Games and Economic Behavior 67 (2009) 36–50

Contents lists available at ScienceDirect

Games and Economic Behavior

www.elsevier.com/locate/geb

Trading networks with price-setting agents ☆

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ARTICLE INFO

Article history:
Received 26 July 2007
Available online 24 December 2008

JEL classification:
C72
L14

Keywords:
Networks
Trade
Price formation

ABSTRACT

In a wide range of markets, individual buyers and sellers trade through intermediaries, who determine prices via strategic considerations. Typically, not all buyers and sellers have access to the same intermediaries, and they trade at correspondingly different prices that reflect their relative amounts of power in the market. We model this phenomenon using a game in which buyers, sellers, and traders engage in trade on a graph that represents the access each buyer and seller has to the traders. We show that the resulting game always has a subgame perfect Nash equilibrium, and that all equilibria lead to an efficient allocation of goods. Finally, we analyze trader profits in terms of the graph structure — roughly, a trader can command a positive profit if and only if it has an "essential" connection in the network, thus providing a graph-theoretic basis for quantifying the amount of competition among traders.

1. Introduction

The baseline analysis of buyers and sellers interacting in markets is the Walrasian model, wherein trade between anonymous buyers and sellers takes place at a single market clearing price. This reduced form view of trade is a powerful model which has led to many insights. However, it does not model how a single market price emerges from the behavior of market participants. The Walrasian model ignores the variety of market institutions and customs, and how traders act given the rules of the game, to agree upon prices at which to trade.

Three facts are common to a variety of market institutions: Individual buyers and sellers often trade through intermediaries, not all buyers and sellers have access to the same intermediaries, and not all buyers and sellers trade at the same price. Two important, and quite different, examples are trade of agricultural goods in developing countries and trade of financial assets.

Consider, for instance, the petty trade of agricultural goods in developing countries. Given inadequate transportation networks, and poor farmers' limited access to capital, many farmers have no alternative to trading with middlemen in inefficient local markets. A developing country may have many such partially overlapping markets existing alongside modern efficient markets (Barrett and Mutambatsere, 2008). Goods flow through a network, from the producer to a trader in one market, through that trader to a second market (or farther) where they finally meet consumers. Some buyers and sellers have links to several traders, while others may be forced to deal with only one trader. In general, most traders do much

☆ A short version of this paper appeared in the EC'07 Conference Proceedings. This work has been supported in part by NSF grants CCF-0325453, IIS-0329064, CNS-0403340, and BCS-0537606, ONR grant N00014-98-1-0589, a Google Research Grant, a Yahoo! Research Alliance Grant, the Institute for the Social Sciences at Cornell, and the John D. and Catherine T. MacArthur Foundation. We would like to thank GEB Guest Editors David Parkes and Moshe Tennenholtz and three referees for helpful comments and suggestions.

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0899-8256/$ – see front matter
doi:10.1016/j.geb.2008.12.002

repeated business with a small clientele, very few traders are "wholesale only," and goods moving from one market to another will move through only a few hands (Fafchamps and Gabre-Madhin, 2007).

In financial markets, much of the trade between buyers and sellers is also conducted through intermediaries, such as brokers, market makers and electronic trading systems. Markets for actively-traded assets are global; there is no one market. Trade in a given asset may occur simultaneously on the floor of an exchange, on crossing networks, on electronic exchanges, and in markets in other countries. Some buyers and sellers have access to many or all of these trading venues; others have access to only one or a few of them. Each individual market, such as the NYSE, NASDAQ or London Stock Exchange, consists of many, densely connected traders. These highly connected markets are themselves linked, though less densely, through traders who arbitrage across markets. One of the most striking examples of this phenomenon occurs in the market for foreign exchange, where there is an interbank market with restricted access and a retail market with much more open access.

In this paper, we develop a framework in which market trade is mediated through middlemen, and in which the flow of goods is constrained by a preexisting network of market relationships. The market is described by a network whose edges represent the direct access that different market participants have to one another. We model trading networks as tripartite graphs, in which distinct types of vertices represent buyers, sellers, and traders. Edges connect buyers and sellers to traders. They represent the direct access market participants have to one another. In principles, such a network model can also contain edges that connect traders to other traders, although we do not consider this here. Networks for different kinds of commodities can be quite different. Networks for petty trade in vegetables, root crops and the like are, as we observed above, fairly sparse, and dominated by low-degree nodes. In a network of financial markets, the discrete markets comprising it are densely connected, with fewer links between them. The degree distribution is highly dispersed. Some trading firms are active on many markets, and may represent many clients, and so their degree is high. Other firms may specialize in only a few assets and trade only their own accounts, and so their degrees are low.

Prices in the markets we study come from the interaction between buyer or seller and the intermediary. In petty trading markets, the price is often the outcome of bargaining between buyer or seller and trader. Financial markets contain a variety of intermediation schemes. In some markets, market makers post bid and ask prices for sellers and buyers, respectively. In U.S. financial markets, new issues are often introduced through auctions. In some markets the intermediary is a software agent that sets prices to clear the market. In most cases, the intermediary makes his profit off the spread, the difference between bid and ask, the buy and the sell price, or (and it amounts to the same thing) fixed per-transaction fees. Spreads for a given asset can differ significantly across markets, depending upon their thickness, characteristics of participants, and upon the rules of trade.

We model trade as a two-stage, complete-information game.[1] Traders strategically choose bid and ask prices to offer to the sellers and buyers to whom they are connected. The sellers and buyers respond by choosing with whom to trade, or not to trade at all. The network encodes the relative power in the structural positions of the market participants, including the implicit levels of competition among traders. We show that this game always has a subgame perfect Nash equilibrium, and that all equilibria lead to an efficient (i.e. socially optimal) allocation of goods. In particular, the market enables the "right" set of people to get the good, subject to the network constraints. We also analyze the division of the surplus from trade — how, in particular, trader profits depend on the network structure.

Our work here is connected to several lines of research in economics, finance, and algorithmic game theory. At a general level, our approach can be viewed as synthesizing two important strands of work: one that considers price-setting intermediaries, but without network-type constraints on who can trade with whom; and another strand that treats buyer–seller interaction using network structures, but without attempting to model the processes by which prices are actually formed.

The study of brokers, intermediaries and middlemen is common to many areas of economics, including finance (O'Hara, 1995), industrial organization (Hall and Rust, 2000; Lamoreaux and Sokoloff, 2002; Rubinstein and Wolinsky, 1987; Spulber, 1999) international finance (Krishna et al., 2004) labor economics (Edid, 1994; Yavas, 1994) and macroeconomics (Hellwig, 2003; Li, 1998). Most of this literature is concerned with the role of intermediaries in facilitating or blocking information flow, their role in transactions cost reduction, and the rents they capture through management of the trading process. None of this research is concerned with the participation constraints created by the network structure of markets.

The computer science literature has taken seriously the effects of network structure on market prices. Kakade et al. (2004) have characterized competitive equilibrium prices when buyer–seller interaction is mediated by a network. Even-Dar et al. (2007) study the strategic aspects of network formation when prices arise from competitive equilibrium. Babaioff et al. (2005), and Chu and Shen (2006) examine mechanism design issues for effecting trade when market participants are connected through a network. Sarma et al. (2007) provide an algorithm that computes a Nash equilibrium for a related game of pricing and trade on a network of buyers and sellers.

The classic results of Shapley and Shubik (1972) on the assignment game can be viewed as studying the result of trade on a bipartite graph in terms of the core. They study the dual of a linear program based on the matching problem, similar to what we use for a reduced version of our model in the next section, but their concern is not with the mechanisms of price formation in markets. Most importantly, we have prices set strategically by traders. Leonard (1983) studies VCG prices

[1] It is important for our analysis that traders know the values that buyers and sellers place on the goods. So our model is best thought of as applying to settings in which the traders have experience in trading with these buyers and sellers. Buyers and sellers, on the other hand, do not need to know each others values. It is enough for them to be able to observe the prices quoted by traders.