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Keeping the AppEconomy Booming: How commercial competition and signaling influence crowding out in complementer communities

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Abstract

Communities of third-party complementers are an important source of innovation for a wide range of technology platforms (Bayus, 2012; Boudreau, 2010; Cennamo & Santalo, forthcoming; Chen, Harper, Konstan, & Li, 2010; Corts & Lederman, 2009; Zhang & Zhu, 2011). While complementers that contribute for free comprise much of these communities, many commercial complementers contribute as well. As a result, free complementers often face competition from commercial alternatives. While the effect of competition on innovation has been extensively studied between commercial actors (Aghion, Bloom, Blundell, Griffith, & Howitt, 2005), how competition affects free contributors is far from understood. Meanwhile, recent studies suggest that free contributors may be sensitive to competition (Boudreau & Jeppesen, 2011; Boudreau, forthcoming). At the same time, many free complementers use their contributions as a way of signaling their abilities (Jeppesen & Frederiksen, 2006). While these contributors make valuable contributions to the platform (Roberts, Hann, & Slaughter, 2006), they also send signals to other complementers. Such signals may greatly influence how free complementers contribute (Chen et al., 2010). This paper aims to understand how free complementers are influenced by competition from each other, signals from other free complementers and competition from commercial alternatives.

By using product market data on the Jailbreak Platform - an underground mobile application marketplace, this paper advances our understanding of how the composition of complementer communities influences the level of free contributors. While individual motivations to contribute may vary and may change over time, these motivations may be affected by changes in the composition of the community which are external to the individual contributor. This paper considers how (1) the availability of existing applications, (2) signaling among free contributors, and (3) competition from commercial complementers influences how free complementers release updates. The analysis shows that increasing the availability of existing complementers, leads to a decline in free contributions. When free complementers signal and promote themselves to the community, other members of the community are likely to increase their contributions. When facing competition from commercial complementers, voluntary contributors increase their contribution levels. Given the importance of attracting highly innovative complements in platform markets (Bayus, 2012; Boudreau, 2010; Corts &

Lederman, 2009), this finding is particularly salient for technology platforms attempting to attract and foster contributor innovation.

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How commercial competition and signaling influence crowding out in complementer communities

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Introduction

The availability of third-party complements is an important determinant of commercial success for technology platforms (Dube et al., 2010; Corts and Lederman, 2009; Clements and Ohashi, 2005; Cennamo and Santalo, orth; Zhu and Iansiti, 2012). The earliest technological platforms sourced complements from a few choice partners through precise and deliberate contracts (Bresnahan and Greenstein, 1999). Later platforms, allowed unaffiliated third parties to contribute and develop complements (Boudreau, 2010). By making the platform accessible to all interested parties, communities of hobbyists, lead users and technology enthusiasts emerged around the platform (Lakhani and von Hippel, 2003). Increasingly platforms try to actively foster the creation and growth of such communities, as a way of generating 'costless complements'. Perhaps the pre-eminent example of this is the ongoing battle between the Apple and Android to build up communities of complementers on their respective platforms. However, attracting large numbers of complementers may have unintended outcomes (Boudreau, 2012). Understanding what conditions affect contributor behavior is extremely salient for technology platforms.

Communities have attracted much recent academic interest, in particular for their importance as a source of complementary innovations (Bayus, 2012; Faraj et al., 2011; von Hippel, 2005). Since contributions by the community constitute complementary innovations for the platform, the terms complementer and contributor are used interchangeably. The motivation to contribute to a community has been extensively studied (Von Krogh et al., 2012; von Hippel and von Krogh, 2003). Participating in a community often serves as an avenue for individuals to signal their abilities (Lerner and Tirole, 2002) or gain recognition (Ghosh, 2005). Contributing to a community may be part of a broader commercial strategy (Dahlander and Magnusson, 2008; Fosfuri et al., 2008; Porter and Donthu, 2008). At the same time individuals may contribute out of some intrinsic motivations (Von Krogh et al., 2012). Over time, conditions within the community are likely to change and evolve. Individual needs may be met by existing complements, and the scope to gainfully contribute may narrow (Boudreau, 2012; Shah, 2006). Moreover, stronger identities are likely to form within the community, leading to stronger norms, governance structures and prescribed behaviors within the community (OMahony and Ferraro, 2007; Hertel et al., 2003). Some developers may see their participation in the com-

munity as a way of pursuing ulterior goals (Mollick, 2005). Others may begin commercializing their contributions to profit from them directly (Baldwin et al., 2006; Shah and Tripsas, 2007). These developments lead to changes in the community that are likely to impact contributor behavior. While such developments have been previously studied, their influence on how individuals contribute is far from understood. In particular, this paper focuses on how (1) contributions by others to the community, (2) signaling behavior within the community and (3) competition from commercial complementers, affect the propensity of individuals to contribute.

This paper studies the Jailbreak marketplace for mobile applications - a community that began as hackers and enthusiasts set about modifying their Apple iPhones. The jailbreak marketplace hosts a community of both free and commercial complementers, actively innovating and developing new applications. This community has been the source of some of the most important innovations on the platform (Wortham, 2010). Much of the Jailbreaking activity was driven by functional and geographic limitations imposed by Apple on the official marketplace. This includes not allowing users to modify the appearance of their devices, or change key localization settings. The jailbreak marketplace hosts primarily free applications that enable this type of functionality. The majority of complementers releasing free applications contribute in anonymity, while others are visible and actively signal to the community. At the same time, a small group of developers charge for their applications. Those charging for applications are classified as commercial complementers.

While commercial complementers may be an important source of contributions within the community, this paper focuses on the contributions of free developers. The motivation for this is twofold: First (1), individuals that freely contribute are an important source of many innovations and supply important inputs to the community (Lakhani and von Hippel, 2003; OMahony and Lakhani, 2011; Shah, 2006). Moreover, understanding how free contributions are affected has implications for innovation in a wide range of community settings (Bayus, 2012; Porter and Donthu, 2008). Second (2), the motivations of contributors and the identities formed within communities have received considerable attention (Bagozzi and Dholakia, 2006; Fosfuri et al., 2011; Hertel et al., 2003; Lakhani and Wolf, 2003; Osterloh and Rota, 2007; Zhang and Zhu, 2011). Some of this literature has considered how the

motivation of individual contributors can change and evolve (Shah, 2006). However, extant literature has not considered how they can be impacted by changes in the community. Since free complementers are most sensitive to changes in motivation and identity, they are the focus of this study.

The first part of this paper aims to understand how free complementers in a community affect each other. As the jailbreak phenomenon gained traction, many developers entered into the community and began releasing free applications. Studies in analogous contexts have found that as the pool of available applications grows, individual contributors are crowded out (Boudreau, 2012; Boudreau and Jeppesen, 2011). In line with earlier work, this paper finds that as more free applications become available in the marketplace, individual contributions decline.

As a further step, this paper looks at how signaling within the community affects contributor behavior. Numerous studies have noted that free contributors often use their free applications to make themselves highly visible and to signal their abilities (Ghosh, 2005; Lerner and Tirole, 2002; Roberts et al., 2006; Zhang and Zhu, 2011). However, this does not apply to the entire community. Most complementers contribute in virtual anonymity. When highly visible complementers contribute, they send a signal to other members of the community. Signals about the contributions of others have the potential to greatly influence behavior (Chen et al., 2010; Shang and Croson, 2009). This paper finds that when highly visible complementers contribute, other community members are likely to follow suit and contribute themselves. Finally, this paper looks at the competitive interactions between free and commercial compelementers within the same community. As the development of software applications for the jailbreak marketplace became economically viable, the community started to attract commercial entrepreneurs. This meant that developers of free complements faced increasing competition from commercial alternatives. These two types of complementers behave in very differently. Free complementers actively contribute to a 'pool' of publically available applications, while commercial developers release software that is commercial, proprietary and a competing alternative to the pool of publically available software. This leads to the creation of distinct identities between free and commercial complementers, and a reinforcement of norms and behaviors within the group (Goette et al., 2012). By analyzing how changes in the intensity of commercial competition affect behavior, this paper finds

that commercial competition leads to an increase in free contributions.

This paper makes several contributions to the literature: First (1), much of the literature on communities has focused on individual motivations and community identity. This paper, shows how developments in the community (existing contributions, signaling and commercial competition) can also influence individual behavior. Second (2), while much of the literature has highlighted how signaling is commonplace among free contributors. How this impacts other members of the community has not been considered. This paper begins to shed light on this by finding that signaling can in fact spur other individuals to contribute. Finally (3), technology platforms actively try attract complementers, and foster an optimal mix of complements. While the intuition may be that commercial alternatives pose a challenge to free complementers, this paper finds that commercial competition can in-fact bolster contributions from free complementers. This has broad implications for communities in a wide range of industrial settings and the technology platforms which seek to foster them.

Theory & Hypothesis

Individuals may freely contribute out of many motivations (Von Krogh et al., 2012). These motivations seldom occur in isolation (Roberts et al., 2006; Lakhani and Wolf, 2003). Often, contributors are motivated at least in part by pro-social orientation towards other members of the community (Zhang and Zhu, 2011; Bowles and Gintis, 1998). As a result, these individuals often freely contribute, building up a public good for the rest of the community (Bessen and Hunt, 2007; von Hippel and von Krogh, 2003). These public goods contributors share a common identity with other members of the community. Sharing a common identity influence individual motivations and behavior (Akerlof and Kranton, 2000, 2005; Tajfel and Turner, 1985; Fosfuri et al., 2011). Individuals are likely to exert more pro-social orientation towards individuals with which they identify (Goette et al., 2012). Moreover, a common identity among individuals brings with it informal governance structures and a reinforcement of norms and prescribed behaviors (Goette et al., 2012; Porter and Donthu, 2008). These norms and behaviors are often unwritten and embodied by prominent members of the community (Fosfuri et al., 2011).

Crowding Between Free Contributors. Contributors often identify with each other ans see themselves as members of a common group (Fosfuri et al., 2011; Kramer and Brewer, 1984; Ren et al., 2007; Porter and Donthu, 2008; Bagozzi and Dholakia, 2006). Many contributors have pro-social motivations and are motivated to contribute for the benefits of other members of the group (Bowles and Gintis, 1998). This is common in a wide variety of 'digital' contexts (Zhang and Zhu, 2011; Chen et al., 2010; Von Krogh et al., 2012). Both theoretical and empirical findings suggest that pro-social contributions tend to decline as the size of the public good grows (Andreoni, 1990; Roberts, 1984). Put another way, individuals are less likely to contribute to the pool of publically available software if others have contributed in the past. Empirical papers looking at the development of software complements tend to find similar outcomes (Boudreau, 2012; Boudreau and Jeppesen, 2011). This suggests as the availability of software complements increases, individual developers are less likely to contribute.

An alternative scenario could be that as the pool of available complements increases, it becomes more difficult to 'find a gap' to make a novel contribution (Boudreau and Jeppesen, 2011). As the 'frontier' advances and applications become more complex, individuals must master a greater range of complex skills to make novel contributions (Jones, 2008). Alternatively, as the availability of existing applications increases, the needs of most community members are met and contributions decline (Shah, 2006). Irrespective, of the underlying mechanism all of these possible explanations suggests that as the availability of software applications increases, individual contributions are likely to decline.

Hyp 1 *The greater the pool of available complementers, the lower the contribution level of free complementers.*

Signaling Among Free Contributors. Most complementers contribute in virtual anonymity, under the cloak of pseudonyms and virtual personas. Some actively disseminate information about their real identities and make themselves visible to the community. Those that do, often do so in pursuit of some ulterior motivation (Jeppesen and Frederiksen, 2006; Lerner and Tirole, 2002). Regardless, such contributors often have a prominent role in the community, and make impactful contributions (Roberts et al., 2006). At the same time, these contributors are

more visible than the rest of the community (Ye and Kishida, 2003). Often these contributors are exemplars of the community, and their contributions prescribe behavior for other contributors (Fosfuri et al., 2011).With every contribution, these individuals send information to the rest of the community, signaling how community members should contribute.

Information about individual contributions sends important signals to the rest of the community (Shang and Croson, 2009). This may occur in different ways. First, social information about other contributors may provide a signal about the quality what they are contributing to (Vesterlund, 2003). It may allow for direct comparisons between the contributions of others and one's own (Charness et al., 2006; Chen et al., 2010; Turner, 1978; Frey and Meier, 2004). Social comparisons may have important behavioral implications. If others have contributed more, individuals are likely to increase their own efforts (Chen et al., 2010; Shang and Croson, 2009). It may also reinforce the norms and expected level of contribution within the community (Goette et al., 2006).

Hyp 2 *The greater the level of contributions made by visible complementers, the greater the contribution level of free complementers.*

Commercial Competition and Free Contributors. Numerous studies have shown that the presence of competition from outside of a contributor group has the capacity to alter contributor behavior (Duggan, 2002; Goette et al., 2012; Gruber and Simon, 2008; Isaac and Walker, 1994). In the case of free contributors, commercial competition is likely to forment a stronger identity and reaffirm the norms and behaviors within the group (Goette et al., 2006). While the distinction between commercial and free contributors may be minute and a consequence of framing, it has the potential to greatly influence how contributors behave (Charness et al., 2006). In particular, stronger identity can lead to increase pro-social behaviors towards other members of the community. This implies that as commercial complementers enter the jailbreak community, free complementers are likely to increase their contributions.

Hyp 3 *The greater the level of competition from commercial complementers, the greater the level of contributions by free complementers.*

Research Setting and Approach

The rapid growth of the smartphone industry in recent years has led to the creation of highly dynamic markets on individual platforms. The Apple iOs platform (consisting of iPhone, iPad iPod Devices) is by and large the most commercially successful of these smartphone platforms. By Apples own estimates, the platform now offers over 800K apps (complements to the platform) and involves over 290K individuals. However, when the first Apple devices were released the platform was completely closed to third party development. At the same time, these initial devices were limited in their functionality and lacked established features such as video recording or customizable ring-tones. To utilize the full potential of their devices, a community of developers set about hacking (or jailbreaking) their phones and developing customized applications for their own needs. The availability of applications grew so rapidly, that before long a jailbreak marketplace (effectively a storefront for jailbreak applications) was created, where developers could sell their applications instead of simply releasing them for free. While Apple's creation of the AppStore enabled some developers to move off of the underground community and onto the official platform sanctioned marketplace, many continued to contribute within the underground community (Mollick, 2011).

The Jailbreak marketplace (Cydia) is automatically available on all devices once they are jailbroken (hacked). Estimate suggest that a sizable proportion of iPhones released have been jailbroken and have access to Cydia [1]. Cydia allows iPhone owners to search for, download and install applications to their devices from any of the major repositories. By hosting their files on these repositories developers make their applications available to all users with hacked devices. Applications can be made available for free or sold through the platform. Developers are limited in their ability to commercialize their applications. While the official marketplace facilitates a wide range of monetization models (freemium, advertising, using the application

[1]Statistics on the proportion of jailbroken devices are difficult to obtain due to the lack of coordination between the community and the hardware manufacturer. In 2009 estimates suggested that almost 9% of all iPhones were jailbroken (http://theapplebites.com/8-43-of-iphone-users-jailbroken/. In 2012, over about 35% of all Apple devices in china , the second largest application marketplace for iDevices, were jailbroken (http://technode.com/2011/05/03/around-35-percent-of-ios-devices-in-china-are-jailbroken-umeng-report/).

to sell a complementary product), jailbreak developers are limited in their ability to commercialize their software. Developers can only earn from their applications through direct sales, otherwise they are forced to release for free and do not have access to other revenue streams such as advertising. As a result, those that charge for applications classified as commercial complementers, while those that do not charge are classified as free.

Most complementers on the platform (commercial or free) are anonymous identified by a pseudonym or a twitter tag. Many of the applications they release go virtually un-noticed by the rest of the community.Only, a small subset of the community creates profiles and actively disseminates information about themselves and their applications to the rest of the community. Their motivation for doing so may be varied, as has been discussed. However, when these complementers innovate and release new updates their updates are publicized on the platform, and the community is made aware of the new releases. Developers that make the active choice to promote themselves and create a profile on the platform, are classified as 'visible'. The release of updates by visible developers sends signals to the rest of the developer community, which can potentially influence their own decision to update.

The Jailbreak context provides a unique context where it is possible to observe the full population of applications in a marketplace, both free and commercial. At the same time, the marketplace is centralized around a single outlet /storefront (Cydia). On the storefront it is possible to observe the full group of developers that make a profile and actively promote themselves. This makes it possible to identify the free complementers whose updates and applications are clearly visible. Within the jailbreak marketplace, it is also possible to identify the individual developers. This makes it possible to see if the developer has ever charged for an application, or created a profile on the storefront. Since many developers that are promoting themselves are attempting to profit indirectly from the complements that they release, only those developers that do not charge and do not have profiles are classified as free.

Econometric Approach and Measures

Individual developers may have released multiple applications in different genres within the community. The challenge within this setting is that they may be facing

different degrees of competition and signaling within each of those communities. This makes it difficult to directly replicate methodology of analogous papers (Aghion et al., 2005; Blundell et al., 1995, 1999; Boudreau, 2012). To overcome this problem, this paper draws inspiration from the approach of Santalo and Becerra (2008). Each application (j) created by a given complementer (i) is weighted by (ω) based on their downloads in a given period (t). [2]

In this study, software updates are used as a proxy for individual contributions. Software updates constitute a major portion of the innovation occurring in software industries (Ghose and Sundararajan, 2005). Releasing new versions of existing products is a prominent strategy the software industry (Ellison and Fudenberg, 2000; Giarratana and Fosfuri, 2007; Sankaranarayanan, 2007). Boudreau (2012) uses a count of application updates to measure innovative behavior in the application marketplace for Palm devices. A similar variable is constructed in this study. An important caveat to consider is that in many software industries, updates may be used as 'bug fixes' to correct for problems in the original software (Arora et al., 2006; Ghose and Sundararajan, 2005). This does not constitute and innovation, and perhaps signifies that the application is of lower quality. This paper distinguishes between 'major updates' and smaller bug-fixes or patches based on the version number of the application.

The **response variable** used in the analysis, number of major updates released by a complementer is calculated in follows.

$$Updates_{i,t} = \sum_{j=1}^{J} \omega_{j,i,t} N_{Updates j,i,t}$$

The econometric model draws inspiration from prior studies of competition and innovation (Aghion et al., 2005; Blundell et al., 1995, 1999). The measures and instruments used also draw considerably from recent studies of analogous contexts (Boudreau, 2012; Boudreau and Jeppesen, 2011; Zhang and Zhu, 2011). The basic model used in this study is as follows:

$$Updates_{i,t} = \alpha_i + X_{i,t}\beta + T_{i,t} + G_{i,t} + \xi_{i,t}$$

Where $T_{i,t}$ is a vector of dummies capturing the periods in which the updates

[2]The weighting for a particular app is defined as: $\omega_{(j,t)} = \frac{NDownloads_{j,t}}{\sum_{j=1}^{J} NDownloads_{j,t}}$

were released, $G_{i,t}$ is a vector of dummies capturing the genres in which the compelementer is present and $\xi_{(i,t)}$ captures the specific residuals. $X_{(i,t)}$ is a vector of the main explanatory variables: the number of free applications, number of visible updates and intensity of competition from commercial complementers, and control variables for the popularity of the application and developer. Fixed effects at the developer level are included in the analysis to control for unobserved heterogeneity across developers. This is especially important, since some developers never release any updates.

The **number of free applications** reflects how many free applications have been released within the same category. Counts have are often used to measure market dynamics in unconventional settings (Boudreau, 2012; Busse and Rysman, 2004; Santalo and Becerra, 2008; Thomas and Weigelt, 2000). Moreover, counts are commonly used in studies where individuals freely contribute (Andreoni, 2007; Zhang and Zhu, 2011).

$$NFreeApps_{i,t} = \sum_{j=1}^{J} \omega_{j,i,t} \frac{N_{j,i,t}}{N_{j,i,0}}$$

Where $N_{j,i,t}$ is a count of the free applications within the same category as application j during period t. $N_{j,i,0}$ is count of the number of free applications, one period before the panel begins. By constructing the variable in this way, it is possible to ensure that the scale of different categories does not bias the analysis while capturing changes in the size of the contributor group over time. In later models, the number of visible updates and intensity of commercial competition are included.

The **Update Signals** variable captures the extent to which highly visible developers release updates, within the same genres as a complementers own applications. Visible developers are those that create profiles and are highly noticeable on the platform. The empirical context makes it possible to cleanly distinguish the developers that create profiles and make themselves visible to the community. The rest of the community contributes in virtual anonymity. As has already been argued, these behavior of these highly visible complementers send a signal to the rest of the community. However, to capture this empirically requires that the signal and contribution be somehow linked (Martin and Randal, 2008; Chen et al., 2010). For

that reason, the highly visible updates are likely to influence the updating behavior of other contributors.

$$UpdateSignals_{i,t} = \sum_{j=1}^{J} \omega_{j,i,t} N_{VisibleUpdates\,j,i,t}$$

Where $N_{VisibleUpdates\,j,i,t}$ is a count of updates released by visible members of the jailbreak community within the same category as application j.

To measure the intensity of competition from commercial complementers a herfindahl style index is used again weighted by the relative importance of the application for the developer ($\omega_{j,i,t}$). Only the market shares of commercial complementers are considered in this variable. The market share of only paid applications is used in this calculation ($MSComerc_{j,i,t}$).

$$CommercComp_{i,t} = \sum_{j=1}^{J} \omega_{i,j,t} (MSComerc_{j,i,t})^2,$$

$$\text{where } MSComerc_{j,i,t} = \sum_{p=1}^{P} {}_{j,t} \frac{NDownloads_{p,t}}{\sum_{p=1}^{P_{j,t}} NDownloads_{p,t}}$$

Where $P_{j,t}$ identifies the paid applications that are in the same genre as application j in period t. The intention behind this measure is not to quantify the intensity of competition between commercial firms, but rather to capture the market power which commercial firms within those industries. As a result, a higher index signifies that commercial firms command a greater share of downloads within those categories that the developer is active in.

Instrumentation Approach

The challenge in estimating any relationship between competition and innovation is that the two are mutually endogenous (Aghion et al., 2005). To correct for this requires an instrument that influences the likelihood that individuals will enter the market, but not their propensity to innovate once they have entered. Within this specific context, this requires instruments that affect developer entry into the marketplace but not their likelihood of releasing updates afterwards. Various factors affect the propensity of developers to join the platform including the user-base popularity of the platform, the availability of infrastructure to facilitate the use of

the platform and changes in the platform itself. However, while these factors may influence the entry of developers onto the platform, they are unlikely to change the conditions of developers that have already entered and are releasing updates. Individual instruments and the motivation for their use are discussed at length.

iOs mobile devices use both mobile telephony and broadband services. Mobile broadband (mobile internet or data services) are particularly important for iOs devices since mobile applications, jailbreak tools and the Cydia marketplace runs via the internet. In fact, most mobile data traffic consumed in the US comes from apple devices. The growth of the smartphone market and mobile data traffic seem to go hand in hand. As broadband access increases, so does the base of users that can access the marketplace via the internet on their devices and download applications. This growth in the user base attracts developers, but at the same time exposes the devices to a larger population of potential user innovators. Given that from anecdotal evidence it is clear that most developers joined the platform as user innovators, an expansion of the user base can potentially open the platform to many new developers. However, once these developers have entered the platform, the growth of mobile internet is unlikely to affect how they behave. A further consideration is that the devices are differently affected by the presence of broadband penetration. For example, iPads do not have any calling functionality, so they are more susceptible to broadband internet penetration. To account for this, the penetration of broadband internet is weighted by the proportion of iDevices that are exclusively for iPad and iPhone devices.

While the platform hardware only utilizes mobile internet, most of the development is carried out off of the platform in online communities. The tools and techniques for developers to begin contributing are all available freely on the internet. As a result, the availability of internet access directly determines the ability of individuals to gain access to the tools to create and disseminate applications. Boudreau and Jeppesen (2011) use a similar instrument to control for the effects of increasing internet penetration in the US and UK on the use of multi-player video games. But unlike the period which they study, it may seem that there is little appreciable change in wired-internet penetration during the period analyzed here. In many countries where Apple did not have an official presence, the App-Store was not available (usually developing countries). At the same time, there

were no localization settings for those markets (there were no local languages, etc.). Only through the jailbreak platform, could these developers in other (non-platform sanctioned) countries develop applications and use them. As a result, the growth of wired broadband internet in developing countries is likely to impact the entry of developers onto the jailbreak platform.

Given that the jailbreak marketplace was unsanctioned by the platform, with every new hardware or operating system release the platform actively sought to 'shut down' the jailbreak marketplace. When new hacks were released, enabling the development of jailbreak applications on new devices and operating systems, developers had the potential to develop more applications and utilize the full potential of the new hardware. At the same time, with each new release the official operating system or hardware would incorporate functionality previously available only through jailbreak. These exogenous changes in the jailbreak marketplace affect the entry behavior of complementers. To instrument these policy changes a Mundlack style instrument (Mundlak, 1996) is used based on when new enabling 'hacks' were released on the platform.

Data and Sample

The data used in this study was assembled from several sources. Data on the individual applications, their features, creators and performance histories were extracted from the repositories which host these files on the internet. Data on updates was assembled by a third party website that aggregates information on updates of all jailbreak applications and was downloaded from that site for use in this research. Only data from the largest repositories was used (ZodTTD, BigBoss, TeleshoreoTangello and ModMyi). There are many minor repositories however they usually host only dozens of apps, as compared to the major repositories which host over ten thousand applications each. The distribution of applications across categories is highly skewed. Some have very few, while others contain thousands of applications. Within a particular category, they may have been only free software or both free and commercial software. There are no categories populated exclusively by commercial software applications. An application can only enter into a single category.

The sample observed captures 79 categories and runs over 24 months. While this

may not seem a long panel, over 23997 applications were launched, 6900 developers entered and 15689 updates were released during this period. Thus, while this may be a short time period, there was considerable entry and innovation in the marketplace. At the same time, this period was insulated from legal battles and other issues which plagued the jailbreak platform in its early days but were resolved by the beginning of the sample.

Results

Although many of the variables used are composites of several count measures, the weighing approach (Santalo and Becerra 2008) effectively converts them to continuous variables with a lower bound at zero. As a result, the main regressions (I to IV) are estimated using a linear regression. Given that the variables are not normally distributed, a GMM model is included as a robustness check. This also ensures that the results are not biased from autocorrelation or heteroskedasticity. Model I only includes, the measure of the number of available applications. Developer and Genre (group) fixed effects account for the propensities of individual developers to innovate and developer heterogeneity. As a further control, average monthly downloads at the developer and category levels are included. This is motivated by the fact that some developers may be more likely to innovate as their applications get more used and the genre grows in popularity. The negative coefficient and highly significant result suggests lends support for hypothesis I that increasing group size can have a negative effect on the propensity of individual developers to contribute. In model II, competition from commercial firms is included in the model. The positive coefficient suggests that as commercial firms gain more of a footing in the market, the community of free developers contribute more. In model III, the number of visible updates is included in the model. In models IV and V, the competition measure is added then instruments are applied. In model V, the 2Stage GMM estimator is used as a robustness check to ensure that the results are not biased by the distribution of the data. There is a notable increase in the coefficient of the commercial competition variable, when the instruments are introduced. Based on the correlations (See Table I) and variance inflation factors (VIF lower than 7 in all cases), it is unlikely that this is a result of correlation between the repressors.

Discussion

The first step of this paper is shedding light on how free complementers influence each other within a community. In line with recent findings (Boudreau, 2012; Boudreau and Jeppesen, 2011), this paper finds that individuals are less likely to update as the pool of available applications increases. Unlike earlier studies, this paper is able to distinguish the developers that promote themselves, from those that don't. While this paper does not attempt to identify or assume specific motivations, those visible in the community are likely to be those garnering some form of extrinsic benefit (Ye and Kishida, 2003). Given that the sample only considers those developers that do not promote themselves, the negative relationship found in this paper falls in line with both theoretical and empirical priors on why individuals freely contribute (Andreoni, 1990, 2007; Isaac and Walker, 1988, 1994; Roberts et al., 2006; Zhang and Zhu, 2011). While this finding may seem intuitive given the rich body of prior research on the topic, much of the literature why individuals contribute within communities has treated these motivations as static and dependent on the individual. However, this result builds on a recent string of results (Boudreau, 2012; Zhang and Zhu, 2011) which show that free contributors are affected by other members of the community.

While the first result confirms other recent findings, the latter two have been unstudied. While much of the literature on communities has highlighted the importance of individuals that signal within the community, what effect this has on the community has not been discussed. The second finding (in support for Hyp 2) is that highly prominent and visible members of the community release updates, the other free contributors are more likely to follow suit and release updates themselves. While information and signals as potential motivators has attracted attention in other contexts (Chen et al., 2010; Shang and Croson, 2009), this paper considers how signals originating within a community can affect the behavior within that community. While prior studies have shown that these prominent individuals may make important contributions to a community (Roberts et al., 2006; Ye and Kishida, 2003), this finding also suggests that they provide signals to the community spurring other members of the community to contribute as well.

The final component of the analysis looks at how free complementers within the community respond to commercial competitors. Literature on groups of public

goods contributors suggests that competition from outside the group may forment a stronger group identity (Goette et al., 2012). Identity is a central tenet of many communities and has can greatly influence the behavior of community members (Fosfuri et al., 2011; Hertel et al., 2003). Moreover, group identity can reinforce norms and lead individuals to alter how and how much they contribute. However, whether this plays out in a community setting hasn't been tested. Much of the literature on communities implicitly assumes away or disregards the issue that free contributors are affected by competition. However, this study shows (in line with Hyp 3) that free contributors are in fact affected by commercial competition. While communities may provide useful inputs for commercial firms, this finding suggests that commercial entities may have a more important role in motivating contributions to a community. As anecdotal evidence suggests (Lakhani and Wolf, 2003; Mollick, 2005), the tension between free and commercial developers may be a critical motivator of free contributions.

To date, most studies looking at competition and contributor groups, or signaling have been experimental. The lack of empirical analysis of real-world contexts may be attributed to difficulty in capturing the entire population of community members, their signaling behavior and commercial competitors in a particular setting. Being able to capture all of these dimensions affords considerable benefits. Studying such dynamics in an experimental setting can lead to different outcomes than when observing real-world groups, due to the challenge of fostering an actual identity within an experimental setting (Goette et al., 2012). At the same time, individual preferences ultimately affect the sorting process and the groups that individuals choose to join. As a result individual participation in a real world setting is much more in line with their own preferences (Lazear et al., 2012). This is particularly salient in digital contexts, where individual behavior and participation are almost exclusively influenced by preferences (Belenzon and Schankerman, 2008; Van Alstyne and Brynjolfsson, 2005). While extant research provides highly valuable insights on how other contributors, commercial competition and signaling affect individuals, this paper analyzes how these dynamics occur in an actual community of contributors.

Conclusion

This paper studies how free and commercial complementers affect each other on platform based communities. The availability of existing applications (the size of the pool of publically available software), signaling and competition from commercial alternatives have received considerable attention in the literature. However, this paper takes a further step, by considering how these factors affect contributions within a community. While previous literature has identified the importance of free complementers, this paper shows that contributions by free complementers increase as a result of commercial competition. Moreover, visible updates by prominent members of the community send a positive signal to other free complementers and lead to an increase in contributions. This has implications for a wide variety of platforms attempting to attract platforms and sustain a community generating 'costless contributions'.

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Table 1: Summary Statistics

	Mean	**Std. Dev.**	$Updates_{i,t}$	$Nfree._{i,t}$	$PaidComp_{i,t}$	$Upd.Sig._{i,t}$	$AppDL_{i,t}$	$GenreDL_{i,t}$	$BBand(iPhone)_{i,t}$	$BBand(iPad)_{i,t}$	$InternetGrowth_{i,t}$
$Updates_{i,t}$	0.02	0.17	1								
$Nfree._{i,t}$	9.7404	53.53	0.00	1							
$PaidComp_{i,t}$	0.0001	0.00	0.07	-0.02	1						
$Upd.Sig._{i,t}$	0.0251	0.15	0.10	-0.02	0.26	1					
$AppDL_{i,t}$	44.4792	837.59	0.02	0.00	0.00	0.00	1				
$GenreDL_{i,t}$	8.3506	3.94	-0.04	-0.07	-0.11	-0.09	-0.05	1			
$BBand(iPhone)_{i,t}$	2.9926	6.17	0.08	-0.03	0.03	0.02	0.01	-0.03	1		
$BBand(iPad)_{i,t}$	0.6751	3.79	0.05	0.02	0.04	0.05	0.00	-0.04	0.13	1	
$InternetGrowth_{i,t}$	7.8495	4.64	-0.03	0.06	-0.03	0.03	0.00	0.01	-0.21	-0.03	1
$JBShocks_{i,t}$	1.091	0.47	-0.04	0.07	-0.05	0.04	-0.01	0.00	-0.38	-0.07	0.67

Table 2: Main Results Table

$Udpates_{i,t}$	(I) (OLS)	(II) (OLS)	(III) (OLS)	(IV) (2SLS)	(V) (2S GMM)
$Nfreeapps_{i,t}$	-0.001***	-0.001***	-0.001***	-0.009***	-0.009***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
$PaidComp_{i,t}$		9.611***	9.212***	125.956***	167.885***
		(2.322)	(2.328)	(37.783)	(31.451)
$UpdateSignals_{i,t}$			0.041***	0.025***	0.020**
			(0.007)	(0.009)	(0.009)
$AppDL_{i,t}$	0.000***	0.000***	0.000***	0.000*	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$GenreDL_{i,t}$	0.007***	0.007***	0.007***	0.003	0.005**
	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)
Section Dummies	Yes	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes	Yes
Developer FE	Yes	Yes	Yes	Yes	Yes
N	234427	234427	234427	234427	234427
log likelihood	131038.668	131092.154	131172.519	80392.006	76741.717