Design and ownership of two-sided networks: implications for Internet intermediaries

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Abstract[1]

Many Internet intermediaries are two-sided networks, i.e. they provide the infrastructure to bring two sides (e.g. buyers and sellers) together. We develop a model that characterizes the value created by two-sided networks, and the allocation of that value across the two sides. When the asymmetry of the network effects is large, then the side with the low network effect participates for free. We depart from existing networks literature by endogenizing the network effects and focusing on the network design resulting from investments in network effects. We show that under certain assumptions about the returns to scale of available technologies, the design of a two-sided network is characterized by *maximally asymmetric allocation of surplus* independent of the ownership regime. Exceptions are cases where there is significant reusability of investment across sides, or the designer has little influence over the network effect (i.e., the network effects are predominantly exogenous). The optimal ownership is either ownership by the side enjoying the strongest inherent network effect, or by the side enjoying the design technology with the strongest return.

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1. Introduction

There is an extensive literature on network effects (Katz and Shapiro 1985; Economides 1996) that focuses on networks with a single type of participants, such as subscribers to a telecommunications network or users of a software application. In this work we study two-sided networks, i.e. networks in which there are two sides of participants, each deriving positive externalities from the participation of the other side in the network. Such networks are commonplace, including many Internet intermediaries such as business-to-business marketplaces (e.g. Covisint), consumer-to-consumer and business-to-consumer marketplaces (e.g. eBay), matching services (e.g. match.com), information intermediaries, and electronic communities with information contributors and information consumers.

Two-sided networks play an important role in the Internet economy, but many aspects of these networks are not well understood, such as the determinants of participants' benefits, the implications of actions by the intermediary, and how the value created by the network is allocated between the two sides and the intermediary. Independent intermediaries seek concrete insights on how to design their networks, and how to allocate their investment budgets. Potential participants ask whether they should also seek ownership of the network and how ownership matters. Policy-makers that observe the multitudes of designs and ownership structures of Internet intermediaries would value insights on the socially optimal design and ownership.

Motivated by the above observations, we seek to study two aspects of these networks:

1. What is the value created by two-sided networks and how is that value allocated to the network participants?
2. What is the optimal design of a two-sided network and who should own it and therefore be responsible for design and investment decisions?

We focus our analysis on intermediated two-sided networks, but our framework also applies to non-intermediated two-sided networks.

The paper analyzes equilibrium participation and pricing of two-sided networks with pure network services and side heterogeneity. It captures the effect of different side sizes and different strengths of network externalities. It considers investments in the network, therefore the network design is endogenous (endogenous network effects), while at the same time we allow for the presence of inherent network effects. The core contribution is the analysis of the relationship between ownership and design of two-sided networks, where network effects are endogenous.

There are a few recent papers that analyze the features of two-sided networks (or two-sided markets for some of the papers) and all focus on pricing. (Parker and Van Alstyne 1999) study strategic complements and substitutes in the information goods context, and they identify subsidization conditions across the two-sides. We focus on an intermediation context and as a result the specification of the two models is different in many points, e.g. our specification involves two-sided pure network services, and our network effects are multiplicative as opposed to additive. We identify subsidization conditions across the two-sides in our context. (Rochet and Tirole 2001) study competition between platforms in two-sided markets. Their model does not consider differential network effects on the two sides and participants get positive utility only when they are matched successfully. While we focus on the structure of participation fees, they characterize the structure of matching fees for monopoly and oligopoly settings, considering also for-profit and not-for-profit joint undertakings. Moreover their model considers only the relationship between ownership and pricing and ignores the relationship between ownership and design, which is the primary focus of this work. (Caillaud and Jullien 2001) consider homogeneous populations on the two sides of matchmakers and they analyze competition with both participation and matching fees. (Armstrong 2002) provides a synthesis of existing literature and analyzes some examples of two-sided markets. (Evans 2003) provides a recent survey focusing on policy issues. We depart from all these papers by focusing on the design of two-sided networks. The design of a two-sided network is defined as the level of investment on the network effect of each side.

In addition to the two-sided network literature, the paper contributes to the literature on intermediaries, electronic intermediaries and electronic markets (Bakos 1991; Bakos 1991; Spulber 1996; Bakos and Nault 1997).

Several types of asymmetry might characterize a two-sided network, i.e. asymmetric network effects (AN), asymmetric equilibrium prices (AP), asymmetric revenue generation (AR), *asymmetric allocation of surplus* created (ALS), asymmetric investment (AI). A theory of two-sided networks should characterize the relationships between these types of asymmetry. We focus on the ALS type of asymmetry. We define a network as *buyer ALS* when the buyer surplus is greater than the seller surplus, and *seller ALS* when the seller surplus is greater than the buyer surplus.

We analyze a single two-sided network, with two types of participants and an intermediary that determines the design of the network. We show that the network asymmetry affects significantly the participation, the value created by the two-sided network and the allocation of that value. We then analyze the design of networks where design decisions determine the form of the resulting network effects. We demonstrate that ownership has a significant effect on design. We show that under certain assumptions about the returns to scale of the underlying technology, a network will be ALS, i.e. it will offer more value to one side of the network, even when there are not any inherent network effects favoring one side over the other.

We focus on three different ownership regimes of the network: ownership by an independent intermediary, and ownership by the buyer side or the seller side. We also analyze the case of a network that is designed by a specific side, but then sets prices as an independent unit (spin-off network). We discuss more general ownership regimes that include joint ownership by a subset of buyers and a subset of sellers in the appendix.

2. The Model

We consider an intermediated network with two types of participants (two "sides"), which without loss of generality we call "buyers" and "sellers." We assume an exogenous mass N_b, N_s of potential buyer and seller network participants. The buyers and the sellers enjoy network externalities from the number of sellers and buyers respectively. Buyers and sellers are heterogeneous with respect to their respective valuation of the network externality $\theta_b \sim U[0,1]$ and $\theta_s \sim U[0,1]$. Buyers and sellers face participation prices p_b and p_s respectively set by the intermediary, and choose to participate or not to participate in the network based on their respective participation utilities $U_{\theta_b} = \theta_b f_b(n_s) - p_b$ and $U_{\theta_s} = \theta_s f_s(n_b) - p_s$, where n_b, n_s the measure of buyers and sellers that participate in the network. The network externalities are captured by the functions $f_b(n_s), f_s(n_b)$ that are increasing and concave and $f_b(0) = 0, f_s(0) = 0$. The participation utility functions capture the value for variety in the other side, and the increased probability of finding a satisfactory match in the other side. The functions capture also the fact that intermediation services are predominantly pure network goods, i.e. there is zero participation value when the size of the network is zero. Our specification is in-line with previous research on electronic intermediaries (Bailey and Bakos 1997; Bakos 1998).

In what follows we focus on linear network externalities functions that give participation utilities $U_{\theta_b} = \theta_b \alpha n_s - p_b$ and $U_{\theta_s} = \theta_s \beta n_b - p_s$. The parameters α and β capture the strength of the network externalities. The assumption of linear network externalities enables us to characterize in detail the equilibria and it is a common assumption in the network economics literature. We discuss however how our results would be affected by more general network externalities functions in the appendix.

As a benchmark, a social planner would maximize total social surplus. The corresponding first-best total value created by the network is achieved under total participation on both sides and it is given by $N_b\int_0^1 \theta_b \alpha N_s \partial\theta_b + N_s\int_0^1 \theta_s \beta N_b \partial\theta_s = \frac{(\alpha+\beta)N_b N_s}{2}$.

3. Network pricing and participation

We analyze the pricing and participation equilibria under different ownership regimes.

3.1. Independent network pricing

In the above setting, we first explore the following game, looking for subgame perfect Nash equilibria:

1. The intermediary sets prices
2. Buyers and sellers decide on participation.

The intermediary's profit function is $\pi = n_b p_b + n_s p_s$.

Proposition 1

There is a unique non-trivial SPNE given by the following:[2]

$$
(n_b, n_s; p_b, p_s) = \begin{cases} \left(\frac{N_b(\alpha+\beta)}{3\alpha}, \frac{N_s(\alpha+\beta)}{3\beta}; \frac{N_s(\alpha+\beta)(2\alpha-\beta)}{9\beta}, \frac{N_b(\alpha+\beta)(2\beta-\alpha)}{9\alpha}\right), \text{if } \frac{\alpha}{2} \le \beta \le 2\alpha, \ \text{(E1)} \\ \left(N_b, \frac{N_s}{2}; 0, \frac{N_b\beta}{2}\right), \text{if } \beta > 2\alpha, \ \text{(E2)} \\ \left(\frac{N_b}{2}, N_s; \frac{N_s\alpha}{2}, 0\right), \text{if } \beta < \frac{\alpha}{2}, \ \text{(E3)} \end{cases}
$$

Proof. See appendix for all proposition proofs.

[2] There is a trivial equilibrium with zero participation and prices that represents a "coordination" failure across the sides. The monopoly intermediary can influence expectations and avoid that failure.

This equilibrium has a number of interesting properties:

1. Only the differential network externalities affect the equilibrium regions.
2. There is no equilibrium in which the network covers 100% of both sides, as it is always optimal for the intermediary to price out some of the participants, thus creating some deadweight loss.
3. When the network externality for the buyers (sellers) is more than twice the network externality for the sellers (buyers), the network subsidizes and attracts all the sellers (buyers) and makes its profits exclusively from buyers (sellers).
4. In general, it is not optimal to set the same participation price for both sides of the network. Same participation price is only a special case, i.e. when $N_b = N_s$ and $\alpha = \beta$.
5. In (E1) the participation and price ratios are $\frac{n_b}{n_s} = \frac{\beta N_b}{\alpha N_s}, \frac{p_b}{p_s} = \frac{\alpha(2\alpha - \beta) N_s}{\beta(2\beta - \alpha) N_b}$, while in (E2) they are $\frac{n_b}{n_s} = \frac{2N_b}{N_s}, \frac{p_b}{p_s} = 0$.

The buyers' realized surplus is $BS = N_b \int_{1-\frac{n_b}{N_b}}^{1} (\theta_b \alpha n_s - p_b) \partial\theta_b$ and the sellers' surplus is $SS = N_s \int_{1-\frac{n_s}{N_s}}^{1} (\theta_s \beta n_b - p_s) \partial\theta_s$. The total surplus is $TS = BS + SS + NP$.

Equilibrium Region	Buyer Surplus (BS)	Seller Surplus (SS)	Network Profit (NP)	Total Surplus (TS)
(E1)	$\frac{(\alpha+\beta)^3 N_b N_s}{54\alpha\beta}$	$\frac{(\alpha+\beta)^3 N_b N_s}{54\alpha\beta}$	$\frac{(\alpha+\beta)^3 N_b N_s}{27\alpha\beta}$	$\frac{2(\alpha+\beta)^3 N_b N_s}{27\alpha\beta}$
(E2)	$\frac{\alpha N_b N_s}{4}$	$\frac{\beta N_b N_s}{8}$	$\frac{\beta N_b N_s}{4}$	$\frac{(2\alpha+3\beta) N_b N_s}{8}$
(E3)	$\frac{\alpha N_b N_s}{8}$	$\frac{\beta N_b N_s}{4}$	$\frac{\alpha N_b N_s}{4}$	$\frac{(3\alpha+2\beta) N_b N_s}{8}$

Table 1. Equilibrium characterization of independent network

Table 1 shows that the network is seller ALS in region (E2) and buyer ALS in region (E3), while the surplus is symmetrically allocated in region (E1).

Proposition 2 (comparative statics)

- In (E1), an increase of the parameter α leads to an increase of p_b, a reduction of n_b, a reduction of p_s, and an increase of n_s. It also leads to an increase of BS, SS, NP.
- In (E2), an increase of the parameter α does not affect the equilibrium prices and participation. However, the surplus of the buyer side increases.
- In (E3), an increase of the parameter β does not affect the equilibrium prices and participation. However, the surplus of the seller side increases.

3.2. Buyer-side owned network pricing

A buyer-side owned network maximizes the buyer-side surplus plus the profits from the participation of the sellers.

Proposition 3

There is a unique non-trivial SPNE given by the following:

$$\left(n_b, n_s; p_b, p_s\right) = \begin{cases} \left(N_b, N_s; 0, 0\right), & \text{if } \alpha \geq 2\beta, \text{ (B1)} \\ \left(N_b, \dfrac{(\alpha+2\beta)N_s}{4\beta}; 0, \dfrac{(2\beta-\alpha)N_b}{4}\right), & \text{if } \alpha < 2\beta, \text{ (B2)} \end{cases}$$

The allocation of value is as follows.

Equilibrium Region	Buyer Surplus (BS)	Seller Surplus (SS)	Network Profit (NP)	Total Surplus (TS)
(B1)	$\frac{\alpha N_b N_s}{2}$	$\frac{\beta N_b N_s}{2}$	0	$\frac{(\alpha+\beta) N_b N_s}{2}$
(B2)	$\frac{\alpha(\alpha+2\beta) N_b N_s}{8\beta}$	$\frac{(\alpha+2\beta)^2 N_b N_s}{32\beta}$	$\frac{(2\beta-\alpha)(2\beta+\alpha) N_b N_s}{16\beta}$	$\frac{3(\alpha+2\beta)^2 N_b N_s}{32\beta}$

Table 2 Equilibrium characterization of buyer-side owned network

The socially optimal participation is achieved when the network effect that the buyers enjoy is sufficiently strong, i.e. $\alpha \geq 2\beta$. The buyers face a trade-off between value from their participation (which is maximal when there is complete seller participation) and profit from the sellers (which is maximized when seller participation is restricted). The former force dominates in region (B1) therefore the first-best is achieved.

The equilibrium is symmetric for pricing under seller-side ownership.

3.3. Comparison of ownership regimes

We first compare the ownership regimes in terms of total surplus.

Proposition 4

When network effects are exogenous, then optimal ownership is ownership by the seller-side when $\beta > \alpha$ and ownership by the buyer side when $\alpha > \beta$. In addition, seller-side ownership is first-best when $\beta > 2\alpha$, and buyer-side ownership is first-best when $\alpha > 2\beta$.

The proposition demonstrates an interesting relationship between ownership and value created by the intermediary. First, the optimal ownership is always ownership by the side that enjoys the strongest network effect from the participation of the other side. Independent ownership is never optimal. Second, and most importantly when the network effect that the owner side enjoys is strong enough (i.e. the network asymmetry is large), then the first-best participation and value are achieved. This happens even though the intermediary market is a monopoly. There is not any deadweight loss and there is no need for regulation or other policy intervention to improve social welfare (FTC 2000).

It is also interesting to compare how sellers fair under a buyer-side owned network compared to an independent network.

Proposition 4a

When all network effects are exogenous, the seller participation and surplus is higher under buyer-side ownership compared to independent ownership, i.e. $n_s^{IO} \le n_s^{BO}$, $SS^{IO} \le SS^{BO}\ \forall \alpha, \beta$. However, there is a region of parameters for which the sellers pay a higher price under buyer side ownership compared to independent ownership, i.e. $p_s^{IO} < p_s^{BO}, \textit{iff}\ \frac{4}{5} \le \frac{\alpha}{\beta} \le 2$.

4. Design and ownership

We assume that the network effect parameters α and β are design parameters whose actual value results from investments by the intermediary. To our knowledge this is a novel approach in the networks literature where network effects are typically assumed exogenous. The network effects in two-sided networks, however, typically are not exogenous, and are significantly affected by design choices and investments made by the intermediary, such as the quality of technology offered to each side, the services offered to each side, the mechanism or the rules of interaction between the two sides. We abstract these dimensions of network design in the choice of parameters α and β.

We study a two-stage game in which the intermediary first designs the network, and then pricing and participation decisions follow. We are looking for the subgame perfect Nash equilibrium $<\left(\alpha^*, \beta^*\right); \left(p_b, p_s\right)>$. Our objective is to explore how an independent intermediary designs the network and how the design is affected when one of the sides is the owner of the network and hence has the advantage to design the network.

We consider concave design technologies (i.e., technologies with diminishing returns to the level of investment). In particular, the network has a design technology $\alpha(x) = rx^{1/2}, \beta(y) = ry^{1/2}$ where x, y are investments required to create network effects α, β and a scale coefficient r. These design technologies are equivalent to quadratic costs of network effects. We discuss how the results are affected by more general convex cost functions in the appendix.

4.1. Independent Ownership

The design problem is $\max_{\alpha,\beta}\left[\pi - \frac{\alpha^2+\beta^2}{r^2}\right]$.

Proposition 5 *(maximally ALS design)*

The equilibrium design of an independent intermediary is maximally ALS, i.e. $(\alpha^*, \beta^*) \in \left\{\left(0, \frac{N_b N_s r^2}{8}\right), \left(\frac{N_b N_s r^2}{8}, 0\right)\right\}$.

It is important to understand the intuition behind this result. The intermediary faces the choice of investing on network effects (α, β) so that next stage pricing equilibrium region is in (E1), or (E2) or (E3). Therefore the intermediary compares the optimal design across the three regions. The crucial feature is that as long as the design is e.g. in (E3) an additional investment in β does not bring any additional profit to the intermediary, since it does no affect the second stage equilibrium prices and participation.

The independent intermediary is indifferent to buyer or seller ALS. The intermediary is indifferent between:

- Allowing participation to the "short side" for free and extracting a relatively low rent from each participant of the "long side"; and
- Allowing participation to the "long side" for free and extracting a relatively high rent from each participant of the "short side".

Therefore the size difference between the two sides does not affect the design.

4.2. Buyer side ownership

The optimization problem is $\max_{\alpha,\beta}\left[\pi + BS - \frac{\alpha^2+\beta^2}{r^2}\right]$.

Proposition 6

The equilibrium design of a buyer-side owned network is unique and buyer ALS i.e. $(\alpha^*, \beta^*) = \left(\frac{r^2 N_b N_s}{4}, 0 \right)$. The ALS toward the buyer side is increased compared to independent ownership.

The buyer side designs the network such that the participation equilibrium is within (B1). All the sellers are allowed to participate for free, and the buyer side captures the value through participation (the network profit is zero).

The seller-side ownership case is symmetric.

4.3. Spin-off buyer-side owned network

The buyer side designs the network, but in the second stage the network sets prices like an independent unit, i.e. sets prices to maximize the network profit. The analysis of this case is motivated by the observation that very often the owners and sponsors of an intermediary announce that it will be operated as an independent unit (e.g. Covisint, MusicNet, PressPlay). This usually happens after the fundamental design decisions have been made.

Proposition 7

The equilibrium design of a spin-off buyer-side owned network is unique and ALS i.e. $(\alpha^*, \beta^*) = \left(\frac{3r^2 N_b N_s}{16}, 0 \right)$. The ALS toward the buyer side is increased compared to independent ownership, but it is reduced compared to buyer-side ownership.

The buyer side designs the network such that the participation equilibrium is within (E3). The sellers are allowed to participate for free, while half of the buyers participate for a fee. All the profit of the network comes from buyer participation fees.

The results are symmetric for a spin-off seller-side owned network.

4.4. Design comparison

The following table summarizes the equilibrium network design under different ownership regimes.

Ownership	Design (α^*, β^*)		Total Surplus	
Independent	$\left\{\left(0, \frac{r^2 N_b N_s}{8}\right), \left(\frac{r^2 N_b N_s}{8}, 0\right)\right\}$		$\frac{8r^2 N_b^2 N_s^2}{256}$	
		Spin-off		Spin-off
Buyer side	$\left(\frac{r^2 N_s N_b}{4}, 0\right)$	$\left(\frac{3r^2 N_s N_b}{16}, 0\right)$	$\frac{16r^2 N_b^2 N_s^2}{256}$	$\frac{9r^2 N_b^2 N_s^2}{256}$
Seller side	$\left(0, \frac{r^2 N_b N_s}{4}\right)$	$\left(0, \frac{3r^2 N_b N_s}{16}\right)$	$\frac{16r^2 N_b^2 N_s^2}{256}$	$\frac{9r^2 N_b^2 N_s^2}{256}$
Social planner	$\left(\frac{r^2 N_b N_s}{4}, \frac{r^2 N_b N_s}{4}\right)$	$\left\{\left(\frac{r^2 N_b N_s}{8}, \frac{3r^2 N_b N_s}{16}\right), \left(\frac{3r^2 N_b N_s}{16}, \frac{r^2 N_b N_s}{8}\right)\right\}$	$\frac{32r^2 N_b^2 N_s^2}{256}$	$\frac{13r^2 N_b^2 N_s^2}{256}$

Table 3 Summary of design under different ownership regimes.

Proposition 8 (investments)

1. When the independent intermediary is buyer ALS, then it underinvests on the seller side always. Symmetrically, when the independent intermediary is seller ALS.
2. A buyer-owned network underinvests on the seller-side always. It either invests optimally or overinvests on the buyer-side.
3. A buyer-owned spin-off network underinvests on the seller-side always. It either invests optimally or underinvests on the buyer-side.

Proposition 9 (optimal ownership)

When all network effects are endogenous, then the optimal ownership is either buyer-side or seller-side ownership. These ownership structures dominate independent ownership and the spin-off cases. None of the designs is first-best.

4.5. Asymmetric design technologies

The design technologies might well be asymmetric in the sense that creating value for one of the two sides might be more costly. Let $\alpha(x) = r_\alpha x^{1/2}, \beta(y) = r_\beta y^{1/2}$.

Proposition 10

The independent intermediary equilibrium design is *maximally ALS*, but it is unique, i.e. $(\alpha, \beta) = \begin{cases} \left(\dfrac{r_\alpha^2 N_b N_s}{8}, 0 \right), & \text{if } r_\alpha \geq r_\beta \\ \left(0, \dfrac{r_\beta^2 N_b N_s}{8} \right), & \text{if } r_\beta \geq r_\alpha \end{cases}$.

When the design technologies were symmetric, the independent intermediary was indifferent between investing on the buyer side and the seller side. In the presence of asymmetric design technologies however, the intermediary invests on the side that enjoys the most efficient design technology (largest scale factor).

Proposition 11

Optimal ownership is ownership by the side that enjoys the most efficient design technology, i.e. buyer side ownership when $r_\alpha \geq r_\beta$, otherwise seller side ownership.

4.6. Reusable investment across sides

We now consider a case in which the investment is reusable across the two sides. This case may be realistic when the services or technologies provided to the two sides are functionally similar. For example in the personals Internet industry (e.g. match.com) the services offered to males and females are almost identical, therefore investments are reusable across sides.

Let a share $0 \le g \le 1$ of the investment on α be reusable. Then by investing (x, y) the intermediary achieves design $\alpha(x) = rx^{1/2}$ and $\beta(y; g) = r(gx + y)^{1/2}$.

Proposition 12 (reusable investment)

The equilibrium design of an independent intermediary is characterized by symmetric allocation of surplus when there is sufficient investment reusability, i.e. when $g > 1/4$.

5. Discussion

The analysis of Internet intermediaries as two-sided networks provides us with significant insights. The intermediary often sets a very low, maybe zero, price to one of the two sides. We showed that when the network effect of the one side is much larger than the network effect of the other side then the independent intermediary sets a zero price for the low network effect side and generates a profit only from the large network effect side. An analysis focusing only on one of the two sides, ignoring the interaction between the two sides, would lead to a sub-optimal intermediary pricing strategy.

Many Internet intermediaries (e.g. Match.com) set the same participation price for both sides of the network. Our model shows that this can be optimal only under the special case that the two-sided network is perfectly symmetric. Therefore, an intermediary that currently sets the same price should look for ways to optimize its pricing strategy by evaluating the asymmetry between the two sides.

The crucial finding of the paper is that, under standard assumptions about the design technologies, the network has a strong incentive to invest only on one of the sides and let the other side participate with a marginally positive investment. That result provides an answer for the central question on the two-sided networks literature: Why do we observe so often asymmetric pricing in two-sided networks? It is because very often the optimal design of the network is asymmetric, which in turn leads to an asymmetric pricing equilibrium.

That optimal design strategy suggests a rule of thumb for Internet intermediaries: *identify the right side and invest to create value for that side*. A two-sided network designer should focus first on an investment strategy that influences the network effect of each side in an optimal way. The intermediary should evaluate the relative strength of the inherent network effects in the specific industry. Then the intermediary should evaluate the design technologies available for investment on each side. The designer should set the optimal two-sided pricing strategy following the optimal network design.

Our analysis provides a roadmap for designing two-sided networks. That is particularly important in the Internet, where designers face many design alternatives.

Our theory suggests an explanation of many Internet intermediaries failed in the early 2000. The reason is that they did not focus on any of the two sides trying to take a symmetric network. As a result their investment strategies were sub-optimal.

The ownership of a network has been a particular important question in the B2B marketplaces context (Lucking-Reily and Spulber 2001). Consider the following quote from a 2000 Federal Trade Commission workshop on B2B marketplaces (FTC 2000):

> "Several panelists strongly endorsed this third-party model as being essential to providing a *fair* and *neutral* marketplace…Other workshop participants rejected that premise insisting instead that any marketplace has the incentive to act *fairly* and *neutrally…*"

Our model suggests that both arguments given by panelists are incorrect. A marketplace owned by a single side is very likely to be ALS favoring the owner side. But that is true also for an independent intermediary. The optimal strategy of an independent intermediary is to invest predominantly to create value for one of the sides and just attract marginally the other side to participate. This justifies the success of intermediaries such as FreeMarkets in industrial procurement that invests in creating value for big buyers and charges the buyers only.

The finding that the design of a two-sided network follows a similar ALS structure independent of ownership is important for a theory of two-sided networks. Ownership matters as far as the level of investment is concerned, but it seems not to matter when the structure of investment is at stake.

The insight for policy makers is that there is an important relationship between ownership and value created by the intermediary. The main reason for that is that ownership affects the incentives to invest on the two sides, as well as the incentives to regulate participation through pricing. An independent intermediary has weaker incentives to invest than a participating network side, thus independent ownership is generally sub-optimal. The first-best value of the network can be attained under ownership by a single side when the network effect the side enjoys is sufficiently strong.

6. Concluding remarks

We developed a model with two-sided network effects that captures the value of Internet intermediaries that facilitate matching. We characterized the intermediary pricing strategy and the allocation of the network value. We focused primarily on the relationship between the network ownership and the design that results from investments in network effects.

Future research includes the analysis of competition between two-sided networks under non-cooperative network design. Another important future research direction is the prediction of the evolution of two-sided network structures, when intermediaries face competition from private networks (Katsamakas 2003).

There are many empirical open research problems. These involve estimation of the inherent and the endogenous network effects in various Internet intermediary settings, and evaluation of the network asymmetry (pricing, revenue, investment, allocation of surplus). Pricing and revenue asymmetries are relatively easy to recognize. However, asymmetries involving investment and allocation of surplus are more difficult to recognize and we do not know whether they are widespread. The investment asymmetries are important, because they are the primary source of all the other types of asymmetries (price, revenue, allocation of surplus). Research to that direction could help us map the various types of Internet business models and explain their relative success better.

There is also significant work to be done on understanding the main features of design technologies on the Internet, since that is crucial for an optimal network design. A related important question is to what extent the Internet and IT in general affect the features of network design technologies (e.g. the convexity of design costs), since that could change the nature of intermediation. If the design technologies of Internet intermediaries are different from the design technologies of physical intermediaries, these two types of intermediaries should follow different design and pricing strategies.

Appendix

Proof of Proposition 1

Buyers and sellers have rational expectations about the participation of the other side, i.e. $n_b^e = n_b$ and $n_s^e = n_s$. Let q_b, q_s be the proportion of N_b, N_s that participate in the network, i.e. $q_b = \frac{n_b}{N_b}, q_s = \frac{n_s}{N_s}$. Then the utility functions can be written as $U_{\theta_b} = \theta_b \alpha q_s N_s - p_b$ and $U_{\theta_s} = \theta_s \beta q_b N_b - p_s$. Let $\hat{\theta}_b$ the indifferent buyer then $\hat{\theta}_b \alpha q_s N_s - p_b = 0$, therefore $(1-q_b)\alpha q_s N_s = p_b$. Similar for the seller side we get $(1-q_s)\beta q_b N_b = p_s$. The profit function then becomes $\pi = N_b N_s \left(\alpha(1-q_b)q_b q_s + \beta(1-q_s)q_b q_s\right)$.

The optimization problem is $\max\limits_{q_b, q_s} \pi$, s.t. $q_b \le 1, q_s \le 1$. We form the Langrangean and take the Kuhn-Tucker first-order conditions. When the q_b constraint is binding i.e. $q_b = 1$ we get $q_s = 1/2$ and $\alpha > 2\beta$. Similarly when $q_s = 1$ we get $q_b = 1/2$ and $\beta > 2\alpha$. When $\frac{\alpha}{2} \le \beta \le 2\alpha$ we get $q_b = \frac{\alpha+\beta}{3\alpha}, q_s = \frac{\alpha+\beta}{3\beta}$. The equilibrium participation and prices in the three regions (E1), (E2), (E3) follow.

It is easy to see that the profit function is concave in (E2) and (E3). In (E1) the second order conditions are also satisfied as the determinants of the leading minors of the Hessian matrix alternate in sign, i.e. $|\mathrm{H}_1| = \frac{\partial^2 \pi}{\partial q_b^2} = -2\beta q_b < 0$ and $|\mathrm{H}_2| = 4\alpha\beta q_b q_s - \left(\alpha(2q_b - 1) + \beta(2q_s - 1)\right)^2 > 0$ at $q_b = \frac{\alpha+b}{3\alpha}, q_s = \frac{\alpha+b}{3\beta}$.

Participation equilibrium under more general network externality functions

When we assume more general concave network externality functions the pricing and participation equilibrium follows a similar pattern with three equilibrium regions. However, in general the conditions that characterize the three regions are not symmetric and the equilibria are not symmetric either. For example, assume $U_{\theta_b} = \theta_b \alpha n_s^{k_b} - p_b$ and $U_{\theta_s} = \theta_s \beta n_b^{k_s} - p_s$, where $0 < k_b, k_s < 1$. For $k_b = 1, k_s = 1/2$, the mass of buyers matters in the conditions for the three equilibrium regions. In particular, $(n_b, n_s) = \begin{cases} (n_b^{'}, n_s^{'}), \text{ if } \frac{\alpha^2 N_b}{8} \le \beta^2 \le 16\alpha^2 N_b, \text{ (E1)} \\ (N_b, n_s^{''}), \text{ if } \beta^2 > 16\alpha^2 N_b, \text{ (E2)} \\ (n_b^{''}, N_s), \text{ if } \beta^2 < \frac{\alpha^2 N_b}{8}, \text{ (E3)} \end{cases}$ where $n_b^{'}, n_s^{'}, n_b^{''}, n_s^{''}$ are interior solutions.

Proof of Proposition 2

$$\frac{\partial n_b}{\partial \alpha} = -\frac{\beta}{9\alpha^2} < 0, \quad \frac{\partial n_b}{\partial \beta} = \frac{N_b}{3\alpha} > 0, \quad \frac{\partial p_b}{\partial \alpha} = \frac{(4\alpha+\beta)N_s}{9\beta} > 0$$

$$\frac{\partial p_b}{\partial \beta} = -\frac{(2\alpha^2+\beta^2)N_s}{9\beta^2} < 0, \quad \frac{\partial BS}{\partial \alpha} = \frac{(2\alpha-\beta)(\alpha+\beta)^2 N_s}{54\alpha^2\beta} > 0$$

$$\frac{\partial BS}{\partial \beta} = \frac{(2\beta-\alpha)(\alpha+\beta)^2 N_s}{54\alpha\beta^2} > 0, \quad \frac{\partial NP}{\partial \alpha} = 2\frac{\partial BS}{\partial \alpha}, \quad \frac{\partial NP}{\partial \beta} = 2\frac{\partial BS}{\partial \beta}$$

Proof of Proposition 3

The objective function now is $f = N_b \int_{1-q_b}^{1} \theta_b \alpha q_s N_s \partial\theta_b + q_s N_s p_s$. The indifferent seller gives $(1-q_s)\beta q_b N_b = p_s$. The integral is $\int_{1-q_b}^{1} \theta_b \alpha q_s N_s \partial\theta_b = \alpha q_s q_b \left(1 - \frac{q_b}{2}\right) N_s$. Substituting into f we get $f = N_b N_s \left[\alpha q_s q_b \left(1-\frac{q_b}{2}\right) + \beta q_s q_b (1-q_s) \right]$.

The optimization problem is $\max_{q_b, q_s} f$, s.t. $q_b \le 1, q_s \le 1$. When the q_s constraint is binding we get $q_b = 1$ and $f = \frac{\alpha}{2}$. When the q_b constraint is binding we get $q_s = \frac{a+2\beta}{4\beta}$ and $f = \frac{(\alpha+2\beta)^2}{16\beta}$, when $\alpha \le 2\beta$. The equilibrium follows.

Proof of Proposition 4

Compare the total surplus under different ownership structures characterized in tables 1, 2.

Proof of Proposition 4a

Compare the seller participation, seller surplus and seller price under different ownership structures characterized in tables 1, 2.

Proof of Proposition 5

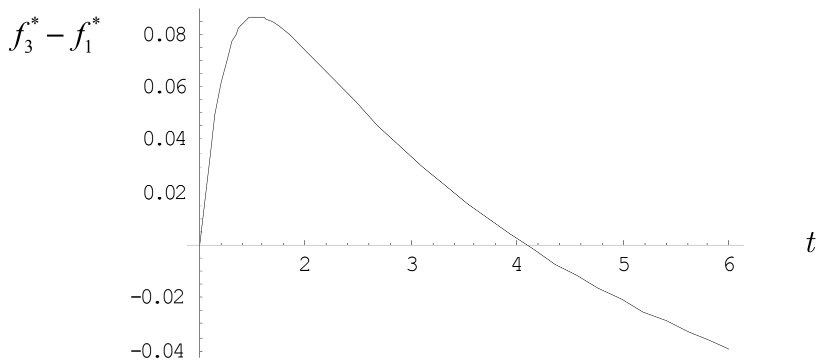
The intermediary solves the maximization problem in each equilibrium region and decides on the optimal design. It is $\pi_1^* = \frac{r^2 N_b^2 N_s^2}{80}, \pi_2^* = \pi_3^* = \frac{r^2 N_b^2 N_s^2}{64}$. Therefore $\pi_2^* = \pi_3^* > \pi_1^*$. The design follows.

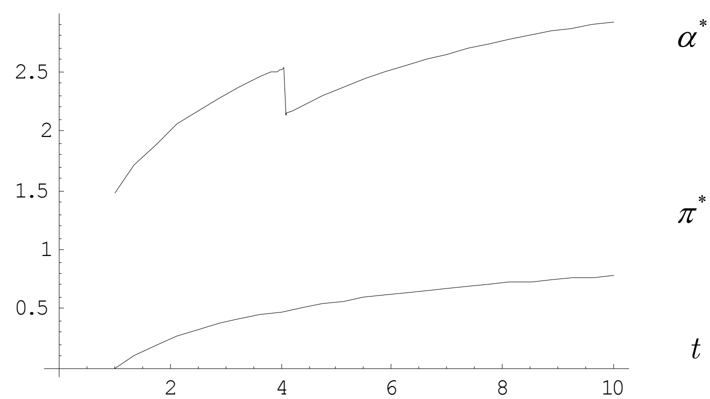
General design technologies

Let $\alpha(x) = rx^{1/t}, \beta(y) = ry^{1/t}$, where $1 < t$. The design objective function in (E3) is $f_3 = \frac{\alpha}{4} - \frac{\alpha^t + \beta^t}{r^t}$, which gives $\left(\alpha^*, \beta^*\right) = \left(\left(\frac{r^t}{4t} \right)^{\frac{1}{t-1}}, 0 \right)$ and $f_3^* = \frac{\alpha^*}{4} - \frac{\alpha^{*t}}{r^t}$.

Due to symmetry, a critical point in (E1) should satisfy $\alpha = \beta$ and therefore the FOC of the design problem in (E1) is $\frac{8\alpha}{27} - \frac{2\alpha^t}{r^t} = 0$, which gives $\left(\alpha^*, \beta^*\right) = \left(\left(\frac{4r^t}{27t} \right)^{\frac{1}{t-1}}, \left(\frac{4r^t}{27t} \right)^{\frac{1}{t-1}} \right)$ and $f_1^* = \frac{8\alpha^*}{27} - \frac{2\alpha^{*t}}{r^t}$.

Studying the sign of $f_3^* - f_1^*$, it is easy to see that there exists $\hat{t} \approx 4$ such that $f_3^* - f_1^* > 0, \mathit{iff}\ 1 < t < \hat{t}$. Therefore the *maximally ALS design* result holds more generally for design technologies with weakly decreasing economies of scale (or equivalent not strongly convex design costs).





The above graph shows that there is a discontinuity on the design as t increases.

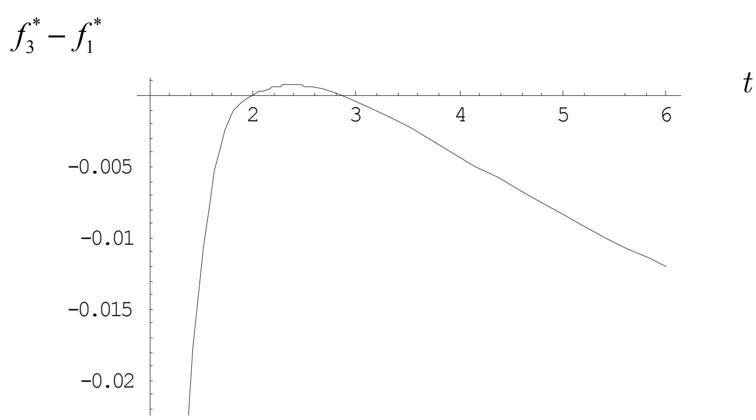
Effect of inherent network effects

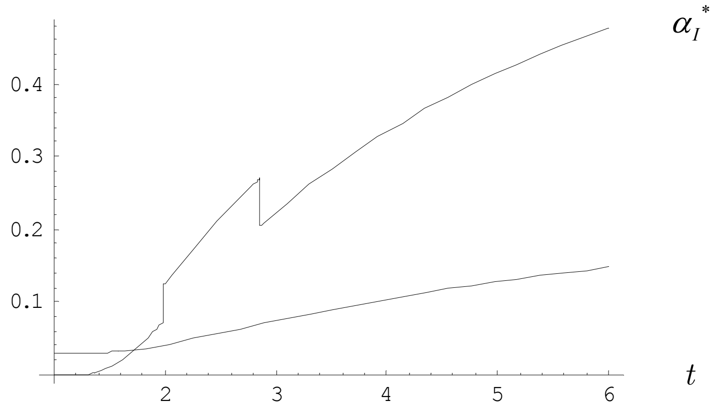
We further generalize the design technologies by assuming also the existence of inherent network effects, i.e. network effects that do not require investment by the network. We show two results. First, strong symmetric inherent network effects expand the area of t for which the network allocation of surplus is symmetric. This happens, because it is more costly to achieve the investment asymmetry required for an ASL network (i.e. $\alpha > 2\beta$). However, for the values of t that the network is ASL it is still *maximally ASL.* Second, strong asymmetric inherent network effects expand the area of t for which the design is ASL, favoring the side that enjoys the larger inherent network effect.

Let an inherent network effect $\alpha_0 = \beta_0$ such that $\alpha(x) = \alpha_0 + \alpha_I(x), \beta(y) = \beta_0 + \beta_I(y), \alpha_I(x) = x^{1/t}, \beta_I(y) = y^{1/t}$. The design objective function in (E3) is $f_3 = \frac{\alpha_I + \alpha_0}{4} - (\alpha_I{}^t + \beta_I{}^t)$, which gives $\alpha_I^* = \begin{cases} \left(\frac{1}{4t}\right)^{\frac{1}{t-1}}, & \text{if } \left(\frac{1}{4t}\right)^{\frac{1}{t-1}} > \alpha_0 \\ \alpha_0, & \text{otherwise} \end{cases}$, and $f_3^* = \frac{\alpha_I^* + \alpha_0}{4} - \alpha_I^{*t}$.

Due to symmetry, a critical point in (E1) should satisfy $\alpha = \beta$ and therefore the FOC of the design problem in (E1) is $\frac{8(\alpha_I + \alpha_0)}{27} - 2\alpha_I{}^t = 0$, which gives $(\alpha_I^*, \beta_I^*) = \left(\left(\frac{4}{27t}\right)^{\frac{1}{t-1}}, \left(\frac{4}{27t}\right)^{\frac{1}{t-1}} \right)$ and $f_1^* = \frac{8(\alpha_I^* + \alpha_0)}{27} - 2\alpha_I^{*t}$.

Studying the sign of $f_3^* - f_1^*$, it is easy to see that the area for which $f_3^* - f_1^* > 0$ shrinks or disappears. Therefore the *maximally ALS design* result holds for a smaller region of t. The following graphs depict that result for $\alpha_0 = .1$.





Proof of Proposition 6

The buyer-owned network solves the maximization problem in each equilibrium region. The design follows from $(\pi_1 + BS_1)^* = \frac{r^2 N_b^2 N_s^2}{16} > (\pi_2 + BS_2)^* = \frac{r^2 N_b^2 N_s^2}{20}$.

Proof of Proposition 7

The intermediary solves the maximization problem in each equilibrium region. The design follows from $(\pi_1 + BS_1)^* = \frac{9r^2 N_b^2 N_s^2}{320} < (\pi_3 + BS_3)^* = \frac{9r^2 N_b^2 N_s^2}{256}$.

Proof of Proposition 8 (investments)

Follows directly from table 3 by comparing the investment at each side with the social planner investment.

Proof of Proposition 9 (optimal ownership)

Follows directly from table 3. The total surplus created by all ownership regimes examined is always lower than the total surplus created when the social planner designs the network.

Proof of Proposition 10

The intermediary solves the maximization problem in each equilibrium region. The design follows.

Proof of Proposition 11

Follows by comparing the total surplus created in each case. For $r_\alpha > r_\beta$ the total surplus under buyer side ownership is $\frac{\left(N_b N_s r_\alpha\right)^2}{8}$ (the design is $\left(\frac{r_\alpha{}^2 N_b N_s}{4}, 0\right)$) and under independent ownership is $\frac{3\left(N_b N_s r_\alpha\right)^2}{64}$ (the design is $\left(\frac{r_\alpha{}^2 N_b N_s}{8}, 0\right)$).

Proof of Proposition 12

The intermediary compares the optimal design in (E1) which is $\left(\frac{r^2 N_b N_s}{10-8g}, \frac{r^2 N_b N_s}{20-16g}\right)$ and gives profits $\frac{r^2 N_b^2 N_s^2}{80-64g}$, with the optimal design in (E2) which is $\left(0, \frac{r^2 N_b N_s}{8}\right)$ and gives profits $\frac{r^2 N_b^2 N_s^2}{64}$. The condition $g > 1/4$ follows.

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