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Optimal Software Free Trial Strategy: The Impact of Network Externalities and Consumer Uncertainty

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Many software firms offer a fully functional version of their products free of charge, for a limited trial period, to ease consumers' uncertainty about the functionalities of their products and to help the diffusion of their new software. This paper examines the trade-off between the effects of reduced uncertainty and demand cannibalization, uncovers the condition under which software firms should introduce the time-locked free trial software, and finds the optimal free trial time. As software firms have the option of providing free trial software with full functionalities but a limited trial time or limited functionalities for an unlimited trial time, we develop a unified framework to provide useful guidelines for deciding which free trial strategy is preferred in the presence of network externalities and consumer uncertainty.

Key words: software free trial; time-locked free trial; demo software; experience goods; network effect; product trial; product sampling
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1. Introduction

Free trial offers are used by many companies to sell various products including books, CDs, magazines, and Internet access. Offering free trials can be an effective strategy to promote the diffusion of experience goods. Unlike physical goods, some information goods—such as software, movies, and music—have a somewhat peculiar property where a consumer might not be able to assess the goods accurately and reliably before the consumption of the goods. Sometimes, the process of evaluating such information goods per se is the very process of consumption. This uncertainty of product functionality reduces consumers' willingness to adopt the product and is considered by many to be a source of market failure. Because of the negligible marginal production cost of digital goods, offering free trials to help reduce consumers' uncertainty is more favorable to the digital goods vendors than physical goods makers, thereby resulting in the prevalence of free trials from software companies nowadays.

There are two general forms of free trial software in the market—a free, fully functional version with limited trial time (termed *time-locked free trial*) and a free "demo" version with limited functionalities (commonly referred to as limited version free trial). Companies in the software industry seem to favor either time-locked free trial or limited version free trial, but rarely the combination of both. Examples of time-locked free trial include Ilium Software, offering a 30-day free trial plan for its newly released *NewsBreak*, a media software product that delivers industry news, weather forecast, as well as stock information to pocket PC or Smart phones; and Apple Inc., offering its recently released professional photo processing software *Aperture* with all features included (e.g., advanced color controls, onscreen controls, etc.) free of charge, but only for 30 days. RealNetworks exemplifies the limited version demos by giving away its *RealPlayer*, which in essence is a "light" version of RealPlayer Plus that offers many more advanced features such as advanced CD burning, movie-on-demand, and live music stations in order to establish a sizable network of users for the benefit of RealPlayer Plus. Another example is PQ Computing's *PQ DVD*, a video converter suite that converts DVD movies to iPod video. PQ DVD's free evaluation version offers almost identical functionalities of the full version, except that it converts only the first two minutes of the movie.

Which version of a software free trial to offer, either time-locked or limited functionalities demo, has been a central issue facing many software firms, as evidenced by many postings of questions at "The

Business of Software," a community discussing the business of software from the smallest shareware operation to Microsoft. For instance, one member asked, "I plan to release one software, but am not sure whether upload one demo version to download.com for example, or a fully functional version with time/usage restrictions?"[1] Intuitively, the time-locked free trial is suitable for reducing consumers' uncertainty about functionality of the software because a consumer using the time-locked free trials has access to full functionality of the software. Offering time-locked free trials, however, can have a negative impact on the software firm. When the firm introduces a time-locked free trial along with its commercial product, it risks losing part of the demand for its commercial product because consumers who have only short-term usage can now utilize the time-locked free trial without buying the commercial product. Furthermore, if the trial users decide not to buy the product after the trial period, no positive network effect can be derived from those trial users.

Unlike the time-locked free trial, the limited version free trial has the advantage of capturing the network effect from both trial users and buyers. Partial demand of the commercial software, however, can still be cannibalized by the limited version free trial. For example, some consumers might find it sufficient to use only the functionalities provided in the trial version instead of purchasing the commercial product.

This paper will first focus on analyzing the time-locked free trial strategy and then address the issue of which software free trial strategy, time-locked or limited version, the firm should choose to achieve optimal results. In particular, our research aims at answering the following critical questions. First, should the software firm offer time-locked free trial to take advantage of the reduced consumers' uncertainty of its product, or forgo the free trial to avoid the negative "cannibalization" effect? Second, if it is more profitable to offer a time-locked free trial, what is the optimal length of time for the free trial, and what is the associated optimal price for the commercial product? Thirty-day time-locked trial periods seem to be the most common length for a free trial but is it truly the optimal length of free trial time that maximizes the software firm's profits? Finally, under what condition will the time-locked free trial be a better strategy than the limited version free trial?

Our research provides several useful insights into whether the software firm should offer a time-locked free trial. First, we find that when the network effect is not very strong and the consumers' prior expectation about the software is relatively low, the firm should introduce the time-locked free trial software. Second, when it is in the firm's best interests to introduce the time-locked free trial to the market, the optimal free trial time depends on four key factors: the usage cost of the software, the network effect, consumers' prior expectation, and how fast consumers learn about the software's functionalities during free trial. In general, the stronger the network effect or the higher the consumer's prior belief about the functionality of the software, the shorter the optimal free trial time. The common industry practice of 30-day free trial period is not always optimal to all software firms. Failing to set the optimal trial time can result in substantial profit losses. Finally, the time-locked free trial strategy analyzed in this paper outperforms the limited version free trial when the network effect is moderate. If the network effect is intense, the firm should opt for a limited version free trial to exploit the positive network effect.

The rest of this paper is organized as follows. A review of literature relevant to the software free trial problem is presented in §2. To study the software firm's time-locked free trial problem, we describe several models in §3 to capture salient features of the decision process of offering time-locked free trials facing the software firm. This section provides further discussions on the impact of a positive correlation between consumers' preferences for functionality and their software usage time, risk-averse versus risk-neutral consumers, and the lock-in effect of free trial. Useful managerial insights derived from analytical and computational analyses are reported with empirical observations of industry practice corroborating our findings. We present a unified framework in §4 that enables the software firm to compare the time-locked free trial strategy with that of limited version, and we derive guidelines on which strategy outperforms the other under what conditions. We conclude the paper and discuss some future research possibilities in §5.

2. Literature Review

Product trial and sampling, a long-standing research topic in marketing, is a stream of literature relevant to the software free trial issue as software free trials are in essence a form of product trial and sampling. Most of the prior studies on product trial, defined as a consumer's first usage experience with a brand or product by Kempf and Smith (1998), had been conducted in an internal (e.g., the show room product trial) or external (i.e., direct mail sampling) laboratory setting and examined the impact of the trial on belief strength and attitude (Scott and Yalch 1980, Marks and Kamins 1988), affect (Oliver 1992), or perception of the brand

[1] See http://discuss.joelonsoftware.com/default.asp?biz.5.499021.12.

(Bettinger et al. 1979) with a focus on analyzing consumer's probability of purchasing the same product again after the trial.

Theoretical quantitative models of sampling behavior include the pioneering work of Goering (1985), Jain et al. (1995), and Heiman et al. (2001). Goering (1985) focused on the effects of incomplete information and consumer learning through product trial on consumer expectations and demands. The effect of consumer learning on future demand for a product depends on both the information acquired by consumers and the number of consumers who acquire information. Jain et al. (1995) used simulation to determine the optimal level of product sampling for a new product. To do so, they modified the Bass diffusion model by assuming that the coefficient of innovation is a function of the sampling level. They found that sampling is critical in the initial stages of a product's life, because increasing the number of first adopters not only leads to a future customer base but also provides a source for product promotion by word-of-mouth. Their analysis provided insight into the optimal initial level of investment in sampling and how this affects the dynamics of product diffusion. Similarly, Heiman et al. (2001) developed a model that decomposes the sampling effort into the immediate sales and longer-run (goodwill-building) effects. Their model identified the optimal sampling effort of a firm over time. More recently, Bawa and Shoemaker (2004) studied the effects of free samples sent to and consumed at home via direct mail. They examined three potential effects of free direct mail samples on sales: (1) an acceleration effect, whereby consumers begin repeat purchasing of the sampled brand earlier than they otherwise would; (2) a cannibalization effect, which reduces the number of paid purchases of the brand; and (3) an expansion effect, which induces purchasing by consumers who would not consider buying the brand without a free sample. They found that free samples can produce measurable long-term effects on sales, and the effectiveness of a free sample promotion can vary widely, even between brands in the same product category.

The research by Heiman and Muller (1996) is perhaps the most relevant to our study on issues involved in time-locked software free trial. Investigating the optimal length of demonstration time for manufactures in such industries as motor vehicle and computer hardware, they found that the time needed by the consumers to learn about the performance of different features of a product varies from one feature to another, and the longer the demonstration, the more information is gained by the consumer. They proved both theoretically and experimentally that given consumers' prior expectations about the functionality of the product, the probability of purchase after the demonstration will first increase with more demonstration time and then decrease. This finding is similar to what we discovered in our analyses reported in §3 of this paper. We found that the total profits of a software producer who offers a time-locked free trial will first increase with the length of the free trial time and then decrease. However, our study aims at finding the optimal trial time that maximizes software firms' profits, while Heiman and Muller (1996) focused on finding the optimal demonstration time that maximizes consumer's probability of purchase.

While the product trial and sampling literature on physical goods helps shed some light on understanding software free trial issues, software as information goods has several distinct characteristics that are not addressed in prior literature. First, product trial or sampling of physical goods is usually available to a group of preselected customers because the cost of reaching more consumers is significant, while free trial software is available for downloading to all interested consumers. As a result, software companies risk losing more demand to the free trial users. Second, the difference between small samples and the underlying commercial product is in quantity, not in functionality (e.g., small samples of shampoos). In this respect, the length of software free trial time amounts to the limit of consumption quantity of free samples. This free trial time, as we will show later, has significant impact on the firm's optimal profit and thus should be treated as an important decision variable for the firm. Third, the marginal production cost of information goods is negligible, whereas that of the physical goods is not. Finally and most importantly, most prior analysis of the product trial does not take the network effect into consideration, while we show in this paper that the network effect is one of the key factors for the decision of software free trial.

There is a surprising lack of research addressing the software free trial issue, despite an apparent need of useful guidelines for such a prevalent practice in the software industry.[2] Cheng and Tang (2010), among others, extend Conner's (1995) models to study the optimal strategy for the limited version free trial software by explicitly considering consumers' aggregate software usage cost that includes, for example, search cost associated with finding a particular software product of interest and learning cost of time and effort spent to get familiarized with the functionalities of the software. They show that under a strong network effect a firm will introduce limited

[2] For example, using software free trial as the phrase to search Social Science Research Network produces only three research papers.

version free trial software, and the firm is better off offering a limited version free trial than segmenting the market by charging a price for the product of lower functionality. Interestingly, we find that the time-locked free trial strategy is favorable to the firm when the network effect is moderate. We show that the time-locked free trial strategy outperforms that of the limited version when the network effect drops below a certain threshold. This finding suggests that these two forms of software free trial are complementary rather than competing against each other. Faugere and Tayi (2007) develop a vertical differentiation game-theoretic model to study the optimal design of potentially reinstallable free software samples (shareware). They show that the software monopolist might not want to deter reinstallation when consumers' learning is progressive. Using data collected from download.com, Lee and Tan (2007) empirically test what factors contribute to the total number of downloads of freeware (limited version free trial) and trialware (time-locked version). They find that sampling intensity is different among software categories.

Table 1 compares and contrasts extant literature on product trial and sampling and software free trial with this paper. The first five columns of Table 1 list various important features of the software free trial problem, including network effect, consumers' belief updating, optimal trial level, optimal pricing of the commercial product, and prescriptions for the optimal trial strategy. A check mark indicates that the listed paper takes the corresponding feature into consideration. The last two columns show objects of the study and research methodology employed in the paper, as well as major research objectives.

3. Time-Locked Free Trial: How Long Is Optimal?

In the study of demonstration time by Heiman and Muller (1996), the firm determines the time of demonstration and the number of potential customers to receive a demonstration. Software companies, however, cannot pick and choose which customers will download and try their software. Therefore, the only leverage left in their hands is the length of free trial time so that the loss of demand is balanced against the benefit of consumers' increasing willingness to pay due to free trial.[3] This section analyzes the free trial product design problem facing the software firm. We first describe the model in §3.1 and examine the time-locked free trial problem where there is no correlation between consumers' valuation and usage time and consumer's belief updating process is linear in §3.2. We then study the more involved problems when there is a positive correlation between consumers' valuation and usage time in §3.3. In both §§ 3.2 and 3.3, we first treat the trial time as exogenous and derive the optimal price for the commercial product. Then we relax this assumption to find both the optimal length of the free trial and the optimal price of the commercial product. In both cases, we derive conditions under which the software firm is better off providing a time-locked free trial.

3.1. The Model

Consider the software firm selling a software product of functionality s_0 at price P. If the firm chooses to offer a free trial version, let the length of the free trial time be denoted by τ. Without loss of generality, τ is normalized between 0 and 1 by dividing the free trial time by the expected life-span of the software product under consideration. Moreover, let t denote consumers' expected usage time of the software. For simplicity, t is uniformly distributed among all consumers and again normalized between 0 and 1.

Following the model setup in Conner (1995), let K be the size of the total population in the market, N be the number of potential customers for the software product under consideration, and $K = aN$, where $a > 1$.[4] Then, $K - N = (a-1)N$ represents those who are not interested in the software. When N is normalized to 1 without loss of generality, the intervals $[-(a-1), 1]$ and $[0, 1]$ represent the total population and potential customers of the market, respectively. For simplicity, let each individual's "type" (i.e., valuation of functionality) for the software be denoted by θ uniformly distributed over $[-(a-1), 1]$, see Table 2 for summary of notation.

Network externality increases each consumer's valuation (i.e., θ) by γQ_τ, where Q_τ is the installed base or network size of the software and γ is the network effect intensity, which reflects the increase in willingness to pay when an additional consumer joins the network. Network effect intensity is a conceptual metric for the interdependence among consumers, and different software might have different magnitudes of network effect intensity. For example, communication software (i.e., Instant Messenger, Skype, etc.) typically demonstrate stronger network effect than regular antivirus software or most offline PC games.

Shapiro (1983) points out that the optimal pricing strategies are qualitatively very different under cases when consumers initially overestimate ($s > s_0$) or underestimate ($s < s_0$) the functionality of a

[3] For the ease of presentation, the term *free trial* henceforth refers to time-locked free trial unless noted otherwise.

[4] K and a are introduced for the sake of notation completeness. They are not needed in subsequent analyses after N is normalized to 1.

Table 1 Comparison of Product Trial and Sampling Versus Software Free Trial Literature

Literature category	Authors	Network effect	Belief update	Optimal trial level	Optimal pricing	Conditions for trial strategy	Object of study	Research methodology and research objectives
Product trial, sampling, and versioning	Scott and Yalch 1980		v				Physical goods—general	Bayesian model to assess consumers' responses to new product trial
	Goering 1985		v		v		Physical goods—general	Analytical models on the effects of private information acquired through product trial
	Jain et al. 1995			v			Durable products	Using simulation to determine the optimal levels of product sampling
	Heiman and Muller 1996		v	v		v	Physical goods—Cars and printers	Bayesian model to evaluate the optimal demonstration time
	Kempf and Smith 1998						Physical goods—general	Empirical test on how consumers process and respond to advertising and trial experiences in a laboratory setting
	Heiman et al. 2001		v	v	v		Physical goods—general	Analytical modeling on optimal design of sampling effort
	Bawa and Shoemaker 2004		v				Physical goods—small samples	Empirical testing and measuring the effect of free samples with two field experiments
	Chellappa and Shivendu 2005		v	v	v		Digital experience goods	Two-stage decision model of heterogeneous consumers to explore sampling as a piracy-mitigating strategy
	Wu and Chen 2008			v	v		Digital goods	Mixed integer programming models to show versioning as an effective strategy to control piracy
Software free trial	Faugere and Tayi 2007		v	v	v	v	Potentially reinstallable shareware	Game-theoretic model on optimal design of potentially reinstallable shareware
	Lee and Tan 2007					v	Freeware and trialware	Empirical testing of factors affecting total number of downloads
	Cheng and Tang 2010	v		v	v	v	Limited version free trial	Analytical modeling on optimal design of limited version free trial
	This paper	v	v	v	v	v	Limited version and time-locked free trial	Analytical models on optimal design of time-locked free trial and when to adopt which free trial strategy

Table 2 Notation

s:	consumer's prior belief about the functionality of the software before free trial
δ:	speed of consumer's belief update measured by the increment of consumer's belief about the functionality of the software per unit of time
s_0:	true functionality of the commercial software
θ:	consumer type, i.e., consumer's valuation for the functionality of the software
c:	aggregate cost of using the software
t:	the length of time consumers will use the commercial software
τ:	length of the free trial
Q_τ:	total number of buyers that purchase the commercial software given that the length of the free trial time is τ
γ:	the network effect intensity, measuring how much each addition to the number of buyers increases the software's perceived value
P:	price of the commercial software

product. In a more recent study, Chellappa and Shivendu (2005) also separate the information goods that have been either overestimated or underestimated. In their model, piracy offers a consumption opportunity before purchase similar to that of free trial. Time-locked free trial strategy in essence is the legal counterpart of pirating except with no moral cost involved. In addition to the free trial, previous literature also recognizes the role of versioning to combat piracy. Wu and Chen (2008) show that versioning can be an effective and profitable instrument to fight piracy, even though a single version is the optimal strategy for the information goods providers not experiencing piracy.

Offering time-locked free trial software, however, becomes meaningless if consumers overestimate the functionality of the commercial software. In this case,

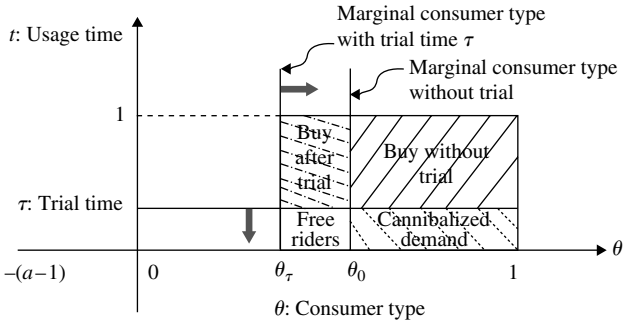
the software firm will choose not to offer any free trial product because doing so will only "disappoint" the potential consumers and reduce their willingness to pay. Consequently, for the rest of the paper, we will turn our attention to the case where consumers underestimate the functionality of commercial software. In addition, we assume that the average consumers' prior belief is known to the software firm before the release of its software.[5] This can be achieved based on either historical data or market research. Let s be the consumer's prior belief about the software functionality. Furthermore, let c denote the aggregate cost of time and effort spent by consumers to get familiarized with the functionality of the software. We note that the aggregate cost c is a critical component of the model because of the zero-price nature of the free trials, a finding first discovered in Cheng and Tang (2010).[6]

A consumer θ obtains the following net utility when purchasing the software after free trial:

$$U = (\theta + \gamma Q_\tau) \cdot (s + \tau\delta) - P - c. \quad (1)$$

The utility function in Equation (1) incorporates both the network effect and the effect of consumer's reduced uncertainty through the free trial. The network effect is modeled as in Jing (2000, 2007) by the increase of consumers' valuation from θ to $\theta + \gamma Q_\tau$, where Q_τ is the installed base or network size of the software and γ represents the network effect intensity. The effect of consumer's reduced uncertainty through the free trial is reflected by the improvement of consumer's perceived functionalities about the software, which rises from s before the free trial to $s + \tau\delta$ after the free trial, where δ represents the increment of consumers' belief about the functionality of the software per unit of time. Because consumers' updated belief on the functionality is bounded by the true functionality (s_0) of the commercial software under consideration, we restrict $s + \tau\delta \le s_0$. We assume that the improvement of consumer's belief is linearly proportional to the length of the free trial time. Similar assumptions are observed in Pynadath and Marsella (2004) and Liu et al. (2003), where linear belief update functions are recommended techniques

Figure 1 Distribution of Potential Consumers with Network Effect



that can exploit structured problem domains to more efficiently solve the modeling and planning tasks in decision-theoretic frameworks.[7]

Let θ_τ denote the marginal consumer type who is indifferent between adopting the commercial software and doing without under trial time τ, and let θ_0 denote the same marginal consumer type when the free trial software is not offered (i.e., $\tau = 0$).

Consumers of higher valuation type than the marginal consumer θ_0 represent those who will purchase the software even when the free trial software is not offered. Among them, those consumers with usage time longer than the free trial time (the upper-right area in Figure 1) will purchase the software without free trial, while those with shorter usage time than τ (the lower-right area) are the potential buyers content with using the time-locked free trial. For example, consumers using table planning software for wedding occasion will not purchase the software if they get their work done in time before the trial time expires.[8] Note that this segment of consumers corresponds to the *cannibalized demand* due to free trial because they would have purchased the software if there was no trial product available.

Consumers with a valuation type lower than θ_0 but higher than θ_τ (i.e., $\theta_\tau < \theta < \theta_0$) will purchase the software only if the trial product is offered. For this group of consumers, those with usage time longer than the trial time (the upper-left area in Figure 1) will purchase the software after the free trial. They are the converted buyers attributed to the free trial. However, those in this group with shorter usage time than the trial time (the lower-left area) become the free riders due to the free trial.

[5] In the absence of free trials, Bergemann and Schlag (2008) propose a regret-minimizing pricing strategy when the seller has minimal information regarding the true valuation of the buyer.

[6] Cheng and Tang (2010) found that the absence of the software usage cost c in their free trial model will lead to a nonsensical conclusion that no free trial should be offered in all circumstances. Because of the zero-price nature of free trial software, the abnormality discovered in Cheng and Tang (2010) arises when the software usage cost is ignored. Normalizing this cost to zero will result in total demand being independent of the quality of the free trial software and the gain of demand from positive network effect being exactly offset by cannibalization.

[7] It is conceivable that consumers update their beliefs faster at the beginning of the trial as the gap between their prior expectations and true functionality is large, and the belief updating slows down as the gap diminishes. This learning process can be captured by a concave belief updating function. We find that the linear function in our model offers exactly the same managerial insights to the time-locked free trial problem as does a concave function.

[8] A comment raised in http://discuss.joelonsoftware.com/default.asp?biz.5.499021.12.

Recall that θ_τ denotes the marginal consumer type who is indifferent between adopting the commercial software and doing without under trial time τ. Setting the net utility function in Equation (1) to zero, one derives the marginal consumer type as

$$\theta_\tau = \frac{P+c}{s+\tau\delta} - \gamma Q_\tau. \tag{2}$$

The intuition might suggest that the software firm should decrease the free trial time to minimize short-term users who enjoy a free ride. One can easily derive from Equation (2) that decreasing free trial time will lead to the marginal consumer's type shifting to the right, i.e., reducing the number of potential buyers; see Figure 1. Increasing the trial period improves the consumers' updated valuation of software, and a higher price can be charged by the software firm. A longer trial period, however, results in increased number of free riders. That is, there exists a trade-off between increasing the number of buyers and decreasing the number of free riders.

Because both t and θ are uniformly distributed, the area under the product of two subintervals $[\theta_\tau, 1] \times [\tau, 1]$ corresponds to buyers (i.e., the demand) of the commercial software. Thus, the demand D for the software is described by

$$D = (1-\theta_\tau)(1-\tau). \tag{3}$$

Substituting Equation (2) into (3) and invoking rational expectation equilibrium $D = Q_\tau$, one derives the demand (i.e., the installed base Q_τ) of the commercial software as

$$Q_\tau = \frac{(1-\tau)(s+\tau\delta-P-c)}{(s+\tau\delta)(1-\gamma+\gamma\tau)}. \tag{4}$$

Because both $(1-\tau)$ and $(s+\tau\delta)$ are positive, $Q_\tau \geq 0$ implies that

$$0 \leq P \leq s+\tau\delta-c, \tag{5}$$

$$0 \leq \gamma \leq \frac{1}{1-\tau}, \quad \text{and} \tag{6}$$

$$\tau \geq \max\left\{\frac{c-s}{\delta}, 0\right\} \quad \text{because } s+\tau\delta-c>0. \tag{7}$$

Inequality (5) implies that the higher the consumer's prior belief, the higher the price the software firm can charge for its commercial product. This is consistent with our previous observation on pricing the commercial product. It is worth noting that when both inequalities (5) and (6) are reversed, the condition of positive demand is still satisfied. However, this in turn renders a positive relationship between the price and the demand. Setting $P=\infty$ leads to $Q_\tau \to \infty$ for any $\gamma > 1/(1-\tau)$. Obviously, this result contradicts the law of demand, where the higher the price, the lower the quantity demanded. As a result, we require the constraint for positive demand be given by inequalities (5) and (6). Inequality (7) shows that there is a trial time threshold, which is decided by the aggregate cost and consumer's prior belief. When $c<s$, τ can be any value between 0 and 1. If $c>s$, which implies the cost of using the software is higher than consumer's prior expectation about the functionality of the software, then $(c-s)/\delta$ is the least amount of free trial time a firm should offer if it wants to secure positive demand. A higher cost of using the software c leads to a longer minimum required free trial time.

In reality, as software becomes more sophisticated, the aggregate software usage cost c (which includes the learning cost) becomes higher. A longer free trial time is required to help alleviate the increased learning cost. For example, breaking away from the traditional 30-day free trial, Microsoft starts offering its newly released Visual Studio 2008, Internet Security and Acceleration server 2006, Windows server 2008 for 90 days, 180 days, and 240 days free trial, respectively. Table 3 clearly shows that as software products contain more sophisticated functionalities, resulting in higher learning cost for consumers to get acquainted with them, a longer trial time is observed.

To determine the impact of a change in γ on Q_τ, while holding τ constant, one has the following:

$$\frac{\partial Q_\tau}{\partial \gamma} = \frac{(1-\tau)^2(s+\tau\delta-P-c)}{(s+\tau\delta)(1-\gamma+\gamma\tau)^2}, \quad \text{and}$$

$$\frac{\partial Q_\tau}{\partial \gamma} > 0 \quad \text{if } (s+\tau\delta-P-c)>0, \quad \text{or equivalently}$$

$$\tau > \frac{P+c-s}{\delta}. \tag{8}$$

Inequality (8) implies that the increase of network effect will increase the number of total buyers if the length of the free trial is greater than $(P+c-s)\delta$. Similarly, to determine the impact of a change in τ on Q_τ, while holding γ constant, we have

$$\frac{\partial Q_\tau}{\partial \tau} = \frac{(s+\delta(1-\gamma(1-\tau)^2))(P+c)-(s+\tau\delta)^2}{(1-\gamma+\gamma\tau)^2(s+\tau\delta)^2}.$$

Depending on the underlying parameters, the impact of a change in the free trial time on the total demand of the software could first be positive and then negative or negative all the time as the free trial time τ varies from 0 to 1. However, for most cases the total demand will first increase as free trial time increases, then decreases, and eventually goes to zero as the free trial time keeps increasing. Indeed, offering a trial time that is shorter than optimal reduces the number of free riders, but doing so weakens the demand of the software. Offering a trial time longer than optimal leads to too many free riders, thereby offsetting

Table 3 Examples of Time-Locked Free Trial Software with Various Trial Time

Time-locked free trial				
Trial <30 days	30-day trial	60-day trial	60 days < Trial < 180 days	Trial ≥ 180 days
McAfee (14 days)	Mathtype	Microsoft Office 2007	Microsoft CRM 3.0	Windows 7
SPSS (14 days)	EndNote	Windows Server 2008	Visual Studio 2008	
World of Warcraft (10 days)	VMware	Apple MobileMe		
Wordtracker (7 days)	Apple iWork09		Sun-Ray Software 4	
	Adobe Acrobat Pro9			

the increased demand. One of the major contributions of this study is to provide the software firms useful guidelines when such a dilemma exists.

3.2. Time-Locked Free Trial Basic Models: Correlation Between Consumers' Valuation and Usage Time

3.2.1. Optimal Pricing Strategy While τ Is Given. In this subsection, we explore the optimal pricing strategy when the software firm faces a common established free trial period in the industry.[9] When the speed of consumer's belief updating (δ), the free trial period (τ), the consumer's prior belief (s), the network effect (γ), and the aggregate software usage cost (c) are exogenously given, the software firm seeks to set the price of the commercial product to maximize its profit as follows:

$$\max_P \ \pi = PQ_\tau = \frac{(1-\tau)(s+\tau\delta-P-c)}{(s+\tau\delta)(1-\gamma+\gamma\tau)}P,$$
$$\text{s.t. } 0 \le P \le s+\tau\delta-c. \tag{9}$$

Note that the total revenue function in Equation (9) amounts to the profit function due to the negligible marginal production cost of software. Solving the above problem yields the following optimal price, demand, and profit of the commercial software.

$$P^* = \frac{s+\tau\delta-c}{2}, \tag{10}$$

$$Q_\tau^* = \frac{(1-\tau)(s+\tau\delta-c)}{2(s+\tau\delta)(1-\gamma+\gamma\tau)}, \tag{11}$$

$$\pi^* = \frac{(1-\tau)(s+\tau\delta-c)^2}{4(s+\tau\delta)(1-\gamma+\gamma\tau)}. \tag{12}$$

To address the question whether the firm should offer a time-locked free trial, we compare the above results with those of the benchmark case when no free trial is offered, where $P_B^* = (s-c)/2$, $Q_B^* = (s-c)/(2s(1-\gamma))$, and $\pi_B^* = (s-c)^2/(4s(1-\gamma))$. We find that the software firm will be able to charge a higher optimal price for its commercial software by offering a time-locked free trial. However, the cannibalized demand and free riders problem described in Figure 1 result in a smaller overall demand than when the free trial is not offered. When the network effect is strong, the increase in price premium cannot compensate the cannibalized demand and free riders problem, and the firm is better off not to offer time-locked free trial. In summary, the firm will realize more profit by offering the time-locked free trial if the network effect γ is less than $\bar{\gamma}_1$ specified in Equation (13).

$$\bar{\gamma}_1 = \frac{(s-c)^2(s+\tau\delta)-(1-\tau)(s+\tau\delta-c)^2 s}{(1-\tau)[(s-c)^2(s+\tau\delta)-s(s+\tau\delta-c)]}. \tag{13}$$

We thus have the following proposition.

Proposition 1. *Offering time-locked free trial software using a common free trial period established in the industry, the firm can charge a higher price premium for its commercial software at the expense of a smaller demand. That is,*

$$P^* = \frac{(s+\tau\delta-c)}{2} > \frac{s-c}{2} \quad \textit{and}$$
$$Q_\tau^* = \frac{(1-\tau)(s+\tau\delta-c)}{2(s+\tau\delta)(1-\gamma+\gamma\tau)} < Q_B^*.$$

Overall, offering time-locked free trials result in a higher profit of

$$\pi^* = \frac{(1-\tau)(s+\tau\delta-c)^2}{4(s+\tau\delta)(1-\gamma+\gamma\tau)}$$

when the network effect is modest, i.e.,

$$\gamma < \bar{\gamma}_1 = \frac{(s-c)^2(s+\tau\delta)-(1-\tau)(s+\tau\delta-c)^2 s}{(1-\tau)[(s-c)^2(s+\tau\delta)-s(s+\tau\delta-c)]}.$$

3.2.2. Finding Both Optimal Price P^* and Optimal Trial Time τ^*. By relaxing the restriction that the free trial time is exogenously given, the problem is generalized into one where the software firm seeks to find both the optimal free trial time and optimal price of its commercial product, so that its profit is maximized as follows:

$$\max_{\tau,P} \ \pi = PQ_\tau = P\cdot\frac{(1-\tau)(s+\tau\delta-P-c)}{(s+\tau\delta)(1-\gamma+\gamma\tau)},$$
$$\text{s.t. } 0 \le P \le s+\tau\delta-c, \quad \text{and} \quad 0 \le \tau \le 1. \tag{14}$$

[9] For example, 30 days free trial time seems to be used by most software producers.

Solution procedure to derive the optimal free trial time τ^* and optimal price P^* to the above problem is described in the online appendix.[10] In particular, the software firm is better off offering a time-locked free trial when the network effect is smaller than the threshold $\bar{\gamma}_2$, where

$$\bar{\gamma}_2 = 1 - \frac{s(s-c)}{\delta(s+c)}. \tag{15}$$

It can be easily shown that $\partial\bar{\gamma}_2/\partial s < 0$ when $s > c$. This implies that the higher the consumer's prior belief, the less likely the time-locked free trial strategy is desirable. Recall that the best strategy for the software firm is not to offer any free trial if consumers initially overestimate the software. Apparently, even if consumers initially underestimate the functionality about the software, the firm may still be better off not to offer a time-locked free trial in the presence of a high consumers' prior belief.

To gain further insights into the software firm's time-locked free trial design problem, we plot the behavior of the firm's profit with respect to various free trial times and network effect intensities in Figure 2(a), and the impact of different consumers' prior beliefs and network effect intensities on the optimal free trial time in Figure 2(b). In performing the numerical analyses for these figures, we let consumers' prior belief vary between 10% and 60% of the true functionalities and set the software usage cost at 10 percent of the true functionalities, i.e., $s \in [0.1s_0, 0.6s_0]$, and $c = 0.1s_0$. A key benefit of this approach is that the insights from the analyses will not be affected by the absolute value of the true functionalities of software s_0.[11] Choosing $c = 10\%$ corresponds to a low aggregate usage cost so that the effect of c will not overshadow the effect of the free trial. Note that we start plotting consumer's prior belief from $s = 10\%$ because it is required to have $s - c \geq 0$ when $\tau = 0$ in order to ensure a positive demand. The upper bound of consumer's prior belief is $s = 0.6s_0$ as prescribed by Equation (15), because offering time-locked free trial is not desirable for the case of consumer's belief exceeding 60% of true functionalities of the software.

Two observations are in order regarding Figure 2(a). First, the overall profit increases with γ due to the positive network effect, and the shape of the overall profit curve shifts from concave to convex as the network effect increases and the point where the overall profit function changes from concave to convex is the threshold value $\bar{\gamma}_2$ (which equals 0.7 in the figure). Second, the optimal trial time τ^* decreases as the network effect increases, and eventually converges to zero (i.e., no free trial is desirable) when the network effect exceeds the threshold value $\bar{\gamma}_2$.

Figure 2(a) **The Impact of γ on Software Firm's Profit π for Different Trial Times ($s = 0.4s_0$, $c = 0.1s_0$)**

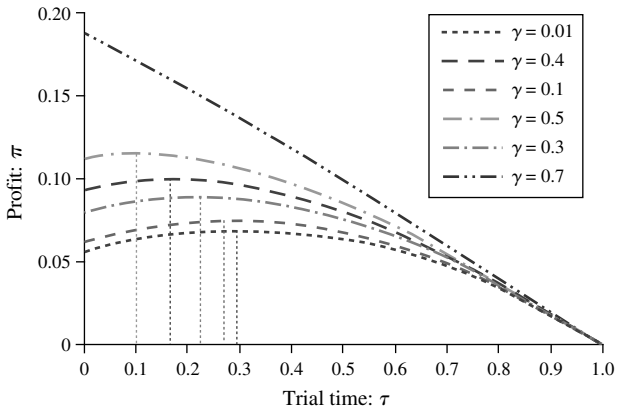


Figure 2(b) **Behavior of Optimal Trial Time τ^* for Different Network Effect Intensities ($c = 0.1s_0$)**

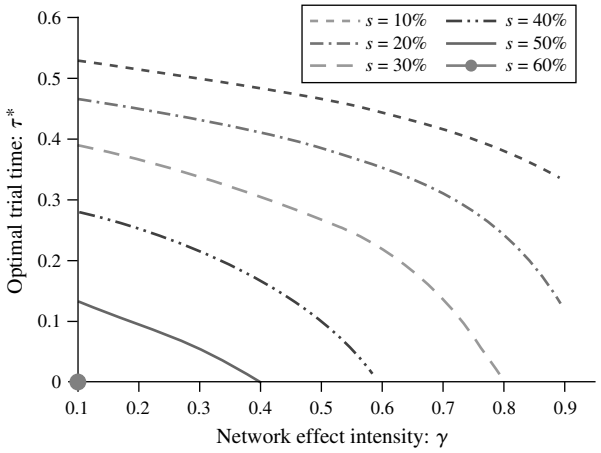


Figure 2(b) shows that the optimal free trial time τ^* decreases as the network effect intensity γ increases. A stronger network effect will benefit the firm and thus entails a shorter optimal free trial time. This pattern holds for all feasible ranges of consumer's prior belief. Furthermore, given the same network effect intensity, the optimal trial time becomes shorter when consumers have a higher prior belief about the software functionality.

Proposition 2 summarizes the key findings of the software firm's time-locked free trial design problem.

Proposition 2. *The firm realizes more profit offering time-locked free trial software with an optimally set free trial time when the network effect is below the threshold* $\bar{\gamma}_2 = 1 - s(s-c)/(\delta(s+c))$. *The optimal free trial time is specified by Equation* (A.8) *in the online appendix, and it decreases as the network effect or consumer's prior belief increases.*

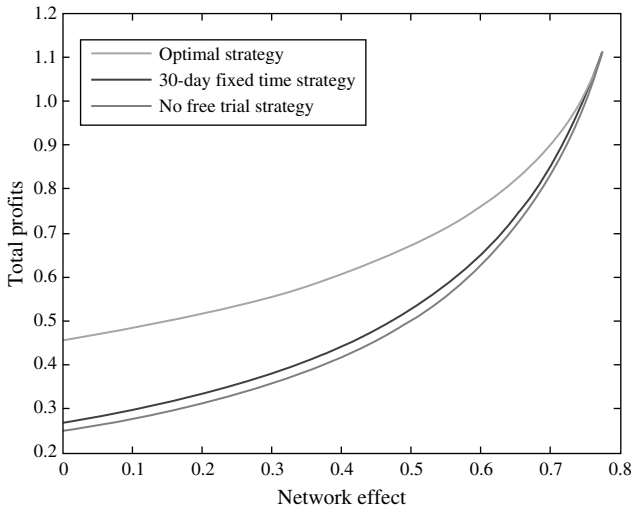
[10] An electronic companion to this paper is available as part of the online version at http://dx.doi.org/10.1287/isre.1110.0348.

[11] We thank the associate editor for suggesting this approach.

3.2.3. Why Setting the Optimal Free Trial Time Matters. From the perspective of a software product manager, a question of significant interest is: Why does it matter to find the optimal free trial time for software? A 30-day free trial seems to be an intuitively reasonable time. Gallaugher and Wang (1999) have shown that firms that offer a 30-day trial version of their products were able to price their products roughly 1.33 times higher than firms that did not offer a trial, but whether the 30 days is the optimal free trial time remains unanswered. To address this question, we consider a software product with a three-year lifespan where a 30-day free trial time corresponds to $\tau = 30/(365 \times 3) = 0.027397$. We exhaust all possible combinations of model parameters to compare the performance of a 30-day free trial strategy with that of an optimally set trial time under various consumers' prior beliefs and network externalities. We demonstrate through a representative example in Figures 3(a) and 3(b) that the profit difference between the two can be substantial, especially when the network effect of the software is moderate.

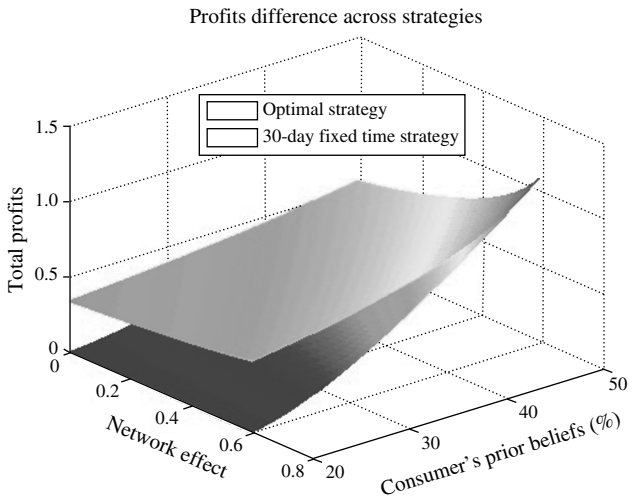
In Figures 3(a) and 3(b), we explore the behavior of profits with no free trial, a 30-day free trial, and a free trial with the optimal trial time in respect to the changes of network effect and consumer's prior belief. As shown in Figure 3(a), where $c = 0.1s_0$ and $s = 0.3s_0$, a 30-day fixed time free trial strategy performs only marginally better than the no free trial strategy. However, once the firm implements the optimal trial time, a significant improvement in profit is observed. In the experiment shown, the profit gain of adopting the optimal trial time over a 30-day free trial can be as much as 80%, which shows how crucial it is for the software firms to set an optimal trial time specified in Equation (15).

Figure 3(a) Profits Difference w.r.t. γ



Note. $s = 0.3s_0$, $c = 0.1s_0$, Software life span = 3 years.

Figure 3(b) Profits Difference w.r.t. s and γ



Note. $c = 0.1s_0$ and software life span = 3 yrs.

In Figure 3(b), we further allow consumers' prior belief to change between 20% and 50% of the software's true functionality while holding all other parameters the same as those in Figure 3(a). The same finding is observed. The surface of setting the optimal free trial time dominates that of the 30-day free trial, and the lower the consumer's prior belief, the larger the profit gap between the two. We note that recently Microsoft Visual Studio 2008 offered a 90-day free trial rather than the traditional 30 day trial. As software becomes more sophisticated, the gap between consumers' prior belief and the software's true functionality will become larger, leading to a longer optimal trial time. Because implementing the optimal free trial time requires the knowledge of consumers' prior belief s and software usage cost c, some firms might simply conform to the popular practice of offering a 30-day free trial for the lack of information on s and c. Investing in market research and software usability testing to identify the values of s and c should help overcome this obstacle to implementing an optimal free trial time.

3.3. Time-Locked Free Trial Extended Models: Positive Correlation Between Consumers' Valuation and Usage Time, Risk-Averse Consumers, and Switching Cost Effect

3.3.1. Correlation Between Consumer Type and Usage Time. The consumers in our model are uniformly distributed over consumer type θ and usage time t in Figure 1. This uniform distribution implicitly implies an independence between θ and t. The area under the product of two subintervals $[\theta_\tau, 1] \times [\tau, 1]$ therefore corresponds to the demand (i.e., buyers) of the software. However, consumers' high valuation for functionality might be caused by the need to use the

software for a long period of time. That is, there might be a positive correlation between consumers' software usage time and their type.

To account for this positive correlation between consumer type and the software usage time, we let the joint density function of usage time t and consumer type θ, $f(t,\theta)$, be the Morgenstern (1956) bivariate uniform distribution in Mardia (1970, p. 76) as follows:

$$f(t,\theta) = 1 + \alpha(2t-1)(2\theta-1), \quad \text{where } 0 \le \alpha \le 1.$$

The parameter α captures the intensity of the correlation as the Pearson correlation coefficient ρ between t and θ equals one third of α (i.e., $\rho = \alpha/3$). The total number of buyers in this positive correlation case is thus derived as

$$\begin{aligned} D &= \int_{\theta_\tau}^{1}\int_{\tau}^{1} f(t,\theta)\,dt\,d\theta \\ &= (1-\theta_\tau)(1-\tau) + \alpha\tau\theta_\tau(1-\tau)(1-\theta_\tau). \end{aligned} \quad (16)$$

We note that the new demand function meets the following three requirements.

1. When $\tau = 0$, the model converges to the no free trial case, where the demand of the commercial software is equal to $1-\theta_\tau$.

2. When $\tau = 1$, because the trial time is unlimited, all users enjoy the free ride, and hence the demand of the commercial software should equal 0.

3. As the free trial time τ varies in $[0,1]$, the total number of buyers should never exceed that of the market potential: $(1-\theta_\tau)\times 1$.

Invoking the rational expectation equilibrium, one has the demand of the commercial software in the presence of a positive correlation between t and θ by substituting θ_τ, described in Equation (2), into Equation (16) and setting $D = Q_\tau$. The demand Q_τ is thus the positive root of the following quadratic function of Q_τ,

$$\begin{aligned} f(Q_\tau) = (1-\tau)\Bigg(1 - \frac{p+c}{s+\delta\tau}\Bigg(1 + \alpha\tau + \alpha\tau\frac{p+c}{s+\delta\tau}\Bigg) \\ - \gamma\Bigg(\alpha\tau - 2\alpha\tau\frac{p+c}{s+\delta\tau} - 1\Bigg)Q_\tau - \alpha\tau\gamma^2 Q_\tau^2\Bigg) = 0. \end{aligned}$$

That is,

$$Q_\tau = \frac{\sqrt{s+\delta\tau}\sqrt{U} - s(\gamma(1-\tau)(1-\alpha\tau)-1) - \tau(\gamma(1-\tau)(2\alpha(P+c)+\delta-\alpha\delta\tau)-\delta)}{2\alpha\gamma^2(1-\tau)\tau(s+\delta\tau)}, \quad (17)$$

where

$$\begin{aligned} U = s\cdot\big[1 + \gamma(-1+\tau)(2 - 2\alpha\tau - \gamma(1-\tau)(1+\alpha\tau)^2)\big] \\ + \tau\cdot\big[\delta - \gamma(1-\tau)(4c\alpha + 4P\alpha \\ + \delta(2 - 2\alpha\tau - \gamma(1-\tau)(1+\alpha\tau)^2))\big]. \end{aligned}$$

Because the expression of Q_τ in Equation (17) is quite complicated, for managerial insights into the impact of the positive correlation between t and θ we first derive closed-form solutions to the case of no network externalities and subsequently study the case of network externalities via computational analyses. When no network externalities exist, i.e., $\gamma = 0$, the demand of commercial software is expressed by $Q_\tau = (1-(p+c)/(s+\delta\tau))(1-\tau) + \alpha\tau((p+c)/(s+\delta\tau))(1-\tau)(1-(p+c)/(s+\delta\tau))$. The corresponding optimal price and profit for the software firm under no network externalities and a positive correlation between t and θ are

$$P^* = \frac{1}{3\alpha\tau}[W - s(1-\alpha\tau) - \tau(2c\alpha + \delta(1-\alpha\tau))], \quad \text{and}$$

$$\begin{aligned} \pi^* = \frac{1}{27\alpha^2\tau^2(s+\delta\tau)^2}(1-\tau) \\ \cdot(s - c\alpha\tau + 2s\alpha\tau + \delta\tau + 2\alpha\delta\tau^2 - W) \\ \cdot[s(2+\alpha\tau) + \tau(c\alpha + \delta(2+\alpha\tau)) + W] \\ \cdot[W - s(1-\alpha\tau) - \tau(2c\alpha + \delta(1-\alpha\tau))], \end{aligned}$$

where

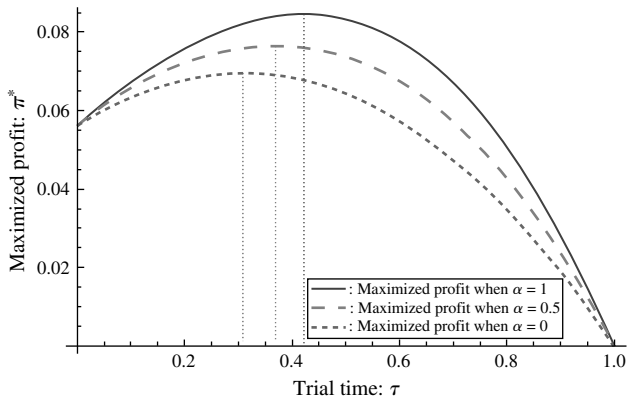
$$W = \sqrt{3\alpha\tau(s+\delta\tau-c)(s+(c\alpha+\delta)\tau) + (2c\alpha\tau + (1-\alpha\tau)(s+\delta\tau))^2}.$$

We then compare the above results with those of no correlation case by setting $\gamma = 0$ in Equations (10) and (12). Figure 4(a) shows that in the presence of a positive correlation between the consumers' type and usage time without network externalities, the firm enjoys a higher optimal profit and sets a longer optimal free trial time. The stronger the correlation, the higher the optimal profit and the longer the optimal free trial time.

Our computational analyses indicate that when the network externalities effect is superimposed on a positive correlation between the consumers' type and usage time, the same pattern in Figure 4(a) holds. That is, for a given network effect, the stronger the correlation, the higher the optimal profit and the longer the optimal free trial time. Conversely, for a given correlation, the effect of network externalities on the firm's profit and optimal trial time exhibits the same behaviors as those observed in Figure 2(a).

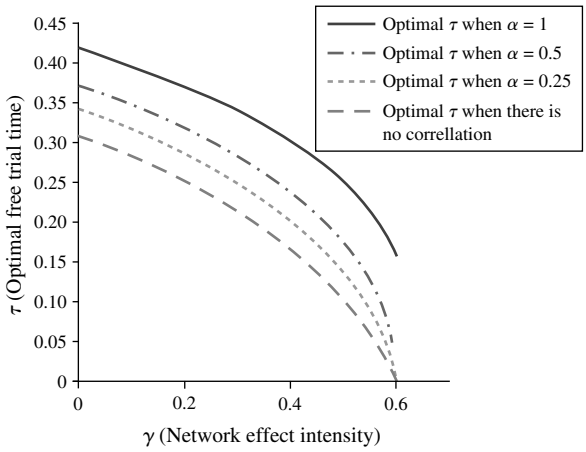
Figure 4(a) plots the change of the optimal trial time under the impact of different correlation intensities. We find that as the correlation intensity α increases, the optimal trial time increases accordingly, and the higher the network effect, the shorter the optimal trial time. The optimal trial times under different correlation intensities converge to zero approximately at $\gamma = 0.615$ for the shown experiment. Not surprisingly, the point where all curves converge is equivalent to the threshold value $\bar{\gamma}_2$ defined in Equation (15).

Figure 4(a) Optimal Profits—No Network Externalities and Various αs



Note. $s = 0.4s_0$, $\delta = 0.6s_0$, $c = 0.1s_0$, $\gamma = 0$, software life span = 3 years.

Figure 4(b) Change of Optimal Trial Time τ^* w.r.t. Network Effect and Various αs



Note. $s = 0.4s_0$, $\delta = 0.6s_0$, $c = 0.1s_0$, software life span = 3 years.

3.3.2. Software Free Trial Model for Risk-Averse Consumers. In our model, the effect of consumers' reduced uncertainty through free trial is reflected by the improvement of consumer's perceived functionalities about the software from s to $s + \tau\delta$ in Equation (1), which leads to an increase in consumers' willingness to pay with free trial. However, the reduced uncertainty might come in the form of reduced variance on perceived functionality. This reduction of variance on perceived functionality is most beneficial to risk-averse consumers, while for risk-neutral consumers, their willingness to pay does not necessarily increase as a result of reduced variance.

To model the effect of reduced variance on perceived functionality for risk-averse consumers, we let σ^2 correspond to the variance on perceived functionality for risk-averse consumers and the benefit of this reduction of variance be $-(1-\tau)\sigma^2$. The negative sign in the $-(1-\tau)\sigma^2$ term reflects the disutility of variance to risk-averse consumers, and the longer the free trial time, the greater the reduction of this disutility. We employ a commonly used square root functional form to capture the concave nature of risk-averse consumers' utility function (Friedman and Savage 1948). Thus, we have the utility function for risk-averse consumers as

$$U = \sqrt{(\theta + \gamma Q_\tau)s - (\theta + \gamma Q_\tau)(1-\tau)\sigma^2 - P - c}. \quad (18)$$

For risk-averse consumers described by Equation (18), the software free trial does not affect their perceived expected functionality s. Rather, the benefit of the free trial is reflected by a reduction of the variance term $(1-\tau)\sigma^2$, which in turn increases risk-averse consumers' utility.

The indifferent customer, between purchasing commercial software and doing without, in this case becomes $\theta_\tau = ((P+c)/(s-\sigma^2(1-\tau))) - \gamma Q_\tau$, and the demand of commercial software is given by $Q_\tau = (1-\tau)(s-\sigma^2(1-\tau)-P-c)/(s-\sigma^2(1-\tau))(1-\gamma+\gamma\tau)$. For a given free trial time τ, the corresponding optimal price and profit of the commercial software for risk-averse consumers are

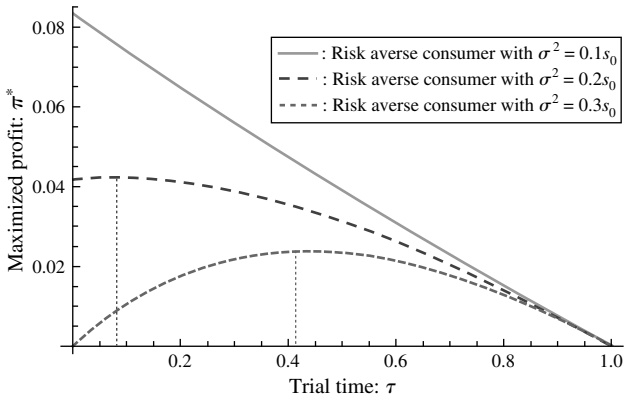
$$P^* = \frac{s - \sigma^2(1-\tau) - c}{2} \quad \text{and}$$

$$\pi^* = \frac{(1-\tau)(s-\sigma^2(1-\tau)-c)^2}{4(s-\sigma^2(1-\tau))\cdot(1-\gamma+\gamma\tau)}.$$

Figure 5 shows the impact of the variance on the optimal free trial time and the profit of the firm. In particular, a larger variance of risk-averse consumers on perceived functionalities entails a longer optimal free trial time.

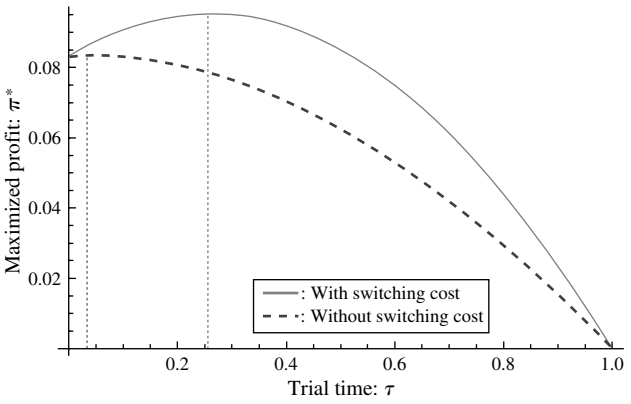
3.3.3. Software Free Trial Model with Switching Cost Effect. In reality, the provision of the software free trial enables consumers to become familiarized with the inner workings of the software, which reduces the learning cost of using it, a major component of the aggregate usage cost. The longer the free trial,

Figure 5 Change of π^* w.r.t. τ for Risk-Averse Consumers



Note. $s = 0.4s_0$, $\delta = 0.6s_0$, $c = 0.1s_0$, and $\gamma = 0.4$.

Figure 6 Optimal Profit and Trial Time With and Without Switching Cost



Note. $s = 0.4s_0$, $\delta = 0.6s_0$, $c = 0.1s_0$, $\gamma = 0.2$, software life span = 3 years.

the lower the aggregate usage cost incurred by consumers. This lowered aggregate usage cost through software free trial translates into a higher switching cost (Chen and Hitt 2002) for consumers because they have to learn the competitor's product anew should they switch. A locked-in effect thus ensues from an increased switching cost. We show how our model, with minor modification, is capable of capturing such locked-in effects, and we examine the locked-in effects on the firm's optimal profit and free trial time when the switching cost is considered. Specifically, we revise the aggregate usage cost in consumers' utility function in Equation (1) to become a decreasing function of free trial time as follows:

$$U = (\theta + \gamma Q_\tau) \cdot (s + \tau\delta) - c(1 - \tau) - P. \qquad (19)$$

Solving the same maximization problem under this new formulation of the aggregate usage cost that takes into account consumer's switching cost, the software firm obtains the optimal price $P^* = (s + \tau\delta - c(1-\tau))/2$ and optimal profit $\pi^* = (1-\tau)(s+\tau\delta - c(1-\tau))^2/(4(s+\tau\delta)(1-\gamma+\gamma\tau))$.

Figure 6 reports a representative example where the dashed line indicates the profit curve without considering the switching cost effect, while the solid line shows the profit curve when the switching cost effect is considered. In the presence of the switching cost effect, the firm realizes a higher profit and purposely sets a much longer optimal trial time of $\tau^* = 0.25$ (≅274 days) versus 0.04 (≅44 days) in the case where the switching cost effect is not considered.

The following proposition summarizes the key findings of time-locked free trial extended models.

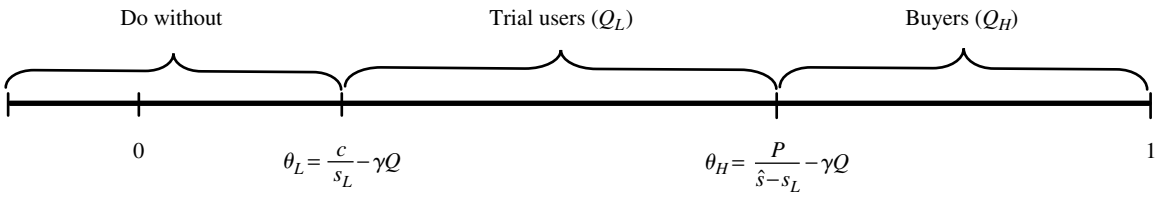
Proposition 3. (1) *When a positive correlation exists between consumers' type (preference for software functionality) and their usage time, the firm realizes a higher profit than the case without this positive correlation. A stronger correlation entails a longer optimal free trial time.* (2) *A longer optimal free trial time is needed for risk-averse consumers to overcome a larger variance on their perceived software functionality.* (3) *When the switching cost effect is considered, the firm will purposely set a much longer optimal free trial time.*

4. A Unified Framework for Comparing Limited Version with Time-Lock Free Trial

4.1. Limited Version Free Trial

Instead of offering a time-locked free trial, the software firm has the strategic option of providing a limited version free trial software to the market. As shown in Figure 7, there are two marginal consumers in the model of limited version free trial—the marginal consumer who is indifferent between doing without and trying the free limited version software (denoted by θ_L) and the marginal consumer who is indifferent between the free and the commercial software (denoted by θ_H). We consider the rational expectation equilibrium where consumers do not switch between products and there are no repeat purchases. Furthermore, each individual in the market chooses one and only one of the following three options: do without, use the free trial software, or buy the commercial software. A potential consumer of type θ derives $(\theta + \gamma Q) \cdot s_L - c$ net utility from trying the software and $(\theta + \gamma Q)\hat{s} - P - c$ from purchasing the software, where s_L is the functionalities offered by the trial product and $\hat{s}$ is the consumer's belief about the functionalities offered by the commercial product, on which they base their purchase decisions. The market segment between θ_L and θ_H corresponds to the users of free trial software (Q_L), and the segment between θ_H and 1 corresponds to the buyers of the commercial software (Q_H). Because limited ver-

Figure 7 Model of Limited Version Free Trial



sion free trial users have unlimited trial time, the total installed base Q of the software includes both commercial and trial users, i.e., $Q = Q_L + Q_H$.

To have $Q_L \geq 0$, the seller has to set the price of its commercial software such that $P \geq c((\hat{s} - s_L)/s_L)$. In other words, when the price of the commercial product is lower than $c((\hat{s} - s_L)/s_L)$, no one wants to use the less functional trial software, and all potential consumers with positive net utility will simply buy the commercial product, which nullifies the firm's strategic offering of the free trial software. Similarly, to have a nonnegative demand of the commercial product, the price P must satisfy an upper-bound constraint $P_H \leq (\hat{s} - s_L)/(s_L(1-\gamma))(s_L - c\gamma)$.

By setting an optimal price of $P^* = (\hat{s} - s_L)(s_L - c\gamma)/(2s_L(1-\gamma))$, the software firm realizes the maximized profit of $\pi^* = (\hat{s} - s_L)(s_L - c\gamma)^2/(4s_L^2(1-\gamma)^2)$. It can be verified that introducing a limited version free trial is not desirable for the software firm if $\gamma < 2 - s_L/c$. Apparently, this threshold value decreases for a smaller software usage cost c. This explains why the software industry strives to improve the user-friendliness of software products, which lowers consumer's learning cost of using the software.

4.2. Optimal Product Design of Limited Version Free Trial

In the previous section, we treat the functionality of the free trial software s_L as an exogenous parameter. In this section, we relax this assumption to see how the optimal solution varies. The monopoly's optimal design problem is thus described as the constrained profit maximization problem as follows:

$$\max_{P,\, s_L} \quad \pi = PQ_H = \frac{P(s_L - c\gamma)}{s_L(1-\gamma)} - \frac{P^2}{\hat{s} - s_L},$$

$$\text{s.t.} \quad c\frac{\hat{s} - s_L}{s_L} \leq P \leq \frac{s_L - c\gamma}{s_L(1-\gamma)}(\hat{s} - s_L) \quad \text{and} \quad 0 \leq s_L \leq \hat{s}.$$

Note that the price P must satisfy the upper- and lower-bound conditions in order to guarantee nonnegative demands for both trial users Q_L and buyers Q_H. The functionalities of the trial product s_L must satisfy the second constraint in order to guarantee that at least some consumers will purchase the software (i.e., $0 \leq \theta_L \leq \theta_H \leq 1$). The optimal functionality of the limited version free trial and the price of the commercial software from Cheng and Tang (2010) are summarized in Proposition 4.

Proposition 4. *The optimal solution to the software firm's limited version free trial design problem is described by*

$$P^* = \frac{4\hat{s} + 5c\gamma - 3\sqrt{(c\gamma)^2 + 8c\gamma\hat{s}}}{8(1-\gamma)}, \quad \textit{and}$$

$$s_L^* = \frac{-c\gamma + \sqrt{(c\gamma)^2 + 8c\gamma\hat{s}}}{2}.$$

The optimal profit equals

$$\pi^*_{\text{Limited}} = \frac{8c^3\gamma^3 + 26c\gamma\hat{s}^2 + 47c^2\gamma^2\hat{s} - (2\hat{s}^2 + 17c\gamma\hat{s} + 8c^2\gamma^2)\sqrt{(c\gamma)^2 + 8c\gamma\hat{s}}}{4(1-\gamma)^2(c\gamma - \sqrt{(c\gamma)^2 + 8c\gamma\hat{s}})(c\gamma + 2\hat{s} - \sqrt{(c\gamma)^2 + 8c\gamma\hat{s}})},$$

and the software firm prefers to offer the limited-version free trial for greater profit if $2c/(c + \hat{s}) < \gamma < (c^2 - 4c\hat{s} + 4\hat{s}^2)/c^2$.

It is of interest to note that offering a limited version free trial is more suitable for software products that exhibit strong network effect. However, when the network effect is higher than the upper bound $(c^2 - 4c\hat{s} + 4\hat{s}^2)/c^2$, described in Proposition 4, the firm is better off not to offer a limited free trial to take advantage of the extra high network effect and to avoid the cannibalized demand caused by the limited version free trial. We show in the following discussion that with a simple extension, the above results can be incorporated into a unified framework and compared against the optimal solutions for the time-locked free trial problem derived in §3.

Similar to what we proposed in the time-locked free trial analysis, we extend the one-dimensional limited version model by introducing the free trial time parameter τ. Instead of treating τ as a decision variable, we set $\tau = 1$ to represent the unlimited trial time nature of limited version. The limited version strategy also helps consumers reduce their uncertainties and update their beliefs about the functionalities of the commercial product. However, because free trial users have access to only limited functionalities, we assume limited version trial users have a slower belief updating speed than time-locked users (i.e., $\delta_{\text{limited}} < \delta$). In addition, we let $\hat{s} = s + \tau\delta_{\text{limited}}$ so that the limited version trial users share the same prior belief s as the time-locked users but with unlimited trial time ($\tau = 1$) and slower belief updating speed ($\delta_{\text{limited}} < \delta$). Then, the consumer's utility function for the limited version trial users can be rewritten as $(\theta + \gamma Q)(s + \tau\delta_{\text{limited}}) - c$, in the same way as the one for the time-locked users. After this transformation, optimal solutions to the time-locked free trial problem become directly comparable to those from the limited version analysis.

4.3. Limited Version or Time-Lock?

The software firm will adopt the time-locked free trial strategy over the limited version if the firm realizes more profit with the time-locked free trial software, i.e., $\pi^*_{\text{Time-Lock}} \geq \pi^*_{\text{Limited}}$, where

$$\pi^*_{\text{Time-Locked}} = \frac{(1-\tau^*)(s + \tau^*\delta - c)^2}{4(s + \tau^*\delta)(1 - \gamma + \gamma\tau^*)}, \tag{20}$$

$$\pi^*_{\text{Limited}} = \frac{8c^3\gamma^3 + 26c\gamma\hat{s}^2 + 47c^2\gamma^2\hat{s} - (2\hat{s}^2 + 17c\gamma\hat{s} + 8c^2\gamma^2)\sqrt{(c\gamma)^2 + 8c\gamma\hat{s}}}{4(1-\gamma)^2(c\gamma - \sqrt{(c\gamma)^2 + 8c\gamma\hat{s}})(c\gamma + 2\hat{s} - \sqrt{(c\gamma)^2 + 8c\gamma\hat{s}})}, \tag{21}$$

and

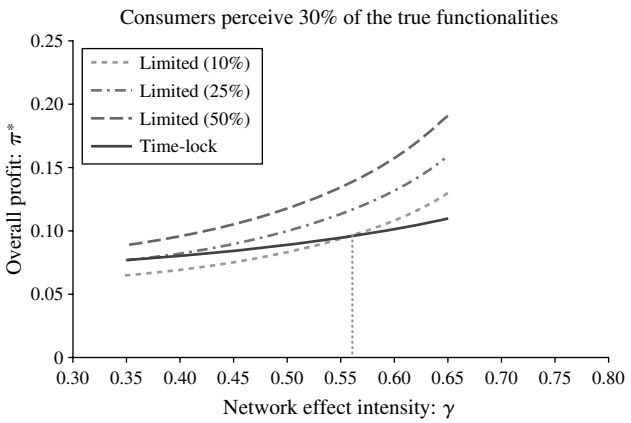
$$\frac{2c}{c+\hat{s}} \le \gamma \le \min\left\{\frac{c^2-4c\hat{s}+4\hat{s}^2}{c^2}, 1-\frac{s(s-c)}{\delta(s+c)}\right\}. \quad (22)$$

Inequality (22) ensures that adopting either free trial strategy is desirable for the software firm. Equation (20) represents the optimal profit for adopting the time-locked free trial strategy in the absence of a correlation between consumer type and usage time as described in Proposition 2, while Equation (21) is the optimal profit of the limited version strategy from Proposition 4.

Although we have closed-form solutions for maximum profits to both time-locked and limited version free trial problems specified in Equations (20) and (21), it is intractable to derive analytical conditions to describe which strategy generates more profit for the software firm. We thus turn to numerical analyses to answer this question. Figure 8(a) reports the results of comparing the limited version strategy with the time-locked strategy where no correlation exists between consumer type and usage time. Figure 8(b) shows the impact of this correlation.

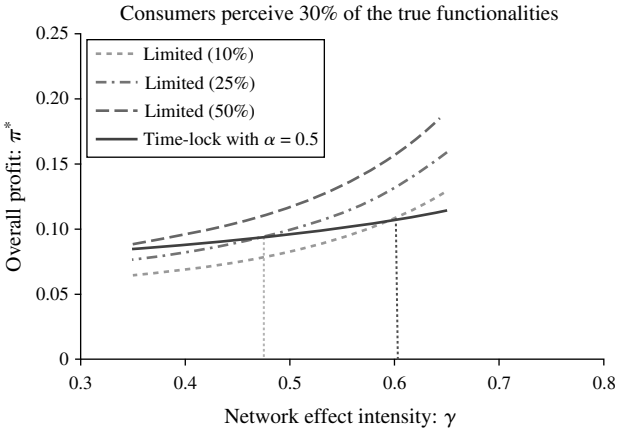
Because it is not clear how fast a consumer updates his belief with a limited version trial (δ_{limited}) compared with that of a time locked trial (δ), we vary the relative gap between the two variables and plot the scenarios where δ_{limited} is 10%, 25%, and 50% of δ in Figure 8(a). It shows that the trajectory pattern of overall profit is increasing in the network effect for both strategies, thereby suggesting that a stronger network effect is beneficial for the software firm. Limited version free trial dominates the time-locked strategy by generating more profit when consumers' limited version belief updating speed is greater than a quarter of that of the time-locked version (i.e., $\delta_{\text{limited}} \ge 25\%\delta$). However if consumers' limited version belief updating speed is one-tenth that of the time-locked (i.e., $\delta_{\text{limited}} = 10\%\delta$), the limited version strategy becomes more desirable under strong network effect, while time-locked free trial is preferred when the network effect is moderate. For example, $\gamma < 0.558$ is the condition under which time-locked free trial strategy outperforms that of the limited version when users perceive 30% of the true functionalities before the trial.

Figure 8(a) Time-Lock (No Correlation) vs. Limited Version



Note. $s = 0.3s_0$, $c = 0.1s_0$, software life span = 3 years.

Figure 8(b) Time-Lock (with Correlation) vs. Limited Version



Note. $s = 0.3s_0$, $c = 0.1s_0$, software life span = 3 years.

Using the same parameters, Figure 8(b) clearly shows that the existence of a correlation between consumer type and usage time moves the profit curve of time-locked free trial strategy upward, making it a more desirable strategy than the limited version one when $\delta_{\text{limited}} = 10\%\delta$ and $\gamma < 0.605$, or $\delta_{\text{limited}} = 25\%\delta$ and $\gamma < 0.475$.

In summary, we find that the software firm should offer the time-locked free trial over the limited version free trial for greater profit if the network effect is moderate and a bigger gap between consumer's prior belief and the true functionality of the software exists. When the network effect is strong, the firm will achieve greater profit by offering the limited version free trial to exploit the network effect.

5. Conclusions and Future Research

Providing free trial software, a prevalent practice in the software industry, usually comes with two flavors—a limited version and a time-locked version. The limited version free trial software has some functions disabled (e.g., print, save, etc.), but it can be used without any time constraint. The time-locked free trial allows users to access full functionality of the software for a predetermined time, typically 30 days.

In this paper, we address issues pertinent to time-locked free trial software with the following key findings. First, we find that a threshold of network effect exists. Only when the network effect is smaller than this threshold will the time-locked free trial become more profitable for the software firm than the benchmark case of no time-locked free trial. This threshold value decreases with the increase in consumer's

prior belief about the software's functionality. Second, the optimal trial time depends on a variety of factors, including the functionality of the software, consumers' prior belief about this functionality, the network effect, and the aggregate cost of using the software. The optimal trial time also is shown to decrease as the network effect increases. To simply conform to the common practice of 30-day free trial without setting an optimal trial time might result in a substantial profit loss. Third, the existence of a positive correlation between consumer type and the software usage time renders the time-locked free trial strategy more attractive to the firm for a wider range of network effect levels. Finally, we build a unified framework to help the software firm decide which form of free trial—limited version or time-locked—is the best free trial strategy. We find that limited version free trials generate greater profits in the presence of a strong network effect, while time-locked free trials outperform limited versions when the network effect is modest. Furthermore, software with sophisticated features and functionalities typically favors the time-locked free trial strategy, a finding corroborated by a recent empirical study of Lee and Tan (2007).

This paper is not without some limitations. First, the users' valuation type θ and their expected usage time t are both assumed to be uniformly distributed. They might follow a different distribution. For example, tax return software users are more likely to follow a skewed normal distribution about their expected usage time rather than a uniform one. Second, the aggregate usage cost in our model reflects the *net present value* of the cost that consumers incur across the usage time of the software, and consumers do not realize the true value of this cost unless they try out the software. Thus, a least amount of the trial time is needed to make it worthwhile for consumers to try the software. Our model employs the rational expectation equilibrium analysis to find the *equilibrium* results from the firm's perspective. Rational expectation equilibrium analysis cannot capture the dynamic process of consumers usage cost, the improvements of the software product throughout its life-cycle, or the evolution of the network size. Third, the software firm in our analysis is a monopoly. It is of interest to examine the impact of competition on a firm's free trial decision in a duopoly market, where both firms offer substitute software products and one firm has the advantage over the other with better functionalities. In the presence of competition, what will be the conditions for both firms to offer time-locked free trials and what will be the best strategy to the firm that has the functionality advantage? Another possible direction of future research is to examine the mixed free trial strategy by offering both limited version and time-locked free trials, albeit a strategy rarely observed so far. Several intriguing issues arise. Should the firm introduce both versions of free trials at the same time? Or should the firm first introduce the time-locked free trial, which turns into limited version upon expiration of the free trial period? What will be the optimal trial time, and what will be the optimal amount of functionalities offered by the limited version strategy in this context?

Electronic Companion

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