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Economics of an Information Intermediary with Aggregation Benefits

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The widespread use of the Internet has led to the emergence of numerous information intermediaries that bring buyers and sellers together and leverage their knowledge of the marketplace to provide value-added services. Infomediaries offer matching services that facilitate establishment of a buyer-seller agreement, and value-added services that either provide a standalone benefit or enhance benefits from matching services. This paper develops and analyzes economic models of intermediaries to examine their pricing and product line design strategies. Intermediaries provide aggregation benefits: Buyers find an intermediary's service more valuable if it provides access to more sellers, and sellers value it more if it provides access to more buyers, but also when they compete with fewer sellers. Due to this unique combination of network effects, we find that an intermediary has stronger incentives to provide quality-differentiated versions of its service relative to other information goods sellers. When buyers have constant marginal valuations for service quality, the intermediary should offer only two levels of service. While it is optimal for the intermediary to offer two levels of service, increasing the quality of the low-level service reduces the intermediary's profits due to increased cannibalization of the premium service. Hence, the optimal menu consists of a basic matching service and a premium service that includes matching and value-added services. The intermediary's profits are larger when positive network effects are stronger, and lower when negative network effects are stronger.

Key words: infomediary; two-sided markets; online marketplace; product differentiation; network externalities; information goods versioning
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1. Introduction

It is often said that information is power in today's economy, and this is aptly demonstrated by the emergence of many new types of information intermediaries in the last decade. The term infomediary is used for many such intermediaries, since their role is to capture, aggregate, and exploit information about participating parties in order to facilitate the efficient allocation of goods or services. Wise and Morrison (2000) note, in the context of business-to-business markets, that with the spread of digitization "value has shifted from the product itself to information about the product." Intermediaries create value via information collection, aggregation, display, and information processing; by managing workflow for a set of transactions between a buyer and seller; by coordinating logistical services to buyers and sellers; or by providing information processing services for end-to-end transaction management. Such infomediaries are becoming commonplace in many business and consumer market settings, including in hotel and travel coordination (Dube and Renaghan 2000), retail marketing (Chen et al. 2002), and private online exchanges for B2B commerce (Hoffman et al. 2002).

Bailey and Bakos (1997) discuss four services offered by intermediaries: (a) aggregation of buyer demand and seller products, (b) providing trust between participants, (c) market facilitation, and (d) matching buyers and sellers. Kaplan and Sawhney (2000) reinforce the notion that electronic intermediaries fulfill aggregation and matching roles (e.g., via catalogs and auctions respectively), bringing "a large number of buyers and sellers under one roof" and enabling real-time negotiation of terms and price

discovery. More recently, the academic and industry literature suggest that infomediaries have evolved from being merely matchmakers to purveyors of an array of services (see, e.g., Sarkar et al. 1995, Wise and Morrison 2000).

This paper studies the design of infomediary services. Our analysis focuses on a distinctive aspect of intermediation that we refer to as an aggregation benefit: buyers (and sellers) perceive greater value when there is a larger network of sellers (respectively, buyers) affiliated with the intermediary. We examine the impact of an intermediary offering multiple classes of service when faced with a heterogeneous market of users, and discuss how the intermediary might design a menu of quality-differentiated services. We draw a contrast with prior results in versioning of information goods, and show that the intermediary-specific aggregation benefit improves the incentives for versioning. From a practical perspective, our findings are significant in that they suggest that intermediaries can increase their chances of success by employing a versioning strategy. The rest of this section expands on the aggregation role of intermediaries and discusses the different types of value offered in intermediary systems. Following this, we develop and analyze the intermediary model in §2–§4. In §5, we discuss how our results contribute to understanding the design of intermediary services. Section 6 concludes the paper.

1.1. Aggregation Role of Intermediaries

An important characteristic of intermediaries is the *aggregation benefit* they provide to buyers and/or sellers. For example, `Expedia.com` allows buyers to search and book airline seats, hotel rooms, or car rentals from a list of subscribed travel service providers. Intuitively, `Expedia`'s value to providers increases with the number of buyers that use its service; conversely, the likelihood of a buyer using `Expedia` and making a booking increases with the number of providers with which `Expedia` links. Another example is `OneMediaPlace.com`, an intermediary between buyers and sellers of advertising space on print and broadcast media. Its `MediaPassage` service manages end-to-end transactions between buyers and sellers, covering functions such as price discovery, order placement, invoice handling, and settlement. The value of this service to buyers (or sellers) goes up as `MediaPassage` builds a larger network of sellers (or buyers).

The aggregation benefit offered by intermediaries is closely related to the concept of network externalities, which arise when a user's valuation of a good "depends upon the number of other users who are in the same *network* as is he or she" (Katz and Shapiro 1985). Such network externalities are widely discussed in the economics (see, e.g., Katz and Shapiro 1986, Liebowitz and Margolis 1994) and IS literatures (see, e.g., Chismar and Meier 1992, Clemons and Kleindorfer 1992, Kauffman et al. 2000), but largely in the context of networks that have only one type of members (e.g., users of a telephone network). The intermediary setting, however, involves two types of players, which we label as buyers and sellers. Furthermore, the utility of a buyer increases in the size of the *seller* network, rather than the size of the buyer network, which is sometimes referred to as cross-network externalities. The distinctive effects of two-sided networks have been recognized in recent literature (see, e.g., Corbett and Karmarkar 1999, Parker and Alstyne 2000, Rochet and Tirole 2002, Yoo et al. 2002). This paper contributes to this emerging literature.

Generally, the network benefit is defined as a function of the size of the network and the *intensity* of the network benefit. In the intermediary setting, the *intensity of the aggregation benefit* provided by an intermediary to buyers (sellers) is determined by market characteristics and the mix of information processing features made available to buyers (sellers). For example, if an intermediary makes information such as seller or product features and price available in an aggregated form, then buyers realize an aggregation benefit. The benefit might increase if buyers are able to sort and search this information, or perform more complex computations to select the best seller with respect to their preferences.

1.2. Value-Added Services and Matching Services

We classify intermediary services into two categories: *matching services* such as listing, matching, and price discovery that facilitate establishment of a buyer-seller agreement; and *value-added services* such as workflow coordination, transaction management, industry reports, and account management. For

example, the B2B exchange GNX.com offers various *marketplace tools* (i.e., matching services, such as conducting an auction) to facilitate buyers and sellers in creating a match, and various *collaborative tools* (i.e., value-added services such as exchange of real-time information about inventory levels between trading partners) that either facilitate execution of an agreement or provide benefits independent of a buyer-seller relationship.

- *Matching services* are marketplace tools—such as listing, price discovery, and matching of buyers and sellers—that facilitate establishment of a buyer-seller agreement. The aggregation benefit obtained by buyers or sellers stems solely from the matching services provided by the intermediary.
- *Value-added services*—such as workflow coordination, transaction management, industry reports, account management, and consultation about safety and environmental aspects of materials—provide additional value to participants. We distinguish between two kinds of value-added services: *standalone value-added* and *enhanced matching* services.

Enhanced matching services include those, such as collaborative workflow integration, that make transaction execution more efficient: The infomediary sets itself up in a better position to manage the data and document flow between the transacting firms. Enhanced matching services are valuable only when used in conjunction with the basic matchmaking role of the infomediary. Standalone value-added services include industry reports, account management, and consultation about safety and environmental aspects of materials; such services provide value to the user even when the infomediary is not employed for choosing the trading partner or setting up the transaction.

For example, consider Elemica.com, an online B2B exchange that represents pharmaceutical and chemicals firms. Elemica's matching service includes contract management. It also offers a range of value-added—enhanced matching—services covering creation of a customized buyer-specific searchable catalog of suppliers, online negotiation and approval, and support for order fulfillment. In contrast, consider the travel agency AAA.com, which offers standalone value-added services such as traveller's checks, international driving permits, and trip protection insurance, in addition to basic matching services (for selection of flights, car rentals, and hotel rooms that match the member's criteria).

1.3. Infomediary Services and Versioning

How might an infomediary employ a versioning strategy in the design of its services? In the early years when infomediation firms such as online exchanges entered the market, most infomediaries—like many other new firms and products—tended to employ a "one-size-fits-all" strategy, offering only a single set of matching-related services that enabled buyers and sellers to agree on a transaction. More recently, we have witnessed various efforts at service differentiation. As explained in §1.2, infomediary firms offer standalone value-added services and those that enhance the matching service. The quality level of an intermediary's product relates to the collection of services that are offered at a specific price. For example, AAA.com has a primary membership level that includes services such as traveller's checks, international driving permits, and insurance protection. It also offers a higher-priced premium level (AAA Plus) that includes the above services as well as travel accident insurance and additional trip protection insurance.[1]

This discussion suggests a natural set of possibilities for versioning. An infomediary could offer a menu consisting of basic matching and (various levels of) value-added services. When users are heterogeneous in their valuation of matching services, the intermediary can offer a premium service where the value-added services are enhanced matching services. This approach allows the infomediary to induce self-selection and separation between higher- and lower-type users. On the other hand, when users are homogeneous in their valuation of matching services, then the infomediary can use standalone value-added services to create a menu of offerings. For example, premium levels might include a variety of standalone value-added services in addition to matching services, while the entry-level service would consist of matching services only.

[1] AAA offers a premium membership level (AAA Plus) at $75 and a basic primary membership level at $46. July 31, 2001, from http://www.aaa.com/.

We explore these ideas in a systematic way by developing and analyzing models of infomediary services, in which the infomediary chooses quality levels and price. Meanwhile, buyers and sellers make decisions to participate, taking into account both quality levels and aggregation benefits. We first develop a general model of intermediary service and pricing, and then analyze pricing and versioning decisions for two specific types of intermediaries: those who provide standalone value-added services, and those whose value-added services enhance the value of matching services.

2. Model Formulation

The focus of our analysis is on the intermediary and its relationship with buyers and sellers. In our setting, the intermediary does not own or price the goods or services that might be transacted between buyers and sellers. Buyers and sellers may interact with each other as well, but we do not model the buyer-seller interaction in detail, instead capturing it abstractly through the seller's profit expectations from future interactions with buyers. The intermediary provides services to facilitate interactions between buyers and sellers. Buyers and sellers participate with the intermediary due to an increase in surplus from such interaction, due to a better match, reduced transaction costs, or better supply chain management. Following prior research in information goods and services, we analyze intermediary services with negligible marginal costs, and with sunk fixed costs of service development. The results are easily extended to the case of positive marginal costs, but the zero cost assumption is consistent with prior research. For example, Jones and Mendelson (1998) and Meyer (1996) examine versioning strategies for vertically differentiated information goods with zero marginal costs, and find that versioning is not optimal. Bhargava and Choudhary (2001) have shown that these versioning results hold even for products that exhibit positive marginal costs that are concave in product quality. Our research and model structure is also related to other work in vertical differentiation (e.g., Mussa and Rosen 1978, Jing 2002), but is different from the intermediation analysis of Spulber (1996), who examines the role of search costs in the pricing power of an intermediary who earns profit by arbitraging price differences between the buyers and sellers, rather than by charging for intermediation.

To examine the intermediary's versioning strategy, we assume the context where the intermediary is endowed with two quality levels. In §§3.3 and 4.3, we show that it is optimal to offer just two quality levels. We study separately the cases of enhanced matching and standalone value-added services. We solve the intermediary's pricing problem to obtain a rational expectations equilibrium where the expectations (of the intermediary, buyers and sellers) regarding the sizes of the buyer and seller networks are fulfilled in equilibrium. In the first stage, the intermediary is endowed with quality levels q_L and q_H. These quality levels are public information, and all players, including buyers and sellers, have perfect information about the intermediary's quality. Based on this information and knowledge of the demand function of buyers and sellers, the intermediary determines its optimal pricing strategy in the second stage. Finally, buyers and sellers form rational expectations about the level of participation by other buyers and sellers and decide whether or not to subscribe to the intermediary's service.

From the buyers' perspective, the quality levels q_L and q_H are vertically differentiated substitutes; hence, each buyer will choose to use at most one service, the one that maximizes her surplus. The intermediary charges buyers a price p_j for a service of quality q_j (this price does not include any products supplied by the seller). When optimal prices are such that each quality level gets a strictly positive market coverage, then it is optimal for the intermediary to offer both versions.

Sellers are heterogeneous in the benefit they expect from subscribing to the electronic intermediary's service and decide to subscribe if their expected benefit exceeds the listing fee charged by the intermediary. Let y represent seller type. Sellers with small y have smaller gains from subscribing to the intermediary's service compared to those with larger y. This gives rise to a downward-sloping demand function. For convenience, we use the linear quality-adjusted demand function from Banker et al. (1998). The seller-side demand function for listing with the intermediary is given by $\tau = bm - cn$, where τ is the intermediary's listing fee for sellers, n is the fraction of sellers, and m the fraction of buyers who subscribe

to the intermediary. The term bm indicates that the sellers' valuation of the intermediary service is a function of the size of the buyer network m, where b is a scalar parameter for the aggregation effect. The term cn is the negative effect due to competition with other sellers, and c is a parameter that measures the scale of the negative effect. To relate these parameters to the *demand responsiveness* characterized in Banker et al. (1998), the demand function can be rewritten as $n = ((bm - \tau)/c)$. It becomes evident that b/c determines the responsiveness of seller demand (n) for intermediation based on the level of participation of buyers (m). We normalize seller type (y) to lie in the interval $[0, 1]$ and assume that y is uniformly distributed in this interval. Let y_i be the seller who is indifferent to subscribing, therefore $n = 1 - y_i$ and $\tau = bm - c(1 - y_i)$. Table 1 summarizes the notation used in the paper.

Buyers are heterogeneous in their valuation of the intermediary's services. We model buyer heterogeneity with a type parameter θ that influences their willingness to pay for the quality of service provided by the intermediary. Buyers are distributed in the interval $[0, 1]$, as given by a cumulative density function $F(\theta)$. We assume that the term $F'(\theta)/(1 - F(\theta))$ (often called the hazard rate function) is nondecreasing, which is true for most commonly used distributions such as the uniform, normal, and exponential distributions (Fudenberg and Tirole 1991).

Let $U(\theta, q_j, n)$ represent the benefit derived by a type θ buyer for service level q_j when a fraction n of sellers lists with the intermediary. The intermediary benefits buyers by providing both value-added services q_j and matching services that depend on the number of sellers (n). By construction, the valuation function satisfies $U(\theta, q_H, n) > U(\theta, q_L, n)$ and is increasing in n due to positive aggregation benefits; hence, $U_n = -U_{y_i} > 0$ (since $n = 1 - y_i$). Further, without loss of generality, buyer types θ may be ordered such that $U_\theta > 0$. We define two marginal buyer types: θ_L type buyers are indifferent between buying the low-quality service and not buying, whereas type θ_H buyers are indifferent between buying the low-quality service and the high-quality service. Based on this definition, we obtain the following indifference equations:

$$U(\theta_L, q_L, n) = p_L$$

$$U(\theta_H, q_H, n) - p_H = U(\theta_H, q_L, n) - p_L.$$

All buyers of type $\theta \in [\theta_H, 1]$ buy the high-quality service from the intermediary, and buyers of type $\theta \in [\theta_L, \theta_H)$ buy the low-quality service. Recall that the cumulative density of buyers along θ is given by $F(\theta)$; therefore, the fraction of buyers using the high-quality service (q_H) is $1 - F(\theta_H)$, and the fraction of buyers using q_L is $F(\theta_H) - F(\theta_L)$. Hence, the total fraction of buyers subscribing to the intermediary's service is $m = (1 - F(\theta_L))$.

The intermediary's profit function combines the fees from buyers and sellers:

$$\pi = p_H(1 - F(\theta_H)) + p_L[F(\theta_H) - F(\theta_L)] + \tau(n).$$

Replacing for p_L, p_H, τ and using $m = 1 - F(\theta_L)$ and $n = 1 - y_i$, the profit function simplifies to

$$\begin{aligned}\pi = {} & [U(\theta_H, q_H, n) - U(\theta_H, q_L, n)] \\ & \cdot (1 - F(\theta_H)) + U(\theta_L, q_L, n)[1 - F(\theta_L)] \\ & + [b(1 - F(\theta_L)) - c(1 - y_i)](1 - y_i). \qquad (1)\end{aligned}$$

The intermediary's decision problem is to choose prices to maximize profits. Alternately, we can solve for optimal indifference points θ_L^*, θ_H^*, and y_i^*. The optimal prices p_L^*, p_H^*, and τ^* are then obtained from the indifference equations. Buyers and sellers both care about the number of sellers and buyers, and make decisions based on their expectations; the optimal indifference points are determined simultaneously

Table 1 Summary of Notation

q_j	quality level of value-added service j
p_j	price for q_j
θ	index for buyer types, $\in[0, 1]$
$F(\theta)$	distribution of buyers
θ_H	buyer type who is indifferent between q_H and q_L
θ_L	buyer type who is indifferent to q_L
m	fraction of buyers who transact via intermediary, $=1 - F(\theta_L)$
y	index for seller types, $\in[0, 1]$
y_i	indifferent seller type
n	fraction of sellers who subscribe with intermediary, $=1 - y_i$
τ	listing fee for sellers
e	intensity of aggregation benefit to buyers (quality of matching service)
b	intensity of aggregation benefit to sellers
c	negative externality due to competition between sellers

and endogenously to obtain a rational expectations equilibrium. The stationary points for the profit function are the feasible triplets $(\theta_H, \theta_L, y_i)$ that satisfy the conditions

$$\theta_H^* \quad \text{solves} \quad \left[1 = \frac{1-F(\theta_H)}{F'(\theta_H)} \cdot \frac{[U_\theta(\theta_H, q_H, n) - U_\theta(\theta_H, q_L, n)]}{U(\theta_H, q_H, n) - U(\theta_H, q_L, n)} \right] \tag{2}$$

$$\theta_L^*, y_i^* \quad \text{solve} \quad \left[\begin{array}{l} 1 + \dfrac{b}{1+y_i} \dfrac{1}{U(\theta_L, q_L, n)} \\ \qquad = \dfrac{1-F(\theta_L)}{F'(\theta_L)} \dfrac{U_\theta(\theta_L, q_L, n)}{U(\theta_L, q_L, n)} \\ (1-F(\theta_L))(b - U_y(\theta_L, q_L, n)) \\ \qquad = 2c(1-y_i) - \kappa(y_i) \end{array} \right] \tag{3}$$

where $\kappa(y_i) = (1 - F(\theta_H^*))[U_y(\theta_H^*, q_H, n) - U_y(\theta_H^*, q_L, n)]$.

If the solution $(\theta_L^*, \theta_H^*, y_i^*)$ is unique and satisfies second-order conditions for optimality, we have an optimal solution to the intermediary's problem. Further analysis of this solution requires additional information about the benefit functions. Knowledge about specific real-world intermediaries allows us to develop specific formulations to suit specific categories of intermediated markets. In the next two sections, we develop two such models, determine the optimal versioning strategy in each, and examine comparative statics. However, before doing so, a few general observations can be made using the system of simultaneous equations stated above.

- The system of equations yields feasible solutions when it satisfies the constraints $0 \le \theta_L^* \le \theta_H^* \le 1$ and $0 \le y_i^* \le 1$. When $\theta_L^* < \theta_H^*$, it is optimal for the intermediary to offer multiple versions.
- The first-order conditions for y_i and θ_L show the interlinked nature of the intermediary's problem, where the number of buyers and the price charged to buyers is dependent on the number of sellers, while the price charged to sellers depends on the number of buyers.
- When is it optimal for the intermediary to offer multiple qualities of value-added services? The first-order conditions emphasize the unique nature of this optimization and how it is different from standard second-degree price discrimination (Mussa and Rosen 1978). The model presented in this section is a generalization of the second-degree price discrimination (vertical differentiation) model, and it can be verified that setting $b = c = 0$ in Equation (3) would eliminate the seller side of the intermediary's pricing problem so that the model would become the standard second-degree price discrimination model.

3. Enhanced Matching Services

Matching services provided by intermediaries enable buyers and sellers to reach an agreement to conduct a transaction. In many such intermediated markets, the intermediary offers additional value-added services that pertain to the execution of the transaction. For example, `Elemica.com` helps chemicals buyers by managing RFQs, creating customized buyer-specific searchable catalogs of suppliers, and facilitating online negotiation and approval. These matching services enable a buyer to develop a purchase contract with a seller. Execution of the contract involves several additional steps, such as logistics and financial settlement. `Elemica` provides many such value-added services, including preparation of shipping documents; cost-effective credit evaluation; invoicing and payment solutions; and tax, duty, and currency computations. These services have little standalone benefit, but they enhance the buyers' gains from the matching services. Further, since the value-added services pertain to the execution of a contract, they are useful only in conjunction with matching services. This suggests the following specific form for the buyers' valuation function:

$$U(\theta, q, n) = \theta e q (1 - y^2),$$

where the fraction of sellers listed with the intermediary is $1 - y$. The parameter e is a measure of the strength of the aggregation benefit accruing to buyers based on the number of sellers.

When buyers are heterogeneous in valuations, this raises the possibility that offering quality-differentiated versions q_j can lead to better allocations and profits for the intermediary. Not all buyers may be willing to pay a premium price for high-end value-added services such as greater information and automated workflow. Is the intermediary better off following a versioning strategy and offering multiple quality levels for the matching service? For

example, the intermediary may offer a very basic matching service that simply matches buyers and sellers, and a premium service that bundles other value-added services that support additional steps in execution and fulfillment of a match. How should the basic and premium services be configured, and should the intermediary offer two or more service levels?

This section analyzes the case where the value-added services enhance the buyers' gains from the matching services, but provide no standalone benefit. Plugging the valuation function $U(\theta, q_j, n) = \theta e q_j(1 - y^2)$ into the intermediary's profit function (Equation (1)) for the case when there are at most two quality levels for the value-added service, q_L and q_H, we get

$$\begin{aligned}\pi &= p_H(1 - F(\theta_H)) + p_L(F(\theta_H) - F(\theta_L)) + \tau(1 - y_i)\\ &= ((1 - F(\theta_H))\theta_H(q_H - q_L) + (1 - F(\theta_L))\theta_L q_L)e(1 - y_i^2)\\ &\quad + b(1 - F(\theta_L))(1 - y_i) - c(1 - y_i)^2.\end{aligned}$$

Using Equations (2) and (3), the stationary points are the triplets $(\theta_L, \theta_H, y_i)$ that satisfy the first-order conditions:

$$\theta_H^* \text{ solves } \left[1 = \frac{1 - F(\theta_H)}{F'(\theta_H)}\frac{1}{\theta_H}\right] \tag{4}$$

$$\theta_L^*, y_i^* \text{ solve } \left[\begin{array}{c} 1 + \dfrac{b}{1 + y_i}\dfrac{1}{\theta_L e q_L} = \dfrac{1 - F(\theta_L)}{F'(\theta_L)}\dfrac{1}{\theta_L} \\ (1 - F(\theta_L))(b + 2eq_L\theta_L y_i) \\ = 2c(1 - y_i) - 2y_i K \end{array}\right] \tag{5}$$

where $K = (1 - F(\theta_H^*))\theta_H^* e(q_H - q_L)$. These equations in general may have multiple solutions that satisfy second-order conditions for maxima; the optimal solution is either a feasible triplet in the interior region or may have components at the boundary. We will characterize the optimal solution and examine the implications on the intermediary's versioning strategy. For ease of exposition, we illustrate our results in the case where F is a uniform distribution over the interval $[0, 1]$. The formal proof for the general case is given in the Appendix. For the uniform case, setting $F(\theta) = \theta$ and $F'(\theta) = 1$, Equation (4) yields a unique solution $\theta_H^* = \frac{1}{2}$. For the other two indifference points, the first-order conditions reduce to

$$1 + \frac{b}{1 + y_i}\frac{1}{\theta_L e q_L} = \frac{1 - \theta_L}{\theta_L} \tag{6}$$

$$-(1 - \theta_L)(b + 2q_L e\theta_L y_i) = 2y_i\left(\frac{e(q_H - q_L)}{4} + c\right) - 2c. \tag{7}$$

3.1. To Version or Not?

Proposition 1. *It is optimal for the intermediary to offer multiple versions of matching service.*

The proof is easy to illustrate for the special case where F is uniform in $[0, 1]$; please see the Appendix for the proof of the general case. For uniform F, $\theta_H^* = \frac{1}{2}$, and Equation (6) yields

$$\theta_L^* = \frac{1}{2} - \frac{1}{2}\left(\frac{b}{(1 + y_i)eq_L}\right),$$

proving that $\theta_L^* < \theta_H^*$; hence, versioning is optimal.

Several researchers (Meyer 1996, Bhargava and Choudhary 2001) studying versioning of information goods in the absence of network externality have noted that versioning is not optimal for information goods. Jing (2002) explains that this finding crucially depends on an assumption that consumers have constant marginal valuations (CMV) for quality (as when $U(\theta, s) = \theta s$). Jing further explains that the inclusion of a network externality creates the necessary incentive to version even under a CMV setting. Proposition 1, derived under a CMV setting (each user's marginal valuation for quality is a constant $\theta e(1 - y_i)^2$) is consistent with this explanation. The intermediary's additional incentive to version comes from the additional revenue it can get from suppliers. This revenue potential, due to the aggregation benefit, is higher when the intermediary can attract more buyers, justifying the intermediary's versioning strategy: More buyers leads to more supplier revenue, which offsets the loss in buyer revenue caused by cannibalization.

3.2. Comparative Statics

As stated earlier, the profit function may have multiple stationary points that satisfy conditions for maxima. The detailed conditions that characterize the *global maximum* are tedious and unnecessary. The versioning result, as shown above, follows directly from the implicit functions (Equation (5)) that define the

stationary points. In addition, we can derive important properties of the equilibrium outcome and examine how these outcomes change with changes in the quality levels and other exogenous parameters, as follows. The comparative statics are obtained as an application of the conjugate pairs theorem, and the impact of parameter changes on the profit is understood by applying the envelope theorem (see Currier 2000, pp. 80–83; Varian 1992, pp. 491–493).

Proposition 2. *When the intensity of aggregation benefits to the supplier* (b) *is greater or the intensity of the aggregation benefit to buyers* (e) *is greater, the intermediary achieves a greater profit in equilibrium.*

Proof. Applying the envelope theorem, $(\partial\pi^*/\partial b) = (1 - y_i)(1 - F(\theta_L)) > 0$; hence, the intermediary makes greater profit when b is greater. Applying the envelope theorem again, the intermediary's profit increases with e, since $(\partial\pi/\partial e) = ((1 - F(\theta_H))\theta_H(q_H - q_L) + (1 - F(\theta_L))\theta_L q_L)(1 - y_i^2) > 0$. □

An increase in b has positive effects for the intermediary—it increases the valuations of sellers. The intermediary's desire to expand the number of participating sellers is limited by two factors: the negative externality due to competition, c, and the buyers' valuation for q_L. When b is sufficiently large relative to q_L and c, the intermediary wants all buyers to enter the market even if this reduces the price of q_L. It is willing to forego revenue from q_L because it gets additional listing revenue from sellers because there are more buyers, and because it can increase the price of q_H due to the increased aggregation benefit. When b is large enough relative to q_L and c, the positive effects dominate the loss in revenue. However, when q_L is large, the potential revenue loss from making q_L free is larger; hence, q_L is priced high enough to exclude low-value buyers. Similarly, when c is large, sellers have a higher disutility due to competition; hence, the intermediary wants to limit the number of sellers in the market, and consequently is less willing to sacrifice revenues from q_L. Specifically, for the uniform case, $b > 2eq_L$ implies that $\theta_L^* = 0$ (this follows from Equation (6)); it is then easy to show that $y^* = ((2c - b)/(2c + 2K))$ (when $c > b/2$; 0 otherwise) where $K = e((q_H - q_L)/4)$.

The effect of an increase in the buyer-side aggregation benefit e is similar to the effect of an increase in the seller-side aggregation benefit b. Hence, we see that an increase in e improves the intermediary's profits.

Proposition 3. *When the intensity of the competition among suppliers* (c) *is greater, this* (i) *reduces the intermediary's profit in equilibrium and* (ii) *leads to reduced coverage on the sellers' side* (y_i^* *increases*).

Proof. Applying the envelope theorem, $(\partial\pi^*/\partial c) = -(1 - y_i)^2 < 0$; hence, the intermediary's profit drops when c is greater. We see that it reduces coverage on the sellers' side, since (using the conjugate pairs theorem applied at the optimal solution) $(\partial^2\pi^*/\partial c\,\partial y_i) = 2(1 - y_i) > 0$. □

This result is not surprising. Greater intensity of competition among suppliers forces the intermediary to limit the number of suppliers in the marketplace. This actually improves revenues from listing fees, because the result moves towards the monopoly optimal; however, it reduces buyer valuations and revenues by a greater amount.

Proposition 4. *An increase in q_L reduces the intermediary's profit.*

Proof. Applying the envelope theorem, we examine the derivative

$$\frac{\partial\pi^*}{\partial q_L} = (1 - F(\theta_L^*))\theta_L^* - (1 - F(\theta_H^*))\theta_H^*.$$

The optimality condition for the term $(1 - F(\theta))\theta$ is $((1 - F(\theta))/F'(\theta))(1/\theta) = 1$, which is identical to Equation (4). Therefore, $(1 - F(\theta))\theta$ is maximized at θ_H^*, the unique solution of Equation (4). Consequently, the term $(1 - F(\theta_L^*))\theta_L^* - (1 - F(\theta_H^*))\theta_H^*$ is negative. Hence, the intermediary's profit reduces with an increases in q_L. □

An increase in q_L reduces the differentiation between the high- and low-quality levels. This increases the potential for cannibalization, since high-type buyers are now more willing to switch to the lower quality level. This effect reduces the intermediary's profits.

3.3. How Many Versions?

Now consider the more general case where the intermediary may offer N quality levels $q_1, \ldots, q_N$ for the matching service; for convenience, let q_0 be a null service. Let the optimal indifference points be θ_j $(j = 1, \ldots, N)$, where θ_j is indifferent between

q_j and q_{j-1}. Let p_j be the price for service level q_j; hence, from the indifference equations we get $p_j = \theta_j(q_j - q_{j-1})(1 - y_i^2) + p_{j-1}$ for $j = 1, \ldots, N$. The intermediary's profit function is

$$\pi = (1 - F(\theta_N))p_N + \sum_{j=1}^{N-1} (F(\theta_{j+1}) - F(\theta_j))p_j + b(1 - \theta_1)(1 - y_i) - c(1 - y_i)^2.$$

Simplifying and computing first derivatives, we see that the stationary points θ_j satisfy the conditions

$$\text{for } j = 2, \ldots, N, \quad \theta_j^* \text{ solves } \left[1 = \frac{1 - F(\theta_j)}{F'(\theta_j)} \frac{1}{\theta_j} \right] \tag{8}$$

$$\theta_1^* \text{ solves } \left[1 + \frac{b}{1 + y_i} \frac{1}{\theta_1 e q_1} = \frac{1 - F(\theta_1)}{F'(\theta_1)} \frac{1}{\theta_1} \right]. \tag{9}$$

Because Equation (8) is identical for all $j = 2, \ldots, N$, we see that $\theta_2^* = \cdots = \theta_N^*$; hence, quality levels $q_2, \ldots, q_{N-1}$ are not offered. Therefore, it is optimal for the intermediary to offer two quality levels only, and the pricing problem is reduced to the two-quality problem solved earlier.

Proposition 5. *When the intermediary's value-added services only enhance the benefit from matching, then it is optimal for the intermediary to pursue a versioning strategy and offer exactly two quality levels for the value-added service.*

How should the intermediary set quality level q_L and q_H? We assume that given a high-quality service, the additional lower quality level can be developed costlessly. The higher quality level q_H is defined by the intermediary's competitive desire to offer the best possible quality subject to development constraints, so that q_H^* equals some upper limit $\bar{q}_H$. For the lower quality level q_L, Proposition 4 indicates that q_L^* equals some minimal threshold level $\underline{q}_L$. From a practical perspective this means that the intermediary offers a lower-priced basic matching service (with no value-added services) and a higher-priced premium service that bundles matching service with additional value-added services. In essence, the basic matching service serves to expand the size of the buyer network (making the intermediary more attractive to sellers), while the higher-quality service brings higher revenues from buyers; other quality levels in the middle are unattractive because they would only cannibalize the high-quality service without expanding the size of the buyer network.

4. Standalone Value-Added Services

Several intermediaries provide standalone value-added services in addition to their matching services. For example, many B2B exchanges have services such as industry reports, training and education courses, and consultation about safety and environmental issues. These services provide benefits to buyers even when they are not engaged in seller-oriented transactions with the intermediary. For example, AAA.com provides matching services to buyers to help them select travel products from airlines, car rental firms, and hotels. In addition, AAA also offers its members additional value-added services such as maps, trip planning, and travel insurance. These services can be used independently of the matching services, in contrast to the value-added services of Elemica, which are useful only in conjunction with matching services.

In this case, we write the valuation of buyers for the intermediary's services as the sum of the benefits from matching services $e(1 - y_i^2)$ and the benefits from value-added services θq_j, $j \in \{L, H\}$. In the expression $e(1 - y_i^2)$, y_i refers to the indifferent supplier, $(1 - y_i)$ is the fraction of suppliers expected to list with the intermediary, and e is an exogenous scaling constant that represents the intensity of the aggregation benefits accruing to buyers. Note that $e(1 - y_i^2)$ is a concave function of the number of suppliers $(1 - y_i)$ listing with the intermediary. As before, θ is the buyers' type parameter and q_j, $j \in \{L, H\}$ the quality level purchased by the buyer. Formally, we state these valuation functions as:

$$U(\theta, q_j) = \theta q_j + e(1 - y_i^2). \tag{10}$$

This formulation is consistent with prior approaches for modeling utility functions under network-related benefits. Kauffman et al. (2000) and Saloner and Shepard (1995) write the valuation function as $a + b(N)$, where a represents standalone benefit and $b(N)$ represents a benefit due to the network. Earlier work (e.g., Katz and Shapiro 1992, Farrell and Saloner 1992, Farrell and Katz 1998) also adopts a two-part additive valuation.

Substituting the valuation function into Equation (1), the intermediary's profit function π is

$$\begin{aligned}\pi &= p_H(1-F(\theta_H)) + p_L(F(\theta_H)-F(\theta_L)) + \tau(1-y_i)\\ &= (1-F(\theta_H))\theta_H(q_H-q_L) + (1-F(\theta_L))\\ &\quad\cdot(\theta_L q_L + e(1-y_i^2) + b(1-y_i)) - c(1-y_i)^2.\end{aligned}$$

Substituting Equation (10) into Equations (2) and (3), we obtain the first-order conditions:

$$\theta_H^* \text{ solves } \left[1 = \frac{1-F(\theta_H)}{F'(\theta_H)}\frac{1}{\theta_H}\right] \tag{11}$$

$$\theta_L^*, y_i^* \text{ solve} \left[\begin{array}{l} 1+\dfrac{(1-y_i)(b+e(1+y_i))}{\theta_L q_L} = \dfrac{1-F(\theta_L)}{F'(\theta_L)}\dfrac{1}{\theta_L} \\ (1-F(\theta_L))(b+2ey_i) = 2c(1-y_i)\end{array}\right]. \tag{12}$$

These equations in general may have multiple solutions that satisfy second-order conditions for maxima; the optimal solution is either a feasible triplet in the interior region or may have components at the boundary. Again, to examine the implications for the intermediary's versioning strategy, we illustrate our results for the case where F is uniform on the support $[0, 1]$. The first-order conditions reduce to

$$\theta_H = \frac{1}{2} \tag{13}$$

$$\theta_L = \frac{1}{2} - \frac{1}{2q_L}(b(1-y_i) + e(1-y_i^2)) \tag{14}$$

$$y_i = \frac{2c - b(1-\theta_L)}{2c + 2e(1-\theta_L)}. \tag{15}$$

4.1. Versioning Strategy

Proposition 6. *It is optimal for the intermediary to offer multiple versions of the value-added service.*

This result can be easily verified for the case where $F(\theta)$ is uniform, since Equation (14) shows that $\theta_L^* < \frac{1}{2}$. For the general case, we provide the proof in the Appendix. Interestingly, we note that the versioning result holds even when $b = 0$; i.e., sellers get no aggregation benefit by subscribing with the intermediary (e.g., when the intermediary is giving sellers access to buyers, but provides no information or aggregated content). This contrasts with the case of enhanced matching services where versioning is optimal only in the presence of seller-sided aggregation benefits.

4.2. Comparative Statics

The first-order conditions for the case of general distribution $F(\theta)$ stated in Equations (11) and (12) may yield multiple stationary points. As in §3.2, we compute comparative statics to examine the impact of changes in the exogenous parameters (b, c, e, q_L) on the decision variables θ_L and y_i as well as profit (recall that θ_H is unaffected by any of the exogenous parameters).

Proposition 7. *When the intensity of aggregation benefits to the supplier (b) is greater or the intensity of the aggregation benefit to buyers (e) is greater, the intermediary achieves a greater profit in equilibrium.*

Proof. Applying the envelope theorem,

$$\frac{\partial \pi^*}{\partial b} = (1-y_i)(1-F(\theta_L)) > 0$$
$$\frac{\partial \pi^*}{\partial e} = (1-F(\theta_L))(1-y_i)^2 > 0;$$

hence, the intermediary's profit increases when either b or e is greater. □

Proposition 8. *When the intensity of the competition among suppliers (c) is greater, this* (i) *reduces the intermediary's profit in equilibrium, and* (ii) *leads to reduced coverage on the sellers' side (y_i^* increases).*

Proof. Applying the envelope theorem, $(\partial \pi^*/\partial c) = -(1-y_i)^2 < 0$; hence, the intermediary's profit drops when c is greater. Coverage on the sellers' side is reduced, since (using the conjugate pairs theorem) $(\partial^2 \pi^*/\partial c\, \partial y_i) = 2(1-y_i) > 0$. □

Proposition 9. *An increase in the quality of the low-level value-added services (q_L)* (i) *reduces the intermediary's profit in equilibrium, and* (ii) *leads to reduced coverage on the buyers' side (θ_L^* increases).*

Proof. Applying the envelope theorem, we get $(\partial \pi^*/\partial q_L) = \theta_L^*(1-F(\theta_L^*)) - \theta_H^*(1-F(\theta_H^*))$. Following the proof given in Proposition 4, this derivative is negative; hence, profit reduces as q_L increases. To compute the effect of an increase in q_L on θ_L^*, we apply the conjugate pairs theorem,

$$\frac{\partial^2 \pi}{\partial q_L\, \partial \theta_L} = (1-F(\theta_L) - \theta_L F'(\theta_L)) > 0,$$

which shows that θ_L^* increases. □

4.3. How Many Versions?

Now consider the more general case where the intermediary may offer N quality levels $q_1, \ldots, q_N$ of the value-added service. Let the optimal indifference points be θ_j $(j = 1, \ldots, N)$, where θ_j is indifferent between q_j and q_{j-1}. Let p_j be the price for service level q_j; hence, from the indifference equations we get $p_j = \theta_j(q_j - q_{j-1}) + p_{j-1}$ for $j = 2, \ldots, N$ and $p_1 = \theta_1 q_1 + e(1 - y_i^2)$. Therefore, the intermediary's profit function is

$$\pi = (1 - F(\theta_N))p_N + \left[\sum_{j=1}^{N-1} (F(\theta_{j+1}) - F(\theta_j))p_j\right] + b(1 - \theta_1)(1 - y_i) - c(1 - y_i)^2.$$

Simplifying and computing first derivatives, we see that the stationary points θ_j satisfy the conditions

$$\text{for } j = 2 \ldots N, \quad \theta_j^* \text{ solves } \left[1 = \frac{1 - F(\theta_j)}{F'(\theta_j)} \frac{1}{\theta_j}\right] \tag{16}$$

$$\theta_1^* \text{ solves } \left[1 + \frac{(1 - y_i)(b + e(1 + y_i))}{\theta_1 q_1} = \frac{1 - F(\theta_1)}{F'(\theta_1)} \frac{1}{\theta_1}\right]. \tag{17}$$

Because Equation (16) is identical for all $j = 2, \ldots, N$, we see that $\theta_2^* = \cdots = \theta_N^*$; hence, quality levels $q_2, \ldots, q_{N-1}$ are not offered, reducing the problem to the two-quality problem solved earlier. Hence, it is optimal for the intermediary to offer just two quality levels.

5. Discussion

This paper has examined the design of infomediary services, especially with regard to the use of a versioning strategy. We find that versioning would help improve an infomediary's profitability and participation of buyers and sellers in the marketplace. While versioning is well understood to be profitable in general, researchers in information systems have shown that under certain circumstances—zero marginal costs, and constant marginal valuations for quality—versioning is not optimal, because the revenue loss due to cannibalization is not offset by any savings in costs. In contrast, our analysis of an intermediary's pricing strategy demonstrates that versioning is optimal even under these circumstances (Propositions 1 and 6). How do we explain this increased incentive to version? The answer is the aggregation benefit, which is an essential characteristic of infomediaries: Since the infomediary aggregates information about the participants and offerings in the marketplace, its users (buyers and, respectively, sellers) obtain greater value from the infomediary's services when there is a larger number of sellers (buyers). Therefore, the intermediary has a greater incentive to deploy an additional low-quality service, at a relatively lower price, that will obtain participation of low-type buyers who are not willing to purchase the higher-priced, premium-quality service. That in turn provides a greater incentive to sellers to participate, and when there is a larger number of sellers in the market, this substantially increases the valuation of the high-type buyers. Therefore, the infomediary can charge a higher price from users of the high-quality service.

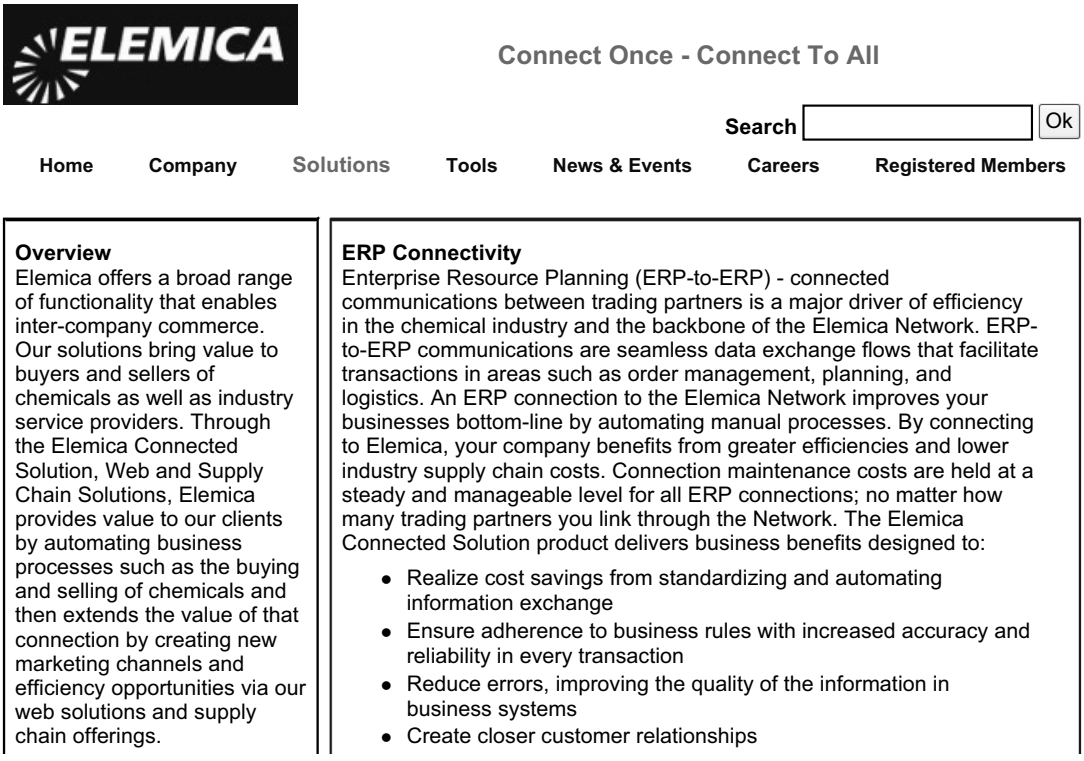
Compared with the traditional argument for versioning, the impact of the aggregation benefit on the intermediary's versioning strategy is as follows. The number of listed sellers is a critical element in buyers' valuation of the intermediary's matching service. If this were not the case (i.e., we remove the term $1 - y_i^2$ from the valuation function, or assume that all sellers are listed), then the intermediary would have no incentive to segment the market (standard result in prior literature cited earlier). Were the intermediary to offer just one quality level, then increasing participation of buyers would carry the cost of a lower price, thus reducing revenue. Offering multiple versions provides a solution to this problem: The intermediary introduces a low-priced service q_L to attract more users; this increases the number of sellers and the valuation of high-type buyers, allowing the intermediary to get higher revenues for the premium service.

Our versioning results and the qualitative distinctions and analysis of matching versus value-added services offer concrete ideas regarding how to design differentiated versions. We have shown that it is optimal to offer exactly two—rather than multiple—quality levels. Further, we find that the intermediary's profits decline as the lower-quality version improves: The cannibalization effect increases as the two quality levels move closer. Therefore, it is optimal for the

intermediary to make the low-quality service as basic as possible, i.e., to offer only matching services in the low-quality service. The basic matching service helps the intermediary to expand the size of the buyer network (making the intermediary more attractive to sellers), while the higher-quality service brings higher revenues; other quality levels in the middle are not offered because they would only cannibalize the high-quality service without expanding the size of the buyer network.

In settings where there are standalone value-added services, the intermediary should offer a basic matching service and a second premium service that bundles matching and standalone value-added services. In this case, the value-added services include features such as industry data and intelligence, conferences, insurance, and litigation support. A popular example of this is AAA.com, which provides various matching services for travel planning and also offers its members additional value-added services such as maps, trip planning, and travel insurance. In settings where value-added services have no standalone value, but tend to enhance the benefit from matching, the intermediary's menu would again consist of a basic matching service and a premium service that includes enhanced matching services. These enhanced matching services include IT services—such as collaborative workflow, data integration, systems connectivity, and automatically checking adherence of transaction to business rules—that provide support for logistics and fulfillment. Figure 1 illustrates the use of such a strategy by an intermediary in the chemical industry, which offers a basic *transaction-enabling engine* and a premium *ERP connectivity* service that promises to increase efficiency through seamless data-exchange flows. This analysis finds support in the real world, where intermediaries initially offered only a single quality level—a matching service—but have more recently employed a versioning strategy, treating value-added services as a critical offering to high-end users. This transition is also documented in the recent industry and academic literature (see, e.g., Sarkar et al. 1995, Wise and Morrison 2000).

Figure 1 Basic Matching and Value-Added Services (ERP Connectivity) Offered by Elemica, an Infomediary in the Chemical Industry



6. Conclusions

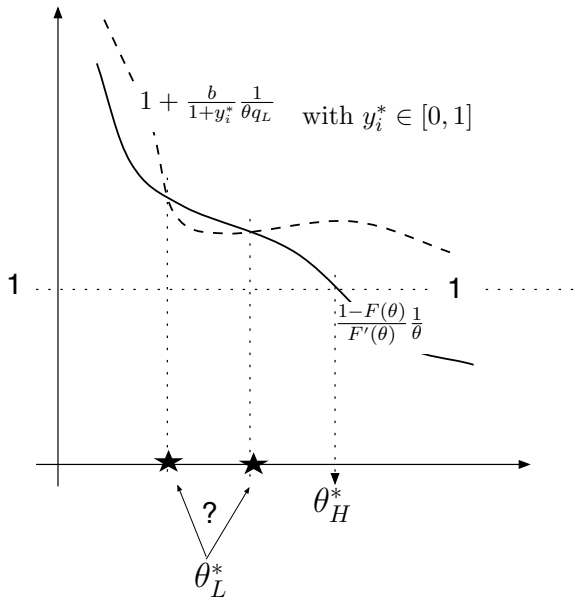
This paper has developed a model of infomediary services, in which the infomediary chooses quality levels and price, while buyers and sellers make decisions to participate while forming rational expectations about how many buyers and sellers would participate with the intermediary. The intermediary offers a number of services such as matching, price discovery, transaction management, industry reports, and account management. Services that help establish an agreement between buyers and sellers are considered to be matching services, and other services are called value-added services. Participants in an intermediated market care about the size of the intermediary's network. Buyers find an intermediary's service more valuable if it provides access to more sellers, and sellers value it more if it provides access to more buyers. Further, competition between sellers lowers the benefit to sellers when there are many sellers subscribing to the intermediary's service.

We have examined two settings of intermediary services: one where value-added services increase the benefits from matching services but have no standalone value, and the second where value-added services provide a standalone benefit independent of the matching services. Adopting a buyer-oriented perspective, we have shown that it is optimal for the intermediary to pursue a versioning strategy and offer two quality levels to buyers, where the lower quality level consists of matching services and the higher quality includes additional value-added services. This paper contributes to existing literature on versioning and intermediary services by formally analyzing the intermediary's pricing strategy—taking into account the aggregation effects and the different types of intermediary services—and showing that versioning is an especially useful strategy for intermediaries, more so than for other information goods sellers. Further, we provide insights into implementing such a strategy by creating two versions, one that includes matching services and another that bundles matching and value-added services. We have also examined different types of value-added services to classify them into those that help in transaction management and execution, such as logistics and payment services, and other value-added services that provide standalone benefits such as reports, education, and training.

We treat the availability of standalone value-added services and enhanced matching services as exogenously determined. Future research may address the problem of choosing between these two types of value-added services as well as the possibility of both being offered by a single intermediary. Standalone value-added services may be offered by third parties whereas the intermediary has an intrinsic advantage when offering enhanced matching services. Therefore, the competitive environment for the standalone value-added services is one of the key factors in deciding whether to offer such services. The range of enhanced matching services is inherently limited and depends on the technology used to implement the marketplace as well as features of the product being traded on the intermediary's platform. Certain products lend themselves to advanced search techniques, such as books that can be searched along a number of product attributes including author, title, publisher, price, etc.

Further extensions to this work can also be made by adopting a multiperiod model. Intermediation services such as online exchanges face the well-known chicken-and-egg problem: Initially, the lack of sellers makes the service unattractive to buyers, and lack of buyers makes it unattractive to sellers. While we have solved for a single-period rational expectations equilibrium, in the real world different players are likely to have a variety of different expectations, and the evolution and eventual success of an intermediary depends on how buyers and sellers make their decision to join when the network is still quite small. Therefore, value-added services can be used as a catalyst to jump start the process of aggregation. This is consistent with the conclusion of Wise and Morrison (2000), that intermediaries will survive only if they go beyond the matching role. A multiperiod setting may allow researchers to better address these questions. This paper can also serve as a useful framework for examining the recent trend among sellers to set up their own retailing websites, while some large buyers are experimenting with private marketplaces where the buyer can directly interact with various sellers.

Figure 2 Optimal Indifference Points θ_L^* and θ_H^* for Intermediary Service: Enhanced Matching Case



Note. There may be multiple candidates for θ_L^* but all must lie strictly to the left of θ_H.

Technical Appendix

Proof of Proposition 1. The RHS in Equation (4) is decreasing in θ (under the assumption of nondecreasing price elasticity of demand) and lies between ∞ and 0; hence, the equation yields a unique $\theta_H^* \in (0,1)$. Now consider the first part of Equation (5): The RHS is identical to that of Equation (4) while the LHS always exceeds 1. Hence, while Equation (5) may have multiple solutions—critical points for θ_L—all are strictly less than θ_H^*. Therefore, we conclude that it is optimal for the intermediary to segment the market and offer both the lower- and higher-quality service. Figure 2 graphically explains the result. □

Proof of Proposition 6. The proof is similar to that of Proposition 1. The RHS is identical in Equation (11) and the first part of Equation (12); it is decreasing in θ (under the assumption of nondecreasing price elasticity of demand) and lies between ∞ and 0; hence, Equation (11) yields a unique $\theta_H^* \in (0,1)$. Further, the LHS of Equation (12) always exceeds the LHS of Equation (11) (which equals 1). Hence, while Equation (12) may have multiple solutions—critical points for θ_L—all are strictly less than θ_H^*. Therefore, it is optimal for the intermediary to segment the market and offer both the lower- and higher-quality service. □

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