Journal of Economic Dynamics & Control 52 (2015) 150–165

Contents lists available at ScienceDirect

Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

Self-organization of knowledge economies ☆

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ARTICLE INFO

Article history:
Received 11 September 2013
Received in revised form
11 November 2014
Accepted 14 December 2014
Available online 29 December 2014

JEL classification:
D83
D85
O31
O33

Keywords:
Innovation
Diffusion
Two-mode networks
Power law

ABSTRACT

Suppose that homogeneous agents fully consume their time to invent new ideas and learn ideas from their friends. If the social network is complete and agents pick friends and ideas of friends uniformly at random, the distribution of ideas' popularity is an extension of the Yule–Simon distribution. It has a power-law tail, with an upward or a downward curvature. For infinite population it converges to the Yule–Simon distribution. The power law is steeper when innovation is high. Diffusion follows logistic curves.

1. Introduction

The importance of knowledge in explaining economic outcomes has been widely documented. At the individual level, educational training and skills determine income (Schultz, 1961) and capabilities (Sen, 1999). At the firm level, innovation is the source of competitive advantage and profits (Schumpeter, 1934). At the country level, technological change explains most of GDP growth (Solow, 1957).

To understand the process of economic development, one should therefore study the generation and diffusion of ideas. The literature on endogenous growth has significantly clarified the mechanisms through which knowledge can lead to GDP growth (Lucas, 1988; Romer, 1990), but less efforts have been devoted to the study of the detailed distribution of ideas in simple, decentralized “knowledge economies” in which agents create and exchange ideas. Some patterns are more likely or efficient than others (Cowan and Jonard, 2004). For economists, it is crucial to have expectations about the structure of who knows what (the distribution of ideas). For instance, since production relies on knowledge, the structure of who knows what influences the structure of who produces what (product differentiation and countries' specialization). Moreover, since

☆ This paper supplants the relevant parts of “Learning and the structure of citation networks”, UNU-MERIT working paper 2012-071, where the model is extended to explain the structure of citation networks.

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http://dx.doi.org/10.1016/j.jedc.2014.12.004
0165-1889/

knowledge is (mostly) a public good, and is (mostly) cumulative in nature, the structure of who knows what determines and is determined by the rate and direction of inventive activity. Therefore, long-run economic progress depends intimately on the detailed organization of knowledge systems.

This paper analyzes the structure of who knows what by deriving the distribution of ideas' popularity in a simple model based on the assumption that attention is allocated between innovation and imitation. The objectives are first, to find conditions under which a stable system can be characterized, and second, to characterize the resulting organization. In other words, this paper studies the self-organization of knowledge economies: when a collection of agents produces and consumes knowledge, can we expect a certain form of stability in the distribution of knowledge? and if so, which is this stable form? I find that if the trade-off between innovation and imitation is constant, then a stable distribution of ideas' popularity emerges, in spite of the disturbing force of innovation being at play, with new ideas arriving regularly. Moreover, even though which ideas diffuse and which agents are chosen to receive and diffuse knowledge are stochastic events, self-organization produces a certain stability in the average overlap among agents' ideas' portfolios, and hence in the distribution of ideas' popularity. Self-organization can be understood at the mean-field level, where there exists a fixed point, self-consistency equation from which one can derive a steady-state that is unique. In other words, when agents create new ideas and learn random ideas of random friends, after some time the structure of who knows what will be such that the diffusion process is compatible with that same structure, even though it is growing due to innovation. Hence it is a stable, self-organized knowledge economy.

The distribution of ideas' popularity is, roughly speaking, a power law, due to the fact that learning random ideas of random friends produces cumulative advantage (or self-reinforcing dynamics) in ideas' diffusion: the more an idea is known, the higher the chances that it is found at random in a random friend. However, since population is bounded, which ensures bounded diffusion, the power law has finite support (ideas are known by at most the number of agents in the population). When the social network is complete, this finite support power law is characterized precisely, as a discrete distribution which is a particular case of a Generalized Hypergeometric Distribution, and an extension of the Yule–Simon distribution. Changing the social network can change the distribution of ideas' popularity to some extent, and this is investigated mostly using simulations.

The relationship between the special Pfaff–Saalschützian Generalized Hypergeometric distribution derived here and the Yule–Simon distribution follows from the fact that the proposed model can be seen as an extension of Simon (1955) model. In Simon's original model, there are agents and ideas. At each period, a new idea arrives. With some fixed probability b, it goes to a new agent (created simultaneously). Otherwise, it goes to an agent chosen with probability proportional to the number of ideas that he holds. This process leads to a steady-state distribution of the number of ideas per agent which has power law tail, and is called the Yule–Simon distribution. For instance, among many other fields of application, Simon fitted his distribution using scientific authors and their papers. My starting point is that diffusion is missing. Scientific papers, like technologies and social norms, diffuse through the population. For clarity let me abstract from agent heterogeneity, and consider a fixed number of agents. I still want to have a growing number of ideas, consistent with reality, but also wish to allow agents to learn ideas of/from others. Since I contend that attention is limited, I assume that at each period, a randomly

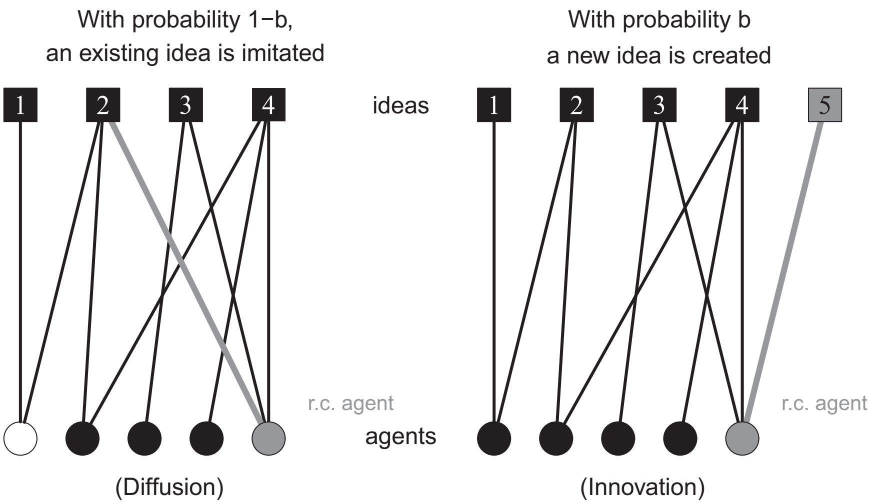

Fig. 1. Schematic description of the model. At each time step, one and only one of the two events represented above happens. In both cases, a link is added. The main focus here is on the degree distribution of the top nodes (ideas' popularity), $p(k)$. The degree distribution of the bottom nodes is discussed in Appendix B but is purposefully uninteresting (agents are homogeneous so it is binomial). On the left panel, the r.c. agent (in gray) is learning. In this case, a neighbor has been randomly chosen and turns out to be the leftmost (in white). There are only two ideas unknown by the r.c. agent and known by the r.c. neighbor (1 and 2). The randomly chosen agent chooses uniformly at random an idea of the r.c. neighbor that he does not know himself— in the example above he turns out to choose the second idea (a link (in gray) is added between the r.c. agent and this idea). On the right panel, the r.c. agent has created a new idea. The social network between bottom nodes, not depicted here, is assumed to be full throughout the paper except in Section 5.1.