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### Abstract

We study the compatibility decisions of two competing platforms that generate profits through both hardware sales and royalties from content sales. We consider a game-theoretic model in which the platform hardware may offer different standalone utilities to users who have different preferences over the two platforms. We find that incentives to establish one-way compatibility—the platform with smaller standalone value allows users of the competing platform to access its content—can arise from the difference in their profit foci. As the difference in the standalone utilities increases, royalties from content sales become less important to the platform with greater standalone value but becomes more important for the other platform. Compatibility increases asymmetry between the platforms' profit foci and, when the difference in the standalone utilities is sufficiently large, yields greater profits for both platforms. We further show that social welfare is greater under one-way compatibility than under incompatibility, and there exist no incentives for either platform to establish one-way compatibility the other way round. We investigate as well how factors such as different platform production costs, exclusive content, and endogenized royalty rates affect compatibility incentives.



*Keywords:* compatibility; two-sided markets; platform competition; e-reader market

# 1 Introduction

An increasing number of markets today are organized around platforms that 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 in order to interact or conduct transactions. An operating system (OS) like Windows, Macintosh, or Linux, for example, serves as a platform connecting consumers who need an OS to access software applications with independent software developers who need access to the OS's programming interface to develop software applications that can be sold to consumers. Other examples of two-sided markets include video game consoles, newspapers, smartphones, e-books, credit cards, shopping malls, and social networking sites.

The literature on platform-based markets has examined 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; Seamans and Zhu 2014; Cennamo and Panico 2015), quality investment (e.g., Casadesus-Masanell and Llanes forthcoming; Zhu and Iansiti 2012), adopting innovative business models (e.g., Economides and Katsamakas 2006; Casadesus-Masanell and Zhu 2010), enveloping adjacent platform markets (e.g., Eisenmann et al. 2011), and managing relationships with complementors (e.g., Carrillo and Tan 2008; Hagiu and Spulber 2013; Huang et al. 2013; Kapoor 2013). Our work complements these studies by examining competing platform providers' compatibility decisions.

The study is motivated by empirical observations in the e-reader market, in which two major platforms, Apple's iPad and Amazon's Kindle, compete aggressively against each other. These devices enable consumers to read e-books through their respective proprietary e-book readers, iBooks and Kindle Reader. The Kindle device was introduced in 2007, the iPad in 2010. After Apple's entry into the market, Amazon decided to make its Kindle Reader available on the Apple device, thereby enabling consumers to read e-books purchased from Amazon on the iPad.[1] Apple, well known for rejecting third-party applications that compete directly with its own offerings, nevertheless approved Amazon's Kindle Reader for iPad, effectively rendering the two platforms frenemies (friends and enemies). Apple has not, however, made iBooks available for the Kindle.

[1] As Apple takes 30% of in-app purchases, Amazon allows iPad users to use its Kindle Reader to read e-books in their Kindle libraries. To purchase e-books, iPad users need to purchase directly from Amazon.com via web browser.

What motivates competing platforms to choose this asymmetric equilibrium of one-way compatibility? How does such compatibility affect their profits and social welfare? How do such factors as production costs and exclusive content affect compatibility incentives? To answer these questions, we develop a game-theoretic model in which two competing platforms with different standalone value to users generate profits from both hardware sales and royalties from content sales. Both platforms make compatibility decisions first and then set their hardware prices, and finally users purchase hardware and content. Compatibility is achieved when one decides to make its proprietary content reader available on the competing platform, and the competitor agrees.

We find that incentives to establish one-way compatibility—the platform with smaller standalone value allows users of the competing platform to access its content—can arise from the difference in profit foci. As the difference in the standalone utilities increases, royalties from content sales become less important to the platform with greater standalone value but more important for the other platform. Compatibility increases asymmetry between the platforms' profit foci and, when the difference is sufficiently large, also yields greater profits for both platforms. Compatibility incentives can also arise when the royalty from content sales is large. In such cases compatibility reduces incentives of platforms to compete for users and thus enables the two platforms to charge high hardware prices. We further show that there exist no incentives for either platform to establish compatibility the other way round, and that social welfare is greater under one-way compatibility than under incompatibility.

Our findings relate to the e-reader market. Apple's iPad provides many features beyond reading e-books, while Amazon's Kindle is almost exclusively an e-book reader. As a result, in equilibrium, compared to Amazon, Apple's hardware profits are more important to its total profits. In contrast, for Amazon, royalties from from e-book sales are more important to its total profits relative to Apple.[2] When this difference in profit foci is large enough, having the Kindle Reader available on iPad is agreeable to both Apple and Amazon: Amazon's e-book sales increase because iPad users can now purchase e-books from Amazon and read them via Kindle Reader, and Apple's hardware sales increase because greater value accrues to the iPad with access to Kindle Reader than in the case of incompatibility. The additional profits Apple generates from hardware sales more than

[2]The result is consistent with reports that Apple profits from every iPad sale, but Amazon earns no profits on Kindle sales. Source: http://www.forbes.com/sites/kellyclay/2012/10/12/amazon-confirms-it-makes-no-profit-on-kindles/, accessed March 2015.

compensate its loss in royalties from e-book sales through its iBooks. Similarly, the additional profits Amazon generate from e-book sales are greater than its loss in Kindle device sales. In particular, when Amazon subsidizes Kindle sales, it is always in Amazon's interest to have Kindle Reader on Apple's iPad. We also show that it is never in Apple's or Amazon's interest to have iBooks available on the Kindle device.

Extending our baseline model to examine a variety of factors that may affect the platforms' compatibility incentives, we find that factors that reduce (increase) asymmetry in profit foci tend to reduce (increase) incentives to become compatible. Higher production cost for the platform with greater standalone value, for example, increases the importance of content sales to the platform. As a result, the profit foci become more similar between the two platforms, thereby reducing their incentives to be compatible. Exclusive content on the platform with smaller standalone value, on one hand, increases its reliance on content sales, and thus heterogeneity in profit foci and the likelihood of compatibility. On the other hand, exclusive content increases the platform's value to users, thereby reducing the difference in utilities from the two platforms. This reduction in heterogeneity reduces the likelihood of compatibility. In the end, whether exclusive content increases the likelihood of compatibility depends on its relative impact on utility difference and extra profits from additional content sales to the platform. We also examine the case in which royalty rates of e-book sales are endogenized such that they depend on market shares of e-book readers. We find that when market shares of e-book readers have significant influence on the royalty rates platforms can negotiate with book publishers, platforms' compatibility incentives may decrease with the difference in the standalone utilities. This is because as the difference in the standalone utilities increases, the platform with greater standalone value may gain more profits from e-book sales than from hardware sales when a greater hardware market share leads to a higher royalty rate. Thus a greater difference in the standalone utilities may decrease the asymmetry in profit foci of the two platforms and their incentives to be compatible.

The rest of the paper is organized as follows. We discuss the related literature in Section 2. In Section 3, we present the setup for our baseline model. Equilibrium results under incompatibility and compatibility are reported in Section 4. In Section 5, we compare the two cases and derive the conditions under which platforms prefer compatibility over incompatibility. Extensions of our model are presented in Section 7. We discuss the generalizability of our results and conclude in

Section 8.

## 2 Literature Review

Our model shares features elaborated in the theoretical literature on two-sided markets (e.g., Rochet and Tirole 2003; Caillaud and Jullien 2003; Hao et al. 2015; Bhargava and Choudhary 2004). Theoretical models in this literature are often industry-specific to incorporate the unique features of different industries. Rochet and Tirole (2003), for example, model the credit card market; Armstrong (2006) models shopping malls and newspapers; and Zhu and Iansiti (2012) model competition between video game consoles. We follow this tradition in building a model concerned with competition between e-reader providers.

Many of the extant theoretical models focus on competition between symmetric platforms. The few papers examining competition between asymmetric platforms tend to focus on platforms with very different business models. Casadesus-Masanell and Ghemawat (2006) and Economides and Katsamakas (2006), for example, investigate competition between proprietary and open source platforms; Casadesus-Masanell and Zhu (2010) investigate competition between a platform that is both subscription-based and ad-sponsored, and a platform entirely ad-sponsored. Niculescu and Wu (2014) study different business models in selling software products such as freemium and uniform seeding models. Our baseline model, in contrast, examines two platforms with similar business models distinguished only by the amount of standalone value they create for users. We show that this difference alone yields opportunities to become frenemies.

A subset of the literature on two-sided markets addresses the issue of compatibility. Doganoglu and Wright (2006), examining the difference between multi-homing and compatibility, find the latter to reduce incentives to pursue the former. Maruyama and Zennyo (2013) find compatibility to depend on product life cycles: when most users have purchased hardware, platform profits accrue largely from content purchases, and then competing platforms have incentives to become compatible. The few studies that examine asymmetric platforms typically find weak platforms to seek compatibility in order to steal market share from stronger platforms, and stronger platforms to have no incentive to establish compatibility. Casadesus-Masanell and Ruiz-Aliseda (2009), for example, explain large platforms' preference for incompatibility in terms of the quest for market dominance, and Viecens (2011) shows that compatibility will always be preferred by a platform with smaller standalone value and never by its competitor. Dou (2014) finds, in a model with vertically differentiated platforms and content, that when an inferior platform owns premium content, it is optimal for the inferior platform to offer such content to a superior platform. The paper assumes that one-way compatibility can be established without the permission of the rival. In contrast, in our model, content quality does not have to differ across the two platforms for compatibility incentives to emerge. In addition, our model assumes compatibility to be a consensus decision by both platforms. Another related study is that of Matutes and Regibeau (1988), who consider two firms competing in an industry in which consumers can assemble their own systems. Each firm produces the components required for a system and needs to decide whether to make them compatible with those of its rival. The firms in their setting sell products, whereas in our setting profits are earned not only from hardware sales, but also from transactions conducted on the platform. The business models of the firms in these two settings thus differ. Moveover, we focus on an asymmetric case with one-way compatibility, whereas Matutes and Regibeau (1988) study a symmetric case with two-way compatibility.

Our work is also related to studies of the e-book industry. Most studies focus on pricing for e-books. Gaudin and White (2014) and Hao and Fan (2014), for example, investigate the pricing of e-books under the wholesale and agency models. Reimers and Waldfogel (2014) find that e-books on Amazon appear to be priced below the static profit maximizing levels. De los Santos and Wildenbeest (2014) find that book publishers have incentives to set higher retail prices for their e-books than Amazon.

More broadly, our paper is related to the pricing literature in the information systems field. For example, Chen and Huang (2014) study pricing of data service by considering pricing by minutes, by gigs, or by mega bytes per second. Chellappa et al. (2011) study price dispersion in the airline industry. By contrast, our work focuses on the effect of firms' compatibility decisions on their price competition.

## 3 Baseline Model

For ease of exposition, we use Apple's iPad and Amazon's Kindle as two competing platforms in our model. We use the standard Hotelling setup to model them as horizontally differentiated products. We use $i$ to index iPad and $k$ to index Kindle, and assume them to be respectively situated at locations 0 and 1 on a line of length 1. 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 a consumer derives from the platform net the price and disutility from the mismatch between the platform and the consumer's taste. The mismatch is measured by the distance between the platform's and consumer's locations on the line. For platform $j$, $j \in \{i, k\}$, we denote the price as $p_j$, and the utility derived from platform as $U_j$. The utility for a consumer located at $x$ from each device can be formulated as

$$U_i = v_i - tx - p_i \tag{1}$$

$$U_k = v_k - t(1-x) - p_k, \tag{2}$$

where $v_j$ is the value derived from platform $j$ and $t$ the unit mismatch cost. Note that $v_j$ captures the value a consumer derives from using the platform, such as reading e-books and using other platform features. As discussed below, because book publishers multi-home and platform providers use an agency model, the utility from reading books is the same for both platforms. Because iPad provides more features than Kindle (e.g., map, flashlight, and iTune store), and thus offers extra standalone utility, we assume $v_i > v_k$. We denote the difference in the standalone utilities as $v_d = v_i - v_k$, and assume that $v_d$ is not too large such that, in equilibrium, both platforms have positive market shares. Because hardware and software can be decoupled on both devices, we assume the unit mismatch cost, $t$, to consist of both unit hardware mismatch cost, $t_h$, and software/reader mismatch cost, $t_s$; that is, $t = t_h + t_s$. Consumers compare the two platforms and choose the one that offers greater utility.

When Kindle Reader is available on iPad, consumers who purchase iPad have the option to choose between the two free software applications—iBooks and Kindle Reader—and choose the application that provides a lower mismatch cost. To take into account consumers who purchase iPad hardware but prefer Kindle Reader over iBooks because of lower mismatch cost, we reformulate the consumer utility from using iPad as

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

As is shown below, in equilibrium, whether iBooks is available on Kindle device makes no difference. We assume for the moment that iBooks is unavailable on Kindle and the utility consumers derive from using Kindle remains the same as in Equation (2).

We assume book publishers to multi-home and sell their e-books on both devices. Consistent with the practice in the e-book market, we assume both platform providers to use an agency model in which publishers set book prices and Amazon and Apple earn a commission or royalty on each book sale transacted through them.[3] We denote the commission earned from selling books to a consumer as $\gamma$. For ease of exposition, the baseline model assumes the devices' marginal costs to be zero. We thus formulate Apple's and Amazon's profits 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 devices from platform $j$, and $D_{js}$ the number of consumers who use platform $j$'s software to read e-books. When Kindle Reader is unavailable on iPad, the number of consumers who purchase hardware from a platform equals 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 which case, $D_{ih} \geq D_{is}$ and $D_{kh} \leq D_{ks}$.

# 4 Equilibrium Analysis

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

[3]When Amazon released Kindle Reader for Apple's iPad, both Amazon and Apple were using the agency model (Gaudin and White 2014).

### 4.1 Incompatible Case

When neither platform's software is available on the rival's device, competition between the platforms is similar to the standard Hotelling setup, except that the two platforms offer different values, $v_i$ and $v_k$, and the revenue for each comes from two sources, hardware sales and royalties from e-book sales. As in the standard setup, by letting $U_i = U_k$ we can define the indifferent consumer's location as $x^* = \frac{v_d-(p_i-p_k)+t}{2t}$. Consumers whose mismatch with platform $i$ is smaller than that of the indifferent consumer purchase platform $i$, and the rest platform $k$. The profit functions of the two platforms in Equation (4) can thus 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 platforms yields the equilibrium prices, profits, and indifferent consumer, as summarized by the following lemma.

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

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

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

$$\pi_i = \frac{(3t+v_d)^2}{18t}$$
$$\pi_k = \frac{(3t-v_d)^2}{18t}.$$

*Proof.* All proofs are included in an appendix. □

A number of observations related to the equilibrium are worth highlighting. First, note that $p_i > p_k$, $x^* > \frac{1}{2}$, and $\pi_i > \pi_k$. This result is expected because iPad, being more attractive to users than Kindle (captured by $v_i > v_k$ in the model), enables Apple to charge a higher price as well as garner a larger market share. Apple consequently earns higher profits than Amazon.

Second, when the per-user e-book profit, $\gamma$, increases, both $p_i$ and $p_k$ decrease and can even become negative (i.e., below cost). In such cases, the platforms have incentives to subsidize consumers' device purchases in return for profits from e-book sales. This pricing pattern and business model are generally similar to those for complementary products, such as the cases of selling printers and toner, or selling razors and blades.

Third, equilibrium profits are unrelated to $\gamma$, even though prices depend on it. This is because profits from e-book sales are competed away for the two platforms. As long as a platform can attract a user, it earns $\gamma$ amount of additional profit. Platforms are therefore willing to subsidize each user up to $\gamma$ amount in a competitive setting.

## 4.2 Compatible Case

To facilitate comparison, we use regular notation (e.g., $p_j$) for outcome variables in the incompatible case and notation with a hat (e.g., $\hat{p}_j$) in the compatible case.

When Kindle Reader is available on iPad, consumers who purchase iPad can choose whichever of two software applications provides the better fit. If the indifferent consumer is located at $\hat{x}^* \geq \frac{1}{2}$, we can derive the indifferent consumer by letting $U_i = U_k$. Based on Equations (2) and (3), we have

$$v_i - t_h\hat{x}^* - t_s(1-\hat{x}^*) - \hat{p}_i = v_k - t_h(1-\hat{x}^*) - t_s(1-\hat{x}^*) - \hat{p}_k. \tag{7}$$

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

In this case, consumers whose mismatch with product $i$ is lower than that of the indifferent consumer purchase platform $i$ and the other consumers platform $k$. Demand for the hardware for platform $i$ and $k$ are $\hat{x}^*$ and $(1-\hat{x}^*)$, respectively. Demand for the software depends on the location of $\hat{x}^*$. When $\hat{x}^* < \frac{1}{2}$, consumers who purchase iPad prefer iBooks and the demand for iBooks is $\hat{x}^*$. When $\hat{x}^* \geq \frac{1}{2}$, consumers located at $\left[\frac{1}{2}, \hat{x}^*\right]$ purchase iPad, but use Kindle Reader instead of iBooks. In other words, half of iPad users prefer iBooks, and half Kindle Reader. Note that e-books on iBooks generate profits for Apple, whereas those on Kindle Reader generate profits for Amazon.

Amazon's profits now come from Kindle hardware sales and e-book sales through Kindle Reader on both Kindle and iPad. The profit functions of the two platforms in Equation (4) can thus be specified as

$$\hat{\pi}_i = \hat{p}_i \hat{x}^* + \gamma \min\left\{\frac{1}{2}, \hat{x}^*\right\} \tag{8}$$

$$\hat{\pi}_k = \hat{p}_k(1-\hat{x}^*) + \gamma\,(1-\hat{x}^*) + \gamma \max\left\{\hat{x}^* - \frac{1}{2}, 0\right\}. \tag{9}$$

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

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

$$\hat{p}_i = \frac{1}{3}(3t_h + v_d)$$
$$\hat{p}_k = \frac{1}{3}(3t_h - v_d),$$

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

$$\hat{\pi}_i = \frac{(3t_h + v_d)^2}{18t_h} + \frac{\gamma}{2} \tag{10}$$

$$\hat{\pi}_k = \frac{(3t_h - v_d)^2}{18t_h} + \frac{\gamma}{2}. \tag{11}$$

In equilibrium, as in the incompatible case, $\hat{p}_i > \hat{p}_k$, $\hat{x}^* > \frac{1}{2}$, and $\hat{\pi}_i > \hat{\pi}_k$; in other words, Apple charges a higher price for iPad than Amazon charges for Kindle, and Apple has greater market share and earns higher profits than Amazon. As the indifferent consumer is located at $\hat{x}^* > \frac{1}{2}$, half of the consumers use Kindle Reader and the other half use iBooks. Revenue contribution from e-book sales is hence simply $\frac{\gamma}{2}$ for each platform. Because the number of consumers using iBooks or Kindle Reader is independent of hardware prices, Apple's and Amazon's pricing decisions will depend only on the value their hardware devices offer to consumers. As iPad offers a higher value than Kindle, Apple's iPad price is higher and its market share greater in equilibrium. Also note that although hardware prices are independent of the per-user e-book profit $\gamma$, the equilibrium profits are increasing with $\gamma$, which is different from the incompatible case.

## 5 Comparison of the Two Cases

We next compare the equilibria in the two cases and examine the conditions under which both platforms have incentives to make Amazon's Kindle Reader available on Apple's iPad.

Comparing equilibrium prices in the two cases summarized in Lemmas 1 and 2 yields 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 platform revenue consists of hardware and e-book sales. On one hand, compatibility reduces competition for e-book sales because it is always the case that the platforms split e-book demand evenly, whereas in the incompatible case the platforms compete for e-book demand as well. On the other hand, compatibility increases competition between the platforms because of a reduction in platform differentiation. In the compatible case consumers located at $(1/2, \hat{x}^*)$ can now choose to use Kindle Reader, whereas in the incompatible case they could choose only iBooks, which has a higher mismatch for them than Kindle Reader. The reduction in competition for e-book sales is reflected by the per-user book profit $\gamma$, and the increase in competition due to the reduction in differentiation by $t_s$. Whether platforms charge higher prices in the compatible case therefore depends on which force dominates.

Also note changes in the demand for each platform from the incompatible to the compatible case:

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

As illustrated in Figure 1, with compatibility Apple sales of iPad increase (from $x^*$ to $\hat{x}^*$), but its e-book sales via iBooks decrease (from $x^*$ to 1/2). Amazon, in contrast, expects decreased sales of Kindle but increased e-book sales. Each platform thus experiences increased demand for one component, either hardware or software, and decreased demand for the other. In some sense, being compatible functions as a differentiation mechanism. Conventional wisdom suggests that being compatible may make two platforms more similar; in our case, however, making Kindle Reader available on iPad gives users the option of using Kindle Reader even if purchasing iPad. The software component is thus "unbundled" from the hardware component. This unbundling effect drives the differentiation of their profit models: one platform dominates the hardware market and the other the software market.

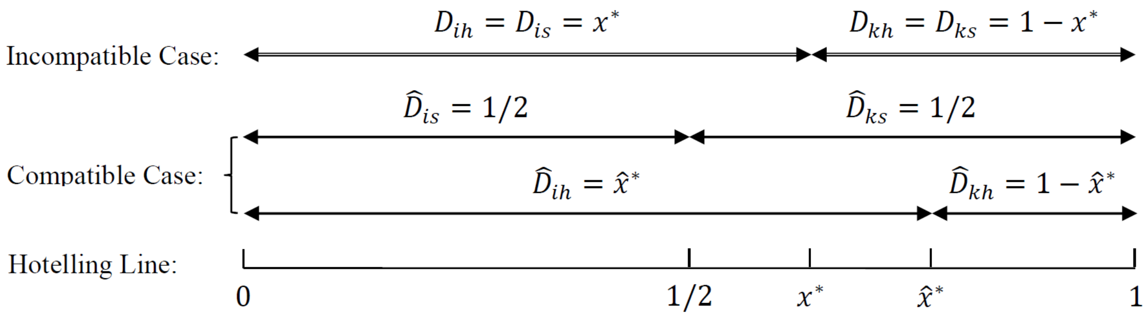
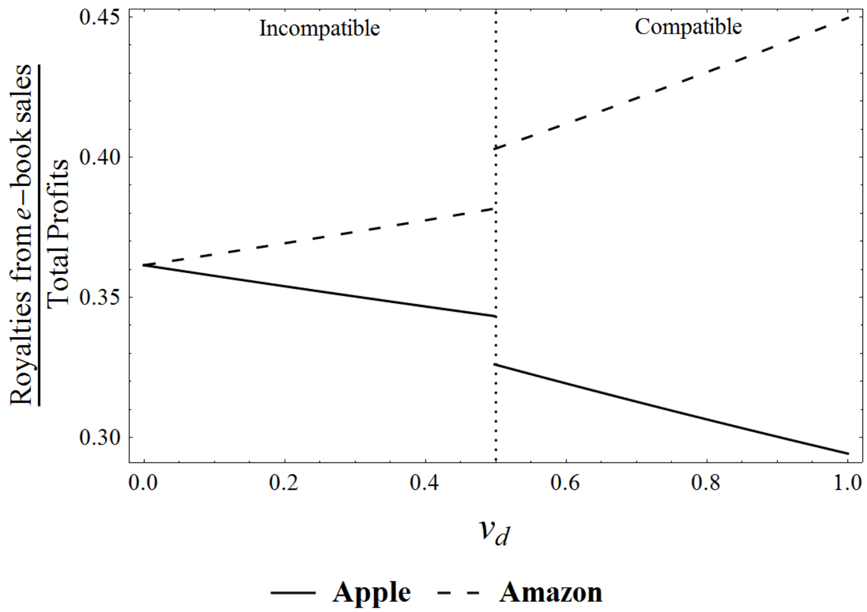



Figure 1: Changes in demand for each platform

Having examined changes in price and demand for each platform, we next compare equilibrium platform profits to determine when both platforms have incentives to make Kindle Reader available on iPad.

**Proposition 3.** *(a) If and only if* $9(\gamma - t_s) + v_d^2(\frac{1}{t_h} - \frac{1}{t}) \geq 0$*, both Apple and Amazon have incentives to make Kindle Reader available on iPad; (b) both are more willing to pursue one-way compatibility as* $v_d$ *or* $\gamma$ *increases.*

In the incompatible case, as $v_d$ increases, Apple's competitive advantage in hardware becomes greater and iPad sales become more important to its profitability. At the same time, royalties from e-book sales become more important to Amazon's profitability. Having Kindle Reader available on iPad increases iPad sales and decreases e-book sales through iBooks. It also increases e-book sales through Kindle Reader and decreases Kindle sales. When $v_d$ is sufficiently large (i.e., when the two platforms' profit foci are sufficiently different), Apple is then willing to sacrifice e-book sales to increase iPad sales, and Amazon to sacrifice hardware sales to increase its royalties from e-book sales. Figure 2 illustrates this intuition with an example. The figure shows how each platform's fraction of total profits from royalties from e-book sales changes with the difference in standalone value, $v_d$. When $v_d$ is small, both platforms prefer incompatibility. As $v_d$ increases, royalties from e-book sales become less important to Apple but more important to Amazon. As their profit foci continue to diverge, at around $v_d = 0.5$ the two platforms prefer one-way compatibility to incompatibility. With compatibility, their profit foci diverge even further and profits increase for both platforms.




*Note*: In this example, we set $t = 3.15$, $t_h = 2$, and $\gamma = 1.15$.

Figure 2: Fraction of total profits from e-book sales for each platform as $v_d$ changes

Interestingly, Apple is more likely to make Kindle Reader available on iPad when the per-user book profit $\gamma$ is larger, which seems counterintuitive. E-book sales being part of each platform's total revenue, one would expect Apple to be less willing to let Amazon take its book business as $\gamma$ increases. This counterintuitive result is rooted in the fundamental difference in competition between the two cases. In the incompatible case, profits from e-book sales are competed away: platforms are willing to subsidize each user up to $\gamma$ amount and the equilibrium profits are independent of $\gamma$. In the compatible case, each platform earns $\frac{\gamma}{2}$ profits from e-book sales and the profits are increasing in the per-user book profit $\gamma$. As a result, when $\gamma$ is larger compared to the incompatible case, platforms charge relatively higher hardware prices and are more likely to earn higher profits when they are compatible.

Two special cases are worth highlighting. First, even when $v_d = 0$ such that the two platforms are symmetric, it is possible for them to be compatible if the per-user book profit exceeds software differentiation. In this case, each platform receives half of the demand in both the incompatible and compatible cases, but the price in the compatible case could be higher because of the softened competition. Second, when the value difference $v_d$ or per-user book profit $\gamma$ is large such that Amazon is incentivized to subsidize users' device purchases in return for profits from e-book sales in the incompatible case, both platforms always have an incentive to be compatible because these scenarios afford profitable opportunities to differentiate and for each to exploit users on one dimension, either hardware sales or e-book sales.

We next examine the effect of compatibility on social welfare, defined here as the sum of consumer utilities and platform profits. In our setting, it equals the total consumer value realized from the consumption of the products. Total social welfare generated in the incompatible case can therefore be formulated as

$$W(x^*) = \int_0^{x^*} (v_i - t_h x - t_s x)dx + \int_{x^*}^1 [v_k - t(1-x)]\, dx, \tag{12}$$

and in the compatible case, as

$$\hat{W}(\hat{x}^*) = \int_0^{\hat{x}^*} (v_i - t_h \hat{x} - t_s \min\{\hat{x}, 1-\hat{x}\})d\hat{x} + \int_{\hat{x}^*}^1 [v_k - t(1-\hat{x})]\, d\hat{x}. \tag{13}$$

The main difference between these formulations of social welfare is the mismatch cost associated with software applications. It can readily be seen that if the locations of the indifferent consumers were the same (i.e., $x^* = \hat{x}^*$), social welfare in the compatible case would always be higher than that in the incompatible case. This is because the software mismatch cost for consumers at $x \in [0, \hat{x}^*]$ in the compatible case is $t_s \min\{x, 1-x\}$ and in the incompatible case $t_s x$, and 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 a more efficient allocation.

**Proposition 4.** *The one-way compatible case generates greater social welfare than the incompatible case.*

The efficiency gain in the compatible case comes from two parts. First, being compatible results in a better allocation of hardware because more consumers buy iPad, which pushes toward an efficient allocation. Second, being compatible also leads to a better allocation of book buyers because iPad users now have the choice of using Kindle Reader.

## 6 Apple's iBooks on Kindle?

We next examine whether Apple has incentives to make iBooks available 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 both scenarios yields the following result.

**Proposition 5.** *Whether or not Amazon's Kindle Reader is available on Apple's iPad, both platforms are indifferent to having iBooks on Kindle.*

The intuition is that in both scenarios fewer than 50% of consumers will buy Kindle. All these consumers will choose Kindle Reader regardless of whether iBooks is available because their mismatch cost with Kindle Reader is smaller. Having iBooks available on Kindle devices therefore makes no difference.

## 7 Extensions

We extend the baseline model to examine how such factors as different production costs, exclusive content, and endogenized royalty rates affect platform compatibility incentives.

### 7.1 Different Production Costs

The baseline model assumes two platforms with identical production costs and normalizes their costs to be zero. In this extension, we allow the platforms to have different costs. Specifically, we assume that Apple's iPad has a higher production cost than Amazon's Kindle. This assumption is more sensible than the other way because iPad provides a higher standalone utility to consumers than Kindle (i.e., $v_d > 0$), and a higher value product is typically associated with a higher production cost. As in the baseline model, we normalize the production cost for Kindle to be zero and let the production cost for iPad be $c$, $c \geq 0$.

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

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

**Proposition 6.** *(a) If and only if $v_d \geq c$ and $9(\gamma - t_s) + (v_d - c)^2(\frac{1}{t_h} - \frac{1}{t}) \geq 0$, both Apple and Amazon have incentives to make Kindle Reader available on iPad; (b) both are more willing to pursue one-way compatibility as $(v_d - c)$ or $\gamma$ increases.*

Different from the baseline model, instead of the value advantage $v_d$, the difference $(v_d - c)$ affects platforms' incentives to be compatible. Hence, it becomes more difficult for the two platforms to be compatible, compared with the baseline case. The intuition here is that it is more difficult for Apple to generate large profits from hardware sales because of the higher production cost. Apple's profits from selling books thus become more important. The platform providers' profit foci become more similar as a result of this production cost, thereby reducing their incentives to be compatible.

### 7.2 Exclusive Content on Amazon

The baseline model assumes that all book publishers multi-home and all e-books are available on both platforms. In practice, having established itself as the primary online book retailer, Amazon may have bargaining power over some book publishers or authors and thus be able to secure exclusive deals.[4] In this extension, we examine platform compatibility incentives in the case in which Amazon has some exclusive e-book titles.

We decompose the value $v_j$ that consumers derive from platform $j$ into two components: the value derived from reading e-books ($v_{jb}$), and the value of using other functions ($v_{jo}$). In the baseline model, because book publishers are multi-homing, consumer utility from book consumption is identical on both platforms; that is, $v_{jb}$, being the same for both platforms, is denoted $v_b$. We can thus view $v_k = v_b + v_{ko}$ and $v_i = v_b + v_{io}$, where $v_{io} - v_{ko} = v_d$. As the value derived from reading e-books does not affect consumers' platform preferences, we have not explicitly accounted for these utilities in our utility functions. In this extension, the number of exclusive titles on Amazon affects consumer preferences between the two platforms. We thus explicitly account for utilities from

[4]Conversations with Amazon and Apple in March 2014 revealed that both Amazon's Kindle Store and Apple's iBooks store had in excess of two million e-books, and Amazon had another ~500,000 exclusive titles (including self-published Kindle e-books) unavailable to readers anywhere else.

reading books.

We normalize the number of e-books available on both platforms to be 1. In addition, Amazon has $k$ exclusive titles. The number of exclusive titles on Amazon directly affects both the utility consumers derive from its Kindle device and its profit. When Amazon has $k$ exclusive titles, consumer utility with iPad is the same as in the baseline model, $U_i = v_{io} + v_b - tx - p_i$. Because of the increased number of book titles, the utility consumers derive from Kindle becomes $U_k = v_{ko} + (1+k)v_b - t(1-x) - p_k$, which is different from the baseline model. With more exclusive titles, Kindle appears more attractive to consumers. We redefine the value difference $\bar{v}_d = (v_{io} + v_b) - [v_{ko} + (1+k)v_b] = v_d - kv_b$. Because of the exclusive titles on Amazon, the value of Kindle is enhanced, and the value difference is smaller than is in the baseline case. We also assume $k$ to be relatively small such as $\bar{v}_d$ is greater than zero; that is, Apple's iPad continues to offer greater utility after taking e-book availability into account.

Note that while not required for our analysis below, the value $v_b$ can be interpreted in a more specific way. We assume that each book publisher offers one e-book. For a given book, each consumer derives utility $\tilde{v}$, which is randomly drawn from a uniform distribution, $[0, \bar{v}_b]$. Each book publisher is a monopoly for the e-book it publishes, for which it charges price $p_b$. Consumers purchase all e-books from which they derive non-negative utilities: $\tilde{v} - p_b \geq 0$. Given this setup, the optimal monopoly price book publishers set is $p_b^* = \bar{v}_b/2$, and each consumer purchases half of the e-books available on the platform. Hence, each consumer derives total utility $\int_{p_b^*}^{\bar{v}_b} (\tilde{v} - p_b^*) d\tilde{v} = \bar{v}_b^2/8$ from books on iPad and $(1+k)\bar{v}_b^2/8$. Therefore, under this setting, $v_b = \bar{v}_b^2/8$.

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

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

Note that when $k$ is zero, the above conditions reduce to the one in Proposition 3. Interestingly, when $k$ is positive, incentives to have Amazon's Kindle Reader on iPad are not always aligned between the platforms: Apple's incentive to be compatible is generally greater than Amazon's, the reason being that compatibility affords iPad users access to exclusive e-books in addition to Kindle Reader and, hence, provides greater value.

Compared to the baseline case, it is unclear whether the two platform providers are now more willing to engage in one-way compatibility. Exclusive titles increase Amazon's reliance on content sales and, consequently, heterogeneity between the platforms' profit foci and thus the likelihood of compatibility. But exclusive titles also increase the value of Amazon to its users, thereby reducing the difference between the platforms' utilities ($\bar{v}_d < v_d$) and the likelihood of compatibility. Whether exclusive titles increase or decrease the likelihood of compatibility thus depends on the relative impact on the difference in utilities and extra profits from additional content sales. When $\gamma$ is large, the exclusive content generates significant profits for Amazon and the former effect will likely dominate, in which case the exclusive content will increase willingness to pursue compatibility.

### 7.3 Endogenized Royalty Rates

The baseline model assumes per-user book profit, $\gamma$, to be the same for both platforms. This assumption is consistent with the e-reader market, in which the two platforms charge similar prices for, and use the same royalty rate for, e-books. In the interest of generalizability to other settings, we extend the model to endogenize royalty rates. Royalty rate is typically determined through negotiations between a platform and book publishers, the former's bargaining power being likely to depend on its market share of e-book readers. We therefore assume royalty rate, $r_j$, $j \in \{i, k\}$, to be a constant, $b \in [0, 1]$, multiplied by the platform's equilibrium market share of e-book readers. The parameter $b$ reflects the importance of market share to the negotiation outcome. Thus, in the incompatible case, for Apple, $r_i = bx^*$, and for Amazon, $r_k = b(1 - x^*)$.

We assume an average user to pay $g$ for e-books, such that $\gamma$ can be viewed as $\gamma = r_j g$. Thus, in the incompatible case, while the consumers' utility functions remain the same, the platforms' profit functions become:

$$\begin{aligned} \pi_i &= p_i x^* + bgx^{*2} \\ \pi_k &= p_k(1 - x^*) + bg(1 - x^*)^2. \end{aligned}$$

To avoid corner solutions, we assume $bg < t$. Solving the first order conditions, we find the indifferent consumer to be located at $x^* > 1/2$, and obtain the equilibrium profits as:

$$\begin{aligned}\pi_i &= \frac{(2t - bg)(v_d + 3t - 2bg)^2}{4(3t - 2bg)^2} \\ \pi_k &= \frac{(2t - bg)(v_d - 3t + 2bg)^2}{4(3t - 2bg)^2}.\end{aligned}$$

With compatibility, the profit functions become:

$$\begin{aligned}\hat{\pi}_i &= \hat{p}_i \hat{x}^* + bg\left(\min\left\{\frac{1}{2}, \hat{x}^*\right\}\right)^2 \\ \hat{\pi}_k &= \hat{p}_k(1 - \hat{x}^*) + bg\left[(1 - \hat{x}^*) + \max\left\{\hat{x}^* - \frac{1}{2}, 0\right\}\right]^2,\end{aligned}$$

and the equilibrium profits:

$$\hat{\pi}_i = \frac{bg}{4} + \frac{(v_d + 3t_h)^2}{18t_h} \tag{14}$$

$$\hat{\pi}_k = \frac{bg}{4} + \frac{(v_d - 3t_h)^2}{18t_h}. \tag{15}$$

Comparing equilibrium profits in these two cases yields the following proposition.

**Proposition 8.** *There exist two thresholds, $b^*$ and $b^{**}$, such that $b^* < b^{**}$ and*

*(a) when $b < b^*$, Apple's willingness to be compatible increases with $v_d$; when $b \geq b^*$, Apple's willingness to be compatible decreases with $v_d$;*

*(b) when $b < b^{**}$, Amazon's willingness to be compatible increases with $v_d$; when $b \geq b^{**}$, Amazon's willingness to be compatible decreases with $v_d$.*

We find that when $b$ is small, our result in Proposition 3 that both platforms' compatibility incentives increase with $v_d$ continues to hold. However, when $b$ is large, this relationship reverses. The intuition is that when royalty rate is endogenized, market share of e-book readers affects not only the total number of e-book sold but also per-book profit each platform makes. When $b$ is sufficiently large, the e-book market share has a large impact on the royalty rate. As $v_b$ increases, in the incompatible case, Apple has a greater market share on hardware, which in turn benefits Apple even more in e-book sales because of the increased royalty rate. In other words, while

Apple's hardware profits increase, its royalties from e-book sales increase even more. Thus, an increase in $v_b$ in this case actually reduces the asymmetry in profit foci between the two platforms, and consequently the two platforms' incentives to become compatible. Apple's threshold for $b$ is lower than Amazon's because in the equilibrium of the incompatible case, Apple has a larger market share of e-book reader than Amazon, and thus an increase in $b$ increases profit gains from e-book sales to Apple faster than to Amazon, making Apple less willing to allow its users to buy e-books from its rival's platform.

# 8 Discussion and Conclusions

The multi-sided nature of platform-based markets allows platform owners to generate profits from multiple groups of participants. It thus provides flexibility to platform owners to choose their profit foci, and creates opportunities for competing platform owners with different profit foci to cooperate to capture more value for both. In this paper, we develop a model that explains the incentives for two platforms to become frenemies when the difference in their profit foci is sufficiently large.

## 8.1 Managerial Implications

Although our model is specific to the e-reader market, the insight that competing platforms with different profit foci may have incentives to cooperate applies in other settings. Platforms should consequently actively seek opportunities to cooperate with rivals with different approaches to value capture. Among platform providers that have begun to recognize such opportunities is Microsoft. Microsoft's Surface competes with Apple's iPad in the tablet market. The tablets are differentiated in that Surface, for example, comes with such Microsoft software applications as Microsoft Office, and iPad with Apple developed applications like Keynote, among many others. On March 27, 2014, Microsoft made Office available for purchase by iPad users. As in the case of iPad and Kindle, Microsoft's decision to achieve one-way compatibility is likely driven by a willingness to sacrifice some amount of Surface's share in the tablet market for additional profits from software sales to iPad users. Because iPad is arguably more attractive than Surface, consistent with our theoretical prediction, both Microsoft and Apple have incentives to make Microsoft Office available on iPad.[5] Our model likewise helps to explain Amazon's March 2015 opening of a store on Alibaba's Tmall.com, even though Amazon operates its own e-commerce site in China, Amazon.cn.[6] Amazon and Alibaba are competitors in the Chinese e-commerce market, but their profit foci differ, Amazon operating as a reseller and earning profits from consumers, Alibaba as an intermediary that offers its service free to consumers and earns profits from merchants through store setup fees, advertising, and commissions. Amazon's market share being much smaller than Alibaba's in China, the collaboration enables Amazon to sell more products to Chinese consumers and Alibaba to earn more profits from service fees.

Our results also shed light on why many two-sided platforms choose to remain incompatible. Casadesus-Masanell and Ruiz-Aliseda (2009) show the market dominance incentive to prevent many platforms from becoming compatible. Our study shows similarity in profit foci to be another reason that more instances of compatibility between competing platforms are not observed. In the video game industry, for example, because Microsoft's Xbox and Sony's PlayStation offer similar sets of features and have closely matched pricing strategies, there is little interest on the part of either firm to pursue platform compatibility.

Nor do all differences between two platforms give rise to incentives to cooperate. As demonstrated by our extensions, the impacts of some differences may offset each other. Different product costs, for example, may offset the impact of different standalone values and reduce platforms' incentives to cooperate. Moreover, the impact of some differences can be ambiguous. We find, for example, that exclusive titles on Amazon's Kindle do not necessarily increase compatibility incentives. Our analysis reveals that compatibility incentives result only from differences that generate greater asymmetry in platforms' profit foci. Hence, it is important for platforms to pay attention to how their competitors capture value to make compatibility decisions.

Core in our analysis is the identification of asymmetric incentives. Recognizing the "room for maneuver" enabled by these asymmetries helps us understand the rise of collaboration in the face of competitive pressures. Beyond compatibility choices, future work can examine implications for choices regarding leadership and followership in interdependent settings (e.g., Adner et al. 2013).

[5] In November 2014, Microsoft made the basic version of its Office app on iPad free, requiring users to pay only for premium features.

[6] Source: HTTP://WWW.USATODAY.COM/STORY/TECH/2015/03/08/AMAZON-ON-ALIBABA-TMALL/24610123/, accessed March 2015.

More generally, digitization is driving increasing decoupling of hardware and software in many traditional industries (e.g., automotive, refrigerators, and thermostats, to name a few). Firms in these industries will, like Apple and Amazon in our setting, have to confront the compatibility decision. In the automotive industry, for example, car manufacturers such as General Motors, Ford, and Tesla are seeking to attract car buyers with value-added services provided by internally-developed software apps. Profit models differ, Ford and Tesla providing their apps free to car buyers, General Motors charging a subscription fee for its Onstar service. Should these manufacturers allow their customers to use competitors' software apps? Our results provide guidelines that help to inform such strategic decisions.

Our finding that one-way compatibility increases social welfare suggests that policy makers should encourage platforms to innovate and compete differently to create more opportunities for compatibility. Compatibility enables consumers to combine hardware and software in ways that are closer to their ideal. It should be noted that additional research and development cost incurred to achieve compatibility will reduce firms' incentives to establish compatibility and should also be deducted from the social welfare improvement before making a welfare judgement.

### 8.2 Limitations and Future Research

We have made a few simplifying assumptions in developing our model. For example, consistent with most cases, we study only the situation in which compatibility requires consensus by both platforms. It is possible that in some contexts, compatibility can be achieved by means of an adaptor. Future research might study how such possibilities affect platforms' pricing and compatibility decisions.

The second limitation is that, in our model, consumer tastes for hardware and software are correlated. We make this assumption to simplify the analysis. While we believe the intuition of our results applies to cases with different assumptions, future research might investigate how such assumptions (e.g., independent consumer tastes for hardware and software) affect the conditions in the propositions.

Finally, we assume that the market does not tip; that is, we do not admit the possibility of one platform fully capturing the market. Future work might conduct a more comprehensive analysis of compatibility decisions that includes the possibility of tipping.

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## Appendix

*Proof of Lemma 1.* As $x^* = \frac{v_d-(p_i-p_k)+t}{2t}$, we can rewrite the two profit functions as

$$\begin{aligned}\pi_i &= (p_i+\gamma)\frac{v_d-(p_i-p_k)+t}{2t}\\ \pi_k &= (p_k+\gamma)(1-\frac{v_d-(p_i-p_k)+t}{2t}).\end{aligned}$$

Using the first order conditions, $\frac{d\pi_i}{dp_i}=0$ and $\frac{d\pi_k}{dp_k}=0$, we have

$$\begin{aligned}p_i &= \frac{1}{2}(p_k+t+v_d-\gamma)\\ p_k &= \frac{1}{2}(p_i+t-v_d-\gamma).\end{aligned}$$

It is easy to verify that the second order conditions are negative in both cases. Solving the two equations above yields the equilibrium prices of $p_i$ and $p_k$ in the lemma. We can then derive the equilibrium $x^*$, $\pi_i$, and $\pi_k$ using the equilibrium prices. □

*Proof of Lemma 2.* We first look at the case where $\hat{x}^* \geq \frac{1}{2}$. In this case, $\hat{x}^* = \frac{v_d-(\hat{p}_i-\hat{p}_k)+t_h}{2t_h}$, and half of the users will use iBooks to read e-books and half will use Kindle Reader. The profit functions can be rewritten as

$$\begin{aligned}\hat{\pi}_i &= \hat{p}_i\frac{v_d-(\hat{p}_i-\hat{p}_k)+t_h}{2t_h}+\frac{1}{2}\gamma\\ \hat{\pi}_k &= \hat{p}_k(1-\frac{v_d-(\hat{p}_i-\hat{p}_k)+t_h}{2t_h})+\frac{1}{2}\gamma.\end{aligned}$$

Using the first order conditions, $\frac{d\hat{\pi}_i}{d\hat{p}_i}=0$ and $\frac{d\hat{\pi}_k}{d\hat{p}_k}=0$, we have

$$\begin{aligned}\hat{p}_i &= \frac{1}{2}(\hat{p}_k+t_h+v_d)\\ \hat{p}_k &= \frac{1}{2}(\hat{p}_i+t_h-v_d).\end{aligned}$$

It is easy to verify that the second order conditions are negative in both cases. Solving the two equations above yields the equilibrium prices of $\hat{p}_i$ and $\hat{p}_k$ in the lemma. We can then derive the equilibrium $\hat{x}^*$, $\hat{\pi}_i$, and $\hat{\pi}_k$ using the equilibrium prices. It is easy to verify that $\hat{x}^* > \frac{1}{2}$.

We then look at the case where $\hat{x}^* < \frac{1}{2}$. This case is the same as the incompatible case as none of the iPad users will use Kindle Reader to read e-books. Hence, according to Lemma 1, we have $\hat{x}^* = \frac{1}{2}+\frac{v_d}{6t}$, which is greater than $\frac{1}{2}$. This case is thus impossible. □

*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.* Note that $x^* = \frac{1}{2} + \frac{v_d}{6t}$ and $\hat{x}^* = \frac{1}{2} + \frac{v_d}{6t_h}$ by Lemmas 1 and 2. Because $t_h < t$, $x^* < \hat{x}^*$. □

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

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

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

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

*Proof of Proposition 4.* We can verify that $\hat{W}(\hat{x}^*)$ in Equation (13) 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 for $\hat{x}^*_{sc} \in [1/2, 1]$. By the first order condition of Equation (13), 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 the efficient indifferent point $\hat{x}^*_{sc} = \frac{1}{2} + \frac{v_d}{2t_h}$. Note $\hat{x}^* = \frac{1}{2} + \frac{v_d}{6t_h} < \hat{x}^*_{sc}$. By Proposition 2, $x^* < \hat{x}^*$. We thus have $\frac{1}{2} < x^* < \hat{x}^* < \hat{x}^*_{sc}$, and by the concavity, $\hat{W}(x^*) < \hat{W}(\hat{x}^*)$. Meanwhile, as explained in the paper and easily verified, $W(x^*) < \hat{W}(x^*)$. We therefore have $W(x^*) < \hat{W}(\hat{x}^*)$. □

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

*Proof of Proposition 6.* Solving the first order condition for the two profit-maximizing platforms, we can derive equilibrium prices, demand, and profits. For example, in the incompatible case, the equilibrium prices are

$$\begin{aligned} p_i &= \frac{1}{3}(2c + 3t + v_d - 3\gamma) \\ p_k &= \frac{1}{3}(c + 3t - v_d - 3\gamma), \end{aligned}$$

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

$$\begin{aligned} \pi_i &= \frac{(3t + v_d - c)^2}{18t} \\ \pi_k &= \frac{(3t - v_d + c)^2}{18t}. \end{aligned}$$

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 lower demand. In the baseline case, Apple's demand is always greater than $\frac{1}{2}$ (i.e., $x^* > \frac{1}{2}$ by Lemma 1). In contrast, when Apple has a cost disadvantage its demand is lower, and can even be below $\frac{1}{2}$ when the value advantage cannot compensate for the additional cost (i.e., when $v_d < c$).

We can verify that when $v_d < c$, both platforms are indifferent to having Kindle Reader on iPad. We next examine the case with $v_d \geq c$. Similarly, in the compatible case, we obtain the equilibrium prices as

$$\begin{aligned} \hat{p}_i &= \frac{1}{3}(2c + 3t_h + v_d) \\ \hat{p}_k &= \frac{1}{3}(c + 3t_h - v_d). \end{aligned}$$

The indifferent consumer is located at $\hat{x}^* = \frac{1}{2} + \frac{v_d - c}{6t_h}$. As in the baseline model, we can derive the equilibrium profit for the compatible case as

$$\begin{aligned} \hat{\pi}_i &= \frac{(3t_h + v_d - c)^2}{18t_h} + \frac{\gamma}{2} \\ \hat{\pi}_k &= \frac{(3t_h - v_d + c)^2}{18t_h} + \frac{\gamma}{2}. \end{aligned}$$

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

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

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

*Proof of Proposition 7.* Based on this utility function, as in the baseline model, we can derive the indifferent consumer's location for each case and formulate each platform's demand and profit function. Based on the platforms' 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 the newly defined $v_d$, the expression for the indifferent point $x^*$ is the same as in the baseline model. Apple's profit function remains the same as in Equation (5), and its 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 derived from 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 obtain the equilibrium prices

$$\begin{aligned} p_i &= \frac{1}{3}\left[3t + \bar{v}_d - (3 + k)\gamma\right] \\ p_k &= \frac{1}{3}\left[3t - \bar{v}_d - (3 + 2k)\gamma\right]. \end{aligned}$$

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

$$\begin{aligned}\pi_i &= \frac{(3t + \bar{v}_d - k\gamma)^2}{18t} \\ \pi_k &= \frac{(3t - \bar{v}_d + k\gamma)^2}{18t}.\end{aligned}$$

Note that now even if the value difference is positive (i.e., $\bar{v}_d > 0$), the indifferent point can be less than $\frac{1}{2}$ such that Kindle has more equilibrium demand than iPad. The reason is that because 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, based on the newly defined $\bar{v}_d$, Apple's profit function takes the same form as in the baseline model, and Amazon's profit function is adjusted by $k$ as follows:

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

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

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

because of the exclusive titles.

(a) Recall that $\hat{\pi}_i = \frac{(3t_h + \bar{v}_d)^2}{18t_h} + \frac{\gamma}{2}$. $\hat{\pi}_i \geq \pi_i$ requires

$$\frac{t_h}{2} + \frac{\bar{v}_d^2}{18t_h} + \frac{\gamma}{2} \geq \frac{t}{2} + \frac{(\bar{v}_d - k\gamma)^2}{18t} - \frac{k\gamma}{3}.$$

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

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

$$\frac{t_h}{2} + \frac{\bar{v}_d^2}{18t_h} + \frac{(1+k)\gamma}{2} \geq \frac{t}{2} + \frac{(\bar{v}_d - k\gamma)^2}{18t} + \frac{k\gamma}{3}.$$

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

*Proof of Proposition 8.* Differentiating $\hat{\pi}_i - \pi_i$ with respect to $v_d$, we have

$$\frac{d(\hat{\pi}_i - \pi_i)}{dv_d} = \frac{1}{36}\left(12 + \frac{4v_d}{t_h} - \frac{18(2t - bg)(v_d + 3t - 2bg)}{(3t - 2bg)^2}\right).$$

We find that $\frac{d(\hat{\pi}_i - \pi_i)}{dv_b} > 0$ when $b < b^*$ and $\frac{d(\hat{\pi}_i - \pi_i)}{db} \leq 0$ when $b \geq b^*$, where

$$b^* = \frac{3}{4}\left(\frac{3tt_h + 8tv_d - 3t_hv_d}{3gt_h + 4gv_d} - \sqrt{\frac{t_h\left(9t^2t_h + 2tv_d(15t_h + 8v_d) + 9t_hv_d^2\right)}{g^2(3t_h + 4v_d)^2}}\right).$$

Similarly, we have

$$\frac{d(\hat{\pi}_k - \pi_k)}{dv_d} = \frac{1}{36}\left(-12 + \frac{4v_d}{t_h} - \frac{18(2t-bg)(v_d-3t+2bg)}{(3t-2bg)^2}\right),$$

and we obtain another threshold

$$b^{**} = \frac{3}{4}\left(\frac{3tt_h - 8tv_d + 3t_h v_d}{3gt_h - 4gv_d} - \sqrt{\frac{t_h\left(9t^2 t_h + 2tv_d(8v_d - 15t_h) + 9t_h v_d^2\right)}{g^2(3t_h - 4v_d)^2}}\right).$$

We can verify that $b^* < b^{**}$. □