Multilayer Two-sided Platforms: The Role of Exclusive Contracts

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Abstract

Mobile platforms are multilayer in the sense that application developers can access the users only through the two layers of the platform, namely operating systems (OS) and the carrier. Therefore, mobile platforms require contracting between OS and carrier as no firm has ability to connect both the layers of the platform. We develop a framework to study multilayer two-sided platforms and then examine the optimality of an exclusive contract by an entrant OS firm when the incumbent OS firm has non-exclusive contracts, such as Apple launching the iPhone when Blackberry was widely available. We show that exclusive contracts benefit entrant firm only if users have strong preferences for OSes, and paradoxically users benefit if developers enjoy weak cross-side network effects from those users. We also study the implications of exclusive contracts on social welfare and its implications for competition.

1. Introduction

In 2007, Apple introduced the iPhone, and within the United States it was bundled with mobile service from AT&T. This has become the most-discussed exclusive contract since Standard Oil. The iPhone was not the first smartphone, or even the first smartphone to launch exclusively on a single carrier, but the iPhone was the first to have sales driven largely by the availability of third-party applications. That is, the iPhone was the first smartphone with an economically important two-sided market connecting application developers and end users.

In a two-sided market, multiple firms are involved in connecting the two types of customers, but typically only one of these intermediaries is of strategic importance. For example, the relationship between a software publisher and an end user on the Microsoft Windows platform involves Microsoft as well as retailers, marketing agencies, PC hardware vendors, etc. Microsoft is the only one whose strategic decisions materially affect the relationship between the software publisher and the end user; the other firms are neutralized by strong competition in their steps of this particular supply chain. However, in some cases joining the two sides of a network requires the cooperation of two or more strategic firms with arms-length transactions between one another.

In the case of a smartphone platform, operating system vendors and mobile service providers each have the opportunity to strategically affect the relationship between developers and end users. The most well-known instance is the exclusive contract between Apple and AT&T which required all customers in the United States to purchase their iPhones bundled with mobile service from AT&T. Note that our use of the term “exclusive contract” is different than that in most of the extant literature. For a two-sided market with a single firm serving both sides, an “exclusive contract” is one which prevents a customer from joining more than one platform. For example, video game consoles join game publishers and players. In this context, an “exclusive contract” makes a particular video game available to the players on one console but no others, and a number of interesting and useful results have emerged from studying precisely this type of structure. In our multilayer framework, each side of the market is served by a different firm (e.g., developers by smartphone vendors, and end users by mobile service carriers) and an “exclusive contract” restricts a firm on one side to interact with a single firm on the other side (e.g., Apple’s smartphone was available through AT&T and no other mobile service carrier). Both senses of the term “exclusive contract” are in common usage in the popular press, although it is important to distinguish between them when developing a framework.

The platform owner facing a two-sided market usually subsidizes customers on one side of the network in order to attract paying customers on the other side. For example, video game makers pay high licensing fees to access Microsoft’s Xbox network while players get their consoles below manufacturer’s cost. When multiple networks of this...
type compete, one option is to employ exclusive contracts, which has led to a number of interesting studies examining the implications for prices, profits, and social welfare [2,5,7,9,10]. There is tremendous variance across industries and platforms along two dimensions: (i) whether the contract is exclusive between the provider and the platform; and (ii) who has the control rights over strategic variables like advertising and pricing [3]. These two-sided platforms have been studied extensively in literature (see [8] for detailed literature review of two-sided markets). This literature uses the first sense of the term “exclusive contract” meaning that customers on one side of the market are potentially enticed to contract with a single platform provider.

In this paper we develop a framework to address several research questions related to multilayer two-sided markets. How does the existence of multiple layers between market sides affect the results of prior models? What would an operating system vendor like Apple or a mobile carrier like AT&T have to gain from an exclusive contract? How does this type of contract affect customers on the two sides of the market (in this case third-party developers and end users)?

2. Theoretical framework

But what if one side of a two-sided network is another two-sided network? A cell phone operating system is obviously a two-sided network because application developers are attracted to a network with more end-users while end-users are attracted to a network with more application developers. However, while the operating system owner has direct contractual relationships with application developers, it can only connect end-users to its network through intermediaries, namely mobile carriers. The operating system company and mobile carrier company form a multilayer platform that ultimately links developers to users, but instead of one platform owner between the two sides, we have two. When two or more self-interested firms are needed to deliver service, contract theory predicts that a number of distortions will manifest compared to the case of a single entity being able to perform all of the functions (i.e., connect developers and users directly).

The first major distortion introduced by a multilayer network is double marginalization. Because each OS company and each carrier company sets prices to maximize their own profits, the set of “optimal” prices that would maximize total profits is never achieved. Since it would be more profitable for a single owner to control the OS and the carrier, the situation may lead to anticompetitive behavior. It is therefore critical to identify contractual arrangements that improve joint profitability (such as risk-sharing for investments to improve quality) without impeding a fair and competitive marketplace.

The second major distortion arising in a multilayer network is a weakening of incentives to invest in quality. Suppose that it would be in Apple’s interest to subsidize an upgrade to wireless broadband capacity so that end-users would find its OS more valuable, which would in turn attract more application developers. Unfortunately for Apple, an investment in improving a carrier’s capacity will improve the performance of any OS on that carrier’s network, thereby weakening Apple’s incentive to subsidize the investment. Similarly, if it was in Verizon’s interest to subsidize an investment in the software development kit for Android OS, the spillover to other Android-using carriers would discourage the investment. The only ways to ensure that these investments are made would be to extract payments from competitors (which are not feasible) or restrict the recipient of the investment from contracting with the investing company’s competitors at all (which requires exclusive contracts).

The third major distortion in a multilayer network is exclusive contracting. Was the exclusive contract between Apple and AT&T of the type that improved profitability, encouraged investments, or reduced competition? A handful of studies have looked at exclusive contracts from a variety of perspectives. [4] and [12] have analyzed the decision to enter the market as a new OS vendor; [3] have examined pricing mechanisms in detail; and [1] looks at entire systems as if the OS and carrier are owned by the same firm. However, none of these studies has considered the special nature of the multilayer networks involved.

In the standard model of a two-sided market, a network owner acts as a broker between customers on the two sides of the market. One interesting complication of this standard model is that one side of the market might have stronger preferences for using a particular network than the other side. For example, online sellers find it expensive to build and maintain reputations on multiple auction sites while buyers switch sites with ease. On the other hand, video game publishers can “port” their games to multiple consoles relatively cheaply while players find it prohibitively expensive to own multiple consoles. These differences between the sides lead to several interesting pricing anomalies, but at least each side is dealing with preferences for the same firm.
In a multilayer network, multiple sets of preferences become important. Many end-users in the US were anxious for access to the iPhone, but were dissatisfied with AT&T’s service as a carrier. As the number of applications available on the iPhone increased, network effects increased the value of the iPhone such that more and more of these end-users (grudgingly) signed up with AT&T service to get iPhones. Absent the exclusive contract, these end-users believe they would have been better off with the OS they wanted on the carrier of their choice. Of course the question remains: absent the exclusive contract, would Apple have released an iPhone at all? Artificially constraining the availability of iPhones during its early release period could benefit Apple in a number of ways. First, limiting early adoption to only those who really wanted an iPhone increased the chances of favorable reviews and positive word of mouth [6]. Second, the exclusive contract guaranteed Apple a distribution channel in an industry unlike any it had competed in before. Third, the relatively uniform operating environment simplified the process of correcting problems during the initial launch.

3. Model

3.1 Model Setup

We consider a setting in which there are two Carriers $C_0$ and $C_1$, and there are two operating systems (OS), an incumbent operating system $M_0$ and an entrant operating system $M_1$. Applications (Apps) which run on an OS are valuable to Users, but they can access them only by connecting to the OS through a Carrier. In that sense, OSes and Carriers form vertical supply chains to connect Developers to Users. We consider a market consisting of customers (Developers and Users) who are horizontally differentiated in their preferences for OSes and Carriers, and we model the two-dimensional horizontal differentiation as a Hoteling square. Users and Developers are each indexed along the $x$ and $y$ axes, with $x$ representing preferences for OSes and $y$ representing preferences for Carriers. Following prior literature, we model these preferences as transport costs from the customer’s location to the Carrier-OS location. The four potential bundles of Carrier and OS are located at the corners of the Hoteling square given by: \{$M_0, C_0\}$, \{$M_0, C_1\}$, \{$M_1, C_0\}$ and \{$M_1, C_1\}$, although all four Carrier-OS bundles may not be available for purchase. The multilayer platform and industry structure is shown in Figure 1.

A Developer (User) gets cross-side network effect benefit of $N_D (N_U)$ from a unit mass of Users (Developers) on the other side. For ease of exposition, we normalize same-side network effects to zero and focus on cross-side network effects. Developers and Users incur transport cost based on their location in the Hoteling square. The transport cost for Developers along $x$ axis (OS) and $y$ axis (Carrier) is denoted by $t_i^M$ and $t_i^D$. Similarly, transport for Users along $x$ axis (OS) and $y$ axis (Carrier) is denoted by $i_u^C$ and $i_u^D$. Following [3], we consider the inherent payoff accruing to a User (Developer) for homing with at least one Carrier (OS) is denoted by $u (v)$; to avoid an artificial incentive to multihome, this value does not increase with additional connections. On the other hand, strategic players face an internal cost $c$ to connect to other players, for example a Carrier incurs $i_u^C$ to connect to each OS while an OS incurs $i_i^M$ to connect to a unit mass of Developers. Finally, we use $S$ to denote sets of Users and Developers. For example, $S_{U(C_0, M_0)}$ is the set of all Users choosing the bundle of $C_0$ and $M_0$.

![Figure 1: Multilayer two-sided network](image)

Note, that there is an important asymmetry between Users and Developers in our model. Users consume a bundle of services including one OS and one Carrier, whereas Developers simply choose
which OS(es) to contract with. That is, a Developer contracting with an OS implicitly chooses to work with every Carrier connected to that OS. Note that our results still hold even if the Developers’ transport cost to Carriers \( t_y^D \) is zero, so this is not a critical assumption.\(^2\) A summary of our notation is given in Table 1.

<table>
<thead>
<tr>
<th>( C_0, C_1 )</th>
<th>Mobile Carriers located at ( y=0 ) and ( y=1 ), respectively</th>
</tr>
</thead>
<tbody>
<tr>
<td>( i_k^j )</td>
<td>Investment (internal cost) incurred by ( j ) to connect/serve a unit of ( k )</td>
</tr>
<tr>
<td>( M_0, M_1 )</td>
<td>Mobile OS vendors located at ( x=0 ) and ( x=1 ), respectively</td>
</tr>
<tr>
<td>( N_D )</td>
<td>Network effect benefit from a unit mass of Developers, received by a Developer</td>
</tr>
<tr>
<td>( N_U )</td>
<td>Network effect benefit from a unit mass of Developers, received by a User</td>
</tr>
<tr>
<td>( p_k^j )</td>
<td>( j )'s price to ( k ). For example, ( p_{M1}^{C1} = -p_{C1}^{M1} ), and ( p_{M1}^{S1} = M_1 )'s price to Developers.</td>
</tr>
<tr>
<td>( p_{k(\theta)}^j )</td>
<td>Price charged by ( j ) to ( k ) conditional on ( \theta ). For example, an exclusive contract or not.</td>
</tr>
<tr>
<td>( \pi_j )</td>
<td>Payoff (profit or surplus) for ( j )</td>
</tr>
<tr>
<td>( S_{k(\theta)} )</td>
<td>Set of ( k ) meeting condition ( \theta ). For example, ( S_{M1(C1)} ) are Users of ( M_1 ) on ( C_1 )'s service.</td>
</tr>
<tr>
<td>( t_x^D, t_y^D )</td>
<td>Transport cost for Developers along the ( x ) axis (OS) and ( y ) axis (Carrier)</td>
</tr>
<tr>
<td>( t_U^x, t_U^y )</td>
<td>Transport cost for Users along the ( x ) axis (OS) and ( y ) axis (Carrier)</td>
</tr>
<tr>
<td>( u )</td>
<td>Inherent utility received by a User for homing with at least one Carrier</td>
</tr>
<tr>
<td>( v )</td>
<td>Inherent value received by a Developer for homing with at least one OS</td>
</tr>
<tr>
<td>( x )</td>
<td>Location indices for Developers and Users for preference between Carriers</td>
</tr>
<tr>
<td>( y )</td>
<td>Location indices for Developers and Users for preference between OSes</td>
</tr>
</tbody>
</table>

### 3.2 Model Assumptions

For ease of exposition in introducing our framework, we make the following six assumptions in our paper.

\(^2\) One counterintuitive implication of Developer indifference between Carriers \( (t_y^D = 0) \) is that the market for Developers will never be fully covered. See the proof for Proposition 3 in the Appendix.

**A1:** The transport cost is higher along the \( x \) dimension than the \( y \) dimension. That is, Developers and Users have stronger preferences for OSes than Carriers.

This assumption reflects the general opinion of the popular press that consumer preferences for marquee electronics are stronger than they are for the underlying service providers. This was particularly relevant for the iPhone [11]. Proposition 1 still holds if this assumption is violated, although it would limit the admissible values for other model parameters.

**A2:** The outside option for Carriers and Users are “feature phones” that do not use a platform-style OS. We normalize the profits and utility for “feature phones” to zero.

Assumption A2 states that feature phones are perfectly competitive. If this is not the case, it will introduce an affine transformation to the payoffs in our model leaving the Proposition results unchanged.

**A3:** If an OS is not connected to at least one Carrier, it attracts no Developers and essentially exits the market.

This assumption rules states that a “smartphone” that is not available via a Carrier contract (*e.g.*, a WiFi-only device) is not competing in the “smartphone” market. Such devices are thus an outside option rather than a direct competitor.

**A4:** The only information asymmetry present in the model concerns preferences: Developers and Users know their preferences (locations), whereas OSes and Carriers only know the distribution of preferences.

Assumption A4 rules out the possibility of contracting with the “wrong” firm. Since our model includes only pure horizontal differentiation, this assumption is innocuous.

**A5:** No side-payments are made between OSes and Carriers.

This assumption is made for expositional clarity to introduce the framework. Side payments and revenue sharing between strategic players is an important topic for future research in this area.

**A6:** Outside option for any player has zero net surplus. This rules out outcomes with negative payoffs.

Assumption A6 is a normalization to simplify notation. It asserts that the payoffs are relative to the best available outside option (*e.g.*, for a User these are feature phone, WiFi-only device, etc.). Similar to A2, assigning a positive utility to the outside option would introduce an affine transformation to the payoffs in our model leaving our Proposition results unchanged.
3.3 Timing and Payoffs

In an initial state of $M_0$ available on both Carriers and $M_1$ not yet available, the payoff for a Developer located at $(x,y)$ is based on the cross-side network effect, the disutility (transport cost) of the OS, and the price. Since the OS is available on both Carriers, a Developer who enters the market must pay the sum of transport costs to $C_0$ and $C_1$ (which always adds up to exactly $t^D_s$).

\[ \nu_{(x,y)}^{M_0} = v + S_{U(M_0)} N_D - P_D^{M_0} - x t^D_s - t^D_y \]  

(1)

or zero as an outside option. The payoff for a User is similar, except that a User has a choice of Carriers and thus only pays one Carrier transport cost.

\[ U_{(x,y)}^{COMBO} = u + S_{P(M_0)} N_U - P_U^{M_0} - x t^U_s - y t^U_y \]  

(2a)

\[ U_{(x,y)}^{CIMO} = u + S_{P(M_0)} N_U - P_M^{M_0} - x t^M_s - y t^M_y - (1-y) t^M_y \]  

(2b)

or the outside option of a feature phone, for which we normalize the utility to zero. A Carrier’s payoff derives from its market share among Users multiplied by the marginal for selling service. The final term represents a side-payment to the OS and an internal investment required to connect to the OS.

\[ \pi_{C_0} = S_{U(C,0,M_0)} \left( P_{U(M_0)} - i^C_U \right) + \left( P_{M_0}^{C_0} - i^C_M \right) \]  

(3a)

\[ \pi_{C_1} = S_{U(C,1,M_0)} \left( P_{U(M_0)} - i^C_U \right) + \left( P_{M_0}^{C_1} - i^C_M \right) \]  

(3b)

The OS’s payoff derives from its market share among Developers multiplied by the margin for selling licenses. The final term represents potential side-payments and connection costs to both Carriers.

\[ \pi_{AR0} = S_{D(M_0)} \left( P_{D}^{M_0} - i^D_U \right) + \left( P_{M_0}^{C_0} - i^C_M \right) + \left( P_{M_0}^{C_1} - i^C_M \right) \]  

(4)

The stages/timings of the game are shown in Figure 2.

There are many permutations of connections between OSES and Carriers, although our motivating example of Apple and AT&T causes us to focus on two in particular. Suppose that $M_0$ is already available on both carriers, and new entrant $M_1$ joins the market it might be available on both Carriers or on $C_1$ exclusively. This models the situation of Blackberry (which decided to be widely available on major carriers) and Apple (which had to decide on whether to engage in an exclusive contract). Later in 2007, Google faced a similar decision regarding the entry of its Android OS.

4. Contracts and payoffs with one OS

The market shares for Developers and Users depend on cross-side network effects, which set up a recursive system. $M_0$ will capture all of the Developers to the left of some indifference line, while $C_0$ and $C_1$ will split Users in a manner similar to that shown in Figure 3. The Users to the left of the dashed lines would get positive surplus from either Carrier, but with both available they prefer the closer Carrier. To begin, we determine the market size for $C_0$ (the blue polygon in Figure 3) in the initial state with one OS. First, since the Carriers are symmetric, the horizontal indifference line will be at $y = .5$ and therefore two vertices of the polygon are $(0, 0)$ and $(0, .5)$. The vertices $(x^*, .5)$ and $(x^*, 0)$ are located at

\[ x^* = \frac{u + S_{D(00)} N_U - P_{U(00)} - 5t^U_y}{t^U_s} \]  

(5a)

\[ x^* = \frac{u + S_{D(00)} N_U - P_{U(00)}}{t^U_s} \]  

(5b)

which might be points outside the unit square. If $x^* \geq 1$ then the market is fully covered, and we will assume that this is the case in our initial state. The competitive Carrier price makes the consumers at $y = .5$ indifferent.

\[ p_{U(00)}^{C_0} = p_{U(00)}^{C_1} = i^C_U + t^C_y \]  

(6)

![Figure 3: User market shares (red dots indicate available bundles)](image)

It is straightforward to calculate the market size of Developers in terms of price and User market share for $M_0$.

\[ S_{D(00)} = \frac{v + S_{U(00)} N_D - P_D^{00} - t^D_y}{t^D_s} \]  

(7)

Both Carriers use $M_0$, and the User market is fully covered, so $S_{U(M_0)}$ equals one. The optimal price for the OS vendor is
which allows us to calculate $M_0$’s market share for Developers.

\[
P_D^{CO} = \frac{v + N_D - t_D^{s} - t_D^{c}}{2} \tag{8}
\]

We now have all the quantities needed to check our assumption of full User coverage.

**Proposition 1:** When one operating system is available, the market for Users is covered if User transport costs for OSes are at or below a threshold value of $u + N_U \left( v + N_D - t_D^{s} - t_D^{c} \right)/2t_s^{D} - t_C^{c} - 3t_U^{c}/2$.

**Proof:** See appendix.

At these prices, the payoffs are as follows. In the present study, we assume that coordination through contracts is illegal or infeasible, so all side-payments are zero.

\[
\pi_{CO} = \frac{1}{2} \left( \frac{v + N_D - t_D^{s} - t_D^{c}}{2} \right)^2 - 2t_C^{c} \tag{10a}
\]
\[
\pi_{C1} = t_U^{c} - t_C^{c} \tag{10b}
\]
\[
\nu_{CO} = \frac{v + N_D - t_D^{s} - t_D^{c}}{2} - xt_s^{D} \tag{10c}
\]
\[
U^{CO}_{(s,y)} = u + \frac{v + N_D - t_D^{s} - t_D^{c}}{2t_s^{D}} N_U - \frac{1}{2} \left( 1 + y \right) t_U^{c} \tag{10d}
\]
\[
U^{CO}_{(s,y)} = u + \frac{v + N_D - t_D^{s} - t_D^{c}}{2t_s^{D}} N_U - \frac{1}{2} \left( 1 + y \right) t_U^{c} \tag{10e}
\]

Consumer welfare for Developers and Users is

\[
CW_D = \frac{v + N_D - t_D^{s} - t_D^{c}}{2} \tag{11a}
\]
\[
CW_U = \frac{v + N_D - t_D^{s} - t_D^{c}}{2t_s^{D}} N_U - \frac{t_C^{c}}{2} - \frac{5t_U^{c}}{4} \tag{11b}
\]

5. **Entrant OS using a non-exclusive contract**

Apple and Google reached different decisions for their entry strategies. For expositional clarity we begin with non-exclusive entry, corresponding to the Android entry and counterfactual to the iPhone entry.

Since the User market is fully covered with one operating system, the addition of a second competing operating system will leave the User market covered in equilibrium. Since $M_1$ enters the market in a manner completely symmetric to $M_0$, the symmetric outcome will be to split the Users across the four bundles in equal quadrants. The competitive price is the same for all four bundles, and the same as derived above in (6):

\[
P_{C1}^{CO} = P_{C1}^{CO} = P_{C1}^{CO} = P_{C1}^{CO} = \frac{1}{2} \tag{12}
\]

Developers now have three options to participate in the market. The respective payoffs are:

\[
V_{(s,y)}^{CO} = \frac{v + N_D - t_D^{s} - t_D^{c}}{2} \tag{14a}
\]
\[
V_{(s,y)}^{CO} = \frac{v + N_D - t_D^{s} - t_D^{c}}{2} \tag{14b}
\]
\[
V_{(s,y)}^{CO} = \frac{v + N_D - t_D^{s} - t_D^{c}}{2} \tag{14c}
\]

The operating systems are symmetric, so their prices will be the same. If the Developer market it not completely covered, then the market sizes are:

\[
S_{D(00)} = S_{D(01)} = \frac{v + N_D - t_D^{s} - t_D^{c}}{2} < \frac{1}{2} \tag{15}
\]

If the Developer market is completely covered, there may be some Developers in the middle who multihone on both OSes.

\[
S_{D(00,only)} = S_{D(01,only)} = 1 - \frac{N_D - t_D^{s} - t_D^{c}}{2} \leq \frac{1}{2} \tag{16a}
\]
\[
S_{D(both)} = \frac{N_D - 2t_D^{s}}{2} \tag{16b}
\]

The optimal price for not fully covered and fully covered, respectively, is

\[
P_{D}^{CO} = P_{D}^{CO} = \frac{v + N_D - t_D^{s} - t_D^{c}}{2} \tag{17a}
\]
\[
P_{D}^{CO} = P_{D}^{CO} = \frac{v + N_D - t_D^{s} - t_D^{c}}{2} \tag{17b}
\]

**Proposition 2:** When both operating systems are available on both carriers, the Developer market is fully covered if cross-side network effects accruing to Developers are weak, specifically if

\[
N_D < \left( v + 3t_D^{c} \right) / \left( t_U^{c} + v \right) / 2t_s^{D} + 2t_D^{c}. \tag{16}
\]

**Proof:** See appendix.

If the Developer market is fully covered, the payoffs are:
\[ \pi_{00} = \pi_{01} = \left( \frac{N_D - i_D^o}{2} - i_C^o \right)^2 \]  
\[ \pi_{c0} = \pi_{c1} = \frac{i_U^o}{2} - 2i_C^o \]  
\[ V_{(s,y)} = v + \frac{N_D - i_D^o}{4} - t_y - \min \left[ x_{s}^o, (1-x) t_y^o + i_C^o \right] \]  
\[ \U_{(s,y)} = u + \frac{N_D - 2i_D^o}{4} - N_U - i_C^o - \min \left[ x_{s}^o, (1-x) t_D^o + i_D^o \right] \]  
\[ (18a) \]  
\[ (18b) \]  
\[ (18c) \]  
\[ (18d) \]  
6. Entrant OS using an exclusive contract

In this situation, which corresponds to the iPhone entry and is counterfactual to Android entry, the Carriers and OSes are no longer symmetric. \( C_0 \) sets a price for access to \( M_0 \), while \( C_1 \) sets prices for access to \( M_0 \) and \( M_1 \). We continue to assume that the User market will be covered since it was covered in the initial state, none of those options disappeared, and there is an additional option available.

The payoffs to Users in this environment are:
\[ U^{C_{0}(0)}_{(s,y)} = u + S_{M(0)} N_U - p_{C_{0}(0)} - x_{s}^o - y t_y^o \]  
\[ U^{C_{1}(0)}_{(s,y)} = u + S_{M(0)} N_U - p_{C_{1}(0)} - x_{s}^o - (1-y) t_y^o \]  
\[ U^{C_{0}(0)}_{(s,y)} = u + S_{M(1)} N_U - p_{C_{0}(1)} - (1-x) t_s^o - (1-y) t_y^o \]  
\[ (22a) \]  
\[ (22b) \]  
\[ (22c) \]  
\[ (19a) \]  
\[ (19b) \]  
\[ (19c) \]  
\[ (19d) \]  
\[ (20a) \]  
\[ (20b) \]  
\[ (20c) \]  
\[ (20d) \]  
\[ (21a) \]  
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\[ U^{C_{0}(0)}_{(s,y)} = u + S_{M(1)} N_U - p_{C_{0}(1)} - (1-x) t_s^o - (1-y) t_y^o \]  
\[ (22a) \]  
\[ (22b) \]  
\[ (22c) \]  
\[ (19a) \]  
\[ (19b) \]  
\[ (19c) \]  
\[ (19d) \]  
\[ (20a) \]  
\[ (20b) \]  
\[ (20c) \]  
\[ (20d) \]  
\[ (21a) \]  
\[ (21b) \]  
\[ (21c) \]  

Figure 4: User market shares with one exclusive OS (red dots indicate available bundles)

Now there is a strategic tension for \( C_1 \): to sell more of \( M_1 \) (which gives no indirect benefit to its
competitor), \( C_i \) must compete less aggressively on \( M_0 \). In the extreme case, \( C_i \) unilaterally stops selling \( M_0 \), but this is unlikely to be optimal.

The areas of these regions are given by:

\[
S_{U(c)}(o) - S_{U}(c) = \frac{1}{4t_{y}^c t_{y}^u} \left( (S_{D(o)} - S_{D(o)}) N + \right.
\]

\[
t_{y}^c + P_{U(c)}^c - P_{U(c)}^U \times \left( \frac{t_{y}^c + P_{U(c)}^c}{t_{y}^c} \right) +
\]

\[
\frac{(t_{y}^c + P_{U(c)}^c)}{8t_{y}^c} \left( 1 + \frac{P_{U(c)}^c - P_{U(c)}^U}{t_{y}^c} \right)
\]

\[
S_{U(c)}(o) = \sqrt{\left( t_{y}^c + P_{U(c)}^c \right) \left( t_{y}^c + P_{U(c)}^c \right) - \left( (S_{D(o)} - S_{D(o)}) N + \right.}
\]

\[
\frac{1}{2} \left( \frac{S_{D(o)} - S_{D(o)}}{2t_{y}^U} \right) N + \frac{P_{U(c)}^c - P_{U(c)}^U}{t_{y}^c}
\]

\[
S_{U(c)}(o) = \frac{1}{4t_{y}^c t_{y}^u} \left( (S_{D(o)} - S_{D(o)}) N + \right.
\]

\[
2N \left( S_{D(o)} - S_{D(o)} \right) + P_{U(c)}^c \times \left[ \frac{3}{2} + \frac{1}{t_{y}^c} \right]
\]

\[
-2P_{U(c)}^c \left( P_{U(c)}^c + t_{y}^c \right) \]

\[
S_{U(o)}(o) = \frac{1}{2} \left( \frac{4N}{8t_{y}^c} \left( S_{D(o)} - S_{D(o)} \right) - P_{U(c)}^c \right.
\]

\[
-3P_{U(c)}^c - 4P_{U(c)}^U + t_{y}^c \]

The tension facing \( C_i \) is apparent in equation (25b) because \( C_i \)’s price for access to \( M_0 \) has three times the impact on \( M_i \)’s share of Users than does \( C_d \)’s price for access to \( M_0 \).

7. Discussion and conclusion

While many platforms require a number of firms to connect both sides of a market, usually only one of these firms is of strategic importance. This strategic firm is usually modeled as if it has free reign to set prices on either side of the network, and it is often in this firm’s interest to subsidize users on one of the sides. In this paper, we have begun to examine what happens when more than one strategic player is required to connect the network sides. It turns out that if the two firms are unable to coordinate their prices, the multilayer network leaves firms worse off.

The primary distortion introduced by a multilayer network is double marginalization. The set of “optimal” prices that would maximize total profits for the platform is never achieved unless self-enforcing contracts can be written to coordinate the firm’s actions. Such coordination may take the form of side payments or subsidies for the partner firm’s customers. Our present model operates as though such contracts are infeasible, but future work in this area may be able to identify self-enforcing contract mechanisms that improve industry profits. One interesting question that immediately arises is how this affects consumer welfare of Users and Developers.

One major obstacle to coordination through contracts is leakage to one’s competitor. This is parallel to the disincentive to invest in quality, because absent an exclusive contract any investment will leak and benefit one’s competitor. Although several studies have looked at exclusive contracting, none has considered the multilayer nature of the networks involved.

One thing that is clear is that exclusive contracting changes the basis of competition greatly. A firm that has an exclusive service and a non-exclusive one must balance how hard it competes in each market. After BlackBerry ceded its leadership status in the smartphone market, competition between Android and iPhone resembled Section 6 with AT&T needing to balance its support for each OS. More importantly, the exclusive contract may make feasible the types of subsidies and investments with a partner firm that leverage cross-side network effects.

An important goal for future research is to identify the conditions under which exclusive contracts are beneficial to firms and customers. It is clear that Apple anticipated an advantage from an exclusive contract for its iPhone OS while Google did not anticipate one for its Android OS. Such decisions must take into account the potential for investments in vertical differentiation that may become optimal in the presence of side-payments, revenue sharing and other contract provisions. It would be interesting to determine the conditions under which these provisions might be feasible only with exclusive contracts.

In 2011, Apple’s exclusive contract with AT&T expired. The welfare implications of this expiration are a fruitful avenue for future research, particularly compared to the counterfactuals of non-exclusive entry, perpetual exclusivity, and non-entry. Such an
extension of our framework would inform decision-makers on the optimal length of an exclusive contract.

8. References


9. Appendix

Proof of Proposition 1: Substitute (9) and (6) into (5a) to ensure that \( x^* \geq 1 \). This translates to:

\[
t^*_y \leq u + \frac{N_D}{2t^*_y} (v + N_D - t^*_y - t^*_D) - t^*_D - \frac{3t^*_D}{2} \tag{A1}
\]

This inequality states that the costs of providing service are not too high, and that User preferences for OSes are stronger than they are for Carriers. Q.E.D.

Proof of Proposition 2: Coverage of the Developer market depends on model parameters and strategic pricing decisions by each OS. If the payoff from the lower market-covering price is higher to the OS, then the OS will choose that price. This condition reduces to an inequality based on model parameters that ultimately hinges on the cross-side network effect enjoyed by Developers. Specifically, the OSes will choose to fully cover the market if this cross-side network effect is weak:

\[
N_D < \frac{\left( 3t^*_D + v \right) \left( t^*_D - v \right)}{\left( t^*_D + v \right)} + 2t^*_D \tag{A2}
\]

Although this condition does not rely on any User parameters, Users benefit directly if the Developer market is covered. This is because the cross-side network effect enjoyed by Users is larger without affecting the price they pay. Q.E.D.

Proof of Proposition 3: Inspection of equations (19b) and (20a) shows that the former is greater when \( t^*_D > v \). As can be seen from comparing equations (18a) and (20a), this condition is always met if OS payoffs are greater under full Developer coverage. Q.E.D.

Proof of Proposition 4: The OSes induce full Developer coverage by reducing prices while none of the other components of Developer welfare change. Therefore, Developer consumer welfare is always higher if the Developer market is covered. Q.E.D.

Proof of Proposition 5: The indifference lines implied by the utility payoffs are:

\[
y = \frac{1}{2} + \frac{p^{C^1}_{O(i|0)} - p^{C^0}_{O(i|0)}}{2t^*_y} \tag{A3}
\]

\[
x = \frac{1}{2} + \frac{\left( S^D_{O(i|0)} - S^D_{O(i|1)} \right) N_D + p^{C^1}_{O(i|0)} - p^{C^0}_{O(i|0)} + t^*_D}{2t^*_y} \tag{A4}
\]

These three lines have a unique common solution:

\[
x = \frac{1}{2} + \frac{p^{C^1}_{O(i|0)} - p^{C^0}_{O(i|0)}}{2t^*_y}
\]

The User at this point is indifferent between any available bundles. Q.E.D.