Foreclosure, Entry, and Competition in Platform Markets with Cloud

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August 27, 2015

Abstract
Platforms in two-sided markets compete over time by introducing new generations of their platform which they sell to consumers. New generations also allow the seller side of the market to produce and sell new products to consumers. For example, smartphones and video game consoles develop a new generation of their platform that is sold to consumers and that allows developers to produce and sell new apps or games to consumer. New platform generations are often backward compatible. That is, apps and games from the previous generation of the platform can be used on the current platform. Thus, cloud storage that is offered by the platform allows consumers to access previously purchased products which generates an opportunity cost for consumers that previously used a platform. When platforms compete over time, this opportunity cost acts as a switching cost on the consumer side of the market. This paper analyzes how backward compatibility affects dynamic platform pricing, the extent of platform focality, and platform entry and foreclosure. I find that unless the entrant’s platform is of significantly higher quality than the incumbents existing platform, an incumbent platform is able to retain its consumer base resulting in the entrant’s platform only capturing the least profitable consumers and making minimal profits. Thus, being first to market in a two-sided market where an incumbent can successfully retain its customers creates a significant competitive advantage.

Keywords: Platforms, Two-sided markets, Dynamic platform competition, E-commerce, Entry and foreclosure, Platform generations, Cloud, Backward compatibility

JEL Classifications: D40, L41, L22
1 Introduction

Many platforms are updated over time with new “generations.” For example, the iPhone is now in its sixth generation while the video game console industry began its eighth generation in November 2013. By updating a platform, app and game developers on the seller side of the market can develop new products of higher quality and the platform makes additional sales to its existing customer base. For consumers that own the previous generation, the new generation often provides more than new games and updated technologies. Platforms develop their new generation so that purchases made for the previous generation can still be used, that is, they are backward compatible. This carryover can be understood as the cloud storage by a platform for its customers. For example, content purchased on iTunes is stored for consumers to use on any Apple device over many generations of a device. Similarly, using previous generation video games on new consoles serves as the same type of cloud storage over time.

In many platform industries there are different dynamic equilibria. In the market for smartphones, the Blackberry was the first platform to market and it was extremely successful in maintaining market share while being profitable over several generations until Apple entered the market with the iPhone. With Apple’s higher quality smartphone, the iPhone, Blackberry quickly lost share and profits. Since then Apple has sustained relatively high prices over time even though their market share on both sides of the market has decreased over time. Furthermore, Apple has faced entrants that charge lower prices (Google and Microsoft) some of which have succeed and gained market share over time (Google) and others who have struggled to gain share in the market for smartphones (Microsoft). However, these entrants have not been as profitable as Apple with its iPhone. Similarly, the market for video game consoles has seen entrants succeed over multiple generations (Microsoft’s Xbox) and others that have failed to reach a second generation (Saga’s Dreamcast). To understand the differences in dynamic platform equilibria that arise across platform industries, a model of dynamic platform competition is needed.
In this paper a dynamic model of a platform that uses cloud storage or backward computability is considered. This cloud storage provides consumers that joined the platform and purchased platform compatible products in the previous period with carryover utility in the current period. In every period, consumers and sellers are heterogeneous so that the prices set by platforms affect the extent of participation on each side of the market. For an incumbent platform, the use of dynamic pricing strategies and cloud storage affects the switching costs agents face when considering an entrant platform.

I find that the entrant is unable to overcome the incumbent’s advantage of having locked-in consumers to become the larger market share firm with greater profitability unless the entrant’s platform is of significantly higher quality. The success of the entrant platform also depends on the effectiveness of the cloud storage for the incumbent. When the effect from the cloud is strong then the incumbent’s position strengthens relative to entrant as more effective cloud storage increases consumer’s carryover utility from the previous generation which makes it easier for the incumbent to increase the switching costs of its previous customers. However, when the cloud effect is strong then it is more profitable for the incumbent to increase its price. This makes successful entry easier for the entrant’s platform. This tradeoff of incentives is consistent with similar problems found in the switching cost literature.

The modelling assumptions regarding consumers differ here than in the traditional models on markets with consumer switching costs. As a result, this paper makes a contribution to the existing literature on markets with consumer switching costs by identifying a new marketplace where switching costs exists and by showing how differences in quality plays an important role in determining the effects of switching costs on entry and the strength

\footnote{In markets where a new generation allows sellers to develop and sell an updated edition of a previous game suggests that sellers may not want the platform to be backward compatible since backward compatibility results in greater competition from previous games. The Xbox One was originally not backward compatible, much to the dismay of its customers; Xbox claimed backward compatibility was impossible; however, they eventually fixed this issue. For more regarding Xbox’s issue see Makedonski (2015). This paper focuses on how backward compatibility affects platform competition and the complete interaction with the seller side is left for future research.}

\footnote{Farrell and Klemperer (2007) provide an overview of the literature on switching costs and consumer lock-in.}
of incumbency. If platforms are symmetric in quality then the incumbent platform (the platform with locked-in customers) acts as the large and less-aggressive fat cat charging higher prices and making greater profits leaving the entrant platform (the platform without locked-in customers) with some market power over the residual demand and relatively lower profits. This is consistent with the previous literature on switching costs; Farrell and Shapiro (1988) and Padilla (1995). The contribution of this paper to the switching cost literature is the analysis of the asymmetric model where platform qualities differ between the incumbent with its locked-in consumers and the entrant. I show how the entrant must have a significant quality advantage over the incumbent to overcome the incumbent’s advantage of locked-in consumers to become the larger market share firm with greater profitability. However, the main contribution of this paper is the analysis of dynamic platform competition.

There has been some recent research on dynamic competition with switching costs that lead to an incumbency advantage, Biglaiser and Crémer (2011) and Biglaiser et al. (2013). However, these models do not consider network effects. Halaburda et al. (2014) develop a dynamic model with network effects where the platform that “won” in the previous period is focal in the current period. That is, the consumers see which platform was successful in the previous period and form favorable beliefs toward that platform in the current period. This makes it more difficult for the non-focal platform to convince consumers to join their platform even if it is of higher quality. With dynamic quality shocks Halaburda et al. (2014) find that the winning platform will switch over time; this provides intuition for platform markets where the dominant platform changes across platform generations.

In developing their model, Halaburda et al. (2014) assume the platform is one-sided where homogeneous consumers receive a network benefit from additional consumers joining the platform. This implies the winning platform will capture all consumers and the losing platform will have no participation. In many cases platforms compete in two-sided markets with consumers as sellers: video game consoles with consumers and game developers, smart-
phones with customers and app providers, and online marketplaces with buyers and sellers. To this point, a complete investigation of how switching costs affect dynamic competition in a two-sided market has not been done. This research intends to fill this gap in the literature by investigating a dynamic two-sided market with switching costs. Furthermore, this is the first to incorporate how the incumbent platform uses its prices and cloud computing to determine the extent for which switching costs exist.

In Section 2, the static model of a platform in a two-sided market with consumers and sellers is introduced. Then the dynamic model of a platform that uses cloud storage is developed in Section 3. This leads to the dynamic model with an incumbent platform and a second period entrant in Section 4. Lastly, Section 5 concludes followed by an appendix containing the proofs of the theorems in this paper.

2 Static Base Model

Consider a platform with consumers on one side and sellers on the other side. The platform charges consumers a fixed fee to purchase or become a member of the platform. Sellers generate profits from selling their product or service to the platform’s consumers and platforms charge sellers a percentage of these profits to join the platform. This is the fee structure used by many platform marketplaces; app stores take a percent of app sales, as do video game platforms and online marketplaces.

4 Depending on the type of platform market consumers are either members of the platform (e.g., consumers are members of Pandora) or consumers own the platform (e.g., consumers own a smartphone or video game console).

5 The sellers’, as opposed to the platform, ability to set prices for their products varies across platform marketplace; this is examined by Hagiu and Lee (2011). It is also possible that the platform is the seller of some products which is examined by Hagiu and Wright (2014) and Johnson (2014). In this paper the sellers have all the pricing power for their products and all the products are developed by third party sellers.
2.1 The Platform

Consumers pay a fixed membership fee, $P$, to join the platform. For example, this is the retail price that consumers pay to purchase a smartphone or video game console. Similarly, the platform charges an ad valorem fee, $f$, to sellers; that is, the platform takes a percent of each sale. The platform’s fees may be negative in order to subsidize membership.

Platform profits are given by:

$$\Pi = N_1 \cdot (P - C) + f \cdot (q \cdot N_2) \cdot p, \quad (1)$$

where $N_1$ ($N_2$) is the number of consumers (sellers) that join the platform. The constant marginal cost to the platform for an additional consumer is given by $C$, and the constant marginal cost to the platform for an additional seller is assumed to be zero.\(^6\) For simplicity assume fixed costs are zero. The expected total number of transactions is given by $q \cdot N_2$ where $q$ is the expected number of sales made by each of the $N_2$ sellers that join the platform.\(^7\) Lastly, the expected price of a product is given by $p$. Thus, the profits that the platform receives from the consumer side is the number of consumers times the profit per consumer and the profits the platform receives from the seller side is the ad valorem fee times the expected total revenue generated by all of the transactions between consumers and sellers.

The timing of play is as follows. First, the platform sets prices, $P$ and $f$, either of which can be less than zero. For many apps and games the quality is unclear upon release to the market and it takes time for consumers to experience and review a new product. Thus, the popularity of products are realized after sunk participation decisions are made and consumers and sellers decide whether or not to join the platform based on expected gains from joining the platform and the prices the platform sets. Once participation decisions are made, the

\(^6\)That is, the marginal cost to the platform for providing an additional app or game is zero.

\(^7\)Alternatively, the expected number of total transactions can be given from the consumer’s perspective; however, due to the heterogeneity on the consumer side, consumers make different amounts of purchases and so the expression is less intuitive.
resulting payoffs are realized.\footnote{Coordination failure and no-trade equilibrium are not the focus of this paper. In equilibrium, agents must have consistent beliefs that support the equilibrium prices and allocations of agents.}

2.2 Consumers and Sellers

Consumers are on Side 1 and sellers on Side 2. Characterizing the seller side first leads to a more natural development of this kind of marketplace. Individual sellers are indexed by $\theta \in [0, \infty)$ and each seller has one product (e.g., for smartphones this may be a map app, a weather app, a car racing app, etc.). Thus, the number of products available on the platform is the same as the number of sellers that join the platform; denoted by $N_2$.

The expected profits from product sales are given by $\pi(\theta)$ and sellers have heterogeneous sunk costs of product development. Let $F \cdot \theta$ be the sunk cost to develop product $\theta$. That is, low $\theta$-type sellers have lower sunk costs than high $\theta$-sellers. This leads to endogenous entry of sellers on the platform. For simplicity, the marginal cost for every seller is zero; thus, differences in seller profitability stem from the demand side (i.e. the popularity of that product, captured by $\sigma_\theta$) and not the marginal cost side. Thus, a seller of product $\theta$ when joining the platform has utility

$$u_2(\theta) = (1 - f)\pi(\theta) - F \cdot \theta,$$  \hfill (2)

where $f$ is the ad valorem fee the platform charges a seller that joins the platform. Every seller has a reservation utility that is normalized to zero. Thus, a seller of type $\theta$ joins the platform when $u_2(\theta) \geq 0$.

There exists a mass of consumers on Side 1, normalized to 1, with individual consumers indexed by $\tau \in [0, 1]$. The number of consumers that decide to join the platform is denoted by $N_1 \in [0, 1]$.

Consumers have unit demands for each product that is available. However, consumers

\footnote{In the case for app or video game sellers, marginal cost is nearly zero.}
are heterogeneous in their value for a particular product. For a given product, $\theta$, consumers indexed with a lower $\tau$ are more likely to value the product. Thus, some consumers are more likely to value a product than other consumers. For example, teens may have many apps on their smartphone relative to their parents; whereas, their parents may have a few apps that they value. The expected utility for consumer $\tau$ from product $\theta$ is given by $CS(\tau, \theta)$ and $CS(\tau, \theta)$ is decreasing in $\tau$ which captures this consumer heterogeneity.

Consumers also gain utility from the platform that is not generated by the seller side of the market. This utility is denoted by $V$ and can be large, as in the case of smartphones where there are many uses for a smartphone outside of using apps, or close to zero, as in the case with Pandora where there is little gain from the platform outside of interaction with content. Thus, a consumer of type $\tau$ has utility

$$u_1(\tau) = V + \int_0^{N_2} CS(\tau, \theta)d\theta - P,$$

where $N_2$ is the number of products that are made available on the platform and $P$ is the price a consumer pays to join the platform. Every consumer has a reservation utility that is normalized to zero. Thus, a consumer $\tau$ joins the platform when $u_1(\tau) \geq 0$.

### 2.3 Equilibrium

To determine the equilibrium for the game, a further development of the interaction between consumers and sellers is required. To set up the interaction more formally, let $v_{\tau, \theta}$ be the reservation value that consumer $\tau$ has for product $\theta$. Consumer $\tau$ has a positive reservation for a given product $\theta$, $v_{\tau, \theta} > 0$ with probability $(1 - \tau)$. Thus, $\tau$ captures the probability that a consumer has any interest in a given product. Formally, this is captured in Assumption 1.
**Assumption 1.** Consumers are heterogeneous so that for product $\theta$:

$$
\begin{align*}
\upsilon_{\tau,\theta} > 0 & \quad \text{with probability } (1 - \tau) \\
\upsilon_{\tau,\theta} = 0 & \quad \text{with probability } \tau.
\end{align*}
$$

(4)

Assumption 1 implies that consumers are heterogeneous in their probability of having a positive value for a given product. Thus, consumers with lower $\tau$ have a positive value for more products (teens with apps) than consumers with higher $\tau$ (parents with fewer apps), in expectation.

**Assumption 2.** Given consumer $\tau$ has a positive value for product $\theta$, $\upsilon_{\tau,\theta} > 0$, let

$$
\upsilon_{\tau,\theta} \sim U[0, \sigma_{\theta}],
$$

(5)

where $\sigma_{\theta}$ depends on product $\theta$.

Assumption 2 implies that all consumers that have a positive value for product $\theta$, ($\upsilon_{\tau,\theta} > 0$) the value is distributed uniformly between zero and $\sigma_{\theta}$, where $\sigma_{\theta}$ captures the popularity of product $\theta$. Given that $N_1$ consumers join the platform, the demand for product $\theta$ is given by:

$$
q(\theta) \equiv \int_0^{N_1} P_r(\tau \text{ buys}|p(\theta)) d\tau
= \int_0^{N_1} \left(1 - \frac{p(\theta)}{\sigma_{\theta}}\right) (1 - \tau) d\tau
= \left(1 - \frac{p(\theta)}{\sigma_{\theta}}\right) (1 - \frac{N_1}{2}) \cdot N_1.
$$

(6)

where $p(\theta)$ is the price of product $\theta$. Thus, assuming consumer’s valuations follow the uniform distribution results in consumers having linear demand for a given product. The corresponding inverse demand is:

$$
p(\theta) = \sigma_{\theta} \left(1 - \frac{1}{\left(1 - \frac{N_1}{2}\right) N_1}\right) \cdot q(\theta).
$$

(7)
Seller profits from product sales are given by:

$$\pi(\theta) = p(\theta) \cdot q(\theta) = p(\theta) \cdot \left(1 - \frac{p(\theta)}{\sigma_\theta}\right) \left(1 - \frac{N_1}{2}\right) \cdot N_1.$$  \hfill (8)

Maximizing seller profits gives the following solution for seller $\theta$\hspace{1cm} \footnote{The second-order conditions hold for profit maximization.}

$$p^*(\theta) = \frac{\sigma_\theta}{2}, \hfill (9)$$

$$q^*(\theta) = \frac{1}{4} (2 - N_1) \cdot N_1, \hfill (10)$$

$$\pi^*(\theta) = \frac{\sigma_\theta}{8} \cdot (2 - N_1) \cdot N_1. \hfill (11)$$

Given product prices from Equation (9), the consumer surplus from product $\theta$ for a consumer of type $\tau$ is given by:

$$CS(\tau, \theta) \equiv E[v_{\tau, \theta} - p^*(\theta)|v_{\tau, \theta} \geq p^*(\theta)] \cdot Pr(\tau \text{ buys}|p^*(\theta)) = \frac{\sigma_\theta}{8} (1 - \tau). \hfill (12)$$

The popularity of a product, $\sigma_\theta$, has distribution $G(\cdot)$ on the support $[\sigma, \bar{\sigma}]$ and expected value $E[\sigma_\theta] = \sigma$. Furthermore, the popularity, $\sigma_\theta$, is not realized until after a seller joins the platform. Agents take expectations with respect to $\sigma_\theta$ in making participation decisions. Thus, the expected utilities agents face when making participation decisions are given by:

$$u_1(\tau) = V + \frac{\sigma}{8} (1 - \tau) \cdot N_2 - P, \hfill (13)$$

$$u_2(\theta) = (1 - f) \frac{\sigma}{8} \cdot (2 - N_1) \cdot N_1 - F \cdot \theta, \hfill (14)$$

Notice that $u_1(N_1) = 0$ and $u_2(N_2) = 0$ identify the marginal agents that join the platform, $\tau = N_1$ and $\theta = N_2$. Thus, Equations (13) and (14) imply that the platform can solve for $P$ and $N_2$ as functions of $N_1$ and $f$: $P = V + \frac{\sigma}{8} (1 - N_1) \cdot N_2 = V + \frac{\sigma^2}{64F} (1 - N_1) \cdot N_1$.
$(1 - f) (2 - N_1) \cdot N_1$, and $N_2 = \frac{f}{8F} \cdot (2 - N_1) \cdot N_1$. Hence, the platform’s profit is a function of $N_1$ and $f$. To simplify calculations, let $V = C^{11}$.

Solving the platform’s problem gives the equilibrium of the entire game:

$$N_1^* = \frac{3}{4}, \quad N_2^* = \frac{9\sigma}{128F}, \quad P^* = C + \frac{9\sigma^2}{4096F}, \quad f^* = \frac{2}{5}, \quad (15)$$

The platform also charges consumers a price that is higher than the marginal cost. Full participation on the consumer side is not reached because of this markup. The ad valorem fee the platform charges sellers is forty percent. That is, the platform takes forty percent of the profits from sellers. This fee is high relative to many platform industries. For example, the industry standard for app stores is thirty percent, [Mackenzie (2012)](https://example.com); in fact, this is exactly Google Play’s rate, [Google (2015)](https://example.com). In the video game industry the fee is lower, usually around twelve percent according to [Pham (2010)](https://example.com). Thus, the equilibrium fee in the static model is relatively high; however, in the following section with dynamics the model produces fees that are closer to these industry standards.

### 3 A Dynamic Platform: The Cloud

Many platforms are updated over time with new “generations.” Platforms develop their new generation so that purchases made for the previous generation can still be used on the new generation.\footnote{This assumption is not critical and it makes computations straightforward: In the market for smartphones and video game consoles it would be the case that the marginal cost to produce the platform and the membership gains consumers receive are positive and approximately equal.} In this section a dynamic model of a platform that uses cloud storage when introducing new generations of its platform to consumers and sellers is developed.

\footnote{Alternatively, the new generation or a renewal of a platform membership subscription implies that consumer preferences within the platform will carry over as in the case for Pandora where internet radio preferences are maintained over time for its customers.}
3.1 Dynamic Consumers and Sellers

There are two periods. In the first period the platform sells the first generation platform. For example, Apple sells the first generation iPhone or Nintendo sells its first generation video game console. The platform sets first period prices, $P_1$ to consumers and $f_1$ to sellers, and then consumers and sellers make participation decisions. In the second period, the platform sells an updated platform, the second generation, to consumers and sellers with updated prices $P_2$ and $f_2$. The first generation platform is obsolete in the second period so if consumers want to use the platform in the second period they must purchase the new generation.

The consumers in the first period that purchased the platform, $N_{11}$, the products, apps or games, that they purchased, $Q_1 = q_1 \cdot N_{21}$, can be used on the new platform in the second period; however the utility that a consumer receives from the products in the first period depreciates in the second period by a factor of $\phi \in [0, 1]$, where $\phi$ denotes the strength of the cloud effect. Thus, if consumer $\tau$ has utility $CS_1(\tau) \cdot N_{21}$ from product purchases in the first period then the utility they receive in the second period from their first period purchases is given by $\phi \cdot CS_1(\tau) \cdot N_{21}$. A larger $\phi$ implies a stronger cloud effect and a higher carryover utility for consumers.

A seller of type $\theta$ develops a new product in the second period and again incurs the fixed cost, $F_\theta$, to develop the product. The popularity of the new product, $\sigma_\theta$, is uncorrelated with the popularity of the seller’s previous product and is not revealed until participation decisions in the second period are made. Thus, agents take expectations with respect to $\sigma_\theta$ in making participation decisions.

The utility function for consumers in the first period is as before:

$$u_{11}(\tau) = V + \frac{\sigma}{S}(1 - \tau) \cdot N_{21} - P_1,$$

\[\text{(17)}\]
In the second period, consumer utility depends on whether or not the consumer purchased the platform in the first period. Suppose consumer $\tau$ purchased the platform in the first period, then the expected carryover utility that consumer $\tau$ receives from their first period purchases is the expected number of purchases times the expected utility of each purchase. The carryover utility for consumer $\tau$ is denoted by $\bar{u}(\tau)$. Formally this is given by:

$$
\bar{u}(\tau) \equiv \phi \cdot E(v|v > p^*(\theta)) \cdot \Pr(v > p^*(\theta)) = \phi \cdot \frac{\sigma}{4} (1 - \tau) N_{21}.
$$

(18)

The utility function for consumers in the second period is given by:

$$
u_{12}(\tau) = V + \frac{\sigma}{8} (1 - \tau) \cdot N_{22} - P_2 + 1_{\{\tau \leq N_{11}\}} \cdot \bar{u}(\tau),
$$

(19)

where $1_{\{\tau \leq N_{11}\}} = 1$ when $\tau \leq N_{11}$ and equals zero otherwise. The utility functions for sellers in the first period and in the second period are given by:

$$
u_{2t}(\theta) = (1 - f_t) \frac{\sigma}{8} \cdot (2 - N_{1t}) \cdot N_{1t} - F \cdot \theta,
$$

(20)

for $t = 1, 2$.

The platform, sellers, and consumers are forward looking. The platform cannot commit to future prices or price discriminate in the second period through a loyalty program where there is one price for returning consumers and a different price for new consumers.

The additional carryover utility for consumers that make purchases in the first period provides the platform with new incentives in maximizing profit. If the platform increases the number of purchases by consumers in the first period then the platform can charge higher prices in the second period. The platform can increase first period purchases in two ways. First, the platform can increase purchases by providing additional sellers to the marketplace through a lower ad valorem fee. Alternatively, the platform can charge consumers a lower price in the first period to increase the number of consumers with a carryover utility.
3.2 Equilibrium

The platform is forward looking and for simplicity there is no depreciation for second period profits. The platform sets prices $P_1$, $f_1$, $P_2$, and $f_2$, to maximize profits over the two periods which is given by:

$$\Pi = N_{11} \cdot (P_1 - C) + f_1 \cdot (q_1 \cdot N_{21}) \cdot p + N_{12} \cdot (P_2 - C) + f_2 \cdot (q_2 \cdot N_{22}) \cdot p.$$ (21)

Since $u_{1t}(N_{1t}) = 0$ and $u_{2t}(N_{2t}) = 0$ identify the marginal agents, $\tau = N_{1t}$ and $\theta = N_{2t}$, that join the platform on each side; these implicitly define consumer prices, $P_1$ and $P_2$, and seller participation levels, $N_{21}$ and $N_{22}$, as functions of the ad valorem fees, $f_1$ and $f_2$, and the consumer participation levels, $N_{11}$ and $N_{12}$. Thus, the platform maximizes profits with respect to $N_{11}, N_{12}, f_1,$ and $f_2$.

Before solving the platform’s problem it is important to consider the platform’s dilemma in choosing the second period consumer participation level, $N_{12}$. If the platform sets prices so that more consumers join the platform in the first period, $N_{11} > N_{12}$, then the platform is not capturing all of the carryover utility from the consumers that make purchases in the first period, the consumers $\tau$ such that $\tau \in (N_{12}, N_{11}]$. Alternatively, if the platform sets prices so that more consumers join the platform in the second period, $N_{11} < N_{12}$, then the platform must reduce its prices to capture those additional consumers that do not have carryover utility from the first period. Thus, it is costly, in terms of requiring lower prices, for the platform to capture additional consumers in the second period, especially when the carryover utility is large, $\phi$ close to one.

In solving the platform’s problem gives the following result:

**Theorem 1.** In equilibrium, the platform sets prices so that some of its first period consumers do not join the platform in the second period when the cloud effect exists, $N_{12}^* < \frac{3}{4} = N_{11}^*$ when $\phi > 0$. Furthermore, the number of second period consumers that the platform supports is diminishing in the strength of the cloud, $\frac{\partial N_{12}^*}{\partial \phi} < 0$ for all $\phi \in [0,1]$. 

13
The platform distorts first period consumer participation as in the static model, \( N_{11}^* = \frac{3}{4} = N_1^* \), and the carryover utility results in the platform creating an even larger distortion with reduced consumer participation in the second period, \( N_{12} < N_{11}^* = \frac{3}{4} = N_1^* \) for all \( \phi > 0 \). The carryover utility creates an incentive for the platform to further distort participation in the second period with higher prices that reduce participation. Furthermore, this distortion is increasing in the cloud effect, \( \frac{\partial N_{12}^*}{\partial \phi} < 0 \). This implies that a dynamic monopoly platform will not ensure that all of its previous consumers join the platform in the second period.

Changes in the strength of the cloud effect have an impact on equilibrium prices and seller participation levels. These effects are captured in the following theorem:

**Theorem 2.** For all \( \phi \in [0, 1] \) an increase in \( \phi \) leads to lower ad valorem fees in both periods, higher consumer prices in both periods, and more sellers in the first period; \( \frac{\partial f_1^*}{\partial \phi} < 0 \) and \( \frac{\partial P_1^*}{\partial \phi} > 0 \) for \( t = 1, 2 \), and \( \frac{\partial N_{21}^*}{\partial \phi} > 0 \). The effect on seller participation in the second period is ambiguous.

Theorem 2 states several important effects on the platform due to an increase in the strength of the cloud, \( \phi \). First, as the cloud effect increases and the carryover utility for returning customers increases, the platform has an incentive to provide consumers with more sellers in the first period and then charge its existing consumers a higher price in the second period. Thus, an increase in the cloud effect leads to a decrease in first period seller ad valorem fee which increases first period sellers and an increase in second period consumer price (\( \frac{\partial f_1^*}{\partial \phi} < 0, \frac{\partial N_{21}^*}{\partial \phi} > 0 \), and \( \frac{\partial P_2^*}{\partial \phi} > 0 \)).

Second, the increased number of first period sellers from an increase in the cloud effect creates an incentive to increase the first period price to consumers. Since the platform holds the number of first period consumers constant across the strength of the cloud, it must be the case that an increase in the cloud effect results in the platform increasing its first period consumers a price as the number of first period sellers increases due to an increase in the cloud effect; thus, \( \frac{\partial P_1^*}{\partial \phi} > 0 \).
Lastly, since the number of consumers that join in the second period is decreasing in the cloud effect, it is more difficult for the platform to support second period sellers without lowering the second period ad valorem fee. Thus, to ensure a sufficient number of sellers, the platform reduces its ad valorem fee as the cloud effect increases, \( \frac{\partial f^*_2}{\partial \phi} < 0 \).

In comparing the ad valorem fees the platform uses in the dynamic model with the ad valorem fee used in the static model we see that a dynamic platform sets a lower fee to the seller side of the market. In fact, for the stylized example with \( \phi = 1 \) so that \( N_{12} \approx .6 \) and then \( f^*_1 \approx 15\% < 40\% = f^* \) and \( f^*_2 \approx 27\% < f^* \). In the dynamic model, the platform has more of an incentive to capture sellers in the first period then it does in the second period which is reflected by the lower first period ad valorem fee, \( f^*_1 < f^*_2 \). Furthermore, these dynamic ad valorem fees resemble the fees found in the market for apps and games, Google (2015), Mackenzie (2012) and Pham (2010), which suggests that there do exist cloud effects in these markets and these platforms account for how greater consumption tied to a platform will make the platform more valuable to existing consumers in the future.

With a single platform, the objective of the platform is to generate and extract the most surplus over the two periods when there is a carryover in product use for consumers across two generations of a platform. In many platform markets, after a platform successfully launches its first generation it faces a competing platform when it launches its second generation. This affects the incumbent’s pricing strategy in the first period as the incumbent uses the carryover utility of its existing consumers to better compete with the entrant in the second period. Thus, if the incumbent affectively “locks-in” its existing customers then the entrant is not a threat. This is the first model that investigates how consumer lock-in affects platform competition in a two-sided market where platforms can use their cloud computing to lock-in existing consumers.
4 Platform Competition, Foreclosure, and Entry

In this section dynamic platform competition where the incumbent platform uses the cloud to compete against an entrant is analyzed. This captures the effects of cloud computing and backward compatibility on dynamic entry in markets with network effects. In the first period the incumbent is the only platform that exists and in the second period there are two platforms, the incumbent and the entrant. The cloud effect provides the incumbent platform’s previous customers with carryover utility from their purchases on the platform in the first period. This effectively creates an opportunity cost for those consumers who purchased the incumbent’s platform in the first period. Depending on the strength of the cloud effect and relative quality of the incumbent’s platform compared to the entrant’s platform different equilibria arise.

4.1 Multiple Platforms

In the first period there exists one platform, the incumbent, that sets prices to consumers and sellers who then decide whether or not to participate on the platform. In the second period there exists a potential entrant that also sets prices in an attempt to compete with the incumbent platform. The platforms set prices simultaneously and then agents make their allocation decisions.

The platforms have different quality levels in terms of technologies so that the base membership utility from the incumbent (entrant) platform is $V^I (V^E)$ where the incumbent is denoted by superscript $I$ and the entrant by superscript $E$. For example, in the case of smartphones, $V^E > V^I$ can be interpreted as the entrant having a camera and other hardware features not related to apps that are better than the incumbent. Similarly, $V^E > V^I$ can be interpreted as the entrant’s video game console having a built-in Blu-ray player while the

\footnote{Note, when analyzing welfare in platform markets it is not always the case that platform competition increases welfare, see Jeitschko and Tremblay (2015). When entry is foreclosed by the incumbent platform because the incumbent sets low prices to block entry then a similar result may hold: the potential entrant forces the incumbent to price low, agents only join the incumbent’s platform, and so many agents participate and concentrate on one platform which potentially leads to greater welfare.}
incumbent’s only has a DVD player.

Alternatively, the membership benefit for a platform incorporates all of the preloaded content and content that is exclusive to a platform. For example, if the entrant has exclusive content, an app or a game, available on its platform then \( V^E > V^I \). This occurred with Microsoft’s Xbox video game platform where Microsoft developed a popular game in house that was exclusive to their platform; however, exclusive content can also be done by a third party and an exclusive contract.\(^{15}\)

Let the difference in quality between the entrant’s platform and the incumbent’s platform be denoted by \( \Delta := V^E - V^I \). Thus, if \( \Delta > 0 \) then the entrant’s platform is of higher quality and if \( \Delta < 0 \) then the incumbent’s platform is of higher quality. To simplify computations \( V^I \) is constant over the two periods and let \( V^I = C \). This implies that \( \Delta \) characterizes both the entrant’s quality advantage over the incumbent and the entrant’s added marginal benefit to a consumer relative to the marginal cost of a consumer.\(^{16}\)

Sellers can either single-home, join one platform, or multi-home and join both platforms. If a seller multi-homes then it is able to sell its product to consumers on each platform. For simplicity, assume consumers single-home.\(^{17}\) The utilities that a second period consumer receives from joining the incumbent’s platform or the entrant’s platform are given by:

\[
u^I_{12}(\tau) = V^I + \frac{\sigma}{8}(1 - \tau) \cdot N^I_{22} - P^I_2 + 1_{\{\tau \leq N^I_{11}\}} \cdot \phi \cdot \frac{\sigma}{4}(1 - \tau) N^I_{21}, \tag{22}
\]

\[
u^E_{12}(\tau) = V^E + \frac{\sigma}{8}(1 - \tau) \cdot N^E_{22} - P^E_2,
\tag{23}
\]

where \( P^I_2 \) and \( P^E_2 \) are the second period prices to consumers by the incumbent and the

\(^{15}\text{Exclusive contracts are not the scope of this paper; however, this is one way to incorporate such deals into the model.}\)

\(^{16}\text{Pinning down the incumbent’s quality relative to marginal cost allows results to be interpreted more easily. Furthermore, when investigating entry the focus of the analysis falls on the perspective of the entrant and its relative advantage over the incumbent, either in quality or in costs; by assuming } V^I = C \text{ the analysis follows consistently when interpreting results.}\)

\(^{17}\text{Allowing consumers to multi-home is difficult as there are a variety of assumptions one can make regarding a multi-homing consumer’s membership utility } V \text{. For more on endogenous homing decisions see } \text{Jeitschko and Tremblay (2015).} \)
entrant, \( N_{22}^I \) and \( N_{22}^E \) are the number of second period sellers available on the incumbent’s platform and the entrant’s platform, and \( N_{21}^I \) is the number of sellers that join the incumbent’s platform in the first period.

Assume that the reservation utility for a consumer is zero. Thus, a consumer \( \tau \) joins the incumbent’s platform if \( u_{12}^I(\tau) > u_{12}^E(\tau) \) and \( u_{12}^I(\tau) > 0 \). Alternatively, consumer \( \tau \) joins the entrant’s platform if \( u_{12}^E(\tau) > u_{12}^I(\tau) \) and \( u_{12}^E(\tau) > 0 \). Consumers do not have favorable beliefs towards either platform; if a consumer is indifferent between joining the two platforms then it joins each with equal probability.

The utilities that a seller in the second period receives for joining the incumbent’s platform, the entrant’s platform, or both platforms are given by:

\[
u_{22}^I(\theta) = (1 - f_2^I)\frac{\sigma}{8} \cdot (2 - N_{12}^I) \cdot N_{12}^I - F \cdot \theta,
\]

\[
u_{22}^E(\theta) = (1 - f_2^E)\frac{\sigma}{8} \cdot (2 - N_{12}^E) \cdot N_{12}^E - F \cdot \theta,
\]

\[
u_{22}^M(\theta) = \nu_{22}^I(\theta) + \nu_{22}^E(\theta),
\]

where \( f_2^I \) (\( f_2^E \)) is the incumbent’s (entrant’s) ad valorem fee to sellers. In multi-homing, a seller incurs the cost \( F\theta \) twice. This can be thought of as the heterogeneous synchronization cost for an app or game to be synchronized to an additional platform.\(^{18}\) The reservation utilities for a seller to join a platform are zero. Thus, a seller in the second period joins the incumbent’s platform if \( u_{22}^I(\theta) > 0 \) and joins the entrant’s platform if \( u_{22}^E(\theta) > 0 \).

Platform profits for the incumbent and the entrant are given by:

\[
\Pi^I = N_{11}^I \cdot (P_1^I - C) + f_1^I \cdot (q_1^I \cdot N_{21}^I) \cdot p + N_{12}^I \cdot (P_2^I - C) + f_2^I \cdot (q_2^I \cdot N_{22}^I) \cdot p.
\]

\[
\Pi^E = N_{12}^E \cdot (P_2^E - C) + f_2^E \cdot (q_2^E \cdot N_{22}^E) \cdot p.
\]

\(^{18}\)To see how discounting in synchronization costs affects endogenous homing decisions see Jeitschko and Tremblay (2015).
where $C$ is the marginal cost of an additional consumer for each of the platforms.

4.2 Dynamic Equilibrium

The incumbent platform maximizes profits given the entrant’s second period prices and the entrant maximizes profits given the incumbent’s prices and first period allocation of consumers. In solving each platforms’ problem, implicit reaction functions are generated which determine the equilibrium.

As a base case, suppose $\Delta = 0$; that is, $V^I = V^E = C$ and the only difference between the platforms is that the incumbent has previous customers with carryover utility. This case provides much of the intuition regarding dynamic platform competition. Note that when the cloud effect does not exist, $\phi = 0$, then the incumbent has no advantage in any way over the entrant in the second period. When $\Delta = 0$ and $\phi = 0$, the platforms are identical from the perspective of both consumers and sellers and there is no solution; each platform will always have the incentive to undercut the consumer price of the other platform. In this case, the market fails to launch as there is a chicken and the egg problem and additional assumptions regarding the timing of the game are required, see Caillaud and Jullien (2003) and Hagiu (2006). The focus of this paper is on how backward compatibility affects platform entry and so the case where backward compatibility does not exist, $\phi = 0$, is not of particular interest and so we focus on the cases when $\phi > 0$.

Consider the base case when platform qualities are equal and the cloud effect exists, $\Delta = 0$ and $\phi > 0$. Now the incumbent platform has an inherent advantage over the entrant because its previous customers have carryover utility from the first period. In the dynamic monopoly case, when the platform did not face a second period entrant, the platform reduced consumer participation in the second period with $N^*_{12} < N^*_{11}$. However, with a second period entrant, it is more difficult for the incumbent to charge consumers a higher price since the entrant provides consumers with an additional outside option.

\footnote{In a static platform competition model that is similar to this case, Jeitschko and Tremblay (2015) show how endogenous homing leads to a solution to this problem.}
To solve the incumbent’s problem, note that the last consumer \( \tau \) to join the incumbent’s platform, \( \tau = N_{I12} \), is given by \( u_{I12}(N_{I12}) - u_{E12}(N_{I12}) = 0 \). Let \( N_{I12} \) be the total number of consumers that join a platform; that is, \( N_{I12} = N_{I12} + N_{E12} \). For the entrant, the last consumer \( \tau \) that joins the entrant’s platform, \( \tau = N_{12} \), is given by \( u_{E12}(N_{12}) = 0 \). That is, given that both platforms have consumer participation then the consumers that join the incumbent’s platform in the second period are the consumers that have the most to lose by switching platforms and the consumers that join the entrant’s platform are either new consumers or the incumbent’s previous consumers that have less to lose by switching platforms.

**Theorem 3 (Equal Quality Platforms).** For \( \Delta = 0 \) and \( \phi > 0 \) we have,

1. The entrant’s platform enters the market by setting its consumer price equal to marginal cost, \( P_{E2} = C \), and all consumers join a platform, \( N_{I12} + N_{E12} = 1 \).\(^{20}\)

2. There exists \( \tilde{\phi} \in (0,1) \) such that when the cloud effect is weak, \( \phi \leq \tilde{\phi} \), the incumbent aggressively competes with the entrant by setting relatively low consumer prices that result in all previous customers returning to the incumbent platform in the second period, \( N_{I12} = N_{I11} \).

3. When the cloud effect is strong, \( \phi > \tilde{\phi} \), the incumbent sets a high consumer price in the second period, it is however less than the second period monopoly price, resulting in some of its previous consumers joining the entrant’s platform, \( N_{I12} < N_{I11} \).

4. Moreover, as the cloud effect increases, the number of second period consumers on the incumbent’s platform decreases and the number of second period consumers on the entrant’s platform increases, \( \frac{\partial N_{I12}}{\partial \phi} < 0 \) and \( \frac{\partial N_{E12}}{\partial \phi} > 0 \).

If there do not exist quality differences between the two platforms, \( \Delta = 0 \), then the entrant’s platform enters the market. The entrant sets a low consumer price equal to consumer’s membership value of the platform which makes it attractive to consumers, especially

\(^{20}\)Full consumer participation occurs because \( V^E \geq C \); if \( V^E < C \) then a similar result holds however not all consumers will join as \( P_{E2} = C > V^E \).
those consumers that value the platform more as a product than for the apps or games the
seller side provides. As a result, all consumers participate but the consumers that value
the seller side of the market highly, the most profitable consumers, join the incumbent’s
platform. Both platforms make positive profits; however, the incumbent has higher profits
as it charges a higher price to consumers while having more consumer participation than the
entrant and the entrant only makes profits on the seller side with lower participation levels
on each side.

When the cloud effect is small, $\phi \leq \tilde{\phi}$, there is not a lot of carryover utility for the
incumbent’s previous consumers and so competition is strong. The incumbent aggressively
competes with the entrant, its consumer price is relatively low but still larger than the
entrants, and the incumbent captures all its previous consumers. Thus, the incumbent uses
the cloud effect to the full extent in competing with the entrant. However, as the cloud effect
increases, this becomes more costly to the incumbent as it is losing out on capturing this
larger second period carryover surplus.

As the cloud effect becomes large, $\phi > \tilde{\phi}$, it becomes more attractive for the incumbent to
set a higher second period price to consumers to extract some of the larger carryover surplus
from its previous consumers. So the incumbent increases its consumer price in the second
period and does not retain all its previous consumers. As the cloud effect increases the
entrant obtains more consumers and receives greater profits while the incumbent has fewer
second period consumers but also obtains greater profits through greater rent extraction
from the most profitable consumers.

Notice that Theorem 3 implies that it is optimal for the incumbent to reduce its market
share on the consumer side over time when the cloud effect is strong. Even though the entrant
successfully enters the market, the incumbent captures the most profitable consumers and
when the cloud effect is strong the incumbent platform forgoes capturing all its previous
consumers. This suggests that it is not unreasonable to see successful incumbents losing
market share over time as Apple’s iPhone has done in the market for smartphones.
Theorem 3 also provides insight regarding why an incumbent would like to sell multiple, slightly differentiated platforms at different price points. In the market for smartphones this is often seen where multiple products of a new generation are unveiled and only differ in hard drive space but are priced differently. Although a proper analysis is outside the scope of this paper it is clear that such a strategy allows the platform to target different types of consumers.

In this base case when the quality level of the platforms are equal, the threat of an entrant is not substantial as the incumbent uses the cloud effect to ensure that it captures the most profitable consumers in the second period when entry occurs. To this end, the incumbent platform is considered focal or favored. The effects of a focal platform competing with a non-focal platform originated with Caillaud and Jullien (2003) and Hagiu (2006). This concept continues to have important impacts on platform competition; see Jullien (2011), Halaburda et al. (2014) and Jeitschko and Tremblay (2015). However, in those papers the magnitude for which a platform is focal is exogenous. In this model, the focality or strength of incumbency “endogenously” determines the extent to which the incumbent is focal and it depends on the strength of the backward compatibility of the platform. In the case when platforms are of the same quality, the non-focal platform, the entrant, successfully enters the market but only captures the remaining least profitable consumers, makes minimal profits, and has less participation than the focal or incumbent platform. However, it is often the case that an entrant and incumbent differ in the quality that they provide for their consumers.

When the two platforms are of different quality it follows that:

**Theorem 4** (Platforms of Different Quality). There exist $\Delta_E < 0 < \Delta_S < \Delta_{EM}$ such that

1. For $\Delta \leq \Delta_E$ the entrant’s platform fails to enter.

2. For $\Delta_E < \Delta \leq \Delta_S$ the entrant’s platform enters the market with consumer membership benefit pricing, $P^E_2 = V^E$, and makes little profit relative to the incumbent.

3. For $\Delta_S < \Delta \leq \Delta_{EM}$ the entrant’s platform enters the market with a consumer price
markup, \( P^E_2 > V^E \). The incumbent retains the most profitable consumers, however, as the quality difference increases the incumbent captures fewer consumers and the entrant eventually earns greater profits than the incumbent.

4. For \( \Delta_{EM} < \Delta \) the entrant’s platform enters the market and the incumbent’s platform fails to enter in the second period.

When the platforms differ in quality there exist three critical quality difference levels that bifurcate the dynamic equilibrium. When the entrant’s quality is sufficiently low, \( \Delta \leq \Delta_E \), then the entrant’s platform fails to enter the market and compete with the incumbent platform. The number of equilibrium consumers on the incumbents platform when the entrant fails to enter is described in Figure 1a. Note that when \( \Delta < 0 \) the entrant is subsidizing the consumer side of the market at a cost of \( P^E_2 - C = V^E - V^I = \Delta < 0 \) per consumer and at the marginal case where \( \Delta = \Delta_E \), this cost exactly equals the maximum revenues that the entrant generates from the seller side of the market. As the entrant’s quality increases so that \( \Delta > \Delta_E \) then the entrant successfully enters the market.

Once the entrant’s quality is sufficient so that entry occurs there are several equilibria that arise depending on the quality difference between the two platforms. When the entrant’s quality is moderate, \( \Delta_E < \Delta \leq \Delta_S \), the entrant uses consumer membership benefit pricing, \( P^E_2 = V^E \), and enters but only captures the least profitable consumers. The entrant only makes profits on the seller side of the market and the incumbent’s profits are greater than the entrant’s profits. This case is characterized by the equilibrium results found in Theorem 3 and the resulting equilibrium number of consumers is characterized in Figure 1b where the number of consumers that join the entrant’s platform is simply \( 1 - N^I_{12} \) or the distance above the curve.

As the entrant’s platform begins to have a significant quality advantage of the incumbent’s platform, \( \Delta_S < \Delta \leq \Delta_{EM} \), the entrant begins pricing to consumers above the membership benefit, \( P^E_2 > V^E \) and the entrant makes profits on both sides of the platform. An example of this case is shown in Figure 1c where it is no longer the case that every consumer joins a
platform. As the quality difference increases the entrant captures more of the incumbent’s previous customers. Once $\Delta > \Delta_{EM}$, the incumbent acts as a single period monopolist in the first period and exits the market in the second period.

Thus, Theorem 4 implies that the entrant is able to overcome the incumbent’s advantage only when the quality difference sufficiently favors the entrant’s platform. Otherwise the focality that the incumbent gains from being the first to market is enough to skew competition significantly in favor of the incumbent in the second period. Alternatively, this shows the importance of entering the market with a better platform or with a platform that has exclusive content that consumers find desirable enough to prefer the entrant’s platform over the incumbent’s existing platform.

Furthermore, Theorem 4 gives insight toward the different equilibrium configurations found across platform industries. When Google’s Android entered the smartphone market to compete with Apple’s iPhone it was touted as having a better operating system and of being of better quality. Android successfully entered the market; however, Apple was able to charge a higher price and maintain many of its consumers even though the Android’s price was much lower. This equilibrium follows the spirit of the second case of Theorem 4 where the Android phone was of higher quality but the difference in quality was not enough to dominate the iPhone’s position. In the market for video game consoles, Microsoft’s Xbox entered the market with a popular video game (Halo) that was exclusive to Xbox. In this model, this exclusive deal improved the quality of Microsoft’s Xbox and Microsoft was able to successfully enter the market and charge a price to consumers that was similar to the incumbent consumer prices set by Playstation and Nintendo. The three giants split the market in shares and profits. This equilibrium follows the spirit of the third case of Theorem 4.

Similar results exist in comparing Theorems 4 and 3 to previous models on consumer switching costs and lock-in. Results are similar even though the models differ in several

\footnote{For more on the successful entry of Xbox see Lee (2013).}
Figure 1: Equilibrium for Platforms of Different Quality

(a) $\Delta \leq \Delta_E$ and $\Delta_{EM} < \Delta$

(b) $\Delta_E < \Delta \leq \Delta_S$

(c) $\Delta_S < \Delta \leq \Delta_{EM}$
respects. First, models on switching costs focus on the market for a good or collection of components when there exists some exogenously given switching cost for consumers which differs significantly, in terms of context and market structure, from the two-sided market structure. Second, in those models the results on entry, prices, and market share depend on costs and an exogenously given switching cost consumers face; for platforms, the results depend on quality differences and the strength of the carry over utility. Furthermore, the consumer heterogeneity found in platform marketplaces is not used in much of the consumer switching cost literature, instead the standard assumptions are that consumers are homogeneous in their value of the good but there exist new and old customers. In spite of their differences, these models provide similar results; this suggests that these problems maybe isomorphic to an extent. In terms of parameters, cost differences are similar to quality differences, and the given switching cost relates closely to the strength of the carry over for platforms. There is also a similar isomorphic relationship between the two models in terms of the assumptions for consumers; the heterogeneity of consumers in the platform model results in a similar partition of old customers (the high value consumers) and new customers (the low value consumers).

Thus, this model also makes a contribution to the existing consumer switching cost literature. When consumers that are heterogeneous in terms of their value of the good (value for the platform) and this value directly corresponds to the switching cost that exists for that consumer (the carry over utility for the consumer), then the entrant must have a significant quality advantage over the incumbent to overcome the incumbent’s advantage of locked-in consumers to become the larger market share firm with greater profitability.

5 Conclusion

A key feature of competition in two-sided markets is the result that if one platform gains significant membership on one side of the market then that platform has an advantage
over its competitors. This paper examines dynamic platform competition and entry when consumers that stay on the same platform over time experience carryover utility across platform generations through backward computability in platform content. Platforms enable their consumers, through cloud storage or backward computability, to use products purchased on previous generations, apps or games or ebooks, on the current platform generation. This creates an opportunity cost in the form of lost content that acts as a switching cost for consumers when considering an alternative platform.

In a dynamic game where the incumbent platform develops a platform in the first period and then competes with a potential entrant in future periods, I find that the incumbent has a competitive advantage in future periods. When both the incumbent and the entrant develop an updated generation in the second period, the incumbent uses backward compatibility so that its previous consumers can use their previously purchased content only on the incumbent’s platform. If the second period platforms are of the same quality, in terms of inherent quality or exclusive content, then the incumbent allows the entrant to enter the market; however, only a few consumers join the entrant’s platform and the consumers that join are the consumers that are the least profitable resulting in less profit compared to the incumbent.

If the platforms differ in quality then the extent for which entry is successful varies. The entrant must be of sufficiently higher quality to successfully enter the market and obtain profits that are comparable to the incumbent. Depending on the industry, there has been a wide range of success in terms of gaining shares and profitability in platform markets. These results imply that the incumbent’s ability to remain focal over time allows it to capture the most profitable consumers and successfully compete against an entrant even when the entrant’s platform is of higher quality or has exclusive content advantages (unless these advantages are significantly large).
Appendix

Proof of Theorem 1: In solving the platform’s problem the function $P_2(N_{11}, N_{12}, f_1, f_2)$ is discontinuous at $N_{12} = N_{11}$. However, in maximizing profits the platform sets $N_{12} < N_{11}$ and this discontinuity is not an issue. The first order conditions for $f_1$ and $f_2$ imply:

$$f_1 = \frac{N_{11} - 2\phi(1 - N_{12})N_{12}}{2(2 - N_{11})N_{11}},$$

$$f_2 = \frac{1}{2(2 - N_{12})}.$$

Then, using the equation for $f_1$, the first order condition for $N_{11}$ implies $N_{11}^* = 3/4$. Lastly, the first order condition for $N_{12}$ implies:

$$N_{12}(3 - 4N_{12})(3 - 2N_{12}) + 2\phi(1 - 2N_{12})[9/8 + 2\phi(1 - N_{12})N_{12}] = 0. \quad (29)$$

Solving this for $N_{12} \in [0, 1]$ leads to two solutions, one a minimum and the other a maximum. Figure 2 shows the equilibrium number of second period consumers, $N_{12}^*$, as a function of the cloud effect, $\phi$. Thus, $N_{12}^* \leq 3/4 = N_{11}^*$ and $\frac{\partial N_{12}^*}{\partial \phi} < 0$ for all $\phi \in [0, 1]$. □

Proof of Theorem 2: From the proof of Theorem 1 the equation for $f_1$ and $N_{11}^* = 3/4$ imply that $f_1^* = 2/5 - 16/15 \cdot \phi(1 - N_{12})N_{12}$. For all $N_{12} > 1/2$ a decrease in $N_{12}$ increases $(1 - N_{12})N_{12}$; note, from Figure 2 we see that $N_{12}^* > 1/2$ for all $\phi$. Thus, an increase in $\phi$
increases \( \phi \cdot (1 - N_{12})N_{12} \) and so \( \frac{\partial f_1}{\partial \phi} < 0 \). From the proof of Theorem 1, we have \( f_2 = \frac{1}{2(2 - N_{12})} \).

It follows that \( \frac{\partial f_2}{\partial \phi} < 0 \).

In solving \( N_{21} \) as a function of \( f_1 \) and \( N_{11} \) using Equations (20) and since \( N_{11} = \frac{3}{4} \) we have \( N_{21} = (1 - f_1) \frac{\sigma_I}{4} \cdot \frac{5}{4} \cdot \frac{3}{4} \). An increase in \( \phi \) implies a decrease in \( f_1 \) which implies an increase in \( N_{21} \). Thus, \( \frac{\partial N_{21}}{\partial \phi} > 0 \). Similarly, we have \( N_{22} = (1 - f_2) \frac{\sigma_I}{8F}(2 - N_{12})N_{12} \). However, an increase in \( \phi \) decreases \( N_{12} \) which decreases \( (2 - N_{12})N_{12} \) but an increase in \( \phi \) also increases \( (1 - f_2) \) and so the effect on \( N_{22} \) is ambiguous.

In solving for \( P_1 \) using Equation (17) with \( u_{11}(N_{11}) = 0 \) we have \( P_1 = V + \frac{\sigma_I}{8}(1 - N_{11})N_{21} = V + \frac{3}{32}N_{21} \). An increase in \( \phi \) increases \( N_{21} \) which implies \( P_1 \) increases. Thus, \( \frac{\partial P_1}{\partial \phi} > 0 \). Similarly, in solving for \( P_2 \) we have \( P_2 = V + \frac{\sigma_I}{8}(1 - N_{12})N_{22} + \phi \cdot \frac{\sigma_I}{4}(1 - N_{11})N_{21} \). By differentiating with respect to \( \phi \) we see there exists a positive direct first order effect and two second order effects, one is positive while the other is ambiguous. Thus, the first order effect dominates and \( \frac{\partial P_2}{\partial \phi} > 0 \).

**Proof of Theorem 3:** In solving the platform’s problem there are two conditions that arise in the maximization problem. First, the function \( P_2^I(N_{11}, N_{12}, f_1, f_2) \) given by \( u_{12}^I(N_{12}) - u_{12}^E(N_{12}) = 0 \) is discontinuous at \( N_{12}^I = N_{12}^E \) and unlike in the monopoly platform’s problem this condition does bind in the case for \( \phi \leq \tilde{\phi} \). Second, it must be that the consumer side is at most covered by the two platforms, \( N_{12}^I + N_{12}^E \leq 1 \).

The entrant’s problem is simpler; the entrant maximizes profits given the incumbents choice variables. The last consumer \( \tau \) that joins the entrant’s platform, \( \tau = N_{12} \), is given by \( u_{12}^E(N_{12}) = 0 \) which implies \( P_2^E = V^E + \frac{\sigma_I}{8}(1 - N_{12}^I - N_{12}^E) \cdot N_{22}^E \). Similarly, the last seller \( \theta \) that joins the entrant’s platform, \( \theta = N_{22}^E \), is given by \( u_{22}^E(N_{22}^E) \) which implies \( N_{22}^E = (1 - f_2^E) \cdot \frac{\sigma_I}{8F}(2 - N_{12}^E)N_{12}^E \). Maximizing the entrant’s profits with respect to \( f_2^E \) and \( N_{12}^E \) given \( N_{12}^I \) implies:

\[
f_2^E = \frac{1 + N_{12}^I}{2(2 - N_{12}^E)}\cdot \frac{N_{12}^E}{2} \cdot (3 - 2N_{12}^E - N_{12}^I) \cdot [2(3 - 2N_{12}^I) - 3N_{12}^E(3 + N_12)] = \frac{64F}{\sigma^2} \cdot \frac{N_{12}^E}{2(2 - N_{12}^E)} = 0,
\]

(30)
where the last equality is since $\Delta = 0$. The left two terms in Equation (30) are each positive which implies it must be that $0 = [2(3 - 2N_{12}^I) - 3N_{12}^E(3 + N_{12}^E)]$. This implies that

\[ N_{12}^E = \frac{2(3 - 2N_{12}^I)}{3(3 + N_{12}^I)}, \]

which implies that $N_{12}^I + N_{12}^E \leq 1$ becomes $N_{12}^I \leq \frac{-1 + \sqrt{10}}{3} \approx .72$. In solving the incumbent’s problem it takes the entrant’s choices as given. Using the utility functions to measure the last agent, $u_{it}(N_{it}) =$, gives $P_{1}^I, N_{21}^I$ and $N_{22}^I$ as functions of $N_{11}^I, N_{12}^I, f_{1}^I$, and $f_{2}^I$. Lastly, $u_{12}^I(N_{12}^I) - u_{E}^I(N_{12}^E) = 0$ implies that $P_{2}^I = \frac{2}{8}(1 - N_{12}^I)(N_{22}^I - N_{22}^E) + P_{2}^E + 1_{(\tau \leq N_{11}^I)} \cdot \varphi \cdot \frac{2}{4}(1 - N_{12}^I)N_{24}^I$. In maximizing the incumbent’s profits with respect to $f_{1}^I, f_{2}^I, N_{11}^I$ and $N_{12}^I$, given the entrant’s choice variables, the first order conditions for $f_{1}^I$ and $f_{2}^I$ imply:

\[ f_{1}^I = \frac{N_{11}^I - 2\phi(1 - N_{12}^I)N_{12}^I}{2(2 - N_{11}^I)N_{11}^I}, \]

\[ f_{2}^I = \frac{1}{2(2 - N_{12}^I)}. \]

Using the above equation for $f_{1}^I$ and the first order condition for $N_{11}^I$ we have $N_{11}^I = \frac{3}{4}$. Lastly, the first order condition for $N_{12}^I$ when $N_{12}^I < N_{11}^I$ implies the following:

\[ (1 - f_{2}^E)(2 - N_{12}^E)N_{12}^E(1 - 2N_{12}^I) - \frac{64E}{\sigma^2}(P_{2}^E - V^E) = \frac{1}{2} \cdot N_{12}(3 - 4N_{12})(3 - 2N_{12}) + \phi(1 - 2N_{12})^9[8 + 2\phi(1 - N_{12})N_{12}]. \]

This equation will also be important in proving the next theorem when $\Delta$ is nonzero. If a interior solution, $N_{12}^I + N_{12}^E < 1$, exists then Equations (30) and (31) define the equilibrium. However, in solving these equations no solution exists for $\phi \in [0, 1]$. Thus, we have a corner solution for all $\phi$. This implies $P_{2}^E = V^E$ and the consumers that do not join the incumbents platform will join the entrants platform.

Given the corner solution and the entrant’s consumer price, $P_{2}^E = V^E$, the incumbent’s
first order condition for $N_{12}^I$, Equation (31), becomes:

$$\Delta \cdot \frac{64F}{s} + (1 + N_{12}^I)(1 - N_{12}^I)(1 - 2N_{12}^I) = N_{12}(3 - 4N_{12})(3 - 2N_{12}) + 2\phi(1 - 2N_{12})[\frac{9}{8} + 2\phi(1 - 2N_{12})].$$

This equation implicitly defines $N_{12}^I$ when $N_{12}^I < N_{11}^I = \frac{3}{4}$. However, for $\phi \leq 0.1832508 := \tilde{\phi}$ it is the case that $N_{12}^I > \frac{3}{4} = N_{11}^I$. Thus, when $\phi \leq \tilde{\phi}$ we must solve the incumbent’s problem with $N_{12}^I \leq N_{11}^I$ binding. In solving the new incumbent’s problem an implicit function for $N_{11}^I = N_{12}^I$ of $N_{12}^I$ is found and combined with Equation (30) there does not exist a solution for $N_{12}^I + N_{12}^E \leq 1$. Thus, it is again the case there is a corner solution and $P_2^E = V^E$.

Thus, for $\phi \leq \tilde{\phi}$ the incumbent platform captures all its first period consumers and the entrant prices to consumers so that all consumers participate in the second period. In this case the incumbent’s first order condition for $N_{11}^I$ implies:

$$[3 - 2N_{11}^I + 2\phi \cdot (1 - N_{11}^I)]N_{11}^I[3 - 4N_{11}^I + 2\phi(1 - 2N_{11}^I)] + (3 - 2N_{11}^I)N_{11}^I(3 - 4N_{11}^I) = 1 - 2N_{11}^I - 3(N_{11}^I)^2 + 4(N_{11}^I)^3.$$

This equation gives the optimal number of first period and second period consumers the incumbent platform attracts when $\phi \leq \tilde{\phi}$. This completes the equilibrium outcomes over $\phi \in (0, 1]$. The entrant always sets its consumer price equal to the consumer membership benefit so that it captures all the remaining consumers that do not join the incumbent’s platform, $P_2^E = V^E$. The incumbent platform’s consumers over $\phi \in (0, 1]$ is described in Figure 3 where the orange line characterizes the incumbent’s equilibrium number of second period consumers. For $\phi \leq \tilde{\phi}$, the incumbent retains all its previous customers; note, this is more than is more first period consumers than in the monopoly platform case as the first piece of the orange line is greater than $N_{11}^M$. Then for $\phi > \tilde{\phi}$ the incumbent sets the usual monopoly platform consumer level with $N_{11}^I = N_{11}^M = \frac{3}{4}$ but does not capture all its previous consumers in the second period; however, the incumbent does obtain more consumers in the second period then in the case for a monopoly platform as the orange line is higher than the
Figure 3: The Incumbent’s Equilibrium Second Period Consumers.

Proof of Theorem 4. To determine the existence of the cutoff points found in this theorem it is easiest to begin from $\Delta = 0$ and the results found in Theorem 3. As $\Delta$ becomes negative, the equations used in Theorem 3 that implicitly define the interior solution, $N_{12}^I + N_{12}^E < 1$, also define the interior solution for $\Delta < 0$ when it exists, Equations (30) and (31). Initially, for $\Delta$ just below zero, these equations continue to not give a solution and the corner solution, $N_{12}^I + N_{12}^E = 1$, exists with $P^E_2 = V^E_2 < C$. This pricing scheme implies that for $\Delta < 0$ the platform is supporting consumers at a cost. Eventually, as $\Delta$ decreases, an interior solution exists where the entrant sets $P^E_2 > V^E_2$ as keeping the low consumer price is too costly. In this case, the entrants platform loses participation on each side of the market and eventually, for $\Delta = \Delta_E$, entrant profits go to zero and for $\Delta < \Delta_E$ the entrant fails to enter.

As $\Delta$ becomes positive, Equations (30) and (31) continue to fail to provide a solution and the equilibrium continues to be the corner solution with $P^E_2 = V^E_2 > C$. However, with $\Delta > 0$ the entrant is making profits on the consumer side of the market. Eventually, as $\Delta$ increases, Equations (30) and (31) provide an interior solution for $\phi \in (0, 1]$. Let $\Delta_S$ be the $\Delta > 0$ when this interior solution exists. This implies for all $\Delta \in [\Delta_E, \Delta_S)$ the entrant’s platform enters the market with $P^E_2 = V^E_2$.

In the case where $\Delta > \Delta_S$ we have $P^E_2 > V^E_2$, that is the incumbent is optimally restrict-
ing consumer participation to increase profits. To this end, the entrant has some market power and the platforms are splitting the market where the incumbent earns profits from the more profitable consumers while the entrant earns profits from the less valuable consumers. Platforms compete over the location of the marginal consumer, \( \tau = N_{12}^I \). Equation (31) implies the number of consumers that join the entrant’s platform, \( N_{12}^E \), is increasing in \( \Delta \).

This implies \( N_{12}^I \) is decreasing in \( \Delta \) since \( N_{12} = N_{12}^I + N_{12}^E \) is decreasing in \( \Delta \). Eventually, as \( \Delta \) increases, there exists \( \Delta_{EM} > \Delta_S \) so that the incumbent fails to enter the market in the second period for all \( \phi \in (0, 1] \). Thus, the entrant is a monopoly in the second period for all \( \Delta > \Delta_{EM} \).

\[ \square \]

References


Makedonski, B. (2015). Xbox originally thought backwards compatibility was impossible. 

http://www.destructoid.com/xbox-originally-thought-backwards-compatibility-was-impossible-294387.phtml

