The Incumbency Protection Power of Network Effects: Hype or Reality?

Completed Research Paper

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Abstract

Many IT enabled networks have attained a large user base induced by strong network effects, which are thought to create an economic moat by increasing switching costs, thus offering protection against new entrants. The underlying assumption behind this result is that users completely adopt one network at any given time. Is the incumbency protection power of the moat as strong in multi-homing when users co-exist on multiple networks and can incrementally adopt a new entrant? We develop a multi-period analytical model of endogenous adoption decisions in a setting where a new network arrives with a superior capability, and where users have a resource constraint and derive value from technological capability as well as network effects. We demonstrate that the moat created by network effects for the case of incremental adoption is weaker than that in the case of complete adoption. Thus the protection power of network effects and the resulting competitive intensity may be overrated and underplayed respectively in many modern technology settings.

Keywords: Network effects, switching cost, incumbency protection, new entry, multi-homing, adoption dynamics
1. Introduction

Many IT-enabled networks like Facebook, LinkedIn and Twitter have grown large by building strong network effects (Stross 2010). Such positive externalities increase switching costs (Farrell, Shapiro 1988; Klemperer 1987), and are believed to create an economic moat that protects incumbents against new entrants, thereby lowering the intensity of competition. The network effects literature would suggest that due to large installed user bases, early online social networks such as MySpace and Orkut would witness minimal migration of their users to late entrants like Facebook. Yet it is well documented that most adopters of early social media significantly reduced the time spent on incumbent networks like MySpace to embrace newer networks like Facebook, even though the latter did not arrive with revolutionary capabilities or features. Figure 1 shows that during 2007-09, the average time spent on MySpace dropped from thirty to ten minutes, while that spent on Facebook increased steadily. By January 2011, the average time on MySpace had declined to just five minutes, while that on Facebook increased to thirty four minutes (Source: www.alexa.com). If network effects helped MySpace grow in the first place, how can we explain the rapid decline in MySpace activity and a corresponding increase on Facebook? In other words, did network effects not offer sufficient protection to the incumbent?

![Figure 1: Time spent on MySpace and Facebook (www.compete.com)](image)

A closer scrutiny of the early network effects literature (e.g., Katz and Shapiro, 1985, 1994) reveals that the key results involving incumbency protection implicitly assume that a user can be a member of only one network at a point in time. For example, in the case of Beta and VHS standards battle or QWERTY and DVORAK keyboard adoption (Liebowitz and Margolis, 1994), users are assumed to completely adopt only one of the standards. Traditionally, the focus of the network effects literature has been on such binary adoption decisions or single homing (SH) (Rochet and Tirole, 2003). However, in many instances today, users do not have to choose one network or technology over another. Rather, they may choose to co-adopt multiple networks simultaneously, which is referred to as multi-homing (MH) (Rochet and Tirole, 2003, Gabszewicz and Wauthy, 2004). For example, the Super Audio Compact Disc (SACD) and Digital Versatile Disc Audio (DVD-A) are competing formats for multi-channel audio. In spite of predictions of a standards war driving out one format (e.g., Shapiro and Varian 1998), both continue to co-exist a decade after their introduction. Such co-adoption is made possible by the availability of universal players, which allow consumers to buy their favorite albums on DVD-A or SACD based on availability, and rely on CD or MP3 for other albums (Mock 2004). With switching costs due to format differences being reduced, consumers are able to choose multiple formats simultaneously.

However, as shown in Table 1, the extant literature on MH (e.g., Rochet and Tirole, 2003; Gabszewicz and Wauthy, 2004; Armstrong and Wright, 2005; Parker and Van Alstyne 2005; Armstrong, 2006; Doganoglu and Wright, 2006; Eisenmann et al. 2006) does not consider the extent and dynamics of adoption of multiple platforms or networks through the allocation of limited resources. For example, in Gabszewicz and Wauthy (2004), a visitor can buy passes to more than one exhibition center, while an exhibitor can choose to display in multiple exhibition centers. That is, either single homing (i.e., choosing one center to visit and/or display

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1 “In business, I look for economic castles protected by unbreachable moats.” - Warren Buffett


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products) or the complete adoption of multi-homing (i.e., choosing multiple centers) is considered. The model does not investigate the case where a visitor and an exhibitor may have a time and budget constraint respectively, which may lead to a division of resources and hence the extent of adoption of multiple exhibition centers.

In many multi-homing scenarios such as social networks or traditional CD versus DVD-A/SACD, users or adopters have a limited amount of resources such as time and money which can be allocated toward the adoption of networks, products or platforms. That is, users have a choice of the amount of resource to allocate to a platform (and hence the extent of adoption), which can vary from period to period in a temporal model. Our key research question involves whether network effects offer strong protection to incumbents in MH settings where users can incrementally adopt a new network by dividing limited resources between the incumbent and a new entrant, and then gradually increase the resource(s) allocated to the new entrant under certain conditions. The dynamics of migration in such cases remain an open question in the literature. For example, how large a technological capability does the new entrant need to enter the market? Should it initially target users with high affinity to technological capability or network effects? How long can the incumbent afford to wait before improving its capabilities in order to maintain its market share in the presence of a new entrant with superior capabilities?

Table 1: Extant literature on multi-homing

<table>
<thead>
<tr>
<th>Study</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rochet and Tirole (2003)</td>
<td>Analyzes the role of governance structure on pricing in the presence of multi-homing, where users choose multiple platforms completely.</td>
</tr>
<tr>
<td>Gabszewicz and Wauthy (2004)</td>
<td>Analyzes two-sided markets and price competition in the presence of multi-homing. Complete adoption is assumed, e.g., a visitor can buy passes to two exhibition centers, while an exhibitor can also exhibit in both centers.</td>
</tr>
<tr>
<td>Armstrong and Wright (2005)</td>
<td>Analyzes pricing dynamics of two sided markets in the presence of multi-homing and externalities. Different levels of adoption for multiple platforms are not considered.</td>
</tr>
<tr>
<td>Parker and Van Alstyne (2005)</td>
<td>Analyzes when a firm can offer a free good in two-sided markets. The study does not focus on the extent of adoption in a multi-homing context.</td>
</tr>
<tr>
<td>Armstrong (2006)</td>
<td>Analyzes the equilibrium prices to be paid by platform users in the presence of cross group externalities in two sided markets. There is no discussion about the extent or timing of adoption of multiple platforms.</td>
</tr>
<tr>
<td>Doganoglu and Wright (2006)</td>
<td>Analyzes the effect of compatibility on private and social incentives in multi-homing, which involves complete adoption of multiple platforms.</td>
</tr>
<tr>
<td>Eisenmann et al. (2006)</td>
<td>Analyzes strategies for two-sided markets, and suggests that “winner-take-all” scenarios are possible when multi-homing costs are high for users along with strong network effects. The study does not focus specifically on the dynamics of incremental adoption of multiple networks.</td>
</tr>
</tbody>
</table>

A user derives benefits from the capability of a network or technology, and from network effects (Katz and Shapiro, 1985; Liebowitz and Margolis, 1999). Network capability may be attributed to proprietary technology, functionality, control over information/privacy, interface, customizability, applications, etc. Network effect is the benefit that each user of a good or service realizes as more people use the same good or service. For instance, both Skype and Gtalk have instant messaging and voice-over-IP features, though Skype is believed to be superior in voice quality and PC-to-phone calls. However, Google’s Gtalk is integrated with Gmail, Google Docs and other applications, thus enabling a user to add new contacts from her mailing list and manage all interactions through email or chat. Thus a user may choose Skype for superior voice quality and PC-to-phone calls, but also use Gtalk to interact with her contacts already using the latter option.

We demonstrate through a multi-period analytical model that in the MH case where a user coexists on the incumbent and the new entrant networks by dividing her total time spent on networking, even a marginally superior technological capability of the new network will start a slow bleeding of the incumbent network, thus triggering a decline in the total time spent on the incumbent. Eventually, the network effects on the new entrant may become strong at the cost of that in the incumbent network. This may create an avalanche, whereby the remaining users on the incumbent network allocate increasing amounts of time to the new network, leading to a major shrinkage of time spent on the former. By contrast, in the SH case considered in the early network effects literature, a quantum leap in capability is necessary to make users migrate to the new network. Thus the
incumbent may be more vulnerable than previously considered on the basis of the extant literature. Further, the highest technological capability required to cause migration in a SH network must be provided before that in the case of MH. Therefore, in the latter setting, the new entrant does not have to deliver the highest required capability upfront; since the required capability increases gradually for MH, the new entrant has more time relative to SH to improve its technology to attract users. Since the extant MH literature has not focused on partial and incremental adoption of multiple platforms or networks, the required capability of the new entrant and the dynamics of the migration process have received scant attention.

The key contribution of our study is to demonstrate that the incumbency protection power of network effects may be overrated or hyped in today’s world where other types of switching costs have been lowered to enable co-adoption of multiple technologies or networks. Our results underscore an increase in competitive intensity where a new entrant can arrive with only a marginally superior capability and improve its offering over time to breach the incumbent’s moat created by network effects. Our work also contributes to the diffusion literature by treating migration or diffusion across networks as an endogenous and incremental choice by users rather than an exogenously specified model parameter. To the best of our knowledge, this is also the first attempt in the multi-homing literature to model and analyze the temporal dynamics of incremental adoption of multiple platforms.

2. Past Research

The 'Information Economy' has traditionally been believed to be propelled by strong network effects (Shapiro and Varian 1998; Katz and Shapiro 1985; Katz and Shapiro 1994). For example, a Facebook user who uses the network to keep in touch and/or play multi-player games like Farmville with friends would value the network more as more of her friends join the network. It is believed that such positive externalities would make a strong network stronger and a weak network weaker (Shapiro and Varian 1998). However, this result is based on the fact that the incumbent network induces a large switching cost for users through network effects, thus shielding the incumbent from a new entrant with superior capabilities. In the context of online social networks as well as many other technologies, there is no direct membership cost, while the learning curve is minimal owing to similarity in the basic functionality and usability across networks. Thus, network effects are the primary source of switching cost in online social networks. In spite of the presence of network effects, history shows that new technology products and services have been launched successfully in competitive markets and that market segments have been penetrated into and captured. This is often made possible due to innovation in terms of revolutionary technology (e.g., the Apple iPhone), path breaking business models (e.g., Apple iTunes) or an evolutionary strategy, whereby the new player enters the market by being compatible with the incumbent. The revolutionary strategy is marked by a large improvement or “discontinuity” in technological capability, whereas the evolutionary strategy follows a smoother transition (Shapiro and Varian 1998).

The SH literature assumes that users choose only one of the networks. Katz and Shapiro (1985) discuss a single period model where a consumer’s decision to adopt a technology or network depends on the price and the rational expectations about the final network size. When new products are introduced, the market may display a bias towards existing product, resulting in excess inertia or a rush to the new entrant due to insufficient friction (Katz and Shapiro, 1985). In a two-period SH model of dynamic competition with new adopters entering the market, Farrell and Shapiro (1988) show that an inferior product can enter a market where there are economies of scale and switching cost for consumers. However, they note that it will be difficult for such a new entrant to lure the installed base, and that it may be more successful in attracting new adopters. Beggs and Klemperer (1992) propose an infinite period model where new consumers arrive in the market every period and a fraction of old consumers leaves. Switching costs make the market more attractive to a new entrant in spite of an installed base. Farrell & Saloner (1985) model sequential decisions to completely adopt one amongst multiple platforms (i.e., single homing) where the timing of adoption is endogenous. However, in our model, the participants sequentially decide on the extent of adoption of the incumbent and the new entrant in a multi-homing context.

Another relevant stream of literature involves the diffusion of innovation. Diffusion is a process of communicating ideas about an innovation amongst users who are potential adopters (Rogers, 1962). Rogers proposed that the adoption curve follows a normal distribution. He classified adopters into innovators, early adopters, early majority, late majority and laggards. Bass (1963, 1969) presented an analytical model describing this phenomenon, popularly known as the ‘Bass diffusion model’, which is a special case of the Gompertz distribution. The Bass diffusion model considers the adoption of new innovations as a result of interactions between existing user base and potential adopters. In this model, the rate of change of adoption depends on the
cumulative adopters at a given time, the 'coefficient of external influence' and the 'coefficient of internal influence'. The model aids practitioners in predicting sales based on historic information or derived from analogous product sales in the past. However, in the Bass model, the adoption pattern is exogenously specified, whereas we treat the adoption process as endogenous. The Bass diffusion model does not explicitly specify if new adopters enter the market. Thus it is not clear if the adopters are leaving a product to adopt one whose diffusion pattern is being predicted. In our model, there are no new adopters in order to isolate the dynamics of network effects and technological capabilities and their impact on diffusion. Thus, in our work, users have to leave the existing product either completely (in SH) or partially (in MH) to adopt the new entrant’s offering.

### 3. The Model

We consider an incumbent (network 1) with technological capability $c_1$. A new entrant (network 2) arrives with better capability denoted by $c_2$ ($c_2 > c_1$). The capability of a network may depend on the features provided by specific technologies. For instance, suppose the incumbent and the new entrant networks serve gaming and music applications only, such that $c_1 = f(m_1, g_1)$ and $c_2 = f(m_2, g_2)$, where $f(m, g)$ is an increasing function in $m$ and $g$, the features provided by the music and the gaming application respectively in network $i$. We consider the case where each network is superior in one dimension than the other network, although network 2 is superior from an overall standpoint. For example, MySpace is considered to be superior to Facebook in entertainment oriented social networking. Therefore, many users with inclination towards the capability offered by MySpace may split their time between MySpace and Facebook, and not completely migrate to the latter.

As noted earlier, networks offer benefits in the form of technological capability and network effects. We also assume that each user is in all other users’ contact lists. User $i$ on network 1 has a benefit function given by $B_i(c, t_i, \zeta_{-i}, \theta_i)$ where $c$ is the capability of the network, $t_i$ is the amount of time spent by user $i$ on the network in period $\rho$, and $\zeta_{-i}$ is the total time spent by all users (excluding user $i$) on the network 1 in period $\rho$. While some users perceive higher benefits from capabilities than others, the latter may have higher benefits from network effects. This is reflected in the user type: $\theta_i = [\alpha_i, \beta, \gamma_i]$, where $\alpha_i$ and $\gamma_i$ are the capability and network effects coefficients respectively, and where $\beta \in (0,1)$ denotes the importance that users assign to their own time. In this model, all users are assumed to have the same $\beta$. Since $\beta$ is a user characteristic, it does not change across the incumbent and the new entrant. We assume $0 < \alpha_i < 1, 0 < \beta \leq 1, 0 < \gamma_i \leq 1$ and $\alpha_i + \gamma_i = 1$. A user with higher capability coefficient perceives higher benefits from the capability of a network, while those with higher network effects coefficient perceive higher benefits from network effects. User $i$ will allocate time between the two networks such that the net benefit is maximized. The total benefit for user $i$ in a given period is given by $B_i(.) = B_i(c_1, t_{i1}, \zeta_{-i1}, \theta_i) + B_i(c_2, t_{i2}, \zeta_{-i2}, \theta_i)$, where $t_{i1}$ and $t_{i2}$ are the times spent by $i$ on network 1 and 2 respectively, and where $\zeta_{-i1}$ and $\zeta_{-i2}$ are the total times spent by all other users in network 1 and 2 respectively.

#### 3.1 Model assumptions

The diffusion of information about the new entrant (network 2) to users in network 1 occurs at a rate $R$, such that in each period, $R$ users of the same type receive the information about the new entrant for the first time. Thus all users do not make a simultaneous decision to allocate time to the new network. Rather, the flow of information about the new network is such that more capability affine users make a first-time decision regarding migration before more network effect affine users. This is a plausible assumption because usually early adopters are attracted to a new network because of its capabilities, while late adopters generally tend to place a higher

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5 If the new network’s gaming and music technology capabilities are both better than that of the incumbent, i.e., if $m_2 > m_1$ and $g_2 > g_1$ then a user would have no reason to spend time on the incumbent network from a capability standpoint.

6 This benefit is for period $\rho$ only, and will change from period to period; however, in this section of the paper we consider myopic, period-by-period optimization, and hence omit $\rho$ from the benefit function for compactness of notation.

4 A period is a sampling interval in time space.

3 This simple diffusion pattern is assumed for modeling simplicity. Later in the paper, we use the well-known Rogers curve in numerical examples to model the diffusion of information among users in the incumbent network.

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value on interactions with contacts. Later we also analyze the adoption patterns when information diffuses in the opposite direction.

For analytical tractability in a temporal framework, all users are assumed to make myopic decisions (Sobel 1981, Farrell and Shapiro, 1988; Beggs and Klemperer, 1992) to allocate time to the new network, i.e., they perform period-by-period optimization. However, even if the users consider all future periods in choosing the time allocation to the new network in a particular period, they would not choose to spend less time on the new network than in the case of myopic decision making; with full and accurate information about the network capabilities and user types, in a given period, no user will reduce the time allocated to the new network below that in an earlier period. However, users may allocate more time to the new network relative to the myopic levels, since they know that by spending more time in a given period on the new entrant, they can induce others to follow suit in future periods because of network effects. Thus, our results regarding the vulnerability of the incumbent are likely to hold even when users make globally optimal decisions.

Katz and Shapiro (1985) consider the case of single-homing in a single-period model with rational expectations. In our multi-period model, even if users form rational expectations about the final states of the two networks, they may not alter their current period allocation because the diffusion of information about the new entrant is such that not all users are informed of the new network until the last period. This is true regardless of whether the diffusion pattern follows the Rogers curve or the forms we use in the model (e.g., uniform for homogeneous users). Thus even if the new entrant is expected to capture the entire market in period $N$, in a period $p < N$, $p$ informed users will not allocate the full time $T$ to the new network because in this period, they can still get larger benefits by splitting their time between the new entrant and the incumbent, since the latter may still have sufficient network effects to prevent complete migration in period $p$.

Initially, the total number of users in network 1 is $N$ such that $RP = N$ where $P$ denotes the period in which all users in network 1 become aware of network 2. We initially assume $R = 1$. Later, we relax this assumption and show that the results are actually reinforced in the process. In any period, $t_{1i} + t_{12} = T$ for all $i$, and thus $\zeta_{-1i} + \zeta_{-12} = (N - 1)T$. The specific form of the benefit function in period $\rho$ is given as:

$$B_{i}(.) = a_{i}c_{1}(t_{1i})^{\beta_{i}} + \gamma_{i}\zeta_{-1i}t_{1i} + a_{i}c_{2}(t_{12})^{\beta_{i}} + \gamma_{i}\zeta_{-12}t_{12}$$

In the presence of a new entrant with a superior capability, but which may lag behind the incumbent on one or more dimension(s), a user derives value by dividing time between the two networks in a MH network. The capability dependent part of the benefit function captures this effect. The benefits of network effects on each network increases with the time the user spends on the network and also the total time spent by all other users on the network. In the initial periods of migration when the network effect on the new entrant is weak, the capability required by the new entrant is high in order to compensate for the loss in a user’s utility from the network effect on the incumbent network. The relatively more capability affine users make a first-time allocation decision in the initial periods and are therefore more prone to migration due to this higher capability of the new entrant. As the migration continues and network effects build up in the new network, more users with moderate affinity to both capability and network benefits make an allocation decision. This represents the bleeding phase, where the total time on the new network increases slowly over time. Subsequently, if adequate network effects have developed, users with high affinity for network effects making a first-time decision will allocate large chunks of time to the new network, potentially resulting in an avalanche.

We start with the case of homogenous users, who have the same characteristics $\theta = \{\alpha, \beta, \gamma\}$. For the SH user, the decision is whether to adopt the new entrant network completely (by choosing $T$) or stay with the incumbent. We investigate the MH case where a user can allocate less than $T$ to the new network. For analytical tractability, we assume that the first user making the decision can increment her time on the new network by either 0 or $T/N$ (i.e., small increments for a large user base) in each period. Since the information received about the new entrant is reliable, the users have no incentive to reduce their time on the new network in a later period. For users 2, 3, ... $N$, we consider two possible cases: (1) User $i$ ($i \neq 1$) allocates an increment of $T/N$ in the $ith$ period (the first time $s/he$ makes an allocation decision) and later (Table 1), (2) User $i$ ($i \neq 1$) allocates $iT/N$ in the $ith$ period (the first time $s/he$ makes an allocation decision) and later (Table 2). The logic behind case 2 (which is more plausible) is that when users are homogeneous, all informed users in a given period will allocate the same time to the new entrant.
Table 2: Time allocation in MH by homogeneous users for case 1

<table>
<thead>
<tr>
<th>User #</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>. . .</th>
<th>Period N</th>
</tr>
</thead>
<tbody>
<tr>
<td>User 1</td>
<td>T/N</td>
<td>2T/N</td>
<td>3T/N</td>
<td>. . .</td>
<td>T</td>
</tr>
<tr>
<td>User 2</td>
<td>0</td>
<td>T/N</td>
<td>2T/N</td>
<td>. . .</td>
<td>(N-1)T/N</td>
</tr>
<tr>
<td>. . .</td>
<td>0</td>
<td>0</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>User N</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>. . .</td>
<td>T/N</td>
</tr>
</tbody>
</table>

Table 3: Time allocation in MH by homogeneous users for case 2

<table>
<thead>
<tr>
<th>User #</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>. . .</th>
<th>Period N</th>
</tr>
</thead>
<tbody>
<tr>
<td>User 1</td>
<td>T/N</td>
<td>2T/N</td>
<td>3T/N</td>
<td>. . .</td>
<td>T</td>
</tr>
<tr>
<td>User 2</td>
<td>0</td>
<td>2T/N</td>
<td>3T/N</td>
<td>. . .</td>
<td>T</td>
</tr>
<tr>
<td>. . .</td>
<td>0</td>
<td>0</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>User N</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>. . .</td>
<td>T</td>
</tr>
</tbody>
</table>

**Proposition 1:** For homogeneous users, the capability required by the new entrant to initiate migration in a SH network is highest in the first period. In a multi-homing network, the corresponding capability is lower in both cases 1 and 2. Further, in all periods, the capability required in case 2 is lower than that in case 1.

**Proof:** All proofs are provided in the Appendix.

A numerical example illustrates the implications of Proposition 1. With $c_1 = 50, \beta = 0.5, T = 40, N = 200$, the capabilities required of the new network in period 1 for SH and MH (both cases 1 and 2) are shown in Table 4, while the capabilities required in each of the $N$ periods (with $N$ users) for the migration to continue are shown in Figure 2. With a much smaller capability relative to the SH case, a new entrant in MH can initiate migration away from the incumbent. Further, the maximum capability required across all periods in MH occurs later than in SH, where the highest capability must be provided upfront. It is also interesting to note that the maximum capability requirement in SH is over three times larger than in MH case 2. Figure 3 shows the growth of the new entrant network for SH and MH cases.

Table 4: Capabilities required to initiate migration in SH and MH networks

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$\gamma$</th>
<th>Capability required to initiate migration in SH</th>
<th>Capability required in MH (both cases 1 and 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>0.1</td>
<td>5643.7</td>
<td>396.3</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>50393</td>
<td>3562.7</td>
</tr>
<tr>
<td>0.1</td>
<td>0.9</td>
<td>453140</td>
<td>31960</td>
</tr>
</tbody>
</table>
As seen in Figure 3, in both SH and MH case 2, complete migration occurs by the last period. However, relative to SH, in MH case 2, the total time increases at a slower rate in the initial periods (‘bleeding of the incumbent’) and a rapid rate in the latter periods. We also note that all users in MH case 1 may not migrate completely in $N$ periods. Unless the new entrant provides additional capability improvements at such time, the network may stall into a niche platform, whereby both the incumbent and the new entrant share the market between themselves.

The assumption of increments by $T/N$ is to make the analysis tractable and to demonstrate that small increments in time allocation to the new entrant can ultimately lead to large scale migration. Similar results would be obtained if we allow users to increment time by $xT$, $x < 1$. As $x$ increases, the highest capability required by the new entrant also increases, but remains lower than the highest capability required in SH. Furthermore, this highest capability will not be required in the first period. E.g., when $x = 1/100$, the highest capability required in MH case 2 is less than $1/6$th the capability required in SH and needs to be delivered only in the eighth period. It should be noted that due to the constraint on increments of $T/N$ (or $xT$ in general), the network effect on the new entrant will build slower in later periods than what it would in an unconstrained setup, if $x$ is small. That is, in the real world where users can freely allocate time across the two networks, the incumbent may be even more vulnerable than that implied by Proposition 1.

Nault and Vandenbosch (1996) suggest that incumbent firms should “eat their own lunch” by leapfrogging in innovation to face competition from a new entrant. Our paper shares the spirit of continuous innovation, but suggests how a new entrant may not have to leapfrog in technology; rather, in the MH setting, the new entrant can introduce small increments in technology at regular intervals and still manage to gain market share. For
example, MySpace and Facebook were launched in 2003 and 2004 respectively with very similar social networking tools like the ability to add friends by searching existing profiles, and posting messages and photos. Facebook continuously improved the social networking experience by adding capabilities gradually, while MySpace began losing its main demographics of teenagers in 2007 due to design and privacy issues\(^7\). While Facebook incrementally added features like Share, News Feeds, Mini-Feed, Marketplace, Translation tools, Facebook Chat, Like feature, Virtual Gift Shop, etc., and created a platform for Facebook application developers maintaining transparency in design and privacy control, MySpace struggled with its design or privacy related issues. Thus, MySpace’s decline was not a result of a revolutionary technology shift induced by Facebook, but can be attributed to the latter’s gradual but steady stream of improvements. Similarly, Google+ entered the market in 2011 with a different concept of social networking and is gaining membership rapidly. Google+ is also slowly but steadily adding features to its platform. If the incumbent (Facebook) does not innovate continuously, as it has in the past, it may slowly lose market share to Google+ in spite of strong network effects.

3.2 Heterogeneous users

We now analyze the case of heterogeneous users, who have different capability and network effects coefficients. As noted in the model development section, with increasing period, the affinity toward capability decreases while that toward network effects increases. We assume that in period \(\rho\), \(\gamma_{\rho} = \frac{\gamma_{\min}}{\alpha_{\max}} \Delta^{\rho-1}\), where \(\Delta > 1\) and \(\gamma_{\min} / \alpha_{\max}\) is the ratio of first user’s characteristics. As \(\alpha\) reduces and \(\gamma\) increases, the ratio increases from \(\gamma_{\min} / \alpha_{\max}\) in period 1 to \(\gamma_{\max} / \alpha_{\min}\) in period \(N\). For \(N\) users, \(\gamma_{\max} / \alpha_{\min} = \gamma_{\min} \Delta^{N-1}\), or \(\ln \Delta = \ln \left(\frac{\gamma_{\max} / \alpha_{\min}}{\gamma_{\min} / \alpha_{\max}}\right) / (N-1)\). For a large user base, this assumption implies that adjacent users differ in characteristics by small amounts. A heterogeneous user makes a full adoption decision between the incumbent and new entrant in the SH scenario, whereas the choice of increment is between \(0\) and \(T/N\) in the MH setting. In SH with heterogeneous users (represented by \(H\)), the capability \(c_{2SH,\rho}\) required of network 2 to ensure migration of an informed user in period \(\rho\), is given by:

\[
c_{2SH,\rho} > c_1 + \frac{\gamma_{\rho}}{\alpha_{\rho}} T^{2-\beta} (N - 2\rho + 1)
\]

Thus, the period in which \(c_{2SH,\rho}\) reaches a maximum is given by:

\[
\rho^*_S = \frac{N + 1}{2} - \frac{1}{\log \Delta}
\]

In MH, the capability \(c_{2MH,\rho}\) required to ensure that an informed user gives an additional time \(T/N\) in any period \(\rho\) is given by:

\[
c_{2MH,\rho k} = c_1 \left(\frac{(N - \rho + k)^\beta}{(\rho - k + 1)^\beta} - \frac{(N - \rho + k - 1)^\beta}{(\rho - k)^\beta}\right) + \Delta^{k-1} \frac{\gamma_{\min}}{\alpha_{\max}} \left(\frac{T}{N}\right)^{2-\beta} \left(\frac{(N + \rho - 1)(N - \rho) - 2(k - 1)}{(\rho - k + 1)^\beta - (\rho - k)^\beta}\right).
\]

It is analytically difficult to find the period in which the highest capability is required. Therefore we resort to numerical illustrations to show that the peak capability required in SH needs to be delivered before the peak capability required for MH, which has implications for the vulnerability of the incumbent.

\(^7\)http://www.msnbc.msn.com/id/19717700/

\(9\) Thirty Second International Conference on Information Systems, Shanghai 2011
Figure 4: Maximum capability required for heterogeneous users in SH and MH ($c_1 = 50, T = 40, N = 100, \beta = 0.5$)

As shown in Figure 4, in the SH network of heterogeneous users, the initial capability required to cause migration of the first user is fourteen times higher than that in MH. This observation is encouraging for new entrants, for it is more challenging for the new entrant to deliver a large capability upfront than to do so gradually. We also note that the highest capability required of the new entrant in SH needs to be delivered earlier than in the MH case. Thus we note that a new entrant in MH can take longer to develop and deliver improvements in capability compared to the SH case. Of course, the network effect builds faster on the SH network due to complete adoption, while MH witnesses a slow increase in network effects because (for analytical tractability) we have constrained users to increment their time by 0 or $T/N$ in the MH case. In later periods, the SH network is predominantly driven by increasing network effects, while the MH network requires a high capability to compensate for the slow rate of increase in network effects. However, the high required capability in later periods for MH is an artifact of our constraint of increments in steps of $T/N$. In the next section we remove the constraint on the increment, and show that complete migration can take place with much lower maximum capability requirements in MH.

So far we have assumed that the diffusion of information is such that capability affine users make a decision before users with higher affinity for network effects. Next we analyze the case where information diffuses to users with higher affinity to network effects before it does for capability affine users. We focus on the difference in capabilities required of the new entrant in this reverse diffusion pattern, for the result has implications for campaign strategies that the new entrant would use in order to spread information about its network.

Proposition 2: If the diffusion of information in a SH or MH network takes place such that the user with the highest affinity to capability makes the first decision to migrate, the highest capability required by the new entrant is lower than the case when the diffusion of information takes place in the reverse direction.

The new entrant may build capabilities to target network and/or capability affine users to spread information about its network. While the capability required to lure network affine users may be high, a relatively lower capability may suffice to attract a capability affine user. For example, in an online social network catering to music, a capability affine user may be attracted by a technology that can understand her taste in music and recommend new songs. However, this may not be sufficient to attract a network affine user, who may need additional capabilities to interact and share content with other users. From the new entrant’s perspective it should be easier to reach capability affine users initially by building a superior capability rather than network affine users. Thus, the new entrant should devise strategies to enable diffusion of information such that users who value capability more than network effects get the information and therefore the opportunity to migrate first.

So far we have assumed that only one user makes a first-time decision per period to migrate or increment time in single and MH networks respectively. When multiple users receive information and take a first-time decision to initiate migration to the new network, the network effect on the new entrant builds faster than the case when a single user makes a migration decision. Thus the capability required by the new entrant to attract multiple homogeneous users is less than that required to attract a single homogeneous user.
**Proposition 3:** If diffusion of information occurs in a way such that $R (>1)$ homogeneous users receive the information about the new network, the highest capability required (to move the first user) will be lower than the case when $R=1$. This holds true for both $S$ and $MH$ networks.

### 3.3 Optimal decisions of heterogeneous users

In this section we analyze the case where heterogeneous users can choose any increment of time (up to $T$) to spend on the new network. We use nonlinear programming tools in Matlab 7.9 to perform nonlinear optimization. The definition of optimality is based on Karush–Kuhn–Tucker (KKT) conditions, which ensure that the gradient is zero at the minima but are modified by the total time constraint. Active Set algorithms are used to compute optimal time allocation. The algorithm starts from a feasible point, approximates the solution to the problem defined by active constraints, computes a Quasi-Newton approximation of the Hessian of the Lagrangian, removes constraints with negative Lagrange multiplier and searches for infeasible constraints in order to compute an optimal solution.

When users are heterogeneous, the optimal decision is attained by simultaneously solving the first order conditions of informed users in the $p^{th}$ period. To assess the difference in capabilities required to cause migration in single and MH for heterogeneous users without constraints on time increments, we assume that $\alpha$ lies between 0.2 (low sensitivity to capability) and 0.8 (high sensitivity to capability). Further, 20% of users have $\alpha$ uniformly distributed between 0.7 and 0.8 (i.e., these are “innovators and early adopters” of an innovation). 60% have $\alpha$ uniformly distributed between 0.4 and 0.6 (“early and late majority”). The remaining 20% users have $\alpha$ uniformly distributed between 0.2 and 0.3 (“laggards”). This distribution follows a pattern similar to the Rogers curve (Rogers 1962).

Figure 5 shows that with $c_2/c_1 = 1.6$, the SH network stalls in period 20, while the MH network continues to grow smoothly. This observation reaffirms the analytical results obtained earlier under constrained choices in the case of MH, where users derive more value by dividing their time on the two networks, while in SH users have to make a binary decision, thus requiring a revolutionary technology to completely abandon the incumbent.

Figure 6 shows the migration patterns with the same parameter values as in Figure 5 but with a higher capability of the new network ($c_2/c_1 = 2$). We observe that due to the higher capability of the new entrant, complete migration takes place successfully in SH. As expected, migration is initially slow in the case of MH, but the total time spent on the new network catches up to the level of SH in later periods. Only innovators and early adopters may choose to migrate to a new entrant when only SH is permitted; however, the same group of users may act as a trigger for slow bleeding of the incumbent network in MH. Since the bleeding is slow when users make unconstrained optimal decisions, it may go undetected initially or not raise an alarm even when detected. It is critical for the incumbent to take corrective action in order to pull back the users migrating away from the incumbent, before the avalanche stage is reached. Once the avalanche begins, the demise of the incumbent is inevitable. However, there are cases where the incumbent may not be in a position to react to capability improvements by the new entrant. For example, MySpace lost a majority of its user base to Facebook, but could not match the capabilities being delivered steadily by the latter. Thus, we suggest that the economic moat of network effects is susceptible to breach in the case where users do not have to give up on the incumbent in a single period to embrace the new entrant.

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8 http://www.mathworks.com/help/toolbox/optim/
Figure 5: Effect of new entrant’s capability $c_2$ on total time on the new network in SH and MH. $c_1 = 10000, c_2 = 16000, N=100, T=40, \beta = 0.6$.

Figure 6: Effect of new entrant’s capability $c_2$ on total time on new entrant. $c_1 = 10000, c_2 = 20000, N=100, T=40, \beta = 0.6$.

To demonstrate how an incremental technological progress may breach the incumbency protection provided by network effects, we isolated the model from the incumbent’s reaction to the new entrant’s arrival. In the following section, we analyze the effect of the incumbent’s delivery of an improved capability as a reaction to the new network’s superior technology. We also relax the assumption of myopic optimization by the users.

3.4 Incumbent’s reaction to the new entrant

We analyze a SH scenario where the incumbent introduces an increased capability after the arrival of the new network. We assume that homogenous users use a discount factor $\delta (0 < \delta < 1)$ to optimize over an infinite time horizon. Since users are homogeneous, we only need to analyze the first user’s decision problem. The sequence of events is as follows: In period 1, the new entrant arrives with capability $c_2$ that is sufficient for the first homogenous user (and thereafter subsequent users) to migrate to the new entrant completely. Thus, in period 1, the first user shall migrate to the new entrant network. However, the incumbent realizes that this will eventually result in a large scale migration, and therefore reacts by providing an improved capability $c'_1 = \sigma c_1$ in period $\rho$ where $1 < \rho < N$. In the absence of switching costs other than those due to network effects, informed users will
migrate to the new entrant until period $\rho - 1$; then, depending on $c'_i$ such users may return permanently to the incumbent (assuming no further improvements by the new entrant). Therefore, the incumbent foregoes the network effects from the informed users until period $\rho - 1$ due to migration to the new network. Thereafter, depending upon the level of improvement, all past decision makers who migrated to the new network may return to the incumbent, while the remaining users prefer to stay back with the incumbent. Since the users are homogeneous, we only consider the first user’s decision problem to migrate to the new entrant and return upon the delivery of improved capability by the incumbent. The condition is given by:

$$
\begin{align*}
&\alpha c_2 T^\beta \left( 1 + \delta + \delta^2 + \ldots + \delta^{\rho-2} \right) + \gamma T^2 \left( 0 + \delta + 2\delta^2 + \ldots + \left( \rho - 2 \right) \delta^{\rho-2} \right) \\
&+ \alpha c'_i T^\beta \left( \delta^{\rho-1} + \delta^\rho + \ldots + \delta^\infty \right) \geq \\
&\alpha c_2 T^\beta \left( 1 + \delta + \delta^2 + \ldots + \delta^\infty \right) + \gamma T^2 \left( 0 + \delta + 2\delta^2 + \ldots + \left( N - 1 \right) \delta^{N-1} \right) \\
&+ \gamma T^2 \left( N - 1 \right) \left( \delta^N + \delta^{N+1} + \ldots + \delta^\infty \right)
\end{align*}
$$

This can be simplified to $\sigma \geq 1 + \frac{\gamma}{\alpha} c'_i \cdot T^\beta \cdot \left( (\rho - 1) + \left( \frac{1}{1 - \delta} \right) \left( 1 - \delta^{N-\rho} \right) \right)$. 

**Proposition 4a:** As the delivery period increases, the improvement that the incumbent has to deliver to reverse the migration also increases.

**Proposition 4b:** As the total number of users increases, the period by which the incumbent must deliver the improved capability increases.

**Proposition 4c:** As the affinity of homogeneous users to capability increases, the period by which the incumbent must deliver the improved capability decreases; for a given period of delivery, the incumbent will need a lower improvement in capability for users with higher affinity to capability.

The network effect on the new network becomes progressively stronger over time. The improved capability delivered by the incumbent has to overcome the pull created by the network effects developing on the new network. Thus, the incumbent should strive to deliver the desired improvement in capability as early as possible. Because of the pattern of decision to migrate, an incumbent with a large user base will enjoy a strong network effect for a longer period of time. Since the new entrant will take more time to build up stronger network effects, the incumbent has the opportunity to deliver an improved capability relatively later. As the affinity to capability increases, the user derives more benefit from a given capability level. Thus, the capability improvement required to ensure that the user has an incentive to migrate back to the incumbent is lower for a user with higher affinity to capability. If the incumbent comes up with an improvement soon enough, then it may cause the reversal of migration with a capability lower than that of the new entrant owing to its large user base. The period by which the incumbent can deliver a capability lower than the new entrant and still cause reverse migration is given by

$$
3 \rho + \frac{\delta}{1 - \delta} \left( 1 - \delta^{N-\rho} \right) < N + 2
$$

It should be noted that the period of delivery above is independent of user characteristics $\theta_i = \{\alpha, \beta, \gamma\}$. However, as the users discount the future more, the incumbent needs to provide the improved capability faster.

In the first part of the paper, we have shown how a new entrant can induce migration with capability smaller than the incumbent and slowly develop its capabilities over time to cause a large scale migration if the incumbent does not react with innovation. In the latter part we see how the incumbent can combat such a strategy by the new entrant and innovate in order to cause a reverse migration. In reality, both the incumbent and the new entrant should strive for continuous innovation and not rely only on network effects. The demise of online networks like MySpace and ensuing competition between Facebook and Google+ accentuate the importance of continuous innovation.
4. Conclusions

The “information economy” has been characterized as a setting with strong network effects, and prior research has indicated that such forces favor the incumbent and can make it difficult for superior new technologies or networks to be adopted. In this study we have noted that in the increasingly common scenario of multi-homing, an incumbent may be more vulnerable to a new entrant’s threats than previously believed in the network effects literature. We also demonstrated that in a setting where users may incrementally adopt a new network by increasing the level of adoption over time, a new entrant need not provide the maximum technological capability at the outset as in the case of single homing; it has the opportunity to arrive with a marginally superior capability and to improve such capability over time. In other words, the incumbency protection power of network effects appear to be overrated in the modern context of simultaneous and incremental adoption of multiple technologies.

We have also demonstrated that in the absence of switching costs other than network effects, the incumbent can regain lost market share by delivering an improved capability before the network effects have built up sufficiently on the new entrant’s network. Further, there is a tradeoff between the required capability improvement and the maximum delivery time, which, in turn, depend on the number of users and the affinity of users for technological capabilities. These results indicate that network effects may contribute less to the competitive advantage of an incumbent than previously believed, and that competitive intensity may increase considerably due to the opportunity to compete with a powerful incumbent with just a marginally superior offering followed by incremental improvements.

5. References


Appendix

Proof of proposition 1

In SH, in period 1, the first user will migrate completely if \( c_2 \geq c_1 + \frac{\gamma}{\alpha} T^{2^{-\beta}} (N - 1) \). In period \( \rho \) the \( \rho^{th} \) user will migrate completely to the new entrant if \( c_2 \geq c_1 + \frac{\gamma}{\alpha} T^{2^{-\beta}} (N - 2\rho + 1) \). Let this value of \( c_2 \) (the maximum capability that must be provided by the new entrant in period \( \rho \) in the SH case of homogenous users) be denoted by \( c_{2Sh\rho} \), which is decreasing in \( \rho \), i.e., \( \max(c_{2Sh\rho}) = c_{2Sh1} \).

For MH cases 1 and 2, every users can increment their time only by 0 or \( T/N \). In period 1, user 1 spends \( T/N \) on the new entrant while all other users still allocate \( T \) each to the incumbent. In order to make this feasible, the benefit that user 1 accrues by incrementing the allotment to the new entrant by \( T/N \) must be larger than that from incrementing by 0. This can be written as:
\[
\alpha c_2 \left( \frac{T}{N} \right)^{\beta} + \alpha c_1 \left( \frac{T - T}{N} \right)^{\beta} + \gamma (N - 1)T \left( \frac{T - T}{N} \right) \geq \alpha c_1 T^{\beta} + \gamma (N - 1)T^2
\]
\[c_2 \geq c_1 \left( N^{\beta} - (N - 1)^{\beta} \right) + \frac{\gamma}{\alpha} \left( \frac{T}{N} \right)^{2-\beta} \left( N + (N - 1)^{\beta} \right) \]

Comparing the maximum capability required for SH network and MH network in case of homogenous users, \( c_{2S_h} - c_{2Mh_1} = c_1 \left( 1 - (N^{\beta} - (N - 1)^{\beta}) \right) + \frac{\gamma}{\alpha} T^{2-\beta} (N - 1) (1 - N^{\beta - 1}) > 0 \), for \( 0 < \beta < 1 \) \( 0 < N^{\beta} - (N - 1)^{\beta} < 1 \) and \( 0 < 1 - N^{\beta - 1} \). Therefore, \( c_{2S_h} > c_{2Mh_1} \).

For MH case 1, for any period \( \rho \), the capability required to motivate all informed users to increment their time on the new entrant by \( T \) is given by:
\[c_{2Mh_1} = c_1 \left( \frac{(N - \rho + 1)^{\beta}}{\rho^{\beta}} - \frac{(N - \rho)^{\beta}}{(\rho - 1)^{\beta}} \right) + \frac{\gamma}{\alpha} \left( \frac{T}{N} \right)^{2-\beta} \left( N + \rho - 1 \right) \left( N - \rho \right) \rho^{\beta} - (\rho - 1)^{\beta}
\]

For MH case 2, in any period \( \rho \), the capability required to motivate all informed users to allot \( T \) to the new entrant is given by:
\[c_{2Mh_2} = c_1 \left( \frac{(N - \rho + 1)^{\beta}}{\rho^{\beta}} - \frac{(N - \rho)^{\beta}}{(\rho - 1)^{\beta}} \right) + \frac{\gamma}{\alpha} \left( \frac{T}{N} \right)^{2-\beta} \left( N + 4 \rho - 2 - \rho^2 \right) \left( N - \rho \right) - N \rho^{\beta} - (\rho - 1)^{\beta}
\]
\[c_{2Mh_2} - c_{2Mh_1} = \frac{\gamma}{\alpha} \left( \frac{T}{N} \right)^{2-\beta} \left[ N + (N - \rho) \left( (\rho - 1)(\rho - 2) - 1 \right) \right] > 0
\]

**Proof of Proposition 2**

In SH of heterogeneous users, when \( \alpha_\rho \) is decreasing, \( \frac{\gamma_\rho}{\alpha_\rho} = \frac{\gamma_{\min}}{\alpha_{\max}} \Delta^{\rho - \Delta} \) and when \( \alpha_\rho \) is increasing, \( \frac{\gamma_\rho}{\alpha_\rho} = \frac{\gamma_{\min}}{\alpha_{\max}} \Delta^{\rho - \Delta} \). In the case of heterogeneous users (denoted by \( H \)), the capability \( c_{2SH_\rho} \) required to ensure migration of a first time decision maker user in period \( \rho \) is given by:
\[c_{2SH_\rho} = c_1 + \frac{\gamma_\rho}{\alpha_\rho} T^{2-\beta} \left( N - 2 \rho + 1 \right)
\]

When the affinity to capability is decreasing with increasing periods, the period in which the maximum capability needs to be delivered by the new entrant is given by:
\[\rho_{S_{(dec)}} = \frac{N + 1}{2} - \frac{1}{\log \Delta}
\]
\[c_{2SH_{\rho_{(dec)}}} = c_1 + \frac{\gamma_{\min}}{\alpha_{\max}} \Delta \left( \frac{2}{\log \Delta} \right)^{N - 1 \Delta}
\]
Similarly, when the affinity to capability is increasing with period, the minimum capability required is delivered in period:
\[\rho_{S_{(inc)}} = \frac{N + 1}{2} + \frac{1}{\log \Delta}
\]
and maximum capability must be delivered in the first period itself, i.e.,
\[\rho_{S_{(inc)}} = 1 \text{ where } c_{2SH_{\rho_{(inc)}}} = c_1 + \frac{\gamma_{\min}}{\alpha_{\max}} \Delta \left( N - 1 \right)
\] and
\[c_{2SH_{\rho_{(inc)}}} = c_{2SH_{\rho_{(dec)}}}
\]

**Proof of Proposition 3**

From proposition 1, we know that the capability requirement for the first agent is the highest. Therefore, comparing the first agent’s capability requirements for \( R = 1 \) and \( R > 1 \) should suffice.
In a SH network, when \( R = 1 \), \( c_{2Sh} = c_1 + \frac{\gamma}{\alpha} T^{2-\beta} (N-1) \). When \( R > 1 \), user 1’s problem is given by,
\[
\alpha c_{2ShR} T^\beta + \gamma (R-1)T^2 \geq \alpha c_1 T^\beta + \gamma (N-1)T^2.
\]
This can be simplified to, \( c_{2ShR} = c_1 + \frac{\gamma}{\alpha} T^{2-\beta} (N-R) \) or
\[
c_{2Sh1} - c_{2ShR} = \frac{\gamma}{\alpha} T^{2-\beta} (R-1) > 0
\]
In a MH network, when \( R = 1 \), \( c_{2Mh} \geq c_1 + \frac{\gamma}{\alpha} \left( \frac{T}{N} \right)^{2-\beta} (N-1)N \).
When \( R > 1 \), user 1’s problem is given by,
\[
\alpha c_{2MhR} \left( \frac{T}{N} \right)^\beta + \gamma \left( \frac{(R-1)T}{N} \right) \left( \frac{T}{N} \right) + \alpha c_1 \left( T - \frac{T}{N} \right)^\beta + \gamma \left( (N-1)T - \frac{(R-1)T}{N} \right) \left( T - \frac{T}{N} \right)
\]
\[
\geq \alpha c_1 T^\beta + \gamma (N-1)T^2
\]
This can be simplified to \( c_{2MhR} \geq c_1 \left( N^\beta - (N-1)^\beta \right) + \frac{\gamma}{\alpha} \left( \frac{T}{N} \right)^{2-\beta} \left( N^2 - 2(N+R) + 2 \right) \).
\[
c_{2MhR} - c_{2Mh1} = \frac{\gamma}{\alpha} T^{2-\beta} \left( N + 2(R-1) \right) > 0
\]
**Proof of propositions 4a, 4b and 4**
These proofs follow directly from comparative statics.