An Analytic Framework of Exclusive Contracts in Multilayer Two-sided Platforms

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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 the entrant firm only if users have strong preferences for OSes and the exclusive carrier softens its competition for users of the non-exclusive OS. We also show that paradoxically users benefit if the cross-side network effects enjoyed by developers are relatively weak. We also study the implications of exclusive contracts on social welfare and its implications for competition.

Keywords: Multilayer two-sided platform, cross-side network effects, exclusive contract, social welfare

Word count: 6,732
1. Introduction

In 2007, Apple introduced the iPhone, and within the United States it was bundled with mobile service from AT&T. The immense popularity of the iPhone and the hundreds of thousands of app downloads per day (Garg & Telang, 2012) have made this 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 (Sinkinson, 2011), but the iPhone was the first to have sales driven largely by the availability of third-party applications (Lin & Ye, 2009). 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 the supply chain joining the two sides of a network requires the cooperation of two or more strategic firms with arms-length transactions between one another, and it is not clear that existing models of two-sided markets can characterize the effects of an exclusive contract in this context. Prior analytical models have addressed the role of exclusive contracts in two-sided networks (Armstrong & Wright, 2007; Hagui & Lee, 2011) and the role of exclusive contracts in supply chains (Cai, et al., 2012), but to
the best of our knowledge no existing literature has considered all three features in the same model.

All three features are essential because 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 with pricing and exclusive contracts.\(^1\) The best-known example 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. In that literature, the two sides of a market can be joined by a single firm, and 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 game publisher’s content 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 the structure described by 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

\(^1\) Sinkinson (2011) shows that, from the point of view of end users, mobile operating systems are imperfect substitutes for one another and that mobile carriers are imperfect substitutes for one another, giving each some power to act strategically. Sinkinson does not consider application developers in his model and therefore treats smartphones as a traditional vertical supply chain rather than a two-sided market.
common usage in the popular press, although it is important to distinguish between them when developing an analytical framework because they have very different effects on the platform.

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 of exclusive contracts for prices, profits, and social welfare (Katz & Shapiro, 1986; Rasmusen et al., 1991; Balto, 1999; Shapiro, 1999). Tremendous variance exists 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 (Hagiu & Lee, 2011). These two-sided platforms have been studied extensively in literature (see Rochet & Tirole, 2006, 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.

We contribute to the literature on two-sided markets by generalizing the ownership structure of the platform, using a model that captures the behaviors predicted by contract theory when ownership must be shared between strategic actors. To this end we develop an analytical framework to address two research questions related to multilayer two-sided markets. First, how does the existence of multiple layers between market sides affect the results of prior models? Second, how does this type of contract affect customers on the two sides of the market (in this
case third-party developers and end users)? We show that cross-side network effects can substitute for the revenue sharing previously thought essential for exclusive contracts to exist in equilibrium, that cross-side network effects have a strong impact on consumer welfare (and not necessarily firm profits), and that exclusive contracts between OS vendors and mobile carriers create a strategic tension for the exclusive carrier between selling the OSes available to it.

The rest of the paper is organized as follows. In §2, we describe the theoretical framework for multi-layered two-sided platform. In §3, we describe the analytical model and key assumptions. In §4 we develop optimal contracts and study market outcome in the presence of single Operating System (OS). In §5 and §6, we develop optimal contracts and study market outcomes when a new OS enters the market with non-exclusive and exclusive contracts respectively. We conclude by discussing our results, implications of relaxing some of our assumptions and by identifying suitable managerial recommendations in §7.

2. Theoretical Framework

2.1 Market Structure

The market for smartphones is a two-sided market, which distinguishes it from the typical vertical supply chain model applicable to previous generations of mobile phones. A market is “two-sided” if two conditions are met. First, transactions between two distinct sets of customers require a third party organization to act as a mediator known as a platform, and second, the volume of transactions depends on the fee charged to each side as opposed to just the sum of the two fees (Rochet & Tirole, 2006). Mediators arise in a market when transaction costs are high, such as adverse selection or high search costs. Specialist firms can provide value-added services
related to matching and escrow for which they charge the two distinct customers; however, the presence of a mediator is not sufficient for a market to be two-sided.

A market is only truly two-sided if transaction volume depends on how the fee is partitioned between the two customers. For example, a real estate agent charging a 6% commission could partition the fee in any proportion between the buyer and seller without affecting the volume of sales because sellers can adjust their asking prices to account for the fee structure. On the other hand, a cross-side network effect materializes if customers’ willingness to pay depends on the number of customers on the other side, and in that case how much each side is charged becomes a critical decision variable for the mediator. For example, advertisers’ willingness to pay is higher in media channels with more readers, so the mediator (the media channel) strategically shifts most (or all) of their fees to advertisers in a bid to attract more readers.

But what if mediation requires the coordination of two or more strategic actors, as it does in a smartphone platform? A smartphone platform is obviously a two-sided market because application developers are attracted to a platform with more end-users while end-users are attracted to a platform 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 who are imperfect substitutes for one another. The operating system firm and mobile carrier firm form a multilayer platform that ultimately links developers to users, but instead of one platform owner between the two
sides, we have twoingo ownership structure can have a dramatic impact on the size and profitability of a platform (Yoo, et al., 2007). When two or more strategic 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).

2.2 Consequences of Market Structure

The first major distortion introduced by a multilayer network is double marginalization. Because each OS firm and each carrier firm 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

\(^2\) Perfectly competitive mobile carriers would be strategically neutralized, leaving the operating system vendor as the sole “owner” of the platform. It is interesting to note that mobile carriers exercised near-total authority over their platforms prior to the advent of smartphones (Sharma et al., 2007), indicating that feature phone operating systems are in effect perfectly competitive.
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 firm’s competitors at all (which requires exclusive contracts).

The third major distortion in a multilayer network is exclusive contracting, which brings us to Apple and AT&T. Was the exclusive contract between Apple and AT&T of the type that improved profitability, encouraged investments, or reduced competition? A handful of studies (some inspired by the Apple/AT&T contract) have looked at exclusive contracts from a variety of perspectives. Katz (2010) and Sharma et al. (2011) have analyzed the decision to enter the market as a new OS vendor; Hagui & Lee (2011) and Cai et al. (2012) have examined pricing mechanisms in detail; and Armstrong & Wright (2007) look 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 two-sided 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 current-generation consoles. These differences between
the sides lead to several interesting pricing anomalies, but at least each side of the market is dealing with preferences for a single platform owner.

In a multilayer network, multiple sets of preferences become important. In the case of the iPhone’s multilayer network, 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 (Kuksov & Vie, 2010). 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

We consider a setting in which there are two Carriers $C_0$ and $C_1$, and there are two operating systems (OS), an incumbent mobile operating system $M_0$ and an entrant mobile 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 chain 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 ofCarrier 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. We model the bundles as neutral platforms (\textit{i.e.}, no Carrier or OS participates as a Developer) because this provides a lower bound for firm profitability and social welfare (Yoo, \textit{et al.}, 2007). The multilayer platform and industry structure are 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 \( t^D_x \) and \( t^D_y \). Similarly, transport for Users along \( x \) axis (OS) and \( y \) axis (Carrier) is denoted by \( t^U_x \) and \( t^U_y \).

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3 We do not model “jailbreaking” an iPhone (\textit{i.e.}, using it on a Carrier other than those contracted with Apple). At the time we are modeling, a User intent on jailbreaking had to initiate a contract with AT&T then pay an early termination fee. The value to Apple and AT&T is similar to a normal customer.
axis (Carrier) is denoted by $t^U_x$ and $t^U_y$. Following Hagiu & Lee (2011), 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 to connect to other players, for example a Carrier incurs $i^C_O$ to connect to each OS while an OS incurs $i^O_D$ to connect to a unit mass of Developers (all of our results still hold if these costs are normalized to zero). 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 $M_0$.

![Multilayer two-sided network](image)

**Figure 1: Multilayer two-sided network**

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 $t^D_y$ is zero, so this is not a critical assumption.$^4$

3.1 Model Assumptions

For ease of exposition in introducing our framework, we make the following six assumptions.
The implications of relaxing these assumptions are discussed in §7.

A1: 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 A1 rules out the possibility of contracting with the “wrong” firm. Since our model
includes only pure horizontal differentiation, this assumption is innocuous.

A2: 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.

A3: 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 A3 states that feature phones are perfectly competitive to establish them as a
uniform outside option for expositional clarity.

$^4$ One counterintuitive implication of Developer indifference between Carriers ($t^D_y=0$) is that the market for
Developers will never be fully covered. See the proof for Proposition 3 in the Appendix.
**A4:** 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 (Sharma *et al.*, 2007).

**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.

A summary of our notation is given in Table 1.

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_0, C_1$</td>
<td>Mobile Carriers located at $y = 0$ and $y = 1$, respectively</td>
</tr>
<tr>
<td>$i^j_k$</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 Users, 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>$p^j_k$</td>
<td>$j$’s price to $k$. For example, $p^{M_1}<em>{M_1} = -p^{M_1}</em>{C_1}$, and $p^{M_1}_{D}$ is $M_1$’s price to Developers.</td>
</tr>
<tr>
<td>$p^j_{k(\theta)}$</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, $S_{U(M_1,C_1)}$ are Users of $M_1$ on $C_1$’s service.</td>
</tr>
<tr>
<td>$t^D_x, t^D_y$</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 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 $t^D_y$).

$$V^M_{(x,y)} = v + S_{U(M0)} N_D - P^M_D - xt^D_x - t^D_y$$

(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.

$$U^{COM}_{(x,y)} = u + S_{D(M0)} N_U - P^{C0}_U - xt^U_x - yt^U_y$$

(2a)

$$U^{C1M0}_{(x,y)} = u + S_{D(M0)} N_U - P^{C1}_U - xt^U_x - (1-y)t^U_y$$

(2b)

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

$$\pi_{C0} = S_{U(C0,M0)} \left( P^{C0}_U - i^C_U \right) + \left( P^{C0}_M - i^C_M \right)$$

(3a)

$$\pi_{C1} = S_{U(C1,M0)} \left( P^{C1}_U - i^C_U \right) + \left( P^{C1}_M - i^C_M \right)$$

(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.
\[
\pi_{00} = S_{D(M_0)}\left( P_{D_0}^{M_0} - i_{D_0}^M \right) + \left( P_{C_0}^{M_0} - i_{C_0}^M \right) + \left( P_{C_1}^{M_0} - i_{C_1}^M \right)
\]  

(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.

Figure 2: Sequence of events and timing

4. Contracts and payoffs with only 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 in regions I and III 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 union of regions III and IV 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
\[
x^* = \frac{u + S_{D(M0)}N_U - p_{C0}^{M0} - 0.5t^U_y}{t_x^U}
\]

\[
x^{**} = \frac{u + S_{D(M0)}N_U - p_{C0}^{M0}}{t_x^U}
\]

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 \( y = 0.5 \) indifferent.

\[
p_{U(M0)}^{C0} = p_{U(M0)}^{C1} = i^C_U + t^U_y
\]

**Figure 3: User market shares with one OS.** Bundle \( \{C_1M_0\} \) is sold to regions I and II while bundle \( \{C_0M_0\} \) is sold to regions III and IV. Region V is unserved.

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

\[
S_{D(M0)} = \frac{v + S_{U(M0)}N_D - p_{D}^{M0} - t^D_y}{t_x^D}
\]
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

$$p_{D}^{M_0} = \frac{v + N_D - t_y^D + i_D^M}{2}$$

which allows us to calculate $M_0$’s market share for Developers.

$$S_{D(M_0)} = \frac{v + N_D - t_y^D - i_D^M}{2t_x^D}$$

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

**Proposition 1:** When only one operating system is available, the market for Users is fully covered if the User transport cost for OSes ($t_x^U$) is equal to or less than

$$u + N_U \left( v + N_D - t_y^D - i_D^M \right)/2t_x^D - i_U^C - 3t_y^U/2.$$

**Proof:** See appendix.

The intuition behind this result is that the User market can be fully covered by a single OS only if the transport cost in the $x$ direction (preferences for OSes) is sufficiently low. The first three components of the maximum transport cost come from the location of $x^{**}$ which is increasing in the intrinsic utility of a smartphone, increasing in the cross-side network effect from Developers (conditional on a covered User market), and decreasing in the Carrier’s marginal cost of serving Users. The fourth component is decreasing in User’s preference for Carriers which creates the difference between $x^*$ and $x^{**}$.

At these prices, the payoffs are as follows. Per assumption A5, in the present study we assume that price coordination through contracts is illegal or infeasible, so all side-payments are zero.
\[
\pi_{M0} = \frac{1}{\mu} \left( \frac{v + N_D - t^y_D - i^M_D}{2} \right)^2 - 2i^C_C
\] (10a)

\[
\pi_{C0} = \pi_{C1} = \frac{t^U_y}{2} - t^C_M
\] (10b)

\[
\nu^{M0}_{(x,y)} = \frac{v + N_D - t^y_D - i^M_D}{2} - xt^D_x
\] (10c)

\[
U^{CM0}_{(x,y)} = u + \frac{v + N_D - t^y_D - i^M_D}{2t^D_x} N_U - i^C_U - xt^U_x - (1 + y)t^U_y
\] (10d)

\[
U^{CM0}_{(x,y)} = u + \frac{v + N_D - t^y_D - i^M_D}{2t^D_x} N_U - i^C_U - xt^U_x - (2 - y)t^U_y
\] (10e)

Consumer welfare for Developers and Users is

\[
CW_D = \frac{v + N_D - t^y_D - i^M_D}{2}
\] (11a)

\[
CW_U = u + \frac{v + N_D - t^y_D - i^M_D}{2t^D_x} N_U - \frac{t^U_x}{2} - \frac{5t^U_y}{4} - i^C_U
\] (11b)

In the next section, we consider the entry of the second OS, M1 in the market with no exclusive contracts between the OS and Carriers.

5. Contracts and payoffs with entrant OS and non-exclusive contracts

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 M1
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 as shown in Figure 4.

![Diagram](image)

**Figure 4: User market shares.** Bundle $\{C_i M_0\}$ is sold to region I, bundle $\{C_i M_1\}$ is sold to region II, bundle $\{C_0 M_0\}$ is sold to region III, and bundle $\{C_0 M_1\}$ is sold to region IV.

The competitive price is the same for all four bundles, and the same as derived above in (6):

$$P^C_{U(M0)} = P^C_{U(M1)} = P^C_{U(M0)} = P^C_{U(M1)} = i^C_U + t^U_y$$

(12a)

However, Users with $x > .5$ will be better off by choosing one of the new bundles. The payoffs to the Carriers (who compete away the entire surplus from cross-side network effects) are:

$$\pi_{C0} = \pi_{C1} = \frac{t^U_y}{2} - 2t^C_M$$

(13a)

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

$$V^{M0}_{(x,y)} = v + \frac{N_D}{2} - p^M_D - xt^D_x - t^D_y$$

(14a)

$$V^{M1}_{(x,y)} = v + \frac{N_D}{2} - p^M_D - (1-x)t^D_x - t^D_y$$

(14b)

$$V^{both}_{(x,y)} = v + N_D - p^M_D - p^M_D - t^D_x - t^D_y$$

(14c)
The operating systems are symmetric, so their prices will be the same. If the Developer market is not completely covered, then the market sizes are:

\[ S_{D(M0)} = S_{D(M1)} = \frac{v + \frac{N_D}{2} - p_D^{M0} - t_y^D}{t_x^D} < \frac{1}{2} \] (15)

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

\[ S_{D(0\text{only})} = S_{D(1\text{only})} = 1 - \frac{N_D}{2} - \frac{p_D^{M0}}{t_x^D} \leq \frac{1}{2} \] (16a)

\[ S_{D(both)} = \frac{N_D - 2p_D^{M1}}{t_x^D} - 1 \] (16b)

The optimal OS price for a Developer markets that is not fully covered and fully covered, respectively, is

\[ p_D^{M0} = p_D^{M1} = \frac{v + \frac{N_D}{2} - t_y^D + i_M^D}{2} \] (17a)

\[ p_D^{M0} = p_D^{M1} = \frac{\frac{N_D}{2} + i_M^D}{2} \] (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

\[ N_D < (v + 3t_y^D)(t_y^D - v) / (t_y^D + v) + 2i_M^D. \]

**Proof:** See appendix.
The intuition behind this result is that each OS offers Developers a valuable intrinsic benefit as well as a cross-side network effect. If the network effect is very strong, each OS can act as a local monopoly and avoid competing in the middle of the market. When the cross-side network effect is relatively weak, each OS must defend against possible encroachment by its rival. The defensive price-cutting is sufficient to cover the Developer market.

If Developer market is fully covered, the payoffs are:

\[
\pi_{M0} = \pi_{M1} = \left( \frac{N_D - i_D^M}{2} \right)^2 - 2i_C^M \quad (18a)
\]

\[
\pi_{C0} = \pi_{C1} = \frac{t_y^U}{2} - 2i_C^M \quad (18b)
\]

\[
V_{(s,x)} = v + \frac{N_D}{4} - \frac{i_D^M}{2} - t_x^D - \min \left[ x t_x^D, (1-x) t_x^D, \frac{i_D^M}{2} + t_x^D \right] \quad (18c)
\]

\[
U_{(s,y)} = u + \frac{N_D}{4} - \frac{2i_D^M}{4t_x^D} - N_U - i_U^C - \min \left[ x t_y^U, (1-x) t_y^U \right] - \min \left[ (1+y) t_y^U, (2-y) t_y^U \right] \quad (18d)
\]

Consumer welfare for Users and Developers if Developers are fully covered are:

\[
CW_D = v - t_y^D + \frac{1}{t_x^D} \left[ \left( \frac{N_D}{2} - i_D^M \right) \left( t_x^D + \frac{i_D^M}{2} \right) - \left( \frac{t_x^D + i_D^M}{2} \right)^2 + \left( \frac{N_D}{2} - i_D^M - t_x^D \right)^2 \right] \quad (19a)
\]

\[
CW_U = u - i_U^C - \frac{5t_y^U + t_x^U}{4} + N_U \left( \frac{N_D - 2i_D^M}{4t_x^D} \right) \quad (19b)
\]

If the Developer market is not fully covered, the payoffs are:

\[
\pi_{M0} = \pi_{M1} = \left( \frac{v + N_D - t_y^D - i_D^M}{2} \right)^2 - 2i_C^M \quad (20a)
\]
\[ \pi_{C0} = \pi_{C1} = \frac{t_y^U}{2} - 2t_y^C \]  

(20b)

\[ V_{(x,y)} = \frac{N_D}{4} + \frac{v + t_y^D - i_D^y}{2} - t_y^D - \min \left[ xt_x^U, (1-x)t_x^D \right] \]  

(20c)

\[ U_{(x,y)} = u + \frac{v + N_D}{2} - t_y^M \]  

(20d)

Consumer welfare for Users and Developers if Developers market is not fully covered are:

\[ CW_D = \frac{\left( 2t_D^M - N_D + 10t_D^y - 2v \right) \left( 2t_D^M - N_D - 6t_y^D - 2v \right)}{16t_y^D} \]  

(21a)

\[ CW_U = u - i_u^C - \frac{5t_y^U}{4} + \frac{N_U}{2t_x^D} \left( v + \frac{N_D}{2} - i_D^y - t_y^D \right) \]  

(21b)

**Proposition 3:** Consumer welfare for Users is higher when the market for Developers is fully covered in equilibrium.

**Proof:** See appendix.

The intuition behind this result is that Carriers compete away any premium for cross-side network effects, so Users benefit from having the Developer market fully covered. The consumer welfare in (21b) is not axiomatically greater than it is in (19b), but it is greater under the conditions that lead to full coverage of the Developer market.

**Proposition 4:** Consumer welfare for Developers is higher when the market for Developers is fully covered in equilibrium.

**Proof:** See appendix.
The intuition behind this result is that under full coverage of the Developer market, OSes compete away any premium for cross-side network effects. Since the User market is always covered in our model, Developers gain the same overall value for a lower price under the conditions that lead to full coverage of the Developer market.

In the next section, we consider the case where the new entrant OS $M_1$ has an exclusive contract with Carrier $C_1$. Therefore, Users can access OS $M_1$ only through Carrier $C_1$, but can access OS $M_0$ through Carriers $C_0$ and $C_1$.

6. Contracts and payoffs with 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:

$$U_{(x,y)}^{CM0} = u + S_{D(M0)}N_U - p_{U(M0)}^{C0} - xt_U - yr_U$$ (22a)

$$U_{(x,y)}^{CM1} = u + S_{D(M0)}N_U - p_{U(M0)}^{C1} - xt_U -(1-y)t_U$$ (22b)

$$U_{(x,y)}^{CM1} = u + S_{D(M1)}N_U - p_{U(M1)}^{C1} -(1-x)t_U -(1-y)t_U$$ (22c)

**Proposition 5:** The three indifference lines implied by equations (22a), (22b), and (22c) cross at a single point, leading to User preferences such as those in Figure 5.

**Proof:** See appendix.
Figure 5: User market shares with one exclusive OS. Bundle \{C_1M_0\} is sold to region I, bundle \{C_0M_0\} is sold to region II, and bundle \{C_1M_1\} is sold to region III.

The intuition behind this result is that if the set of Users indifferent between \{C_0M_0\} and \{C_1M_0\} intersects with the set indifferent between \{C_0M_0\} and \{C_1M_1\}, it must do so where Users are indifferent between \{C_1M_0\} and \{C_1M_1\}. Our Hoteling setup guarantees that indifference sets between any pair of bundles are straight lines; assumption A4 guarantees that the \{C_0M_0\}-\{C_1M_0\} and \{C_0M_0\}-\{C_1M_1\} lines cannot be parallel;\(^5\) therefore they must cross somewhere.

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

\(^5\) The lines would be parallel if \(t_i^\prime = 0\), and collinear if the OSes’ Developer market shares were symmetric.
The areas of these regions are given by:

\[
S_{U(C0M0)} = \frac{1}{4t_x^U t_y^U} \left( \left( S_{D(00)} - S_{D(M1)} \right) N_U + t_x^U + p_{U(M1)}^C - p_{U(M0)}^C \right) \left( t_x^U + p_{U(M0)}^C - p_{U(M0)}^C \right)
+ \frac{t_y^U}{8t_x^U} \left( 1 + \frac{p_{U(M0)}^C - p_{U(M0)}^C}{t_y^U} \right) \tag{23a}
\]

\[
S_{U(C1M0)} = \frac{1}{4t_x^U t_y^U} \left[ \left( t_y^U + p_{U(M0)}^C - p_{U(M0)}^C \right)^2 + \left( S_{D(M0)} - S_{D(M1)} \right) N_U \left( t_x^U + p_{U(M0)}^C - p_{U(M0)}^C \right) \right] \tag{23b}
\]

\[
S_{U(C1M1)} = \left( \frac{1}{2} - \frac{\left( S_{D(M0)} - S_{D(M1)} \right) N_U + p_{U(M1)}^C - p_{U(M0)}^C}{2t_x^U} \right) \frac{t_y^U}{8t_x^U} \left( 1 + \frac{p_{U(M0)}^C - p_{U(M0)}^C}{t_y^U} \right) \tag{23c}
\]

Unlike the model in Cai et al. (2012), all three of these regions can have positive area even in the absence of revenue sharing which we disallowed in assumption A5. The Carrier compensates the OS with a cross-side network effect in lieu of direct payments per customer. The User share for each OS is:

\[
S_{U(M0)} = \frac{t_y^U + p_{U(M0)}^C - p_{U(M0)}^C}{4t_x^U} \times \left[ \frac{3}{2} + \frac{1}{t_y^U} \left[ 2N_U \left( S_{D(M0)} - S_{D(M1)} \right) + p_{U(M0)}^C - 2p_{U(M0)}^C + p_{U(M1)}^C + t_x^U \right] \right] \tag{24a}
\]

\[
S_{U(M1)} = \frac{1}{2} - \frac{1}{8t_x^U} \left[ 4N_U \left( S_{D(M0)} - S_{D(M1)} \right) - p_{U(M0)}^C - 3p_{U(M0)}^C + 4p_{U(M1)}^C + t_y^U \right] \tag{24b}
\]

The solutions for User shares are recursive (User share depends on Developer share which depends on User share) but in this form the tension facing \( C_1 \) is apparent in equation (24b) because \( C_1 \)’s price for access to \( M_0 \) has three times the impact on \( M_1 \)’s share of Users than does \( C_0 \)’s price for access to \( M_0 \).
7. Discussion and conclusion

While many platforms require a number of firms to connect the two 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 compared to a single platform owner. We have used this worst-case scenario to illustrate the essential features of our model and how it addresses the market distortions introduced by a multilayer network.

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. Existing two-sided network models cannot address this very important problem because they implicitly assume that the platform partners are perfectly cooperative. One interesting question that immediately arises is how these contracts affect consumer welfare of Users and Developers.

The second distortion, and a 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 in a partner firm 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. We show that the network effect at work in this market is of crucial importance, especially if side payments or revenue sharing are constrained by regulators. The cross-side network effect appears to substitute for the revenue sharing that the Cai et al. (2012) model requires to allow exclusive contracts in equilibrium.

We also show that the third distortion, 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 §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.

When considering feasible contracts, it is important to keep in mind the limitations of our model. Like all models, ours is a stylized representation of reality that relies upon a number of assumptions. Assumptions A1, A2 and A3 are provided to make explicit some of the implicit assumptions of the Hoteling model. Setting the outside option to a nonzero constant would introduce an affine transformation to the payoffs in our model but leave our results qualitatively unchanged. Assumption A4 aligns our model with popular opinion that preferences for smartphone mobile OSes are stronger than preferences for mobile carriers. If this assumption is violated, it constrains the admissible parameter values under Propositions 1 and 5 while making the calculation of payoffs considerably more complex (each would need four versions to account for different ordering of User and Developer preferences). We made assumption A5 to focus on
the essential elements of our model and contrast it with the results of Cai et al. (2012). Relaxing assumption A5 is an important avenue for future research.

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.

References


6 This is distinct from the analysis on whether such a contract is illegal or anticompetitive. “While the iPhone’s business arrangement may prove detrimental to consumers in the long run, antitrust laws ultimately focus on competition, not consumers.” (Greenhalgh, 2008)


Proposition 1: When only one operating system is available, the market for Users is fully covered if the User transport cost for OSes ($t_x^U$) is equal to or less than

$$u + N_U \left( v + N_D - t_y^D - t_D^M \right) \geq \frac{2t_x^D - i_U^C - 3t_y^U}{2}.$$  

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

$$t_x^U \leq u + \frac{N_U}{2t_x^D} \left( v + N_D - t_y^D - t_D^M \right) - i_U^C - \frac{3t_y^U}{2} \quad (A1)$$

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.

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 $N_D < \left( v + 3t_y^D \right) \left( t_y^D - v \right) \left( t_y^D + v \right) + 2t_D^M$.

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:

\[ N_D < \frac{(3t_y^D + v)(t_y^D - v)}{(t_y^D + v)} + 2t_D^M \]  

(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.

**Proposition 3:** *Consumer welfare for Users is higher when the market for Developers is fully covered in equilibrium.*

**Proof of Proposition 3:** Inspection of equations (19b) and (21b) shows that the former is greater when \( t_y^D > v \). 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.

**Proposition 4:** *Consumer welfare for Developers is higher when the market for Developers is fully covered in equilibrium.*

**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.

**Proposition 5:** *The three indifference lines implied by equations (22a), (22b), and (22c) cross at a single point, leading to User preferences such as those in Figure 5.*

**Proof of Proposition 5:** The indifference lines implied by the utility payoffs are:
\[ y = \frac{1}{2} + \frac{p_{U(M_0)}^{C_1} - p_{U(M_0)}^{C_0}}{2t_y^U} \]

\[ y = \frac{1}{2} + \frac{\left( S_{D(M_0)} - S_{D(M_1)} \right) N_U + p_{U(M_1)}^{C_1} - p_{U(M_0)}^{C_0} + t_x^U}{2t_y^U} - \frac{t_x^U}{t_y^U} x \]  \hspace{1cm} (A3)

\[ x = \frac{1}{2} + \frac{\left( S_{D(M_0)} - S_{D(M_1)} \right) N_U + p_{U(M_1)}^{C_1} - p_{U(M_0)}^{C_1}}{2t_x^U} \]

So long as \( t_x^U > 0 \), which is guaranteed by assumption A4, these three lines have a unique common solution:

\[ x = \frac{1}{2} + \frac{\left( S_{D(M_0)} - S_{D(M_1)} \right) N_U + p_{U(M_1)}^{C_1} - p_{U(M_0)}^{C_1}}{2t_x^U} \]  \hspace{1cm} (A4)

\[ y = \frac{1}{2} + \frac{p_{U(M_0)}^{C_1} - p_{U(M_0)}^{C_0}}{2t_y^U} \]

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