Co-opetition Between Differentiated Platforms in Two-Sided Markets

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ABSTRACT: Technology is an important factor underlying the value propositions of intermediary platforms in two-sided markets. Here, we address two key questions related to the effect of technology in platform markets. First, how does technology asymmetry affect competition between platforms? Second, how does it affect the incentives for platforms to collaborate? Using a game-theoretic model of a two-sided market where technology strongly influences network value, we show that small asymmetries in platform technologies can translate into large differences in their profitability. We find that technology improvements by the inferior platform do not significantly increase its profits, but can reduce opportunities for fruitful cooperation, since collaboration is less likely in markets with closely matched competitors. We also show that collaboration is most profitable when it takes the form of direct network interconnection. Interestingly, collaboration may provide incentives for a dominant platform to accommodate entry, where it would not otherwise do so.

KEY WORDS AND PHRASES: competitive strategy, co-opetition, game theory, network sharing, platform interconnections, technology platforms, two-sided markets.

TECHNOLOGY-ENABLED PLATFORMS THAT FACILITATE INTERACTIONS between multiple sets of agents are ubiquitous in the modern economy—from personal computer and mobile operating systems (platforms between application developers and application users),

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online advertising networks (between Web properties and advertisers), job boards (between job seekers and recruiters), online dating sites (between singles of both sexes), and real estate brokerages (between property buyers and sellers), to electronic marketplaces and payment card systems (between merchants and consumers). More recently, we have seen mobile payments platforms such as Google Wallet and Isis (between merchants and consumers) also. In the absence of such facilitation by the platforms, these interactions may be difficult, inefficient, too costly, or even impossible. The platforms' economic prominence has drawn wide attention from researchers in economics [29, 36] and information systems [14, 34], who label these markets *two-sided markets* or *two-sided networks.* In these markets, each customer's utility is typically an increasing function of the number of customers of the other type available to interact with, giving rise to *cross-market network effects.* Evans and Schmalensee [17] classify these markets into four different kinds: exchanges, ad-supported media, transaction systems, and software platforms. Our analysis in this paper most directly applies to exchanges but, to a lesser extent, also to software platforms, especially mobile and video game platforms, and transaction systems such as mobile payment systems. Our primary interest is in understanding the role that the level of technology plays in mediating competition and collaboration between such platforms.

In the types of platforms that we are studying, the platform providers typically perform two primary functions: (1) they match agents on the two sides, enabling transactions between them, and (2) they add to the quality of the transactions in different ways. The utility that an agent on each side gets depends not only on the number of agents on the other side of the platform, that is, cross-market network effects, but also on how well the platform facilitates the transactions, that is, the effectiveness of the platform technology. For example, Google serves as an intermediary between the ad inventory provided by advertisers and the Web real estate inventory provided by content sites. The utility to advertisers, in this case, depends on the click-through rates and the fit between their products and services and the advertising vehicle (the content sites); these in turn depend on the effectiveness of Google's contextual mapping and consumer profiling technologies. A better targeting technology also improves the revenue potential of the Web sites where the ads are placed. Electronic stock exchanges serve as trading platforms for different financial instruments. A more effective technology underlying such platforms not only increases the efficiency of trades but also facilitates matching the right investor with the right asset, maximizing the utility of both investors and asset owners. Improvements in the technology of the platform provided by real estate brokers enable sellers to showcase their properties better and buyers to more efficiently find and assess properties of interest. Along similar lines, a better technology for an electronic job board improves the efficiency of the search process as well as the quality of the match between job seekers and recruiters, creating gains for both. These examples point to the potential for technology to be an important determinant of competition in such two-sided platform markets.

The nature of competition and cooperation in two-sided markets is different from that in traditional markets because of the influence of network effects. In network markets, small differences, in either perception or reality, of the platforms' capabilities can result in significant differences in their adoption patterns. Collaboration, in the form of network sharing between platforms, can significantly boost customer value, as access to a larger network size translates to higher levels of utility from network effects. This added utility makes the platforms more valuable to potential customers. However, this is usually accompanied by decreased differentiation between platforms, as exclusive access to their networks is an important source of competitive advantage for them. When platforms share networks, technology acts as the only meaningful differentiator, potentially intensifying competition and resulting in rent dissipation. While many of these issues are common to both one-sided and two-sided markets, potential asymmetries between the network effects on the two sides add some extra dimensions in the two-sided case.

A good example of collaboration through network sharing in two-sided markets is electronic stock exchanges, as we noted earlier. Stock exchanges (platforms between investors and asset owners) often create contracts that allow their members to cross-list assets on multiple stock exchanges while the members have standing only in a single exchange [33]. Shared ATM (automated teller machine) networks (platforms between banks and bank customers) allow customers of one network to transact through ATMs owned by another [9]. Real estate brokers (platforms between property buyers and sellers) interconnect their Multiple Listing Services (MLS) offering deeper visibility into both supply and demand for properties [21]. Yahoo! and Microsoft have partnered in the online advertising network market to share their partner sites and advertiser networks. However, such cooperation may sometimes not happen despite its social desirability. A good example is the global distribution systems (GDS) that serve as platforms between service providers (airlines, hotels, etc.) and travel agents [24, 25]. Despite the obvious advantages of interconnecting their networks, these platforms rarely cooperate, forcing service providers to join multiple GDSs.

Our primary objective in this paper is to understand when cooperation can, and cannot, arise between platforms—in particular, to examine the role that technology plays in these decisions. To investigate this issue, we build a simple model of a two-sided market where technology plays a central role in determining the platform value and use this model to study the following questions. How do asymmetries in technology levels affect market outcomes? When, if at all, does collaboration emerge between platforms with differentiated technologies? What form does this collaboration take? The answers to all three questions turn out to be interrelated. We find that even small differences in the platforms' technologies can translate into significant differences in their profits. Further, investments to improve technology may have poor returns, and may even destroy incentives for collaboration. Collaboration through both direct and indirect network sharing is most likely when firms are quite asymmetric with respect to their technology levels and becomes increasingly less likely as the firms head toward technology parity. As a consequence, collaboration between platforms may not be observed as often in highly competitive platform markets. Interestingly, we find that opportunities for collaboration may pave the way for otherwise dominant platforms to accommodate entry, although this may have an adverse effect on some customers.

Literature Review

Two-sided markets have been actively researched in the past decade. Roson [37] and Wright [40] provide excellent summaries of the early literature, highlighting the differences between these markets and traditional nonnetwork or one-sided network markets. A fundamental insight is that platforms can manipulate both the *price level* (the total price charged to members on both sides) and the *price structure* (how the total is split up) to favorably affect market outcomes [36]. A common strategy for platforms is to discount or subsidize one side of the market. This is especially true for information goods because of their near-zero marginal costs [34].

While we do find such discounting in our analysis, our focus is more on understanding the role that technology plays in these markets—an issue that, despite its importance, has not received commensurate attention in the literature. Among the few exceptions, Eisenmann et al. [15, 16] provide a rich description of how technology creates value in platform markets and the importance of managing it optimally to appropriate that value. Katsamakas and Bakos [30] study the effect of different platform ownership structures (independent, buyer, or seller owned) on the choice of technology in a monopoly setting. We study the opportunities for collaboration between competing platforms with heterogeneous technologies. Anderson et al. [1] also study the role of technology in platform competition but separate the effect of technology from network effects, focusing on the investment trade-offs between improving a platform's core technology and increasing its cross-market network effects. In our analysis, these two are not separable since we focus on platforms where technology influences the magnitude of network effects.

Cooperation between networks has long been of interest in the one-sided networks literature, where it generally goes by the name of *compatibility* [4, 8]. Compatibility may either be externally imposed through standards or voluntarily adopted—often through the building of converters or adapters. This paper is similar in spirit to the latter. A broad finding in this literature is that the level of compatibility achieved is generally socially suboptimal [23]. Firms in strong control of the market may resist efforts by rivals to make their networks compatible [19] even when compatibility is socially optimal, whereas the ones with smaller networks or weak reputations may favor compatibility even when the social costs of compatibility outweigh the benefits [31]. The last finding partially mirrors one of our own results. Our analysis also identifies conditions under which the stronger firms may welcome compatibility and conditions under which the weaker firms may not.

A related literature concerns network interconnection, particularly in the context of credit cards [35], messaging and communication platforms [26], and telecommunication networks [2]. The focus in this literature is on designing socially efficient interconnection or transfer payments. Our work is somewhat complementary to these. We do not delve into the details of transfer payments. Instead, we focus on identifying technology conditions under which interconnection can arise between competing platforms. Also related is the work by Foros and Hansen [20], who analyze firm decisions with respect to the level of compatibility in the Internet service provider industry. Their analysis allows them to go beyond treating interconnections as binary decisions and probe deeper into the nature of interconnection, much as we do with the distinction between direct and indirect interconnection, and different variants of the latter.

Within the two-sided markets literature, compatibility has been studied in the context of open or nonproprietary platforms, often with a focus on social efficiency and the incentives of different players toward compatibility. Schiff [38] shows that duopoly with compatibility is socially preferable to monopoly, whereas monopoly is socially preferable to duopoly without compatibility. Economides and Katsamakas [14] study the impact of platform compatibility on the profitability of the market for complements and show that the proprietary applications sector of an industry based on an open source platform may be more profitable than the total profits of a proprietary platform industry. Echoing a somewhat similar finding, Ceccagnoli et al. [7] establish empirically that it may be more beneficial for a small independent software vendor to join a major platform ecosystem than produce a platform-independent stand-alone application.

An alternative to compatibility is multihoming, a situation where customers join multiple platforms. When customers multihome, compatibility may not be important, and vice versa—either from a platform or an efficiency perspective. Using a model similar to ours, Gabszewicz and Wauthy [22] study multihoming and find that it happens only on one side of the market. Doganoglu and Wright [11] claim that multihoming may be a poor substitute for compatibility. In their analysis, Doganoglu and Wright find that multihoming weakens competition and introduces costs that firms do not internalize. Thus, multihoming can increase the social desirability of compatibility, while making compatibility less attractive for firms. Given our focus on platform collaboration, we assume that customers single-home and do not consider the relative social merits of compatibility versus multihoming. We conjecture that multihoming is more likely to be observed in situations where conditions that facilitate platform collaboration fail.

From an analytical perspective, two different kinds of pricing schemes are generally considered in the two-sided markets literature: membership pricing and transaction pricing. Armstrong [3] finds that the distinction between the two only matters when there are competing platforms, but not in the case of a monopoly. Schiff [38] reports that the two kinds are equivalent, from a profit perspective, in a Cournot duopoly model. The two kinds of pricing will also be equivalent if consumers are homogeneous with respect to the number of transactions and there is no uncertainty related to this number. However, in general, the results may be sensitive to the type of pricing scheme used [36], and the choice between the two depends on a variety of factors, including the difficulty of monitoring usage and the nature of the externality between the two sides [17]. We assume that platforms use membership pricing (similar to [11, 14, 22, 30]), an assumption that may somewhat limit the generalizability of our findings. We discuss this issue further in the final concluding section.

The primary contribution of this paper is that it combines several features that are important in the context of technology platforms: (1) the effect of technology on competition between platforms in two-sided markets, (2) possibilities for collaboration in the form of network or technology sharing, and (3) different types of network sharing. By combining these features, some of which have been studied in other contexts, we present a rich analysis of co-opetition in this important class of markets. Table 1 highlights how our research focus and modeling relate to and extend the existing literature.

The Basic Model of Utility

We consider a two-sided market with heterogeneous customers on both sides. (See Table 2 for the our mathematical notation and related definitions.) We refer to the customers on one side as *sellers* (s), and the other side as *buyers* (b). Transactions between buyers and sellers are facilitated by platforms. The use of the terms *sellers* and *buyers* is purely expositional, and transactions can generically be any type of gainful interactions between the two sets of agents, including trade, social interaction, information transmission, and so forth [36]. Details of transactions are abstracted away, and the net benefit of these interactions to the buyers and sellers is represented by the reduced form utility function described below. The platforms are independently owned and serve as both platform sponsors and providers [16].

Sellers and buyers are denoted by their types θ_s and θ_b. A customer's type represents a measure of his or her expected value from each potential transaction, and customers are assumed to be heterogeneous in this regard. We assume that θ_s and θ_b are uniformly distributed over the range [0, 1]. This assumption enables us to derive analytical solutions, but we believe that our qualitative insights extend more generally to other kinds of continuous distributions. We further assume that there are N_s potential sellers and N_b potential buyers.

The net utility to a customer on side i ($i \in$ {sellers (s) or buyers (b)}), from joining a platform j ($j \in$ {Platform 1 or Platform 2}), is given by

$$U_{ij}\left(\theta_i; n_{\hat{i}j}\right) = \theta_i t_j \alpha_i n_{\hat{i}j} - p_{ij}, \tag{1}$$

where $n_{\hat{i}j}$ is the number of customers joining Platform j on the other side, that is, $\hat{i} \neq i$; t_j is the level of technology provided by Platform j; α_i is the strength of the cross-market network effects enjoyed by customers on side i; and p_{ij} is the membership price charged by Platform j to customers on side i. Customers do not incur any other costs beyond the price of membership, and platforms are assumed to have zero marginal costs associated with serving customers.[1]

The utility function in Equation (1) reflects a number of important features related to customer value in two-sided markets. First, it incorporates cross-market network effects; a customer's utility increases with the number of members he or she can interact with on the other side of the platform. Second, it permits the utility from interactions to be different for sellers and buyers; α_s, α_b may not be equal. Third, it explicitly considers how the technology level of the platform can influence customer value. The multiplicative form used here implies that the technology level influences the value from each potential transaction (or, equivalently, the probability of a transaction), and is suitable for platforms that primarily perform a matching function or enable interactions such as game play and rich-media personal interaction. In contexts where a platform

Table 1. The Focus and Modeling in the Current Paper Versus the Existing Literature

	Research issues		Modeling approach		
Title	Effect of technology	Network interconnection/ compatibility	One-side/ two-sided network	Single versus multihoming	Membership versus transaction pricing
Anderson et al. [1]	✓		T	M	M
Doganoglu and Wright [11]		✓	T	M	M
Farrell and Saloner [19]		✓	O	S	M
Gabszewicz and Wauthy [22]			T	M	M
Foros and Hansen [20]		✓	O	S	M
Katsamakas and Bakos [30]	✓		T	S	M
Katz and Shapiro [31]		✓	O	S	M
Rochet and Tirole [36]			T	S	M,T
Schiff [38]		✓	T	S	M,T
This paper	✓	✓	T	S	M

Note: {O = one-sided, T = two-sided}, {S = single-homing, M = multihoming}, {M = membership, T = transaction}.

Table 2. Summary of Frequently Used Notation

Description	Notation
Customer side index	$i, \hat{i} \in \{s, b\}$
Platform index	$j, \hat{j} \in \{1, 2\}$
Customer type distribution on side i	$\theta_i \sim U[0, 1]$
Total potential customers on side i	N_i
Level of platform technology	$t_1, t_2; t_1 > t_2$
Strength of network effects on side i	α_i
Price of platform j on side i	p_{ij}
Ratio of platform technology	$r = t_2/t_1$, $0 < r < 1$
Cross-platform experience of members of j	$\gamma_j(t_1, t_2)$ or γ_j

primarily serves as a base, or infrastructure over which people interact, it may be more appropriate to use an additive specification and make the value from technology and network effects separable.[2] However, such platforms are not our focus here.

Finally, the multiplicative relationship with customer type gives network value a "quality" connotation; all customers prefer more of it to less, but the higher types get a higher marginal value from the network, making our model a vertical model [5]. Such models are common in the literature on two-sided markets, and more broadly, network markets [22, 30]. An alternative is to make customers' preferences for platforms horizontal, where customers have differing tastes with respect to platforms but all enjoy the same marginal value from technology and network effects. Our analysis (not included in the paper) indicates that many of our results concerning platform collaboration carry over to this case as well. In the next section, we use the model to analyze pure competition between duopoly platforms with different technology levels. Later, we extend the analysis to consider different forms of collaboration between the platforms.

Pure Competition in a Duopoly

Analysis

Consider competition between two platforms, characterized by technology levels t_1 and t_2. Without loss of generality, assume $t_1 > t_2$, that is, Platform 1's technology is superior, and define $r = t_2/t_1$. Assume that there is no collaboration of any form between the platforms. Each platform, say Platform j, chooses a pair of membership prices (p_{bj}, p_{sj}) for buyers and sellers. A customer joins a platform only if his or her net utility, as defined in Equation (1), from doing so is nonnegative (the individual rationality [IR] constraint), and it is higher than the net utility from joining the other platform (the incentive compatibility [IC] constraint). Assessing utility, however, requires the knowledge of the number of members on the other side of the platform, which is not available until the customers make their choices. To get around this circularity, we follow the network effects literature in assuming that customers form rational expectations about future network sizes and make choices accordingly. We also assume that customers single-home; they join no more than one platform.

The structure of the game is as follows. In Stage 1, with full knowledge of each other's technologies, the two platforms simultaneously choose membership prices for both sides. In Stage 2, the customers form rational expectations about the equilibrium network sizes of the two platforms. In Stage 3, the customers make platform adoption decisions based on their expectations, platform prices, and the IR and IC constraints. Following the network externalities literature [12, 31], we assume that the expectations are fulfilled in equilibrium. Thus, our equilibrium concept is the following:

Definition (Fulfilled Expectations Nash Equilibrium, FENE): A FENE is defined by the two tuples of prices (p^*_{bj}, p^*_{sj}), j = 1, 2, and the two tuples of expectations (n^e_{i1}, n^e_{i2}) such that (a) given the expectations, (n^e_{i1}, n^e_{i2}), i = b, s, the choices of Platform j, (p^*_{bj}, p^*_{sj}), are the best responses to the choices of Platform $\hat{j}$; $j, \hat{j} = 1, 2$; $j \neq \hat{j}$; and (b) given the two tuples of prices, (p^*_{bj}, p^*_{sj}), j = 1, 2, the customers' expectations are rational, that is, demands D_{ij} ({p^*_{ij}}, {n^e_{ij}}) = n^e_{ij} for all i = b, s; j = 1, 2.

Note that the above definition implies that the price choices of platforms are not only best responses to each other's prices but also a platform's price in each market is a best response to its price in the other market.

Following the choice of prices by the platforms, let n^e_{sj} and n^e_{bj}, respectively, be the buyers' and sellers' expectations about how many customers from the other side join the Platform *j*. Let $D_{bj}(.)$ and $D_{sj}(.)$ be the corresponding platform demands on the two sides. Each platform's choice problem, thus, is

$$\max_{p_{bj}, p_{sj}} \pi_j = p_{bj} D_{bj}\left(p_{bj}, p_{sj}\right) + p_{sj} D_{sj}\left(p_{bj}, p_{sj}\right). \tag{2}$$

A customer of type θ_i will join Platform *j* if the following two conditions are satisfied:

$$\text{IR: } \theta_i t_j \alpha_i n^e_{\hat{i}j} - p_{ij} \geq 0, \tag{3}$$

$$\text{IC: } \theta_i t_j \alpha_i n^e_{\hat{i}j} - p_{ij} \geq \theta_i t_{\hat{j}} \alpha_i n^e_{\hat{i}\hat{j}} - p_{i\hat{j}}. \tag{4}$$

The customer will participate in the market only if the IR condition is satisfied for at least one platform. The demand for each platform, on each side, is given by the measure of the set of θ_i satisfying the above two conditions: $D_{ij}(\{p^*_{ij}\}, \{n^e_{ij}\}) = N_i \int_\Theta d\theta_i$ such that Θ = {all θ_i that satisfy Equations (3) and (4)}. The resulting FENE could either have both platforms active in the market (each with positive demands on both sides) or have only a single active platform. We label the former type the *Competitive Equilibrium* and the latter type the *One-Platform Equilibria.* We start by describing a Competitive Equilibrium, where the superior technology platform serves the higher-end customers in both markets, in Lemma 1. Following that, Lemma 2 will describe the One-Platform Equilibria. (See Appendix A for the proofs of our main results.)

Lemma 1 (Competitive Equilibrium): Under pure duopoly competition with both platforms active, and the superior technology platform serving the upper end of the *customer population, the equilibrium prices and demands for side i, $(i, \hat{i} \in \{b, s\}; i \neq \hat{i})$ and platform profits are given by*

$$p_{i1}^* = \frac{8N_{\hat{i}}t_1^2\left(2t_1 - t_2\right)\alpha_i}{\left(8t_1 - t_2\right)^2};\ D_{i1} = \frac{4N_i t_1}{\left(8t_1 - t_2\right)};$$
$$\pi_1^* = \frac{32N_b N_s t_1^3\left(2t_1 - t_2\right)\left(\alpha_b + \alpha_s\right)}{\left(8t_1 - t_2\right)^3}; \tag{5}$$

$$p_{i2}^* = \frac{2N_{\hat{i}}t_1 t_2\left(2t_1 - t_2\right)\alpha_i}{\left(8t_1 - t_2\right)^2};\ D_{i2} = \frac{2N_i t_1}{\left(8t_1 - t_2\right)};$$
$$\pi_2^* = \frac{4N_b N_s t_1^2 t_2\left(2t_1 - t_2\right)\left(\alpha_b + \alpha_s\right)}{\left(8t_1 - t_2\right)^3}. \tag{6}$$

The customers at the upper end ($\theta \geq (4t_1 - t_2)/(8t_1 - t_2)$) on each side join the superior technology platform, while the customers in the middle ($(2t_1 - t_2)/(8t_1 - t_2) \leq \theta < (4t_1 - t_2)/(8t_1 - t_2)$) join the inferior platform. The lower end of the market ($\theta < (2t_1 - t2)/(8t_1 - t_2)$) on each side is left uncovered. The prices charged by the platforms to the two sides are typically asymmetric, with customers on the side with the stronger network effects generally paying a higher price. There are two related reasons for this. First, customers with weaker network effects have lower value. Second, and more interesting, a drop in the price on one side not only increases demand on that side but also on the other side indirectly through an increase in network value. Thus, at a fixed *price level* (total price across the two sides), it is beneficial to move away from a *symmetric price structure* by dropping price on the low value side, and increasing it on the other.[3] (See Appendix B for results related to a benchmark monopoly model.)

Comparing the outcomes, we see that the superior technology platform charges much higher prices to both sides than the inferior technology platform ($p_{i1}^*/p_{i2}^* = 4t_1/t_2$), but still has twice the market share, and makes substantially more profits ($\pi_1^*/\pi_2^* = 8t_1/t_2$). Thus, although the outcome may not be winner-take-all in terms of market shares, it is close to that in terms of profit shares. Comparative statics of market shares, equilibrium prices, and profits, associated with the FENE specified in Lemma 1, are described below.

Proposition 1 (Technology Asymmetry of the Platforms): Under the Competitive Equilibrium specified in Lemma 1, as the platforms' technological asymmetry decreases, so as $r = t_2/t_1$ increases: (a) Equilibrium demands of both platforms increase on both sides of the market, but relative market shares remain unchanged. As t_2 approaches t_1, that is, as $t_2 \to t_1$, the total customer participation approaches 6/7ths of the total potential market. (b) Prices decrease for the superior platform, while they increase for the inferior platform. (c) Profits decrease for the superior platform, while they increase for the inferior platform. However, for any value of $r \in (0,1)$, $\pi_1^*/\pi_2^* > 8$.

Clearly, a decrease in the technological asymmetry decreases the differentiation between the two platforms. To mitigate this effect, Platform 1 decreases its price to increase the endogenous source of differentiation—its network size. Nevertheless, Platform 1 suffers some profit erosion, while Platform 2 improves its profits, thereby reducing the profit ratio between the two platforms. Despite this improvement in the profit of Platform 2, the profit difference continues to be large, and Platform 1's profit share remains at least 8/9ths of the total platform profit even as $t_2 \to t_1$. Further, even under near-parity, in the competitive equilibrium, the superior platform makes almost 75 percent of the profits of a monopoly platform with a similar technology level. Thus, small differences in technology can lead to significant differences in profits, and competition does not significantly hurt the superior technology platform.[4]

While very interesting, this kind of result is not unique to our situation. For instance, Jones and Mendelson [28] find a similar result for all information goods, and others have observed similar results in one-sided networks [13]. While the driver in the Jones and Mendelson case is the significant asymmetry in qualities chosen by the firms, in our case (as well as in the other network effects papers), the driver is the differentiation between the firms arising from the asymmetry in endogenous network sizes. Here, even under near technology parity, the larger network size of the superior technology platform provides significantly higher value, leading to the disparity in the prices and profits. The result is also consistent with experimental findings by Hossain et al. [27], who show that vertically differentiated platform markets inevitably tip to the more efficient platform even when multiple platforms can theoretically co-exist.

In addition to the FENE specified in Lemma 1, a pair of One-Platform Equilibria exist for all values of $r \in (0,1)$. In this kind of equilibrium, one platform completely dominates the market, and the second platform receives no demand. The following lemma describes the outcomes associated with these equilibria:

Lemma 2 (One-Platform Equilibria): In addition to the FENE specified in Lemma 1, there exists a second set of FENEs, where only a single platform j, $j \in \{1$ or $2\}$, is active in the market. The corresponding equilibrium prices, demands, and platform profits, with $\alpha_i \leq \alpha_{\hat{i}}$, ($i, \hat{i} \in b, s$; $i \neq i$, $j \neq j$), are given by

$$p_{ij}^* = 0;\ D_{ij} = N_i;\ p_{\hat{i}j}^* = \frac{t_j \alpha_{\hat{i}} N_i}{2};\ D_{\hat{i}j} = \frac{N_{\hat{i}}}{2};\ \pi_j^* = \frac{t_j \alpha_{\hat{i}} N_b N_s}{4}$$

$$p_{i\hat{j}}^* = 0;\ D_{i\hat{j}} = 0;\ p_{\hat{i}\hat{j}}^* = \frac{t_{\hat{j}} \alpha_{\hat{i}} N_i}{2};\ D_{\hat{i}\hat{j}} = 0;\ \pi_{\hat{j}}^* = 0.$$

The active platform provides the service for free on the side with the weaker network effects and makes all of its revenues from the other side. The outcomes associated with this equilibrium are identical to those under a monopoly market structure, where the monopolist's technology level corresponds to that of the active platform. The active and dominant platform could either be Platform 1 or Platform 2, thus giving rise to two possible equilibria. Which of the two platforms ends up being the active one depends on customers' expectations. Generally, we expect the superior technology platform to be the active one, but it is also possible for the inferior technology platform to fill that role. For instance, this may happen if the inferior technology platform has a strong reputation (perhaps in a different market) that might tilt customer expectations toward it despite its technological inferiority.

Discussion

The results described in Lemma 1 and Proposition 1 help explain some of the asymmetry in the profitability between the Google and Yahoo! third-party advertising platforms.[5] Initially, Google had a technological advantage in its contextual mapping and ad targeting technologies, giving it the early lead and dominance. Despite improving its technology, and closing the gap with Google on the technology dimension, Yahoo! has significantly lagged in terms of profitability. This highlights the role that customer expectations play in helping the leading platform build a strong source of endogenous differentiation through its network size. For the inferior platform, closing the technology gap is insufficient if a perception gap still persists in the market.

The kind of market outcomes described in Lemma 2, where a single platform completely dominates the market at the exclusion of others, are harder to spot in real-world platform markets since the inactive firms, by definition, are not easily visible. A good example is the portable document format (PDF) created by Adobe—a platform between creators and consumers of documents. By giving the document readers away for free on one side, and charging for the creation software on the other, Adobe has made PDF the de facto standard, and successfully dominated this market for the past two decades [34]. Another good example may be eBay's dominance of online auctions, where the service is free to buyers, and eBay makes all of its revenues from sellers. Other prominent online firms, such as Amazon.com and Yahoo!, have tried competing with eBay in online auctions over the years, with little success. Finally, although not a monopoly, Google's dominance in the search advertising market, where it provides the search service for free to consumers, and maintains a fair amount of power in the market for advertisers, also fits this pattern [10]. Despite these examples, attempting market dominance, rather than coexistence, is a very risky strategy for platforms. Success here depends even more crucially on customer expectations, and an inability to convince customers about the inevitability of its success might doom a platform to failure.

Platform Co-opetition

HAVING ANALYZED PURE DUOPOLY COMPETITION IN THE PREVIOUS SECTION, we now turn to an exploration of the potential for collaboration between competing platforms. Platforms can collaborate by interconnecting their networks, enabling members of one platform to transact with members of the other. We consider both direct and indirect access to each other's networks. Note that even when the platforms collaborate through interconnection, they continue to compete through prices for the same set of customers. Since this relationship involves both cooperation and competition, it is more aptly labeled *co-opetition* [6]. For each type of interconnection, we investigate if collaboration increases the overall industry profits, thereby providing opportunities for mutual benefit through appropriate contracting.

Platform Interconnection

In the absence of an external mandate, interconnection between platforms generally requires the consent of both platforms.[6] Here, we start by assuming that the platforms are interconnected, and analyze the resulting equilibrium in order to identify conditions under which platforms have an incentive to interconnect. With interconnection, while the utility from a transaction between two members of the same platform remains the same as before, the utility from a cross-platform transaction may depend on the technologies of both platforms. In particular, we use $\gamma_1(t_1, t_2)$ and $\gamma_2(t_1, t_2)$ to represent the cross-platform technologies experienced by members of Platforms 1 and 2, respectively. The utility to a customer on side i on Platform j, ($j, \hat{j} \in \{1,2\}$; $j \neq \hat{j}$; $i, \hat{i} \in \{b,s\}$; $i \neq \hat{i}$), is now given by

$$U_{ij}(\theta_i; n_{\hat{i}1}, n_{\hat{i}2}) = \theta_i t_j \alpha_i n_{\hat{i}j} + \theta_i \gamma_j(t_1, t_2)\alpha_i n_{\hat{i}\hat{j}} - p_{ij}. \tag{7}$$

In the absence of interconnection, $\gamma_1 = \gamma_2 = 0$, and Equation (7) is identical to Equation (1). Lemma 3 characterizes the equilibrium outcomes assuming that the platforms are interconnected. Note that $\gamma_1(t_1, t_2)$ and $\gamma_2(t_1, t_2)$ have been shortened here to γ_1 and γ_2, respectively, to simplify notation.

> *Lemma 3 (Interconnected Platforms): When the platforms are interconnected, the equilibrium prices and demands for side i, (i, $\hat{i} \in \{b,s\}$; $i \neq \hat{i}$), and platform profits are given by*

$$p_{i1}^* = \frac{2\alpha_i N_{\hat{i}} \left(2t_1 + \gamma_1\right)^2 \left(2t_1 - t_2 + \gamma_1 - 2\gamma_2\right)}{\left(8t_1 - t_2 + 4\gamma_1 - 2\gamma_2\right)^2};\ D_{i1} = \frac{2N_i \left(2t_1 + \gamma_1\right)}{\left(8t_1 - t_2 + 4\gamma_1 + 2\gamma_2\right)};$$

$$p_{i2}^* = \frac{\alpha_i N_{\hat{i}} \left(2t_1 + \gamma_1\right)\left(2\gamma_2 + t_2\right)\left(2t_1 - t_2 + \gamma_1 - 2\gamma_2\right)}{\left(8t_1 - t_2 + 4\gamma_1 - 2\gamma_2\right)^2};\ D_{i2} = \frac{N_i \left(2t_1 + \gamma_1\right)}{\left(8t_1 - t_2 + 4\gamma_1 - 2\gamma_2\right)};$$

$$\pi_1^* = \frac{4\left(\alpha_b + \alpha_s\right) N_b N_s \left(2t_1 + \gamma_1\right)^3 \left(2t_1 - t_2 + \gamma_1 - 2\gamma_2\right)}{\left(8t_1 - t_2 + 4\gamma_1 - 2\gamma_2\right)^3};$$

$$\pi_2^* = \frac{\left(\alpha_b + \alpha_s\right) N_b N_s \left(2t_1 + \gamma_1\right)^2 \left(2\gamma_2 + t_2\right)\left(2t_1 - t_2 + \gamma_1 - 2\gamma_2\right)}{\left(8t_1 - t_2 + 4\gamma_1 - 2\gamma_2\right)^3}.$$

Lemma 3 establishes that, in equilibrium, the platform with the superior technology continues to serve a larger share of the market (directly) than the inferior platform ($D_{i1}/D_{i2} = 2$), generally sets a higher price ($p_{i1}/p_{i2} = 2(2t_2 + \gamma_1)/(2\gamma_2 + t_2) > 1$ unless $\gamma_1 \ll \gamma_2$), and earns a larger profit ($\pi_1/\pi_2 = 4(2t_2 + \gamma_1)/(2\gamma_2 + t_2) > 1$ unless $\gamma_1 \ll \gamma_2$). The prices on the two sides of the market are also generally asymmetric.

Discussion

Comparing the outcomes in the interconnection case with the corresponding ones in the pure competition case, we can see that the demands with interconnection are generally higher than those in the pure competition case. The prices and profits of the platforms may or may not be higher, depending on the details of the cross-platform experience. Thus, interconnection between platforms grows the pie from a societal perspective, but how the pie is split between the firms and customers depends on the details of the interconnection. Such a growth in demand following interconnection, for instance, has been observed in the ATM market. Interconnection between ATM networks in the 1980s was generally followed by an increase in the number of ATMs, the number of customers accessing them, as well as the average number of ATM transactions conducted by each customer [32]. We examine the effects on prices and profits more closely in the next two sections, as we probe deeper into the details of the interconnections between the platforms—both direct and indirect. The general conclusion from these analyses is that the access to a larger network increases the value to customers and society, but its profitability depends on the platforms' ability to differentiate themselves.

Collaboration Through Direct Network Access

Here we consider direct interconnection. With direct interconnection, each platform provides its competitor with direct, nonmediated access to its member networks. This kind of interconnection is particularly relevant in the context of modern electronic matching markets, where such interconnection can be implemented relatively easily through the provision of access to each other's databases via a Web-based interface. In this case, the cross-platform experience is unaffected by the other platform's technology. Therefore, this situation is equivalent to specifying $\gamma_j(t_1, t_2) = t_j$, for $j = 1, 2$, in Equation (7).

Lemma 4 (Direct Network Access): When platforms provide direct access to each other's customers, the equilibrium prices and demands for side i, ($i, \hat{i} \in \{b, s\}$; $i \neq \hat{i}$), and platform profits are given by

$$p_{i1}^* = \frac{6\alpha_i N_{\hat{i}} t_1^2 (t_1 - t_2)}{(4t_1 - t_2)^2};\ D_{i1} = \frac{2N_i t_1}{(4t_1 - t_2)};$$

$$p_{i2}^* = \frac{3\alpha_i N_{\hat{i}} t_1 t_2 (t_1 - t_2)}{(4t_1 - t_2)^2};\ D_{i2} = \frac{N_i t_1}{(4t_1 - t_2)};$$

$$\pi_1^* = \frac{12(\alpha_b + \alpha_s) N_b N_s t_1^3 (t_1 - t_2)}{(4t_1 - t_2)^3};\ \pi_2^* = \frac{3(\alpha_b + \alpha_s) N_b N_s t_1^2 t_2 (t_1 - t_2)}{(4t_1 - t_2)^3}.$$

Comparing these results with the ones in Lemma 1, it is clear that the demands under direct interconnection are higher than those under the Competitive Equilibrium.

Although not as clear, it can be shown that the prices under direct interconnection are also higher than those under pure competition when r is low, but lower when r is high. The following proposition sheds more light:

> *Proposition 2 (Technology Asymmetry in the Presence of Direct Access): Under direct access, higher values of* $r = t_2/t_1$ *are associated with (a) higher equilibrium demands, for both platforms, on both sides of the market; (b) lower prices and profit for the superior platform; and (c) a nonmonotonic change in the prices and profit for the inferior platform.*

The prices and the profit for the inferior platform initially increase but decline thereafter. The comparative statics of demand with respect to r are similar to those in the pure competition case (Proposition 1), but the effect on the prices and profits is different, and interesting. Unlike the case of pure competition, here the platforms are *substitutes* as well as *complements:* a larger network size for each also benefits the other. Further, with direct interconnection, the two platforms are undifferentiated in terms of network sizes, leaving technology as the only differentiator. As technology parity increases, at some point, the gain in the price and profits due to improved value is overpowered by the pricing pressure due to reduced differentiation, causing Platform 2's prices and profit to be nonmonotonic. Technology parity pushes the platforms toward undifferentiated Bertrand competition, causing the prices to fall to zero.

We use the results derived above, along with those under pure duopoly competition, to identify opportunities for fruitful collaboration between the platforms. We compare the equilibrium profits in the network-sharing case with the corresponding ones in the pure competition case and identify conditions under which profits can improve through collaboration. We primarily focus on comparisons with the Competitive Equilibrium (Lemma 1). However, we also briefly discuss the comparison to the One-Platform Equilibria (Lemma 2). We follow this general methodology for the rest of the analysis. Details of the contracts used to implement the strategic partnerships are beyond the scope of this paper, and we limit ourselves to identifying the conditions under which such contracting may be feasible. Theorem 1 identifies these conditions for the direct interconnection case in comparison to the competitive equilibrium described in Lemma 1. Note that in the following theorem, $r_1 \approx 0.67$ is the solution to $3(1 - r)(8 - r)^3 = 8(2 - r)(4 - r)^3$, in $0 < r < 1$; and $r_2 \approx 0.71$ is the solution to $3(4 - 3r - r^2)(8 - r)^3 = 4(16 - 6r - r^2)(4 - r)^3$, in $0 < r < 1$:

> *Theorem 1 (Collaboration Through Direct Interconnection): Collaboration through direct interconnection is (a) Pareto optimal, for* $r \in (0, r_1]$*; (b) feasible, through transfers from Platform 2 to Platform 1, for* $r \in [r_1, r_2]$*; and (c) not feasible for* $r > r_2$.

Figure 1 compares the corresponding platform profits, with and without direct network sharing, and establishes the intuition for the result. The horizontal axis, depicting technology asymmetry, is broadly split into three regions. In region 1, both platforms' profits under direct sharing are higher than the corresponding profits under the Competitive Equilibrium. Therefore, sharing is a dominant strategy for

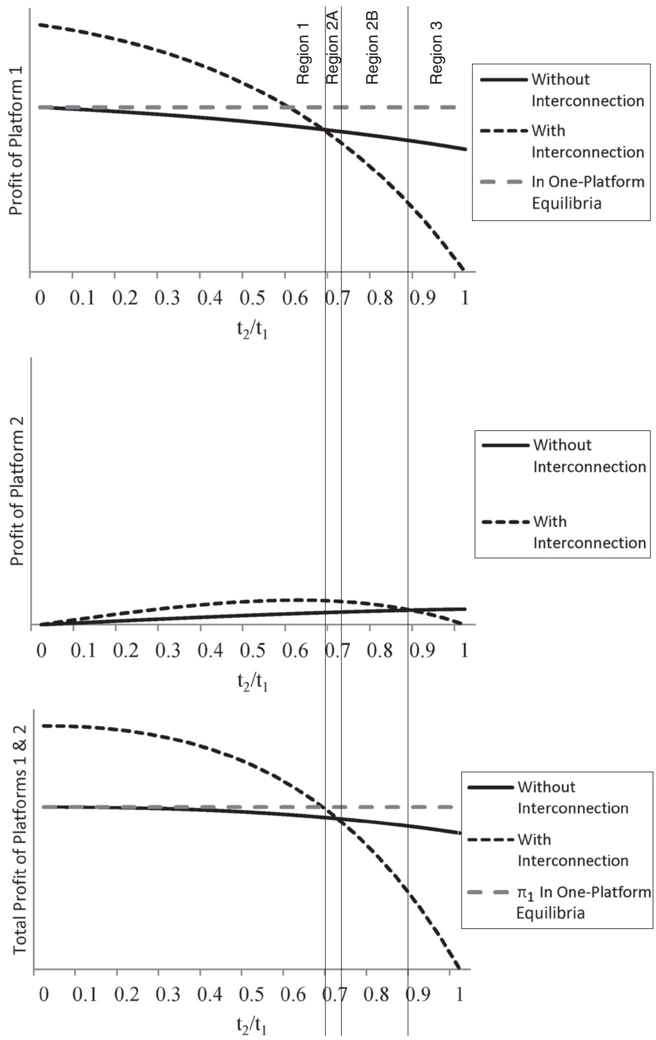

Figure 1. Profit Comparison Between Direct Access Sharing and Pure Competition

both platforms in this region. The additional profits from network sharing are due to the increase in network value. In region 2 (regions 2A and 2B combined), while Platform 2's profit under sharing is still higher, Platform 1's profit is lower than the competitive case. Here, while Platform 2 still has an incentive to interconnect, Platform 1 is likely to resist such attempts unless it is sufficiently compensated. Within region 2, the total combined profits in the sharing case are higher than the competitive case in subregion 2A, while they are lower in subregion 2B. Therefore, contracting for direct network sharing, through appropriate transfers from Platform 2 to Platform 1, can result in a Pareto improvement in region 2A, but not in region 2B. In region 3, where both platforms' profits under sharing are lower than the corresponding ones under pure competition, neither platform desires compatibility. This last result is a departure from the standard results in the compatibility literature [19, 31], where the weaker network almost always has an incentive to make its network compatible with the leading network.[7]

Before concluding the analysis on this case, we compare the direct interconnection case with the One-Platform Equilibria (Lemma 2):

> *Theorem 2 (Direct Access Versus One-Platform Equilibria): For all $\alpha_i, \alpha_{\hat{i}}$, such that $\alpha_i \le \alpha_{\hat{i}}$, $(i, \hat{i} \in \{b, s\}; i \ne \hat{i})$, and $\alpha_i/\alpha_{\hat{i}} > 1/3$, there exist values of $r > 0$ for which the total industry profit under direct interconnection is higher than the active platform's profit under the One-Platform Equilibria.*

Theorem 2 provides a very interesting result, which is also illustrated in Figure 1.[8] It shows that when the network effects on the two sides are not highly asymmetric, that is, when one of them is not more than three times the other, there exist values of *r* for which the co-opetition equilibrium produces higher platform profits than the One-Platform Equilibria setting. Thus, under these conditions, the dominant platform may, under suitable transfers from the other platform, prefer a co-opetitive existence to a virtual monopoly market structure. Therefore, under these conditions, collaboration may create possibilities for market entry, which would not otherwise exist. The result is driven by the fact that the second platform helps create significant network effects, while simultaneously allowing the platforms to raise prices. The active platform no longer needs to set a price of zero on the weaker network effects side. Ironically, this may leave at least some of the customers on this side worse off than they were in a One-Platform Equilibria setting because they pay a higher price and some cannot even afford the service any longer.

Discussion

The fact that platform cooperation can be mutually beneficial is well recognized in the online advertising platform industry. Such cooperation is most natural when the capability gap between the platforms is large. An early example of this kind of cooperation between online advertising platforms is the one between Ask Jeeves and Google, where Ask contracted with Google to supply advertising for its Web properties. Yahoo! explored a similar option in 2008, but the deal came under scrutiny from federal antitrust authorities, and was dropped [18]. Yahoo! later partnered with Microsoft for the same purpose.

Despite the potential gains from cooperation, platforms in closely matched markets are unlikely to pursue this option. In the GDS market, the platforms' primary source of differentiation comes from the exclusive access to their agent networks, rather than any significant technology advantages. Therefore, co-opetition in these markets is likely to be profit destroying, although it enhances customer value. This may account for the reluctance of major GDS platforms to interconnect with each other. Indeed, in industries where the technology is maturing, the leader might find it difficult to sustain a significant technological superiority. Therefore, in such industries, network sharing, even where possible, might be time limited.

Dominant firms may be open to collaboration with rivals (Theorem 2) so long as they are secure in their leadership position. For example, after keeping the PDF format propriety for over 15 years, Adobe finally opened it up in 2008, making it possible for anyone to use, sell, and distribute PDF compatible implementations. However, when a dominant platform feels that its dominance is threatened by such collaboration, which is the case when potential competitors have closely matched capabilities, collaboration is unlikely.

Collaboration Through Mediated/Indirect Network Access

We now turn to the case where the platforms interconnect, but do not allow the members of one platform to access the other's members directly; cross-platform transactions are routed through both platforms. Consequently, the utility to agents on each platform potentially depends on the technologies of both platforms. We consider three prototypical cases for the cross-platform technology experience function, $\gamma_j(t_1, t_2)$: (1) $Min(t_1, t_2)$, (2) $Avg(t_1, t_2)$, and (3) $Max(t_1, t_2)$. We believe that this set provides a good representation for analysis because the cross-platform technology experience is likely to be no worse than the experience provided by the inferior technology alone and no better than that provided by the superior technology alone.

The analysis here follows a path similar to that in the previous section. Theorem 3 specifies the conditions required for collaboration in the three cases. The boundary values r_{1m}, r_{2m}, r_{1A}, r_{2A}, and r_{2M} are specified in Table 3.

Theorem 3 (Collaboration Through Indirect Network Sharing): Collaboration through indirect network sharing is

(a) Pareto optimal,

$$\text{for } \begin{cases} r \in (0, r_{1m}] \text{ when } \gamma_j(t_1, t_2) = Min(t_1, t_2) \\ r \in (0, r_{1A}] \text{ when } \gamma_j(t_1, t_2) = Avg(t_1, t_2), \end{cases}$$

(b) feasible, through transfers from Platform 2 to Platform 1,

$$\text{for } \begin{cases} r \in [r_{1m}, r_{2m}] \text{ when } \gamma_j(t_1, t_2) = Min(t_1, t_2) \\ r \in [r_{1A}, r_{2A}] \text{ when } \gamma_j(t_1, t_2) = Avg(t_1, t_2) \\ r \in (0, \mathrm{r}_{2M}] \text{ when } \gamma_\mathrm{j}(t_1, t_2) = Max(t_1, t_2), \end{cases}$$

(c) not feasible for other values of r.

The structure of the results here is qualitatively similar to the direct network access case depicted in Figure 1. Interconnection is most likely when the platform technologies are significantly asymmetric, and the likelihood decreases with increasing technology parity.[9] Potential for collaboration also decreases as the cross-platform technology experience improves—from *Min,* through *Avg,* to *Max*. Comparisons with the profits of the active platform in the One-Platform Equilibrium yield results

Table 3. Boundary Values for the Conditions in Theorem 3

Boundary value	Is the solution to	Approximate numerical value
r_{1m}	$(1 - r)(8 - r)^3(2 + r)^3 = 4(2 - r)(8 + r)^3$	0.30
r_{2m}	$(1 - r)(8 + 7r)(2 + r)^2(8 - r)^3 = 2(2 - r)(8 + r)^4$	0.45
r_{1A}	$(1 - r)(8 - r)^3(5 + r)^3 = 31104(2 - r)$	0.09
r_{2A}	$(1 - r)(11 + 4r)(5 + r)^2(8 - r)^3 = 7776(16 - 6r - r^2)$	0.30
r_{2M}	$9(1 - r)(14 + r)(8 - r)^3 = 4(16 - 6r - r^2)(10 - r)^3$	0.01

similar to that presented in Theorem 2, with similar implications—albeit the range of r, and the asymmetry in network effects, over which the theorem holds, are reduced in this case. Formally:

Theorem 4 (Indirect Network Sharing Versus One-Platform Equilibria): When the strengths of the network effects on the two sides are equal, $\alpha_b = \alpha_s$, for each of the indirect interconnection cases, there exist values of $r > 0$, where the total industry profit under indirect interconnection is higher than the active platform's profit in the One-Platform Equilibria setting.

In deriving the results in Theorems 3 and 4, we assumed the cross-platform experience to be symmetric for both platforms to avoid complicating the parameter space. However, some numerical analyses that we conducted reveal that asymmetries in the cross-platform experience can affect the results. A better cross-platform experience for members of Platform 1 makes interconnection more likely, while the opposite makes it less likely.

Discussion

For the same gain in incremental network size, indirect interconnection offers a lower level of differentiation between the platforms as compared to direct interconnection. This is especially true in cases where the cross-platform experience is symmetric across the two platforms. Therefore, indirect interconnection offers fewer opportunities for mutual gain through collaboration. Nevertheless, the weaker platforms usually have a bigger incentive to attempt to interconnect to the network of the stronger platform. The attempt, in 2004, by RealNetworks to make its Harmony service compatible with the iPod [39] is a good example of this tendency. Apple immediately countered this attempt by updating the firmware on the iPods to make them incompatible with RealNetwork's network. Although there were likely other strategic considerations guiding Apple's response, we believe that Apple may potentially have benefitted by allowing RealNetwork to maintain the compatibility, since it would have increased the value of the iPods without posing a significant threat to Apple's dominance in this market.

In a departure from traditional results on compatibility [19, 31], we find that when the platforms are closely matched in terms of their technological capabilities, even the weaker platforms are averse to interconnection. A tussle is currently under way in the e-book market where Apple, Amazon.com, and Barnes & Noble each have a competitive platform. Given the closeness of their capabilities, it is unlikely that attempts at bringing a degree of compatibility to e-book formats across platforms will succeed in the short run. Unless one of the platforms takes a significant technological lead, compatibility might be hard to implement in this industry.

Conclusion

Our objective has been to understand the role that technology plays in shaping competition and collaboration between platforms with heterogeneous capabilities. We have obtained a number of clear and interesting insights.

The most important result in the context of pure platform competition is that small differences in technology can translate into much bigger differences in profitability in vertically differentiated technology markets (Lemma 1 and Proposition 1). This result, while not completely new in the literature on network markets, does shed some light on the differences in the profitability between some real-world platform markets. It is also highly relevant in competitive platform markets, where technology differences are often small, but these can translate into large payoff differences and often do so through their influences on customer expectations. An extension to our analysis suggests that platform markets with taste-based, rather than capability-based, differentiation are less susceptible to such extreme asymmetries in payoffs.

Another important result we find in this context of vertical platform competition is that one of the platforms may be able to shut its rival out of the market through aggressive price discounting on one side (Lemma 2), and customer expectations are even more influential in these kinds of outcomes. Thus, such intermediary markets may not be competitive even in the absence of exogenous entry barriers. Further, attempts by inferior platforms to improve their technology may not produce a commensurate return, as the gains in profitability from reduced technology asymmetry are often relatively small (Proposition 1). Ironically, such improvements may even make it harder for these platforms to pursue profitable collaboration opportunities with their stronger rivals. (See Table 4.)

Our primary insight about network sharing is that such collaboration is most likely when the rival platforms are significantly different in terms of their technological capabilities (see Table 4 for the appropriate ranges). Of the two possible types of network sharing, direct interconnection is the more promising one. Both the superior and the inferior platform may have a natural incentive to interconnect, even without any explicit payments from one to the other. This is because direct interconnection tends to preserve, and indeed in some cases enhance, the degree of differentiation between the two platforms while simultaneously increasing their value. We also show that cooperation between platforms is very unlikely in markets where the rivals have near parity in technology (Theorems 1, 2, and 3). In these situations, even the inferior rival is averse to interconnection—a result that differs significantly from common results in the one-sided network compatibility literature. More than the two-sided nature of the

Table 4. Summary of Platform's Collaboration Choices

Type of collaboration	Optimal even without side payments	Optimal with payments from the inferior to the superior platform	Theorem
Direct interconnection	$r \in (0, 0.67]$	$r \in [0.67, 0.71]$	1
Direct interconnection versus one-platform equilibrium		for some $r > 0$	2
Indirect interconnection (Min)	$r \in (0, 0.30]$	$r \in [0.30, 0.45]$	3
Indirect interconnection (Avg)	$r \in (0, 0.09]$	$r \in [0.09, 0.30]$	3
Indirect interconnection (Max)	No	$r \in (0, 0.01]$	3

market, it is the impact of technology in delivering differentiation that gives rise to this result. This may help explain why interconnection between platforms does not seem to be as commonly observed in practice as one would expect. Most platform markets that have been around for a while are likely to have competitors that are reasonably closely matched, if not at exact technological parity.

The two-sidedness of platform markets is particularly critical to one of our key results relating to dominant platforms. Interestingly, a dominant platform that has a natural incentive to shut out an inferior rival actually prefers to accommodate it when a collaborative arrangement can be worked out (Theorems 2 and 4). The primary reason for such a motive is that with an interconnection to the rival's network, the dominant platform can deliver a higher network value even without offering significant price discounts to one side of the market. Although this causes the dominant platform to reduce its market coverage, it is still able to increase its revenues. Ironically, many customers who were getting the service for free earlier now have to pay for it. In fact, some customers who would have been served in a monopoly-like dominant platform market would get squeezed out of the market. Thus, we find that entry can actually hurt some customers, and the biggest beneficiary of an entry may indeed be the dominant incumbent platform. In cases where both platforms are active in a competitive setting, co-opetition between rivals generally expands the market (Proposition 2) and typically improves customer surplus despite higher prices.

Perhaps the most important limitation of our analysis is that we have analyzed a membership pricing scenario, while many real-world platforms use transaction pricing, or a combination of the two. Indeed, several of the examples we have used to motivate the model and interpret the results fall into this category. Our primary reason behind using membership pricing was tractability. Besides, as can be seen from Table 1, this assumption is common in the literature. Despite this shortcoming, we are confident that the results from the model generalize, at least qualitatively, to a transaction pricing scenario.

The reason for our confidence is the following. First, in the simplest case, if all the customers in the market participate in an identical number of transactions, then the two pricing schemes are equivalent. Going beyond this simple case, even if the number of transactions were different for different customers, a logical equivalence between the outcomes in the two pricing scenarios can be made so long as the demand for transactions is inelastic. So each customer will have a constant value per transaction and will indulge in a full quota of transactions if the customer transacts at all. Under this assumption, multiple transactions by a single customer can be transformed (recast) into multiple customers, with each undertaking a single transaction. The number of transactions undertaken on the platform, the platforms' profits, as well as the platform choice by different customer types will all remain unaltered. The transformation can be accomplished by altering the density of customer types from a uniform distribution, as currently assumed, to a nonuniform density distribution, whose density at a point would represent the number of transactions undertaken by the corresponding customer type. The insights will carry over, as none of our main results depend crucially on a uniform density.

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Notes

1. In general, it is possible that customers have other costs associated with their interactions. In that case, we can think of $U()$ as the net benefit that customers get from transactions after accounting for the associated transaction costs. Thus, the assumption of zero costs (beyond membership price) for customers does not qualitatively affect the results so long as the other costs per transaction are not influenced by the variables we are explicitly modeling.

2. An example of an additive specification that is similar to the one we use is $U_{ij}(\theta_i; n_{\hat{ij}}) = \theta_i(t_j + \alpha_i n_{\hat{ij}}) - p_{ij}$. When technology does not affect the value from transactions, then the incentive for platforms to collaborate is reduced. Thus, while results under pure competition will remain qualitatively similar to ours, the results concerning network sharing do not extend to these kinds of platforms.

3. Interestingly, when the network effects on the two sides are asymmetric, it is always optimal for a monopoly platform to give away the service for free on the lower value side.

4. The heterogeneity in customers' marginal value for quality (vertical heterogeneity) is necessary for this result. If customer heterogeneity is with respect to taste (horizontal), then the asymmetry between profits is smaller.

5. Here, we are not referring to the search advertising market, which Google also dominates. Our discussion concerns the AdSense component of Google's online advertising platform, through which Google places ads on third-party Web properties. The corresponding platform at Yahoo! is the Yahoo! Publisher Network.

6. If one party unilaterally interconnects (say, through the development of a one-way converter), the other can typically take recourse to legal action or alter its technology to make the converter ineffective

7. One reason that the literature provides for why the weaker firm may not seek compatibility is the cost of achieving compatibility. This cost is not a transfer to the stronger firm. Rather, it is the investment needed to make the networks compatible, which is above and beyond any transfers between the firms. In our case, this cost is zero, and still the inferior platform does not wish to make its network compatible in region 3.

8. Unlike the case of Theorem 1, the different regions are not demarcated here in Figure 1. Nevertheless, it is clear that, for a substantial range of values for r, the direct interconnection

profit is higher than the Platform 1 profit in a One-Platform Equilibria setting in which Platform 1 is active.

9. To contrast, in a horizontally differentiated market, direct interconnection can always be implemented through transfers, but indirect interconnection cannot be supported even through payments.

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Appendix A: Proofs of the Lemmas, Propositions, and Theorems

Proof of Lemma 1

ASSUME THAT PLATFORM 1 IS THE ONE SERVING THE TOP END. Let θ^*_{i1} be the customer type, on side i, $(i = b, s)$, who is indifferent between joining the two platforms, and θ^*_{i2} the customer type who is indifferent between joining Platform 2 and not joining at all. We have

$$\text{IR: } t_2\theta^*_{i2}\alpha_i n^e_{\hat{i}2} = p_{i2},$$

$$\text{IC: } t_1\theta^*_{i1}\alpha_i n^e_{\hat{i}1} - p_{i1} = t_2\theta^*_{i1}\alpha_i n^e_{\hat{i}2} - p_{i2}.$$

This implies $\theta^*_{i2} = p_{i2}/t_2\alpha_i n^e_{\hat{i}2}$ and $\theta^*_{i1} = (p_{i1} - p_{i2})/(t_1\alpha_i n^e_{\hat{i}1} - t_2\alpha_i n^e_{\hat{i}2})$. The platform profits are then given by

$$\pi_1 = p_{b1}\left(1-\theta^*_{b1}\right)N_b + p_{s1}\left(1-\theta^*_{s1}\right)N_s,$$

$$\pi_2 = p_{b2}\left(\theta^*_{b1}-\theta^*_{b2}\right)N_b + p_{s2}\left(\theta^*_{s1}-\theta^*_{s2}\right)N_s.$$

The profit functions are concave, and therefore, the four first-order conditions (FOCs) $(\{(\partial\pi_j/\partial \mathrm{p}_{bj}) = 0, (\partial\pi_j/\partial p_{sj}) = 0\}, j = 1, 2)$ are sufficient and yield a unique solution. The solution set $\{(p^*_{bj}, p^*_{sj}), j = 1, 2\}$ constitutes price choices that are best responses to each other's strategies, and therefore satisfies the Nash condition. At this point, the prices $\{(p^*_{bj}, p^*_{sj}), j = 1, 2\}$ are all functions of the customer expectations $\{(n^e_{bj}, n^e_{sj}), j = 1, 2\}$. We then impose the fulfilled expectations conditions by equating the demands implied by these prices to the corresponding customer expectations. Solving $(\{(1 - \theta^*_{i1})N_i = n^e_{i1}, (\theta^*_{i1} - \theta^*_{i2})N_i = n^e_{i2}\}, i = b, s)$, after substituting for $\{(p^*_{bj}, p^*_{sj}), j = 1, 2\}$ obtained by solving the four FOCs above, we get $\theta^*_{i1} = (4t_1 - t_2)/(8t_1 - t_2)$; $\theta^*_{i2} = (2t_1 - t_2)/(8t_1 - t_2)$.

Substituting the associated network sizes in place of the customer expectations in the platforms' price choices, $\{(p^*_{bj}, p^*_{sj}), j = 1, 2\}$, we obtain the equilibrium prices. These are then used to arrive at the associated demands and profits shown in the lemma.

Proof of Proposition 1

From Lemma 1:

(a)
$$D_{i1} = \frac{4N_i}{8-\left(t_2/t_1\right)} \Rightarrow \frac{dD_{i1}}{d\left(t_2/t_1\right)} > 0;\ D_{i2} = \frac{2N_i}{8-\left(t_2/t_1\right)} \Rightarrow \frac{dD_{i2}}{d\left(t_2/t_1\right)} > 0;$$

$$\lim_{\left(t_2/t_1\right)\to 1}\left(D_{i1}+D_{i2}\right) = \frac{6N_i}{7};$$

(b)
$$\frac{dp_{i1}}{d\left(t_2/t_1\right)} = \frac{dp_{i1}}{d\left(t_2\right)}\cdot t_1 = -\frac{8\left(N_{\hat{i}}\right)\alpha_i t_1^3\left(4t_1+t_2\right)}{\left(8t_1-t_2\right)^3} < 0;$$

$$\frac{dp_{i2}}{d\left(t_2/t_1\right)} = \frac{dp_{i2}}{d\left(t_2\right)}\cdot t_1 = \frac{4\left(N_{\hat{i}}\right)\alpha_i t_1^3\left(8t_1-7t_2\right)}{\left(8t_1-t_2\right)^3} > 0;$$

(c)
$$\frac{d\pi_1}{d(t_2/t_1)} = \frac{d\pi_1}{d(t_2)} \cdot t_1 = -\frac{128 N_b N_s (\alpha_b + \alpha_s) t_1^4 (t_1 + t_2)}{(8t_1 - t_2)^4} < 0;$$

$$\frac{d\pi_2}{d(t_2/t_1)} = \frac{d\pi_2}{d(t_2)} \cdot t_1 = \frac{8 N_b N_s (\alpha_b + \alpha_s) t_1^3 (16t_1^2 - 12t_1 t_2 - t_2^2)}{(8t_1 - t_2)^4} > 0;$$

$$\frac{\pi_1^*}{\pi_2^*} = \frac{8t_1}{t_2} > 8.$$

Proof of Lemma 2

Let $\alpha_i \leq \alpha_{\hat{i}}$. Given this, per Lemma B1 (see Appendix B), if Platform j were a monopoly, it would choose the prices $p_{ij}^* = 0$, $p_{\hat{i}j}^* = t_j \alpha_{\hat{i}} N_i / 2$, and the corresponding Platform j profit would be $\pi_j^* = t_j \alpha_{\hat{i}} N_b N_s / 4$. Assume that both platforms choose these pairs of prices in Stage 1. Following this choice, in Stage 2, there are two feasible tuples of rational expectations. One tuple where Platform 1 gets the monopoly outcomes in equilibrium and Platform 2 gets no demand on either side; and the opposite case, where the platforms are transposed. Given the prices, both tuples of expectations will be fulfilled in the ensuing equilibrium, and hence, both are rational. Further, both pairs of prices satisfy the Nash conditions since (1) each firm's price in one market is a best response to its price in the other market, and (2) the pair of prices for the active platform are a best response to any pair of prices for the nonactive platform. The resulting equilibrium could have either platform active (depending on customer beliefs), but only one platform can be active.

Proof of Lemma 3

Let θ_{i1}^* and θ_{i2}^* be the marginal customers for firms 1 and 2 on side i.

$$\text{IR: } t_2 \theta_{i2}^* \alpha_i n_{\hat{i}2}^e + \gamma_2 \theta_{i2}^* \alpha_i n_{\hat{i}1}^e = p_{i2},$$

$$\text{IC: } t_1 \theta_{i1}^* \alpha_i n_{\hat{i}1}^e + \gamma_1 \theta_{i1}^* \alpha_i n_{\hat{i}2}^e - p_{i1} = t_2 \theta_{i1}^* \alpha_i n_{\hat{i}2}^e + \gamma_2 \theta_{i1}^* \alpha_i n_{\hat{i}1}^e - p_{i2}.$$

The corresponding platform profits are

$$\pi_1 = p_{b1}(1 - \theta_{b1}^*) N_b + p_{s1}(1 - \theta_{s1}^*) N_s,$$

$$\pi_2 = p_{b2}(\theta_{b1}^* - \theta_{b2}^*) N_b + p_{s2}(\theta_{s1}^* - \theta_{s2}^*) N_s.$$

Similar to Lemma 1, solving the four FOCs and imposing the fulfilled expectations condition, we get

$$\theta_{i1}^* = \frac{(4t_1 + 2\gamma_1 - t_2 - 2\gamma_2)}{(8t_1 + 4\gamma_1 - t_2 - 2\gamma_2)};\ \theta_{i2}^* = \frac{(2t_1 + \gamma_1 - t_2 - 2\gamma_2)}{(8t_1 + 4\gamma_1 - t_2 - 2\gamma_2)}.$$

Substituting back the values of θ_{i1}^* and θ_{i2}^*, we get the equilibrium outcomes.

Proof of Lemma 4

Substituting $\gamma_j(t_1, t_2) = t_j$ into Lemma 3, we obtain the result.

Proof of Proposition 2

Based on the outcomes in Lemma 4:

(a)
$$D_{i1} = \frac{2N_i}{4-(t_2/t_1)} \Rightarrow \frac{dD_{i1}}{d(t_2/t_1)} > 0;\; D_{i2} = \frac{N_i}{4-(t_2/t_1)} \Rightarrow \frac{dD_{i2}}{d(t_2/t_1)} > 0.$$

(b)
$$\frac{dp_{i1}}{d(t_2/t_1)} = \frac{dp_{i1}}{d(t_2)} \cdot t_1 = -\frac{6(N_{\hat{i}})\alpha_i t_1^3(2t_1+t_2)}{(4t_1-t_2)^3} < 0,$$

$$\frac{d\pi_1}{d(t_2/t_1)} = \frac{d\pi}{d(t_2)} \cdot t_1 = -\frac{12(\alpha_b+\alpha_s)N_b N_s t_1^4(t_1+2t_2)}{(4t_1-t_2)^4} < 0.$$

(c)
$$\frac{dp_{i2}}{d(t_2/t_1)} = \frac{dp_{i2}}{d(t_2)} \cdot t_1 = \frac{3(N_{\hat{i}})\alpha_i t_1^3(4t_1-7t_2)}{(4t_1-t_2)^3},$$

which is nonmonotonic in t_2/t_1;

$$\frac{d\pi_2}{d(t_2/t_1)} = \frac{d\pi_2}{d(t_2)} \cdot t_1 = \frac{3(\alpha_b+\alpha_s)N_b N_s t_1^3\left(4t_1^2-6t_1t_2-t_2^2\right)}{(4t_1-t_2)^4},$$

which is nonmonotonic in t_2/t_1.

Proof of Theorem 1

The results follow from comparing platform profits in the Competitive Equilibrium (CE) (Lemma 1) with those in the direct interconnection (DI) case (Lemma 3) (see Table A1). As per the first column in Table A1, each of the ratios is monotonically decreasing in r for $r \in (0,1)$, each starts at a value higher than 1 (as per the second column), and tends to zero as $r \to 1$ (as per the third column). Therefore, each ratio equals unity at a unique value of r. Let r_1, r_2, and r_3, respectively, be values of r for which $\pi^*_{1DI}/\pi^*_{1CE} = 1$; $(\pi^*_{1DI} + \pi^*_{2DI})/(\pi^*_{1CE} + \pi^*_{2CE}) = 1$; and $\pi^*_{2DI}/\pi^*_{2CE} = 1$. It can be shown that $r_1 \approx 0.67$, $r_2 \approx 0.71$, and $r_3 \approx 0.87$. Network sharing is Pareto optimal when $\pi^*_{jDI} \geq \pi^*_{jCE}$ for $j = 1, 2$, and feasible through a transfer from Platform 2 to Platform 1 when $\pi^*_{1DI} < \pi^*_{1CE}$ but $\pi^*_{1DI} + \pi^*_{2DI} \geq \pi^*_{1CE} + \pi^*_{2CE}$. This gives us the necessary result.

Proof of Theorem 2

Since the profits of Platform 2 are strictly lower than those of Platform 1 in a One-Platform Equilibrium, it suffices to show the result for the case where Platform 1 is the active one. Consider the profit ratio

Table A1. Ratio of Profits in Competitive Equilibrium and Direct Interconnection Cases

For $(0 < r < 1)$	At $(r = 0)$	At $(r = 1)$
$\frac{d}{dr}\left(\frac{\pi_{1DI}^{*}}{\pi_{1CE}^{*}}\right) = \frac{3(8-r)^2(-8-24r+11r^2)}{8(4-r)^4(2-r)^2} < 0$	$\left(\frac{\pi_{1DI}^{*}}{\pi_{1CE}^{*}}\right) = \frac{3}{2}$	$\left(\frac{\pi_{1DI}^{*}}{\pi_{1CE}^{*}}\right) = 0$
$\frac{d}{dr}\left(\frac{\pi_{2DI}^{*}}{\pi_{2CE}^{*}}\right) = \frac{3(8-r)^2(-8-24r+11r^2)}{4(4-r)^4(2-r)^2} < 0$	$\left(\frac{\pi_{2DI}^{*}}{\pi_{2CE}^{*}}\right) = 3$	$\left(\frac{\pi_{2DI}^{*}}{\pi_{2CE}^{*}}\right) = 0$
$\frac{d}{dr}\left(\frac{\pi_{1DI}^{*}+\pi_{2DI}^{*}}{\pi_{1CE}^{*}+\pi_{2CE}^{*}}\right) = \frac{9(8-r)^2 r(-448+112r+16r^2+5r^3)}{4(4-r)^4(-16+6r+r^2)^2} < 0$	$\left(\frac{\pi_{1DI}^{*}+\pi_{2DI}^{*}}{\pi_{1CE}^{*}+\pi_{2CE}^{*}}\right) = \frac{3}{2}$	$\left(\frac{\pi_{1DI}^{*}+\pi_{2DI}^{*}}{\pi_{1CE}^{*}+\pi_{2CE}^{*}}\right) = 0$

$$\frac{\pi^*_{1DI}+\pi^*_{2DI}}{\pi^*_{1Dom}}=\frac{12\left(4-3r-r^2\right)}{\left(4-r\right)^3}\left(\frac{\alpha_i+\alpha_{\hat{i}}}{\alpha_{\hat{i}}}\right).$$

Evaluating this ratio at $r = 0$ yields $(3/4)((\alpha_i + \alpha_{\hat{i}})/\alpha_{\hat{i}})$, which is >1 for all $((\alpha_i + \alpha_{\hat{i}})/\alpha_{\hat{i}}) > 4/3$.

Proof of Theorem 3

The proof for Theorem 3 mirrors that of Theorem 1. As in the proof of Theorem 1, it can be shown that all of the profit ratios shown below start at a value higher than 1, and decline to a value lower than 1, crossing 1 at a unique point.

Case 1: $\gamma_j(t_1, t_2) = \text{Min}(t_1, t_2)$

$$\frac{\pi^*_{1Im}}{\pi^*_{1CE}}=\frac{(1-r)(8-r)^3(2+r)^3}{4(2-r)(8+r)^3}\geq 1 \text{ for } r\in(0,0.3];$$

$$\frac{\pi^*_{1Im}+\pi^*_{2Im}}{\pi^*_{1CE}+\pi^*_{2CE}}=\frac{(1-r)(8+7r)(2+r)^2(8-r)^3}{2(2-r)(8+r)^4}\geq 1 \text{ for } r\in(0,0.45].$$

Case 2: $\gamma_j(t_1, t_2) = \text{Avg}(t_1, t_2)$

$$\frac{\pi^*_{1IA}}{\pi^*_{1CE}}=\frac{(1-r)(8-r)^3(5+r)^3}{31104(2-r)}\geq 1 \text{ for } r\in(0,0.09];$$

$$\frac{\pi^*_{1IA}+\pi^*_{2IA}}{\pi^*_{1CE}+\pi^*_{2CE}}=\frac{(1-r)(11+4r)(5+r)^2(8-r)^3}{7776\left(16-6r-r^2\right)}\geq 1 \text{ for } r\in(0,0.30].$$

Case 3: $\gamma_j(t_1, t_2) = \text{Max}(t_1, t_2)$

$$\frac{\pi^*_{1IM}}{\pi^*_{1CE}}=\frac{27(1-r)(8-r)^3}{8(2-r)(10-r)^3}<1 \text{ for } r\in(0,1);$$

$$\frac{\pi^*_{1IM}+\pi^*_{2IM}}{\pi^*_{1CE}+\pi^*_{2CE}}=\frac{9(1-r)(14+r)(8-r)^3}{4\left(16-6r-r^2\right)(10-r)^3}\geq 1 \text{ for } r\in(0,0.01].$$

Proof of Theorem 4

Since the profits of Platform 2 are strictly lower than those of Platform 1 in a One-Platform Equilibrium, it suffices to show the result for the case where Platform 1 is the active one. Similar to Theorem 2, the proofs mostly rely on showing that the appropriate profits ratios are greater than 1 at $r = 0$ when $\alpha_b = \alpha_s$ or $((\alpha_i + \alpha_{\hat{i}})/\alpha_{\hat{i}}) = 2$. At $r = 0$:

$$\frac{\pi^*_{1IA}+\pi^*_{2IA}}{\pi^*_{1Dom}}=\frac{(1-r)(11+4r)(5+r)^2}{486}\left(\frac{\alpha_i+\alpha_{\hat{i}}}{\alpha_{\hat{i}}}\right)\approx 1.13;$$

$$\frac{\pi^*_{1IM}+\pi^*_{2IM}}{\pi^*_{1Dom}}=\frac{36(1-r)(14+r)}{(10-r)^3}\left(\frac{\alpha_i+\alpha_{\hat{i}}}{\alpha_{\hat{i}}}\right)\approx 1.008;$$

$$\frac{\pi^*_{1Im}+\pi^*_{2Im}}{\pi^*_{1Dom}}=\frac{8(1-r)(8+7r)(2+r)^2}{(8+r)^3}\left(\frac{\alpha_i+\alpha_{\hat{i}}}{\alpha_{\hat{i}}}\right)=1.$$

However,

$$\frac{d}{dr}\left(\frac{\pi^*_{1Im}+\pi^*_{2Im}}{\pi^*_{1Dom}}\right)=\frac{8\left(128-440r-672r^2-224r^3-7r^4\right)}{(8+r)^4}\left(\frac{\alpha_i+\alpha_{\hat{i}}}{\alpha_{\hat{i}}}\right)>0 \text{ at } r=0.$$

Appendix B: Monopoly Analysis

Consider a monopoly platform, with a technology level t. Let p_b and p_s be the monopoly prices for the buyers' and sellers' sides. Let n_s^e and n_b^e, respectively, be the buyers' and sellers' expectations about how many customers from the other side join the platform. Customers join the platform if their IR constraints are satisfied. Let $D_b(.)$ and $D_s(.)$ be the corresponding monopoly demands on the two sides. The monopolist's problem is

$$\max_{p_b,p_s}\pi_M=p_bD_b\left(p_b,p_s;n_s^e,n_b^e,t\right)+p_sD_s\left(p_b,p_s;n_s^e,n_b^e,t\right).$$

Lemma B1 specifies the outcomes associated with the monopoly equilibrium. Two different kinds of equilibriums are possible. The first kind involves the monopolist setting a membership price of zero on one side of the market and a positive membership price on the other. The second involves the monopolist setting positive membership prices and getting a subset of customers on both sides of the market.

Lemma B1 (Monopoly Outcomes): For all values of α_i and $\alpha_{\hat{i}}$, $(i, \hat{i} \in \{b, s\}; i \neq \hat{i})$ such that $\alpha_i \leq \alpha_{\hat{i}}$, the outcome is an asymmetric equilibrium with optimal prices and demands, and the platform profit given by

$$p_i^*=0;\ p_{\hat{i}}^*=\frac{t\alpha_{\hat{i}}N_i}{2};\ D_i=N_i;\ D_{\hat{i}}=\frac{N_{\hat{i}}}{2};\ \pi_M^*=\frac{t\alpha_{\hat{i}}N_bN_s}{4}.$$

In addition, when $\alpha_i = \alpha_{\hat{i}}$, there is a unique interior equilibrium for which the monopoly prices, demands, and the platform profit are given by

$$p_i^*=\frac{t\alpha_iN_{\hat{i}}}{4};\ p_{\hat{i}}^*=\frac{t\alpha_{\hat{i}}N_i}{4};\ D_i=\frac{N_i}{2};\ D_{\hat{i}}=\frac{N_{\hat{i}}}{2};\ \pi_M^*=\frac{tN_bN_s\left(\alpha_i+\alpha_{\hat{i}}\right)}{4}.$$

Proof: We start by characterizing the optimal interior choice of prices. Given the prices p_b, p_s chosen by the monopolist and expectations n_s^e, n_b^e, the indifferent consumer type on each side is given by $\theta_i^* = p_i/t\alpha_i n_{\hat{i}}^e$, $(i, \hat{i} \in \{b,s\};\ i \neq \hat{i})$, leading to a monopoly platform profit of

$$\pi_M = p_s\left(1-\theta_s^*\right)N_s + p_b\left(1-\theta_b^*\right)N_b.$$

The profit function is concave in prices and hence yields a unique solution. Profit maximization by the monopolist gives the following FOCs: $p_i = t\alpha_i n_{\hat{i}}^e/2$. Equating the equilibrium demands to expectations gives marginal consumer types on each side as $\theta_b = \theta_s = 1/2$. Substituting back into the FOCs and profit function, we have

$$p_b^* = \frac{t\alpha_b N_s}{4};\ p_s^* = \frac{t\alpha_s N_b}{4};\ D_b = \frac{N_b}{2};\ D_s = \frac{N_s}{2};\ \pi_M^* = \frac{tN_b N_s\left(\alpha_b + \alpha_s\right)}{4}.$$

Now considering the asymmetric equilibrium, let access be free on side i. Therefore, all customers on side i will join the platform, giving a market size N_i on that side. The optimal market coverage on the other side once again yields a coverage of 1/2 (see above). Therefore, the demand on side $\hat{i}$ is $N_{\hat{i}}/2$. The price choice of the monopolist makes the IR constraint for the marginal customer binding, thus giving $p_{\hat{i}} = t\alpha_{\hat{i}} N_i/4$, and therefore the profit is $\pi_M^* = t\alpha_{\hat{i}} N_b N_s/4$. From the profit expression, it is clear that it is optimal to give access away to the lower α_i side. Further, comparing this profit to the profit under the interior equilibrium, it is clear that the asymmetric profit is always higher than the interior profit, except when the cross-market network effects are symmetric, in which case both equilibriums yield identical profits.