Two-sided markets: a progress report

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We provide a road map to the burgeoning literature on two-sided markets and present new results. We identify two-sided markets with markets in which the structure, and not only the level of prices charged by platforms, matters. The failure of the Coase theorem is necessary but not sufficient for two-sidedness. We build a model integrating usage and membership externalities that unifies two hitherto disparate strands of the literature emphasizing either form of externality, and obtain new results on the mix of membership and usage charges when price setting or bargaining determine payments between end-users.

1. Introduction

■　　Two-sided (or, more generally, multi-sided[1]) markets are roughly defined as markets in which one or several platforms enable interactions between end-users and try to get the two (or multiple) sides "on board" by appropriately charging each side. That is, platforms court each side while attempting to make, or at least not lose, money overall.

Examples of two-sided markets readily come to mind. Videogame platforms, such as Atari, Nintendo, Sega, Sony Play Station, and Microsoft X-Box, need to attract gamers in order to persuade game developers to design or port games to their platform, and they need games to induce gamers to buy and use their videogame console. Software producers court both users and application developers, client and server sides, or readers and writers. Portals, TV networks, and newspapers compete for advertisers as well as "eyeballs." And payment card systems need to attract both merchants and cardholders. There are many other two-sided markets of interest,[2] only a few of which will be mentioned in this article.

But what is a two-sided market, and why does two-sidedness matter? On the former question, the recent literature has been mostly industry specific and has had much of a "You know a two-sided

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[1] We focus on two-sided markets for expositional simplicity. Many markets or platforms (such as a standard-setting organization attempting to persuade a group of patent owners to join forces to establish a standard and various potential users to adopt it) are multi-sided though. The insights obtained for two-sided platforms apply more generally to multi-sided ones.

[2] See, e.g., Armstrong (2006), Evans (2003), Evans, Hagiu, and Schmalensee (2006), and Rochet and Tirole (2003).

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market when you see it" flavor. "Getting the two sides on board" is a useful characterization, but it is not restrictive enough. Indeed, if the analysis just stopped there, pretty much any market would be two-sided, since buyers and sellers need to be brought together for markets to exist and gains from trade to be realized. We define a two-sided market as one in which the volume of transactions between end-users depends on the structure and not only on the overall level of the fees charged by the platform. A platform's usage or variable charges impact the two sides' willingness to trade once on the platform and, thereby, their net surpluses from potential interactions; the platforms' membership or fixed charges in turn condition the end-users' presence on the platform. The platforms' fine design of the structure of variable and fixed charges is relevant only if the two sides do not negotiate away the corresponding usage and membership externalities.

Conceptually, the theory of two-sided markets is related to the theories of network externalities and of (market or regulated) multi-product pricing. From the former, initiated by Katz and Shapiro (1985, 1986) and Farrell and Saloner (1985, 1986),[3] it borrows the notion that there are noninternalized externalities among end-users.[4] From the latter, it borrows the focus on price structure and the idea that price structures are less likely to be distorted by market power than price levels. The multi-product pricing literature, however, does not allow for externalities in the consumption of different products: to use a celebrated example, the buyer of a razor internalizes in his purchase decision the net surplus that he will derive from buying razor blades. The starting point for the theory of two-sided markets, by contrast, is that an end-user does not internalize the welfare impact of his use of the platform on other end-users.

The rest of the article is organized as follows. In Section 2, we introduce platforms and end-users as well as the general setting. Section 3 focuses on pure usage charges and provides conditions for the allocation of the total usage charge (e.g., the price of a call or of a payment card transaction) between the two sides not to be neutral; the failure of the Coase theorem is necessary but not sufficient for two-sidedness. We analyze pure membership externalities in Section 4.

Section 5 builds a canonical model of two-sided markets and applies it to pure-usage and pure-membership externalities. This model allows us to unify and compare the results obtained in the two hitherto disparate strands of the literature emphasizing either form of externality. Section 5 then shows that in the presence of (price-setting or bargaining-based) payments among end-users, the pure-membership-externalities model applies under some conditions, and it derives general results for the setting of usage charges. Finally, the section discusses several relevant extensions of the canonical model.

Section 6 summarizes our main conclusions. Needless to say, our overview is somewhat selective in its choice of topics and articles. We highly recommend the excellent and complementary coverages in Armstrong (2006) and Jullien (2005).

2. Membership and usage externalities

■ Suppose that there are potential gains from trade in an "interaction" between two end-users, whom for convenience we will call the buyer (B) and the seller (S). A platform enables or facilitates the interaction between the two sides provided that they indeed want to interact.[5] The interaction can be pretty much anything, but it must be identified clearly. In the case of videogames, an interaction occurs when a buyer (gamer) buys a game developed by a seller (game publisher) and plays it using the console designed by the platform. Similarly, for an operating system (OS), an interaction occurs when the buyer (user) buys an application built by the seller (developer) on the platform. In the case of payment cards, an interaction occurs when a buyer (cardholder) uses his

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[3] Conceptually, this older literature is most closely related to the case of membership externality studied below, although it puts less emphasis on price structure issues.

[4] The theory of network externalities has largely ignored price structure issues, as well as many of the themes of the two-sided–market literature such as multi-homing (focusing on the design of converters by platforms) or the control of interactions among end-users.

[5] The "interaction" in question is thus an interaction through the platform. This does not mean that the two sides cannot interact through an alternative platform (through mail instead of telephone, cash or check instead of credit card, city activities instead of dating club, etc.).

FIGURE 1
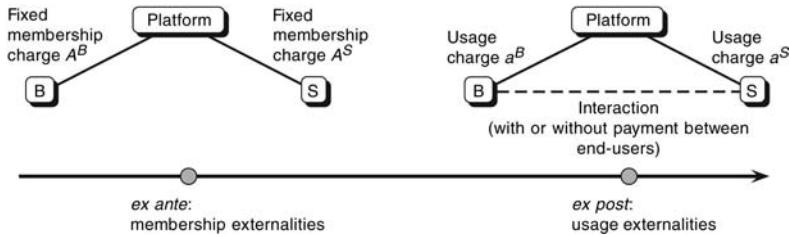
card to settle a transaction with a seller (merchant). The interaction between a "viewer" and an advertiser mediated by a newspaper or a TV channel occurs when the viewer reads the ad. The interaction between a caller and a receiver in a telecom network is a phone conversation, and that between a website and a web user on the Internet is a data transfer.

We distinguish between membership charges and usage charges, and between membership externalities and usage externalities. Gains from trade between end-users almost always arise from usage:[6] the cardholder and the merchant derive convenience benefits when the former uses a card rather than cash; a caller and a callee benefit from their communication, not per se from having a phone; and so forth. Usage decisions depend on how much the platform charges for usage. As depicted in Figure 1, the platform charges a price or access charge a^S to the seller and a^B to the buyer for enabling the interaction. For example, American Express charges a merchant discount to the merchant, so $a^S > 0$, while the buyer pays nothing for using the American Express card, $a^B = 0$.[7] Similarly, a caller is charged a per-minute calling charge and the receiver a per-minute reception charge. Usage externalities arise from usage decisions: if I strictly benefit from using my card rather than cash, then the merchant exerts a (positive) usage externality on me by accepting the card. Similarly, if I benefit from being able to call a friend on his mobile phone, then this friend's willingness to give me his number and receive the call exerts a positive usage externality on me.

Ex ante, the platform may charge interaction-independent fixed fees A^S and A^B. For example, American Express charges yearly fees to cardholders ($A^B > 0$). In the case of videogames, platforms may charge fees to game developers for development kits ($A^S > 0$) on top of royalties per copy sold ($a^S > 0$); they charge gamers for the videogame console ($A^B > 0$). For Windows, Microsoft charges a usage-independent fee to consumers ($A^B > 0$) but no variable fees ($a^S = a^B = 0$). To the extent that an end-user on side i derives a strictly positive net surplus from interacting with additional end-users on side $j \neq i$, membership decisions generate membership externalities.

3. Pure usage externalities

■ Let us first focus on the elementary situation in which membership is given. While restrictive, this situation already encompasses a number of industries of interest, for example a mature telecommunications market in which everyone has a phone or a mature payment system in which no substantial fixed cost or charge stands in the way of membership. Furthermore, and as Section 5 will show, the pure-usage-externalities paradigm is relevant even for some industries with endogenous memberships.

The interesting question is then whether end-users intensively use the platform rather than whether they join it. We therefore introduce a distinction between the price level, defined as the total price charged by the platform to the two sides, and the price structure, referring to the decomposition or allocation of the total price between the buyer and the seller.

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[6] An exception is the image benefit that some people draw from being associated in membership with selected others within a club.

[7] $a^B < 0$ if the customer receives frequent flyer miles or cash-back bonuses.

☐ **Defining two-sidedness.**

Definition 1. Consider a platform charging per-interaction charges a^B and a^S to the buyer and seller sides. The market for interactions between the two sides is one-sided if the volume V of transactions realized on the platform depends only on the aggregate price level

$$a = a^B + a^S,$$

i.e., it is insensitive to reallocations of this total price a between the buyer and the seller. If by contrast V varies with a^B while a is kept constant, the market is said to be two-sided.

Underlying the recent surge of academic interest in two-sided markets is the widespread belief among economists and public and private decision makers that the price structure affects profits and economic efficiency. Managers devote considerable time and resources to figuring out which side should bear the pricing burden, and commonly they end up making little money on one side (or even using this side as a loss leader) and recouping their costs on the other side (see Section 5). Policy makers also seem to strongly believe in the importance of the price structure. The monitoring of termination charges in telecommunications (and soon the Internet) and antitrust involvement in the computation of interchange fees in payment systems reflect this belief. That the locus of intervention is the price structure proceeds from the premise that economic efficiency can be improved by charging more to one side and less to the other relative to what the market delivers.

Private and public decision makers, on the other hand, would be wasting their time if the price structure were neutral, that is, if a price reallocation between the two sides had no impact on economic outcomes. Nonneutrality, though, is not a foregone conclusion. Econ 101 students learn that for a given level of VAT, it does not matter who, of the merchant and the consumer, is charged for it.[8] The transaction price between the two parties adjusts accordingly.

Below we offer some other illustrations of one-sided markets.

Bilateral electricity trading. A related example is that of bilateral electricity trading with injection and withdrawal charges. Consider an electricity market run by bilateral contracts between generators and customers (large industrial customers and load-serving entities), and in which generators pay a variable (per MWh) fee for injecting their power in the transmission system and customers pay a variable (per MWh) fee for withdrawing electricity from the system. As in the case of the VAT, a buyer and a seller, when bargaining for a bilateral energy trade, should take into account only the total fee paid to the transmission system.

Neutrality in payment systems. The choice of an interchange fee paid by the merchant's bank, the acquirer, to the cardholder's bank, the issuer, is irrelevant if the following conditions are jointly satisfied: First, issuers and acquirers pass through the corresponding charge (or benefit) to the cardholder and the merchant.[9] Second, the merchant can charge two different prices for goods or services depending on whether the consumer pays by cash or by card; in other words, the payment system does not impose a no-surcharge rule as a condition for the merchant to be affiliated with the system. Third, the merchant and the consumer incur no transaction cost associated with a dual-price system.[10]

Remark. Are firms two-sided platforms? Firms can be viewed as bringing together input suppliers and output consumers. Consider a competitive widget industry, in which one unit of labor is

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[8] A government levying a value-added or excise tax on a transaction between a merchant and a consumer can be viewed as a platform (with the specificity that the use by end-users of the platform is not motivated by the platform's enabling or facilitating their trade, but results from the state's coercive power).

[9] This is also true if the issuer and the acquirer charge two-part tariffs to their customers, as long as the variable price reflects their per-interaction cost one-for-one.

[10] An early result along these lines is in Rochet and Tirole (2002). The broad generality of the proposition has been demonstrated by Gans and King (2003).

required to produce one widget. A firm then chooses a^S, the "workers' access fee" to the platform, that is minus the wage of the workers, and a^B, the per-unit price of its widgets. According to our Definition 1, the firm is indeed a two-sided platform: if it lowers its wage and reduces its widget price by the same amount, its customers will not be able to redeem their cost saving and compensate the workers (the end-users do not meet, let alone bargain!). We would argue, though, that, at least in competitive environments, firms are often *de facto* one-sided platforms, in that there is little "wriggle room" for them to manipulate the price structure: if they lower the wage, workers will leave, and if they raise their price, consumers will go to other suppliers. If w and p are the market wage and price, then the constraints $|a^S| \geq w$ and $a^B \leq p = w$, together with the non-negative-profit condition $a^S + a^B \geq 0$, do not allow the firm to manipulate the price structure.

□ **Usage externalities, the Coase theorem and conditions for two-sidedness.** The Coase theorem states that if property rights are clearly established and tradeable, and if there are no transaction costs nor asymmetric information, the outcome of the negotiation between two (or several) parties will be Pareto efficient, even in the presence of externalities. Coase's (1960) view is that if outcomes are inefficient and nothing hinders bargaining, people will negotiate their way to efficiency. Because, in the context of a buyer-seller interaction mediated by a platform, the gains from trade between the two end-users depend on the price level but not its allocation, the latter has no impact on the volume of transactions, the platform's profit, and social welfare in a Coasian world: markets are one-sided. The business and public policy attention to price structure issues is then misguided.

The Coase theorem is a useful benchmark. In practice, though, various factors make it unlikely that the two parties will reach an efficient agreement from their perspective (where "efficiency" refers to their joint surplus, and not to social surplus: in the applications at hand, it does not include platform profit or externalities on other end-users, say). As we now show, the following two statements are not equivalent: (i) the end-users cannot reach an efficient outcome through bargaining; (ii) the platform's price structure is non-neutral. That is, (i) is necessary, but not sufficient for (ii): the failure of the Coase theorem to apply does not imply that the market is two-sided.

Asymmetric information bargaining/price setting: the Coase theorem fails to apply, yet the price structure is neutral. One standard reason for why the negotiation between two parties may break down despite the existence of gains from trade is that parties have different views as to the size of these gains from trade. Parties to a negotiation try to get the best for themselves, and under imperfect information about what the other side can bear, they may prove too greedy.[11]

Asymmetric information often implies a suboptimal volume of trade.[12] Yet it does not per se imply that the market is two-sided. Actually, unless at least one of the other assumptions underlying the Coase theorem is relaxed, the platform's price structure is still neutral. When the seller's access charge is increased by Δa and the buyer's access charge is reduced by the same amount, the bargaining strategies of the two parties remain the same, except that they are "shifted by the constant Δa." When making offers, the seller demands an amount equal to what he was demanding earlier in similar circumstances (an amount that depends on the seller's actual cost of selling to the buyer and on the history of the bargaining process), augmented by Δa. Similarly, the buyer shades his price offers systematically by Δa.

Technically, consider a general sequential bargaining game between the buyer and the seller, in which the two parties make offers to each other and respond to these offers in a specified order, and in which the transaction occurs only when one party has accepted the other party's offer. Then, the set of perfect Bayesian equilibria in the game indexed by access charges $(a^S + \Delta a, a^B - \Delta a)$ is isomorphic to the set of perfect Bayesian equilibria of the game with access charges (a^S, a^B) in

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[11] This is the same reason why monopoly pricing in general imposes a deadweight loss. Under imperfect information about consumers' individual preferences, the monopoly trades off efficiency (a high volume of trade) and rent appropriation (through a high markup).

[12] See the literature on bargaining under asymmetric information as well as Myerson and Satterthwaite (1983). Farrell (1987) discusses institutional implications of a failure of the Coase theorem due to informational asymmetries.

FIGURE 2

MULTI-HOMING
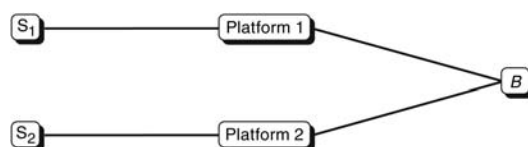
that an equilibrium in the former game and the associated equilibrium in the latter game yield the same economic allocation, including expected payoffs and expected discounted volume of trade: (history- and type-contingent) offers are translated upward by Δa for the seller and downward by Δa for the buyer, and the (history- and type-contingent) acceptance/rejection decisions are unchanged provided that new types are defined (so a seller of cost c in the latter game has fictitious type $c + \Delta a$ in the former game, and similarly for the buyer).[13] Bargaining is inefficient, but the market is one-sided nonetheless.

□ **Factors of nonneutrality under usage pricing.** *Transaction costs.* For an increase in the share allocated to, say, the seller to matter, it must be the case that the seller cannot pass the increase in his cost of interacting with the buyer through to the buyer (this is obviously the case for standard telecom interactions, where there is no monetary transaction between the caller and the receiver, or for the case when monetary transactions are technically possible but transaction costs may hinder this passthrough). Consider, for example, an arrangement in which websites pay for their (mainly) outgoing traffic.[14] As the variable charge for outgoing traffic increases, websites would like to pass this cost increase through to the users who request content downloads. A problem with this is that downloads are requested by thousands or millions of users, and the corresponding payment by the end-user would be very small. This payment may be insufficient to rationalize the costs for the website to set up a payment system and for the user to provide payment-enabling information, especially if the consumer has anxiety about potentially fraudulent use of this information by unknown people. Such concerns of course do not arise if most of the download is already part of commercial transactions, as in the case of the licensing of a music file. By contrast, an increase in their cost of Internet traffic could induce websites that post content for the convenience of other users, or that are cash-strapped, not to produce or else reduce the amount of content posted on the web, as they are unable to pass the cost increase on to the other side.

Prohibition or constraint put by the platform on the pricing of transactions between end-users. Another situation in which end-users fail to haggle or set a price for their transaction arises when the platform prohibits them from doing so. A prominent case in point is a no-surcharge rule imposed by a payment system (the merchant's price must be the same whether the customer uses cash or a card). Another case in point is a price cap imposed by the platform (e.g., the 99-cent pricing rule for iPod song downloads).

4. Membership externalities

■ **Transaction-insensitive end-user costs and nonneutrality.** While the recent literatures on the telecommunications, Internet, and credit card industries as well as the regulatory attention to termination charges and interchange fees have focused on pure usage externalities, both the early literature on indirect network externalities and a number of recent articles, including Armstrong (2006), have analyzed the polar case of pure membership externalities.

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[13] A more limited result along similar lines can for example be found in Tirole (1986), in which a seller bargains with a buyer under the constraint that the seller will have to pay a cancellation fee to the buyer in case of nondelivery.

[14] They currently do, but the charge is limited for the moment by the fact that the backbones have for the most part not charged each other for terminating traffic. Such "bill-and-keep" agreements (in the notation of Figure 2, $a^B = a^S = 0$) reallocate the cost of Internet traffic somewhat from those who request downloads to those whose content is downloaded.

The focus on membership is associated with the existence of transaction-insensitive end-user costs. These include fixed fees levied by the platform as well as technological fixed costs on the user side. For example, a software developer may incur both a fixed payment for the development kit and attendance at trade shows and a fixed cost of developing the software.[15] The dividing line between the two transaction-insensitive costs is sometimes a bit unclear: a software platform may try to attract software developers by charging a low price for the development kit (a fixed fee) and/or by giving away software development support or designing developer-friendly APIs. On the other hand, only the total transaction-insensitive cost matters to the end-user, and so we need not be concerned by our making this artificial distinction between fixed fees and fixed technological costs.

Thus under transaction-insensitive costs, the allocation of fixed fees between buyers and sellers matters unless small changes in fixed fees leave memberships (the set of end-users who decide to incur the transaction-incentive costs) invariant on both sides, a rather unlikely situation. An increase in, say, the buyers' fixed fee A^B is usually not passed through to the sellers. To be certain, one can find examples in which the membership decisions are coordinated. For example, divisions of a firm buying client and server software, or a family joining a tennis club to play with each other, will take a concerted membership decision; the package offered to the firm or the family as a whole is the only relevant aspect of pricing, not the way in which the total price decomposes among divisions or members of the family. But such instances of "*ex ante* Coasian bargaining" are rather rare.

When the two sides transact *ex post*, fixed costs are sunk and therefore irrelevant. This implies that the structure of fixed fees matters. The platform's profit, the volume of trade, and social welfare all in general depend on both fixed fees A^B and A^S. The nonneutrality of fixed fees is most dramatically illustrated by the following extreme but telling example, due to Wright (2003): Suppose that consumers all derive the same per-transaction surplus b^B from the convenience of paying merchants by card rather than by cash, and that merchants are discouraged neither by transaction costs nor by a card system's no-surcharge rule from charging different prices for card and cash payments. Consider a merchant (a monopolist, to simplify the exposition) selling a merchandise with value v (when purchased by cash) to consumers. It is optimal for this merchant to charge v for cash payments and $v + b^B - a^B$ for card payments. Thus a cardholder obtains no transaction-specific surplus from holding a card. She therefore does not want to hold a card in the first place if she must pay a yearly fee or incurs a transaction cost by applying for a card; the corresponding "investment" is then "held up" *ex post* by the merchants' surcharge (to use Williamson's (1975) terminology).[16]

☐ **Platforms' motivations for charging membership fees.** In practice, platforms have several motivations to recoup their costs (and perhaps make a profit) by levying membership fees.

The platform is unable to tax the interaction properly. The interaction between the end-users may not be perfectly observed, as illustrated by the case of a dating club. More generally, even if a transaction is observed, it may not be the entire transaction. Buyers and suppliers may find each other and trade once on a B2B exchange, and then bypass the exchange altogether for future trade. Or they may underreport the trading price and operate side transfers. The platform's ability to tax transactions depends on how much anonymity it can impose on trades. Another case in point is advertising. The actual "transaction"—namely whether the reader carefully reads the ad, thereby

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[15] In their empirical study of network externalities in the automated clearinghouse (ACH) electronic payments system, Ackerberg and Gowrisankaran (2006) find that consumer (large) fixed costs of adoption are the main impediment to the development of this technology. As a consequence, they suggest that a policy of subsidizing ACH adoption for consumers (and banks) would increase welfare significantly.

[16] By contrast, the allocation of the variable fees a^B and a^S keeping the total variable fee $a = a^B + a^S$ constant is still neutral, provided that there are no transaction costs that install grains of sand in the passthrough mechanism. First, the volume of *ex post* transactions is insensitive to the variable-fees allocation for given membership levels. Second, the split of total end-user surplus between the two sides can be shown to be unaffected by the allocation of the total variable fee; membership on either side is therefore unchanged.

generating potential sales—is not observed.[17] The media's purchase price and the advertising fees can be viewed as fixed costs relative to such individual transactions.

Fixed fees may be an efficient way of capturing end-user surplus. As is well known from the price discrimination and Ramsey pricing literatures, it is often efficient (both privately and socially) to recoup the platform's fixed cost (say, the cost of writing the platform's software) and/or to extract consumer surplus through charges on both the variable use of the platform and on general access to the platform.

Relatedly, suppose that a software platform is concerned with independent developers exercising market power over platform users (Hagiu, 2006). The platform can reduce the price of applications through a proportional subsidy on applications. This policy, while encouraging efficient trade, is costly to the platform and may leave large surpluses to both application developers and consumers. Fixed fees levied on both sides are ways of capturing the end-user surpluses and of enabling subsidization. We return to this idea in Section 5.

5. Integrating usage and membership externalities in a simple model

■ **No payment between end-users.** *Model and optimal pricing.* This section develops a formal model that integrates usage and membership externalities for a platform. Most existing models of two-sided markets, as well as earlier models of indirect network externalities, are subcases of this model. In particular, we obtain a pricing formula that encompasses the formulas obtained in the pure-usage-externality model of Rochet and Tirole (2003) and the pure-membership-externality model of Armstrong (2006); we also extend these two articles by rewriting the pricing formulas in ways that are amenable to a straightforward interpretation and comparison (see (10) and (15) below).

There are two sides of the market: $i \in \{B, S\}$, and a monopoly platform.[18] The platform incurs fixed cost C^i per member on side i and marginal cost c per interaction between two members of opposite sides. On each side i, members may be heterogeneous over both their average benefit b^i per transaction and their fixed benefit B^i (often a fixed cost, and therefore negative) of joining the platform.[19] End-users on side i pay to the platform A^i for membership and a usage fee a^i per transaction.

In a first step, we assume that the transaction involves no payment between end-users. This is a fine assumption for advertising or payment systems (to the extent that the merchant does not surcharge the cardholder for the use of the card).[20] Again, and as we will show below, under some conditions the model considered here is still valid when the buyer pays a price to the seller for the transaction.

An important question is the determination of the volume of transactions for a given membership. Much of the literature assumes that the number of transactions is the product $N^B N^S$ of the numbers of members on both sides. More generally, $N^B N^S$ represents the number of potential transactions, and the number of actual transactions is only a fraction of $N^B N^S$.[21] The

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[17] To be sure, there are attempts at measuring these. For example, the seller may ask the buyer to identify the newspaper or magazine from which the buyer learned about the product. On the web, the ability to measure the "eyeball's" path of clicks makes referral payments now common.

[18] The model can be extended to platform competition. Several of the articles analyzing platform competition follow the literature on two-way interconnection in telecommunications (Laffont, Rey, and Tirole (1998a, 1998b); Armstrong (1998); and subsequent articles) by adding a Hotelling model in which platforms are differentiated along the fixed component only. See Armstrong (2006) for a discussion of the implicit commitment assumptions involved in the choice of pricing rules in a platform oligopoly situation.

[19] Benefits and costs can be negative. For example, in the case of a newspaper mediating interactions between readers (the buyers) and advertisers (the sellers), B^B is the utility of reading the newspaper and b^B is the utility of reading an advertisement (which can be positive or negative). Articles with negative benefits from interaction include Anderson and Coate (2005), Gabszewicz et al. (2003), Kind, Hilssen, and Sorgard (2004), and Reisinger (2004).

[20] Recall that in our terminology, a "transaction" refers here to the use of a card for payment of a purchase, and not to the purchase itself. Similarly, in the context of advertising, a "transaction" refers to the reader/viewer seeing an ad.

[21] For example, in the context of payment systems, a cardholder typically patronizes a subset of all available stores.

number of actual transactions may also depend on the usage fees charged by the platform, as is the case for payment cards, for example, where the level of cash-back bonuses influences usage by cardholders.

Finally, the "nonrivalry" condition (i.e., the condition that transactions volume is proportional to membership on each side) is not crucial, but will be made here for convenience as well.[22] The analysis carries through even if one side's return to new membership on the other side is not constant (see footnote 24 below); for example, sellers may be substitutes or complements for a buyer.

The net utility of an agent on side i with usage benefit b^i and membership benefit B^i is thus

$$U^i = (b^i - a^i)N^j + B^i - A^i, \tag{1}$$

where N^j denotes the number of members on the other side connected with the platform. The number of side-i end-users who decide to join the platform is thus

$$N^i = \Pr(U^i \geq 0). \tag{2}$$

Note that N^i depends only on the number of members N^j on the other side and on the "per-interaction price,"[23] defined as

$$p^i \equiv a^i + \frac{A^i - C^i}{N^j}. \tag{3}$$

Indeed, adding and substracting C^i in (1) and dividing U^i by N^j defines demand functions:

$$N^i = \Pr\left(b^i + \frac{B^i - C^i}{N^j} \geq p^i\right) \equiv D^i(p^i, N^j), \qquad i \in \{B, S\}. \tag{4}$$

Under regularity conditions, the system (4) has a unique solution characterizing memberships N^B and N^S as functions of (p^B, p^S):

$$\begin{cases} N^B = n^B(p^B, p^S) \\ N^S = n^S(p^B, p^S). \end{cases}$$

The derivatives of n^B and n^S with respect to p^B and p^S can easily be deduced from those of D^B and D^S by total differentiation of equation (4):

$$\frac{\partial n^B}{\partial p^B} = \frac{\dfrac{\partial D^B}{\partial p^B}}{1 - \dfrac{\partial D^B}{\partial N^S}\dfrac{\partial D^S}{\partial N^B}}, \quad \frac{\partial n^S}{\partial p^B} = \frac{\dfrac{\partial D^B}{\partial p^B} \cdot \dfrac{\partial D^S}{\partial N^B}}{1 - \dfrac{\partial D^B}{\partial N^S} \cdot \dfrac{\partial D^S}{\partial N^B}}, \tag{5}$$

with symmetric formulas for $\partial n^S/\partial p^S$ and $\partial n^B/\partial p^S$.

Similarly, in the context of advertising in media, a reader/viewer typically reads/views only a subset of the ads displayed in the newspaper or TV program.

[22] Among examples that do not fit our multiplicative volume assumption, take a firm (see our "Remark" in Section 3), considered as a platform between workers and consumers, where the volume of transactions is $\min(N^B, N^S)$. Another example is a telephone network: someone may decide to have a telephone only to use in case of emergency, but may get no utility from any other call, in which case the volume of his transactions is independent of N^S (we thank Jennifer Reinganum for suggesting this example).

[23] This is not the standard definition of a per-interaction price, since C^i is subtracted from A^i. The rationale for this convention will become clear shortly.

The platform's profit is equal to

$$\pi = (A^B - C^B)N^B + (A^S - C^S)N^S + (a^B + a^S - c)N^B N^S,$$

and it can be transformed into[24]

$$\pi = (p^B + p^S - c)n^B(p^B, p^S)n^S(p^B, p^S).$$

For a given total price $(p^B + p^S = p)$, the optimal price structure is obtained by maximizing the volume of usage,

$$V(p) = \max \left\{ n^B(p^B, p^S)n^S(p^B, p^S) \text{ under the constraint } p^B + p^S = p \right\}.$$

The price level is determined by a standard Lerner formula,

$$\frac{p - c}{p} = \frac{1}{\eta}, \tag{6}$$

where η is the elasticity of volume with respect to total price: $\eta \equiv -pV'(p)/V(p)$. The optimal price structure is obtained when the derivatives of volume with respect to both prices are equal,

$$-\frac{1}{p - c} = \frac{\dfrac{\partial n^B}{\partial p^B}}{n^B} + \frac{\dfrac{\partial n^S}{\partial p^B}}{n^S} = \frac{\dfrac{\partial n^S}{\partial p^S}}{n^S} + \frac{\dfrac{\partial n^B}{\partial p^S}}{n^B}. \tag{7}$$

Using formulas (5) and multiplying by $1 - (\partial D^B/\partial N^S) \cdot (\partial D^S/\partial N^B)$, we obtain an equivalent condition for an optimal price structure, this time based directly on the derivatives of D^B and D^S,

$$-\frac{\left(1 - \dfrac{\partial D^B}{\partial N^S} \cdot \dfrac{\partial D^S}{\partial N^B}\right)}{p - c} = \frac{\dfrac{\partial D^B}{\partial p^B}}{D^B} + \frac{\dfrac{\partial D^B}{\partial p^B}\dfrac{\partial D^S}{\partial N^B}}{D^S} = \frac{\dfrac{\partial D^S}{\partial p^S}}{D^S} + \frac{\dfrac{\partial D^S}{\partial p^S}\dfrac{\partial D^B}{\partial N^S}}{D^B}. \tag{8}$$

Note that there may be some redundancy in the pricing policy, since only per-transaction prices p^B and p^S matter, whereas the platform has *a priori* four degrees of freedom: (a^B, A^B) on the buyers' side and (a^S, A^S) on the sellers' side (some of these instruments may not be available, though).

No fixed costs and benefits. Consider a situation in which there are no fixed costs and benefits $(B^i = C^i = 0)$ and so end-users on side i differ only in their per-transaction benefit b^i. Formula (4) then shows that $\partial D^j/\partial N^i = 0$, and condition (8) specializes to

$$\frac{-1}{p - c} = \frac{\dfrac{\partial D^B}{\partial p^B}}{D^B} = \frac{\dfrac{\partial D^S}{\partial p^S}}{D^S},$$

or letting $\sigma^i \equiv -[\partial D^i/\partial p^i]/D^i$ denote the semielasticities,

$$p - c = \frac{1}{\sigma^B} = \frac{1}{\sigma^S}, \tag{9}$$

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[24] This analysis can be generalized to benefits that are not constant with the other side's membership level. Suppose for instance that the number of transactions is $N^B f(N^S)$. The per-transaction prices are then $p^B \equiv a^B + [(A^B - C^B)/f(N^S)]$ and $p^S = a^S + [(A^S - C^S)N^S/N^B f(N^S)]$ (since $N^B f(N^S)/N^S$ is the number of transactions per seller); and so $\pi = (p^B + p^S - c)n^B(p^B, p^S)n^S(p^B, p^S)$.

a formula obtained in Rochet and Tirole (2003). This formula can be rewritten as a standard Lerner formula,

$$\frac{p^i - (c - p^j)}{p^i} = \frac{1}{\eta^i},$$ (10)

where $\eta^i \equiv p^i \sigma^i$ is the elasticity of demand on side i.

When there are no fixed costs and benefits, the loss of a transaction on side i due to an increase in the per-transaction price p^i has an opportunity cost $c - p^j$, since the platform cost c of the transaction has to be defrayed by the payment p^j levied on the other side. Except for the replacement of the per-transaction cost by the opportunity cost, formula (10) is the standard Lerner formula.[25]

Homogeneous per-transaction benefits. Consider now Section 3 of Armstrong (2006), where on each side end-users differ only with respect to their membership benefit B^i but obtain identical benefit per interaction b^i, assumed for simplicity to be nonnegative. Let us assume in a first step that the platform does not observe transactions (and thus $a^S = a^B = 0$); it then makes sense to also assume that $c = 0$ (most often, platforms are able to identify end-users when they incur a per-transaction cost). We subsume these two assumptions under the "pure membership pricing" label. The outcome is the same if the platform can monitor transactions; intuitively, monitoring transactions does not help the platform to capture end-users' rents, which are determined by their private knowledge of the fixed benefits B^i. As we will later show, though, the monitoring of transactions allows the implementation of the platform's optimum through different and instructive price structures. We have

$$N^i = D^i(p^i, N^j) \equiv \phi^i(U^i),$$

where $U^i = (b^i - p^i)N^j + B^i - C^i$.

Thus the derivatives of the demand functions with respect to price and membership are given by

$$\frac{\partial D^i}{\partial p^i} = -D^j \frac{d\phi^i}{dU^i} \quad \text{and} \quad \frac{\partial D^i}{\partial N^j} = (b^i - p^i) \frac{d\phi^i}{dU^i}.$$

Moreover, semielasticities are given by

$$\sigma^B = \frac{D^S}{D^B} \frac{d\phi^B}{dU^B}, \quad \sigma^S = \frac{D^B}{D^S} \frac{d\phi^S}{dU^S}.$$

Using formula (8), we obtain the condition characterizing the optimal price structure in Armstrong's model,

$$-\frac{D^S \frac{d\phi^B}{dU^B}}{D^B} - \frac{D^S \frac{d\phi^B}{dU^B}(b^S - p^S)\frac{d\phi^S}{dU^S}}{D^S} = -\frac{D^B \frac{d\phi^S}{dU^S}}{D^S} - \frac{D^B \frac{d\phi^S}{dU^S}(b^B - p^B)\frac{d\phi^B}{dU^B}}{D^B},$$

which gives, after simplification,

$$\sigma^B + \sigma^B \sigma^S(b^S - p^S) = \sigma^S + \sigma^B \sigma^S(b^B - p^B).$$ (11)

Finally, the total price p is given by formula (8). Using the fact that $c = 0$, it can be written

$$\frac{1}{p^B + p^S} = \frac{\lambda}{1 - (b^B - p^B)(b^S - p^S)\sigma^B \sigma^S},$$ (12)

where λ is the common value of both sides of formula (11). Now p^B and p^S can also be drawn

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[25] Another way of obtaining formula (10) is to equalize the costs and benefits for the platform of raising p^i, $(p - c)|\partial D^i/\partial p^i|D^j = D^i D^j$.

from formula (11):

$$p^B = b^B + \frac{1}{\sigma^B}\left(1 - \frac{\lambda}{\sigma^S}\right), \tag{13}$$

$$p^S = b^S + \frac{1}{\sigma^S}\left(1 - \frac{\lambda}{\sigma^B}\right). \tag{14}$$

Thus

$$\frac{1 - (b^B - p^B)(b^S - p^S)\sigma^B\sigma^S}{\lambda} = \frac{1 - \left(1 - \frac{\lambda}{\sigma^B}\right)\left(1 - \frac{\lambda}{\sigma^S}\right)}{\lambda}$$

$$= \frac{1}{\sigma^B} + \frac{1}{\sigma^S} - \frac{\lambda}{\sigma^B\sigma^S}.$$

By formula (12) this is equal to $p^B + p^S$, giving

$$b^B + b^S + \frac{1}{\sigma^B} + \frac{1}{\sigma^S} - \frac{2\lambda}{\sigma^B\sigma^S} = \frac{1}{\sigma^B} + \frac{1}{\sigma^S} - \frac{\lambda}{\sigma^B\sigma^S},$$

or, finally,

$$\lambda = \sigma^B\sigma^S(b^B + b^S).$$

Now, if we plug this value of λ into formulas (13) and (14), we obtain the standard Lerner formula,

$$\frac{p^i - \left(-b^j\right)}{p^i} = \frac{1}{\eta^i}. \tag{15}$$

Under pure membership pricing ($a^i = 0$ and therefore $p^i = (A^i - C^i)/N^j$), the elasticity of demand, $\hat{\eta}_i$, with respect to the membership charge A^i equals the elasticity of demand, η^i, with respect to the per-transaction charge, multiplied by $(A^i - C^i)/A^i$. Furthermore, a lost member on side i involves no per-transaction loss or benefit for the platform, since the latter incurs no per-transaction cost, $c = 0$, nor does it charge for transactions; but the platform loses membership fee A^i as well as the reduction b^j in the membership fee required to keep membership constant on the other side. Thus (15) can also be written as[26]

$$\frac{A^i - [C^i - b^j N^j]}{A^i - C^i} = \frac{1}{\hat{\eta}^i}.$$

The following proposition summarizes our first results.

Proposition 1. Consider the canonical model with utilities and profit,

$$U^i = (b^i - a^i)N^j + B^i - A^i,$$

$$\pi = \sum_{i=B,S}(A^i - C^i)N^i + (a^B + a^S - c)N^B N^S,$$

and let

$$p^i \equiv a^i + \frac{A^i - C^i}{N^j}.$$

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[26] Another way of obtaining formula (15) is to equalize the cost and benefit for the platform of raising A^i, keeping membership on side j constant: $|\partial D^i/\partial A^i|[A^i + b^j N^j] = N^j$.

(i) The monopoly price per interaction, $p = p^B + p^S$, is given by the Lerner formula $(p - c)/p = 1/\eta$, and the price structure is given by condition (7).

(ii) When there are no fixed costs and benefits, the price structure is given by

$$\frac{p^i - \left(c - p^j\right)}{p^i} = \frac{1}{\eta^i} .$$

(iii) Pure membership pricing arises when end-users on each side differ only in their fixed membership benefit B^i (i.e., on each side end-users have the same b^i). The price structure is then given by

$$\frac{p^i - \left(-b^j\right)}{p^i} = \frac{1}{\eta^i} .$$

□ **Defining two-sided markets: another angle.** We defined two-sided markets as ones in which the price structure (the choice of p^B and p^S for a given price level $p = p^B + p^S$) affects the economic outcome (volume, profits, and/or welfare). An alternative and common definition refers to the existence of cross-group externalities: the net utility on side i increases with the number of members N^j on side j.[27] While this alternative definition has much intuitive appeal and we ourselves often use it for expository purposes, it is not without difficulties, as we now point out.

Interpretation of cross-group externalities. When we say that "U^i increases with N^j" we mean, everything else being given, including prices charged to both sides. Consider for instance a not-for-profit platform, say a payment card association. The utility of cardholders increases with the number of merchants who accept the card (so $\partial U^i / \partial N^j > 0$). Suppose, however, that getting more merchants on board requires lowering the merchant discount and therefore the interchange fee. Cardholders then pay more for their card or their card transactions, which creates a countervailing effect (the total derivative dU^i/dN^j can be positive or negative). So the net impact on utility of an increase in membership on the other side depends on how this increase is brought about. Even for a for-profit platform, for which the prices on the two sides are more easily disconnected, an increase in N^j will in general induce the platform to change the terms it applies to side i.

In the rest of this discussion, we will focus on an increase in membership keeping prices charged by the platform to end-users constant; that is, we will adopt the "partial-derivative definition."[28]

Inclusiveness. One can think of cases in which the cross-group externalities definition is under-inclusive. Let us return to the special case of unknown fixed benefits considered above. But assume now that the platform can observe the transactions (and allow $c \geq 0$). Because end-users' per-transaction benefits are known, the platform's ability to observe transactions is irrelevant, because it could include the known transaction benefits $b^i N^j$ into the membership fee A^i. Transaction observability, however, suggests an alternative form for condition (15). Suppose that the platform charges $a^i = b^i$. Then there are no longer cross-group externalities: $U^i = B^i - A^i$ does not depend on N^j. In this formulation, demands are independent, and profit can be written as

$$\pi = (b - c)N^B(A^B)N^S(A^S) + \sum_i (A^i - C^i)N^i(A^i),$$

where

$$N^i(A^i) \equiv \Pr(B^i \geq A^i) \quad \text{and} \quad b \equiv b^B + b^S.$$

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[27] Or, more generally, it depends on the set of members on side j, to the extent that members on side i care about the identity of members on side j.

[28] With the total derivative definition, the cross-group externalities definition would be too inclusive. Taken literally, pretty much any market would then be a two-sided market: An increase in the number of sellers (respectively, buyers) lowers (raises) the market price, i.e. the price of transactions between end-users, and so benefits buyers (sellers).

Condition (15) can be expressed in the following form:

$$\frac{A^i - [C^i - (b-c)N^j]}{A^i} = \frac{1}{\left[\left(-\frac{dN^i}{dA^i}\right)\Big/\frac{N^i}{A^i}\right]}. \qquad (15a)$$

In this Lerner formula,[29] the platform's transaction profit $(b-c)N^j$ per new member on side i must be defrayed from the cost, C^i, associated with a new member on that side. This example shows that cross-group externalities are endogenous; they depend on the platform's pricing policy. Here, the platform neutralizes such externalities by taxing fully marginal benefits.[30]

With fixed fees or fixed costs, our own definition—that the structure of per-transaction prices matters—is not without difficulty either. As for the cross-group externalities definition, there is an endogeneity question to be resolved for the definition to be operational: $p^i = a^i + (A^i - C^i)/N^j$ depends on N^j and therefore on the overall price structure. A market is two-sided if and only if the solution to the maximization of volume $n^B(p^B, p^S)n^S(p^B, p^S)$ subject to the total price constraint $(p^S + p^B \geq p)$ is unique.[31] With two part-tariffs, a similar definition applies. A market is two-sided in two cases:

(i) Either the split of marginal prices satisfying $a^B + a^S = a$ is non-neutral (something we have studied in Section 3),

(ii) or the split of marginal prices is neutral but the structure of fixed fees matters. In this case, membership on each side depends only on fixed charges and total marginal price a,

$$N^S = N^S(A^S, \beta^S(a)N^B)$$

and

$$N^B = N^B(A^B, \beta^B(a)N^S).^{32}$$

Fixing a, this yields two functions,

$$N^i = \hat{n}^i(A^i, A^j), \qquad i, j = B, S.$$

Then the market is two-sided if the program

$$\max_{\{A^i, A^j\}} \sum_i (A^i - C^i)\hat{n}^i(A^i, A^j) + (a-c)\hat{n}^B(A^B, A^S)\hat{n}^S(A^B, A^S)$$

admits a unique solution (or, more generally, a finite number of solutions.)

☐ **Some implications for two-sided platform pricing.** The Rochet and Tirole and Armstrong formulas of Proposition 1 show that with a proper reinterpretation, pricing in two-sided markets obeys the standard Lerner principles. The price charged to side i depends on what that side can bear: in both cases, the price to side i is inversely related to that side's elasticity of demand η^i. The key insight is therefore the reinterpretation of marginal cost as an opportunity cost: under usage pricing, an additional transaction yields p^j on the other side and therefore its net cost is

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[29] One can check easily that both formulas (15) and (15a) are equivalent, after adapting notation, to formula (4) in Armstrong (2006).

[30] With imperfectly known private benefits and voluntary trades, one would expect strictly positive expected surplus from marginal transactions and so strictly positive cross-group externalities. But zero or negative cross-group externalities can then be reintroduced by adding congestion externalities (the platform is more crowded, the prestige of belonging to the platform decreases, the quality of partners goes down, the operating system's code is less optimized in order to accommodate more applications, etc.), say $U^i = (b^i - a^i)N^j + B^i - A^i - dN^j$.

[31] A finite number of solutions is also indicative of two-sidedness. By contrast, one-sidedness obtains if there exists a continuum of (p^B, p^S) that maximize volume subject to the constraint $p^B + p^S = p$.

[32] The precise definition of functions $\beta^S(q)$ and $\beta^B(a)$ is given below.

$c - p^j$; under membership pricing, the presence of an extra consumer on side i raises surplus on side j by b^j and therefore allows the platform to raise its price on that side by as much without losing customers.

A number of articles, including for example Anderson and Coate (2005), Armstrong (2006), and Rochet and Tirole (2003), obtain comparative statics results that fit with standard intuition. For example, in Rochet and Tirole, a factor affecting elasticities on a given side is the size of the installed base of end-users on that side. When the number of, say, captive buyers increases, the buyer price naturally increases, and the seller price decreases as attracting sellers yields a higher collateral profit on the buyer's side. Similarly, attracting one side by lowering price is particularly profitable for the platform if this side creates substantial externalities on the other side. For example, "marquee buyers" are courted as they allow platforms to charge high prices to sellers. (See Rochet and Tirole (2003) for details.)

Other implications of the literature include linkage and skewness. The linkage between the two sides comes from the reinterpretation of costs as opportunity costs. The linkage also shows up in the form of a simple "seesaw principle": a factor that is conducive to a high price on one side, to the extent that it raises the platform's margin on that side, tends also to call for a low price on the other side as attracting members on that other side becomes more profitable. Accordingly, it is quite common for a platform to charge below-cost (perhaps zero) prices to one side and high prices to the other. For example, media platforms usually give away newspapers or free TV programs not to prey on rival platforms, but to be able to charge higher markups to advertisers.[33] Other examples of platforms making no or little money or one side include software platforms (Adobe Acrobat or text processing vendors charge nothing for the reader and make their money on the writer; operating system platforms make no money on application developers and charge users) and videogame platforms (which sell consoles at or below product costs).

The elasticities of demand are also affected by platform competition and the extent of multi-homing (we refer to Armstrong (2006) for more detail). Multi-homing stems from the users' desire to reap the benefits of network externalities in an environment of noninterconnected platforms. For example, in the absence of common listing, the seller of a house may want to enter nonexclusive arrangements with multiple real estate agencies in order to reach a wide range of potential buyers; alternatively, the buyers may deal with multiple real estate agencies. Videogame developers may port their game to several game platforms. More generally, software developers may multi-home to competing but incompatible software platforms. Or, because different payment card systems are not interconnected (a Visa cardholder cannot use her card at a merchant who accepts American Express or MasterCard but not Visa), merchants often accept and consumers often hold multiple cards. More generally, multi-homing by at least one side of the market is necessary for gains from trade to be reaped when platforms are incompatible or not interconnected.

To illustrate the impact of multi-homing, consider two platforms, 1 and 2, that are perfect substitutes from the point of view of both sides. There is one buyer B and two (noncompeting) sellers S_1 and S_2. A seller incurs fixed technological cost $I^S > 0$ of making his technology compatible with a given platform; the buyer incurs no such cost and therefore multi-homes. The sellers and the buyer have known benefits b^S and b^B of interaction, and there is no payment between them. Assume that $v \equiv b^B + b^S > c$, where c is the platform's marginal cost. The platforms can then charge

$$a^B = b^B$$

to the buyer for access to a seller. Put differently, each platform has a monopoly on access to its sellers. The latter, the "competitive bottlenecks," are charged the platform's opportunity cost,

$$a^S = c - b^B,$$

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[33] Several articles (Ambrus and Argenziano, 2004; Bakos and Katsamakos, 2004; and Caillaud and Jullien, 2003) have shown that asymmetries on pricing and other dimensions (design, quality, etc.) may arise even when the two sides are symmetric.

and receive net surplus equal to the entire social surplus,

$$b^S - a^S = v.$$

This is an equilibrium as long as $v > I^S > 0$.

This simple example illustrates the more general insight that the single-homing side receives a large share of the joint surplus, while the multi-homing one receives a small share.

A more general theme of the literature is that flexibility may backfire. Here, the buyers' ability to multi-home is actually a handicap, as it leaves them with no surplus. Relatedly, Hermalin and Katz (2006) consider a situation in which both sides can costlessly multi-home if they want to. An issue arises, when both the buyer and the seller multi-home, as to which platform the transaction occurs on. Hermalin and Katz show that the side that gets to choose the platform may actually be made worse off by this privilege: to avoid letting this side use its privilege, the other side may single-home on the network it prefers on average.[34]

While the basic insight about the mixed blessing attached to being able to multi-home generalizes to situations in which the demand functions are smoother on both sides of the market (e.g., Rochet and Tirole (2003, Proposition 5(3)) and Armstrong (2006, Section 5)), one must be careful as to what generates, say, an increase in buyer multi-homing. Factors that induce more buyer multi-homing may also intensify the degree of network competition for buyers: if more buyers are attracted by both platforms, then platforms may compete harder for their business (in contrast, the increase in multi-homing keeping the network's own demand elasticities constant, as considered in Proposition 5(3) in our 2003 article, has no such effect). An example is provided in Proposition 6 of our 2003 article, in which the impact of platform competition on price structure depends on fine characteristics of the demand functions of final users. Suppose for example that a broader group of buyers find both platforms appealing and so a larger fraction of buyers multi-home. On the one hand, the elasticity of buyers' demand for a given platform increases, due to their ability to switch usage to a competing platform. On the other hand, the elasticity of sellers' demand is corrected by what our 2003 article calls the "single-homing index." Roughly speaking, buyers' multi-homing allows platforms to "steer" sellers, i.e., to induce them to opt out of the competing platforms.[35] The smaller the single-homing index of buyers, the higher the incentive for platforms to steer sellers. Platform competition thus creates downward pressure on prices on both sides of the market, and the impact on relative prices is ambiguous. For linear demands, though, platform competition does not alter the price structure; so, for example, competition among not-for-profit associations (for which the break-even constraint fixes the price level) does not alter prices under linear demands.[36]

Multi-homing becomes less frequent when platforms can demand exclusivity. A number of new and interesting issues then arise: see, for example, Caillaud and Jullien (2003) and Hermalin and Katz (2006). Another rich set of issues arises when platforms can charge tariffs to side i that are contingent on the number of members on side j: we here refer to Armstrong (2006), who shows that when platforms compete in "two-part tariffs" (a fixed fee plus a fee proportional to the realized number of members on the other side), a continuum of equilibria exists.

Finally, the price structure may be affected by the possibility of bundling. Platforms offering several types of interaction services may benefit from bundling them. For example, payment card associations Visa and MasterCard offer both debit and credit cards and, until recently, engaged in a tie-in on the merchant side through the so-called honor-all-cards rule. The motivations for tying in two-sided markets may be different from the usual ones in classical markets (e.g., price discrimination or entry deterrence). In a two-sided market, tying may allow platforms to perform

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[34] In Hermalin and Katz, the benefits from interacting on alternative platforms are realized after the network membership decisions.

[35] What matters here is membership multi-homing rather than usage multi-homing (Rysman (2004) presents some evidence that cardholders multi-home much more in membership than in actual usage).

[36] See Anderson and Coate (2005), Armstrong (2006), Guthrie and Wright (2003), Hagiu (2006), and Rochet and Tirole (2004) for further analyses of multi-homing.

better the balancing act between buyers and sellers; such rebalancing may increase social welfare. (See Rochet and Tirole (2004).)

□ **Payment between end-users.** Many models of membership or indirect network externalities are motivated by industries in which payments between end-users are fundamental. For example, in the software and videogames industries, the application or game developers sell their platform-compatible products to consumers. However, the canonical formulation above,

$$U^i = \left(b^i - a^i\right) N^j + B^i - A^i,$$

which is meant to encompass many such models, as it stands, is inconsistent with the existence of payments between end-users: the number of actual transactions for a member of side i is then endogenous and need not be equal to the total number N^j of potential trading partners; relatedly, side i's per-transaction net surplus $b^i - a^i$ in general depends on the per-transaction charge a^j levied on the other side.

Let us assume that the per-transaction benefit b^i of a given member of side i is drawn from cumulative distribution $F^i(b^i)$ after the end-user has decided to become a member. The benefit can be the same across the N^j potential transactions or drawn for each of these; the key assumption is that the distribution F^i is the same for all B^i. Thus, end-users differ *ex ante* only in their fixed benefit B^i.[37] The hazard rates of the distributions, $f^i/(1-F^i)$, are, for expositional simplicity only, assumed to be increasing. There are still $N^B N^S$ potential transactions, but only an (endogenous) fraction $X \leq 1$ of these transactions will take place (thus, the total number of transactions is $X N^B N^S$).

When a buyer with *ex post* type b^B and a seller with *ex post* type b^S "meet," they bargain over the transaction price. A polar case of bargaining is price setting, in which the seller, say, makes a take-it-or-leave-it offer to the buyer. But haggling and more equal bargaining power are possible too. Let us therefore adopt a broad mechanism design approach.[38]

We know from Section 3 that whether bargaining occurs under symmetric or asymmetric information, the usage price structure is neutral. And so only $a = a^B + a^S$ matters. Let $b \equiv (b^B, b^S)$. Bargaining yields a (present discounted) probability of trade $x(b, a) \in [0, 1]$ and balanced (present discounted) transfers $t^i(b, a^B, a^S)$ that "neutralize" the allocation of a between a^B and a^S. So the per-interaction expected net surplus of a member on side i only depends on $a^B + a^S = a$:

$$\beta^i(a) \equiv E\left[\left(b^i - a^i\right) x(b, a) + t^i\left(b, a^B, a^S\right)\right], \quad (16)$$

where expectations are taken with respect to the product distribution $F^B \times F^S$.

The platform's profit is then

$$\pi = \sum_{i=B,S} (A^i - C^i) N^i + (a - c) X N^B N^S, \quad (17)$$

with

$$X \equiv E[x(b, a)].$$

Substituting and simplifying yields

$$\pi \equiv [p^B + p^S + v(a)] n^B n^S, \quad (18)$$

where[39] the per-transaction price p^i is the same for all users on side $i = B, S$:

$$p^i = \frac{A^i - C^i}{N^j} + a^i X - E\left[b^i x(b, a) + t^i(b, a^B, a^S)\right], \quad (19)$$

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[37] A similar assumption is used in a number of articles on two-sided markets, notably Anderson and Coate (2005), Bakos and Katsamakos (2004), Caillaud and Jullien (2003), Hagiu (2006), and Guthrie and Wright (2004).

[38] As, for example, in Fudenberg and Tirole (1991).

[39] Note that the participation equation becomes $N^i = \Pr[E\left[b^i x(b, a) + t^i(b, a^B, a^S)\right] - a^i X + [(B^i - A^i)/N^j] \geq 0]$.

n^i is defined as above, and

$$v(a) \equiv E\left[(b^B + b^S - c)x(b, a)\right] \tag{20}$$

is the average social surplus from potential interactions.

Formula (18) indicates that use can be made of the canonical model, setting platform per-customer "cost" $(-v)$. The platform's optimization problem thus decomposes into (i) the choice of prices (p^B, p^S) (as above), and (ii) an ancillary problem of finding the per-transaction total access charge a that maximizes the average social surplus from potential transactions $v(a)$. We now obtain some general results on the latter:

(a) *Coasian bargaining*. Suppose that the seller and the buyer know each other's valuations when bargaining (under price setting: that the seller knows the buyer's willingness to pay and therefore can perfectly price discriminate). In this full-information setting, trade occurs if and only if

$$b^B + b^S \geq a.$$

Thus, v is maximized if the end-users are confronted with the social cost of their transaction:

$$a = c.$$

(b) *Asymmetric information bargaining and monopoly price setting*. Under asymmetric information, trade between end-users is quite generally suboptimal if $a = c$.

Price setting. Consider the polar case of price-setting first. The seller chooses to charge the buyer an all-inclusive price t $(= t^S = -t^B$ in our earlier notation) so as to maximize $[t-(a-b^S)][1-F^B(t)]$ (b^S is generally to be interpreted as minus the seller's cost of production), yielding a cutoff type for the buyer $\widehat{b}^B = t$ given by

$$\widehat{b}^B + b^S - a = \frac{1 - F(\widehat{b}^B)}{f(\widehat{b}^B)},$$

defining a function $\widehat{b}^B(a - b^S)$ increasing in a and decreasing in b^S. Total surplus from usage is then

$$v(a) = E_{b^s}\left[\int_{\widehat{b}^B(a-b^S)}^{\infty} (b^B + b^S - c)dF^B(b^B)\right],$$

and so, at the optimal per-transaction charge,

$$\frac{dv}{da} = E_{b^s}\left[-f(\widehat{b}^B(a - b^S))\frac{\partial \widehat{b}^B}{\partial a}\left[a - c + \frac{1 - F^B(\widehat{b}^B(a - b^S))}{f^B(\widehat{b}^B(a - b^S))}\right]\right] = 0.$$

We thus obtain two results:

(i) Subsidization: $a^* < c$.

(ii) When the buyers' demand for usage is exponential (constant hazard rate), the monopoly distortion can be perfectly corrected, and the first-best level of transactions obtains.

Bargaining. Consider for example Chatterjee and Samuelson's (1983) double auction generalization of the Nash demand game: The seller and the buyer choose bids, and trade occurs at the average bid if the seller's demand is smaller than the buyer's stated willingness to pay. With uniform distributions on [0, 1], Chatterjee and Samuelson show that trade occurs if and only if

$$b^B + b^S - a \geq \frac{1}{4}.$$

Thus, setting $a^* = c - 1/4$ delivers the first-best volume of trade.

Pursuing the analysis of familiar bargaining games with (generically) unique outcome,[40] we have checked that the subsidization result also holds for the random proposer game, in which each party makes a take-it-or-leave-it offer with some probability;[41] and for the standard finite- or infinite-horizon price discrimination game where a seller with known cost sequentially makes offers to a buyer with a discrete number of types or with a continuum of types strictly above the seller's cost.[42]

Finally, we can consider efficient bargaining processes. We know from Myerson and Satterthwaite (1983) that constrained efficient outcomes of arbitrary bargaining processes yield trade if and only if

$$\sum_{i=B,S} \left[b^i - \alpha \frac{1 - F^i(b^i)}{f^i(b^i)} \right] \geq a$$

for some weight $\alpha \in [0, 1)$. The Appendix shows that under a (weak) regularity condition (we assume that the volume of trade decreases with the usage fee a), one obtains

$$a^* < c.$$

Proposition 2. Suppose that trade between end-users is the outcome of bargaining (where bargaining includes, as a polar case, price setting), and that on each side i, the *ex post* transaction benefits (or costs) b^i are drawn from distribution $F^i(b^i)$ independently of the end-user's fixed membership benefit B^i.

Then, the platform's optimization problem decomposes.

(i) The transaction charge a is set so as to maximize the average social surplus from potential interactions:

$$v(a) = E[(b^B + b^S - c)x(b, a)].$$

Under symmetric information bargaining between end-users, the platform passes through the per-transaction cost:

$$a^* = c.$$

Under asymmetric information bargaining, in a wide range of cases (including price setting and efficient bargaining processes), the platform optimally subsidizes transactions:

$$a^* < c.$$

(ii) The platform sets the price level and structure as in the pure-membership version of the canonical model of Proposition 1, so as to maximize

$$\pi = [p^B + p^S + v(a^*)]n^B n^S,$$

and utilities from membership are

$$U^i(B^i) = \max\{\beta^i(a^*)N^j + B^i - A^i, 0\}.$$

□ **Beyond the canonical model.** The canonical model is a useful workhorse for analyzing two-sided markets. But one must be aware of its limits and know how to enrich it when needed, as a few recent contributions do. To see what extensions might be relevant, let us return to the

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[40] Bargaining games often have many perfect Bayesian equilibria. The analysis of the impact of a change in a requires an equilibrium selection, and is therefore left for future research.

[41] This result follows trivially from our analysis of the monopoly and monopsony cases.

[42] See Fudenberg, Levine, and Tirole (1985) (the outcome is only generically unique). A reduction in the usage fee a "speeds up" the acceptance of offers by the buyer.

previous modeling of utility,

$$U^i = \mathcal{B}^i(b^i, N^j, a^B, a^S) + B^i - A^i,$$

where $\mathcal{B}^i = (b^i - a^i) N^j$ in the absence of payments between end-users and *ex ante* known b^i and $\mathcal{B}^i = \beta^i(a)N^j$ in the presence of payments and random marginal benefits.

The first implicit assumption[43] is that side i cares, on the other side, only about the number of users N^j. This assumption is violated if the average quality of matches on the other side depends on platform pricing, as in Damiano and Li (2007). Consider for example clubs whose members are snobs or dating agencies whose clients prefer to meet wealthy counterparts; an increase in N^j brought about by a reduction in p^j attracts less-wealthy individuals and reduces the "quality" perceived by side i. It then makes sense to assume that $[\partial \mathcal{B}^i / \partial N^j]/[\mathcal{B}^i / N^j]$ is lower than one and perhaps even negative.

Second, the independence of $\mathcal{B}^i$ relative to N^i excludes same-side externalities. Consider for example a software platform with N^S application developers and N^B consumers. Then, assuming $a = 0$,[44]

$$\mathcal{B}^S = b^S(N^S) N^B,$$

with $\dot{b}^S < 0$ if the applications are substitutes (rivalry effects) and $\dot{b}^S > 0$ if the applications are complements[45]

Third, the possibility that end-users *ex ante* have private information about their future per-transaction benefit b^i creates some complications once one departs from the assumptions made above. In particular, consider the case of payments between end-users. The per-potential-interaction benefit β^i then depends not only on a and on the end-user's *ex ante* signal about b^i, but also on the distribution of b^js on the other side. This introduces quality effects similar to those discussed above: a smaller membership on side j improves the distribution of the b^js, and thereby raises β^i.[46]

Fourth, the canonical model involves simultaneous courting of buyers and sellers. For some industries, such as software, one side may be courted before the other, which raises interesting commitment issues (Hagiu, 2006). In Hagiu's model, one side (the application developers) must decide whether to join and invest in the platform (the videogame platform) before the other side (the gamers) joins it. The former side faces a potential hold up by the platform: once it has invested, the platform may charge a monopoly price to the other side, generating few transactions between end-users. Hagiu shows how the platform can solve its commitment problem by not charging the side that invests first and by claiming royalties on interactions between end-users; this pricing structure commits the platform to charge low prices to the late-coming side, as it will not make profits until it generates lots of transactions between the two sides. Indeed, videogame platforms demand $7 or $8 on the sale of each game written for the platform and sell the console at or often below marginal cost.

6. Summary

■   Let us summarize the article's main points.

(i) Because all markets involve transactions between two (or more) parties and therefore are potential two-sided markets, it is useful to circumscribe the scope of a two-sided-markets theory. Our first objective has been to propose such a definition: a market is two-sided if the platform

[43] In the tradition of the two-way interconnection literature in telecommunications (Laffont, Rey, and Tirole, 1998a, 1998b; Armstrong, 1998).

[44] A reasonable assumption for operating systems, but not for game platforms, which demand per-game royalties.

[45] Ambrus and Argenziano (2004), Belleflamme and Toulemonde (2004), and Ellison, Fudenberg, and Möbius, (2004) develop different models exhibiting rivalry effects.

[46] Another point worth making is that the choice of the total per-transaction charge a no longer serves only an efficiency purpose as in Proposition 2. This charge is also used to extract end-user rents.

can affect the volume of transactions by charging more to one side of the market and reducing the price paid by the other side by an equal amount; in other words, the price structure matters, and platforms must design it so as to bring both sides on board. The market is one-sided if the end-users negotiate away the actual allocation of the burden (i.e., the Coase theorem applies); it is also one-sided in the presence of asymmetric information between buyer and seller, if the transaction between buyer and seller involves a price determined through bargaining or monopoly price-setting, provided that there are no membership externalities.

(ii) Factors making a market two-sided include (a) transaction costs among end-users or, more generally, the absence of, or limits on the bilateral setting of prices between buyer and seller, (b) platform-imposed constraints on pricing between end-users, and (c) membership fixed costs or fixed fees.

(iii) We built a model of two-sided markets encompassing usage and membership externalities, and we derived and interpreted the optimal pricing formulas. We extended this model to allow for payments between end-users. In this extension, Coasian bargaining between end-users calls for a passthrough of platform variable costs to end-users. Price setting or bargaining under asymmetric information by contrast calls for a subsidization by the platform of transactions between end-users.

(iv) Finally, we reviewed some key pricing principles. Because pricing to one side is designed with an eye on externalities on the other side, the standard Lerner pricing formula must be reinterpreted by replacing "cost" by "opportunity cost."

Appendix

■ *Proof of Proposition 2.* An efficient bargaining process solves over the trade function $x(b, a) \in [0, 1]$:

$$L(a) = \max_{\{x(\cdot, \cdot)\}} E\left[\left(\sum_i b^i - a\right) x(b, a)\right]$$

subject to

$$E\left[\left[\sum_i \left(b^i - \frac{1 - F^i(b^i)}{f^i(b^i)}\right) - a\right] x(b, a)\right] \geq 0$$

(the latter condition coming from the budget balance after adding up the individual rationality constraints for the lowest types). Note that

$$L'(a) < -X(a) \qquad \text{where } X(a) \equiv E\left[x(b, a)\right],$$

since when the usage fee a decreases by a unit amount, the same policy $x(\cdot, \cdot)$ satisfies the constraint with slack while the objective function increases by $X(a)$.

The platform maximizes over a:

$$v(a) = E\left[\left(\sum_i b^i - c\right) x(b, a)\right],$$

where x is determined by the optimization above. Because

$$v(a) = L(a) + (a - c)X(a),$$

the first-order condition is

$$v'(a^*) = L'(a^*) + X(a^*) + (a^* - c)X'(a^*) = 0 < (a^* - c)X'(a^*).$$

Make the (weak) regularity assumption that $X' < 0$ (the volume of trade decreases with the usage fee, a property that is satisfied for example for uniform or exponential distributions); then $a^* < c$.

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