Foreclosure, Entry, and Competition in Platform Markets with Cloud Storage*

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October 21, 2016

Abstract

Platform providers in two-sided markets compete over time by introducing new generations of their platforms. New generations are often backward compatible through some form of cloud storage so that consumers' content, preferences, apps, software, and games from the previous generation can still be used on the current generation. When platform providers compete over time, consumers that switch platforms are unable to use their previous content. With two-sidedness, the incumbent platform provider is able to use its price to the other side of the market, the price to content providers, to endogenously determine the strength of the consumer carryover utility that its consumers face when considering switching platforms. Thus, two-sidedness with cloud storage results in endogenously determined switching costs. I find that cloud storage is not used to foreclose platform entry but instead is used to soften competition between platform providers. Furthermore, the resulting equilibria comport with anecdotal evidence of attempted entry across several platform industries, such as smartphones, video game consoles, personal computers, eReaders, and online streaming subscriptions.

Keywords: Two-sided markets, Platform competition, Cloud storage, Consumer lock-in, Endogenous switching costs, entry, entry deterrence
JEL Classifications: D40, L41, L22

*I thank Yong Chao, Jay Pil Choi, Carl Davidson, Jon Eguia, Thomas D. Jeitschko, Amedeo Piolatto, John D. Wilson, the audiences at Universidad Carlos III de Madrid, McMaster University, Gonzaga University, the University of Queensland, and the participants of the Fourteenth Annual International Industrial Organization Conference, the Seventh Annual Searle Conference on Internet Commerce and Innovation, and the Fourteenth Annual Harvard Business School Open and User Innovation Conference for their helpful comments.

1 Introduction

Many platforms are updated over time with new generations. For example, the iPhone is now in its seventh generation while the video game console industry began its eighth generation in November 2013. Similarly, new personal computers and eReaders are updated regularly by their developers. By updating a platform, the content, software, app, and game providers develop new content of higher quality while 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 content and updated technologies. Platform providers develop a new generation so that user preferences and previous content purchases from the last generation are carried over to the new generation; that is, platform generations are backward compatible. This backward compatibility is often achieved through cloud storage technologies. That is, cloud storage enables a platform provider to store content and preferences for its customers facilitating consumer carryover utility in future periods.[1] For example, content purchased on iTunes is stored for consumers to use on any Apple device over many generations of a device; the same is true for software on personal computers and ebooks for eReaders. Similarly, using previous generation video games on new consoles is similar to cloud storage.

The consumer carryover utility acts much like a switching cost since a platform's existing customers face an opportunity cost, in the form of lost content, from switching platforms. However, unlike typical markets with switching costs, the two-sided market allows an incumbent to endogenously affect the consumer carryover utility — the switching cost — in two ways. First, the incumbent affects consumer lock-in on the traditional extensive margin where a lower first period price to consumers results in more consumers purchasing the platform in the first period. Second, the incumbent affects the intensity of the consumer carryover utility through the content side of the market by charging content providers a

[1] While backward compatibility can be achieved through other means, cloud storage is the most common especially for digital content.

lower price in the first period. This results in greater content availability in the first period which increases the consumer carryover utility or switching cost for each consumer.

I find that cloud storage is not used to deter entry. Instead, the carryover utility generated through cloud storage is used to soften future price competition between platform providers. Furthermore, an increase in the strength of the consumer carryover utility results in softened platform competition through higher prices to consumers by both platforms.

In addition, I find that the dynamic equilibria of entry and exit conform to evidence found across many two-sided industries. For example, in the market for smartphones, the Blackberry was tipped out of the market as an incumbent by the entry of Apple's iPhone. Since then the iPhone has sustained relatively high prices as an incumbent, even in the face of several entrants that charge lower prices (e.g., Google Android and Microsoft Windows Phone). Some of these entrants have succeeded (Google) while others have failed (Microsoft). 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). The model presented here suggests which of the multiple entry equilibria seen within these industries will occur, something that is not fully explained by the existing literature on platform competition.

There is a large contemporary literature on platform competition: Rochet and Tirole (2003), Caillaud and Jullien (2003), Armstrong (2006), Hagiu (2006), Jullien (2011) and White and Weyl (2015), all of which consider static competition. A common equilibrium concern in this literature is the tipping equilibrium where an incumbency advantage, sometimes favorable beliefs, results in all participation occurring on a single platform. With cloud storage, I find that entry often occurs as the incumbent uses its ability to lock in consumers to soften future platform competition. This suggests that an asymmetric equilibrium will occur without tipping.

Little research has been done on dynamic competition in two-sided platform markets. The main contributions to this literature have been empirical. Iansiti and Zhu (2012) and

Lee (2013) investigate entry in the video game console industry, and Kim et al. (2013) investigate entry in the daily deal promotions market. One theoretical contribution to this literature is Hałaburda et al. (2016), who develop a dynamic model with network effects where the platform that "won" in the previous period is *focal* in the current period. That is, consumers observe which platform was available in the previous period and form favorable beliefs about that platform in the current period. This essentially acts as an exogenously given switching cost that makes it more difficult for the non-focal platform to convince consumers to join their platform even if it is of higher quality.[2] Thus, this paper contributes to the existing literature on dynamic platform competition by considering entry in two-sided markets where dynamic intra-platform effects allow an incumbent platform to endogenize the switching costs that its consumers face.

This paper also makes a contribution to the existing literature on traditional markets with consumer switching costs and lock-in (see Farrell and Shapiro (1988), Padilla (1995), or Farrell and Klemperer (2007) for an overview). More specifically, the classic paper by Klemperer (1987) finds that an incumbent uses switching costs to create a competitive advantage over a potential entrant. However, his paper mostly focuses on how switching costs are used to deter entry. Unlike Klemperer, I find that the incumbent uses the endogenously determined switching costs, through the consumer carryover utility, to soften platform competition between the incumbent and the entrant instead of deterring entry.[3] Thus, softening of competition is more of a concern than entry deterrence in two-sided markets with switching costs.[4]

[2] Caillaud and Jullien (2003), Hagiu (2006) and Jullien (2011) investigate focal platforms that have favorable beliefs in static models where switching costs are not considered.

[3] There is some recent research on dynamic competition with switching costs that leads to an incumbency advantage (Biglaiser and Crémer (2011) and Biglaiser et al. (2013)). However, in these models it remains the case that, as in the traditional switching cost literature, the incumbent only affects the extensive margin of switching costs. Thus, this paper contributes to the literature on switching costs and consumer lock-in by identifying a new marketplace where switching costs exist (two-sided markets), and by showing how two-sidedness with cloud storage enables the incumbent to endogenously determine switching costs.

[4] One paper that considers the effect of switching costs in two-sided markets is Lam (2016). She considers a model where two platforms compete when consumers face switching costs. Her model follows the symmetric two-sided framework of Armstrong (2006) and does not consider how switching costs affect platform entry and exit. In the paper presented here, dynamic platform competition in a two-sided market with cloud storage

There are two ways in which the switching costs through cloud storage differ from those in traditional models. First, many models of switching costs focus on the holdup problem by consumers. That is, consumers know that if they make a first period purchase, they will face a much higher second period price because it is costly to switch. In this model, the switching cost is generated by the added benefit that only exists if participation occurs in the first period. This implies that switching does not result in an added cost that reduces surplus, but instead results in an opportunity cost in terms of lost content. As a result, this free opt-out choice for consumers eliminates the holdup problem that exists in many other models of switching costs.

Second, switching costs can be thought of being an investment by the platform. That is, two-sidedness with cloud storage is similar to the classic models of switching costs with the addition of an endogenous investment choice in the strength of the switching cost by the incumbent. Strengthening the switching cost intensity, at an investment cost to the incumbent, is similar to the incumbent platform provider forgoing some first period profit generation on the content provider side (the investment cost), in order to strengthen the intensity of the consumer carryover utility (increase the switching costs). Thus, two-sidedness with cloud storage gives rise to a model of endogenously determined switching costs where both the extent and the intensity of the switching costs is endogenous to the incumbent through a switching costs investment.

The rest of the paper is organized as follows. In Section 2, the model of platform entry is proposed and the equilibrium concept is defined. The existence of an equilibrium and an analysis of the equilibria across the relevant parameters is considered in Section 3. Finally, Section 4 concludes, followed by appendices that contain some computations and proofs of all the formal findings.

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allows an incumbent platform to endogenously determine the level of the switching costs. This provides new insights into how the timing of platform entry affects platform pricing decisions, the competition landscape, and the asymmetric equilibrium that are observed in many different two-sided industries.

2 A Model of Dynamic Platform Competition

Consider dynamic platform competition where an incumbent platform provider uses cloud storage across platform generations to compete against a potential entrant. In the first period the incumbent is the only platform provider and in the second period there are potentially two platform providers, the incumbent and the entrant. Depending on the strength of the consumer carryover from previous content and the relative quality of the incumbent's platform compared to the entrant's platform, different equilibria arise.

The timing of the game is as follows. In the first period, the incumbent sets prices of its first generation to consumers, P_1^I, and to content sellers, f_1^I. The consumers and content providers observe these prices and then simultaneously make participation decisions, where N_{C1}^I (N_{S1}^I) denotes the number of consumers (sellers) that join the incumbent's platform in the first period. Once agents join the platform, the consumers purchase content from content sellers in the exchange market. For example, consumers purchase apps, music, videos, etc. from content providers through the iTunes store for their iPhones. Each seller has one item of content that it develops, and each seller sets the price of their content.[5]

At the beginning of the second period, the potential entrant decides whether or not to enter the market with its own platform; however, previous content is not compatible with the entrant's platform. At the same time the incumbent either introduces a new generation of its platform to consumers and sellers, or exits the market. The incumbent's new platform is backward compatible so that previous content purchases by consumers can still be used on the new platform. The first generation platform is obsolete in the second period. If consumers want to use the incumbent's platform in the second period, then they must purchase the new generation.[6]

[5] The sellers', as opposed to the platform's, ability to set prices for their content varies across platform marketplaces; this is examined by Hagiu and Lee (2011). It is also possible that the platform provider is the seller of some content which is examined by Hagiu and Wright (2015) and Johnson (2014). In this paper the sellers have all of the pricing power for their content and all of the content is developed by these third party sellers. In general, this does not affect the equilibrium results found here regarding platform entry and competition.

[6] In the second period there is often a used first generation platform market for some hardware platforms.

Given the entry/exit decisions by the platform providers, the platform providers simultaneously set prices to consumers and sellers in the second period (P_2^I and f_2^I for the incumbent and P_2^E and f_2^E for the entrant). Consumers and sellers observe platform entry and prices and then make participation decisions simultaneously. Once agents join the platforms in the second period, consumers purchase new content from sellers in the exchange market on their platform. Agents are forward looking, and the incumbent cannot commit to future prices or price discriminate in the second period. For simplicity, assume that there is no discounting.

2.1 Consumers, Sellers, and Platform Providers

In deriving consumers' and content sellers' gains from joining a platform, first consider the gains that occur through the exchange market for content, once consumers and sellers are on or own a platform. A consumer that is interested in an item of content draws a value υ for that item of content, where $\upsilon \sim U[0, \sigma]$. Sellers set the price for their content, p, and a consumer purchases the content if their value is greater than the price, $\upsilon > p$.

Not all consumers want all content; some consumers are interested in many items of content while other consumers are only interested in a few. Let $\tau \in [0, 1]$ denote a consumer's type, where a consumer of type τ is interested in an item of content with probability $(1 - \tau)$. Thus, with probability τ, consumer τ's value for a given content is zero. In other words, for each item of content a consumer randomly draws whether or not they find the content interesting and then randomly draws their value for the content if they are interested.

In maximizing profits, sellers take the number of consumers on each platform as given when setting their price. For ease of exposition, and consistent with many digital markets, assume that the seller's marginal cost of production is zero. The entire exchange market equilibrium is solved in the appendix. There it is shown that the resulting expected consumer

This analysis abstracts away from the used market, but this aspect can be incorporated in this model as discussed in the next subsection. Alternatively, this dynamic platform can be thought of as charging reoccurring prices for a subscription over time as in the case of Netflix (where the dynamic cloud storage for a subscription platform is the platform providing a better experience to consumer through learned consumer preferences for movies and TV shows).

surplus per item available for a consumer of type τ is given by $CS(\tau)$ and the resulting expected revenues in period t from content sales for a seller that joins the incumbent's (entrant's) platform is given by π_t^I (π_t^E).[7]

Given the gains to consumers and sellers from exchange, consider the gains from joining the platform. Consider first consumers. In addition to gaining surplus from the exchange market, consumers obtain stand-alone utility from a platform. This utility is denoted by V^I for the incumbent's platform. This stand-alone utility can be large, as in the case of smartphones where there are many uses for the phone outside of using third party content (making calls, checking email, and surfing the web), or close to zero, as in the case of online marketplaces where there is little gain from a platform outside of interaction with sellers.[8] Thus, a consumer of type τ that joins the incumbent's platform in the first period has utility

$$u_{C1}^I(\tau) = V^I + CS(\tau) \cdot N_{S1}^I - P_1^I. \tag{1}$$

Consumers who purchased the incumbent's platform in the first period also purchase content. Through cloud storage and backward compatibility, the content can be used on the incumbent's new platform in the second period. This creates a carryover utility from the first period into the second period for consumers who stay on the incumbent's platform. The degree of carryover is captured by a factor of $\phi \in [0, 1]$. Here ϕ can be thought of as the strength of the carryover effect. If $\phi = 0$, then there is no carryover and the incumbent's platform is not backward compatible so the previously purchased content provides no added value. For $\phi > 0$, the carryover exists and consumers receive utility from continued use of their previously purchased content.[9]

[7]See the exchange market section in the appendix for the detailed solutions of the exchange markets.

[8]The membership benefit for a platform may also incorporate all of the preloaded content and content that is exclusive to a platform. For example, if the entrant has exclusive content that is only 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 provided by a third party through an exclusive contract. This is one way to incorporate exclusive content into the model.

[9]If the first period platform is a durable good, i.e., the first period platform can be used in the second period, then the use of previous content on an old generation provides less utility than if they were used

If consumer τ purchased the incumbent's platform in the first period, then the expected carryover utility that consumer τ receives from their first period content purchases is the expected number of purchases times the expected utility from each purchase. The expected carryover utility for consumer τ is denoted by $\overline{u}(\tau, e_1^\tau, N_{S1})$ where e_1^τ is consumer τ's first period participation decision. The carryover utility is generated from the exchange equilibrium which is given in the appendix. Thus, utility for a consumer of type τ from joining the incumbent's platform in the second period is given by:

$$u_{C2}^I(\tau) = V^I + CS(\tau) \cdot N_{S2}^I - P_2^I + \phi \cdot \overline{u}(\tau, e_1^\tau, N_{S1}^I). \tag{2}$$

If entry occurs, then consumers also have the option of joining the entrant's platform. The utility for a consumer of type τ from joining the entrant's platform in the second period is given by:

$$u_{C2}^E(\tau) = V^E + CS(\tau) \cdot N_{S2}^E - P_2^E. \tag{3}$$

For simplicity, assume consumers single-home; that is, consumers join only one platform. However, sellers can either single-home or multi-home.[10]

Now consider the sellers' decision to join the platforms. Sellers are indexed by $\theta \in [0, \infty)$ which corresponds to their development costs. That is, low θ-type sellers have lower development costs than high θ-type sellers. Sellers are short lived, and a new seller of type θ develops new content in the second period, with a fixed cost θ to develop the content. Thus,

on the new platform. For example, with a new smartphone the existing apps are updated and the new smartphone has updated graphics and software. In this case, ϕ represents the added utility from using the previously purchased content on the new platform instead of the old platform. Thus, the durable platform can be modeled with an alternative interpretation of the value of ϕ and the results presented here will follow.

[10]Jeitschko and Tremblay (2015) show that consumers single-homing always exists with endogenous homing decisions, and this allocation largely reflects the industries of interest in this paper.

the utility functions for sellers in the first period and in the second period are given by:

$$u^I_{St}(\theta) = (1 - f^I_t)\pi^I_t - \theta, \tag{4}$$

$$u^E_{S2}(\theta) = (1 - f^E_2)\pi^E_2 - \theta, \tag{5}$$

$$u^M_{S2}(\theta) = u^I_{S2}(\theta) + u^E_{S2}(\theta), \tag{6}$$

where superscript I (E) denote the utility for a seller that single-homes on the incumbent's (entrant's) platform, and superscript M denotes the utility for a seller from multi-homing.

Sellers generate profits from selling their content to a platform's consumers and platforms charge sellers a percentage of these profits to join the platforms in each period. This is the fee structure used in many platform industries.[11] For example, app stores take a percent of app sales revenue, as do video game platforms and many online marketplaces. Note that in multi-homing a seller incurs the cost θ twice. This can be thought of as the cost for content to be synchronized to an additional platform's operating system.

Lastly, platform profits for the incumbent and the entrant are given by:

$$\Pi^I = N^I_{C1} \cdot (P^I_1 - C) + N^I_{S1} \cdot f^I_1 \cdot \pi^I_1 + N^I_{C2} \cdot (P^I_2 - C) + N^I_{S2} \cdot f^I_2 \cdot \pi^I_2, \tag{7}$$

$$\Pi^E = N^E_{C2} \cdot (P^E_2 - C) + N^E_{S2} \cdot f^E_2 \cdot \pi^E_2, \tag{8}$$

where C is the marginal cost of an additional consumer for each of the platforms.

Let the difference in quality between the entrant's platform and the incumbent's platform be denoted by $\triangle = V^E - V^I$. Thus, if $\triangle > 0$ then the entrant's platform is of higher quality, and if $\triangle < 0$ then the incumbent's platform is of higher quality. To simplify computations, let $V^I = C$ be constant over the two periods.[12] This implies that $\triangle$ represents the quality difference between the two platforms and the cost advantage for the entrant.

[11] Alternative fee structures provide similar results regarding platform competition, entry, and exit.

[12] The assumption that $V^I = C$ is not critical but makes computations simpler. In fact, assuming $\triangle$ is the difference in platform quality relative to each platform's marginal costs, $\triangle = (V^E - C^E) - (V^I - C^I)$, produces the same results.

2.2 Strategies and Equilibrium Concept

In each period, consumers and sellers simultaneously make participation decisions after platform prices are set and observed by all agents. I will refer to each of these as a Participation Game and the whole two period game as the Platform Game. Let $e_1^\tau, e_1^\theta \in \{0, I\}$ be the first period participation decisions and let $e_2^\tau, e_2^\theta \in \{0, I, E, M\}$ be the second period participation decisions. In terms of notation, $e_t = I$ denotes that an agent decides to join the incumbent's platform, $e_t = E$ denotes that an agent decides to join the entrant's platform, $e_t = M$ denotes that a seller decides to multi-home and join both platforms (recall that only sellers can multi-home), and $e_t = 0$ denotes that an agent decides to not participate.

In the first period, a consumer of type τ has strategies $s_1^\tau : (P_1^I, f_1^I) \to \{0, I\}$. That is, a consumer's strategy in the first period maps the observed prices set by the incumbent into the consumer's first period participation decision. In the second period, a consumer of type τ has strategies $s_2^\tau : (e_1^\tau, P_2^I, f_2^I, P_2^E, f_2^E) \to \{0, I, E\}$. That is, a consumer's strategy in the second period maps all platform prices and the consumer's previous participation decision into the consumer's second period participation decision.[13] Let $s^\tau = (s_1^\tau, s_2^\tau)$ denote consumer τ's strategy profile.

In the first period, a seller of type θ has strategies $s_1^\theta : (P_1^I, f_1^I) \to \{0, I\}$. That is, a seller's strategy in the first period maps the incumbent prices into the seller's first period participation decision. In the second period, a seller of type θ has strategies $s_2^\theta : (N_{C1}^I, P_2^I, f_2^I, P_2^E, f_2^E) \to \{0, I, E, M\}$. That is, a seller's strategy in the second period maps the number of consumers that purchased the incumbent's platform in the first period and the second period platforms' prices into the seller's second period participation decision.

Consumers and sellers are sequentially rational. For consumers, this implies that for all

[13] A second period strategy depends on the full history of play, which the agents observe. However, the optimal behavioral strategies in period 2 are invariant over P_1, f_1, and what other consumers did in period 1. For ease of exposition, I consider strategies in which period 2 actions only depend on the consumer first period participation, the P_2's, and the f_2's. Among these strategies I find an equilibrium that is robust to the other strategies with full histories. Similar reduced second period strategies will be used for the sellers and the platforms.

consumer types τ, s^τ maximizes $u_{C1}(\tau) + u_{C2}(\tau)$ for the given price constellations by the platforms and given the sellers' strategies. For sellers, sequential rationality implies that for all seller types θ, s_t^θ maximizes $u_{St}(\theta)$, $t = 1, 2$, for the given price constellations by the platforms and given consumers' strategies.

The incumbent is forward looking when setting its prices. This implies that the incumbent takes into account the effect that its first period prices has on the consumer carryover utility, the entry decision, and the resulting second period equilibrium when making its pricing decisions in the first period. In the first period, the incumbent has strategies $s_1^I = (P_1^I, f_1^I)$. That is, an incumbent's strategy is the first period prices. In the second period, the incumbent has strategies $s_2^I = \left(N_{C1}^I\right) \rightarrow (e^I, P_2^I, f_2^I)$. That is, the incumbent's second period strategy maps the number of first period consumers that joined the incumbent's platform into the incumbent's exit decision ($e^I = 1$ denotes not exiting while $e^I = 0$ denotes that the incumbent exits), and the incumbent's second period prices. Let $s^I = (s_1^I, s_2^I)$ denote the platform's strategy profile. The incumbent chooses s^I to maximize profits (Π^I) given consumers', sellers', and the entrant's strategies.

After the first period, the entrant makes its entry decision given the first period and the resulting carryover utility consumers have for the incumbent's platform. If entry occurs, the entrant and incumbent simultaneously choose prices. Thus, the entrant has strategies $s^E = \left(N_{C1}^I\right) \rightarrow (e^E, P_2^E, f_2^E)$ where $e^E = 0$ denotes foreclosure while $e^E = 1$ denotes a successful entry. That is, the entrant's strategy maps the number of first period consumers that joined the incumbent's platform into the entrant's entry decision and the entrant's second period prices. The entrant chooses s^E to maximize profits (Π^E) given consumers', sellers', and the incumbent's strategies.

Additionally, the no-trade subgame equilibrium where no consumers and no sellers join a platform in the participation game is ruled out on and off path when there exist potential gains from trade.[14] If a strategy profile ($s^I, s^E, s^\tau, s_1^\theta, s_2^\theta$ for all τ and θ) satisfies these prop-

[14] That is, if prices are low enough so that there are gains from trade, then the outcome where no agent joins a platform (a coordination failure), is still a Nash Equilibrium in the participation game. If these

erties, then it is an equilibrium of the platform game with resulting prices and participation levels $\left(P_1^I, f_1^I, N_{C1}^I, N_{S1}^I, P_2^I, f_2^I, N_{C2}^I, N_{S2}^I, P_2^E, f_2^E, N_{C2}^E, N_{S2}^E\right)$.

3 Equilibrium Analysis

In this section, existence of equilibria is established and the variation in equilibria across certain parameters is analyzed. The difference in quality between the two platforms is critical in determining the nature of platform competition. Similarly, the structure of competition also depends on the strength of the consumer carryover. However, some general findings hold across all parameter values.

3.1 Existence

In general, across all quality differences and strengths of the consumer carryover (i.e., for all $\triangle$ and ϕ), there exists at least one and potentially two equilibrium outcomes.

Theorem 1 (Existence). *There is at least one and no more than two equilibria (s^I, s^E, and a collection of s^τ, s_1^θ, and s_2^θ for all τ and θ), for all $\triangle$ and ϕ.*

All proofs are in the appendix.

When comparing equilibria across values of $\triangle$ and ϕ it is important to note that the critical variables $\triangle$ and ϕ affect different constraints. In fact, each variable affects a potential corner solution problem. That is, if a consumer price is sufficiently low, $P \leq V$, then all consumers will purchase a platform and a corner solution with respect to consumer participation exists. In addition, a corner solution with respect to consumer lock-in where no consumer switches to the entrant's platform is possible.

no-trade equilibria exist in the participation games on and off the equilibrium path, then there exists a continuum of trivial equilibria in the platform game where an arbitrary price constellation is an equilibrium in the platform game because no-trade occurs off path (for all other price constellations). Hence, I rule out the no-trade equilibrium in each participation game, on and off the equilibrium path, when there exist gains from trade for a given price constellation.

First consider the equilibria in the simplest case where $\triangle$ and ϕ are such that an interior solution occurs.

Theorem 2 (Interior Equilibrium)**.** *An interior equilibrium consumer prices are:*

$$P_1^I = V^I + CS(N_{C1}^I)N_{S1}^I,$$
$$P_2^I = V^I + CS(N_{C2}^I)N_{S2}^I + \phi\overline{u}(N_{C2}^I, e_1^\tau = 1, N_{S1}^I),$$
$$P_2^E = V^E + CS(\tau^E)N_{S2}^E.$$

In this case, each platform charges consumers a markup with respect to each platform's standalone value, $P > V$. Furthermore, the incumbent charges consumers an additional markup in the second period that captures the carryover utility from its returning customers. Note that the incumbent charges a greater markup to consumers and the entrant is left with the residual consumer demand.[15]

For some interior solution prices given by Theorem 2, a second subgame equilibrium allocation of consumers and sellers exists where all participation by consumers and sellers occurs on the lower consumer priced platform.[16] If this second subgame allocation is the subgame equilibrium, then the incumbent will set lower prices so that this tipping is prevented. These reduced prices generate the second equilibrium of the entire game.

In markets where this allocation equilibrium is more plausible or in markets where consumers have the ability to coordinate, the reduced consumer price equilibrium might be more likely as the potential loss from no participation outweighs the gain from higher prices. This is a potential issue for an incumbent in platform industries where coordination by consumers is possible. In what follows, the equilibrium that always exists will be the focus of the analysis as many of the results are consistent across the two equilibria.

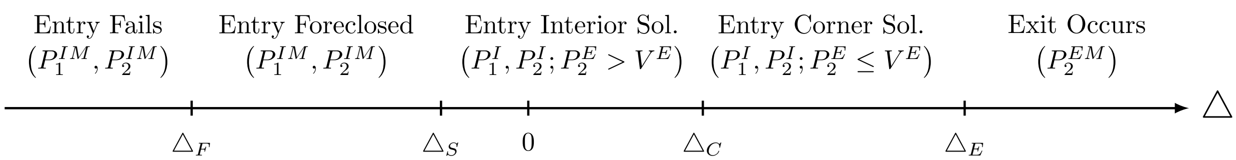
[15] The last consumer type, $\tau = 1$, gains nothing from the content side of the market and so there will always exist some residual demand when the incumbent charges a markup.

[16] This is similar to a failure to launch equilibrium for the higher consumer priced platform.

3.2 Variation in the Platform Quality Difference

In this subsection, the equilibria for different levels of the platform quality, $\triangle$, are characterized. The equilibrium entry, exit, and pricing strategies across $\triangle$ are given by Figure 1. Note that P^{IM} denotes the incumbent's pricing strategy when entry is foreclosed while P^{EM} denotes the entrant's prices when exit occurs. A proof of the existence of the critical $\triangle$ is provided in the appendix.

Figure 1: Platform Entry, Exit, and Pricing Strategies



To analyze the entry, exit, and pricing strategies across $\triangle$, begin with the case where $\triangle < \triangle_F$ is negative so that if the incumbent acts as a two period monopolist, then entry is not profitable. In this case entry fails and the incumbent acts as a two period monopolist. For $\triangle$ larger but still negative, $\triangle \in [\triangle_F, \triangle_S]$, entry is profitable if the incumbent acted as a two period monopolist upon entry. However, if entry occurs, then the incumbent uses its duopoly equilibrium pricing strategy and entry is unprofitable. That is, for $\triangle \in [\triangle_F, \triangle_S]$, entry is foreclosed and the incumbent acts as a monopolist only because its equilibrium reaction to entry is enough to make entry unprofitable for the entrant.

For $\triangle > \triangle_S$, it is profitable for entry to occur given the incumbent's equilibrium response to entry. As a result, entry is successful. However, the entrant's pricing strategy depends on the magnitude of $\triangle$. In particular, suppose that the entrant sets the consumer price equal to consumers' standalone benefit from the entrant's platform, $P_2^E = V^E$.[17] This implies that there is a corner solution in which all consumers participate on one of the two platforms in the second period. When $\triangle \equiv V^E - V^I = V^E - C$ is positive, this pricing strategy results in the entrant earning $\triangle$ from each consumer that joins its platform. Alternatively, if $\triangle$

[17] Note that the entrant may want to charge $P_2^E < V^E$ to lure some of the incumbent's previous customers into switching platforms.

is negative, then the entrant's platform is sold to consumers at a loss. Thus, the sign and magnitude of the difference in quality, $\triangle$, is crucial in determining the entrant's consumer pricing decision.

For $\triangle \in [\triangle_S, \triangle_C]$, the entrant charges a markup to consumers, $P_2^E > V^E$, and an interior solution occurs where not all consumers join a platform. If $\triangle \in [\triangle_C, \triangle_E] > 0$, then the entrant charges the consumers their marginal gain for the platform, $P_2^E \leq V^E$, and there is a corner solution in which all consumers join a platform. Lastly, when the entrant's platform is of superior quality, $\triangle > \triangle_E$, the incumbent is unable to profitably obtain consumers in the second period and the incumbent exits the market. In this case, the incumbent acts as a single period monopolist in the first period while the entrant acts as a single period monopolist in the second period.

The different types of equilibria found in Figure 1 have predictive power regarding the different market outcomes found within and across platform industries. When Apple entered the smartphone market, the iPhone was superior in quality to all other existing smartphones. This allowed Apple to effectively compete with the incumbent, Blackberry. The iPhone had tremendous success and supplanted the Blackberry. This occurred because the iPhone was of significantly superior quality which is shown to be a necessary condition for success in this model.

More recently, Google's Android entered to compete with Apple's iPhone. The Android software was touted as being of better quality. Android successfully entered the market; however, Apple was able to sustain higher prices relative to Android phones. This market outcome is in the spirit of the fourth type of entry equilibrium in Figure 1, where the Android phone was of higher quality and charged low prices to capture the entire residual demand, but failed to overcome Apple's incumbent advantage (see Bresnahan et al. (2015) for more on the smartphone industry).

The model explains other features of competition between Apple and Android. The model predicts that the incumbent will capture consumers that are most interested in content.

This is confirmed with Apple capturing the high content consumers.[18] In addition, the incumbent's consumer lock-in effect suggests that consumer brand loyalty for the incumbent will persist over time. This is confirmed with Apple consumers who are the least likely to switch smartphone providers.[19] Thus, this model appears to explain several phenomena in the smartphone industry that static platform competition models are ill-equipped to consider.

In the market for video game consoles, the model also is in line with the successful entry of Microsoft's Xbox. The Xbox entered the market with a popular video game (Halo) that was exclusive to Xbox. This exclusively enhanced the value of Microsoft's Xbox, and Microsoft was able to successfully enter the market and charge a consumer price that was similar to the prices set by Playstation and Nintendo. The three giants split the market in early 2000s (see Lee (2013)). This equilibrium follows the spirit of the third type of entry equilibrium in Figure 1.

From a welfare perspective, the two equilibria when only one platform is present in each period are of particular interest. When entry fails and the incumbent acts as a two-period monopolist, welfare is harmed since the incumbent uses its monopoly power so that too few consumers are served. Alternatively, the case with entry and exit may also be detrimental in terms of welfare. In this case, each platform acts as a single period monopolist. This implies that the incumbent serves fewer consumers in the first period than it would if exit does not occur, and the entrant serves fewer consumers than if the incumbent stayed in the market. In addition, no consumer carryover utility is generated because the incumbent exits the market. In this case, welfare is reduced if the lost surplus from fewer consumers being served in each period and lost surplus from no consumer carryover outweigh the gains from the entrant's technological advancement.

Given these welfare concerns, it is important to analyze welfare and the structure of competition for the cases where competition occurs in the second period. This is considered in

[18]See Forbes (2014) and TechCrunch (2014).

[19]Unfortunately, Deloitte only surveyed brand loyalty for Australia (Deloitte (2014a) and Deloitte (2015a)), Italy (Deloitte (2015b)), and the Netherlands (Deloitte (2014b)); however, all the reports found that Apple had the greatest lock-in on consumers.

the following subsection where the equilibrium across the strength of the consumer carryover, ϕ, is analyzed.

3.3 Variation in the Strength of Consumer Carryover

For fixed $\triangle$ where competition occurs, consider how the equilibrium is affected by variations in the strength of consumer carryover, ϕ. Recall that when consumers have little gains from their previous content then ϕ is small. Furthermore, when ϕ is small, the incumbent has a much weaker consumer lock-in effect and this results in an equilibrium where the two platforms are fairly competitive. The incumbent sets a relatively low price to its consumers in the second period so that no consumers switch platforms (a corner solution in the consumer switching dimension). In this case, the platforms' problems have $N^I_{C1} = N^I_{C2}$, and the incumbent's second period price exactly captures all of its previous consumers.

For larger ϕ, this strategy by the incumbent of using a low consumer price in the second period to prevent switching becomes costlier as the greater surplus from a larger consumer carryover utility is not being extracted. Thus, for ϕ above a certain threshold, the incumbent charges a standard markup which is given in the statement of Theorem 1 and some consumers switch to the entrant's platform (an interior solution). These results are summarized in the following theorem:

Theorem 3. *When both platforms compete in the second period, there exists $\tilde{\phi} \in (0, 1)$ such that when the carryover is weak, $\phi \leq \tilde{\phi}$, the incumbent aggressively competes with the entrant by setting a relatively low consumer price that results in all previous consumers returning to the incumbent's platform.*

Whereas, when the carryover is strong, $\phi > \tilde{\phi}$, the incumbent sets a high consumer price in the second period and some consumers switch platforms.

When carryover is weak, $\phi \leq \tilde{\phi}$, there is little gain for consumers from staying with the incumbent's platform and competition between platform providers is fierce. The incumbent uses the endogenous switching costs to ensure that no consumers switch platforms in the second period. However, as the carryover increases, it becomes costlier for the incumbent to keep a low consumer price to ensure that no switching occurs.

For stronger carryover, $\phi > \tilde{\phi}$, it is more attractive for the incumbent to set a higher second period price to consumers and extract some of the larger carryover surplus from its previous consumers. This increase in the incumbent's second period consumer price results in some of the marginal consumers switching to the entrant's platform. This implies that it is optimal for the incumbent to let some consumers switch and lose market share on the consumer side. This loss of market shares by the incumbent while maintaining high prices has occurred in the market for smartphones with Apple's iPhone.

Now consider how a change in the strength of consumer carryover, ϕ, affects the nature of competition between the two platforms. For greater ϕ, the impact that the incumbent has on the switching costs that consumers face becomes greater. As a result, the incumbent's ability to endogenously soften competition between the two platforms becomes stronger:

Theorem 4. *Greater carryover ϕ softens equilibrium platform competition.*

More specifically, when the carryover is weak, $\phi \leq \tilde{\phi}$, and the incumbent sets prices to prevent all consumer switching, an increase in ϕ results in the incumbent targeting fewer consumers but charging higher consumer prices. When the carryover is strong, $\phi > \tilde{\phi}$, an increase in ϕ results in increased consumer prices by both platform providers and a decrease in consumer switching. Thus, across all values of the strength of consumer carryover, greater strength in consumer carryover results in softened platform competition.

Furthermore, for all ϕ, an increase in ϕ always results in a greater investment in the switching costs by the incumbent: $\frac{\partial f_1^I}{\partial \phi} < 0$. That is, for a greater switching cost in response to a lower first period content provider price (ϕ increases), the incumbent is willing to invest in a lower first period content provider price; hence $\frac{\partial f_1^I}{\partial \phi} < 0$. Thus, with endogenous switching costs, a greater opportunity to increase the switching costs results in higher switching costs and softened competition.

From an antitrust perspective this implies that the effect of consumer lock-in on platform entry in two-sided markets is less of a concern than the effect on softened platform competition. Furthermore, the incumbent's ability to endogenously affect the switching costs through cloud storage allows the incumbent to endogenously soften price competition in the second period.

This result also suggests that if a policy maker prevented the platforms from using intra-platform compatibility and instead made cloud storage compatible across platforms, then platform competition would increase and there would not exist lost surplus from lost carry-over content. Both effects increase total surplus. However, this also reduces the incentive for platform providers to invest in developing their own content and features, since the platforms would not benefit from the lock-in effects that these developments create. Although investment and the development of exclusive content by the platform providers is outside of the scope of this paper, these are important aspects of many platform industries that should be considered when discussing platform competition policies.

4 Conclusion

This paper examines dynamic platform competition and entry when platform providers use cloud storage to generate consumer carryover utility across platform generations. Cloud storage enables consumers to use their content (media, apps, software, games or ebooks) from the previous generation of the platform on the current generation. This creates an opportunity cost from switching platforms, in the form of lost content, that helps an incumbent platform provider lock consumers in.

The incumbent's ability to lock in consumers depends on the carryover benefit that its consumers receive from previous content. The incumbent uses two pricing mechanisms to affect consumer carryover utility. First, the incumbent uses the traditional consumer lock-in mechanism, namely, a lower first period price to consumers, which affects the extent of consumer lock-in. Second, the incumbent uses its first period price to content providers to affect the amount of content that is available to its consumers in the first period. Expanded content selection for consumers increases the intensity of the carryover utility. Thus, two-sidedness allows the incumbent to endogenously determine the consumer carryover utility (or the switching costs) through its prices to both sides of the market.

The use of cloud storage to affect consumer carryover utility critically affects dynamic platform competition, entry, and exit. The incumbent uses its first period prices to endogenously increase both the extent and the intensity of consumer lock-in, resulting in a competitive advantage in future periods. This pricing strategy is not used to foreclose entry, but is instead used to soften platform competition once entry occurs. Furthermore, the incumbent's ability to soften competition is strengthened when consumers have greater value for their previous content.

When designing policies for platform marketplaces, the natural question this analysis raises is whether or not the intra-platform compatibility that generates consumer lock-in is anticompetitive. I find that intra-platform compatibility softens platform competition and creates deadweight loss from lost content; however, in many industries it also creates a greater incentive for platform providers to develop their own content and features. If cloud storage is instead open access, then this content is not exclusive to the platform providers and this reduces the development of content in industries where platform providers develop their own content (e.g., Netflix and video game consoles). These findings suggest that such investments in platform specific content would need to outweigh the deadweight loss from intra-platform compatibility for universal cloud storage to be socially optimal.

Appendices

The Exchange Market

Consider the exchange market for the consumers that join the incumbent's platform in the first period. The consumer demand for a content provider's product is given by:

$$q_1^I \equiv \int_{\{\tau \text{ that join } I\}} Pr(\tau \text{ buys}|p) d\tau. \tag{9}$$

The consumer valuation assumptions imply that the consumers that join the incumbent's platform are the consumers with lower types and that there exists a cut off type τ^I such that all consumers of the type $\tau \leq \tau^I$ join the incumbent's platform while the other consumers do not. Note that the critical consumer type also provides the total mass on consumer that join the incumbent's platform, $\tau^I = N_{C1}^I$, as consumers are assumed to be distributed uniformly. Thus, the consumer demand for content on the incumbent's platform is given by:

$$q_1^I = \int_0^{N_{C1}^I} \left(1 - \frac{p}{\sigma}\right)(1-\tau)d\tau = \left(1 - \frac{p}{\sigma}\right)\left(1 - \frac{N_{C1}^I}{2}\right) \cdot N_{C1}^I. \tag{10}$$

In the second period for the cases where both platforms are present, the carryover utility that consumers have for the incumbent's platform results in the incumbent again capturing the consumers with lower types. As a result, their q_2^I is similar to that of the first period. However, the entrant is only able to capture the consumers that have higher types beyond those that join the incumbent as consumers are assumed to only single-home. Thus, the consumer demand for content on the entrant's platform is given by:

$$q_2^E = \int_{N_{C2}^I}^{\tau^E} \left(1 - \frac{p}{\sigma}\right)(1-\tau)d\tau = \frac{1}{2}\left(1 - \frac{p}{\sigma}\right)\left[(2-\tau^E)\tau^E - (2 - N_{C2}^I)N_{C2}^I\right]. \tag{11}$$

Sellers take the number of consumers that join the platform, N_{Ct}, as given when maximizing profits. This leads to the following equilibrium for the exchange market:

$$p^* = \frac{\sigma}{2}, \tag{12}$$

$$CS(\tau, p^*) \equiv E[v - p^*|v \geq p^*] \cdot Pr(\tau \text{ buys}|p^*) = \frac{\sigma}{8}(1-\tau), \tag{13}$$

$$q_t^I = \frac{1}{4}(2 - N_{Ct}^I)N_{Ct}^I, \tag{14}$$

$$q_2^E = \frac{1}{4}\Big[(2-\tau^E)\tau^E - (2 - N_{C2}^I)N_{C2}^I\Big], \tag{15}$$

$$\pi_t^I = q_t^I \cdot p^*, \text{ and } \pi_2^E = q_2^E \cdot p^*. \tag{16}$$

For the carryover utility that a consumer τ receives from joining the incumbent's platform in both periods, note that the consumer already owns content. Thus, the expected carryover utility for consumer τ, $\overline{u}(\tau, e_1^\tau, N_{S1})$, is given by:

$$\overline{u}(\tau, e_1^\tau, N_{S1}) \equiv e_1^\tau \cdot E(v|v > p^*) \cdot \Pr(v > p^*) \cdot N_{S1} = \frac{3\sigma}{8}(1-\tau)N_{S1}, \tag{17}$$

where $e_1^\tau = 1$ if consumer τ joined the incumbent's platform in the first period and $e_1^\tau = 0$ otherwise.

Appendix of Proofs

Proof of Theorem 1: Note that there are three pricing subgames: entry fails, the incumbent exits before the second period, and entry with both platforms present in the second period. The argument for proving existence of an equilibrium follows the standard approach of existence of an equilibrium when two competing firms maximize concave profit functions with constraints. Formally, there are multiple cases because of multiple types of possible corner solutions, and discrete comparisons of profits between these potential outcomes gives the unique equilibrium entry, exit, and pricing decisions of the two platforms.

First consider the subgame where both platforms are present in the second period. In the participation subgame for consumers and sellers, the first period consumers and sellers have demands for the incumbent's platform that are given by $u^I_{C1}(\tau = N^I_{C1}) = 0$ and $u^I_{S1}(\theta = N^I_{S1}) = 0$. For consumer demand for the incumbent's platform in the second period note that the marginal consumer to join the incumbent's platform is given by $u^I_{C2}(\tau = N^I_{C2}) = u^E_{C2}(\tau = N^I_{C2})$.

Consider the incumbent's problem given the entrant's prices and in light of the utility constraints of consumers and sellers. The incumbent maximizes profits using its prices over the two periods. However, because of the discontinuity in the second period consumer utility function, $u^I_{C2}(\cdot)$, consumer demand for the incumbent's platform is discontinuous. Thus, there exists a second potential corner solution in that the incumbent can set a second period consumer price so that all its previous customers join the incumbent's platform in the second period, $N^I_{C1} = N^I_{C2}$.[20]

Note that in solving the two platform problems, it is equivalent to use the f and N_{Ct} variables instead of the f and P variables. This makes computations much smoother. Equations (2), (4), and that consumer demand for the incumbent's platform in the second period is given by $u^I_{C2}(\tau = N^I_{C2}) = u^E_{C2}(\tau = N^I_{C2})$ implies that the incumbent solves the following maximization problem:

$$\begin{aligned}
\max_{N^I_{C1}, f^I_1, N^I_{C2}, f^I_2} \quad & \Pi^I \\
\text{s.t.} \quad & N^I_{St} = \frac{\sigma}{8}(1 - f^I_t)(2 - N^I_{Ct})N^I_{Ct}, \text{ for } t = 1, 2 \\
& P^I_1 = V^I + \frac{\sigma}{8}(1 - N^I_{C1}) \cdot N^I_{S1}, \\
& P^I_2 = -\triangle + P^E_2 + \frac{\sigma}{8}(1 - N^I_{C2})(N^I_{S2} - N^E_{S2}) + 3\phi\frac{\sigma}{8}(1 - N^I_{C2})N^I_{S1}, \\
& \text{with } N^I_{C2} \leq N^I_{C1}.
\end{aligned}$$

where the last inequality captures the potential corner solution due to the second period discontinuity in the consumer utility function for the incumbent.

For the entrant's platform, consumer demand is $\tau^E - N^I_{C2}$ where τ^E is given by $u^E_{C2}(\tau^E) =$

[20] This is analyzed specifically in Theorem 3.

0. If the entrant sets its consumer price so that $P_2^E \leq V^E$ then we have a corner solution in the total consumer participation dimension, $\tau^E = 1$. Thus, the entrant's consumer demand has potentially two extensive margins. The marginal agent that is indifferent between joining the two platforms is given by $u_{C2}^I(\tau = N_{C2}^I) = u_{C2}^E(\tau = N_{C2}^I)$ and the marginal agent that is indifferent between joining the entrant's platform and not participating is given by $u_{C2}^E(\tau^E) = 0$. The entrant's maximization problem is the following:

$$\max_{N_{C2}^E, f_2^E} \; \Pi^E$$

$$\text{s.t. } N_{S2}^E = \frac{\sigma}{8}(1 - f_2^E)[(2 - \tau^E)\tau^E - (2 - N_{C2}^I)N_{C2}^I],$$

$$P_2^E = \triangle + P_2^I - \frac{\sigma}{8}(1 - N_{C2}^I)(N_{S2}^I - N_{S2}^E) - 3\phi\frac{\sigma}{8}(1 - N_{C2}^I)N_{S1}^I,$$

$$\text{with } P_2^E = V^E + \frac{\sigma}{8}(1 - \tau^E)N_{S2}^E \;\text{ if } P_2^E > V^E, \text{ otherwise } \tau^E = 1.$$

Given that the second-order conditions hold for each platform's profit maximization (that is, the feedback loops are not to strong so that each platform sets $P_1 \leq V$), there exist unique outcomes from the joint maximization problems for each constraint that induces a possible corner solution. By comparing the discrete number of profit levels for each platform across these different maximization solutions, a unique equilibrium arises and this generates the equilibrium that always exists.[21]

There may also exist an additional equilibrium for some $\triangle$ and ϕ. In the above equilibrium, the demand specification is given by $u_{C2}^I(\tau = N_{C2}^I) = u_{C2}^E(\tau = N_{C2}^I)$, but it is possible that all agents would instead prefer joining the lower priced platform, relative to their respected Vs, resulting in no participation on the higher priced platform (a collective switching). If this is the equilibrium allocation that occurs in the subgame for these prices, then the higher priced platform instead charges a reduced price which generates the second

[21] A complete analysis of the maximization problems for the incumbent and the entrant and the subsequent closed form solutions with detailed computations are provided in the proofs of the Critical $\triangle$ for Platform Entry Conditions and Theorem 3 which further analyze the equilibria across $\triangle$ and ϕ.

potential equilibrium.[22]

In the pricing subgames where entry fails or exit occurs, the platform's act as single or multi-period monopolists. Given the unique equilibrium profits across the three pricing subgames, discrete comparisons are made to determine equilibrium entry and exit choices across all $\triangle$ and ϕ which determines the equilibrium of the entire game. $\square$

Proof of Theorem 2: These prices follow from the consumer utility equations (1), (2), and (3). Since there are no corner solutions ($N^I_{C2} < N^I_{C1}$ and $N^I_{C2} + \tau^E < 1$), the marginal agents (N^I_{C1}, N^I_{C2}, and τ^E) are given by setting each utility equation to zero:

$$u^I_{C1}(\tau = N^I_{C1}) = V^I + CS(N^I_{C1}) \cdot N^I_{S1} - P^I_1 = 0, \tag{18}$$

$$u^I_{C2}(\tau = N^I_{C2}) = V^I + CS(N^I_{C2}) \cdot N^I_{S2} - P^I_2 + \phi \cdot \overline{u}(N^I_{C2}, e^\tau_1 = 1, N^I_{S1}) = 0, \tag{19}$$

$$u^E_{C2}(\tau = \tau^E) = V^E + CS(\tau^E) \cdot N^E_{S2} - P^E_2 = 0. \tag{20}$$

Adding the price to each side in each equation provides the desired equilibrium prices. $\square$

Proof of the Critical $\triangle$ for Platform Entry Conditions: To show that the entrant, upon entry, starts by gathering the lower τ types, note that the entrant either begins with these consumers by charging a price markup ($P^E_2 > V^E$), or the entrant captures all residual consumers with $P^E \leq V^E$. However, capturing all consumers is costly for the cases when $\triangle < 0$ since then $P^E_2 - V^E \leq P^E_2 - V^I < V^E - V^I < 0$. Furthermore, the consumer $\tau = 1$ provides no benefit as they do not purchase content. This implies that the marginal cost of providing a corner solution is negative while the marginal benefit is zero when $\triangle < 0$. Thus

[22] For an example of the second equilibrium, first consider the case when the incumbent is the higher consumer priced platform. In this case, the maximum price to ensure consumer participation is given by comparing Equations (2) and (3) when the incumbent does not have any seller participation. This requires: $V^I + 0 - P^I_2 + \phi\overline{u}(\tau, e^\tau_1, N^I_{S1}) = V^E + CS(\tau)N^E_{S2} - P^E_2$. Solving for the incumbent's price implies that this equilibrium requires $P^I_2 = \max\{P^E_2, P^E_2 - \triangle + \overline{u}(\tau, e^\tau_1, N^I_{S1}) - CS(\tau)N^E_{S2}\}$ when solving the platforms' problems. Similarly, in considering the case when the entrant is the higher consumer priced platform we compare Equations (2) and (3) when the entrant does not have any seller participation. This requires: $V^I + CS(\tau)N^I_{S2} - P^I_2 + \phi\overline{u}(\tau, e^\tau_1, N^I_{S1}) = V^E + 0 - P^E_2$. Solving for the entrant's price implies that this equilibrium requires $P^E_2 = \max\{P^I_2, \triangle + P^E_2 - \overline{u}(\tau, e^\tau_1, N^I_{S1}) - CS(\tau)N^I_{S2}\}$ when solving the platforms' problems.

for $\triangle < 0$ where entry occurs, there is an interior solution with $P_2^E > V^E$.

To determine the critical $\triangle$ defined in the theorem, a comparison between the closed form solution profits is needed. Given the difficulty in solving for closed form solutions, this proof provides the intuition for the existence and ordering of the critical values of $\triangle$ that affect the entry, exit, and pricing equilibria that exist.

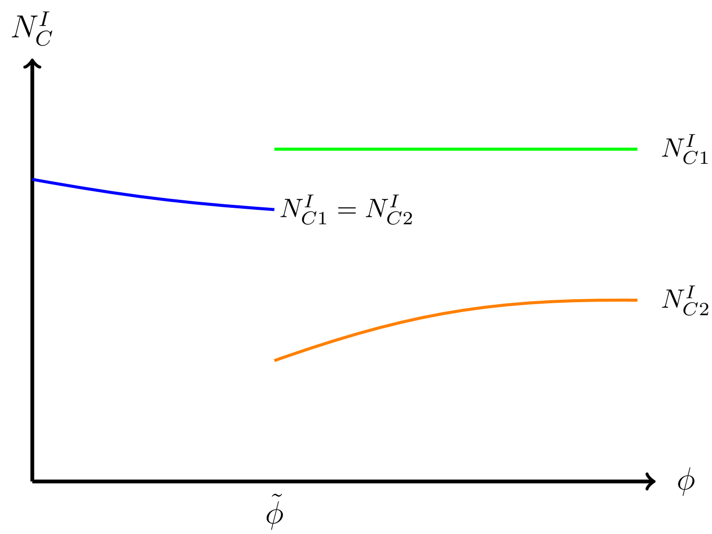
For $\triangle$ that is negative, entry will not be profitable by the entrant when the incumbent acts as a two period monopolist: the revenues from the seller side do not outweigh the losses necessary to attract consumers. In this case, entry fails. For $\triangle$ larger, but still negative, entry would be profitable if upon entry the incumbent still acted as a monopolist. However, if entry occurs then the incumbent would instead update to entry equilibrium pricing strategies which reduce the entrant's profits and so entry is foreclosed. Eventually, for $\triangle < 0$ entry becomes profitable even with the incumbent's response to entry. To show that entry occurs while $\triangle < 0$, note that there exists residual consumer demand for the entrant when $\triangle = 0$, and so the entrant makes profits from both the consumers and the sellers since $P_2^E > V^E = C$ and sellers can be charged a positive price. Thus, profits are strictly positive for the entrant when $\triangle = 0$ and so entry must be profitable for some $\triangle < 0$.

To show that the entrant implements the corner solution with $P_2^E = V^E$ occurs when $\triangle > 0$, note that in the proof of Theorem 3 it was shown that when the entrant implements the corner, the equilibrium content provider fee is $f_2^E = 0$. Thus, if the corner solution is implemented by the incumbent when $\triangle < 0$ then profits will be negative and the entrant would prefer the interior solution. Thus, the corner solution where $P_2^E = V^E$ occurs only for $\triangle$ sufficiently greater than 0. Lastly, when $\triangle > 0$ is large, the incumbent is unable to profitably capture any of its existing consumers and so the incumbent exits and acts as a single period monopolist in the first period while the entrant acts as a single period monopolist in the second period. □

Proof of Theorem 3: The equilibrium is best described with a figure and the detailed solution is provided below. Figure 2 describes the two types of equilibria. For $\phi < \tilde{\phi}$

the incumbent has greater profits when the platform maximization problems are solved with $N_{C2}^I = N_{C1}^I$, and for $\phi > \tilde{\phi}$ the incumbent has greater profits when the platform maximization problems are solved with $N_{C2}^I < N_{C1}^I$. Due to the second period discontinuity in the consumer utility function for the incumbent's platform, gaining a greater number of consumers beyond those obtained in the first period is very costly for the incumbent. To do so, the incumbent must lower its price to each consumer by $3\phi\frac{\sigma}{8}(1 - N_{C1}^I)N_{S1}^I$, and as a result this strategy is not profitable.

Figure 2: Types of Equilibria Across ϕ



In solving the joint profit maximization problem for the incumbent and the entrant, first consider the incumbent's maximization problem:

$$\max_{N_{C1}^I, f_1^I, N_{C2}^I, f_2^I} \Pi^I$$

$$\text{s.t. } N_{St}^I = \frac{\sigma}{8}(1 - f_t^I)(2 - N_{Ct}^I)N_{Ct}^I, \text{ for } t = 1, 2$$

$$P_1^I = V^I + \frac{\sigma}{8}(1 - N_{C1}^I) \cdot N_{S1}^I,$$

$$P_2^I = -\triangle + P_2^E + \frac{\sigma}{8}(1 - N_{C2}^I)(N_{S2}^I - N_{S2}^E) + 3\phi\frac{\sigma}{8}(1 - N_{C2}^I)N_{S1}^I,$$

$$\text{with } N_{C2}^I \leq N_{C1}^I.$$

where the last inequality captures the potential corner solution due to the second period discontinuity in the consumer utility function for the incumbent.

Now consider the entrant's maximization problem:

$$\max_{N_{C2}^E, f_2^E} \Pi^E$$
$$\text{s.t. } N_{S2}^E = \frac{\sigma}{8}(1 - f_2^E)[(2 - \tau^E)\tau^E - (2 - N_{C2}^I)N_{C2}^I],$$
$$P_2^E = \triangle + P_2^I - \frac{\sigma}{8}(1 - N_{C2}^I)(N_{S2}^I - N_{S2}^E) - 3\phi\frac{\sigma}{8}(1 - N_{C2}^I)N_{S1}^I,$$
$$\text{with } P_2^E = V^E + \frac{\sigma}{8}(1 - \tau^E)N_{S2}^E \text{ if } P_2^E > V^E, \text{ otherwise } \tau^E = 1.$$

For simplicity, $P_2^E \leq V^E$ is considered in solving for the closed form solutions. This implies that $\tau^E = 1$ and we are considering the equilibria for when there is a corner solution in consumer participation. In this case, consider the platforms' first order conditions with respect to their content provider fees: $\frac{\partial \Pi^I}{\partial f_1^I}$, $\frac{\partial \Pi^I}{\partial f_2^I}$, and $\frac{\partial \Pi^E}{\partial f_2^E}$. In solving each of these three first order conditions, the equilibrium content provider fees are:

$$f_1^I = \frac{N_{C1}^I - 3\phi(1 - N_{C2}^I)N_{C2}^I}{2(2 - N_{C1}^I)N_{C1}^I},$$
$$f_2^I = \frac{1}{2(2 - N_{C2}^I)},$$
$$f_2^E = 0.$$

The fact that $f_2^E = 0$ in the corner solution where $P_2^E \leq V^E$ implies that the corner solution can only occur for values $\triangle$ that are strictly positive to ensure that $P_2^E > C$ and entrant profits are non-negative. Also notice that $f_1^I < f_2^I$, this occurs because the incumbent is investing in increased switching costs in the first period. Furthermore, as ϕ increases (that is, the marginal benefit to consumers in the second period from first period content increases), then the incumbent invests in greater first period content by decreasing f_1^I.

Now consider the platforms' first order conditions with respect to the consumer demand variables: $\frac{\partial \Pi^I}{\partial N^I_{C1}}$, $\frac{\partial \Pi^I}{\partial N^I_{C2}}$, and $\frac{\partial \Pi^E}{\partial N^E_{C2}}$. Note that with a corner solution where $P^E_2 \leq V^E$ and $\tau^E = 1$, having N^E_{C2} be the endogenous variable for the entrant is equivalent to having the marginal consumer $\tau = N^I_{C2}$ being the endogenous variable for the entrant and using both platforms' first order condition with respect to N^I_{C2} and the constraints $u^I_{C2}(\tau = N^I_{C2}) = u^E_{C2}(\tau = N^I_{C2})$ to implicitly solve for the equilibrium N^I_{C2} and N^E_{C2}.

For the case where the incumbent does not elect to use the pricing strategy of obtaining all its previous consumers (so that $N^I_{C2} \neq N^I_{C1}$ in the maximization problem), the equilibrium levels are given by:

$$N^I_{C1} = \frac{3}{4},$$

$$N^E_{C2} = 1 - N^I_{C2},$$

$$\begin{aligned}\triangle \cdot \frac{64}{\sigma^2} \;=\;& -2 + 3N^I_{C2} - \frac{7 - 4N^I_{C2}}{2(2 - N^I_{C2})} \cdot [2 - 12N^I_{C2} + 18(N^I_{C2})^2 - 7(N^I_{C2})^3] \\ &+ \frac{1 - N^I_{C2}}{2 - N^I_{C2}} \cdot (3 - 2N^I_{C2})N^I_{C2} + \phi \cdot \frac{45}{32}(-2 + 3N^I_{C2}) \left[\frac{9}{8} + 3\phi(1 - N^I_{C2})N^I_{C2}\right].\end{aligned}$$

where the last equation implicitly defines N^I_{C2} which appears in Figure 2 for $\phi > \tilde{\phi}$.

If instead the incumbent chooses to price so that all its previous customers return in the second period then the maximization problems are solved with $N^I_{C2} = N^I_{C1}$ in each of the platform's problems and the marginal consumer equation becomes $u^I_{C2}(\tau = N^I_{C1}) = u^E_{C2}(\tau = N^I_{C1})$. Each platform only has one consumer participation first order condition and it is with respect to N^I_{C1} combined with $u^I_{C2}(\tau = N^I_{C1}) = u^E_{C2}(\tau = N^I_{C1})$, $N^I_{C2} = N^I_{C1}$, and $\tau^E = 1$ to implicitly solve for the equilibrium N^I_{C2} and N^E_{C2}. In this case, the above content provider fees are the same; however, with $N^I_{C2} = N^I_{C1}$. In solving the first order conditions with respect to consumer participation, the equilibrium levels of participation are implicitly defined by:

$$N^I_{C1} = N^I_{C2},$$

$$N^E_{C2} = 1 - N^I_{C2},$$

$$\begin{aligned}\triangle \cdot \frac{64}{\sigma^2} &= (7N^I_{C2} - 4)(1 - N^I_{C2})^2 + (1 - f^I_1)(3 - 4N^I_{C2})(2 - N^I_{C2})N^I_{C2} \\ &\quad + 3\phi(1 - f^I_1) \cdot [-2 + 10N^I_{C2} - 14(N^I_{C2})^2 + 5(N^I_{C2})^3] \\ &\quad + (1 - f^I_2) \cdot [-2 + 12N^I_{C2} - 18(N^I_{C2})^2 + 7(N^I_{C2})^3].\end{aligned}$$

where the f^I_1 and f^I_2 are given above but with $N^I_{C1} = N^I_{C2}$. Thus, the last equation implicitly defines N^I_{C2} and N^I_{C1} which appears in Figure 2 for $\phi < \tilde{\phi}$.

The ϕ such that the incumbent's profits in the corner solution are equal to the profits from the interior solution gives $\tilde{\phi}$. Such a $\tilde{\phi} \in [0, 1]$ need not exist across all $\triangle$; a complete closed form solution analysis of the two incumbent profit levels is needed across $\triangle$ to determine the extent to which both types of pricing strategies exists in equilibrium across $\triangle$. However, note that it will always be the case that the corner solution occurs for the lower values of ϕ while the interior solution occurs for the higher values of ϕ, since the corner solution is decreasing in profits relative to interior as ϕ increases. Thus, as ϕ increases the interior solution becomes more attractive to the incumbent, and this generates the two potential types of equilibrium across ϕ for fixed $\triangle$. □

Proof of Theorem 4: This and the subsequent discussion follows from Figure 2 and the equation for f^I_1 from the proof of Theorem 3. When the carryover is weak, $\phi \leq \tilde{\phi}$, an increase in ϕ results in the incumbent targeting fewer consumers and so the incumbent is also charging higher consumer prices, see Figure 2 for $\phi \leq \tilde{\phi}$. When the carryover becomes strong, $\phi > \tilde{\phi}$, the incumbent is able to use greater switching costs to increase both its and the entrants prices to consumers so that switching decreases in ϕ. Furthermore, for all ϕ, an increase in ϕ always results in a greater investment in the switching costs by the incumbent: $\frac{\partial f^I_1}{\partial \phi} < 0$. These results imply that greater ϕ softens platform competition. □

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