Platform Competition and Compatibility Decisions: The Case of Apple's iPad vs. Amazon's Kindle*

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Abstract

We study compatibility decisions of competing platforms when they generate profits through both hardware sales and royalties from content sales. We show that when the two platforms provide different values to their users, their major sources of profits may differ—one platform may generate most of its profits from hardware sales, while the other's profits will result mostly from royalties of content sales. This difference may give rise to incentives to establish one-way compatibility in a competitive setting: both platforms become more profitable when the platform with greater reliance on content sales allows users of the competing platform to access its content. We relate our results to platform decisions in the e-reader market.

Keywords: compatibility; two-sided platforms; e-reader market

1 Introduction

An increasing number of markets today are organized around platforms, which enable consumers to access and/or purchase complementary goods and services. These platforms are two-sided because both sides—consumers and complementors—need to gain access to the same platform to be able to interact or conduct transactions. For example, operating systems such as Windows, Macintosh or Linux serve as platforms connecting two parties: on one side, computer users need an operating system to access software applications; on the other, independent software application developers need to access the operating systems programming interface to develop software applications which they can then sell to consumers. Other examples of such markets include video game consoles, newspapers, smartphones, e-books, credit cards, shopping malls, and social networking sites. Platform-based markets comprise a large share of the economy today—Ranked by market value, 60 of the world's 100 largest corporations earn at least half of their revenue from platform-based markets (Eisenmann 2007).

The literature on platform-based markets has focused on a number of strategies a platform can use to grow its business such as two-sided pricing (e.g., Rochet and Tirole 2003; Parker and Van Alstyne 2005; Armstrong 2006; Hagiu 2006), quality investment (e.g., Casadesus-Masanell and Llanes forthcoming), competitive interactions between platforms with different business models (e.g., Economides and Katsamakas 2006; Casadesus-Masanell and Zhu 2010), and managing relationships with complementors (e.g., Carrillo and Tan 2008; Hagiu and Spulber 2013). Our study complements these studies by examining platforms' compatibility decisions in a competitive setting. The study is motivated by empirical observations in the e-reader market, where two major platforms—Apple's iPad and Amazon's Kindle—compete aggressively against each other. These hardware devices allow consumers to read e-books through their proprietary e-book readers, iBooks and Kindle Reader. Amazon's first Kindle device was released in 2007 and Apple's first iPad was released in 2010. After Apple's entry into the market, Amazon decided to make its Kindle Reader available on Apple's

device, thus allowing consumers to read e-books purchased from Amazon on Apple's iPad. Interestingly, although Apple is well known for rejecting third-party applications when they compete directly with Apple's own offerings, it approved Amazon's Kindle Reader for its hardware device. On the other hand, however, Apple has not reciprocate and made its iBooks available for Amazon's Kindle device.

What motivates the two competing platforms to make Kindle Reader available on iPad but not vice versa? We develop a formal model to analyze this phenomenon. In our model, two competing platform generates profits from both hardware sales and royalties from content sales. We analyze a three-stage game. In the first stage, both platforms make compatibility decisions. Compatibility is achieved when one platform decides to make its proprietary content reader on its competitor's platform and the competitor agrees. In the second stage, platforms decide on their hardware prices. Finally, users purchase hardware and content.

We show that when the two platforms provide different values to their users, their major sources of profits may differ—one platform may generate most of its profits from hardware sales, while the other's profits will result mostly from royalties of content sales. This difference may give rise to incentives to establish one-way compatibility in a competitive setting: both platforms become more profitable when the platform with greater reliance on content sales allows users of the competing platform to access its content. Our model also allows for social welfare analysis and we find that social welfare is greater under one-way compatibility than incompatibility.

We relate our findings to the e-reader market. In the e-reader market, as Apple's iPad provides many other features beyond reading e-books, Apple in equilibrium generates more profits from its hardware sales than royalties from e-book sales. In contrast, Amazon, whose Kindle is almost exclusively an e-book reader, generates most its profits from royalties from e-book sales in equilibrium. When this difference in profit focuses is large enough, we find that both Apple and Amazon will be willing to have Kindle Reader on iPad. In this case, the additional profits Apple generates from hardware sales more than compensates its loss

in royalties from e-book sales through its iBooks. Similarly, the additional profits Amazon generates from e-book sales is greater than its loss in Kindle device sales. In particular, when Amazon subsidies Kindle sales, we show it is always in Amazon's interest to have Kindle Reader on Apple's iPad. However, it is never in Apple and Amazon's interest to have iBooks available on Kindle device.

We also extend our baseline model to examine how other factors such as hardware cost difference and exclusive contracts with content suppliers may affect our results. We find that with different production costs, our main result remains virtually unchanged. When the platform with smaller value has exclusive titles, its competitor has more incentives to achieve compatibility than itself.

1.1 Literature Review

The setup of our model shares common features with the theoretical literature on two-sided markets (e.g., Rochet and Tirole 2003; Caillaud and Jullien 2003). Theoretical models in this literature tend to be industry-specific to incorporate unique features of different industries. For example, Rochet and Tirole (2003) model the credit card market, Armstrong (2006) studies shopping malls and newspapers, and Zhu and Iansiti (2012) examine competition between video game consoles. We follow this tradition to build a model about competition between e-reader providers. The extant theoretical models often focus on competition between symmetric platforms. The few papers examining competition between asymmetric platforms tend to look at platforms with very different business models. For example, Casadesus-Masanell and Ghemawat (2006) and Economides and Katsamakas (2006) look at the competition between proprietary and open source platforms, and Casadesus-Masanell and Zhu (2010) studies the competition between a platform that is both subscription based and ad sponsored, and a platform that is entirely ad sponsored. In contrast, our paper focuses on two platforms with similar business models; the only difference being the amount of value they create for the users. We show that this difference alone leads to opportunities

for them to cooperate while competing with each other.

A subset of this literature addresses the issue of compatibility. Doganoglu and Wright (2006) examine the difference between multi-homing and compatibility and find multi-homing reduces platforms' incentives to achieve compatiblity. Orman (2008) finds that sometimes a proprietary platform may prefer compatibility when competing with an open, freely accessible platform. Miao (2009) shows that a monopoly platform has an incentive to stay incompatible to prevent competition in the complementary market. Casadesus-Masanell and Ruiz-Aliseda (2009) show that a large platform may prefer incompatibility because of the quest for market dominance. Viecens (2011) shows that a platform with a smaller stand-alone value will always prefer compatibility even though its competitor never will. Maruyama and Zennyo (2013) find that compatibility depends on product life cycles—when most users have purchased hardware, profits for platforms come largely from their content purchases. Typically, in these studies, providers of complementary applications or content are assumed to single-home. As a result, with compatibility, users of one platform can have access to applications or content on the other platform. In contrast, in our model, content providers multi-home (as they typically do in reality) and the benefit from compatibility comes from the access to the content reader that matches with users' preferences.

The rest of the paper is organized as follows. Section 2 presents the setup of our baseline model. Section 3 provides equilibrium results under incompatibility and compatibility separately. Section 4 compares the two cases and derives conditions under which platforms prefer compatibility over incompatibility. We provide several extensions of our model in Section 6. While we build our model specific to the e-reader market, the basic insight—that competing platforms with different focuses on their profit sources may have incentives to cooperate with each other—applies to other platform-based markets as well. We discuss the generalizability of our results and conclude in Section 7.

2 The Baseline Model

We consider Apple's iPad and Amazon's Kindle as horizontally differentiated products. We use i to index iPad and k to index Kindle, and use the standard Hotelling setup to model competition between iPad and Kindle.

In particular, we assume that the two platforms, i and k, are located at locations 0 and 1 of a line of length 1, respectively. A continuum of consumers of measure 1 are uniformly distributed along the line, and each consumer chooses to adopt one of the two platforms. Consumer utility for each platform is the value she derives from the platform net the price and the disutility from the mismatch between the platform and her taste. The mismatch is measured by the distance between the platform's and her locations on the line. We denote p_j as price and U_j as the utility derived from platform j, $j \in \{i, k\}$. The utility for a consumer located at x from each device can be formulated as

$$U_i = v_i - tx - p_i \quad (1)$$

$$U_k = v_k - t(1-x) - p_k \quad (2)$$

in which v_j is the value derived from platform j and t is the unit mismatch cost. Notice that v_j captures the value that a user derives from using the platform, such as reading e-books. Because iPad provides many more additional features than Kindle, we assume that $v_i > v_k$. We also assume the difference between v_i and v_k , $v_d = v_i - v_k$, is not too large such that in equilibrium both firms have positive market shares. Because the hardware and the software can be decoupled on each device, we assume that the unit mismatch cost, t, consists of both unit hardware mismatch cost, t_h, and software/reader mismatch cost, t_s: $t = t_h + t_s$. Consumers compare the two platforms and choose the one that offers higher utility.

When Kindle Reader is available on iPad, consumers who purchase iPad have the option between the two software applications—iBooks and Kindle Reader, and they choose the software that provides a lower mismatch cost. In particular, the software mismatch cost

decreases for consumers who purchase iPad hardware but prefer Kindle Reader over iBooks. In this case, we can reformulate the utility that consumers derive from using iPad as

$$U_i = v_i - t_h x - t_s \min\{x, 1-x\} - p_i \tag{3}$$

As we shall show, in equilibrium, whether iBooks is available on Kindle device does not make a difference. For now, we assume that iBooks is unavailable on Kindle device, and the utility that consumers derive from using Kindle remains the same as in Equation (2).

We assume book publishers multi-home and sell their e-books on both devices. In practice, both Amazon and Apple charge a commission fee for each e-book sold on their devices. Therefore, when the two platform providers sell their devices, they also earn revenue from e-book sales. We denote the average commission fee that each device manufacturer can earn from selling books to a consumer to be γ. For ease of exposition, in this baseline model, we assume the marginal cost of the devices to be zero. Hence, we can formulate the profit functions of Apple and Amazon from device buyers and book publishers as follows:

$$\pi_j = p_j D_{jh} + \gamma D_{js} \tag{4}$$

where $j \in \{i, k\}$, D_{jh} denotes the number of consumers who purchase hardware device from platform j and D_{js} is the number of consumers who use software by platform j to read e-books. When Kindle Reader is unavailable on iPad, the number of consumers who purchase hardware from a platform is equal to the number of consumers who use software offered by the same platform; that is $D_{jh} = D_{js}$. When Kindle Reader is available on iPad, some iPad buyers may use Kindle Reader instead of iBooks. In this case, $D_{ih} > D_{is}$ and $D_{kh} < D_{ks}$.

3 Equilibrium Analysis

We first analyze the incompatible case in which neither platform's software is available on its competitor's device, and then examine the one-way compatibility case in which Amazon's Kindle Reader is available on iPad.

3.1 Incompatible Case

When neither platform's software is available on its competitor's device, the competition between two platforms is similar to the standard Hotelling setup except that two platforms offer different value v_i and v_k and the revenue for each firm comes from two sources—the hardware sales and commissions from e-book sales. As in the standard setup, by letting $U_i = U_k$, we can derive the indifferent consumer's location as $x^* = \frac{v_d-(p_i-p_k)+t}{2t}$. The consumers who have smaller mismatch to product i than the indifferent consumer purchase platform i, and the other consumers purchase platform k. Hence, the profit functions of the two firms in Equation (4) can be specified as

$$\pi_i = p_i x^* + \gamma x^* \tag{5}$$

$$\pi_k = p_k(1 - x^*) + \gamma(1 - x^*) \tag{6}$$

Solving the first order conditions for the two profit-maximizing firms, we obtain the equilibrium prices, equilibrium profits, and equilibrium indifferent consumer, as summarized by the following lemma.

Lemma 1. *When neither platform's software is available on its competitor's device, the equilibrium prices are*

$$p_i = \frac{1}{3}(3t + v_d - 3\gamma) \tag{7}$$

$$p_k = \frac{1}{3}(3t - v_d - 3\gamma) \tag{8}$$

the indifferent consumer is at $x^* = \frac{1}{2} + \frac{v_d}{6t}$*, and the equilibrium profits are*

$$\pi_i = \frac{(3t + v_d)^2}{18t} \tag{9}$$

$$\pi_k = \frac{(3t - v_d)^2}{18t} \tag{10}$$

Proof. All proofs are included in an appendix. □

Several observations of the equilibrium are worth highlighting. First, we notice that $p_i > p_k$, $x^* > \frac{1}{2}$, and $\pi_i > \pi_k$. This result is expected because iPad is more attractive to users than Kindle (captured by $v_i > v_k$ in the model), which allows Apple to charge a higher price as well as gain a bigger market share. As a result, Apple makes more profits than Amazon.

Second, when the per-user e-book profit, γ, increases, both p_i and p_k decreases and can become negative (i.e., below cost). In such cases, the platforms have incentives to subside users for using the devices in return for profits from e-book sales. This pricing pattern and business model in general are similar to that for complementary products, such as the cases of selling printers and toner and selling razors and blades.

Third, the equilibrium profits are unrelated to γ, although the prices depend on γ. This is because profits from e-book sales are competed away for the two platforms: as long as a firm can attract a user, it makes γ amount of additional profits. Hence, firms are willing to subsidize each user up to γ amount in a competitive setting.

3.2 Compatible Case

When Kindle Reader is available on iPad, the consumers who purchase iPad have the choice between two software applications and can choose the one that provides the better fit. If the indifferent consumer is located at $x^* \geq \frac{1}{2}$. We can derive the indifferent consumer by letting

$U_i = U_k$. In particular, based on Equations (2) and (3), we have

$$v_i - t_h x - t_s(1-x) - p_i = v_k - t_h(1-x) - t_s(1-x) - p_k \tag{11}$$

We thus have $x^* = \frac{v_d - (p_i - p_k) + t_h}{2t_h}$. If the indifferent consumer is located at $x^* < \frac{1}{2}$, because of the consumers who purchase iPad prefer the iBooks rather than Kindle Reader, the indifferent condition is the same as in the incompatible case and x^* takes the same form as x^*.

In this case, the consumers who have lower mismatch to product i than the indifferent consumer purchase platform i, and the other consumers purchase platform k. So the demand for the hardware for platform i and k are x^* and $(1 - x^*)$, respectively. The demand for the software, however, depends on the location of x^*. When $x^* < \frac{1}{2}$, the consumers who purchase iPad prefer iBooks and thus the demand for iBooks is x^*. When $x^* \geq \frac{1}{2}$, the consumers located at $\left[\frac{1}{2}, x^*\right]$ purchase iPad but use Kindle Reader instead of iBooks. In other words, half of the users prefer iBooks and the other half prefer Kindle Reader. Notice that e-books sold through iBooks generate profit for Apple and those sold through Kindle Reader generate profit for Amazon. The profit functions of the two platforms in Equation (4) thus can be specified as

$$\pi_i = p_i x^* + \gamma \min\left\{\frac{1}{2}, x^*\right\} \tag{12}$$

$$\pi_k = p_k(1 - x^*) + \gamma\,(1 - x^*) + \gamma \max\left\{x^* - \frac{1}{2}, 0\right\} \tag{13}$$

Amazon's profits now consist of Kindle hardware profits, and profits from e-book sales through Kindle Reader on Kindle and iPad. Solving the first order conditions for the two profit-maximizing platforms, we obtain the equilibrium prices, equilibrium profits, and equilibrium indifferent consumer, as summarized by the following lemma.

Lemma 2. *When Kindle Reader is available on iPad, the equilibrium prices are*

$$\hat{p}_i = \frac{1}{3}(3t_h + v_d) \tag{14}$$

$$\hat{p}_k = \frac{1}{3}(3t_h - v_d) \tag{15}$$

the indifferent consumer is at $x^* = \frac{1}{2} + \frac{v_d}{6t_h}$*, and the equilibrium profits are*

$$\pi_i = \frac{(3t_h + v_d)^2}{18t_h} + \frac{\gamma}{2} \tag{16}$$

$$\pi_k = \frac{(3t_h - v_d)^2}{18t_h} + \frac{\gamma}{2} \tag{17}$$

In equilibrium, as in the incompatible case, $p_i > p_k$, $x^* > \frac{1}{2}$, and $\pi_i > \pi_k$; in other words, Apple charges a higher price for its iPad than Amazon charges for its Kindle device, and Apple has a larger market share and earns a higher profit than Amazon. As the indifferent consumer is located at $x^* > \frac{1}{2}$, half of the consumers use Kindle Reader and the other half use iBooks, which explains the term $\frac{\gamma}{2}$ in the profit functions. As a result, revenue contribution from e-book sales is simply $\frac{\gamma}{2}$ for each platform. Because the number of consumers using iBooks or Kindle Reader is independent of hardware prices, Apple and Amazon's pricing decisions of their devices will only depend on the value their hardwares provide to consumers. Hence, because iPad offers a higher value than Kindle device, Apple's iPad price is higher and its market share is greater in equilibrium. We also notice that different from the incompatible case, although hardware prices are independent of the per-user e-book profit γ, the equilibrium profits are increasing with γ.

4 Comparison of the Two Cases

We next compare the equilibria in the two cases, and examine the condition under which both firms have incentive to have Amazon's Kindle Reader on Apple's iPad. To make the comparison easier, we use regular notation (e.g., p_j) for the equilibrium outcome in the

incompatible case, and use notation with a hat (e.g., $\hat{p}_j$) for the equilibrium outcome in the compatible case.

First, comparing equilibrium prices in the two cases summarized in Lemmas 1 and 2, we have the following result.

Proposition 1. *If and only if $t_s \leq \gamma$, platforms charge higher prices in the compatible case than in the incompatible case, i.e., $p_j \leq \hat{p}_j$.*

The intuition is as follows. Recall that platforms' revenue consists of hardware sales and e-book sales. Having Kindle Reader available on iPad, on the one hand, reduces the competition for the e-book sales, because it is always the case that the two platforms will split the e-book demand evenly, while in the incompatible case, the two platforms will compete for e-book demand, too. On the other hand, compared to the incompatible case, having Kindle Reader available on iPad increases the competition between the two platforms because of a reduction in platform differentiation— consumers located in $(1/2, \hat{x}^*)$ can now choose to use Kindle Reader, while in the incompatible case, they are forced to use iBooks, which has a higher mismatch than Kindle Reader for them. The reduction in the competition for e-book sales is reflected by the per-user book profit γ. The increase in the competition due to the reduction in software differentiation is reflected by t_s. Whether platforms charge higher prices in the compatible case thus depends on the balance between the reduction in the competition for e-book sales and the increase in the competition for hardware.

We also notice changes in the demand for each platform from the incompatible case to the compatible case.

Proposition 2. *More consumers purchase iPads in the compatible case than in the incompatible case: $x^* < \hat{x}^*$.*

As illustrated in Figure 1, with compatibility, Apple increases the sales of its iPad (from x^* to $\hat{x}^*$) but decreases its e-book sales via its iBooks (from x^* to $1/2$). In contrast, Amazon expects decrease in the sales of its Kindle but increase in the e-book sales. Therefore, each

platform gains demand in one component—either hardware or software, but loses demand in the other.

Having looked at changes in prices and demands for each platform, we next compare equilibrium platform profits in these two cases to determine when both platforms have incentives to have Amazon's Kindle Reader on Apple's iPad.

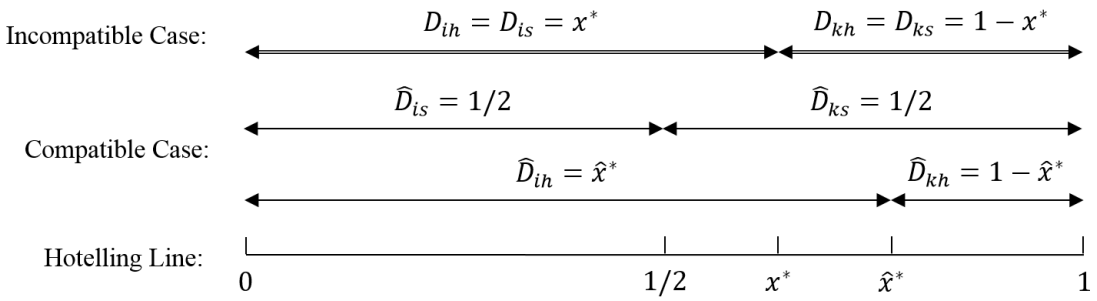

Figure 1: Changes in Demand for Each Firm

Proposition 3. *(a) If and only if* $9(\gamma - t_s) + v_d^2(\frac{1}{t_h} - \frac{1}{t}) \geq 0$*, Apple and Amazon both have incentives to have Amazon's Kindle Reader on Apple's iPad; (b) Both platforms are more likely to take Kindle Reader when* v_d *is large and/or when* γ *is large.*

Apple is more willing to accept Kindle Reader when the device's value advantage (i.e., v_d) is larger. Having Kindle Reader on iPad increases iPad, even though it decreases e-book sales through iBooks. As v_d increases, iPad sales become more important to Apple's profitability. Hence, Apple is more willing to sacrifice e-book sales in return for greater iPad sales.

Interestingly, when the per-user e-book profit γ is larger, Apple is more likely to have Kindle Reader on iPad. This result seems counter-intuitive, because, after all, e-book sales is a part of each platform's total revenue, and one would expect as γ increases Apple should be less willing to let Amazon take its book business. This counter-intuitive result roots in the fundamental difference of the competition in the two cases. In the incompatible case, profits from e-book sales are competed away—platforms are willing to subsidize each user up to γ amount and the equilibrium profits are independent of γ. In contrast, in the compatible case, each platform earns $\frac{\gamma}{2}$ revenue from e-book sales and thus the revenue is increasing

in per-user book sales γ. The different competition structures lead to the counter-intuitive result: when γ is larger, compared to the incompatible case, platforms charge relatively higher hardware prices and are more likely to achieve higher profits.

When v_d and/or γ are sufficiently large, both platforms have incentives to have Kindle Reader on iPad. In such cases, Apple relies more on its hardware sales and Amazon relies more on its book sales. In addition, even when $v_d = 0$, i.e., two platforms are symmetric, it is possible for the two platforms to be compatible if the per-user profit exceeds software differentiation. In this case, each platform gets a half of the demand both incompatible and compatible cases, but the price in the compatible case could be be higher because of the softened competition.

We next examine the effect of compatibility on social welfare. Social welfare here is defined as the sum of consumers' utility and platforms' profits, which equals the total consumer value realized from the consumption of the products. Therefore, in the incompatible case, the total social welfare generated can be formulated as

$$W(x^*) = \int_0^{x^*} (v_i - t_h x - t_s x)dx + \int_{x^*}^1 [v_k - t(1-x)]\, dx \tag{18}$$

and the in the compatible case, the total social welfare generated can be formulated as

$$\hat{W}(\hat{x}^*) = \int_0^{\hat{x}^*} (v_i - t_h x - t_s \min\{x, 1-x\})dx + \int_{\hat{x}^*}^1 [v_k - t(1-x)]\, dx \tag{19}$$

The main difference between the formulations of social welfare under the two cases is the mismatch cost associated with software applications. It is easy to see that if the locations of the indifferent consumers were the same (i.e., $x^* = \hat{x}^*$, social welfare in the compatible case would be always higher than that under the incompatible case. This is because the software mismatch cost for consumers at $[0, \hat{x}^*]$ in the compatible case is $t_s \min\{x, 1-x\}$ and in the incompatible case is $t_s x$. The former is always smaller than the latter. As illustrated in Figure 1, the indifferent consumer's location in the compatible case is to the right of that

in the incompatible case. We can show that moving the indifferent consumer to the right pushes the social welfare toward more efficient allocation.

Proposition 4. *The compatible case generates more social welfare than the incompatible case.*

The efficiency gain in the compatible case comes from the reduction of the total mismatch cost of the consumers. As iPad users can now choose to use Kindle Readers, more consumers will buy iPad, which helps achieve more efficient allocation.

5 Apple's iBooks on Kindle?

We next examine whether Apple has incentives to put iBooks on Amazon's Kindle device. There are two possible scenarios depending on whether Amazon's Kindle Reader is already available on Apple's iPad. Examining each scenario, we have:

Proposition 5. *Regardless of whether Amazon's Kindle Reader is on Apple's iPad or not, Apple is indifferent between having its iBooks on Kindle or not.*

The intuition is that in both scenarios, less than 50% of the consumers will buy Kindle. All these consumers will choose Kindle Reader regardless of whether iBooks is available to them or not because their mismatch cost with Kindle Reader is smaller. Hence, having iBooks on Kindle device makes no difference in the end.

6 Extensions

In this section, we extend the baseline model by considering cases when the two platforms have different production costs and when Amazon has exclusive e-book titles. We show the main insights delivered in our baseline framework remain the same.

6.1 Different Production Costs

In the baseline model, we assume that the two platforms have identical production costs and normalize their costs to be zero. In this extension, we allow the platforms to have different costs. In particular, we consider that Apple has a higher production cost for its iPad than Amazon for its Kindle. This assumption is more sensible than the other way, because we assume that iPad provides a higher value to consumers than a Kindle (i.e., $v_i > v_k$) and typically a higher value product comes with a higher production cost. As in the baseline model, we normalize the production cost for Kindle to be zero and assume that the production cost for an iPad is c, $c \geq 0$.

The main difference from the baseline case is that the profit function for Apple in the incompatible case in Equation (5) now becomes

$$\pi_i = (p_i - c)\, x^* + \gamma x^*$$

and the profit function in the compatible case becomes

$$\hat{\pi}_i = (\hat{p}_i - c)\hat{x} + \gamma \min\left\{\frac{1}{2}, \hat{x}\right\}$$

Solving the first order condition for the two profit-maximizing platforms, we can similarly derive equilibrium prices, demand and profits. For example, in the incompatible case, the equilibrium prices are

$$p_i = \frac{1}{3}(2c + 3t + v_d - 3\gamma) \tag{20}$$

$$p_k = \frac{1}{3}(c + 3t - v_d - 3\gamma) \tag{21}$$

the indifferent consumer is located at $x^* = \frac{1}{2} + \frac{v_d - c}{6t}$, and the equilibrium profits are

$$\pi_i = \frac{(3t + v_d - c)^2}{18t} \tag{22}$$

$$\pi_k = \frac{(3t - v_d + c)^2}{18t} \tag{23}$$

Obviously, Apple's cost disadvantage affects its equilibrium price, demand, and profit. For instance, compared to the baseline case with equal cost, the cost disadvantage induces Apple to charge a higher price and results in a lower demand. In particular, in the baseline case, Apple's demand is always greater than $\frac{1}{2}$ (i.e., $x^* > 1$ by Lemma 1). In contrast, when Apple has a cost disadvantage, its demand now is lower and can be even below $\frac{1}{2}$ when the value advantage cannot compensate the additional cost (i.e., when $v_d < c$).

In the compatible case, we obtain the equilibrium prices as:

$$\hat{p}_i = \frac{1}{3}(2c + 3t_h + v_d) \tag{24}$$

$$\hat{p}_k = \frac{1}{3}(c + 3t_h - v_d) \tag{25}$$

The indifferent consumer is located at $\hat{x}^* = \frac{1}{2} + \frac{v_d - c}{6t_h}$. Because the effect of the cost difference in platforms' equilibrium prices, demands, and profits are similar in both the incompatible and compatible cases, Propositions 1 and 2 continue to hold. The condition under which both firms have incentive to have Amazon's Kindle Reader on Apple's iPad is also similar to the baseline model.

Proposition 6. *(a) If and only if* $9(\gamma - t_s) + (v_d - c)^2(\frac{1}{t_h} - \frac{1}{t}) \geq 0$*, Apple and Amazon have incentive to have Amazon's Kindle Reader on Apple's iPad; (b) Apple is more likely to take Kindle Reader when* $(v_d - c)$ *is large and/or when* γ *is large.*

Different from the baseline model, instead of the value advantage v_d, the difference $(v_d - c)$ affects platforms' incentive to be compatible.

6.2 Exclusive E-Book Titles on Amazon

In the baseline model, we assume that all book publishers multi-home and all e-books are available on both platforms. In practice, Amazon, established as the primary book retailer online, may have bargaining power over some book publishers and thus can request for exclusive deals with Amazon. Also, some book publishers may choose to simply sell their e-books on one platform only, considering the cost of setting up and contracting with platforms. In this extension, we consider the case in which Amazon has some exclusive e-book titles and examine platforms' compatibility incentives.

We normalize the number of the e-books that are available on both platforms to be 1. In addition, Amazon has k exclusive titles. The number of exclusive titles on Amazon directly affects consumers utility derived from Amazon's Kindle device as well as Amazon's profit. Consumer utility from iPad remain the same as in the baseline model $U_i = v_i - tx - p_i$. We model the utility that consumers derive from Kindle as $U_k = (1+k)v_k - t(1-x) - p_k$. Basically, we assume that with more exclusive titles Kindle appears more attractive to consumers. We redefine the value difference $v_d = v_i - (1+k)v_k$. Because of the exclusive titles on Amazon, the value of Kindle is enhanced and the value difference is smaller than that in the baseline case.

Based on this utility function, as in the baseline model, we can similarly derive the indifferent consumer's location for each case, and formulate each platform's demand and profit function. Then, again, based on the best response to each other, we can derive the equilibrium prices, indifferent consumer's location, and equilibrium profits for both the incompatible and compatible cases. For example, in the incompatible case, based on this newly defined v_d, the expression for the indifferent point x^* is the same as in the baseline model. Apple's profit function also remains the same as in Equation (5). Amazon's profit in Equation (6) now becomes

$$\pi_k = p_k(1 - x^*) + (1 + k)\gamma(1 - x^*)$$

which indicates that Amazon has additional $k\gamma$ per-user book sales because its exclusive book titles, compared to Apple's per-user book sales. Solving the first order condition for the two firms' profit maximizing problems, we can obtain the equilibrium prices as

$$p_i = \frac{1}{3}\left[3t + v_d - (3+k)\gamma\right] \tag{26}$$

$$p_k = \frac{1}{3}\left[3t - v_d - (3+2k)\gamma\right] \tag{27}$$

The indifferent consumer is at $x^* = \frac{1}{2} + \frac{v_d - k\gamma}{6t}$, and the equilibrium profits are

$$\pi_i = \frac{(3t + v_d - k\gamma)^2}{18t} \tag{28}$$

$$\pi_k = \frac{(3t - v_d + k\gamma)^2}{18t} \tag{29}$$

Notice now the even if the value difference is positive (i.e., $v_d > 0$), the indifferent point can be less than $\frac{1}{2}$ such that Kindle has more equilibrium demand than iPad. The reason is that now Amazon has exclusive titles, one additional user means more e-book sales for Amazon than for Apple. As a result, Amazon prices more aggressively to compete for consumers.

For the compatible case, similarly, based on this newly defined v_d, Apple's profit function takes the same form as in the baseline model, and Amazon's profit function is adjusted by k as follow:

$$\hat{\pi}_k = \hat{p}_k(1 - \hat{x}^*) + (1+\gamma)\left(1 - \hat{x}^*\right) + (1+\gamma)\max\left\{\hat{x}^* - \frac{1}{2}, 0\right\}$$

We consider the scenario in which the equilibrium indifferent consumer is located at $\hat{x}^* > \frac{1}{2}$, because otherwise whether the platform is compatible makes little difference. Solving the first order condition for the two platforms' profit maximizing problems, we find that the prices, indifferent consumer's location, and Apple's profit take the same form as in the baseline

model. Amazon's profit function becomes

$$\hat{\pi}_k = \frac{(3t_h - v_d)^2}{18t_h} + \frac{(1+k)\gamma}{2}$$

because of the exclusive titles.

We can similarly compare the incompatible and compatible cases. The main difference is that the number of exclusive e-books on Amazon plays a role in the comparison. The condition under which both platforms have incentive to have Amazon's Kindle Reader on Apple's iPad is as follows.

Proposition 7. *(a) When* $9(\gamma - t_s) + v_d^2(\frac{1}{t_h} - \frac{1}{t}) + k\gamma\frac{6t+2v_d-k\gamma}{t} \geq 0$*, Apple has incentives to have Amazon's Kindle Reader on Apple's iPad. (b) When* $9(\gamma - t_s) + v_d^2(\frac{1}{t_h} - \frac{1}{t}) + k\gamma\frac{3t+2v_d-k\gamma}{t} \geq 0$*, Amazon has incentives to have Amazon's Kindle Reader on Apple's iPad.*

Notice that when k is zero, the above conditions reduce to the one in Proposition 3. When k is positive, interestingly, now the two firms' incentives to have Amazon's Kindle Reader on iPad are not always aligned: Apple generally has more incentive to be compatible than Amazon. The reason is that compatibility allows iPad users now to access these exclusive e-books in addition to Kindle Reader, and hence it now provides more value to iPad users.

7 Conclusions

In this paper, we show that two platforms have incentives to achieve one-way compatibility when the difference in their values to consumers is sufficiently large. While we build our model specific to the e-reader market, the general insight is applicable to other industries as well. For example, Microsoft's Surface competes with Apple's iPad in the tablet market. One important differentiation between the two tablets is that Surface comes with Microsoft software applications such as Microsoft Office, while iPad comes with many software applications developed by Apple such as Keynote. On March 27, 2014, Microsoft made its Office

available for iPad so that iPad users can now purchase it. Similar to the iPad vs. Kindle case, Microsoft's decision to achieve one-way compatibility is likely to decrease Surface's market in the tablet market. On the other hand, Microsoft will be able to gain additional profits from software sales to iPad users. Because iPad is much more attractive than Surface, consistent with our theoretical prediction, both Microsoft and Apple have incentives to have Microsoft Office on iPad.

Two-sided platforms are often characterized by incompatibility. Casadesus-Masanell and Ruiz-Aliseda (2009) show that the incentive to dominate the market prevents platforms from becoming compatible. In contrast, our study shows that another reason we do not observe more compatibility might be that competing platforms are too similar to each other and as a result, they provide similar value to users. For example, in the video game industry, Microsoft's Xbox and Sony's PlayStation offer a similar set of features to users, and they closely match each other's pricing strategy. As a result, neither Microsoft nor Sony have incentives to encourage game compatibility.

One limitation of our paper is that we assume that the per-user e-book profits for both platforms are the same. While this matches with platform practices in the e-reader market, it is possible that in other markets, platforms may generate different amount per-user profits.

The second limitation is that we only study the cases in which compatibility requires both platforms to agree. It is possible that in some contexts, compatibility can be achieved by means of an adapter. It will be interesting in future research to study how such possibilities affect platforms' pricing and compatibility decisions.

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Appendix

Proof of Proposition 1. Because $p_i = \frac{1}{3}(3t + v_d - 3\gamma) = \frac{1}{3}(3t_h + v_d + 3t_s - 3\gamma)$ and $\hat{p}_i = \frac{1}{3}(3t_h + v_d)$, $p_i \leq \hat{p}_i$ if and only if $t_s \leq \gamma$. The same reason applies to platform k. □

Proof of Proposition 2. Notice that $x_b^* = \frac{1}{2} + \frac{v_d}{6t}$ and $x^* = \frac{1}{2} + \frac{v_d}{6t_h}$ by Lemmas 1 and 2. Because $t_h < t$, $x_b^* < x^*$. □

Proof of Proposition 3. (a) Notice that $\hat{\pi}_i \geq \pi_i$ requires

$$\frac{t_h}{2} + \frac{v_d^2}{18t_h} + \frac{\gamma}{2} \geq \frac{t}{2} + \frac{v_d^2}{18t}$$

Noticing $t = t_h + t_s$, this condition can be simplified to the one in the proposition.

(b) Notice $\hat{\pi}_i - \pi_i = \frac{1}{18}\left[9(\gamma - t_s) + v_d^2(\frac{1}{t_h} - \frac{1}{t})\right]$, which increasing in v_d and γ. □

Proof of Proposition 4. We can verify that $\hat{W}(\hat{x}^*)$ in Equation (19) is concave in $\hat{x}^*$. Also, we can verify that the socially efficient indifferent point, $\hat{x}_{sc}^*$, cannot be in $[0, 1/2]$. We thus derive the efficient indifferent point considering $\hat{x}_{sc}^* \in [1/2, 1]$. By the first order condition of Equation (19), the efficient indifferent point must satisfy

$$v_i - t_h\hat{x}_{sc}^* - t_s(1 - \hat{x}_{sc}^*) - [v_k - t(1 - \hat{x}_{sc}^*)] = 0$$

Noticing that $t = t_h + t_s$, we have efficient indifferent point $\hat{x}_{sc}^* = \frac{1}{2} + \frac{v_d}{2t_h}$. Notice $\hat{x}^* = \frac{1}{2} + \frac{v_d}{6t_h} < \hat{x}_{sc}^*$. By Proposition 2, $x^* < \hat{x}^*$. We thus have $\frac{1}{2} < x^* < \hat{x}^* < \hat{x}_{sc}^*$, and by the concavity, we have $W(x^*) < \hat{W}(\hat{x}^*)$. Meanwhile, as explained above and it is easy to verify, $W(x^*) < \hat{W}(x^*)$. Therefore, we have $W(x^*) < \hat{W}(\hat{x}^*)$. □

Proof of Proposition 5. The proof is straightforward by noting that all users of Kindle device will prefer Kindle app to iBooks. As a result, no users of Kindle device will use iBooks even if Apple makes iBooks available on Kindle. □

Proof of Proposition 6. Similar to the baseline model, we can derive the equilibrium profit for the compatible case as

$$\hat{\pi}_i = \frac{(3t_h + v_d - c)^2}{18t_h} + \frac{\gamma}{2} \tag{30}$$

$$\hat{\pi}_k = \frac{(3t_h - v_d + c)^2}{18t_h} + \frac{\gamma}{2} \tag{31}$$

Therefore, $\hat{\pi}_i \geq \pi_i$ requires

$$\frac{t_h}{2} + \frac{(v_d - c)^2}{18t_h} + \frac{\gamma}{2} - \frac{t}{2} + \frac{(v_d - c)^2}{18t} \geq 0$$

Noticing $t = t_h + t_s$, this condition can be simplified to the one in the proposition. The condition for firm k can be similarly derived. □

Proof of Proposition 7. (a) Recall $\hat{\pi}_k = \frac{(3t_h + v_d)^2}{18t_h} + \frac{\gamma}{2}$. $\hat{\pi}_i \geq \pi_i$ requires

$$\frac{t_h}{2} + \frac{v_d^2}{18t_h} + \frac{\gamma}{2} \geq \frac{t}{2} + \frac{(v_d - k\gamma)^2}{18t} - \frac{k\gamma}{3}$$

Noticing $t = t_h + t_s$, this condition can be simplified to the one in the proposition.

(b) Notice that $\hat{\pi}_k \geq \pi_k$ requires

$$\frac{t_h}{2} + \frac{v_d^2}{18t_h} + \frac{(1+k)\gamma}{2} \geq \frac{t}{2} + \frac{(v_d - k\gamma)^2}{18t} + \frac{k\gamma}{3}$$

Noticing $t = t_h + t_s$, this condition can be simplified to the one in the proposition. □