Comparing old and new urban hierarchies using agent-based simulation

Xiaomeng Li[1], Zachary P Neal[2]

[1] Department of Geography, Michigan State University, 673 Auditorium Rd, East Lansing, 48824
Telephone: (+1) 517-515-8021
Email:lixiaom2@msu.edu

[2] Department of Psychology, Michigan State University, 316 Physics Road, Rm 262, East Lansing, MI 48824
Institution, contact postal address
Telephone: (+1) 517-432-1811
Email:zpneal@msu.edu

1. Introduction

The early research on urban hierarchies sought to rank cities based on some internal attributes. Population size is often used as the proxy to investigate urban hierarchies, such as Berry and Garrison's (1958) empirical verification of Christaller's central place system. Other attribute indicators are also used, such as number of corporate headquarters, size of airports, and number of cultural events. Other attribute indicators such as number of corporate headquarters, size of airports, and number of cultural events like Rolling Stones concerts were also used (e.g. Short et al. 1996).

Since the second half of the twentieth century, the advances in transportation and communication technologies, and the trend of deregulation in national policies around the world, globalization is argued to have transformed the economies into a global economy(e.g. Friedmann and Wolff 1982; Sassen 1991). Flows of resources, knowledge and capital connect cities together into a world city network. Some cities rise to the central positions in the network while some others become peripheral (Castells 1996; Taylor 2001). Under this theoretical framework of world city network, the connectivity of a city in the network is viewed as more important than the internal attributes of cities in determining its position in the urban hierarchy (Beaverstock, Smith, and Taylor, 2000; Neal, 2011).

Different approaches have been used to identify the new urban hierarchy: some use air traffic flows to indicate the strength of intercity connections(e.g. Derudder, Devriendt, and Witlox, 2007; Neal, 2010); others use corporate networks as the central part in determining urban systems, including transnational corporations as the key players(Alderson & Beckfield 2004), and advanced producer firms and their network to the urban hierarchies(Taylor, 2001; Taylor and Aranya, 2008).

Will the new urban hierarchy formed under a different type of economy be different from the structure of the old urban hierarchy? Chase-Dunn(1985) claims that the new global economy, a world-wide network of various flows of capital, knowledge and commodities etc, does not ***fundamentally*** change the structure of the hierarchy of cities formed hundreds of years ago. Rediscovering the significance of this claim, we aim at testing it with agent-based simulation. We propose the following research question: **Under what circumstances would the new network-based urban hierarchy differ**

from the old attribute-based hierarchy, and under what circumstances does the network merely reproduce the old hierarchy?

2. Model Specification

We build an agent-based model to simulate the process of the formation of the new urban hierarchy. The simulated world contains a given number of cities. A specified amount of resources are distributed among these cities following a given distribution pattern. The “resources” here represent the bundle of *attribute* characteristics that allow a city to serve as a market for a firm. The number of resources indicates the city’s position in the “old” pre-network urban hierarchy.

Each city is the site of a single firm’s headquarters. Some firms are assigned to behave competitively, while others are assigned to behave cooperatively. Both a city’s resources and a firm’s behavior are treated as exogenous and static. Motivated by profit, firms search for cities to establish their new branches on a global scope and thus connect cities into a global network with their corporate networks formed by linkages among branches. Only one branch is allowed for a firm in one city.

For a competitive firm, the attractiveness of a city (attract) is:

$$\text{attract} = R - N \quad (1)$$

For a cooperative firm, the attractiveness of a city (attract) is:

$$\text{attract} = R + N \quad (2)$$

Where R is the amount of resources the city is endowed with, and N is the number of branches.

A firm randomly selects a city to decide whether to open a new branch (or close the branch there if already existing).

If no branch exists in the city, the probability of opening a new branch is

$$\text{Prob} = \text{attract} / \text{max-attract} * \text{max-prob} \quad (3)$$

If a branch already exists in the city, the probability of maintaining the branch is

$$\text{Prob} = \text{attract} / \text{max-attract} * \text{inertia} \quad (4)$$

Where max-attract is the maximum attractiveness among all other cities for the current moment, max-prob is the maximum probability a firm will open a new branch, and inertia is how many times more likely a firm will maintain a branch if controlling all other conditions.

The model simulates the process of firms expand to cities and gradually form an interlocking network among cities. We use the connectivity (degree-centrality) of the city commonly adopted in the literature of world city network as the indicator of a city’s position in the new network-based urban hierarchy. For city i, the connectivity is computed as:

$$\text{connectivity}_{\text{i}} = \sum \text{link}_{\text{ii}',\text{j}} \quad (5)$$

Where $\text{link}_{\text{ii}',\text{j}}$ is 1 when firm j have branches in both city i and city i’, and is zero otherwise.

3. Results and Discussions

Setting the number of cities and firms as 25, the total resources to be distributed as 200 with exponential distribution, and max-prob as 50%, we run the model for 1000 ticks for multiple times by varying the parameters of percent of competitive firms and inertia. We calculate the average Pearson correlation between connectivity and resources of the cities for each parameter setting. The results are demonstrated in the contour plots shown in Figure 1. It shows that as inertia increases, or the percent of competitive firms increases, the correlation increases, and vice versa. But generally the old urban hierarchy represented by the resource distribution and the new urban hierarchy represented by connectivity of the cities are highly correlated (.the highest=0.961 and the lowest=0.720) regardless of how we vary the parameter settings.

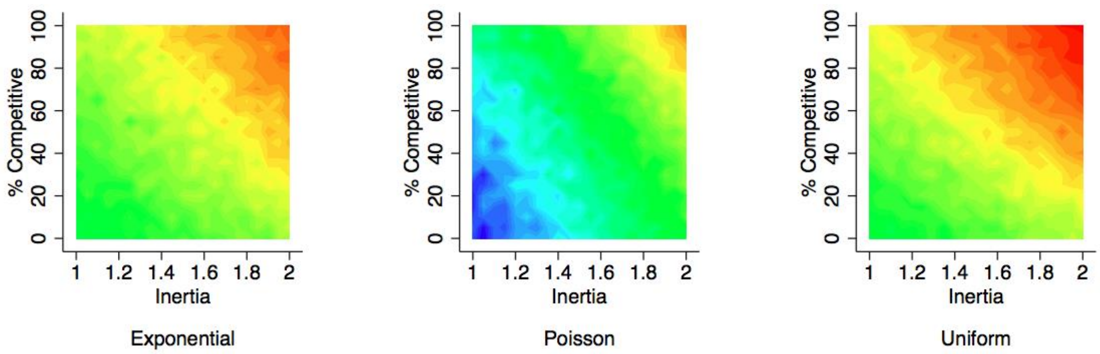

Figure 1. Contour plots of correlation between resources and network degree centrality of cities. Color indicates the Pearson correlation between the “old” and “new” urban hierarchies: **Red = High Correlation (r = 0.961); Blue = “Low” Correlation (r = 0.720)**

4. Conclusion

Using agent-based simulation, we investigate whether and how the new urban hierarchy will be different from the old one. The result suggests that within a realistic range of conditions, the new urban hierarchy will be highly similar to the old one. This indicates a strong effect of historical dependency and thus attests to Chase-Dunn’s claim that the new urban hierarchy in a global economy is not substantively different. But still, the differences in firm behaviors can make moderate impact in the formation of the new urban hierarchy: the more cooperative the firms, the more the new urban hierarchy deviates from the old one.

Our work also demonstrates the potential of agent-based modeling in the research of globalization and world city network. It circumscribes the difficulty of collecting consistent data on a global scale and offers a new channel to test theories of city networks with idealistic thought experiments.

The strength of our current model is limited given the high simplification. For future research, more parameters and more complex behavior rules should be added to reproduce a more realistic process of evolution of urban hierarchies under the new network-based global economy.

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