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WELCOME CONTRIBUTOR OR NO PRICE COMPETITOR? THE COMPETITIVE INTERACTION OF FREE AND PRICED TECHNOLOGIES

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The existence of free technologies is prevalent in a variety of industries from software to design. This study examines the competitive interaction between free and priced technologies. I draw on the literature on economic logics to predict that, in general, technologies that are freely shared are likely to stimulate interest and provide useful market information without directly competing with priced technologies. In contrast, due to direct competition, I predict that the prevalence of priced technologies will decrease the sales of other priced technologies. I find support for these hypotheses using a sample of more than 1 million transactions in over 200 distinct markets for MobileApps for the Palm computing platform. This study highlights how free technologies can be utilized to enhance performance of commercial producers.

INTRODUCTION

Scholarly work on product market formation has largely focused on the study of priced products that are distributed by commercial producers (Agarwal, Sarkar, and Echambadi, 2002; Hargadon and Sutton, 1997; Utterback and Abernathy, 1975). However, in some contexts, technologies and products are made available for free for a variety of reasons such as when they are part of an explicit marketing strategy by a commercial producer, or when they are introduced by noncommercial technologists (Lakhani and Wolf, 2005). In this paper, I postulate that priced and free technologies influence the performance of producers seeking economic gain from goods and services in very different ways. Specifically, I hypothesize that the sales of products introduced for a price will be greater in markets where similar technologies are given away for free, and lower in markets where greater numbers of commercial competitors provide their technologies for a price. This contrasts with the intuitive prediction that the introduction of free technologies serving the same role as a focal product will decrease sales of that product.

I propose that this relationship between new technologies and market outcomes is understood when the different economic logics of commercial and noncommercial producers who each distribute both free and priced technologies are taken into account. The term *economic logic* refers to the concept that within given domains differences exist in how actors perceive value and these differences influence the actions that actors take (Friedland and Alford, 1991; Kaplan and Murrary, 2010). As I explain below, for different reasons both commercial and noncommercial producers who release free technologies typically release technologies that entice potential customers to search for a priced alterative. In contrast, when actors following either

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economic logic introduce priced technologies, they typically introduce technologies that are competitive with other priced technologies.

To test my predictions, I study the competitive interaction of more than 16,000 free and commercial programs—termed MobileApps—that were written for the Palm Handheld Computer and smartphone. These MobileApps were distributed online on an AppStore in more than 200 newly forming distinct high-technology markets for the Palm Platform, which spawned more than 1 million transactions. In the period of my study, considerable uncertainty existed regarding how best to utilize the technology, features that consumers might be interested in, and the extent of consumer demand. I treat MobileApps that can be downloaded and used without paying a fee as free technologies, and I treat MobileApps that must be purchased to be used as priced technologies. I examine the relationship between the public availability of free technologies and the sales of priced MobileApps, as well as the relationship between the prevalence of priced MobileApps and the adoption of specific free technologies.

This paper makes several important contributions. First, prior research and normative theory suggest that commercial producers use priced products introduced by other commercial firms to acquire information about both technology and market demand (Samson and Gurdon, 1993; Utterback, 1994). Indeed, a core claim of the second-mover strategy in commercial markets is that second movers can find information on both changing technology and market demand from observing commercial products introduced by earlier innovators (Levin *et al.,* 1987; Mitchell, 1989; Shamsie, Phelps, and Kuperman, 2004). Traditional studies such as those found in the product lifecycle literature typically focus on the competitive interaction between products introduced by first and second movers that are competing in the same market (Agarwal *et al.,* 2002; Tushman and Anderson, 1986). With this focus on priced products, an important question remains: whether and how free technologies may potentially influence this market process. This paper contributes to answering this question by theoretically and empirically integrating the free technologies into the product lifecycle literature.

Second, scholars have documented that buyers of products, in contrast to suppliers, are an important source of technological innovation (von Hippel, 1988; Shah, 2005). In the case of the Palm Pilot thousands of software developers—either as individuals or as members of organizations—wrote software that improved the value of the device for other users (Butter and Pogue, 2002). As has occurred in many contexts, some developers shared their software technology in the form of a priced product, while others shared their technology for free. As a result, I am able to contribute to the innovation literature by examining how free and priced technologies differentially influence the use of other priced and free technologies for the same device. This issue is also of practical as well as theoretical importance, given the growing incorporation of free technologies into commercial products such as Apple's desktop operating system (OS X).

Lastly, this paper contributes to the theoretical literature on opportunities in entrepreneurship that treats opportunities as an important unit of analysis. According to this literature, an important distinction is the difference between the development of technologies, and the exploitation of entrepreneurial opportunities (Eckhardt and Shane, 2003; Schumpeter, 1934). This literature proposes that the process under which technologies are produced is theorized to be fundamentally different from the process under which technologies become embodied in markets though products (Jewkes, Sawers, and Stillerman, 1958; Rosenberg and Nelson, 1994). This paper advances this literature by introducing and testing the theory that indicates that while the process under which noncommercial technologies is generated may be different from the commercialization process, that noncommercial technologies can directly influence the characteristics of commercial opportunities in a manner that has not been previously understood. Specifically, I find that the sales of commercial products are higher in markets where noncommercial alternatives are readily available when compared to market settings where noncommercial alternatives do not exist. Hence, it appears that noncommercial technologies may facilitate the formation of entrepreneurial opportunities.

THEORY AND HYPOTHESES

I follow Simon (1973) and define technology as a specific means that can be used to accomplish a specific end. This definition is similar to other definitions of the term that emphasize how knowledge

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is used to achieve specific outcomes. For example, dictionaries often define technology as the application of knowledge for practical ends (Urdang and Flexner, 1975). Novelty is typically not included in the definition, partly due to the fact that a known technology can often be used to achieve novel outcomes when applied to new contexts.

When commercial producers attempt to earn revenue from the practical application of a technology, they must resolve two specific problems of design to gain market acceptance and increase sales (Agarwal *et al.,* 2002; Clark, 1985; Winter, 1984). First, commercial producers must resolve uncertainty regarding what is technically feasible with a technology. Second, commercial producers must determine what improvements and features they should incorporate into products. Finding a specific path of improvement hinges on resolving uncertainty regarding the interactions between the features that consumers demand and what is known to be technically feasible. Arriving at solutions to these problems is an uncertain process fraught with errors, blind alleys, failed experiments, and surprise successes (Teece, 1996). For example, in this context, several entrepreneurs made significant investments in the development of mobile news services that ultimately failed to resolve the combined challenges of technical, organizational, and market making activities that would have enabled them to be successful.

Existing theories in strategy regarding how commercial producers successfully solve these two design problems emphasize that producers learn from information generated by commercial products introduced by producers and consumers (Abernathy and Utterback, 1978; Anderson and Tushman, 1990; Utterback and Abernathy, 1975). Through direct feedback as well as through shifts in purchasing patterns, producers learn which applications and features of specific technologies consumers prefer. Further, producers acquire knowledge regarding technical feasibility of potential features from the successes and failures of other commercial products as well from their own (Fleming, 2001). As producers innovate, they adopt technologies, product features, and business processes introduced by others that they perceive as being of interest to consumers. Hence, as consumers and commercial products interact in the market, they produce information that all producers respond to, and in doing so the market coalesces around a dominant design (Utterback, 1994).

In many contexts, technologies can be distributed for free, meaning consumers can acquire the technology without paying a price, and technologies can be priced, meaning consumers can acquire the technology only after paying for it. However, to date research has largely overlooked the potential for free technologies to produce information that may help commercial producers increase the sales of their products. Free technologies are likely to have important implications for theoretical models of drivers of firm performance in product markets, as well as for the management of technological innovation, for several reasons. First, research indicates that free technologies—including those released by competing commercial producers, hobbyists, independent innovators, and academic institutions—are important sources of technological innovation (Jewkes *et al.,* 1958; Klevorick *et al.,* 1995; Stebbins, 2007). Second, free technologies can potentially provide information to firms and entrepreneurs regarding the technological feasibility of specific applications of technology, as well as information regarding specific features that the market might demand. Third, the impact of free technologies on the market acceptance of individual commercial products may not necessarily be the same as that of products introduced by other producers.

Economic logics

To understand how the prevalence of free and priced technologies might influence the market adoption of technologies introduced by commercial producers, I consider the economic logics of the types of actors that introduce free and priced technologies. The term *economic logic* refers to the concept that within given domains differences exist in how actors perceive value and that these differences influence the actions that actors take (Friedland and Alford, 1991; Kaplan and Murrary, 2010). For example, an economic logic that is central to the strategy literature is that of the profit-seeking firm. However, as discussed above, many for-profit firms operate in domains that are occupied by organizational forms operating with economic logics different from the for-profit model.

In the context of software, research indicates that free and priced technologies are distributed by actors with commercial and noncommercial logics (von Hippel and von Krough, 2003; Lakhani and Wolf, 2005; Takeyama, 1994). Actors with a

	Distributed for free (Price = 0)	Distributed for a price (Price > 0)
Commercial	1 Indirect Profit Model	3 Direct Profit Model
Non commercial	2 No Revenue Model	4 Revenue Model

Figure 1. Economic logics in software

commercial logic are defined as commercial producers who are primarily motivated by profits. Actors with a noncommercial logic are defined as producers who are motivated to create and share technologies for reasons other than profits.

Scholars have noted that actors of each type of logic can introduce both free and priced technologies. This fosters four distinct conceptual models that are presented as a matrix in Figure 1. In an indirect profit model (cell 1), commercial producers may distribute products for free as part of a variety of for-profit strategies such as offering free trials to entice future purchases (Takeyama, 1994). In the no-revenue model (cell 2), noncommercial actors may also distribute technologies for free for a variety of reasons including as a means to enhance their reputation (Lerner and Tirole, 2005a), to help others who are working on a similar problem, or to contribute to the scientific commons (Lakhani and Wolf, 2005). In the direct profit model (cell 3) commercial actors earn profits by directly charging for products and services provided. Research also indicates that noncommercial actors may also charge a fee for technologies that they distribute. For example, Jackson Laboratories (JAX) is a nonprofit organization that was formed to develop and distribute mouse models to academic researchers. JAX charges fees to cover the costs of providing mice for experiments to researchers. However, as a nonprofit, they operate under a different economic logic from that of for-profit firms operating in the same domain (Murray, 2010). I refer to this final model as the revenue model (cell 4), as the goal is typically revenue, but not profits.

In the following sections I expand upon these economic logics to postulate that a different relationship will exist between counts of priced and free technologies and revenue earned by commercial technologies. I subsequently reverse my research question by examining how my theory relates to the relationship between the availability of innovations of each type and the adoption of free technologies.

Innovation and commercial performance

Priced technologies

Earlier I defined technology as a specific means that can be used to accomplish a specific end (Simon, 1973). In this context, a technology is a MobileApp for the Palm Handheld Computer, which is a program that enables the Palm device to perform a function. Priced technologies are defined as those technologies that must be paid for to be used. In many markets in this context, priced technologies may include MobileApps distributed by both commercial producers and noncommercial producers operating under the models shown in cells 3 and 4 of Figure 1.

Producers search to reduce uncertainty regarding the intersection between technical feasibility and the characteristics of customer demand (Fleming, 2001). Priced technologies provide the marketplace with information that reduces technical uncertainties and clarifies the characteristics of consumer demand. For interested customers, the availability of priced technologies in the marketplace provides opportunities to experiment with different implementations of the technology, to acquire information regarding the limitations and uses of the technology, and to discover which implementations best meet their specific needs. Similarly, producers can acquire knowledge regarding customer preferences via feedback from consumers who have used products in the marketplace (von Hippel, 1986). Producers may also integrate features that have been introduced by competitors into their own products. More generally, as demand coalesces around specific products, producers learn which products are most desired by the market (Utterback, 1994).

However, at the same time priced technologies provide information that reduces uncertainty they also harm the sales of a focal producer. This impact is likely to overwhelm the informative value of the competitors' technology, so that a negative relationship will exist between the number of competing commercial technologies and the sales of individual technologies. This effect will be likely to unfold for several reasons.

In the case of priced technologies that are distributed by actors operating under a commercial logic (cell 3 of Figure 1), the existence of competing products will decrease revenue of a focal producer due to direct competition when similar features are replicated across multiple products or through market fragmentation, which occurs when

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heterogeneity in product attributes splits demand among producers. This occurs in part because commercial producers have a strong incentive to search for product attributes that meet the needs of users and to deliver quickly products that successfully implement those attributes. Hence, while consumer purchases of a specific technological variant reduce uncertainties regarding which product attributes are important for consumers, demand for competitors' technologies represents lost sales for the focal firm. This is particularly problematic in that research indicates that acquiring customers from competing firms is typically more difficult than securing new customers who have yet to try any technologies within a specific domain (Carpenter and Nakamoto, 1989; Klemperer, 1995; Robinson and Fornell, 1985).

Second, firms may face difficulties in replicating the specific technological advancements of competitors. These difficulties may arise from a lack of absorptive capacity and from the learning curve advantages possessed by leading innovators (Cohen and Levinthal, 1990; Epple, Argote, and Devadas, 1991). In addition, commercial competitors are likely to utilize actively strategies to protect their intellectual property—such as litigation, patents, trade secrets, and standard switching—in order to inhibit the ability of competitors to profit from their innovations (Besen and Raskind, 1991; Gilbert and Newberry, 1982; Shapiro and Varian, 2003). Hence firms may find it difficult to profit quickly from the technological innovations of their competitors.

Priced technologies that are distributed by actors operating under a noncommercial logic (cell 4 of Figure 1) represent technologies that a noncommercial actor decided to price. The decision to price the technology by a noncommercial actor is likely to be driven in part by an expectation that pricing the technology will yield some revenue by meeting the needs of some group of consumers while also managing demand. The priced technology may be part of an explicit cost recovery strategy, or it may be part of a cost-shifting strategy, where the revenue from the priced technology may be used to subsidize another activity undertaken by the noncommercial actor. The priced technology may also be part of a demand management strategy, where the noncommercial actor charges a fee to reduce demand so that they will not be overwhelmed with the costs of providing a technology for free. In the case of software, the costs of providing support for free software can prompt noncommercial producers to begin charging for software.

Priced technologies introduced to a focal producer by noncommercial actors provide information that they can use to improve their product and hence potentially increase sales. However, as in the case of priced technologies introduced by commercial producers, demand for priced technologies introduced by noncommercial producers that have decided to price their technology represents lost sales for the focal producer. Hence, the existence of priced technologies introduced by noncommercial actors are also likely to be associated with decreased sales for an individual commercial product. These arguments lead to the first hypothesis.

Hypothesis 1: The greater the number of priced technologies available in the market, the lower will be revenue earned from an individual priced technology.

Free technologies

Information that is likely to inform market participants is not limited to information generated by priced products. An important source of innovation for entrepreneurs attempting to form markets for novel products consists of information about free technologies that are related to commercial technologies. Free technologies are defined as technologies that can be used without paying a fee. Free technologies may include MobileApps distributed by both commercial and noncommercial producers operating under the economic logics shown in cells 1 and 2 of Figure 1.

Free technologies have the potential to provide information that may help commercial producers reduce uncertainty regarding technological feasibility, the potential total market demand, and features that are likely to be of interest to consumers. I hypothesize that, in general, the information benefits of the free technologies will exceed the potential competitive effect that a free alternative may have on the marketplace.

In the case of free technologies that are distributed by actors operating under a noncommercial logic (cell 2 of Figure 1), the interests these technologists who freely share their technology typically reside in the technology itself, or in finding solutions to their own individual needs, rather than in meeting the needs of large groups of consumers (Basalla, 1988; Hagstrom, 1965). Hence, the characteristics of specific technologies generated by these individuals are generally most likely to represent the needs and interests of the individual who created the technology instead of the needs and interests of the typical end user. Further, because their interests are largely intrinsic to the specific problem they face, or to the technology itself, the direction of further innovation and refinements of the technology on the part of actors guided by the noncommercial logic are also more likely to be driven by their personal considerations than by the needs of the market. Therefore, free technologies that are introduced by actors following the noncommercial logic are less likely to continue to develop into full-fledged alternatives to products created by commercial producers.

Second, the personal interests of actors who have distributed software under the noncommercial logic render these individuals less likely to develop formalized support structures, feedback mechanisms, and organizations designed to meet the needs of end users for their technologies. While technologists may develop means of coordinating technological development with others (Shah, 2005), they themselves are less likely to provide organizational solutions to support the needs of other potential users.

Lastly, commercial producers are less likely to face intellectual property barriers when replicating technologies introduced by actors following the noncommercial logic. Many of these actors do not fully protect or defend their intellectual property due to disinclination or a lack of financial resources to invest in these defenses. In fact, actors following the noncommercial logic often take steps to facilitate the transfer of their commercial property to other parties (Lerner and Tirole, 2005b). Hence commercial producers are likely to be able to integrate what they have learned from these technologies into their products. This integration of knowledge acquired from free technologies with their commercial MobileApps is likely to enable them to secure higher sales by selling additional units.

As indicated in cell 1 of Figure 1, actors who follow the commercial logic may also release free technologies as part of a variety of indirect profit strategies including trial strategies (Takeyama, 1994) and advertising based business strategies (Varshney and Vetter, 2002). The shareware model in software is a commonly used indirect profit model. In this model commercial producers provide free software for a limited duration or with limited functionality, and subsequently charge if the customer wishes to use the software long-term (Takeyama, 1994). In the advertising model, users are provided with software and services for free, but usage is typically accompanied by a mixture of advertisements and features designed to track aspects of the user's behavior. In some cases the advertising model is combined with the shareware model, so that users can pay a fee to receive access to a version of the software that does not include advertisements.

In markets where actors who are following the commercial logic distribute their technologies for free, users are provided with more information about the technology and how it is used to meet a related set of needs than they are in markets where fewer indirect profit technologies exist. In addition, competitors are also provided with information that they can use to improve their offerings. Because indirect profit technologies are typically designed to entice users to convert to becoming a paid user in some manner, in part because they may include undesirable features such as advertisements, they encourage users to search the marketplace for an offering that will more fully meet their needs. While producers of specific indirect profit technologies hope that consumers will decide to upgrade to their full featured offering, in markets where increasing numbers of indirect profit technologies exist, consumers are likely to try several offerings before purchasing a specific priced technology. With each trial, consumers of indirect profit technologies do not represent a lost customer from the perspective of a commercial producer, because consumers are able to use indirect profit technologies without paying a fee. Hence, markets that contain greater counts of free technologies that are introduced by actors following either a commercial or noncommercial logic contain information that reduces uncertainty regarding the alignment between what is technically feasible, and the features that may interest consumers. In markets that lack free technologies, consumers have less information from which to navigate a decision to make a purchase, and commercial producers have less information to find an alignment between the technology and consumer demand. These arguments lead to the next hypothesis.

Hypothesis 2: The greater the number of free technologies available in the market, the greater will be revenue earned from an individual priced technology.

Innovation and the dissemination of free technologies

To further refine the theory, I also examine the relationship between the prevalence of priced and free technologies and downloads of related individual free technologies. An important question is whether the relationships proposed in Hypotheses 1 and 2 are the same as, or different, from those proposed when the dependent variable is switched to examine the acceptance of individual free technologies. My theory suggests that, while priced and free technologies help to reduce technological and demand uncertainties in newly forming markets, it is important to determine whether the information benefits of the introduction of a technological variant are outweighed by its competitive effects. Specifically, the existence of another technology may decrease the adoption of any specific technology. In Hypothesis 1, I argued that the competitive effects of priced technologies would dominate the informative effects, while in Hypothesis 2 I argued that the informative effects of free technologies would dominate the competitive effects—when examining the acceptance of commercial products. Similar to Hypotheses 1 and 2, as I explain below, when examining factors that influence the downloads of free technologies, I postulate that the competitive effect will dominate the uncertainty reducing effects in the case of priced technologies, but that the uncertainty reducing effects will dominate the competitive effects in the case of free technologies.

Priced technologies

As discussed above, actors following commercial and noncommercial economic logics introduce priced technologies. I postulate that for both logics, the greater the number of priced technologies available in the market, the lower will be downloads of individual free technologies. As I wrote above, actors following the commercial logic (cell 3 of Figure 1) have a strong incentive to search for product attributes that meet the needs of users and to deliver quickly products that successfully implement attributes that are desired by users in a way that delivers sufficient value such that users prefer to exchange money for the product. In contrast, producers of free technologies are not as strongly incentivized to create full-featured products that meet the needs of users. Hence, as the count of priced technologies increases in a product category, the likelihood increases that a priced technology will exist that will sufficiently meet the needs of users so that they are willing to purchase the product. Further, individuals who have purchased a priced technology are less likely to a need for a free offering as they have already made an investment in a priced technology.

Similarly, priced technologies introduced by noncommercial actors (cell 4 of Figure 1) represent technologies that noncommercial actors decided to price instead of distributing freely. As I write above, the decision to price the technology is likely to reflect an assessment either that the technology will yield revenue the noncommercial actor plans to use for a variety of purposes or, alternatively, that the technology was priced as a means to control demand. As the count of these priced technologies increases, it becomes increasingly likely that a consumer will find a priced technology that may meet their needs. Further, once an individual has purchased a priced technology provided by a noncommercial actor, it is less likely that they will continue to download free technologies. These arguments lead to the next hypothesis.

> *Hypothesis 3: The greater the number of priced technologies available in the market, the lower will be downloads of an individual free technology.*

Free technologies

As Figure 1 illustrates, free technologies are introduced by actors following both commercial (cell 1) and noncommercial (cell 2) logics. I argue that the greater the number of free technologies in a market, the lower will be the downloads of an individual free technology for both logics. Consistent with my theory developed above, actors following the commercial logic have a strong incentive to introduce technologies that meet the needs of users. In the case of technologies that are distributed with the intent of enticing potential customers to purchase the technology, producers have a strong incentive to build a product that will sufficiently meet the needs of users so that they will becoming paying customers. Commercial producers are similarly incentivized in advertising supported models, where they distribute products for free and earn revenue based on the number of consistent users of their products. Hence, in markets with greater counts of free technologies released by commercial producers, the competitive effect will dominate the information effect and

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hence lower the downloads of any individual free technology.

Markets with greater numbers of technologies released by actors are following a noncommercial economic logic also will be associated with fewer downloads of individual free technologies. According to my theory, noncommercial producers do not have the same incentive to produce technologies that will meet the needs of other users. Instead, noncommercial producers tend to share technologies that are most likely to represent the needs and interests of the individual who created the technology instead of the needs and interests of the typical end user. However, as the count of free technologies released by noncommercial producers increases, the likelihood increases that a free technology may meet the needs of other users better than a focal free technology. Hence, a similar relationship will hold between the number of free technologies released by noncommercial producers, and downloads of an individual free technology. These arguments lead to the final hypothesis.

Hypothesis 4: The greater the number of free technologies available in the market, the lower will be the downloads of an individual free technology.

METHODS AND MEASURES

Research strategy

To test the proposed hypotheses, I examine the interplay between free and commercial computer programs—termed MobileApps—that were designed to solve the same problems for the Palm Handheld Computer and Smartphone. These MobileApps were distributed online on an AppStore, where free software is made available to users and commercial software is provided to users only after they pay a fee. I treat each MobileApp as a technology, as a MobileApp is a program that enables the Palm device to perform a specific function.

This research setting has several important advantages. First, as software in the domain is grouped into categories, I am able to identify specific free technologies that relate to specific priced technologies. Second, outside of marketing strategies that I am able to explicitly control for, the free technologies I examine are just as easy to view and access in the marketplace as priced technologies. Hence, the free technologies have every opportunity to compete with priced offerings, which should yield a conservative test of the hypotheses. Third, because the computing platform that serves as the basis of this study did not exist before 1996, it is possible to identify the start dates for individual MobileApps and markets for the platform. This approach thereby avoids the biases that are inherent in retrospective samples that are constructed after markets have reached maturity (Agarwal and Bayus, 2004; Miner, 1993). To be precise, this study includes data on markets within the first month of existence as well as data on markets that never survive.

MobileApp markets for the Palm Handheld

The Palm Handheld Computer, which was originally released in 1996 as the U.S. Robotics Palm Connected Organizer, is widely recognized as a discontinuous technological breakthrough that created the consumer market for handheld computers (Barnett, 2000; Butter and Pogue, 2002). Unlike its less successful predecessors, where the emphasis had been on providing desktop functionality in a small handheld device, the Palm Computer was designed to provide rapid access to a limited amount of information quickly and inexpensively. To accomplish this objective, the computer utilized a completely new operating system, a special low-power microprocessor, a patented stylus-based input language, and only 128 kB of RAM. Hence, at the point of introduction it was an innovative device with a fundamentally unique technological approach.

While originally marketed as a calendar and a date book, the device was designed to incorporate additional programs, and the managers of Palm Computing invested heavily to encourage third-party developers to write MobileApps for the platform (Butter and Pogue, 2002). As occurred later with other mobile computers, such as Apple's iPhone, a community of programmers, entrepreneurs, hobbyists, and users quickly formed around the device (Butter and Pogue, 2002; Wortham, 2009).

Because it was an innovative product, the device's technical requirements were such that in most cases, developers were unable to modify easily existing software designed for other platforms for use on the new device. The platform

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fostered the need for novel approaches to address new technical and user requirements such as the development of procedures that minimized processing time to extend the battery life of the device, as well as tiny MobileApps to function within the limited RAM requirements. Further, the computer's small screen and stylus-based interface procedure required programmers to design new ways for users to interact with applications that had been designed for other platforms.

Shortly after the Palm was released, two Palm enthusiasts launched an AppStore—PalmGear.com—that rapidly evolved into the primary web location for both free and commercial MobileApps for the Palm device. The AppStore earned revenue by charging a commission on MobileApps purchased though the website. Further, to increase usage of the online store, MobileApps were available with no charge assessed either to software developers for posting them or to end users for downloading them. While modern MobileApp stores are designed to distribute software through cell phone networks, during the period of study this channel had not yet been developed. To install MobileApps on the Palm Device, users first downloaded the software from the Internet AppStore to a personal computer. They then installed the MobileApp using Palm Computing's HotSync™ technology or other technologies developed by third-party developers.

MobileApps listed on the AppStore were grouped into product categories by the function that each program provided to the end user. For example, the data contain the market category "Business & Finance: Calculators," which consists of 68 unique MobileApp packages such as the KK-12C Financial Calculator, APCalc, and NeoCal. Each of these MobileApps is a programmable calculator designed to facilitate the computation of problems that business professionals typically encounter. While imperfections exist in the AppStore's categorization scheme, in several ways it compares favorably to schemes that are commonly used to group related products in management research. The AppStore's scheme rapidly reflected innovation by dynamically grouping and creating software categories as market conditions changed. For example, the MobileApp market identified as "Wireless/Networking/Communications/Ringtones" was created following the introduction of mobile phones that utilized the Palm operating system. Further, the AppStore's classification scheme includes data on market categories that never develop into stable markets, thereby overcoming the sampling bias that is an important limitation of research on the innovation and entrepreneurship (Agarwal and Bayus, 2004; Miner, 1993).

I examine the relationship between the availability of free and priced technologies and downloads of MobileApps offered for a price and for free, using monthly transaction data from the AppStore from February 2004 to February 2007. I treat each MobileApp category as a discrete market, building statistics for each MobileApp and market as described in detail below. The unit of analysis for the statistical investigation is a MobileApp Month.

Dependent variables

Monthly Revenue is the dependent variable for Hypotheses 1 and 2. *Monthly Revenue* is computed as the natural log of revenue for each priced MobileApp per month. Priced MobileApps are defined as those MobileApps that require a payment for users to download and use. Trial versions of priced MobileApps with limited functionality that users can download without paying a fee are excluded from this measure as these downloads do not generate revenue for the seller. If a user downloads a trial version of a MobileApp and subsequently pays to upgrade to the full MobileApp, this transaction is counted as a commercial sale when the fee is paid.

Monthly Downloads is the dependent variable for Hypotheses 3 and 4. *Monthly Downloads* is computed as the natural log of downloads for each free MobileApp per month. Free MobileApps are defined as those MobileApps that can be downloaded and are fully functional without a requirement that a fee be paid. Trial versions of commercial MobileApps with limited functionality that users can download without paying a fee are included in this measure as these applications are available to users without paying a fee.

Hypothesized covariates

Priced MobileApps

The number of priced technologies in month m in market category c is hypothesized to be associated negatively with the *Monthly Revenue* for individual priced MobileApps for Hypothesis 1, and to be associated negatively with *Downloads* for

Hypothesis 3. The number of *Priced MobileApps* is computed as the total number of MobileApps that exist in a given month in the same market as the focal MobileApp that can be downloaded only if a fee is paid and that have been downloaded at least once in the prior 12 months.

Free MobileApps

The count of *Free MobileApps* at month *m* in market category *c* is hypothesized to be associated positively with *Monthly Revenue* for Hypothesis 2 and associated positively with free *Downloads* for Hypothesis 4. The number of *Free MobileApps* is computed as the total count of MobileApps in the same software market as the focal MobileApp that can be downloaded for free and that have been downloaded at least once in the prior 12 months. I include in this measure free MobileApps in which the underlying source code is available for download, as well as MobileApps in which only the binary is provided. Shareware MobileApps that users may download for free on a trial basis but must later remunerate a fee to continue to use are counted as free MobileApps as they can be downloaded and tried by users without paying a fee.

Control variables

I include several variables that are likely to influence the monthly revenue or downloads of individual MobileApps, such as marketing initiatives of the AppStore, specific characteristics of each MobileApp, and characteristics of each market, as well as time. In 2003, the AppStore deployed a technology that reduced the steps users had to take to download and install MobileApps. This technology was used by approximately 50 percent of the MobileApps in the sample. In the absence of this technology, proper installation of products required several steps on the part of the user. As a result, users may be more likely to prefer MobileApps for which this technology is available. Hence, the control for *Easy Download* is set to 1 if this technology is available for a specific software product and 0 otherwise.

I control for several important marketing initiatives. The managers of the AppStore attempt to influence sales by prominently displaying graphical advertisements for select MobileApps on the website's first page. These displays are click-through promotions, meaning that if a user clicks on the advertisement for the featured product, a webpage containing detailed product and ordering information will be displayed. If for any day in a month a MobileApp is featured on the website, the dummy variable *MobileApp Featured* is set to 1 and is coded 0 otherwise. Further, the AppStore publishes a list of MobileApps that the editors of the site believe all users of Palm Handheld devices should own. This list is displayed prominently on the AppStore. If for any day in a month a product is included on the essential product list, the dummy variable *MobileApp Listed* is set to 1, and is coded 0 otherwise. This variable varies over time. Also related to marketing, is that prior to the purchase of a MobileApp, the AppStore provides users with an information page that offers a description of the product as well as an image of the way the MobileApp appears when it is installed on the Palm Handheld device. The images of the MobileApp in use are provided by the software developers, though not all developers elect to provide them. Because users may be more inclined to purchase a MobileApp when a preview image is available, the dummy variable *Screenshot Available* is included in the analysis and is set to 1 if a screenshot is available, 0 otherwise. This variable is time invariant.

As discussed previously, a key feature of the Palm Handheld computer is its ability to communicate easily with personal computers thereby providing a conduit through which information can be transmitted between the base applications on the Palm Handheld and the organizer software on a user's personal computer. Some software developers extend the functionality of their MobileApps by designing desktop applications that complement the products that they sell for the handheld device. Because Microsoft Windows was the dominant personal computing platform during the period of study, I include as a control a dummy variable, *Windows Desktop Software*, which is set to 1 if a complementary software package that is compatible with Microsoft Windows is available and 0 otherwise. This variable is time invariant.

The early Palm computers were monochrome devices, whereas later Palm devices use color screens. The transition to color devices occurred during my study. MobileApps that have been revised to exploit the color features of the hardware are generally viewed as superior to monochrome interfaces that do not utilize the hardware's full functionality. Hence, a control variable, *Color Enabled*, is included and is set to 1 if the

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MobileApp is color enabled and 0 otherwise. This variable does not vary over time.

I control for external indicators of quality for MobileApps. *MobileApp Quality* is measured as counts of high ratings given to the MobileApp by users of the AppStore. When viewing a MobileApp page on the web site, users have the opportunity to assign a quality score to the program; the range is from 1 to 5, with 5 being the best score. I compute my measure of high quality by totaling the number of five ratings a MobileApp received in the prior month. This variable is time variant. As MobileApps that were released earlier in the development of a specific category may receive higher downloads due to being an early mover, I include as a control, *Release Order*, which represents the order in which a MobileApp was released in a category. Lower values of *Release Order* indicate that the MobileApp was released when the category was younger. As the market acceptance of a MobileApp may be influenced by the size of the market, I include as a control, *Sales in Category,* which is measured as the sum of the dollar sales for all Apps sold in the same category as the focal MobileApp.

As market structure has been found to influence the sales of specific products, I control for the concentration of the market by including in the regressions the one-month value of the Herfindahl-Hirschman index (HHI), computed as follows for market category c at month m:

$$HHI_{c,m} = \sum_{i=1}^{n-1} s_i^2$$

where s_i is the market share in units sold of the ith product, n is the total number of products in the software market, and the market share of the focal firm is excluded from the calculation. Higher values of *HHI* indicate that the market is more concentrated, whereas lower values of *HHI* indicate that the market is less concentrated. This variable varies over time.

MobileApp Category Age is included as a control variable given that the maturity of the MobileApp category may influence the unit sales of specific MobileApps. *MobileApp Category Age* is computed as the natural log in age in months of the oldest MobileApp for each market. This variable varies over time.

Because the unit sales of a MobileApp may be influenced by how long the MobileApp has been in the marketplace, I control for the age of the MobileApp. *MobileApp Age* is calculated as the age in months from original submission to the market for each commercial product. This variable varies over time. Lastly, I control for cyclical fluctuations by including dummies for each year quarter, with the first quarter of 2004 being the omitted case.

Palm device shipments

As the acquisition of MobileApps may be driven by the number of new Palm Devices introduced in any given period, I include as a control, *Palm Device Shipments*, which is the number of Palm Handheld devices shipped in the prior year as reported by Palm Computing.

Analysis

I analyze the relationship between *Monthly Revenue* or *Monthly Downloads* and the covariates described previously using the random effects model (Greene, 2000) specified as

$$Y_{im} = X_{im}\beta_1 + Z_i\beta_2 + u_i + \varepsilon_{im}$$

where Y_{im} is the natural log of revenue in the case of Table 3 or the natural log of downloads in the case of Table 4; X_{im} represents a vector of time-varying hypothesized covariates and control variables, including dummy variables for month; Z_i represents a vector of time-invariant controls; and u_i represents estimated product random effects. The random effects regression model is used because this model controls for unobserved heterogeneity between MobileApps while permitting the inclusion of time-invariant covariates. Further, Hausman tests of the differences between a fixed-effects and random-effects specification indicated that random-effects models were appropriate. I address the potential that multiple observations on the same product through time are correlated by using the Huber/White sandwich estimator for variance clustered on each product (Huber, 1967). All right-hand variables except for the age and time variables are lagged one month. As the data originate on the first day of the second month of 2004 and end at the end of the second month of 2007, the regression data contain 37 months, of which one month is omitted from the regressions due to the use of lags.

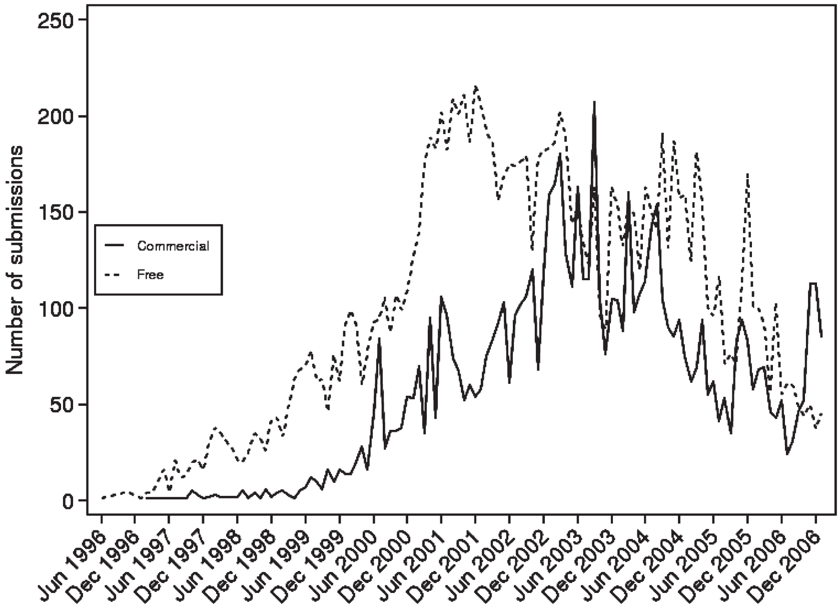

Figure 2. New submissions by month across all MobileApp categories

RESULTS

Overview

I start by providing an overview of the markets for Palm MobileApps. While data on most variables were only archived by the AppStore for 36 months spanning 2004–2007, some descriptive data are available starting in 1996, shortly after the Palm Pilot was launched. As discussed above, MobileApps are organized by the AppStore into more than 200 distinct markets.

Figure 2 shows the number of new submissions for all MobileApps across all categories by license type from June 1996 to February 2007. The figure indicates that from June 1996 until December 2006, the counts of new free and priced MobileApps submitted for the Palm Handheld across all product categories were essentially the same. Table 1 shows the top 10 categories by revenue for the 36-month period that these data are available. Table 1 indicates that while entertainment Apps appear to be important revenue categories, nevertheless the top categories over this period were dominated by professional applications and enhancements to the device. This is consistent with the professional market that the Palm Device served. Further, Table 1 indicates that between 48 and 80 percent of the software in the top revenue categories could be downloaded and used on the device for free.

As the causal theory of this paper is that MobileApps provide information regarding technological feasibility, features that might of interest to consumers, and potential total demand, I provide several illustrative examples of Palm MobileApps that may have helped producers and consumers coalesce around technologies and products.

The free MobileApp Hackmaster, released in late 1996, created a control panel system that enabled the user to manage extensions made to the Palm OS, termed “Hacks.” This technology enabled developers to design MobileApps that added functionality to the operating system. In 2001, TealPoint Software released TealMaster Plus, which is a commercial application compatible with Hackmaster extensions that added functionality beyond that which was provided by the original Hackmaster MobileApp. In this case, it appears as if commercial entrepreneurs launched a MobileApp that was based on technology that was originally developed by a noncommercial software developer. However, noncommercial developers were not the only individuals to develop pioneering technologies for the device. For example, commercial developer Inkmark Software released the program MobileWrite, a handwriting recognition software program that, the provider claimed, made it easier to enter information than with the Graffiti™ handwriting

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Table 1. Top 10 categories by revenue

Category	Revenue rank	Number of MobileApps				
		Free		Priced		
		N	%	N	%	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Travel/general	1	514	52.0	475	48.0	989
Communications/general	2	248	75.4	81	24.6	329
Utilities/general	3	1,747	80.8	414	19.2	2,161
Enhancements/general	4	553	80.4	135	19.6	688
Internet/general	5	395	73.6	142	26.4	537
Business/general	6	723	56.4	558	43.6	1,281
Medical	7	562	67.0	277	33.0	839
Fitness	8	176	67.7	84	32.3	260
Games/general	9	409	69.1	183	30.9	592
Navigation	10	246	48.0	266	52.0	512

Ranked by total revenue from February 2004–February 2007.

recognition technology that came with the original Palm Device. Lastly, software generated by universities is included in my data. For example, the Pebbles Project at Carnegie Mellon University distributed several Free MobileApps on the AppStore.

The statistical analysis is based on a sample of more than 1 million transactions spanning 36 months that are aggregated by product-month. More than 11,000 MobileApps were available for download for free and 5,741 commercial MobileApps were available for purchase through the AppStore. As MobileApps are introduced and withdrawn within the panel, the number of package months in the analysis is 195,720 for commercial MobileApps, and 377,857 for free MobileApps.

The list price for priced MobileApps averaged \$16.04 and ranged between 49 cents and almost \$1,000. Table 2 shows summary statistics and the correlation table. Table 2 indicates that average monthly revenue for priced MobileApps was \$1.74 ($e^{0.54}$), and the highest revenue earned in a single month by a MobileApp was almost \$14,000 ($e^{9.53}$). These statistics reflect the fact that many priced MobileApps captured few sales in any given month while other MobileApps secured significant sales. Row 16 of Table 2 indicates that between 0 and 754 priced MobileApps were offered for sale per MobileApp category, while the number of free MobileApps offered for download per market category ranged from 0 to 1,747. Lastly, the age of the MobileApp category, as captured by the variable *MobileApp Category Age*, ranged from 0 to 127 ($e^{4.84}$) months. Hence, the data include information on some markets within the first month of existence, while other markets included in the sample have been in existence for several years.

Table 3 reports the results of the analysis for Hypotheses 1 and 2. Results of the baseline model shown in column 1 indicate the importance of controlling for the marketing activities of the AppStore and software developers. For example, MobileApps that are listed, or that have a screenshot preview, both appear to be positively associated with monthly revenue. Similarly, the inclusion of controls for specific characteristics of the MobileApps appears to be important. For example, the utilization of color capabilities found on newer devices is positively associated with monthly revenue. Regarding controls for characteristics of market categories, results show a positive relationship between market category concentration, as measured by *HHI*, and revenue. The negative coefficient for *MobileApp Category Age* indicates that MobileApps in older market categories tend to secure lower revenue. However, the positive coefficient on *Sales in Category* indicates that individual MobileApps tend to secure higher revenue in market categories that are experiencing greater demand. Inspection of the baseline model in Table 4, where the dependent variable is *Monthly Downloads* for free MobileApps, indicates a similar pattern among control variables. An interesting difference between the two tables is that while I fail to report a robust relationship between *MobileApp Age* and monthly revenue (Table 3), that my analysis in Table 4 estimates that older free MobileApps tend to secure fewer downloads.

Table 2. Summary statistics and correlation table

	Mean	S.D.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1) Monthly revenue (LN)	0.54	1.37	0.00	9.53	1.00															
(2) Monthly downloads (LN)	0.56	1.19	0.00	9.25	0.58	1.00														
(3) Easy download	0.55	0.50	0.00	1.00	0.04	0.16	1.00													
(4) MobileApp featured	0.00	0.02	0.00	1.00	0.05	0.04	0.00	1.00												
(5) MobileApp listed	0.00	0.05	0.00	1.00	0.20	0.17	0.02	0.05	1.00											
(6) Screenshot available	0.86	0.34	0.00	1.00	0.13	0.12	0.17	0.01	0.01	1.00										
(7) Windows desktop software	0.13	0.34	0.00	1.00	0.04	0.06	0.03	0.00	0.01	−0.04	1.00									
(8) Color enabled	0.63	0.48	0.00	1.00	0.18	0.18	−0.09	0.01	0.03	0.36	−0.04	1.00								
(9) MobileApp quality	0.14	1.15	0.00	46.00	0.33	0.29	0.02	0.07	0.26	0.04	0.03	0.07	1.00							
(10) Release order	4.23	1.51	0.00	6.72	−0.05	−0.07	−0.03	0.00	−0.02	0.14	−0.05	0.10	−0.04	1.00						
(11) MobileApp age	30.24	19.55	0.00	119.00	−0.12	−0.10	0.19	0.00	0.01	0.09	0.07	−0.20	0.01	0.01	1.00					
(12) Sales in category	0.05	0.19	0.00	14.80	0.07	0.08	0.02	0.00	0.02	0.04	0.01	0.04	0.02	0.09	−0.02	1.00				
(13) HHI	0.20	0.22	0.00	1.00	−0.05	−0.05	−0.12	0.00	−0.01	−0.27	0.04	−0.16	−0.01	−0.27	−0.03	−0.10	1.00			
(14) MobileApp category age	4.02	0.74	0.00	4.84	−0.11	−0.08	0.09	0.00	0.00	0.09	0.06	−0.07	−0.01	0.51	0.63	0.05	−0.12	1.00		
(15) Palm device shipments	4.43	0.24	4.10	4.70	−0.10	−0.16	−0.01	0.01	0.00	0.02	−0.02	0.02	0.03	−0.01	0.32	−0.06	0.02	0.17	1.00	
(16) H1/H3: Priced MobileApps	1.16	1.61	0.00	7.54	−0.04	−0.02	0.05	−0.01	−0.01	0.10	−0.05	−0.02	−0.03	0.43	0.01	0.08	−0.27	0.27	−0.38	1.00
(17) H2/H4: Free MobileApps	2.13	2.81	0.00	17.47	0.04	0.07	0.12	0.00	0.02	0.04	0.05	−0.03	0.00	0.46	0.22	0.21	−0.30	0.44	−0.14	0.47

Hypotheses

I examine Hypothesis 1 in Models 2 and 4 of Table 3. In Hypothesis 1, I postulated a negative relationship between the number of priced MobileApps in a market and the unit sales for each priced MobileApp in the same market. Results from Models 2 and 4 indicate that an increase in 10 additional priced products in the same product market is associated with an approximate decrease of between 4.9 and 5.4 percent (p-value < 0.001) in the unit sales of any given priced MobileApp attempting to sell Apps in the same MobileApp category.[1] Hence I report support for Hypothesis 1.

In contrast to Hypothesis 1, for Hypothesis 2 I postulated a positive relationship between the count of free MobileApps available in a specific category and the unit sales of priced technologies in the same market. Overall, I find support for this hypothesis. Model 3 implies that an increase in 10 additional free MobileApps in the product market is associated with an approximate increase of between 3.1 percent (Model 3, p-value < 0.001), and 5.1 percent (Model 4, p-value < 0.001) in unit sales of related priced MobileApps. This finding is robust to the inclusion in the model of the count of priced MobileApps in the software market as shown in Model 4. Hence I report support for Hypothesis 2 across all of these models.

Results for Hypotheses 3 and 4 are shown in Table 4. For Hypothesis 3, I postulated a negative relationship between the number of priced Apps in a market and downloads of free MobileApps in the same category. Models 2 and 4 of Table 4 estimate that an increase of 10 additional priced MobileApps in the category is associated with a decrease of between 2.5 percent (p-value, < 0.001) and 3.1 percent (p-value, < 0.001) in the count of downloads of each free MobileApp. For Hypothesis 4, I postulated that a negative relationship would exist between the count of free MobileApps in the category, and the unit downloads of each free MobileApp in the category. I examine this hypothesis in Models 3 and 4 of Table 4. Model 3 reports that an increase of 10 additional free commercial MobileApps in the category is associated with a decrease of approximately 2.6 percent in the count of downloads of each free MobileApp in the

[1] As the dependent variable is computed as the natural log of unit sales, the estimate of one percent effect is calculated as $x = e^{-\text{coefficient}}$.

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Table 3. Random effects regressions of monthly revenue for priced MobileApps

	Model 1	Model 2	Model 3	Model 4
Marketing				
Easy download	0.124**	0.130**	0.106**	0.103**
	(0.029)	(0.029)	(0.029)	(0.029)
MobileApp featured	0.217	0.22	0.216	0.219
	(0.183)	(0.183)	(0.183)	(0.183)
MobileApp listed	5.387**	5.357**	5.342**	5.282**
	(0.496)	(0.487)	(0.500)	(0.492)
Screenshot available	0.324**	0.344**	0.338**	0.369**
	(0.025)	(0.025)	(0.025)	(0.025)
MobileApp characteristics				
Windows desktop software	0.203**	0.186**	0.195**	0.171**
	(0.046)	(0.046)	(0.046)	(0.045)
Color enabled	0.405**	0.392**	0.403**	0.387**
	(0.028)	(0.028)	(0.028)	(0.028)
MobileApp quality	−0.009	−0.006	−0.009	−0.005
	(0.009)	(0.009)	(0.009)	(0.009)
Release order	0.01	0.011	−0.01	−0.020+
	(0.010)	(0.010)	(0.010)	(0.010)
MobileApp age	0.002*	0	0.002+	0
	(0.001)	(0.001)	(0.001)	(0.001)
Market/category characteristics				
Sales in category	0.050*	0.045*	0.045*	0.036+
	(0.022)	(0.022)	(0.020)	(0.020)
HHI	0.092**	0.089**	0.098**	0.097**
	(0.020)	(0.020)	(0.020)	(0.020)
MobileApp category age	−0.291**	−0.203**	−0.323**	−0.245**
	(0.024)	(0.026)	(0.025)	(0.026)
Palm device shipments	−0.057*	−0.058*	−0.051+	−0.048+
	(0.027)	(0.027)	(0.027)	(0.027)
Time				
2004q2	−0.087**	−0.089**	−0.085**	−0.085**
	(0.014)	(0.014)	(0.014)	(0.014)
2004q3	−0.091**	−0.097**	−0.084**	−0.087**
	(0.016)	(0.016)	(0.016)	(0.016)
2004q4	−0.175**	−0.186**	−0.164**	−0.169**
	(0.018)	(0.019)	(0.019)	(0.019)
2005q1	−0.153**	−0.217**	−0.126**	−0.182**
	(0.021)	(0.022)	(0.021)	(0.022)
2005q2	−0.227**	−0.319**	−0.191**	−0.272**
	(0.023)	(0.025)	(0.023)	(0.025)
2005q3	−0.265**	−0.359**	−0.225**	−0.307**
	(0.025)	(0.027)	(0.026)	(0.028)
2005q4	−0.291**	−0.386**	−0.248**	−0.329**
	(0.027)	(0.029)	(0.028)	(0.030)
2006q1	−0.333**	−0.429**	−0.287**	−0.366**
	(0.030)	(0.032)	(0.031)	(0.032)
2006q2	−0.366**	−0.462**	−0.318**	−0.395**
	(0.032)	(0.034)	(0.033)	(0.034)
2006q3	−0.389**	−0.485**	−0.338**	−0.413**
	(0.035)	(0.037)	(0.036)	(0.037)
2006q4	−0.425**	−0.520**	−0.370**	−0.443**
	(0.038)	(0.039)	(0.039)	(0.039)
2007q1	−0.521**	−0.615**	−0.463**	−0.533**
	(0.040)	(0.042)	(0.041)	(0.042)

Table 3. Continued

	Model 1	Model 2	Model 3	Model 4
Hypotheses				
H1: Priced MobileApps		−0.050**		−0.056**
		(0.003)		(0.003)
H2: Free MobileApps			0.031**	0.050**
			(0.007)	(0.007)
Constant	1.445**	1.263**	1.540**	1.395**
	(0.137)	(0.137)	(0.137)	(0.137)
Number of MobileApps	5,741	5,741	5,741	5,741
MobileApp-months	195,720	195,720	195,720	195,720
Months	36	36	36	36
R^2 overall	0.09	0.10	0.10	0.11

+significant at 10%; *significant at 5%; **significant at 1%
Robust standard errors in parentheses. The unit of analysis is a MobileApp month.

category. However, in Model 4 I fail to reject the null hypothesis of no relationship.

It is important to note that the analysis spanning Tables 3 and 4 do not represent a zero sum game. For example, individuals may initially download Free MobileApps. Per Hypothesis 2, after trying free MobileApps, customers may learn the specific features they desire from a program of a specific type, and then purchase a priced MobileApp that best meets their expected needs.

The effect sizes reported here seem appropriate in light of the causal mechanism proposed, as well as when compared to relationships reported in the product lifecycle literature. The lifecycle literature examines the relationship between changes in the number of producers and industry sales, while here I examine the relationship between an additional product, and the sale of a single MobileApp. However, given that the likelihood of finding statistical significance is positively associated with sample size, and that the sample used to examine the proposed hypotheses is large (more than 160,000 observations), statistical significance was also assessed using Leamer's sample-size adjusted test for significance, calculated as

$$F_{r,n-k} > \left(\frac{(n-k)}{r}\right)\left(n^{\frac{r}{n}} - 1\right)$$

where r is the number of restrictions, n is the sample size, and k is the number of coefficients (Leamer, 1978). For Hypotheses 1–3 in all models reported—using Leamer's more stringent criteria—the null hypothesis of no effect is rejected. Further, for Hypothesis 4 the negative coefficient reported in Model 3 of Table 4 also passes this more stringent test.

As discussed above, *Free MobileApps* includes counts of software that can be downloaded and used for free perpetually—often termed freeware—and shareware MobileApps, which generally refers to software that users may download for free on a trial basis but most later remunerate a fee to continue to use. In exploratory analysis, I separated the *Free MobileApps* variable into counts of Freeware and Shareware programs. These two variables are highly correlated ($\rho = 0.86$). In most unreported regressions, consistent with Hypothesis 2, I find that both counts of freeware and shareware MobileApps are generally positively associated with the unit sales of priced technologies in the same market. However, my analysis of monthly downloads for free MobileApps suggests that the negative relationship between counts of free MobileApps in a category, and the unit downloads of reach free MobileApps in the category, may be driven by counts of shareware MobileApps. In my analysis, I fail to reject the null hypothesis for counts of freeware MobileApps while I find that an increase of 10 additional shareware MobileApps in the category is associated with a decrease of approximately 4.1 percent in the count of downloads of each free MobileApp in the category. This finding might suggest that shareware MobileApps may be of higher quality than similar freeware MobileApps, which is consistent with the theoretical arguments above regarding the likely different effects of technobyte, introduced unto commercial or noncommercial economic logics.

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Table 4. Random effects regressions of monthly downloads of free MobileApps

	Model 1	Model 2	Model 3	Model 4
Marketing				
Easy download	−0.059+	−0.059+	−0.061*	−0.060*
	(0.030)	(0.030)	(0.030)	(0.030)
MobileApp featured	0.288**	0.288**	0.287**	0.288**
	(0.072)	(0.072)	(0.072)	(0.072)
MobileApp listed	3.532**	3.546**	3.583**	3.562**
	(0.288)	(0.289)	(0.292)	(0.291)
Screenshot available	0.325**	0.326**	0.322**	0.325**
	(0.036)	(0.036)	(0.036)	(0.036)
MobileApp characteristics				
Windows desktop software	−0.100*	−0.099*	−0.104**	−0.101*
	(0.040)	(0.040)	(0.040)	(0.040)
Color enabled	0.231**	0.223**	0.215**	0.218**
	(0.030)	(0.030)	(0.031)	(0.031)
MobileApp quality	−0.033**	−0.033**	−0.033**	−0.033**
	(0.008)	(0.008)	(0.008)	(0.008)
Release order	0.053**	0.057**	0.083**	0.068**
	(0.010)	(0.010)	(0.011)	(0.011)
MobileApp age	−0.003**	−0.004**	−0.003**	−0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
Market/category characteristics				
Sales in category	0.021+	0.022*	0.025*	0.023*
	(0.011)	(0.011)	(0.011)	(0.011)
HHI	0.064**	0.065**	0.062**	0.064**
	(0.017)	(0.017)	(0.017)	(0.017)
MobileApp category age	−0.527**	−0.493**	−0.488**	−0.484**
	(0.022)	(0.022)	(0.023)	(0.023)
Palm device shipments	−0.165**	−0.166**	−0.172**	−0.169**
	(0.013)	(0.013)	(0.013)	(0.013)
Time				
2004q2	−0.159**	−0.159**	−0.162**	−0.160**
	(0.007)	(0.007)	(0.007)	(0.007)
2004q3	−0.435**	−0.436**	−0.442**	−0.439**
	(0.010)	(0.010)	(0.010)	(0.010)
2004q4	−0.859**	−0.861**	−0.870**	−0.866**
	(0.013)	(0.013)	(0.013)	(0.013)
2005q1	−0.827**	−0.850**	−0.858**	−0.858**
	(0.014)	(0.014)	(0.015)	(0.015)
2005q2	−0.848**	−0.881**	−0.890**	−0.891**
	(0.015)	(0.016)	(0.017)	(0.017)
2005q3	−0.961**	−0.995**	−1.007**	−1.007**
	(0.016)	(0.017)	(0.019)	(0.019)
2005q4	−0.992**	−1.027**	−1.042**	−1.040**
	(0.018)	(0.019)	(0.020)	(0.020)
2006q1	−1.033**	−1.068**	−1.086**	−1.083**
	(0.019)	(0.020)	(0.022)	(0.022)
2006q2	−1.121**	−1.156**	−1.177**	−1.172**
	(0.021)	(0.022)	(0.024)	(0.023)
2006q3	−1.132**	−1.168**	−1.192**	−1.186**
	(0.022)	(0.023)	(0.025)	(0.025)
2006q4	−1.185**	−1.221**	−1.249**	−1.240**
	(0.024)	(0.025)	(0.027)	(0.027)
2007q1	−1.438**	−1.474**	−1.505**	−1.495**
	(0.026)	(0.026)	(0.029)	(0.029)

Table 4. Continued

	Model 1	Model 2	Model 3	Model 4
Hypotheses				
H3: Priced MobileApps		−0.031**		−0.025**
		(0.005)		(0.006)
H4: Free MobileApps			−0.026**	−0.01
			(0.005)	(0.007)
Constant	4.683**	4.614**	4.564**	4.580**
	(0.100)	(0.099)	(0.100)	(0.101)
Number of MobileApps	11,014	11,014	11,014	11,014
MobileApp-months	377,857	377,857	377,857	377,857
Months	36	36	36	36
R^2 overall	0.09	0.09	0.09	0.09

+significant at 10%; *significant at 5%; **significant at 1%
Robust standard errors in parentheses. The unit of analysis is a MobileApp month.

DISCUSSION AND CONCLUSION

In this study, I proposed that free technologies and priced technologies will influence the sales of commercial products differently. I theorized that this difference will occur because, though both types of technologies provide key information on technology and market demand, in general the free technologies will provide information without simultaneously drawing away sales from commercial products. In regards to unit downloads of free technologies, I hypothesized and found support for an asymmetric relationship. While priced technologies hinder the sales of other priced technologies, the prevalence of priced technologies is positively associated with downloads of free technologies. I argue that this is the case because the prevalence of priced technologies stimulates the search for additional information by consumers and potential producers, and because one source of information is that which can be acquired by trying free technologies.

After controlling for potentially confounding factors such as the age of the market, age of the technology, and marketing efforts, I find that priced technologies earn higher revenue in markets where developers are giving away substitute technologies for free, but they experience lower revenue in markets where competitors charge for substitute technologies. These findings are consistent with the argument that, in general, free technologies are likely to reduce uncertainty regarding desired features, technological feasibility, and potential total demand, without serving as a direct substitute for technologically related priced products. The core argument presented here is that, in general, both commercial and noncommercial actors who release free technologies typically release technologies that entice potential customers to search for a priced alterative.

Limitations

A limitation of this study is the applicability of my findings to products beyond software. Specifically, the findings may be most relevant to markets in which prototypes and functioning products can be shared at low cost, such as publishing, software, film, music, and computer-aided design. An alternative assessment of the research setting is that the software industry provides a conservative test of the general relationship between free technologies and the sales of priced products that are available in the same technological domain. I find that, in markets where a greater number of free MobileApps are available to consumers for download the revenue of priced MobileApps is greater. Hence, the innovative output of actors who distribute technologies for free may be even less likely to detract from the sales of individual products in markets where it is more costly for actors to share their free outputs directly with consumers. Yet even in these markets, free technologies still provide information that reduces uncertainty for actors who have released priced technologies.

It is important to highlight that a limitation of this study is that I am unable to observe directly the underling motivations of the software developers who wrote programs for the Palm Handheld. In the case of producers operating under the

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noncommercial economic logic, the causal mechanism proposed in this study is based on the premise that actors who share technologies for free are often motivated to share for reasons other than perceived profits that may accrue to them from doing so. The difference in motivation leads them to generate different innovative outputs than commercial producers. While this is consistent with the way in which noncommercial technologists are typically treated in the literature, the potential exists that even among these innovators some commercial motivation may exist. For example, Lerner and Tirole (2005a) theorize that individuals may share software innovations to signal their programming abilities to employers. However, as mentioned earlier, the characteristics of programs offered by those who are motivated to demonstrate their programming expertise are often not guided by customer interests, as elegance and technical achievement in programming are generally uncorrelated with aspects of programs of interest to consumers (Levy, 1984).

Implications for theory and research

Despite these limitations, this study has several important implications for theory and research. First, as others have noted, the study of the development of software markets represents a microcosm of the perpetual interaction between commercial and public innovation (Lerner and Tirole, 2005a). This relationship lies at the core of our ability to understand how firms manage the process by which technological information is transformed into marketable products (Nelson, 2004). Hence this study contributes to the literatures on technology management and entrepreneurship.

In the domain of scholarly work on technology management, research on the evolution of product markets has examined how the joint actions of consumers and commercial producers resolve technical and market uncertainties as industries evolve (Anderson and Tushman, 1990; Tushman and Anderson, 1986; Utterback and Suarez, 1993). Omitted from this earlier research is an examination of how free technologies may influence the performance of priced products in the lifecycle. This paper advances this literature by empirically examining whether and how information generated by free technologies influences the sales of individual priced technologies differently from similar information produced by priced technologies. Results for this paper are consistent with the argument that free technologies can reduce uncertainty without having the adverse competitive impact of other priced products. This reasoning implies that the speed with which product markets evolve through phases of the lifecycle may depend on the prevalence of free technologies.

This study also contributes to the developing literature in technology management on free and open source software (von Hippel, 2002; Mockus, Fielding, and Herbsleb, 2002; Paulson, Succi, and Eberlein, 2004). Some of this literature has examined free software development as an alternative to commercial software development (Dalle *et al.,* 2004; von Hippel and von Krough, 2003). This study indicates that an important distinction to pursue further might be price. This study suggests that free software projects may complement—instead of substitute for—priced software technologies in a manner similar to the different roles of academic and commercial research that have been observed in other industries (Klevorick *et al.,* 1995; Rosenberg and Nelson, 1994). Hence, this study suggests that the public actions of private commercial and noncommercial software developers may facilitate the formation of commercial markets for related technologies in a way that has not been previously understood (Mahoney, McGahan, and Pitelis, 2009). Further, this paper suggests that an important area of additional research is the further examination of the effects of differences in the economic logics of innovators.

Lastly, this study contributes to the growing literature that treats opportunities as a central unit of analysis to the study of entrepreneurship (Venkataraman, 1997). A fundamental question in entrepreneurship and the management of technological innovation is how individuals with different interests influence the ways in which entrepreneurial opportunities become assimilated into markets (Venkataraman, 1997). This paper contributes to this literature by examining one mechanism in which actors with very different economic logics interact in newly forming markets. I systematically examined the question of whether free technologies influence the performance of priced technologies in newly forming markets. This paper provides evidence that free technologies influence the sales of priced technologies differently than do their priced counterparts. Hence, in some contexts free technologies may help to form opportunities for commercially minded entrepreneurs.

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