

# Agent-Intermediated Electronic Markets in International Freight Transportation

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## Abstract

In many industries agent-intermediated markets are inefficient because information about latent demand and supply never gets to market. We demonstrate how information technology in the form of an agent-intermediated electronic market (EM) alleviates this problem by enhancing the agent-as-market-maker using the international freight transportation industry as an example. We find that an EM increases agent participation and investment thereby increasing demand and supply. Because of tradeoffs between incentives for investment the EM chooses a profit allocation between agents resulting in limited agent participation. In addition, when price depends on demand and supply balances, price and volume in the market can increase simultaneously.

Keywords: Electronic Markets, Intermediation, Transportation

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# 1 Introduction

In many industries market institutions are inefficient because information about latent demand and supply never gets to market and many feasible transactions between buyers and sellers are not completed. Characteristics of such markets include insufficient numbers of buyers and sellers (thin markets), heterogeneous and complex goods (specificity), and information asymmetries which may hold-up trade. When only partial information about demand and supply is available, individual demand and supply are not properly matched, and markets do not always clear. Consequently, incentives to bring new demand and supply information to the market are reduced. The "traditional market" in many industries uses an agent as an intermediary between customer and supplier to overcome these causes of inefficiency.

Two new institutions based on electronic markets (EMs) have recently emerged. The first substitutes an EM for the agent in the traditional market. This substitution occurs in industries where the quality of the goods can be assessed at low cost, and the transfer of ownership and possession is straightforward. The second EM supports trade between agents. This latter case, which we call an agent-intermediated EM, is the focus of our paper. This support is necessary in industries where the quality of goods is hard to measure and/or the transfer of ownership and possession is complex. In these industries specific domain knowledge held by agents is vital to quality assurance and post-transaction market clearing operations. This view is consistent with the trade press that suggests the critical lesson learnt in electronic marketplaces so far is to specialize [13] - that is, understanding the special characteristics of a given marketplace is crucial for performance. It is also consistent with transaction cost economics, which posits that because of administrative costs, distortions, and inefficiencies from low-powered incentives, most markets have evolved to keep transaction risk low and preserve specialized information the market needs to function efficiently [27,28].

Some believe that information technology (IT) through its cost effective enabling of EMs will be used to disintermediate markets [11,15,26]. However, in the most commonly used examples - on-line securities trading and air travel reservations - markets have not been disintermediated. Rather, the intermediary has been (partially) automated. On-line trading requires a broker to carry out the transaction and most on-line airlines reservations are done through travel agents that have an Internet presence. Indeed, many believe that there will not be disintermediation, just new types of intermediaries [3]. A classic example is Aucnet - the electronic auction for used cars in Japan. Aucnet is an agent-intermediated EM with dealers acting as agents for their customers in the buying and selling of cars. Supporting the value of agent intermediation, research has found that the average contract price of secondhand cars sold through Aucnet is much higher than that of traditional, non-electronic markets [16]. New types of intermediaries provide information to buyers and sellers, aggregate demand or supply, manage physical deliveries and payments, and provide trust and integrity to the EM [4]. Intermediaries such as trusted third parties have been proposed as a way of providing quality assurance [2]. Trust is critical to quality assurance, and it has been found to be an important determinant of EM adoption [7]. Even in financial markets where quality assurance of the process rather than the traded good is the issue, specialist auctions were found to increase market quality by reducing bid-ask spreads, transaction costs, and time to execution as compared to automated order matching systems [8].

IT has also been used to explain restrictions in the number of suppliers that participate in buyer-supplier relationships. For example, incentives can motivate a buyer to limit the number of suppliers it uses [5]. That is, to induce supplier investments in IT-related non-contractible assets, commitments by buyers are more credible if they limit the number of participating suppliers. The number of contract terms in a contract fall with increasing levels of IT due to more economical monitoring [6]. If suppliers face relationship-specific costs, the increases in IT can cause the buyer to limit its number of suppliers. Because

of the negative externalities (e.g., competition) between suppliers, participation growth in interorganizational systems stalls without buyer subsidies [21]. Finally, a supplier's adoption of electronic data interchange (EDI) can generate positive externalities for buyers while producing negative externalities between suppliers [25]. Thus, it may be in the buyers' interest to subsidize suppliers' adoption of EDI. Regardless, if supplier adoption costs are high, then partial adoption by the supplier base may be optimal for the buyer.

**Our Example** An important example where demand and supply information in the market is incomplete is the less-than-full-load ocean shipping industry. Lumpy supply - a container - together with less-than-container size shipments often results in partially empty containers being shipped while partial container shipments that could have filled the partially empty containers remain on the dock. The information required to complete transactions in ocean shipping is extensive. Individual shipments have a specific origin and destination - possibly with a preferred routing, and restrictions on when they must depart and arrive. Available container capacity may not be the right kind of capacity because of shipment dimensions or special shipment requirements such as refrigeration. This market coordination problem is an instance of the more general less-than-full-load problem that prevails in all modes of the transportation industry. A recent report indicates that of a \$921B US logistics market, 18% of capacity moves empty, leading to a collective loss of \$165B [18].

Agents, such as international freight forwarders, brokers, non-vessel operation common carriers (NVOCCs), and third party logistics providers (3PLs), serve as market-makers, providing search, price discovery and numerous market clearing operations for both shippers and carriers. On the demand side, they provide shippers with financial services (letters of credit) and insurance, often assuming some of the liability of carriage. They also have expertise in managing the loading/unloading and pick-up/delivery process - in particular, export permits and customs clearance for international shipments [23]. Consequently, on the

demand side these agents need to invest in specialized knowledge such as customs regulations in particular regions in order to support the above activities. In addition, they need to invest usual demand-generating activities such as promotional visits to customers (i.e., shippers). On the supply side they provide carriers with consolidation of shipments and the discovery of available less-than-full load capacity. Agent investments on the supply side are investments in specialized knowledge of individual carrier operations such as methods used to consolidate freight, and contacts in ports and staging areas.

Agents are specialized to serve niche markets, for example, transporting individual automobiles from Europe to the U.S. As a result, the ocean shipping market has many agents because specialized knowledge resides with individual agents, and each agent's expertise differs from another's. Moreover, the knowledge on which agent expertise is based changes continuously (see [14]). Niche markets and specialized knowledge is the differentiation that mitigates head-on competition between agents. An example of an agent-intermediated EM in ocean shipping is GT Nexus (recently renamed from Tradient) which serves merchant importers and exporters, freight forwarders, 3PLs, and carriers. Testifying to the complexity of commercial shipping, and in our view the need for agent intermediation, *"...a typical commercial shipment involves 9 different participants, 20 separate documents, 35 customer-vendor interactions, and 4 modes of transport. It all can take place over the course of several weeks or months, and can cross multiple international borders."* [12].

Underutilization of capacity occurs precisely because the traditional market is decentralized - individual agents try to match their own demand to their own supply, combining two aspects of each agent's activities - promotion to shippers (generation of demand) and provision of capacity (generation of supply). This coupling is evident when an agent purchases all or part of a container from a carrier and promotes that capacity to shippers or, alternatively, arranges for a shipment and then searches for the needed capacity. The problem is that agents frequently generate demand which they cannot individually satisfy with

their generation of supply, and vice versa. Nonetheless, this traditional market still operates more efficiently than direct shipper (customer) to carrier arrangements because direct shipper to carrier arrangements cannot take advantage of the more extensive expertise an agent provides.

The agent-intermediated EM we propose broadens the traditional market by matching unsatisfied demand generated by one agent to underutilized supply provided by another, freeing agents from needing to match their own demand to their own supply. The EM allows agents to anonymously exchange information about capacity they need or have without revealing the identity of their shipper or carrier (prior to the transaction). It does not require that agents reveal all the demand and supply they generate - when an agent can match its own demand and supply it may operate as it always has in the traditional market. Nor does it preclude off-EM arrangements between individual agents. In these markets agents invest in finding demand (shipments) or supply (capacity). Through the EM agents can be rewarded for generating either side of the transaction. Indeed, the agent-intermediated EM together with the traditional market can result in higher demand than a traditional market alone: because of the difficulties and additional costs of finding capacity for idiosyncratic shipments, many shippers in traditional markets do not complete transactions they otherwise would if access to their specific transportation needs was less expensive.

In our example of ocean shipping there have been two recent regulatory changes. Prior to 1984 ocean shipping was highly regulated and contract terms were standardized and public. The (U.S.) Shipping Act of 1984 deregulated contracts to allow greater flexibility in the types of tariffs and contracts [17,22]. In addition, The Act began the movement towards greater confidentiality such that only the essential terms of a contract (origin and destination) were published. Specifically, prices, capacity, and other contract details are now confidential. The Ocean Shipping Reform Act of 1998 went even further than the earlier Act by removing from public view origins and destinations for through intermodal movements, rates, liqui-

dated damages for non-performance, and service commitments such as assured space, transit time, and port rotation. These regulatory changes have encouraged specialized contracts and terms, thereby fostering traditional markets and EMs we propose. Because traditional markets involve a single agent, these markets provide for the confidentiality of contracts and terms. The EMs we propose use IT specifically designed to protect the confidentiality and anonymity of their participating agents and their clients.

Our research objectives are to examine agent investment and agent participation in agent-intermediated EMs together with traditional markets as compared to investment and participation in traditional markets alone, and to examine the potential effects resulting from the addition of an agent-intermediated EM on market prices. Our main results are as follows. With an agent-intermediated EM, agent investment is higher and more agents participate, increasing demand and supply relative to the traditional market alone. However, the optimal allocation of profits between agents results in limited market participation where only a select group of agents participate. In addition, when price depends on demand and supply balances in the agent-intermediated EM - balances that are affected by the EM through increased agent investment - we find that both price and total volume may increase simultaneously. The limited market participation results because of tradeoffs between incentives for investment in demand and in supply: an increase in the allocation of profit for a given transaction to agents that generate demand raises demand generating investment and lowers supply generating investment (and vice versa). Simultaneous increases in price and volume can occur when an increase in price results in greater volume impacts through supply generating investment and agent participation than through demand generating investment and the direct effect of price on volume.

Apart from ocean shipping, other transportation industries use variants of agent-intermediated EMs. In the motor carrier transport, DAT Services [9] offers electronic freight matching to agents and carriers - providing electronic support to agents generating demand, but bypass-

ing agent provision of supply. Indeed, carriers may carry out the agent function in generating supply in our model. Thus, our results generalize to agent-intermediated EMs where carriers are agents on the supply side. In addition, the National Transportation Exchange [20] allows shippers *or* agents to post loads and member carriers to select loads to fill their unused capacity. NTE pre-authorizes shippers/agents and carriers, and serves standardized loads and domestic routes, thereby eliminating problems of quality assurance and ownership/possession. In a similar industry, air cargo, efforts by carriers to link directly with customers, thereby bypassing agents, failed because carriers did not account for the agents' special knowledge about customers and other carriers [10,1].

The scenario we model is more broadly applicable than transportation. An example of an agent-intermediated EM outside the freight transportation industry is the Multiple Listing Service (MLS) in the real estate industry, a market that evolved in manual form prior to the Internet. That industry is dominated by agent intermediation rather than direct buyer-seller transactions, and has agents representing each side of a transaction - one that serves the buyer and another that lists property for the seller. Still other industries use agent-intermediated EMs. Headhunters use online job markets to match their job candidates to positions and their positions to candidates, brokerage houses use private electronic markets such as Liquidnet to adjust their portfolios, and travel agents use web-based markets for regular and charter services to satisfy customers.

The paper is organized as follows. We first explain the structure of our setting, the notation, and assumptions. Next we compare the traditional market to the agent-intermediated EM when prices are determined outside the EM. Then we consider when prices are affected by demand and supply balances in the EM, and explore the effect of the EM on welfare.



## 2 Structure of the Setting

We represent agents by  $v \in [\underline{v}, \bar{v}]$ , where a larger  $v$  corresponds to an agent with greater potential to generate demand and supply. An agent can have greater potential if it has a larger market niche it can serve with its expertise, or have more individual contacts with shippers or carriers - either would yield a greater return to its investment.  $v$  has the uniform density  $h(v) > 0$  over the support and is zero elsewhere. Agents decide whether to participate in the EM and how much to invest. There are two investment variables for each agent,  $d_v$  and  $s_v$ .  $d_v \in [0, \bar{d}_v]$  is investment in generating demand, for example, finding customers with orders to ship less-than-container loads.  $s_v \in [0, \bar{s}_v]$  is investment in generating supply, for example, finding less-than-full containers being shipped. We measure  $d_v$  and  $s_v$  in dollars so that  $d_v$  and  $s_v$  also represent the costs of each type of investment, which are assumed constant at the margin. Agents also face a fixed cost of operations,  $K$ .

In the traditional market each agent generates demand and then fills that demand with supply it obtains from suppliers, receiving price  $p$ . We refer to this demand as "own" demand and represent it by  $q_a(v, d_v, s_v, p)$ . The price is what remains after accounting for the cost of carrier capacity and the agent's marginal cost of completing the transaction, including additional handling and administrative costs. Initially we assume price is determined outside the EM, and relax this assumption later.

The agent-intermediated EM allows agents to separate their generation of demand from their provision of supply. In addition to the demand generated and filled by the agent in the traditional market, the EM allows one agent to supply the demand generated by another agent. The demand generated by agent  $v$  and filled by supply from other agents is  $q_b(v, d_v, s_{\setminus v}, z, p)$ , where " $\setminus$ " means "other than", and  $z \in [0, 1]$  is the proportion of agents participating in the EM. Demand generated by other agents that is filled by supply from  $v$  is  $q_c(v, d_{\setminus v}, s_v, z, p)$ .

We assume that the demands are real-valued functions and are non-negative over the range of their arguments. The demands are non-decreasing in all of their arguments except price, marginal returns are non-increasing in own investment, and we take the demands to be twice continuously differentiable where needed. Our analysis makes use of several assumptions - the first formalizes an assumption that is implicit in the model structure.

**Assumption 1 (Competing Effects)** *There are no competing effects of the investments in generating demands by one agent on the demands generated by other agents, and similarly for investments in generating supply:*

$$\begin{aligned} & \partial q_a(v, d_v, s_v, p) / \partial d_{\setminus v}, \quad \partial q_a(v, d_v, s_v, p) / \partial s_{\setminus v}, \\ & \partial q_b(v, d_v, s_{\setminus v}, z, p) / \partial d_{\setminus v}, \quad \partial q_c(v, d_{\setminus v}, s_v, z, p) / \partial s_{\setminus v} = 0. \end{aligned}$$

Significant structure is imposed on the type and source of investment that affects each demand from the nature of the real-world problem, and this is reflected in Assumption 1. Specifically, due to niche markets and specialized knowledge which mitigates direct competition between agents, for each demand faced by an individual agent (e.g., each  $q_i$ ) there are no competing effects of investments in generating demands by  $v$  and agents other than  $v$ , and similarly for investments in generating supply. We discuss the implications of relaxing elements of this assumption in the Conclusion.

On the demand side this specialized expertise is in particular industries and with certain types of shippers. This means agents have niche knowledge and have the shipper's trust. For example, an agent may specialize in northwest North American native art. The agent has relationships with wood carvers, painters, museums, and distributors. The agent also understands the types of wood, kinds of paint, and shipping conditions needed to keep goods from being damaged. In addition, the agent knows customs clearance processes for these types of goods at specific origins and destinations, for example native art from British

Columbia to Japan. No other agents have this combination of knowledge, relationships, and shipper trust. So no other agents' demand generating investments can easily penetrate this market niche.

On the supply side individual agents have "territories" such as parts of the docks at ports where containers are marshaled for specific destinations and types of goods such as the shipping of native art from British Columbia to Japan. They have relationships with carriers, dockworkers, etc., and by their presence on the docks they are aware of the dynamic changes in capacity such as which containers are full, which have space available, which carriers are looking to fill space at the last minute, which are reliable at the destination, etc. The agent's expertise is in the transient and ever changing opportunities to put a given shipment into "perishable" capacity. Capacity found by these agents through their investment cannot be found by other agents with a different product shipping/destination focus, different knowledge of freight consolidation and shipment staging processes, and with a different physical "territory" at the port and the specialized relationships that entails.

The agent skill set also differs between demand and supply generating investment. On the demand side it is niche market knowledge combined with shipper trust. On the supply side it is a destination/product shipping niche combined with constant personal monitoring of dynamically changing capacity.

In the demand generated by one agent but filled with supply from another agent (that is  $q_b(v, d_v, s_{\setminus v}, z, p)$ ), own supply generating investment,  $s_v$  does not have an effect because own supply generating investment would be geared to matching own demand to own supply and that would be  $q_a(v, d_v, s_v, p)$ . A similar argument applies to  $q_c(v, d_{\setminus v}, s_v, z, p)$  with respect to  $d_v$ .

**Assumption 2 (Size Economies)** *Agents with greater potential have (weakly) greater re-*

turns to additional investment:

$$\begin{aligned} & \partial^2 q_a(v, d_v, s_v, p) / \partial d_v \partial v, \partial^2 q_a(v, d_v, s_v, p) / \partial s_v \partial v, \partial^2 q_b(v, d_v, s_{\setminus v}, z, p) / \partial d_v \partial v, \\ & \partial^2 q_b(v, d_v, s_{\setminus v}, z, p) / \partial s_{\setminus v} \partial v, \partial^2 q_c(v, d_{\setminus v}, s_v, z, p) / \partial d_{\setminus v} \partial v, \partial^2 q_c(v, d_{\setminus v}, s_v, z, p) / \partial s_v \partial v \geq 0. \end{aligned}$$

As we detailed earlier, agents have greater potential if they have larger market niches or otherwise have more contacts with shippers and carriers. In Assumption 2, for agents with greater potential, marginal returns to investment are larger due to their larger market or more extensive contacts. As such, agent potential is a measure of how "liquid" the agent is as an independent intermediary.

**Assumption 3 (Investment Complementarities)** *Marginal return to investment in demand is (weakly) greater when there is greater investment in supply, and vice versa:*

$$\partial^2 q_a(v, d_v, s_v, p) / \partial d_v \partial s_v, \partial^2 q_b(v, d_v, s_{\setminus v}, z, p) / \partial d_v \partial s_{\setminus v}, \partial^2 q_c(v, d_{\setminus v}, s_v, z, p) / \partial d_{\setminus v} \partial s_v \geq 0.$$

Assumption 3 implies that when there is greater investment in supply there is more capacity available (having been found from carriers). Hence for every additional dollar spent on demand - that is, recruiting shippers - there is a higher chance of a match with available supply. In other words, once there is more supply from increased supply generating investment there is an increased ease in finding the appropriate type of supply for any increases in demand from demand generating investment - and vice versa. We use weak inequalities in Assumptions 2 and 3 to account for shipments that are sufficiently idiosyncratic - for example, live animals - so that the next dollar of investment does not yield a match with capacity, and similarly for matching between idiosyncratic capacity - for example, refrigeration - and shipments.

**Assumption 4 (Separation)** *For each agent, the direct effect of having greater potential to generate demand and supply is larger than the indirect effect of having a lower proportion of agents participate in the EM.*

Let  $dz/dv$  be the change in the proportion of agents participating in the EM as a consequence of agent  $v$  choosing to participate. Then Assumption 4 can be written as

$$\frac{\partial q_b(\cdot)}{\partial v} > \frac{\partial q_b(\cdot)}{\partial z} \frac{dz}{dv} \quad \text{and} \quad \frac{\partial q_c(\cdot)}{\partial v} > \frac{\partial q_c(\cdot)}{\partial z} \frac{dz}{dv}.$$

The direct effect of having greater potential is  $\partial q_b(\cdot)/\partial v$  and  $\partial q_c(\cdot)/\partial v$ , and the indirect effects are through  $z$ .

This assumption puts a greater weight on an agent's potential as a determinant of its profitability than it does the externality from participating in a larger market, noting that the agent's potential to generate demand and supply directly affects not only own demand, but also its demand filled by supply from other agents and its supply fulfilling demand from other agents. This assumption serves to separate the continuum of agents into two segments based on their participation in the EM. Assumption 4 is reasonable in our setting, as we explain when Assumption 4 is used. Note also that if fixed costs,  $K$ , are an increasing function of agent potential, then Assumption 4 still suffices for separation but has a greater impact since the changes in fixed costs would work against the direct effects of agent potential.

### 3 Agent Investment

**The Traditional Market** Each agent chooses its level of investment in generating demand and generating supply,  $d_v$  and  $s_v$  respectively. Throughout we model agents as price-takers whereby each agent is not large enough for its individual investment decision to impact price. We examine the impact of a price determined by aggregate demand and supply conditions

later. Agent profits are price times own demand, less costs of investment and less the cost of operations  $K$ ,

$$\pi(v, d_v, s_v) = p q_a(v, d_v, s_v, p) - d_v - s_v - K.$$

The first-order conditions for agent  $v$  to maximize profits are

$$p \partial q_a(v, d_v, s_v, p) / \partial d_v - 1 = 0 \quad \text{and} \quad p \partial q_a(v, d_v, s_v, p) / \partial s_v - 1 = 0. \quad (1)$$

From Assumptions 2 and 3 all cross-partial derivatives of the profit function are (weakly) positive. The solution to (1) for all agents yields a Nash equilibrium. Because agent profits do not depend on profits by other agents, profits are trivially supermodular in different agents' investments, and being supermodular second-order conditions are not required for an equilibrium. The equilibrium results directly from independent optimizations for each agent and the conditions in (1) are the same as first-order conditions from a monopoly profit maximization. The equilibrium investments are a function of price and are denoted by  $d_v(p)$  and  $s_v(p)$ . Because profits are supermodular in agent potential and each of the investment variables, equilibrium investment levels are increasing in  $v$ .

**The Agent-Intermediated Electronic Market** In an agent-intermediated EM each agent profits as it would in the traditional market, and in addition can profit on its demand when matched with supply from other agents and its supply when matched with demand from other agents. The agent with the demand collects the price, pays a transaction fee to the EM, and pays the margin to the other agent that provides the supply. The agent providing the supply collects the margin from the agent with the demand. The decision of who actually collects and redistributes the price is arbitrary and does not affect the substance of our results. The profit function for the agent using the EM is

$$\begin{aligned} \psi(v, \mathbf{d}, \mathbf{s}, z) &= p q_a(v, d_v, s_v, p) + [p - f - m] q_b(v, d_v, s_{\setminus v}, z, p) + m q_c(v, d_{\setminus v}, s_v, z, p) \\ &\quad - d_v - s_v - K \end{aligned}$$

where  $f$  is the transaction fee paid to the EM,  $m$  is the margin paid to the supplying agent, and  $\mathbf{d}$  and  $\mathbf{s}$  are vectors of demand and supply generating investments for all  $v$ . The first-order conditions for each agent choosing  $d_v$  and  $s_v$  to maximize profits are

$$\begin{aligned} p \partial q_a(v, d_v, s_v, p) / \partial d_v + [p - f - m] \partial q_b(v, d_v, s_{\setminus v}, z, p) / \partial d_v - 1 &= 0 \\ \text{and } p \partial q_a(v, d_v, s_v, p) / \partial s_v + m \partial q_c(v, d_{\setminus v}, s_v, z, p) / \partial s_v - 1 &= 0. \end{aligned} \quad (2)$$

From investment complementarities (Assumption 3) the three non-zero cross-partial derivatives are (weakly) positive,

$$\begin{aligned} \frac{\partial^2 \psi(v, \mathbf{d}, \mathbf{s}, z)}{\partial d_v \partial s_v} &= p \frac{\partial^2 q_a(v, d_v, s_v, p)}{\partial d_v \partial s_v} \geq 0, \\ \frac{\partial^2 \psi(v, \mathbf{d}, \mathbf{s}, z)}{\partial d_v \partial s_{\setminus v}} &= [p - f - m] \frac{\partial^2 q_b(v, d_v, s_{\setminus v}, z, p)}{\partial d_v \partial s_{\setminus v}} \geq 0, \end{aligned}$$

and

$$\frac{\partial^2 \psi(v, \mathbf{d}, \mathbf{s}, z)}{\partial d_{\setminus v} \partial s_v} = m \frac{\partial^2 q_c(v, d_{\setminus v}, s_v, z, p)}{\partial d_{\setminus v} \partial s_v} \geq 0,$$

so that profits are (strictly) supermodular in the choice variables. Supermodularity means that there is at least one Nash equilibrium, and if this equilibrium is not unique, then they can be ordered from smallest to largest, and we assume the largest is obtained (see [24,19]). The equilibrium demand generating investments are a function of the price, transaction fee and margin,  $\mathbf{d}(p, f, m)$ . The equilibrium supply generating investments are a function of the price and margin only,  $\mathbf{s}(p, m)$ . Because the marginal returns to either investment are increasing in  $v$  (Assumption 2), from supermodularity our equilibrium investments are increasing in agent potential. Because the demands have diminishing marginal returns to own investment, demand generating investments are decreasing in the transaction fee and the margin, and supply generating investments are increasing in the margin.

Investment levels in the traditional market can be compared to those obtained in the EM using the first-order conditions (1) and (2), and investment complementarities. If the margin

transferred from the demand generating agent to the supplying agent is positive ( $m > 0$ ) and the price is greater than the transaction fee plus the margin ( $p > f + m$ ), then investment levels are always higher in the EM. Referring to our example, ocean shipping is a very old industry that historically has supported profitable agents in an agent-intermediated institutional structure, that is,  $p > m$ . Recent regulatory changes have reinforced confidentiality of contracts, further mitigating open competition and enhancing the roles of agents. Because no agent is willing to incur a loss,  $p > f + m$ .

It is worth noting that we make no assumptions about the form of our demands, or specific details of how agent investments in generating demand and supply yield increases in demands. In particular, we only require directions on the derivative conditions in our four assumptions rather than quantities. Own demand,  $q_a(v, d_v, s_v, p)$ , is the demand or number of transactions that result from the matching of supply and demand by a given agent  $v$ . The demand generated by agent  $v$  and filled by supply from other agents,  $q_b(v, d_v, s_{\setminus v}, z, p)$ , is the demand or number of transactions of this type for agent  $v$  that result from matching through the EM. Similarly, demand generated by other agents that is filled by supply from  $v$ ,  $q_c(v, d_{\setminus v}, s_v, z, p)$ , is the demand or number of transactions of this type for agent  $v$  that result from matching through the EM. Furthermore, in our assumptions we use weak inequalities to account for idiosyncratic shipments or capacity where matches might not occur. As a consequence, the total demands of type  $q_b(\cdot)$  matched by the EM is by definition equal to the total demands of type  $q_c(\cdot)$  matched by the EM. In this way, a market-clearing condition that would equate total demands of type  $q_b(\cdot)$  with total demands of type  $q_c(\cdot)$  is an outcome of our formulation.



## 4 Agent Participation

We define the smallest agent that participates in the EM as  $\hat{v} = \min\{v|\psi(v, \mathbf{d}, \mathbf{s}, z) = 0\}$ .

This marginal agent must satisfy the indifference condition

$$p q_a(\hat{v}, d_{\hat{v}}(p, f, m), s_{\hat{v}}(p, m), p) + [p - f - m] q_b(\hat{v}, d_{\hat{v}}(p, f, m), s_{\hat{v}}(p, m), z(\hat{v}), p) + m q_c(\hat{v}, d_{\hat{v}}(p, f, m), s_{\hat{v}}(p, m), z(\hat{v}), p) - d_{\hat{v}}(p, f, m) - s_{\hat{v}}(p, m) - K = 0 = \mu(p, f, m, \hat{v}), \quad (3)$$

where  $\mu(p, f, m, \hat{v})$  is an implicit function defining  $\hat{v}$ . Taking the partial derivative with respect to  $\hat{v}$ , we can use the first-order conditions in (2) to eliminate the indirect effects of  $\hat{v}$  through investment in generating demand and supply (or alternatively, the envelope theorem). This yields

$$\frac{\partial \mu(p, f, m, \hat{v})}{\partial \hat{v}} = p \frac{\partial q_a(\cdot)}{\partial \hat{v}} + [p - f - m] \left[ \frac{\partial q_b(\cdot)}{\partial \hat{v}} + \frac{\partial q_b(\cdot)}{\partial z} \frac{dz(\hat{v})}{d\hat{v}} \right] + m \left[ \frac{\partial q_c(\cdot)}{\partial \hat{v}} + \frac{\partial q_c(\cdot)}{\partial z} \frac{dz(\hat{v})}{d\hat{v}} \right], \quad (4)$$

where the arguments of  $q_a(\cdot)$ ,  $q_b(\cdot)$  and  $q_c(\cdot)$  include the equilibrium levels of investment as in (3). Using the fact that the direct effects of agent potential are greater than the indirect effects through market participation (Assumption 4), equation (4) is positive. Notice that in (4) the direct effect of  $\hat{v}$  is positive and the indirect effect through  $z$  is negative. However, included in the indirect effect is a marginal change in a proportion,  $dz(\hat{v})/d\hat{v}$ , a fraction. Hence, Assumption 4 is reasonable in this context, noting that Assumption 4 is sufficient but not necessary as the positive effects through  $q_a(\cdot)$  could dominate. As a consequence, larger agents,  $v > \hat{v}$ , participate in the EM.

We note that if there were fixed costs of participation for agents, for example fixed IT costs, then the EM could provide a fixed transfer as part of its incentive scheme. This implies no loss of generality for our results. Marginal IT costs for any specific transaction within an EM are close to zero.

Using the fact that larger agents participate in the EM, the proportion of agents that

participate in the EM can be written as

$$z(\hat{v}) = \int_{\hat{v}}^{\bar{v}} h(v)dv \quad (5)$$

which is decreasing in  $\hat{v}$ . From (3) the indifferent agent is a function of the price, the transaction fee and the margin:  $\hat{v}(p, f, m)$ . Thus,  $z(\hat{v}) \equiv z(p, f, m)$ .

To determine the optimal settings of the transaction fee and the margin it is necessary to determine the effects of changes in these EM choice variables on the proportion of agents that participate in, and on the volume processed by, the EM. To shorten our notation we substitute  $\hat{v}(\cdot)$  for  $\hat{v}(p, f, m)$ . Similarly for the proportion of agents that participate,  $z(p, f, m)$ , we use  $z(\cdot)$ . Lemma 1 determines the impact of the transaction fee on the proportion of agents that participate in the EM.

**Lemma 1:** *The proportion of agents that participate in the EM is decreasing in the transaction fee.*

*Proof:* From (5) the changes in the proportion of agents that participate in the EM as a result of changes in the transaction fee is  $dz(\cdot)/df = -h(\hat{v}(\cdot))[\partial\hat{v}(\cdot)/\partial f]$ . The impact of an increase in the transaction fee through  $\hat{v}(\cdot)$  can be determined through the implicit function rule using the indifference condition  $\mu(p, f, m, \hat{v}) = 0$  from (3). That is, from the implicit function theorem

$$\partial\hat{v}(\cdot)/\partial f = -\frac{\partial\mu(p, f, m, \hat{v})/\partial\hat{v}}{\partial\mu(p, f, m, \hat{v})/\partial f}$$

The sign of the numerator is positive from (4). The denominator is

$$\frac{\partial\mu(p, f, m, \hat{v})}{\partial f} = -q_b(\cdot) + m\frac{\partial q_c(\cdot)}{\partial d_{\hat{v}}} \frac{\partial d_{\hat{v}}(\cdot)}{\partial f} < 0$$

where the arguments are as in (3). This results in  $\partial\hat{v}(\cdot)/\partial f > 0$ . Substituting back in in  $dz(\cdot)/df$  results in  $dz(\cdot)/df < 0$ . Q.E.D.

Changes in the proportion of agents that participate in the EM as a result of changes in the margin is  $dz(\cdot)/dm = -h(\hat{v}(\cdot))[\partial\hat{v}(\cdot)/\partial m]$ . Using the implicit function theorem with (3) we find

$$\partial\hat{v}(\cdot)/\partial m = -\frac{\partial\mu(p, f, m, \hat{v})/\partial\hat{v}}{\partial\mu(p, f, m, \hat{v})/\partial m},$$

and therefore the sign of  $dz(\cdot)/dm$  follows the sign of

$$\frac{\partial\mu(p, f, m, \hat{v})}{\partial m} = -q_b(\cdot) + q_c(\cdot) + [p - f - m]\frac{\partial q_b(\cdot)}{\partial s_{\setminus\hat{v}}} \frac{\partial s_{\setminus\hat{v}}(\cdot)}{\partial m} + m \frac{\partial q_c(\cdot)}{\partial d_{\setminus\hat{v}}} \frac{\partial d_{\setminus\hat{v}}(\cdot)}{\partial m} \quad (6)$$

through  $\partial\hat{v}(\cdot)/\partial m$ .  $q_b(\cdot)$  and  $q_c(\cdot)$  are the demands of the agent that is indifferent between participating in the EM or not, and the arguments include the optimal value functions of demand and supply generating investment as in (3), and the proportion of agents that participate as in (5).

In (6) the sign of the first two terms together depend on whether smaller agents provide more demand or more supply. If these are balanced or if demand and supply are sensitive to investment, then the effect of demand and supply generating investments in the third and fourth terms determine the effect of the margin on the proportion of agents that participate in the EM. In the third and fourth terms demands are increasing in both investments. In the third term, supply generating investment is increasing in the margin from the analysis following (2) - that is, an increase in the margin transfers profits to the agent generating the supply. In the fourth term, demand generating investment is decreasing in the margin also from the analysis following (2) - in other words, an increase in the margin transfers profits away from the agent generating the demand.

If the effects of changes in the margin on investments and demands are smooth, then starting from a margin of zero,  $m = 0$ , (6) is positive from the third term, and therefore  $dz(\cdot)/dm$  is positive. So, at low values of the margin, increases in the margin increase the proportion of agents that participate in the EM. However, as the margin becomes larger, the

impact through investment in generating demand - the fourth term in (6) becomes larger, and therefore  $dz(\cdot)/dm$  becomes negative. Consequently, at high values of the margin, increases in the margin decrease the proportion of agents that participate in the EM.

Because they are equivalent, either between-agent demand can be used to define EM volume. Total EM volume can be written as

$$Q_b(\hat{v}(\cdot), \mathbf{d}(p, f, m), \mathbf{s}(p, m), p) = \int_{\hat{v}(\cdot)}^{\bar{v}} q_b(v, d_v(p, f, m), s_{\setminus v}(p, m), z(\hat{v}(\cdot)), p) h(v) dv.$$

We simplify the notation by using  $Q_b(\cdot)$  in place of  $Q_b(\hat{v}(\cdot), \mathbf{d}(p, f, m), \mathbf{s}(p, m), p)$ . In addition, we use  $d_v(\cdot)$  in place of  $d_v(p, f, m)$ , and  $s_v(\cdot)$  in place of  $s_v(p, m)$ . Lemma 2 provides our next result.

**Lemma 2:** *EM volume is decreasing in the transaction fee.*

*Proof:* The effect of a change in the transaction fee on EM volume is

$$\frac{\partial Q_b(\cdot)}{\partial f} = \left[ \frac{\partial Q_b(\cdot)}{\partial \hat{v}} + \frac{\partial Q_b(\cdot)}{\partial z} \frac{dz(\hat{v}(\cdot))}{d\hat{v}} \right] \frac{\partial \hat{v}(\cdot)}{\partial f} + \frac{\partial Q_b(\cdot)}{\partial d_v(\cdot)} \frac{\partial d_v(\cdot)}{\partial f}.$$

From Leibnitz's rule the first term in square brackets is negative. From the definition of total volume, the first term in the product in square brackets is positive, and from (5) the second term in the product is negative. Thus, the content of the square bracket is negative. From the proof of Lemma 1,  $\partial \hat{v}(\cdot)/\partial f > 0$  so the term involving square brackets is negative. Using the definition of total volume and the fact that demand generating investment is decreasing in  $f$ , the last product is also negative. Q.E.D.

Increases in the transaction fee transfers profits from agents to the EM. This makes each participating agent less profitable and reduces the agents' investment incentives.

The effect of a change in the margin is

$$\frac{\partial Q_b(\cdot)}{\partial m} = \left[ \frac{\partial Q_b(\cdot)}{\partial \hat{v}} + \frac{\partial Q_b(\cdot)}{\partial z} \frac{dz(\hat{v}(\cdot))}{d\hat{v}} \right] \frac{\partial \hat{v}(\cdot)}{\partial m} + \frac{\partial Q_b(\cdot)}{\partial s_{\setminus v}(\cdot)} \frac{\partial s_{\setminus v}(\cdot)}{\partial m} + \frac{\partial Q_b(\cdot)}{\partial d_v(\cdot)} \frac{\partial d_v(\cdot)}{\partial m}. \quad (7)$$

The term inside the large square brackets takes the sign of  $dz(\cdot)/dm$ , the effect of the margin on the proportion of agents that participate in the EM. Thus, this term captures the effects on total volume of changes in the margin through the proportion of agents that participate in the EM. Referring to the analysis following (6), at low values of the margin, increases in the margin increase the proportion of agents that participate in the EM, and at high values of the margin, increases in the margin decrease the proportion of agents that participate in the EM.

Similar to (6), the impact of the margin through supply generating investments, the next term in (7), is positive, and the impact of the margin through demand generating investment, the third term in (7), is negative. The two terms capture the effects on total volume of changes in the margin through demand and supply generating investment. To explore the relative magnitudes of these two impacts we can use the implicit function rule on each equation in (2) together with concavity of the agent's profit function in each investment to write out the effect of a change in the margin on demand and supply generating investment:

$$\frac{\partial d_v(p, f, m)}{\partial m} = \frac{\partial q_b(v, d_v, s_{\setminus v}, z, p)/\partial d_v}{p \frac{\partial^2 q_a(v, d_v, s_v, p)}{\partial d_v^2} + [p - f - m] \frac{\partial^2 q_b(v, d_v, s_{\setminus v}, z, p)}{\partial d_v^2}} < 0 \quad (8)$$

$$\frac{\partial s_v(p, m)}{\partial m} = \frac{-\partial q_c(v, d_{\setminus v}, s_v, z, p)/\partial s_v}{p \frac{\partial^2 q_a(v, d_v, s_v, p)}{\partial s_v^2} + m \frac{\partial^2 q_c(v, d_{\setminus v}, s_v, z, p)}{\partial s_v^2}} > 0. \quad (9)$$

Focusing on the denominators of the two effects above, at low values of the margin, the positive effect of a change in the margin on supply generating investment is large relative to the negative effect on demand generating investment, and vice versa at high values of the margin.

For the EM, maximizing profit means maximizing the product of the transaction fee and total volume choosing the levels of the transaction fee and the margin:

$$\max_{f, m} \Gamma(f, m) = \max_{f, m} \{f Q_b(\cdot)\}.$$

The first-order conditions for maximizing profit are

$$\frac{\partial \Gamma(f, m)}{\partial f} = Q_b(\cdot) + f \frac{\partial Q_b(\cdot)}{\partial f} = 0 \quad \text{and} \quad \frac{\partial \Gamma(f, m)}{\partial m} = f \frac{\partial Q_b(\cdot)}{\partial m} = 0. \quad (10)$$

An interior solution requires  $\partial Q_b(\cdot)/\partial m$  be increasing at low values of the margin and be decreasing at high values of the margin. This is likely from the two separate effects in (7) described above: at low values of the margin, a change in the margin increases the effect on total volume through increased participation in the EM and through a greater relative impact on supply generating investment compared to demand generating investment. At high levels of the margin a change in the margin decreases the effect on total volume through reduced participation in the EM and through greater impact on demand generating investment relative to supply generating investment. Thus, EM profits are maximized by limiting agent participation. This key result is our first theorem.

**Theorem 1: (Limited Market Participation)** *If total volume is increasing in the margin at low values of the margin and is decreasing in the margin at high values of the margin, then EM profits are maximized by limiting agent participation.*

*Proof:* From the second first-order condition in (10), we require that  $\partial Q_b(\cdot)/\partial m = 0$  in (7). From (8) and (9), the last two products in (7) are offsetting in sign, and are of similar magnitude. For  $\partial Q_b(\cdot)/\partial m = 0$  the remaining term in (7), depends on the sign of  $dz(\cdot)/dm$ , must balance the offsetting difference in (8) and (9), and this difference is small. At low values of  $m$ ,  $dz(\cdot)/dm > 0$ , increasing the proportion of agents that participate. As  $m$  increases,  $dz(\cdot)/dm$  becomes negative, decreasing the proportion of agents that participate. Q.E.D.

The EM's optimization problem does not maximize the proportion of agents that participate. This is because changes in the margin have opposite effects on equilibrium investments in generating demand and in generating supply. An increase in the margin reduces the incentives to invest in generating demand and increases incentives in generating supply. This

impacts not only the direct effects of demand and supply generating investment on EM volume, but also the indirect effect of the proportion of agents that participate in the EM. Therefore, the EM improves service not only by providing a matching mechanism for supply and demand, but also by providing the right combination of investment incentives to balance the generation of supply and demand. Limiting agent participation is critical for the EM's profit maximizing when demand investments are important. In this case, the margin is set low to incent investments from larger agents, and smaller agents may not make enough through the EM to cover their operating costs.

Our theorem is related to results in [5] and [6]. Their results, whereby in a buyer-supplier IT framework it could be optimal for buyers to limit participation by suppliers, derive from the need to provide suppliers with an adequate incentive to invest. In their work the incentive was necessary to induce suppliers to invest in non-contractible IT assets. In our model the EM must provide investment incentives for agents to generate demand and supply because each agent's expertise is different and unobservable to the EM. We also note that these investment incentives for agents to generate demand and supply reduce the uncertainty of matching demand and supply through pooling because this investment increases the probability of matching a given shipment with capacity.

Each agent has the choice of participating in the EM, or not participating in the EM but be active in the traditional market, or be inactive. The Corollary to Theorem 1 indicates the breakdown.

**Corollary:** *All agents that are active in the traditional market participate in the EM. More agents participate in the EM than are active in the traditional market.*

*Proof:* Comparing agent profits in the EM versus the traditional market,  $\psi(v, \mathbf{d}, \mathbf{s}, z)$  versus  $\pi(v, d_v, s_v)$ , and noting that investment levels are always higher in the EM, an agent could set investments to the equilibrium levels from the traditional market and be better off in the

EM. Define the smallest active agent in the traditional market as the smallest agent with zero profits,  $\check{v} = \min\{v|\pi(v, d_v, s_v) = 0\}$ .  $\pi(v, d_v, s_v)$  is increasing in  $v$  so in the traditional market larger agents,  $v > \check{v}$ , are active. Because of the additional value provided by the EM,  $\psi(\check{v}, \mathbf{d}, \mathbf{s}, z(\check{v})) > \pi(\check{v}, d_{\check{v}}, s_{\check{v}}) = 0$ . Therefore  $\hat{v} > \check{v}$  meaning more agents participate in the EM. Q.E.D.

This corollary is important because it indicates that the EM draws agents into the industry that would otherwise not be generating either shipments or capacity. Indeed, this is particularly crucial in an industry such as international freight transportation where significant unsatisfied demand exists. In practice the increase in agent participation is also an increase in the different niche markets served by this industry.

## 5 Endogenous Price and Welfare

### 5.1 Impact on the Price

So far we have considered the price as fixed by conditions outside of the EM such that both individual agents and the industry are price-takers. Although agents may not be able to influence the price individually, their aggregate investments in generating demand and supply may impact the price because they may change the balance between demand and supply. Endogenizing price means incorporating the difference between investments in generating demand and investments in generating supply.

Let the balance between demand and supply generating investment be represented by the vector of differences in investment:  $\vec{\delta}(f, m) = \mathbf{d}(p, f, m) - \mathbf{s}(p, m)$ . Recall that investments in generating demand are decreasing in the transaction fee and the margin,  $f$  and  $m$ , and investments in generating supply are increasing in the margin,  $m$ . Directly from the properties of these investment functions, each vector element of  $\vec{\delta}(f, m)$  is decreasing in the



transaction fee and the margin.

Let  $\rho(f, m)$  be the price that aggregates the effects of the transaction fee and the margin from  $\vec{\delta}(f, m)$ . The price  $\rho(f, m)$  captures the effects of the transaction fee and the margin on the balance between demand and supply. The price must have the same properties as  $\vec{\delta}(f, m)$ , namely  $\rho(f, m)$  is decreasing in the transaction fee because the increases in the transaction fee reduces demand generating investment. Similarly, the price  $\rho(f, m)$  is decreasing in the margin because increases in the margin reduce demand generating investment and increase supply generating investment.

Using this form of price makes price endogenous. That is, price depends on the EM's choice variables  $f$  and  $m$ . We can rewrite total volume by replacing  $p$  with  $\rho(f, m)$ . To simplify the notation we let the demand generating investment vector  $\mathbf{d}(\rho(f, m), f, m)$  be written as  $\mathbf{d}(\cdot)$ , the supply generating investment vector  $\mathbf{s}(\rho(f, m), m)$  be written as  $\mathbf{s}(\cdot)$ , agent  $v$ 's demand generating investment  $d_v(\rho(f, m), f, m)$  be written as  $d_v(\cdot)$ , and  $v$ 's supply generating investment  $s_{\setminus v}(\rho(f, m), m)$  be written as  $s_{\setminus v}(\cdot)$ . Total volume with endogenized price is then

$$\tilde{Q}_b(\hat{v}(\cdot), \mathbf{d}(\cdot), \mathbf{s}(\cdot), \rho(f, m)) = \int_{\hat{v}(\cdot)}^{\bar{v}} q_b(v, d_v(\cdot), s_{\setminus v}(\cdot), z(\hat{v}(\cdot)), \rho(f, m)) h(v) dv.$$

With total volume so defined, we can provide our last theorem followed by a corollary that describes the resulting effects on price.

**Theorem 2: (Endogenous Price)** *If the total effect of an increase in the price on total volume is positive, then the optimal transaction fee and margin are lower when price is endogenous than they are when price is determined outside the EM. Otherwise, the optimal transaction fee and margin are higher when price is endogenous than they are when price is determined outside the EM.*

**Corollary:** *If the total effect of an increase in price on total volume is positive, then the*

endogenous price is higher than the price determined outside the EM. Otherwise, the endogenous price is lower than the price determined outside the EM.

*Proof:* We simplify the notation using  $\tilde{Q}_b(\cdot)$  in place of  $\tilde{Q}_b(\hat{v}(\cdot), \mathbf{d}(\cdot), \mathbf{s}(\cdot), \rho(f, m))$ .

It is not possible to compare total volume with the endogenous price and with the price determined outside the EM,  $\tilde{Q}_b(\cdot)$  and  $Q_b(\cdot)$ , without a fixed point where the endogenous price  $\rho(f_0, m_0) = p$  for the pair  $(f_0, m_0)$ . However, the interior optimal solution for  $\max_{f, m} \Gamma(f, m)$ , profits when the price is determined outside the EM, provides such a fixed point. We use this to compare the optimal transaction fee and margin.

Let  $f^*$  and  $m^*$  be the interior optimal solution to  $\max_{f, m} \Gamma(f, m) = f Q_b(\cdot)$ , the EM profits when price is determined outside the EM. Use this optimum to fix the point  $p = \rho(f^*, m^*)$  where the prices are equal, so at that point EM volume in the two cases is equal  $Q_b(\cdot) = \tilde{Q}_b(\cdot)$  at  $(f^*, m^*)$ . The necessary first-order conditions for the interior optimum with the determined outside the EM price are as in (10), yielding  $(f^*, m^*)$ .

Denote profits when price is endogenous as  $\tilde{\Gamma}(f, m)$ . Evaluated at  $(f^*, m^*)$  we have

$$\frac{\partial \tilde{\Gamma}(f, m)}{\partial f^*} = \tilde{Q}_b(\cdot) + f^* \frac{d\tilde{Q}_b(\cdot)}{df^*} = \tilde{Q}_b(\cdot) + f^* \left[ \frac{\partial Q_b(\cdot)}{\partial f^*} + \frac{d\tilde{Q}_b(\cdot)}{d\rho} \frac{\partial \rho(f^*, m^*)}{\partial f^*} \right]$$

and

$$\frac{\partial \tilde{\Gamma}(f, m)}{\partial m^*} = f^* \frac{d\tilde{Q}_b(\cdot)}{dm^*} = f^* \left[ \frac{\partial Q_b(\cdot)}{\partial m^*} + \frac{d\tilde{Q}_b(\cdot)}{d\rho} \frac{\partial \rho(f^*, m^*)}{\partial m^*} \right],$$

where  $\partial Q_b(\cdot)/\partial f^*$  and  $\partial Q_b(\cdot)/\partial m^*$  represent the direct effects of changes in the transaction fee and the margin like those in (10). The remaining terms are the indirect effects of the transaction fee and the margin through price. If the total effect of an increase in price on total volume is positive,  $d\tilde{Q}_b(\cdot)/d\rho > 0$ , then both  $\partial \tilde{\Gamma}(f, m)/\partial f^*$  and  $\partial \tilde{\Gamma}(f, m)/\partial m^*$  are negative.

The second-order conditions for an interior optimum require concavity in each variable. Thus, if both  $\partial \tilde{\Gamma}(f, m)/\partial f^*$  and  $\partial \tilde{\Gamma}(f, m)/\partial m^*$  are negative, then the decision variables

have been set too high and optimizing profits when price is endogenously determined (as represented by the first-order conditions) requires a transaction fee lower than  $f^*$  and a margin lower than  $m^*$ . Proof of the converse is straightforward. Q.E.D.

Theorem 2 and its corollary embody our second key result: the agent-intermediated EM can cause both volume and price to increase simultaneously. Theorem 2 and its corollary depend on the impact of the price on total volume, and thus on individual agent demands. Referring to the arguments of  $\tilde{Q}_b(\cdot)$ , a change in price has four separate effects. The first is an indeterminate indirect effect through agent participation - similar to but more complex than the one in (6). The second is the negative indirect effect through investments in generating demand. The third is the positive indirect effect through investments in generating supply. And finally, there is a negative direct effect of price on volume.

An increased price is normally associated with decreased volume. However, here an increased price has a positive indirect effect through supply-generating investment and possibly a positive indirect effect through participation, which can simultaneously result in increased volume. That is, if the demand-supply balance is such that identifying and bringing additional supply to the market can increase the number of transactions, then an increase in price can motivate agents to bring that additional supply to market. Due to the conflicting set of direct effects and indirect effects through demand and supply generating investments, it is not possible to determine in general if endogenizing price increases or decreases profits for the EM and for the individual agents.

## 5.2 Effects on Welfare

When price is determined by conditions outside the EM, the effects of the EM on welfare are positive. Four groups of stakeholders must be accounted for: buyers, sellers, agents, and the EM - where in ocean shipping the first two would be shippers and carriers respectively. If

the fixed costs of agents and the EM are covered,  $Q_b(\cdot) > 0$  implies that each of the groups complete transactions they otherwise would not - at the same price - and are therefore better off. Thus, the EM is not only welfare enhancing, it is Pareto optimal for all stakeholders. Although this should be true given that the EM effectively relaxes a constraint in the optimization program for the market, what is important is the way in which each stakeholder benefits.

When price is endogenous - affected by agent investments - the effects of the EM on welfare are less clear. In addition to the direct effects of price on demands, changes in price also have investment impacts on volume through changes in the transaction fee and the margin. However, as we saw in Theorem 2, the direction of these changes - and hence incentives for investment - depend on the sign of the direct effect of a change in price on total volume.

Even ignoring the investment effects, the outcome is equivocal. Consider, for example, when the presence of the EM increases price. Buyers benefit from completing transactions through the EM that would not have been completed otherwise. Nonetheless, those transactions that would have been completed without the EM now face a higher price. Hence, the aggregate impact on the welfare of buyers is mixed. Sellers face a similar tradeoff. Volume is increased by those transactions that occur through the EM. Unfortunately, transactions not requiring the EM face an increased price, reducing the off-EM volume for sellers compared to the traditional market. This reduction may more than offset the new volume from the EM. Similarly, agents that participate in the EM gain from the transactions on the EM, but lose off-EM volume compared to the traditional market. Those agents that do not participate in the EM simply lose volume and the lower profits that result may not be offset by the increased price.

Alternatively, when presence of the EM decreases price, buyers gain from completing

transactions through the EM that they would not complete otherwise, and also gain from lower prices on those transactions completed without the EM. Sellers also benefit from the EM transactions and higher volumes as compared to the traditional market from the lower price. For both buyers and sellers, however, these gains may be negated by a reduced incentive for demand and supply generating investment. The impact on agents is mixed: those that participate in the EM may gain from transactions over the EM, but those that do not participate may be less profitable because of the reduced price - even at higher volumes.

So long as its fixed costs are covered, the agent-intermediated EM is profitable. Making the EM profitable is critical to motivate the needed investment in IT infrastructure to support the development of the centralized repository for demand and supply information. In particular, this investment can be costly since the special information requirements for this market - the specificity and perishability of demand and supply - are more extensive than for financial or commodity markets.

## 6 Conclusion

We have shown that with price determined by the general freight transportation marketplace, an agent-intermediated EM increases agent participation and investment. The importance of agent investment is highlighted by the EM's allocation of profits between demand and supply providing agents on a given transaction whereby the EM balances participation and investment effects in its allocation, consequently restricting agent participation in the market. This restriction of participation is different than what one expects of commodity markets, where market depth and liquidity would suggest greater participation is more profitable for the EM.

When price is endogenous - influenced by the demand and supply balance in the EM,

we found that if price increases supply generating investment and participation, then price and volume on the EM can increase simultaneously. This result is different from what we might expect in a standard microeconomic analysis. Finally, since an endogenous price can be higher or lower with an agent-intermediated EM, the EM may not be welfare enhancing for all the stakeholders.

The driving force behind both our key results is the impact of an EM on agent investment. One important managerial implication for agents is that the agent-intermediated EM changes the returns to different investments. In the traditional market an agent must invest in matching its own demand and supply - for example, once a shipment (demand) is secured, the agent must invest in finding capacity (supply) for that shipment in order to obtain a return on investment. In an EM an agent can obtain an immediate return on investment from generating a single side of the transaction - for example, securing a shipment whose capacity is provided by another agent through the EM. One consequence of the change in returns to investment brought about by the EM is that agents are rewarded for specialization, whereby agents may focus on a particular side of the transaction and a specific niche in that side of the transaction. For example, an agent using an EM may focus its investment on shippers that ship automobiles to the US from Europe rather than having to split its investment between shippers and carriers. This increases the differentiation among agents, providing them with higher profits. Competition among agents ultimately reappears through price - the price that is determined via changes in the demand and supply balances in the EM.

Nonetheless, we recognize that our assumption of non-competition in agent investments is a strong assumption. This assumption could be relaxed for the demands generated by one agent and filled by another agent. In the case of an agent providing demand filled by supply from other agents ( $q_b(\cdot)$ ) for example, the relaxation could take the form of including own investment in generating supply because the effect of that investment could be to enable to agent to both generate and fill the demand, thereby moving that particular transaction

to own demand. However, competition between agents in demand generating or supply generating investments within our approach to a Nash equilibrium would violate our supermodularity conditions. In that case, another approach using quasiconcavity conditions may yield several of our results, but at the expense of additional assumptions.

With an agent-intermediated EM individual agents will eventually be forced out of using the traditional market exclusively because the change in the structure of the returns to agent investments brought about by the EM will make agents that join the EM more profitable through an increase in transaction volume. This will increase the liquidity of the freight transportation marketplace for those agents on the EM. Indeed, the EM may increase price and transaction volume simultaneously. Thus, participating in the EM will become a strategic necessity.

For the EM the critical issue is the balance between providing incentives for agent investment and opening the market to broad agent participation. The EM effectively balances profits from investments by larger agents with increased volume from greater participation - the setting of the margin determines investments by agents and which agents are profitable by participating in the EM. Therefore, calibrating the level of the margin divided between agents is fundamental to the performance of the EM.

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