Chapter 25

Emergence of Networks in Distance-Constrained Trade

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Abstract

Long-distance trade has been rapidly increasing in recent years. As traders from around the world exchange goods, they form networks with traders as nodes and transactions as links. We use an agent-based model of a simple artificial economy to examine the emergence of trade networks when the distance between traders matters. Distance can become an issue if fuel for transportation becomes expensive or if greenhouse gas emissions from transportation become a major concern. We model the distance constraint as a transaction cost proportional to the amount of goods traded and the distance that those goods must be transported. We find that the resulting network topology is a good indicator of the stability and resilience of the economic system. The topology is random when there is no distance constraint. As the transaction cost increases, the topology transitions into a stable scale-free structure with some clustering, and a large fraction of trade occurs within local regions around the network hubs. Under these conditions, the final welfare of the traders decreases only modestly and environmental efficiency increases significantly when each region has a diverse combination of tradable goods.

1.1. Introduction

Long-distance trade is an integral part of globalization and has been rapidly increasing in recent years. As traders from around the world exchange goods, they form networks where the traders represent nodes and transactions between them represent links. We examine the emergence of these trade networks using an agent-based model of a simple artificial economy, in which the distance between traders significantly influences the cost of trading. Distance can become an issue if fuel for transportation becomes expensive, or if greenhouse gas emissions from the fast-growing transportation sector become a major concern [Venkat 2003]. While information technology is rapidly

removing many long-standing obstacles to free trade, the ultimate constraint to trade may well be our ability to physically move material goods between traders over long distances at an acceptable real cost.

We hypothesize that a distance constraint might lead to a restructuring of the fast-growing society of global traders, and stimulate new kinds of trade relationships and networks. We test our hypothesis in this study using the techniques of agent-based computational economics [Tesfatsion 2006] in a simple setting as a first step. While other studies have focused on the effects of fixed network structures [Wilhite 2001; Wilhite 2006], we take the view that trade networks are highly malleable and arise from the same constraints that influence economic performance. Given the evidence so far that complex systems encode their organizing principles at some level in their topology [Barabasi, et al, 2004], we investigate the evolution and structure of the networks in order to characterize the organization and functioning of our artificial economy.

We model the distance constraint as a transaction cost. This cost reflects some degree of internalization of the real environmental costs of long-distance trade, including fossil fuel depletion and greenhouse gas emissions. We study the effect of this transaction cost under two different initial allocations of tradable goods, one where there are regional differences and the other where the goods are uniformly distributed throughout the world. We are particularly interested in the properties of trade networks that emerge as we vary both the transaction cost and the initial allocation, and we examine how the network properties correlate with economic performance and environmental efficiency.

1.2. Trade Model

We formulate the trade problem based on our previous work [Venkat and Wakeland 2006], adapting a simple barter economy that has been used to study economic activity on fixed networks [Wilhite 2001; Wilhite 2006]. Our artificial world consists of 1024 traders spaced uniformly in the four quadrants of a flat space, as shown in Figure 1(a). Each trader is an agent who remains at a fixed location, and is able to trade with others who may be at other arbitrary locations. Traders are presumed to find potential trade partners and negotiate the terms of trade through mechanisms that are independent of their locations, such as globally-accessible electronic trade exchanges.

Each trader starts out with an initial endowment of two durable goods, g1 and g2, ranging from 0 to 1500 units each. The two goods suffer no degradation over time and serve as assets that can be exchanged. There is no production and the aggregate stock of goods changes only to account for the transaction cost as described later. The initial allocation can follow two distinct scenarios, maintaining nearly equal amounts of g1 and g2 in our artificial world:

- "Globally mixed random" (GMR): There are no regional differences. Each trader gets random quantities of the two goods such that the total quantity of both goods together is exactly 1500 units.
- "Local comparative advantage random" (LCAR): The eastern half of the world has more g1 than g2, and the western half has more g2 than g1. Each trader in the east receives at least 1200 units of g1 and no more than 300 units of g2. Each trader in the west receives at least 1200 units of g2 and no more than 300