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Network Economics with Application to Finance

by

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Abstract

Networks are common in financial services. Perfect competition does not decentralize optimality on a network, and coordination of participants expectations and investments is crucial for success. Financial exchange networks exhibit two kinds of externalities: liquidity enhancement by size expansion, and underpriced provision of market price information to outside rivals. We discuss the interaction of these externalities in alternative exchange network structures.

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Networks and network externalities play a central role in the New Industrial Organization. Many network industries, such as telecommunications, railroads etc., are central to modern economic life. Further, the essential relationships among the components of the network, i.e., **complementarity** and **compatibility**, are present in many non-network industries, including financial intermediation and the exchange of financial instruments and assets. In this paper, we analyze and review the essential features of networks and show their application to finance.

A crucial feature of networks is that they exhibit **network externalities**, i.e., production or consumption positive size externalities. In a typical network, the addition of a new customer (or network node) increases the willingness to pay for network services by all participants. When a new node is added to a network, new goods are created. Consumers demand these goods that were unavailable before. Thus, consumers are better off after the new node was added. The benefits of the addition of an extra node (or an extra customer) exceed the private benefits accruing to the particular node (or customer).

As an example of this, consider a simple star network consisting of a central node S and peripheral nodes A, B, C, etc., as in Figure 1. This can be a telecommunications network if S is a central switch and A, B, C, etc. are the locations of the various customers. Customers demand phone calls ASB, BSA, ASC, etc. These are **composite goods**, each comprised of two complementary **components**; for example ASB is comprised of AS and SB. All components AS, BS, etc. are complementary to each other.

<<INSERT FIGURE 1>>

The addition of a new node to an n-node network, say node G (through the creation of link GS), creates 2n new products. This is an economy of scope in consumption that is commonly called a "network externality". The externality affects directly the utility function of consumers through the provision of new goods, and it also may affect consumers indirectly through market-induced decreases in prices.

Alternatively, the network of Figure 1 may be a financial exchange network where S is the central exchange, and A, B, C, etc. are the locations of the brokers or consumers. In an exchange, consumers are differentiated according to their willingness to pay for the traded security. Given a market price, one can divide very broadly the market participants to those willing to purchase (demand) the security at the going price, from those willing to sell (supply) the security at the going price. Of course, traders are further differentiated by differences in their reservation prices, and their particular demand and supply sizes.[1]

Keeping the broad differentiation of demand and supply only, we may describe the financial intermediation network as consisting of two categories of traders, demanders, D_1, ..., D_m, and suppliers, S_1, ..., S_n, who "meet" at the exchange E, as in Figure 2. Both demanders and suppliers of the security demand a "trade," i.e., the matching of their offer with a complementary offer. Thus, each offer to buy, i.e., each component D_iE, is complementary with matching offers to sell, represented by a subset of components such as S_jE. Therefore, in a financial exchange network, not all components are complementary with each other. However, just as in the telephone network, the addition of a new component (say a new offer to buy) affects positively

[1] And, of course, as price varies, some traders switch from the demand to the supply side and vice versa.

the complementary components (the matching offers to sell). Further, the benefits of an additional offer to buy are not limited to the party (component) that directly matches this buy offer. In general, the addition of a new buy offer has beneficial effects (through price) for a wide subset of sell offers. Thus "network externalities" in a financial central exchange network appear in a subset of traders "on the other side" of the market.

<<INSERT FIGURE 2>>

Under uncertainty, the expansion of counter-matching offers (created by the expansion of the network) can be beneficial to market participants even when the counter-matching offers (or the traders who make them) are drawn from the same distribution. This was shown in Economides and Siow (1985, 1988).[2] In these papers, traders are drawn from the same distribution of uncertain endowments. As the network expands, the market uncertainty, measured by the variance of market price) is diminished. This is essentially an effect of the law of large numbers operating on the subsets of matching counter-offers that expand as the number of market participants increases. Thus, in a simple financial exchange under uncertainty, network externalities take the form of a reduction in realized market uncertainty.[3]

The earliest paper noting the existence of network externalities in pure networks is Rohlfs (1974). The basic distinction between those networks where all components are complementary to each other (as in Figure 1) and the ones where only some components are complementary to each other (as in Figure 2) was made by Economides and White (1993), who named the former "two-way networks" and the latter "one-way networks." They also noted that two-way networks

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[2] These papers build on earlier work by Garbade and Silber (1976a,b, 1979)

[3] See also Economides (1992b).

exhibit reversibility (reciprocity) since goods ASB and BSA are different, while the composite good D_iES_j is identical to good S_jED_i in one-way networks. Thus, in the context of Economides and White (1993) a central financial exchange is a one-way network.

The essential relationship between the components of a network is **complementarity**. For some goods, complementarity is realized immediately. For example, a small amount of sugar dissolves immediately in coffee. However, larger quantities of sugar require stirring. Similarly, in most situations the complementarity between two components exists only in potential and is not realized automatically. The components may require a third component (e.g. stirring in the previous example, or a central exchange mechanism in the financial network). Further, to realize the benefits of complementarity, the components require **compatibility** and **coordination**. For example, in telecommunication and railroads coordination takes the form of technical compatibility in the communication standards and the specification of the width between the rails. In a financial network, besides the technical aspects of compatibility, there is a need for **coordination in time and place**. And since compatibility is not immediate, one has to examine carefully the alternatives facing the participants as well as the exchange.

Networks are by their nature self-reinforcing. This is just another way of saying that they exhibit positive size externalities. As a direct consequence of their self-reinforcing nature, networks frequently exhibit **positive critical mass**. This means that no network of size smaller than this positive size, called critical mass, is ever observed, at any price. How does this happen? Because of the self-reinforcing nature of the network, the same price can support two different network sizes associated with quite different utility levels.[4] Despite the multiplicity of equilibria, one expects that, for a given price, only the network that corresponds to the highest utility will be observed. Thus, small network sizes will not be observed, and the network exhibits positive critical mass.[5]

A second direct consequence of self-reinforcing is that optimality will not result from perfect competition. Marginal cost pricing on a network disregards the externality and therefore cannot support the first best. This opens the possibility that some market structures (such as monopoly), which can coordinate expectations, might achieve larger network sizes and higher welfare than perfect competition. A monopolist has, as usual, an incentive to reduce output (network size) because his marginal revenue is below price. However, the monopolist also has an opposing incentive. If the monopolist can coordinate consumers’ expectations so that they flock to the network, he can achieve (because of network externalities) a larger surplus for each consumer, which he can then appropriate. Nevertheless, Economides and Himmelberg (1993) show that, in a large class of cases, the usual output-reducing incentive of the monopolist supersedes, so that he will provide a smaller network and will underperform perfect competition.

A third consequence of the self-reinforcing nature of networks is that history matters. There is a possibility of lock-in at a Pareto inferior equilibrium.[6] For example, David (1985) claims that there are significant inefficiencies in the standard "QWERTY" U.S. keyboard, that

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[4] Katz and Shapiro (1985), Farrell and Saloner (1985, 1986), Cabral (1990), Cabral and Leita (1988), Economides and Himmelberg (1993).

[5] Economides and Himmelberg (1993).

[6] Arthur (1988, 1989). See also the non-network theories on lock-in in Farrell and Shapiro (1989), Gallini and Karp (1989), Klemperer (1987a, b), Beggs and Klemperer (1992).

the Dvorak keyboard is superior, and that the economy is locked-in at the inferior design because of significant switching costs, such as retraining and learning costs.[7] Clearly, the divergence of private and social interest, even under perfect competition can be further accentuated in sequential choices where, once a certain design choice has been made, it is privately optimal (and occasionally socially optimal) to keep improving that design rather than switching to a new design.

An important consequence of these observations is that, in a network setting, coordination to a particular "good" equilibrium is important. Besides coordinating expectations, this may require joint decisions on investment, or sponsorship by a particular firm.

Many networks are **sponsored** by a particular firm or collection of individuals through the setting of the "standards" of the network. For example, the N.Y.S.E. sets its own conditions and specifications of the particulars of the acceptable transactions, including the time and the setup of the matching process. Lock-in is particularly important in the presence of **market power** in **sponsored networks**. In general, firms may be very reluctant to change their way of operation, especially if they have to pay the costs of transition. The self-reinforcing nature of networks creates switching costs for the existing customers. The existence of positive critical mass often means that in the presence of one network, a differently-organized one may not even exist. These facts give market power to firms that sponsor networks, and may impede technological innovation.[8]

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[7] This is disputed by Liebowitz and Margolis (1990).

[8] See Katz and Shapiro (1986a,b), Farrell and Saloner (1985, 1986).

One can view the various financial exchanges (NYSE, NASDAQ, AMEX, Pacific, London, Tokyo, etc.) as well as the various companies that provide matching services (Instinet, Posit, AZX, etc.)[9] as (at least partially) incompatible networks. The existence of such a variety of organizations begs the question of the potential for new innovative ways of organization of transactions, matching of orders and price discovery.[10]

Electronic **call** markets, where all orders are batched together and executed at once, reduce market price uncertainty and utilize to a larger extent the network externality than a continuous market.[11] Technological progress in electronic computers has made it possible to run electronic **call** markets where all stocks are cleared simultaneously.[12] Economides and Schwartz (1993a) propose three calls a day (at the opening, at 12:00 and at the close) on top of continuous trading in the U.S. equity markets. Economides and Heisler (1993b) discusses the theoretical equilibrium of the coexistence of call and continuous markets. Economides and Heisler (1993a) establishes the fee structure for transaction fees in a call market. Traders who

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[9] AZX's system includes price discovery, but because of small volume, it presently acts frequently as a matching network with the clearing price given from outside.

[10] Broadly speaking, exchanges are defined in legal terms as places of interaction among brokers. The present electronic communication technology allows an individual or a firm not in financial intermediation to participate in the exchange on almost equal footing as a broker. One expects that these regulations will be liberalized in the face of technological change.

[11] Economides and Siow (1985, 1988).

[12] The simultaneous closing of the markets for all securities will traders to place contingencies on the orders. For example, a buy order may be contingent on it not representing more than a certain percentage of the total transactions of that security. Or, a contingency may place a limit on the total exposure of a certain category of stocks.

enter their orders early are charged a lower fee as a reward for generating extra liquidity in the market.[13]

Financial markets exhibit significant externalities of two types. So far we have discussed in detail the positive externalities created by traders through the provision of **market liquidity**, the possibility of capturing these externalities in a call market, and the possibility of encouraging higher liquidity through early declaration of market participation induced by lower transaction fees for early participants in call markets. A second externality arises because an **unpriced output** of a financial exchange network is the equilibrium market price. This information is of crucial importance to potential market participants. It shows the potential benefits and losses from a proposed trade done through this network. For the benefit of these potential traders, market price should be reported as accurately as possible. However, the market price established in network X can be used by competing network Y to complete transactions within network Y. Thus, network X has a private incentive to report prices inaccurately (for example to report a large bid-ask discrepancy).

Things are further complicated, when one considers the effects of the utilization of market price information by opponents. The validity of the market price established in network X is an increasing function of the size of this network. Thus, it may be better for a small network Y to use the price established in large network X, and not to engage at all in price discovery itself. This presents a crucial problem for the industrial structure of a market of competing networks. As more customers switch to network Y, the validity of the market price established in network

[13] AZX that presently runs an after-hours call market uses fee discounts for early entrants in their electronic double-sided electronic auction.

X is reduced. Thus, we can end up with price being discovered within a small group of participants and used in a wider group.[14]

The search for increased market liquidity drives the markets toward compatibility and increased coordination. Compatibility increases demand for transactions, but can also increase competition as the services offered by the compatible networks become more similar in dimensions that are of importance to traders. Thus, compatibility is not immediately desirable to a network, which has to balance the benefit of increased demand with the drawback of increased competition.[15] Of course, the compatibility standards set by the sponsor are the most profitable to it.[16] These standards may also be set to raise the costs of a rival network.[17]

In networks that are set up as joint ventures, there are significant benefits because of the coordinating function of the joint venture in bringing together complementary components. These benefits are diminished, and social welfare may suffer when the partners in the joint venture are in horizontal relationships (i.e., sell substitutes) as well. For example, a joint venture among competitors may lead to price fixing or price coordination that may be disguised as a part of the standard-setting process.[18] From a public policy point of view, it is important to make sure that

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[14] This problem does not disappear if network Y pays network X for the use of the price established in network X. Market price will still lose validity as the size of network X decreases.

[15] This balance is discussed in Matutes and Regibeau (1988) and Economides (1988, 1989, 1991).

[16] See Berg (1988).

[17] Economides and White (1993), Salop and Scheffman (1983), Krattenmaker and Salop (1986).

[18] In a recent antitrust suit (see Kauper (1988)) an ATM (automatic teller machine) network was sued for price fixing because it set uniform fees for withdrawals made in the network.

competition is not diminished by the introduction of compatibility standards and the coordination afforded by a sponsored or joint venture network.

In summary, networks are common in the modern economy as well as in the financial services sector. Perfect competition does not decentralize optimality on a network, and coordination of participants expectations and investments is crucial for success. Financial networks exhibit two kinds of externalities: liquidity enhancement by size expansion, and underpriced provision of market price information to outside rivals. Both externalities can produce significant welfare distortions. However, markets structures can be established and fine tuned so as to realize more fully the positive externality of liquidity enhancement (for example through interspersing call and continuous markets). Further, the negative effects of the second externality can be diminished by pricing market information appropriately when used in commercial exchange transactions.

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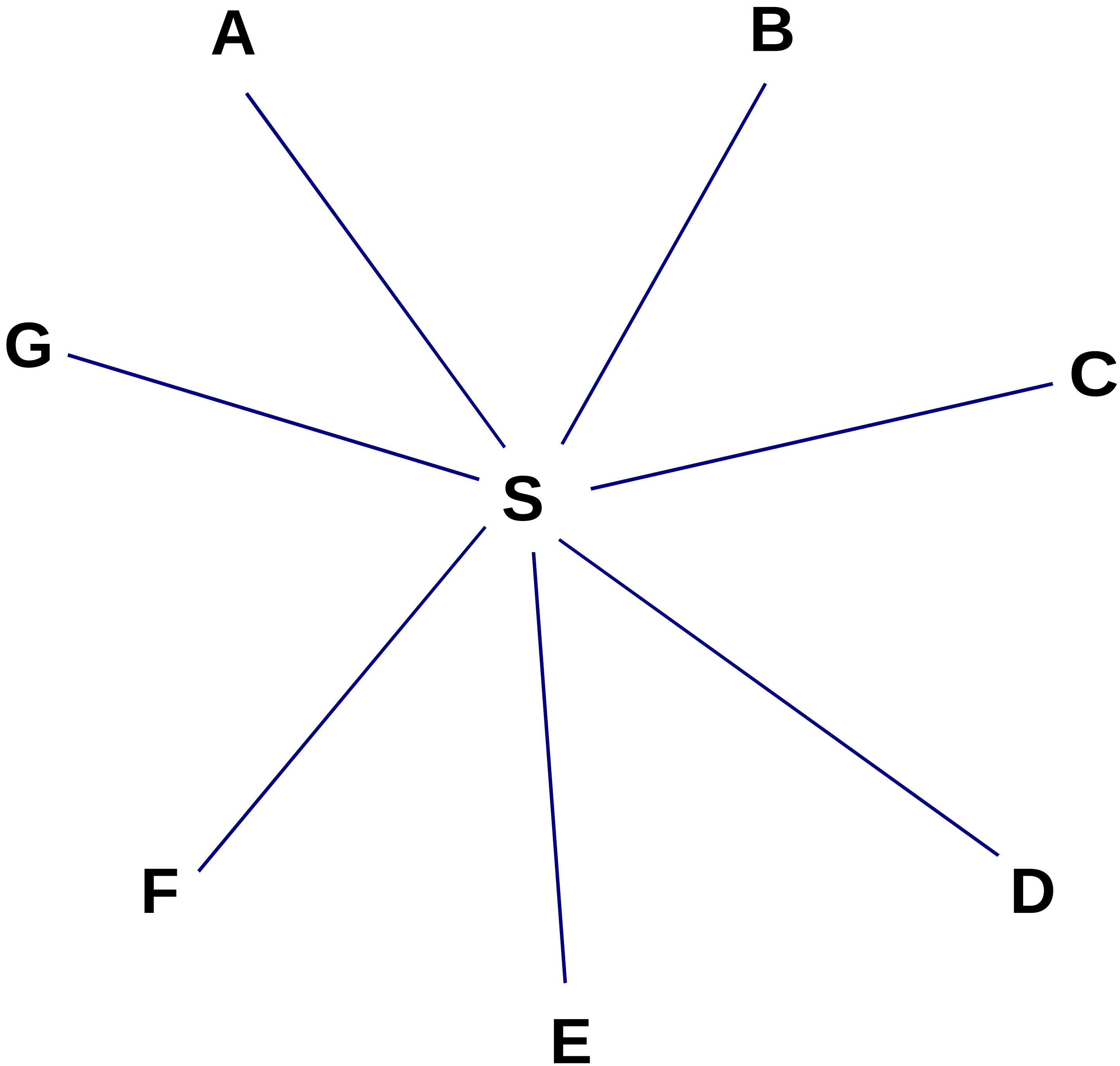
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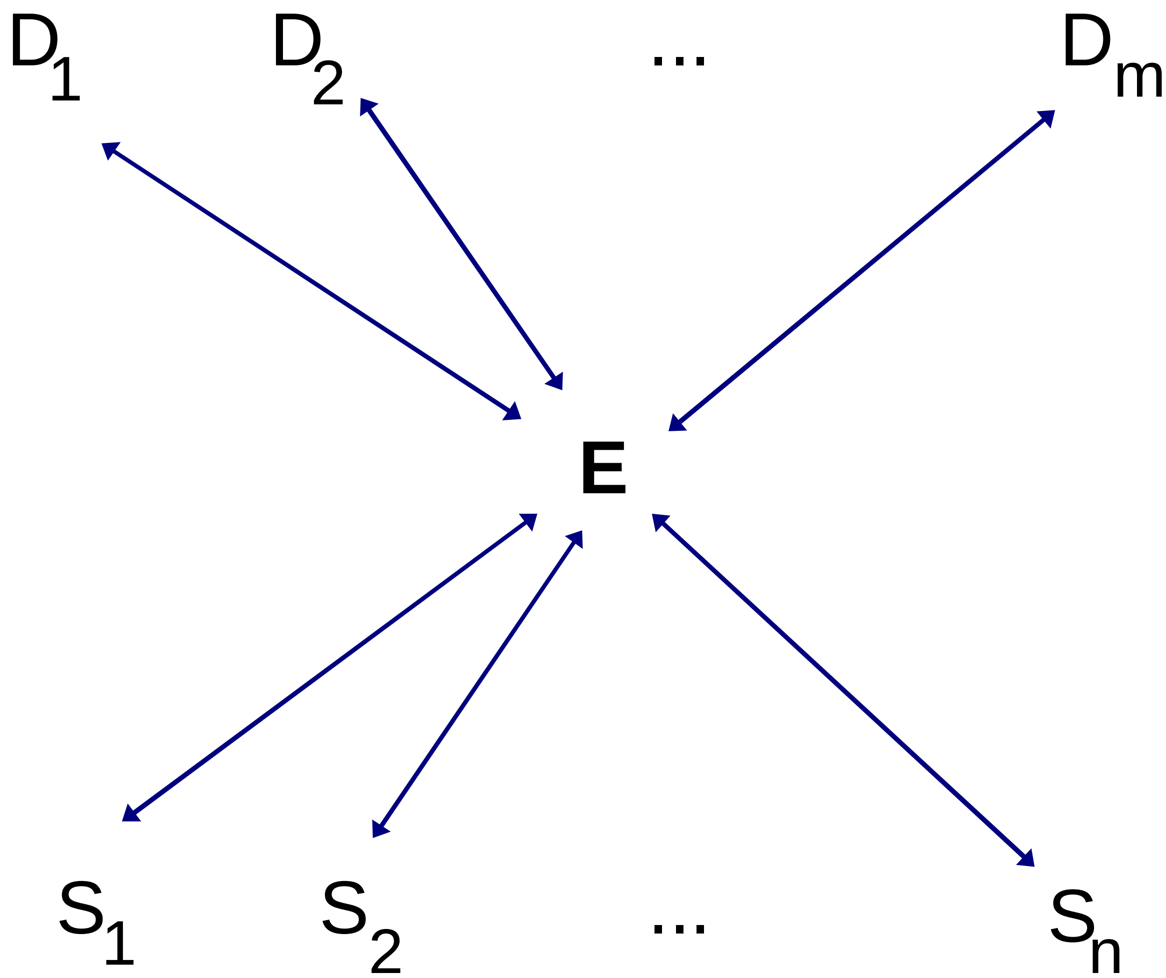

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