Self-Organizing Production and Exchange

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Abstract. Consider autonomous agents endowed with two goods and the capability of producing each. Regularly each agent can produce one (only) of the goods or trade with other agents. Each good yields utility according to a utility function. This paper studies how utility-maximizing agents optimize in these circumstances, examines the aggregate characteristics of the resulting economy, and investigates the internal organization of production and exchange.

Key words: emergent organizations, trade networks, customer loyalty, specialization

1. Introduction

Much of what economists do consists in explaining how, and how well, a society organizes its production and exchange. While we recognize the efficiency gains and the wealth generated by specialization and the division of labor, we have less understanding as to how and under what circumstances such organization arises. This paper investigates the evolution of economic organization by constructing an artificial economy in which autonomous agents deal with production and exchange.

Repeated experiments with different populations suggest that economic structure naturally emerges from agents that are simply trying to do the best they can.

Agent-based computational-economic models allow economists to observe the dynamic behavior of simple economic systems and to compare their performance with theory. For example, Albin and Foley (1992) constructs a pure exchange economy (similar to the pure trade model in this paper) and finds that a decentralized market quickly attains Pareto prices. Vriend (1995) sets up a system of buyers and sellers, gives them a method of communicating, and studies the characteristics of the emerging markets. More recently, Howitt and Clower (2000) and Dawid (2000) construct economies in which intermediaries (stores) emerge to facilitate trade. Finally, several investigators concentrate on the geographical aspects of trade by studying trade networks in which a specific topology is introduced to the system or in which agents evolve their own trade topology. These include the studies in Ioannides (1997), Kirman, Oddou, and Weber (1986) and Epstein and Axtell (1996).

In this study we consider an economy in which artificial agents are able to produce one of two goods which they can trade among themselves. Constrained by
time, agents can take only one action each period, either producing one of the goods or trading for one. We are interested in both the macro and microeconomic consequences of these choices. And though the choices are simple – each agent simply tries to improve his or her situation – we see a variety of strategies adopted by these agents and also witness the emergence of some organizational structure within the artificial society. Specifically, many agents specialize in production or in trade. A subset of those specializing in production specializes further by concentrating on the production of a single good.

Finally, when agents possess some intelligence, they form long-term trade relationships with a select few other agents in the economy.

2. A Model Economy

The two goods of our simple economy are durable in that they survive and suffer no real depreciation (no degradation) during the experiment. Both have value as an intrinsic source of pleasure and as a durable asset to be used in exchange. Examples might be books, toys, works of art, precious stones and other collectibles. One of the goods, $g_2$, is infinitely divisible but the other, $g_1$, must be traded in whole units, a requirement that adds some rigidity and realism to the model. As it turns out, this has little impact on the issues of central concern herein.

In this artificial economy $n$ agents vie for the possession of the goods to maximize their utility according to a symmetric Cobb-Douglas utility function. Agents are initially endowed with a randomly determined allocation of each good and, depending on the experiment, are able to trade these goods among themselves or produce more of each according to their own, unique production function. Agents are rational, non-strategic, and myopic, in that they do not attempt to mislead potential trade partners or plan for future opportunities. They simply try to improve their current position in each period by producing one of the goods or engaging in voluntary exchange.

The utility $U_i$ of agent $i$ depends on the amount of the two goods, $g_1$ and $g_2$ he possesses according to the utility function

$$U^i = g_1^i g_2^i, \quad i \in \{1, \ldots, n\}.$$  

Each agent’s ability to produce good 1 and good 2 is given by a simple production function whose capacity is set at the beginning of the experiment and fixed throughout. Thus, in each period the agent chooses to produce, he may produce $r_i$ amount of good 1 or $s_i$ amount of good 2. So,

$$\Delta g_1 = r^i; \quad \Delta g_2 = s^i \quad r, s \in \{1, \ldots, k\}; \quad i \in \{1, \ldots, n\},$$

where $r$ and $s$ are randomly determined integers lying in the range of 1 to $k$. In the simulations reported here, we set $n = 250$, $k = 30$, initial endowments range from 1 to 60, and the number of rounds equals 200.