomly chooses one of strategies to change its kene to target $\bar{k}_{ij}$ (contains $\bar{T}_m, \bar{S}, \bar{E}$):

- Gridlock: firm's research target is equal to the old one.
- Conservative: firm a_i increase its expertise level ($\bar{E} = E + 1$) without changing T_m and S.
- Incremental: firm a_i modifies its research orientation by changing S to $\bar{S} = (S + 1)\ mod\ 10$ and $\bar{E} = 1$. T_m remains the same.
- Radical: firm a_i changes the previous technology class to a new one: $\bar{T}_m \neq T_m$ and $\bar{E} = 1$. S remains the same.

b. Find the partner. Once the target is determined, the firm starts to find an appropriate partner in radius (R) by choosing one of the follow conditions randomly:

- Spill-over: the partner's kene k'_{ij} contains same T_m and S with $\bar{T}_m$ and $\bar{s}$ in firm a_i. And the E in firm a_i must fulfil this condition: $E(\bar{k}_{ij}) \leq E(k')$.
- Cooperative research: partner's kene k'_{ij} needs to similar to firm a_i.If the inequality ($\left|\bar{E}(\bar{k}_{ij}) - E(k')\right| \leq \delta_1$) is true, the firm a_i could do conservative research with partner. If $\left|\bar{E}(\bar{k}_{ij}) - E(k')\right| \leq \delta_1$ or $\left|\bar{S}(\bar{k}_{ij}) - S(k')\right| \leq \delta_2$ is true, the firm could do incremental or radical research with partner.

Methodology

This paper analyses the descriptive results of simulation by focusing on these indicators:

- The number of firms in each step: This could reflect the trend of firms' scale.
- The total amount of firms' resource in the system.
- The resources distribution among the firms.

The Lorenz curve and Gini index are also used in the paper. For the Lorenz curve, the formula is as follow:

$$L_i = \frac{\sum_{k=0}^{i} R_k}{\sum_{k=0}^{n} R_k} \quad (R_1 \le R_2 \le \cdots \le R_i \le \cdots \le R_n, i \,\&k \; \in [0, n])$$

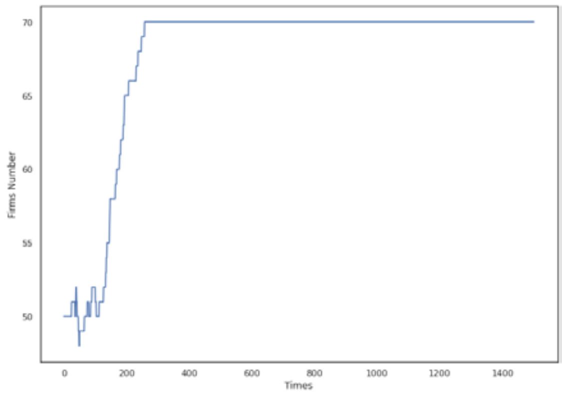
where L_i is Lorenz point i. R_i is resource of firm i. n is total number of firms. For Gini index (G_i), it is calculated by:

$$G_i = \frac{2[G_{i-1} + \left(\frac{i}{n}\right) - L_i]}{n} \quad (G_0 = 0)$$

Results and Conclusion

All initialized variables could be found in the NetLogo interface. The simulation results show that firms' resource grew up steadily, and the rate of growth was steady as time went by (Figure 2). The initial number of firms is 50. It grew up after a short time falling, and finally, it reached the limit (70) the parameter set (Figure 1). For firms' resources distribution, the Gini index in 5-times simulations indicates that the resource gap among firms fluctuated at first, and it narrowed at about 500 step and further (Figure 4). The Lorenz curve and resources distribution at step 1500 are shown in Figure 3 and Figure 5, respectively.

The agents (firms) in this model are living in a random, smooth world. Thus, this ideal world could let them search the partners, create new patents and profit from new patents freely without any boundary. The resource gap could narrow since every firm has the same opportunities to finish its process of innovation. In the future, this model could be modified by adding more restrictions on agents' behaviours and a different resource distribution pattern could emerge.



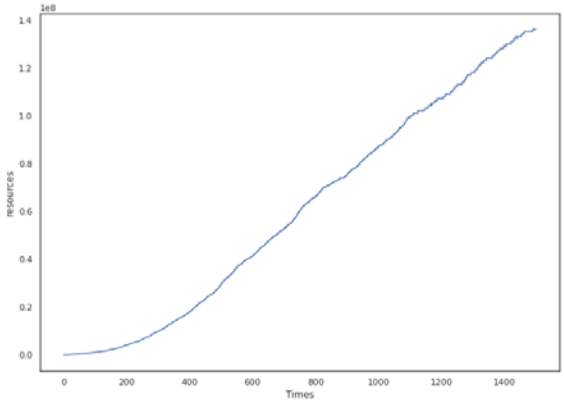
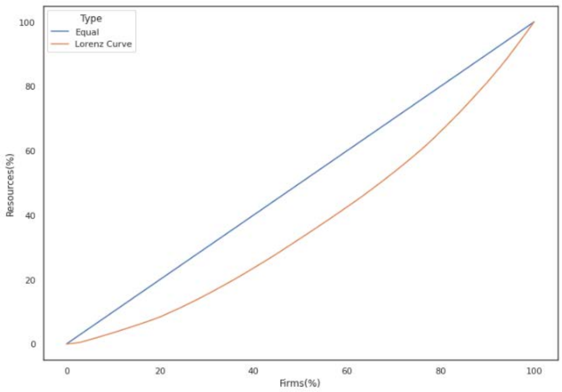


Fig.1. Number of firms **Fig.2.** Total amount of firms' resource



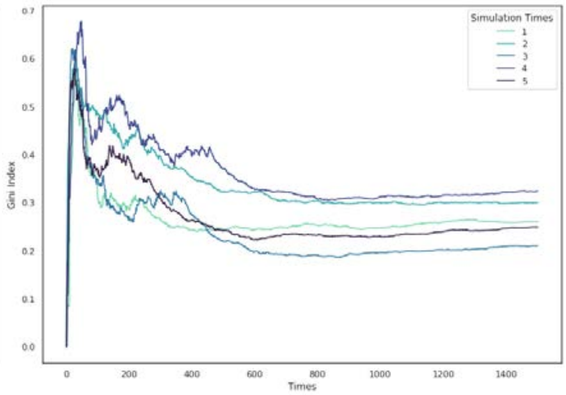


Fig.3. Lorenz curve of firms' resource **Fig.4.** Gini Index of firms' resource

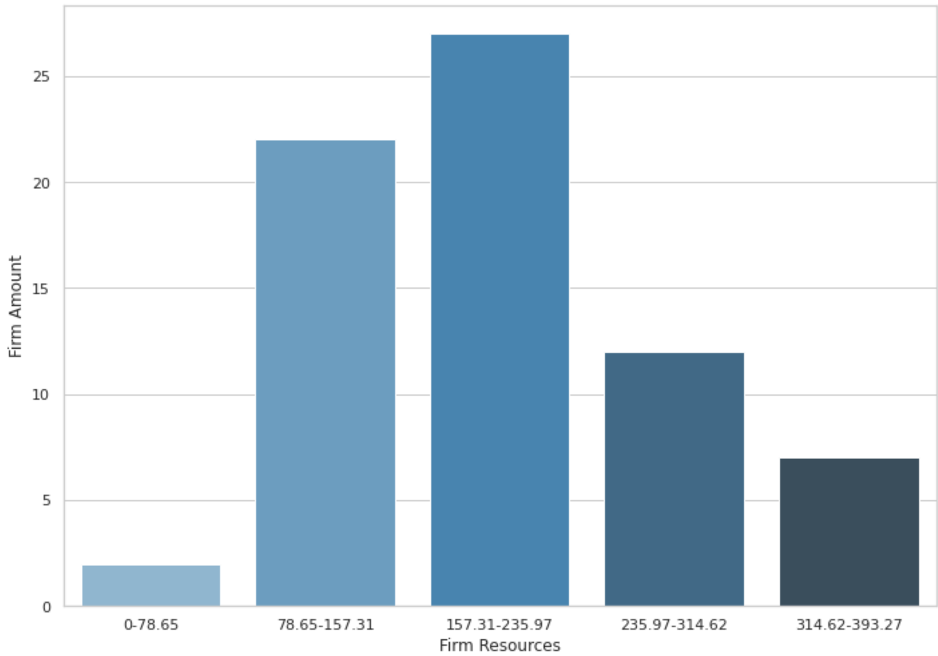


Fig.5. Firms' resource distribution

Bibliography

Paier, Manfred, Martina Dünser, Thomas Scherngell, and Simon Martin. 2017. "Knowledge Creation and Research Policy in Science-Based Industries: An Empirical Agent-Based Model." Pp. 153–83 in *Economic Complexity and Evolution*. Springer Science and Business Media Deutschland GmbH.

Ponsiglione, Cristina, Ivana Quinto, and Giuseppe Zollo. 2017. "Regional Innovation Systems: An Agent-Based Laboratory for Policy Advice." Pp. 185–214 in *Economic Complexity and Evolution*. Springer Science and Business Media Deutschland GmbH.

Appendix

Wohlgezogen's Innovation Ecosystem model could be found in this website:

http://ccl.northwestern.edu/courses/mam2009/student_work/Innovation%20Ecosystem.html