10-2014

Competition between Software-as-a-Service Vendors

Dan MA
Singapore Management University, madan@smu.edu.sg

Robert John KAUFFMAN
Singapore Management University, rkauffman@smu.edu.sg

Competition Between Software-as-a-Service Vendors

Dan Ma, *Member, IEEE*, and Robert J. Kauffman, *Member, IEEE*

***Abstract*—We propose a model of *software-as-a-service* (SaaS) in a competitive marketplace that brings clarity to the choices that competing vendors must make for pricing and quality strategy. We focus on several features of SaaS competition, including differences in vendor offerings, incomplete information on application functionality, the potential lock-in risk of SaaS clients, and their cost of learning about what it will take to make the vendors' software work well. Clients can sample the fit costs of adoption, but can switch to another vendor. We obtained several findings through the use of a game-theoretic model. First, a client's switching cost is important for its decision-making regarding SaaS adoption. With a relatively high switching cost, a more cost-efficient vendor of IT services will be able to drive the less cost-efficient competitor out of its market. Second, the impact of the client's switching cost on vendors works differently. An increase in switching cost enables one vendor to charge a higher price and achieve higher profit, while the other will be forced to charge a lower price and hardly make a profit. Third, what matters is not how much a vendor can enhance service quality, but instead how costly it will be to improve quality enough to attract sufficient customer interest to achieve profitability.**

***Index Terms*—Adverse and beneficial lock-in, cost efficiency, economic analysis, quality, services sampling, software-as-a-service (SaaS), strategy, switching costs, vendor competition.**

I. Introduction

SOFTWARE-AS-A-SERVICE (SaaS) is a cloud computing service in which information technology (IT) resources, including computing power, data storage, software applications, and technical infrastructure, are delivered to users through a network. Due to the rapid growth of the Internet, advances in telecom technologies and the drop in bandwidth costs, as well as the increasing use of productivity tools for the web, we have seen market interest and adoption of SaaS skyrocket [20]. Clients have wanted to reduce software and computing-related investment and operating costs, as well as by the interest of vendors to find new sources of revenues and profits.

We explore problems that IT clients face when they are interested in obtaining the help of a SaaS vendor to meet their on-demand computing needs. A client needs to figure out how to obtain the best long-term risk-adjusted rate of return from the services offered by the vendor it chooses to work with. Similarly, SaaS vendors need to have knowledge about clients' specific business needs, since the product they offer related to the outsourcing of some aspects of their clients' business processes may be new to them also. They may not know all they need in order to effectively incentivize potential clients, price their *offerings*, invest in delivering services of appropriate quality, and act to retain their customers.

To help the clients and vendors, we seek answers to several research questions that relate to the SaaS marketplace. What are the pricing strategy and service quality choices a SaaS vendor should employ to perform well in competition with another SaaS vendor? To what extent should a vendor's applications and services be differentiated from its competitor's applications and services? How should clients choose an appropriate vendor when they face incomplete information on vendors' offerings and potential risk of being locked in?

A. SaaS Market

In the past decade, SaaS delivery has outpaced traditional software application delivery, growing nearly five times faster than the software market as a whole, and has become a significant growth driver for the expansion of all software markets [30].[1] SaaS vendors bundle their software applications with supporting IT services to deliver new levels of value to their clients. The clients, meanwhile, must subscribe to use applications that are installed in a centralized location, and run and maintained by the vendor. Instead of purchasing and owning the software, the clients pay a fixed monthly or annual subscription fee to use the software applications.[2] Most SaaS offerings do not require one-time upfront payments though.[3] In many cases, SaaS may be cheaper for a firm than an in-house system; clients expect to save on support and upgrade costs, IT infrastructure, IT personnel, and implementation.

There are pros and cons with the SaaS business model. The benefits involve scalability, reliability, ease of deployment and management for clients, and rapid cost savings. The benefits trade off against the client's worries about trust, privacy, customization problems, performance, and ownership [14], [21].

Manuscript received May 22, 2013; revised February 17, 2014; accepted June 8, 2014. Date of publication July 16, 2014; date of current version October 16, 2014. The work of D. Ma was supported by Singapore's Ministry of Education Tier 1 Research Support Program. The work of R. Kauffman was supported by the Lee Kuan Yew Faculty Fellowship for Research Excellence at Singapore Management University. Review of this manuscript was arranged by Department Editor R. Sabherwal.

The authors are with the School of Information Systems, Singapore Management University, Singapore 178902 (e-mail: madan@smu.edu.sg; rkauffman@smu.edu.sg).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TEM.2014.2332633

[1]By 2015, about 24% of all new business software purchases will be for service-enabled software, and SaaS delivery will amount to more than 13% of worldwide software spending. The latest Gartner [25] projections suggest that global spending for SaaS will rise by nearly 18% in 2013 to US$14.5 billion, and to around US$26.5 billion by 2016.

[2]There are three layers of services in cloud computing: *infrastructure-as-a-service* (IaaS), *platform-as-a-service* (PaaS), and SaaS. Vendors operate them with the same general business approach: they deliver computing resources as services to clients through a network. Though there are similarities, the SaaS business model has some unique features that are not shared by PaaS or IaaS. For example, the SaaS vendor maintains only one copy of the software and related data on its server. Also, the vendors' pricing strategy for SaaS typically is more complicated than for IaaS and PaaS. For the latter, the vendors simply assign prices based per GB or per CPU hour. For SaaS, so far no standard pricing approach has been embraced on an industry-wide basis.

[3]For instance, Salesforce.com (www.salesforce.com) charges a monthly subscription fee of US$65 per user per month. It is free to subscribe as a user of Saleforce.com. No upfront fee is required.

Although the debates continue, today the SaaS software business model is widely viewed as having shaken the foundations of the software industry, and moving the new practices from niche status to mainstream popularity.

The SaaS business model has a number of novel characteristics. First, software applications from a SaaS vendor are *experience goods* for the people and organizations that use them. In the SaaS market, however, firm-specific and individualized customization is not the main thrust.[4] This is due to its *multitenancy structure*: vendors host one instance of the software on one server and maintain client data on one database [29]. This allows SaaS to achieve economies of scale for database management and code maintenance, which creates the basis for the related cost savings [41]. Multitenancy weighs against the customization of software applications, since the source code cannot be changed. SaaS vendors will have a hard time to profit by developing and maintaining versions to suit each of their clients. Instead, clients have to accept more standardized functionality, and absorb the risks of the ineffective fit.[5]

SaaS acts like an experience good for the clients: it will take a while for clients to figure out how well the software will work with their existing IT components. Also, because SaaS involves the payment of periodic fees instead of a large initial investment, clients will retain the option to switch to another vendor if they believe it is appropriate to do so. We have observed the *sampling and switching* behavior of SaaS clients in industry practice. Most SaaS providers offer clients no-fee sampling: clients can use the SaaS application free-of-charge, typically for one month, and if it does not meet expectations, they can stop using it with no payment required.[6]

Switching, in the SaaS market is not free though, due to the nature of the business relationship between a SaaS client and its vendor. In the SaaS context, a client typically needs to move its data to the vendor's server, and the vendor handles all the IT support services, including daily maintenance of the software, data backups, software upgrades, and security. Close partnerships like this are likely to cause lock-in risk for the client based on the actions of the vendor [31]. Another risk is that the client may lose control over its data and applications, and become dependent on the external vendor in ways that create unexpected vulnerabilities. Shifting away from a specific vendor will require the client to experience data transfer and recovery costs, which are significant switching costs a client must consider when making decisions.

Firm-to-firm competition in the SaaS market is not well understood. To address this gap, we propose a duopoly market structure model with key features of the SaaS market. This offers opportunities for creating new theory, while providing insights on problems that involve IT strategy.

B. Theoretical Background

Researchers have studied SaaS from multiple perspectives. Some have looked at SaaS contract design [48]. Others have studied software functionality investments under SaaS [11]. Various authors have analyzed optimal pricing strategies for SaaS in a monopoly market structure [10], [12], [28]. And still others have focused on SaaS's impact on the traditional software market [4], [22], [24], [37], [38]. We investigate the competition between SaaS vendors.[7] We identify and recommend appropriate price and quality choice strategies in the SaaS marketplace. Our research draws on different streams: competition with heterogeneous products and switching costs.

1) Competition With Heterogeneous Products: Different approaches are possible [5]. *Competition with horizontal heterogeneity* was inspired by Hotelling's linear model and Salop's circular model [46]. The latter represents consumer tastes in a circle, and vendors compete by selecting how to position their products. Spatial competition models showed that products with different features enable vendors to avoid direct competition [3], [17], [18]. Differentiation in product features enables a vendor to attract local clients, raise prices, and achieve higher profit. In the SaaS market, users want customized applications to fit their business needs, but the multitenant structure makes customization hard. So a horizontal differentiation model is appropriate for the issue of fit between a user's software requirements and the application offered by a vendor.

In contrast, *competition with vertical differentiation* assumes that vendors produce products with different quality levels. All consumers prefer higher quality products, but their willingness-to-pay for quality varies [49]. Research with vertical differentiation models is common [2], [8], [26], [39], and some have focused on software market competition [11]. With SaaS, vendors provide a bundle of application and IT services. The quality of the IT services, such as up-time and response time, is key for the choices that clients make. This suggests inclusion of a quality factor in our analysis with vertical differentiation. This allows us to investigate the outcome when SaaS vendors exhibit

[4]Clients must figure out the functionality of software applications and match them to their business needs, and subsequently understand how they can be integrated into existing legacy systems and technical infrastructures. In the traditional software market, users usually manage such risks by customizing the software they build or buy, to be sure that their applications address their business needs.

[5]Vendors in SaaS and cloud computing often create *application configurations* with pre-defined and adjusted scope to address the known circumstances of use. The main difference between *customization* and *configuration* is that the latter does not involve source code changes, whereas customization does [27]. Some configuration is possible in SaaS, which can be set up with pre-defined parameters to change software functionality to some extent, but beyond some cost-effective pre-defined range of functionality, SaaS is not intended to offer customized solutions.

[6]For example, a newly registered client of Salesforce.com or Oracle On-demand CRM is given 30-day free trial use of the SaaS product – which essentially encourages the client to sample the SaaS vendor before total consumption periods start. After this "sampling" period, the client will retain the option to not use the SaaS vendor—a switching option exists. According to a recent industry report, the conversion rates from sampling to long term consumption of SaaS product is only about 25% [42], showing how frequent it is for clients to sample and switch.

[7]Increasingly fierce competition is occurring between SaaS vendors in almost every software niche market. Two giants, Salesforce and Oracle (www.oracle.com)—nearly a duopoly—compete in the on-demand customer relationship management (CRM) software market, for example. Oracle Eloqua (www.eloqua.com), Marketo (www.marketo.com) and Pardot (www.pardot.com) also go head-to-head in the on-demand market for marketing campaign automation services. In addition, FinancialForce (www.financialforce.com) and Intacct (www.intacct.com) are fighting it out in the specialized market for financial accounting systems-focused SaaS.

horizontal differentiation in their software's features, and vertical differentiation in IT service qualities.

2) Role of Switching Costs: Switching costs are important in the conventional wisdom. Some researchers have argued that the possibility of switching makes a product less attractive and reduces a consumer's *ex ante* willingness-to-pay [9], [49]. Hence, prices should be reduced to incentivize a rational consumer to participate. As a result, the market will be more competitive when there are higher switching costs. Others have disagreed. They argue that switching costs reduce market competitiveness, raise prices, and support customer lock-in [6], [23], [32]–[34]. In their models, vendors are allowed to charge different prices in each period. They found that vendors price aggressively to exploit their existing customers. High switching costs also support higher vendor prices and profits, leading to a less competitive market. Other recent research suggests the relationship between switching costs and equilibrium prices may not be simple. Dubé *et al.* [19], and Shin and Sudhir [47] have demonstrated that prices may fall with low switching costs and rise as switching costs become high.

Switching costs affect SaaS clients. Clients face lock-in risk because their data are stored, managed, and maintained in a central location run by the vendor. Once a client wants to stop the use of the existing vendor, it must bear the costs of recovering and moving data out, which is significant in most business settings. Similar to the past works in switching cost literature, in the SaaS setting, the presence of switching costs is likely to enable the vendor to charge higher prices, exploit its clients more, and achieve a higher profit – in the short run at least. On the other hand, different from the literature that switching typically happens when the vendor makes price adjustment after a period of real consumption, switching in our model is triggered by the lack of fit between the client's specific requirements on software attributes and the vendor's standardized offering, after a free-of-charge sampling period. Still, how will vendors implement strategies that recognize the role of pricing choices relative to clients' switching costs?

To study the competition between SaaS vendors, a multi-factor model is appropriate, including differentiated software functionality and service qualities, operational costs, multitenancy transaction costs, *ex ante* incomplete information on the clients' side, and switching costs. We will develop and analyze this kind of model of competition. We want to see how these factors interact with each other and determine how the SaaS competition will play out. To our knowledge, this has not been investigated before.

II. Modeling SaaS Vendor Competition in the Market

We study two competing vendors, Vendor H and Vendor L, in the market. Each delivers a bundle of software applications and IT services to its clients through a network.

A. Competing SaaS Vendors

SaaS vendors differ in two dimensions. First, their software has different attributes and features, which makes them horizontally differentiated competitors. Following Salop [46], we assume that the vendors' product space is a circle of unit circumference. The two vendors are differentiated maximally in the spatial competition.[8] That is, their products will be located at positions opposite to each other on the circle, with a distance of 0.5 between them. Second, they offer IT services of different quality levels, which also makes them vertically differentiated competitors. Vendor H is a higher quality vendor that offers services of higher quality q_H in the market, while Vendor L is a lower quality vendor that offers services of lower quality q_L, with $\Delta q = q_H - q_L > 0$. (See Fig. 1 below, and Table I for our modeling notation.) Each vendor's quality level is common knowledge in the market, since in the SaaS context, service-level

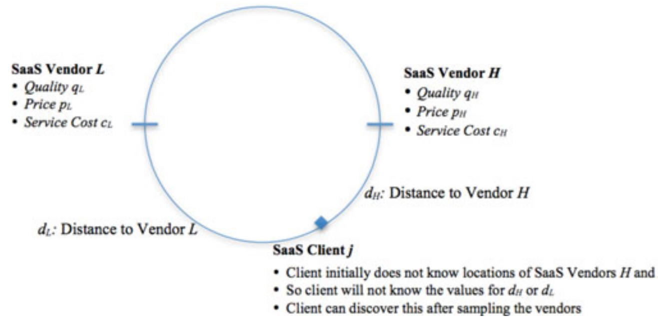

Fig. 1. Salop circle for vendor pricing, quality strategy.

TABLE I
Modeling Notation and Definitions

Notation	Definitions
I	Vendor's initial setup cost to offer SaaS to new clients
S	Switching cost borne by the client when switching vendor
c_H, c_L	Per period recurring service cost for Vendors H and L
q_H, q_L	IT service quality for Vendors H and L
p_H, p_L	Per period price for Vendors H and L
θ_h, θ_l	Willingness-to-pay for SaaS quality by client type
d_i	Distance between client's ideal application and vendor's functionality, for Vendor $i \in \{H, L\}$
T	Client's utility loss per unit distance in the spatial model
$t \cdot d_i$	Client's total utility loss for applications mismatched to client's tech infrastructure and business needs when client is using SaaS vendor i, $i \in \{H, L\}$; this a client's *FitCost.*
$U(\theta_j, q_i, d_i)$	Utility of Client j with willingness-to-pay for IT service quality θ_j, where $j \in \{h, l\}$, when Vendor i is used. We also use U to mean total utility. See proof of Lemma 1.
$\Delta p = p_H - p_L$	Price difference between SaaS vendors
$\Delta q = q_H - q_L$	Service quality difference between SaaS vendors; measures vendors' *vertical differentiation level*
$\Delta\theta = \theta_h - \theta_l$	Willingness-to-pay difference for Clients h and l; measures clients' *vertical differentiation level*
$\Delta c = c_H - c_L$	Service cost difference for SaaS vendors
$\Delta c \Delta q$	Unit cost of IT service quality difference; large values suggest quality is expensive to push to a higher level; measures cost efficiency of SaaS

[8]We follow the *principle of maximum product differentiation*, proposed by D'Aspremont *et al.* [16] for application in duopolistic spatial competition. The competing vendors differentiate themselves as much as possible in the product space so that they can avoid head-to-head price competition. Many authors used this principle in the spatial competition literature [3], [17], [18]. In practice, differentiation is effective to reduce price competition [35], [43].

agreements (SLAs) have been extensively used to describe and guarantee a vendor's service quality.[9]

A SaaS vendor has two types of costs: *I*, the initial setup cost to start the business with a new client, and *c*, the vendor's service cost for delivering services. When it acquires a new customer, the vendor's one-time setup cost, *I*, is small and will include the effort it makes to understand the technical architecture and business needs of the new client. It will include the costs of moving the user's data to a centralized location and making other relationship-related arrangements too. The vendor's recurring service cost c involves maintaining client databases and application code, providing IT services, and managing data security. The service cost difference between vendor is $\Delta c = c_H - c_L > 0$, indicating that delivering higher service quality requires the vendor to bear a higher service cost. The vendors charge clients a fixed subscription price each period. Their prices are p_H and p_L, and their difference is $\Delta p = p_H - p_L$.

B. SaaS Clients

Clients express heterogeneous preferences for different software attributes. This is captured by their even distribution on the circle. A client's location represents the ideal application for the client. It is most likely an individually customized software application, which fits the client's specific IT requirements and business environment, and can be integrated into its legacy systems.

The multitenancy of SaaS disallows the client from obtaining an ideal application. The vendor will offer a standard application on a centralized server. The client will suffer a loss of utility due to the mismatch between what the vendor offers and what the client needs. We call such losses of utility the *FitCost*. In our model, such cost is measured by *t d*, where *d* is the distance between the client's and vendor's positions on the Salop circle, and *t* measures the client's utility loss per unit distance. Fig. 1 depicts a Client *j*, located at position ♦, and the two vendors, *H* and *L*, at a distance 0.5 from each other. The distance from this Client *j* to Vendor *H* is d_H and to Vendor *L* is d_L, and so *FitCost* for this client using Vendor *H* is $t\, d_H$ and for Vendor *L* it is $t\, d_L$.

All clients prefer higher service quality, but their individual levels of willingness-to-pay are different. We assume there are two types of clients: a type θ_h client is the one with higher willingness-to-pay and is willing to spend more to obtain a higher level of service quality than a type θ_l client, with lower willingness-to-pay. The difference, $\Delta\theta = \theta_h - \theta_l > 0$, measures the two types of clients' differences in their levels of willingness-to-pay for quality. We assume there is equal representation in the market for each of the client types.

The utility function for Client *j*, when it uses Vendor *i*'s SaaS, is

$$\mathrm{U}(\theta_j, q_i, d_i) = \theta_j q_i - p_i - t d_i. \quad (1)$$

[9]In a typical SLA, productivity (uptime and network availability), service quality (response time, performance), problem resolution procedures, and provisions for system and data security are defined in detail. Thus, we assume that SaaS vendors are able to reduce their service quality uncertainty through the use of SLAs.

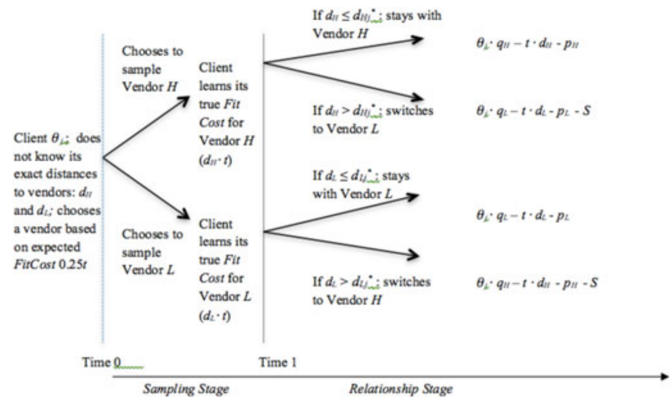

Fig. 2. Decision tree and payoffs for Client *j*.

Here, $i \in \{H, L\}$ indicates Vendor *H* or *L*, and $j \in \{h, l\}$ indicates the client type *h* or *l*, associated with this client's willingness-to-pay levels θ_h or θ_l; q_i is the level of service quality offered by Vendor *i*; p_i is the SaaS subscription price per period charged by Vendor *i*; and d_i measures the distance between Client *j* and Vendor *i* in the circular product space. The last term, $t\, d_i$, is *FitCost*; the utility loss Client *j* experiences from a less-than-ideal application from Vendor *i*.

C. Sampling and Switching

Software applications are experience goods for the clients that use them. Without seeing how a vendor's application actually runs over time, the client will be not able to predict how well a standardized SaaS application will fit its business needs or will be easily integrated into its legacy systems. This information can be learned after using the vendor's SaaS application for a period of time. To represent this aspect of SaaS, that a potential client will not know the extent of the vendor's SaaS application's match to its needs, we assume that the two SaaS vendors' positions on the circle initially are unknown to all potential clients. For example, in Fig. 1, Client *j* does not know the value of d_H and d_L, though it knows the price and quality of the vendors, p_H, p_L, q_H, and q_L. As a result, the best this client can do is to make an estimate of the expected costs that will arise due to a lack of fit, which is 0.25 *t* for both vendors, and choose one that gives higher expected total utility to try out. After using the SaaS' application for a period of time, the client will learn the exact value of d_H for *H* (and d_L for *L*) and therefore the exact *FitCost* of $d_H\ t$ for *H* (and $d_L \cdot t$ for *L*). This process is *vendor sampling*.

The client, after sampling, may decide to stop using the services of this vendor and switch to another vendor. This will force the client to face a switching cost, *S*. In the SaaS market, switching cost includes the cost of discovering another vendor with which to make service arrangements, recovering data from the current vendor, and moving it to the new one.

Fig. 2 shows the decision tree with payoffs for a client *j*. This client's true *FitCost* for Vendor *H* is $d_H\ t$ and for Vendor *L* is $d_L\ t$. The client will not know the value of d_H or d_L *ex ante*. The client must make two decisions.

1) At time 0, decide which vendor's application to sample based on the expected *FitCost* of 0.25 *t*.
2) At time 1, after sampling and learning, based on the new information of d_H and d_L, decide to stay or switch to another new vendor.

The client's switching decision involves a *threshold strategy*: a client who samples Vendor *H* and learns the value of d_H will switch if and only if $d_H > d^*_{Hj}$, and a client who samples Vendor *L* and learns the value of d_L will switch if and only if $d_L > d^*_{Lj}$, where the two critical values d^*_{Hj} and d^*_{Lj} are the positions of Vendor *H*'s and *L*'s marginal clients, defined and derived as below. A *marginal client* of Vendor *H* is the one that chooses to sample Vendor *H* initially and will be indifferent between staying with Vendor *H* or switching to Vendor *L* after learning the true value of d_H. A marginal client of Vendor *L* can be defined analogously.

Consider a θ_j-type client, θ_j with $j \in \{h, l\}$ the willingness-to-pay for quality (θ_h or θ_l). It is the marginal client of Vendor *H* if the client's distance to Vendor *H* is d^*_{Hj}, given by

$$\theta_j q_H - t\, d^*_{Hj} - p_H = \theta_j q_L - (0.5 - d^*_{Hj})t - p_L - S. \quad (2a)$$

The left-hand side of the equation is the client's total utility if it stays with Vendor *H* after sampling. The decision to switch will happen after sampling, and so the client will know its true *FitCost* for using Vendor *H*, $t\, d^*_{Hj}$. The right-hand side is the client's total utility based on a switch to Vendor *L*, where the true *FitCost* of using Vendor *L* is $(0.5 - d^*_{Hj})\, t$ by the maximal differentiation rule. Similarly, the marginal θ_j-type client of Vendor *L* is defined by d^*_{Lj}

$$\theta_j q_L - t\, d^*_{Lj} - p_L = \theta_j q_H - (0.5 - d^*_{Lj})t - p_H - S. \quad (2b)$$

Solving the equations allows us to determine the critical positions of marginal clients

$$d^*_{Hj} = 0.25 + \frac{\theta_j \cdot \Delta q - \Delta p}{2t} + \frac{S}{t} \quad (3a)$$

$$d^*_{Lj} = 0.25\, \frac{\theta_j \cdot \Delta q - \Delta p}{2t} + \frac{S}{t} \quad (3b)$$

where $j \in \{h, l\}$ indicates the client types θ_h and θ_l.

The location of the marginal client provides the threshold value for clients when they make switching decisions, as shown in Fig. 2, and also defines the market share for each vendor. For example, if all clients choose to sample Vendor *H* initially, after clients' switching, Vendor *H*, taking its position in the circle as origin, will serve θ_h-type clients in the interval of $(-d^*_{Hh}, d^*_{Hh})$ and θ_l-type clients in $(-d^*_{Hl}, d^*_{Hl})$; and Vendor *L* will serve the rest.[10]

D. Two-Stage Game

We next lay out a two-stage game for the competition between two SaaS vendors. (See Fig. 3.) The first is the client's

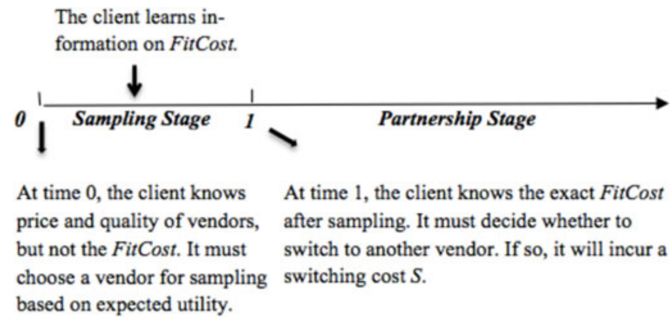

Fig. 3. Timeline for SaaS vendor–client interactions.

Sampling Stage between time 0 and 1, and the second is the client's *Partnership Stage*, which occurs after time 1.[11]

Prior to time 0, the two SaaS vendors will simultaneously post prices p_H and p_L. Their service quality levels, q_H and q_L, will be known by all potential clients from information available in the market. The *FitCost* experienced by each client will not be known though. This reflects uncertainty on the client's part about how far it is to a vendor in the Salop circle; the client does not know the true value of d_H and d_L. At time 0, a client must choose one vendor's offering by comparing the expected utility from both vendors's solutions, based on the expected distance of 0.25 to both vendors.[12] This trial period will be short, from time 0 to 1, the *Sampling Stage*, and the client learns how well the SaaS offering works in its organizational context, and obtains information about its *FitCost*.[13] At time 1, the client, with new information d_H and d_L, will make a decision to remain with its current vendor or switch to another vendor, should unattractive *FitCost* be discovered. In the latter case, the client will have to bear switching cost *S*.

After time 1, the *Partnership Stage* will reflect the stabilization of the service relationship between the client and the vendor. We assume that both SaaS vendors and clients are utility maximizers for the profits that they obtain in the second stage. For simplicity, the discount factor for time is normalized to 1. We also assume that the vendors will not change their prices in between the two stages.[14] We analyze two SaaS vendors that

[10]The final market share and profit function of SaaS vendors depend on clients' initial choices of vendors to sample, which depends on the vendors' prices. We will derive them under three different scenarios in Section 3.

[11]We follow von Weizsacker [50]. Vendors commit to their initial prices and not change them in the later stage. We make this assumption for these reasons. First, some SaaS vendors have maintained stable prices for a long time. Second, by committing to posted prices, SaaS vendors can handle overlapping generations of clients. Third, it is costly for vendors with clients planning to switch, and then give them subsidies or price cuts. We acknowledge the unchanged price in our two-period setting as one of the modeling limitations and will discuss it later.

[12]In practice, clients can get quality information through multiple channels, such as the vendor's website, a detailed SLA published by the vendor, blogs and reviews, other firms, and consulting reports, etc.

[13]We do not consider actions the client can take to accelerate its learning; instead, we assume it will occur and will benefit the client. We also assume that there are no contractual costs or relational constraints associated with the client's option to switch to a new vendor. This problem has been viewed differently in other research, which modeled the embedded option as something that a vendor should price explicitly in its service subscription contracts [7].

[14]The full-market coverage setup is commonly used in the literature on spatial competition [36], [40]. Salop [46] showed that when the market is not fully covered and some clients choose to stay out of the market, it leads to *monopolistic competition*: each vendor is a local monopoly and the vendors will not compete

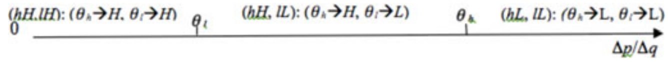

Fig. 4. Sampling market outcomes.

compete directly, up to the marginal client. This is also standard in two-stage games with switching costs [9], [19], [47].

III. Analysis

With two stages—*Sampling* and *Partnership*—and clients that can switch, the market segmentation in the stages will be different. We refer to them as the *Sampling and Relationship Market Outcomes*. The latter is the market equilibrium under rational client decision-making.

A. Market Outcomes for the Sampling Stage

The Sampling Market Outcome arises from clients' choices at time 0, with three outcomes.[15]

1) (*hH*, *lH*): All clients choose to try out Vendor *H*; Outcome $(\theta_h \rightarrow H, \theta_l \rightarrow H)$.
2) (*hL*, *lL*): All clients choose to try out Vendor *L*; Outcome $(\theta_h \rightarrow L, \theta_l \rightarrow L)$.
3) (*hH*, *lL*): Higher willingness-to-pay clients choose Vendor *H* and lower willingness-to-pay clients choose Vendor *L*; Outcome $(\theta_h \rightarrow H, \theta_l \rightarrow L)$.

Although the vendors are differentiated in their application features and service qualities, at time 0 in the clients' eyes, they are only different in their quality levels. The clients have not yet sampled the application and do not have good information about the vendor's *FitCost*. So clients must estimate the expected *FitCost* for both vendors, which is the same for them at $0.25 \cdot t$. The Sampling Market Outcome mimics a vertical differentiation-only market. (See Fig. 4.)

Our analysis identifies $\Delta p/\Delta q$, the vendors' price difference-to-quality difference ratio. It measures how expensive it is for clients to move to higher quality based on the price per unit for quality improvement. We find that the ratio $\Delta p/\Delta q$ determines the Sampling Market Outcome: if this ratio $\Delta p/\Delta q$ increases beyond θ_h (the willingness-to-pay level of the higher valuation client), all clients will try Vendor *L*'s offering at time 0. But when the ratio drops below θ_l (the willingness-to-pay level of the lower valuation client), all clients will try Vendor *H*'s offering initially instead. In addition, when the value of the ratio is in between these extremes, the higher willingness-to-pay clients will select Vendor *H*, and the lower willingness-to-pay clients will choose Vendor *L*. This finding is demonstrated in Fig. 4. (See Lemma 1 in the Appendix.)

Thus, to attract more clients before they know the *FitCost*, Vendor *H* will reduce the price–quality difference, $\Delta p/\Delta q$; Vendor *L* will increase it. When two vendors compete on vertical differentiation—the information about horizontal differentiation is not revealed to clients at time 0—how much clients must pay for additional quality improvement, indicated by $\Delta p/\Delta q$, is critical.

B. Toward a Stable Market Equilibrium

We next analyze the market outcome after clients obtain additional information about their sampled vendor and make the switching decision. A stable market equilibrium will emerge after time 1. The clients' decision to switch will be based on new information they acquire on vendor *FitCost.* The switching cost diminishes the incentive for clients to change vendors, and may be used by the vendor to lock in its clients. Our analysis suggests an upper limit for switching cost, above which no client will switch to another vendor. (See Lemma 2 in the Appendix.) We investigated the equilibrium outcomes and assessed the vendors' strategies for two cases: when they have or do not have lock-in power over their clients in the market.

Case 1: When vendors have lock-in power, no clients can switch. This occurs when switching cost is high and exceeds the upper limit noted in Lemma 2. The vendor sampled in the first stage will lock in all clients and no switching will occur in equilibrium. We show that both vendors have the chance to implement opportunistic pricing, based on their $\Delta c/\Delta q$ ratio.[16] The ratio $\Delta c/\Delta q$ indicates how costly it is for a vendor to improve its quality and thus measures the cost efficiency of the SaaS model. This leads to:

Proposition 1 (Opportunistic Pricing): Cost efficiency improving quality in its SaaS business model affects how a vendor should implement an opportunistic pricing strategy.

1) *Higher cost efficiency:* When the SaaS model has higher cost efficiency, $\Delta c/\Delta q < \theta_l$, Vendor *H* can implement an opportunistic pricing strategy. At $p_H = c_L + \Delta q \theta_l$, H will drive L out of the market and serve all clients.
2) *Lower cost efficiency:* When the SaaS model has lower cost efficiency, $\Delta c/\Delta q > \theta_h$, Vendor *L* is able to employ an opportunistic pricing strategy. At $p_L = c_H - \Delta q \theta_h$, *L* will drive *H* out of the market and serve all clients.

With a higher cost efficiency, it will be cheaper for the vendor to push its SaaS quality to a higher level, according to this proposition. (See Proposition 1 in the Appendix.) So it makes sense for Vendor *H* to implement opportunistic pricing to dominate the market. With a lower cost efficiency, the vendor will incur substantial costs to improve quality. If so, it makes sense for Vendor *L* to implement opportunistic pricing and also try to dominate the market. As technologies supporting IT delivery advance, the cost efficiency of SaaS will improve. This implies that SaaS vendors with higher quality will dominate the market in the future.

directly. Since here we are interested in the competition between SaaS vendors, it is natural to study a fully covered market.

[15] We assume a tie-breaking rule here. When higher willingness-to-pay clients (θ_h) are indifferent to sample Vendor *H* or *L*, they will try out Vendor *H*; and when lower willingness-to-pay clients (θ_l) are indifferent to sampling Vendor *H* or *L*, they will try out Vendor *L*. The tie-breaking rule does not affect our results quantitatively.

[16] In the rational expectation equilibrium, clients will be able to foresee the strong lock-in power of vendors, and they will be cautious when sampling a vendor. In this case though, the vendor may be able to employ an *opportunistic pricing strategy* to drive other competitors out of the market. The first vendor can charge a low price so its competitors will be unable to profit, but this strategy requires the first vendor to serve the whole market to make a profit.

Opportunistic pricing will not be feasible for either SaaS vendor if its cost efficiency is in the mid-range of $\theta_l \leq \Delta c/\Delta q \leq \theta_h$. No vendor will be able to undercut its competitor's price to drive it out of the market. The vendors must implement different strategies that enable them to coexist instead. The only equilibrium outcome will be for the higher willingness-to-pay clients to choose Vendor *H* and the lower willingness-to-pay clients to select Vendor *L* at time 0, $(\theta_h \rightarrow H, \theta_l \rightarrow L)$ and for clients to stay with their selected vendors after the Sampling Stage. The vendors' prices are $p_L = \theta_l q_L - 0.25\ t$; $p_H = \theta_l q_L + \theta_h \Delta_q - 0.25\ t$. (See Lemma 3 in the Appendix.)

The equilibrium prices and market segmentation deserve additional consideration. The price p_L serves to extract all expected consumer surplus from the lower willingness-to-pay clients at time 0. With this price, they will be just willing to try Vendor *L*, only with zero expected consumer surplus. On the other hand, p_H will be set at the level that θ_h type clients will choose Vendor *H* on the margin. The expected surplus of θ_h clients from the selection of Vendor *H* will only be marginally more than from Vendor *L*. This pricing strategy follows the logic for a two-product monopoly market. The monopolist should sell a lower quality product to lower willingness-to-pay consumers, and its price will extract the available consumer surplus. Meanwhile, the monopolist should sell a higher quality product to higher willingness-to-pay consumers. The price of the higher quality product will be just high enough to ensure that consumers in this segment will not be attracted to purchase the lower quality product. This will result in the market being segmented so there is no direct competition.

This is essentially a noncompetitive market: the two vendors implement a *collusive pricing strategy.* Together they behave like the two-product monopolist described above. They avoid competing in the same client segment. Instead, each only targets and serves one client group that has the appropriate level of quality preference: lower willingness-to-pay clients will buy from Vendor *L*, and higher willingness-to-pay clients from Vendor *H*. We propose:

Proposition 2 (Nonconfrontational Market Segmentation): When the SaaS business model has mid-range cost efficiency, $\theta_l \leq \Delta c/\Delta q \leq \theta_h$, both vendors will implement nonconfrontational market segmentation by serving the segments of clients based on the levels of IS services quality they prefer. This will ensure no direct vendor competition.

Case 2: When vendors have less lock-in power, some clients will switch. This is the case when switching cost is not higher than the upper limit given in Lemma 2, so that after sampling, some clients will choose to leave the selected vendor (due to bad fit) and absorb switching cost *S*.

There are three types of equilibria, corresponding to the three types of market outcomes in the Sampling Stage. The equilibrium, (*hH*, *lH*) + *Switch*, occurs when all clients sample Vendor *H* at time 0, leading to the $(\theta_h \rightarrow H, \theta_l \rightarrow H)$ Sampling Market Outcome, and then at time 1, some clients switch from Vendor *H* to *L*. The others are: (*hL, lL*) + *Switch* and (*hH, lL*) +*Switch.* In the paper, we will analyze the (*hH, lL*) + *Switch* equilibrium. We will depict its market segmentation, derive the vendors' objective functions, and explain how we solve the equilibrium prices. (See the Appendix for the solutions for the other equilibria.)

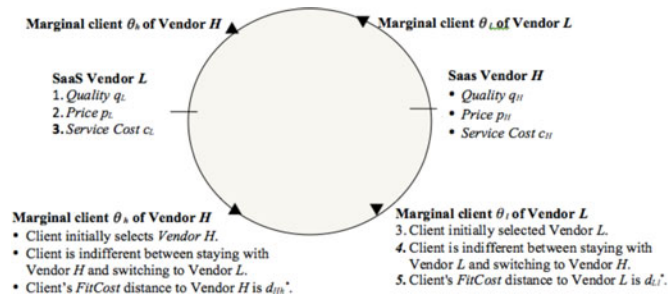

Fig. 5. (*hH, lL*) + *switch* equilibrium market outcome.

Fig. 5 shows the (*hH, lL*) + *Switch* equilibrium outcome.

The positions of the higher willingness-to-pay marginal clients of Vendor *H* are marked with "▲," and the lower willingness-to-pay marginal clients of Vendor *L* with "▼." The distance from Client ▲ to Vendor *H* is d^*_{Hh} and from Client ▼ to Vendor *L* is d^*_{Ll}, from (3a) and (3b).

Vendor H: Let Vendor *H*'s position (*H*) be the origin. *H* serves higher willingness-to-pay clients between $(H - \blacktriangle, H + \blacktriangle)$, who selected *H* at time 0 and chose not to switch. The segment size is $2d^*_{Hh}$. Vendor *H* serves lower willingness-to-pay clients in $(H - \blacktriangledown, H + \blacktriangledown)$, who selected Vendor *L* but switched to Vendor *H*. The segment size is $2(0.5 - d^*_{Ll})$.

Vendor L: Next, let Vendor *L*'s position in the circle (*L*) be the new origin. *L* serves higher willingness-to-pay clients between $(L - \blacktriangle, L + \blacktriangle)$, who selected *H* at time 0 and chose to switch to *L* at time 1. The market segment size is $2(0.5 - d^*_{Hh})$. Vendor *L* also serves lower willingness-to-pay clients between $(L - \blacktriangledown, L + \blacktriangledown)$, who selected *L* at time 0 and did not switch at time 1. The segment size is $2d^*_{Ll}$.

The vendors assign p_H and p_L simultaneously to maximize profit. The decision problems for Vendor *H* and *L* are

$$\underset{p_H}{\text{Max}}\,(p_H - c_H)(2d^*_{Hh} + (1 - d^*_{Ll})) - I - (1 - d^*_{Ll})I$$

$$\underset{p_L}{\text{Max}}\,(p_L - c_L)(2d^*_{Ll} + (1 - d^*_{Hh})) - I - (1 - 2d^*_{Hh})I.$$

In Vendor *H*'s profit function, the first term is the discounted revenue from serving higher willingness-to-pay clients in $(H - \blacktriangle, H + \blacktriangle)$ and lower willingness-to-pay clients in $(H - \blacktriangledown, H + \blacktriangledown)$. The second term is the setup cost for Vendor *H* to acquire higher willingness-to-pay clients who chose Vendor *H* at time 0. The last term is the setup cost for Vendor *H* to acquire lower willingness-to-pay clients who switched to Vendor *H* at time 1. Vendor *L*'s profit function is similar. By solving the vendors' optimization problems, we can obtain equilibrium prices, market shares and profits for them. (Other equilibrium solutions appear in Lemma 4 in the Appendix.)

Our analysis shows that, as long as switching cost *S* is not high enough to lock in all clients, there are always some clients that switch after sampling their initial vendor. The two SaaS vendors will always coexist, suggesting a competitive, not a monopolistic marketplace. We will not observe one vendor's dominance even when the SaaS model's cost efficiency is very high or low. Together with switching cost *S*, SaaS cost efficiency ($\Delta c/\Delta q$) now will play a different role:

Proposition 3 (Switching Cost Effects): Switching cost affects the vendors differently in different situations. When the cost efficiency of the vendor's SaaS business model is low, an increase in switching cost makes Vendor *L* better off via the higher price and profit, but Vendor *H* worse off due to the lower price and profit. When cost efficiency is high, an increase in switching cost will make Vendor *H* better off, but Vendor *L* will be worse off.

The influence of switching cost is thought to be beneficial to vendors, because it gives vendors lock-in power with clients. It also benefits users though, since it increases price competition among vendors. In the prior work, switching cost was found to affect competing vendors always in the same way. However, we show that, in SaaS vendor competition, switching cost may benefit one but hurt the other vendor, depending on their relative cost efficiencies. The Switching Cost Effects Proposition (P3) states that, when the cost efficiency of the SaaS vendor is high, Vendor *H* will be the only beneficiary. This is because Vendor *H* will be selected by all clients in the Sampling Stage, and will be the only one with lock-in power. With increases in switching cost, Vendor *H* will be able to raise its price for higher profitability. Meanwhile, Vendor *L* will need to reduce its price, but even so, it still will experience lower profitability. On the other hand, Proposition 3 suggests that when the cost efficiency of the SaaS vendor is low, the relationships will work in reverse: Vendor *L* will become the only beneficiary of switching cost.

IV. SaaS Vendor's Quality Strategy

We next evaluate how competing SaaS vendors should strategize about their service qualities.

A. Best Strategies and Best Responses

The Switching Cost Proposition (P3) indicates that the impact of switching cost on vendors may be positive or negative, depending on the ratio of the change in service and the change in service cost of the two vendors. Thus, we ask: for the vendor that faces a competitor with a given level of service quality, how should it set its service quality level so it will be the only beneficiary of the switching cost present in the competitive marketplace? To do this, the vendor's strategy must enable it to gain lock-in power in the market, even though this may not entirely coincide with the price and quality combination that maximizes the vendor's profit. This is complex.

To derive the vendor's quality selection strategy, we refer to the conditions for different types of market equilibria when the vendors do not have lock-in power over their clients. Which type of equilibrium will occur depends on the magnitudes of Δc, $(2\theta_h - \theta_l)\Delta q$ and $(2\theta_l - \theta_h)\Delta q$, and the critical difference between them, $2S - I$. (See Table II and Fig. 6.)

Fig. 6 shows a scenario in which the vendors' services cost increases (Δc) are convex in their quality difference levels (Δq). Although the figure is for this specific convex relationship scenario, our analysis applies to any relationship between service cost and quality. We use Δq for the horizontal axis and draw three curves: Δc; $(2\theta_h - \theta_l)\Delta q$; and $(2\theta_l - \theta_h)\Delta q$. We also marked three critical lengths $Z\ |2S - I|$ that are defined as absolute values. They are highlighted as segments between the Δc curve and the two straight lines. According to the equilibrium existence conditions listed in Table II, there are three critical points on the *x*-axis: *a*, *b*, and *e*. These divide the range of $\Delta\ q$ into four regions, with different market equilibria in each. This permits us to explore a vendor's *quality strategy* for gaining lock-in power, when it is able to set its own service quality. We next analyze both vendors' actions.

TABLE II
EQUILIBRIUM EXISTENCE CONDITIONS: WHEN SWITCHING MODE IS POSSIBLE

Equilibrium	Existence Condition
(hH, lH) + Switch	$\Delta c\ <\ (2\theta_l - \theta_h)\Delta q - 2S + I$
(hL, lL) + Switch	$\Delta c\ >\ (2\theta_h - \theta_l)\Delta q + 2S - I$
(hH, lL) + Switch	$(2\theta_l - \theta_h)\Delta q - 2S + I \le \Delta c \le (2\theta_h - \theta_l)\Delta q + 2S - I$

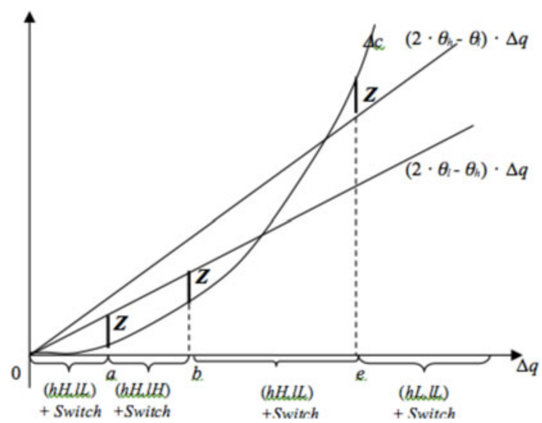

Fig. 6. Equilibria when change in service cost is convex in change in quality.

The lower quality Vendor *L*. Vendor *L* views *H*'s service quality as fixed. It should set the quality low enough so Δq lies in the region $\Delta q\ >\ e$. There, *H* is not cost efficient. This is because, to support such a large quality difference Δq between the vendors, *H* needs to incur a significant Δc, which must be compensated for with a larger price difference Δp. The clients, then, will decide to sample *L*'s service in the Sampling Stage. This will cause *L* to be the only vendor able to achieve lock-in power in the marketplace.

The higher quality Vendor H. Since L's service quality will be fixed, *H* should set its quality level slightly higher than *L*'s. Their quality difference, Δq, is in the region $a \le \Delta q \le b$. Here, *H* will operate with higher cost efficiency, with a smaller cost for improving its service quality via Δc. This eventually will be transferrable to a price difference between the vendors. Thus, all of the clients will be attracted to *H*'s services in the Sampling Stage, making *H* the only vendor that is able to achieve lock-in power.

To summarize, when the vendors' service cost increase, Δc, is convex in their quality difference, Δq, the strategy of Vendor *H*, for any level of q_L for *L*, is to choose a lower level of q_H. This will result in a small quality difference between the vendors. In contrast, Vendor *L*'s strategy, for any level of q_H for *H*, is to choose a low level of q_L, to make a large quality difference between the two vendors. We again point out that our analysis is not limited to a convex $\Delta c - \Delta q$ relationship, but also may be applied to other types of $\Delta c - \Delta q$ functions.

B. Roles of Switching Cost and Client Willingness-to-Pay

Two factors influence the application of the vendor's quality strategy. The first is switching cost *S*. When it increases, the vendor's capability to achieve lock-in power through quality selection strategy will decrease. This is depicted by the length of the segment *Z*, which increases in *S* in Fig. 6. An increase in *S* moves the points *a* and *e* to the right and *b* to the left. As a result, the outcome regions of (*hH*, *lH*) + *Switch* and (*hL, lL*) + *Switch* shrink, which leaves a smaller space for the vendors to employ the strategy we described. In the extreme case when point *a* and *b* meet, the outcome region of (*hH*, *lH*) + *Switch* will disappear, so that Vendor *H* will never be able to gain exclusive lock-in power in the competition.

The second factor is the clients' extent of vertical differentiation, measured by $\Delta\theta$, the difference in their willingness-to-pay for quality. A change in $\Delta\theta$ will shift the two straight lines in Fig. 6. For example, as $\Delta\theta$ increases, the upper line $(2\theta_h - \theta_l)\Delta q$ will move up and the lower line $(2\theta_l - \theta_h)\Delta q$ will move down. The regions in which the vendors can apply the quality strategy will shrink as a result. This suggests that, in a market whose client segments have large differences in their willingness-to-pay for service quality, there will be little room for a vendor to use a quality strategy to gain exclusive lock-in power. In contrast, such a strategy will be more applicable in a market with client segments that have relatively smaller differences in their willingness-to-pay. Thus, we assert:

Proposition 4 (Vendor's Service Quality Strategy) A SaaS vendor can use quality strategy to gain exclusive lock-in power. The efficacy of this strategy will decrease in the switching cost S and the client's vertical differentiation level $\Delta\theta$.[17]

The recommended quality strategy serves as a vendor's best response when its competitor's service quality cannot be controlled by any action of the vendor itself.[18] A best response strategy might be recommended to a new market entrant that needs to compete with an existing SaaS vendor who already has a well-established profile in the marketplace. This may also be instructive for a vendor as market follower who decides to take on the market leader with quality.

[17]The proposition applies to any form of the service cost and quality function, not just the convex function.

[18]We have not solved for the vendors' quality decision-making equilibrium. This will only be tractable if a specific form of the service cost and quality function is assumed. In lieu of doing additional mathematical analysis here, we have chosen to focus on other issues that have more direct applicability to management practice.

V. DISCUSSION

Competition in the SaaS market is more complicated than our model suggests. Nevertheless, it captures interesting and important features, including the vertical and horizontal differentiation of vendors, and the sampling of fit costs and switching costs. The model also has the added benefit of enabling us to draw insightful conclusions about the pricing and quality strategies of service vendors. It will inspire others to think more deeply about how the SaaS market works. We offer several recommendations to managers of SaaS providers.

Recommendation #1: Vendors should try to retain valuable clients and build profitability by implementing beneficial and not adversarial lock-in strategies.

Our model analyzes adverse lock-in caused by exogenous switching cost. Clients that are locked in will sometimes incur high *FitCost,* resulting in a social surplus loss due to the inefficient match between clients and vendors. This encourages us to think more broadly about the impacts of adverse lock-in in the SaaS market. Adverse lock-in can also arise due to a SaaS vendor's intimate knowledge of a client's business data and competitive information. Some SaaS clients may view this as dangerous because it gives rise to the risks of *information misappropriation* and *knowledge poaching* [13]. Adverse lock-in is undesirable, especially longer term, because it unfairly weights the interests of one party, the vendor, relative to the interests of the other party, the client. Clemons *et al.* [14, p. 27] offer an especially instructive comment: "... proper outsourcing is like proper investment management or proper strategic planning. Unfortunately, outsourcing of complex business processes is so new that the risks are seldom understood either by clients or by their outsourcing consultants ..." This points to the need for the vendor to consider what might be the *uncertainty discount for future risks* that a client might experience.[19]

Recommendation #2: Vendors must recognize that switching costs do not reflect the true costs of knowledge recovery, and implement contracts that protect the clients' interests.

We modeled the main switching cost for the client as data recovery from the SaaS vendor, and setup costs with the new vendor. These do not consider *knowledge recovery* though, which will be a much larger cost. Data can be reclaimed from a business partner, but it never is clear whether the knowledge that it contains has been lost or will be exploited. Thus, the SaaS vendor will need to think through what it will take to effectively serve different kinds of clients, where business data and business know how may have much greater value. It will need to structure SaaS relationships with larger clients to ensure that sensitive competitive information is not lost.

Recommendation #3: SaaS vendors should place a high priority on investing to enhance the efficiency of their SaaS software development capabilities, so improvements in quality can be achieved with smaller increments in cost over time.

[19]A forward-looking vendor might create beneficial lock-in early on by weight-averaging its prices so the client pays less earlier when the risks are less certain, and more later when the relationships reach a point where balanced risks and rewards are achievable.

The Vendor's Service Quality Strategy Proposition (P4) showed that, in competition, what really matters is not how high a SaaS vendor's service quality can be pushed, but how efficiently the vendor is able to improve quality while holding the line on costs. Overinvestment and underinvestment by the SaaS vendor could lead to its failure. So we ask: What will a firm need to do to have the capabilities to enhance the efficiency of its SaaS offerings to match the speed of the market's growth in demand for higher quality? A major issue here is investing to shape the underlying efficiency of the production of SaaS-related quality and innovations. We observed that the firm-level cost functions of different vendors will be different. But what firm capabilities will be important for improving cost efficiency? Will a long-established software provider be at an advantage? Or a nimble newcomer?

A large SaaS vendor will need to sort out whether it is underinvesting and overinvesting, since both are possible. Large vendors will be able to leverage their expertise and experience in the packaged software market to provide reliable, high-quality IT services, but they will have a harder time to change their cost efficiency. Start-up firms may be different. Ries [44] reports that a start-up firm should continually experiment, gather feedback from its clients and make near real-time modifications to its software functionality. This approach is unlikely to result in very large-scale investments, and should not be subject to overinvestment risk. But this may permit a start-up to enjoy a process-based efficiency advantage, if it can grow its scale fast enough too.[20] A start-up like this will likely enter the marketplace with a low quality offering, possibly as a market follower with a *minimum viable product* that is made available at a lower price, and then can grow its capabilities from there.

VI. Conclusion

We investigated duopolistic competition in the SaaS market, with vendors differentiated by their application functionality and service quality. Potential SaaS clients face *ex ante* uncertainty in their fit cost of using any vendor, and they must try a vendor's application to learn about its value. The competitive game that models the SaaS setting has two stages. In the first, the clients choose a vendor and sample its application. In the second, the clients have an opportunity to switch to another vendor, although some switching costs will be involved.

The main findings are as follows.

1) In a market setting in which SaaS clients experience high switching cost, a vendor may wish to employ opportunistic pricing to dominate the market or a nonconfrontational pricing strategy to segment the market and avoid direct competition.
2) In addition, switching costs may affect the two vendors in an unpredictable way; they may benefit one and hurt the other.
3) Finally, a vendor may wish to implement a best-response quality strategy by setting its service quality at some appropriate level to obtain exclusive lock-in power.

Our findings were established based on assumptions that deserve scrutiny. We derived the vendors' pricing strategies with an equal number of clients in the high and low willingness-to-pay groups. Will our results be affected if we relax this assumption? This led us to normalize the number of clients that demand high quality SaaS services to one, and assume a proportion of clients that demand low quality services. When the numbers of the two client groups vary, the vendors will adjust prices and focus on the larger client group. When there is a high switching cost and vendors have full lock-in power, the results will be similar as for the Opportunistic Pricing Proposition (P1) and the Nonconfrontational Market Segmentation Proposition (P2). When the vendors do not have full lock-in power and some clients switch after sampling, the vendors' equilibrium prices will vary based on the relative number of clients in each group. The vendors will put more effort toward attracting the group with more potential clients, and their equilibrium prices may increase or decrease based on the change of the relative size of each client group.[21]

Another assumption we made is that vendors are able to commit to their initial prices. We discussed why we made this modeling choice earlier, but we still must acknowledge that it is realistic to allow vendors to reduce their prices at a later stage. Lower prices may serve to: 1) enable the vendor to retain existing clients and diminish their likelihood to switch to a competitor; 2) attract more of the competitor's clients to switch; and 3) generate new demand from clients who may be unwilling to sample the SaaS vendor's offering at a higher price point. When both of the vendors reduce their prices, the market will be more competitive and the equilibrium outcome will be different. To incorporate price adjustments, a different base model will be needed.

A simplification of our current model is that all clients have the same amount of time to sample a vendor's SaaS offering for its fit cost, and must make their switching decisions at a predetermined future time. Different firms will have different capabilities to acquire and process information to make value-maximizing decisions. To assess switching time as a realistic valuation problem, a dynamic model with an embedded option for the switching time can represent a client's decision-making process. This is a good direction for future research.

Finally, we assumed switching costs are exogenously fixed, and the vendors cannot control them. Vendors have some capacity to determine how the large switching costs will be over time

[20]For example, Salesforce.com [45] was launched in 1999 at the height of the dotcom era with an announcement about the "end of the software revolution," and was recognized as a market leader only several years later. It also is a driver of one of the "top 25 tech breakthroughs of all time" [15]. These may involve new ways to package and deliver SaaS, to price it, to incentivize potential clients to make a commitment, and then stay with a vendor, and so on.

[21]For example, in $(hH, lL) + Switch$ equilibrium, Vendor *H*'s price will be decreasing in the number of θ_l–type clients, while Vendor *L*'s price will be increasing in it. As the number of θ_l -type clients grows, that group will get larger, and both vendors will put more effort into serving it. As a result, *H* will reduce its price to attract these clients to switch from *L*. The lower price will mean that the *H* will not be able to exploit its existing θ_h -type clients much. The Vendor *L*, however, will increase its price to exploit its existing θ_l -type clients a little more, although the higher price will make it so that this vendor will attract fewer θ_h -type clients to switch from Vendor *H*. Similarly, when the number of clients in the θ_l -type clients group decreases, both vendors will put more effort toward serving the θ_h -type clients group. Vendor *H* will increase its price to exploit its existing θ_l -type clients more, while Vendor *L* will reduce its price to attract θ_h -type clients to switch from *H*.

though [1]. In addition, market competition and vendor incentives are such that some competitors will do service agreement buyouts, diminishing the stickiness of new clients' commitments to a service vendor. The vendor may be willing to absorb or share the cost. The study of SaaS vendors' competitive strategy should include an endogenous treatment of switching cost under the vendor's control. Another model is needed, but it will give us the power to see how switching cost interacts with price and quality to determine the SaaS market's competitive outcome.

APPENDIX
PROOFS OF THE MAIN RESULTS

Lemma 1 (Price-Quality Difference): The ratio of vendors' price difference to quality difference ($\frac{\Delta p}{\Delta q}$) determines their initial trial decisions. If $\frac{\Delta p}{\Delta q}$ increases and exceeds θ_h, all clients will try the offering of Vendor L; when $\frac{\Delta p}{\Delta q}$ drops below θ_l, all clients will try the offering of Vendor H; and when $\frac{\Delta p}{\Delta q}$ lies in between, θ_h clients will try Vendor H and θ_l clients will try Vendor *L*.

Proof: . We first prove the statement: "*when $\frac{\Delta p}{\Delta q}$ drops below θ_l, all clients will try the offering of Vendor H.*" To prove this statement, it is sufficient if we can show that θ_l type clients will choose to try out Vendor *H* at time 0 when $\frac{\Delta p}{\Delta q} < \theta_l$. Denote the expected utility of a Client θ_l at time 0 from choosing Vendor *H* and Vendor *L* by $E[U_H](\theta_l)$ and $E[U_L](\theta_l)$. We need to prove that $E[U_{H]}(\theta_l) > E[U_L](\theta_l)$.We can write the first of the two values as: $E[U_H]\ (\theta_l) = 2 \cdot d^*_{Hl}(\theta_l\ q_H - p_H - 0.5d^*_{Hl}\ t) + (1 - 2d^*_{Hl})\ [(\theta_l q_L - p_L - 0.5\,(0.5 - d^*_{Hl})\ t) - S]$.

There are two parts in this client's expected total utility. The first term is the client's expected utility if it stays with the current Vendor *H*. With probability $2d^*_{Hl}$, this client will keep using Vendor *H* and the expected distance to Vendor *H* will be $0.5d^*_{Hl}$. The second part is the client's expected utility if it switches to Vendor *L*. With probability $(1 - 2d^*_{Hl})$, the client will switch and the expected distance to *L* is $0.5(0.5 - d^*_{Hl})$. In addition, if this client switches, switching cost *S* will be incurred Based on (2a), we observe that $E[U_H](\theta_l) = (\theta_l q_L - p_L - 0.25t) - S + 2t(d^*_{Hl})^2$. Similarly, we can express $E[U_L](\theta_l)$ as: $\mathrm{E}[U_L](\theta_l) = 2d^*_{Ll}\ (\theta_l q_L - p_L - 0.5d^*_{Ll}\ t) + (1 - 2d^*_{Ll})\ \ [(\theta_l q_H - p_H - 0.5(0.5 - d^*_{Ll})t) - S]$. Applying (2b), we obtain $\mathrm{E}[U_L](\theta_l) = (\theta_l q_H - p_H - 0.25t) - S + 2t(d^*_{Ll})^2$.

Thus, we have $\mathrm{E}[U_H](\theta_l,) - \mathrm{E}[U_L](\theta_l,) = (\Delta p - \theta_l \Delta q) + 2t(d^{*2}_{Hl} - d^{*2}_{Ll})$. Plugging in (2a) for d^*_{Hl} and (2b) for d^*_{Ll}, we obtain $\mathrm{E}[U_H](\theta_l,) - \mathrm{E}[U_L](\theta_l,) = (\Delta p - \theta_l \Delta q)(\frac{-2S}{t}) > 0 \Leftrightarrow \Delta p - q_l \Delta q \leq 10 \Leftrightarrow \frac{\Delta p}{\Delta q} \leq \theta_l$. So when $\frac{\Delta p}{\Delta q} < \theta_l, \theta_l$ clients will try out Vendor *H*. And, θ_h clients will choose Vendor *H*. This proves the statement that "*when $\frac{\Delta p}{\Delta q}$ drops below θ_l, all clients will try the offering of Vendor H.*"

Using the same method, we can prove that $\frac{\Delta p}{\Delta q} > \theta_h \Leftrightarrow \mathrm{E}[U_L](\theta_h) > \mathrm{E}[U_H(\theta_h)]$, which means that "*if $\frac{\Delta p}{\Delta q}$ increases and exceeds θ_h, then all of the clients will try the offering of Vendor L.*" And also, we can show that $\theta_l < \frac{\Delta p}{\Delta q} < \theta_h \Leftrightarrow$

TABLE III
EQUILIBRIUM TYPES AND PRICES: WHEN SWITCHING IS POSSIBLE

Equilibrium	Equilibrium Prices
(hH, lH) + Switch	$p_H = 0.5t + (S + I)/3 + (2c_H + c_L)/3 + (\theta_h + \theta_l)$ $\Delta q/6$ $p_L = 0.5t + (2I - S)/3 + (c_H + 2c_L)/3 - (\theta_h + \theta_l)$ $\Delta q/6$
(hL, lL) + Switch	$p_H = 0.5t + (2I - S)/3 + (2c_H + c_L)/3 + (\theta_h + \theta_l)$ $\Delta q/6$ $p_L = 0.5t + (S + I)/3 + (c_H + 2c_L)/3 - (\theta_h + \theta_l)$ $\Delta q/6$
(hH, lL) + Switch	• *When* $(2\theta_l - \theta_h)\Delta q < \Delta c < (2 \cdot \theta_h - \theta_l)\Delta q$: $p_H = 0.5t + 0.5I + (2c_H + c_L)/3 + (\theta_h + \theta_l)\Delta q/6$; $p_L = 0.5t + 0.5I + (2c_L + c_H)/3 - (\theta_h + \theta_l)\Delta q/6$ • *When* $(2\theta_h - \theta_l)\Delta q \leq \Delta c \leq (2 \cdot \theta_h - \theta_l)\Delta q + 2 \cdot S - I$: $p_H = 0.5t + 0.5I + c_L + (3\theta_h - \theta_l)\Delta q/2$; $p_L = 0.5 \cdot t + 0.5I + c_L + (\theta_h - \theta_l)\Delta q/2$ • *When*$(2\theta_l - \theta_h)\Delta q - 2S + I \leq \Delta c \leq (2\theta_l - \theta_h)\Delta q$: $p_H = 0.5t + 0.5I + c_H + (\theta_h - \theta_l)\Delta q/2$; $p_L = 0.5t + 0.5I + c_H + (\theta_h - 3\theta_l)\Delta q/2$

$\mathrm{E}[U_H](\theta_h) > \mathrm{E}[U_L](\theta_h)$ and $\mathrm{E}[U_L](\theta_l) > E[U_H](\theta_l)$, which means "*when $\frac{\Delta p}{\Delta q}$ lies in between θ_l and θ_h,, the θ_h clients will try Vendor H and the θ_l clients will try Vendor L.*" □

Lemma 2 (Switching Cost): When $S \geq 0.5t$, no clients will switch. This is proved together with Lemma 4 below.

Lemma 3 (Vendor Coexistence): When vendors coexist and the market reaches $(\theta_h \to H, \theta_l \to L)$ competitive equilibrium, the equilibrium prices will be $\{p_L = \theta_l q_L - 0.25t; p_H = \theta_l q_L + \theta_h \Delta q - 0.25t\}$.

Proof: When *switching cost S* is high enough to lock in all clients, all other types of equilibria, such as $(\theta_h \to H, \theta_l \to H)$ and $(\theta_h \to L, \theta_l \to L)$, will make at least one vendor not serve the market. So when both vendors coexist, the market must reach the $(\theta_h \to H, \theta_l \to L)$ competitive outcome. From Lemma 1, $\theta_l \leq \frac{\Delta p}{\Delta q} \leq \theta_h$ must hold. This results in these conditions for the equilibrium prices: $p_H \geq p_L + \theta_h \Delta q$ and $p_L \leq p_H - \theta_l \Delta q$. Meanwhile, there is an upper bound for the vendors' prices to assure that at time 0, the vendors must give the clients nonnegative expected utility so that the clients will not stay out of the market: $p_H \leq \theta_h q_H - 0.25t$ and $p_L \leq \theta_l q_L - 0.25t$. Also, when these conditions for p_H and p_L are satisfied, the two vendors will try to charge as high prices as possible. Thus, we conclude that the optimal equilibrium prices must be $p_L = \theta_l q_L - 0.25t; p_H = \theta_l q_L + \theta_h \Delta q - 0.25t$. □

Lemma 4 (Equilibrium Solutions): When switching cost is not high enough to lock in all of the clients, different market equilibria will appear. The existence conditions for each of the equilibria are in Table II, and the equilibrium prices are as shown in Table III.

Proof: To illustrate our approach, we will prove the equilibrium for *(hH, lL) + Switch*. The vendors' respective optimization problems involve choosing their profit-maximizing prices, p_H and p_L. These results are shown in Section III. Via the first-order conditions, we obtained the equilibrium prices $\{p_H = 0.5t + 0.5I + (2c_H + c_L)/3 + (\theta_h + \theta_l)\Delta q/6;\ \ p_L = 0.5t + 0.5I + (2c_L + c_H)/3 - (\theta_h + \theta_l)\Delta q/6\}$. Under the condition $(2\theta_l -$

$\theta_h)\Delta q < \Delta c < (2 \cdot \theta_h - \theta_l)\Delta q$, the stated price pair satisfies $\theta_l < \frac{\Delta p}{\Delta q} < \theta_h$, as required by the Price–Quality Difference Lemma 1. Positions of the marginal clients then can be derived accordingly: $d^*_{Hh} = 0.25 + \frac{S}{2t} + \frac{\Delta q}{6t}(2\theta_h - \theta_l) - \frac{\Delta c}{6t}$; $d^*_{Ll} = 0.25 + \frac{S}{2t} + \frac{\Delta q}{6t}(\theta_h - 2\theta_l) + \frac{\Delta c}{6t}$. Note that if $S \geq 0.5t$, $d^*_{Hh} > 0.5$ and $d^*_{Ll} > 0.5$. This means that vendors, if switching cost is greater than 0.5*t*, are able to lock in all existing clients. It is a proof for Lemma 2. However, under the condition $(2\theta_h - \theta_l)\Delta q \leq \Delta c \leq (2\theta_h - \theta_l)\Delta q + 2S - I$, the above equilibrium prices will violate the right-hand side inequality of $\theta_l \leq \frac{\Delta p}{\Delta q} \leq \theta_h$. Hence, we need to rederive the equilibrium prices that make the constraint $\frac{\Delta p}{\Delta q} \leq \theta_h$ binding, that is, $\Delta p = \theta_h \Delta q$.

By the tie-breaking rule stated in Footnote 15, at this $\frac{\Delta p}{\Delta q}$ ratio, we will get an (*hH, lL*) Sampling Stage outcome. Such *constrained equilibrium prices* are $\{p_H = 0.5t + 0.5I + c_L + (3\theta_h - \theta_l)\Delta q/2; p_L = 0.5t + 0.5I + c_L + (\theta_h - \theta_l)\Delta q/2\}$. The positions of the marginal clients are $d^*_{Hh} = 0.25 + S/2t$ and $d^*_{Ll} = 0.25 + S/2t + (\theta_h - \theta_l)\Delta q/t$. When $S \geq 0.5t$, $d^*_{Hh} \geq 0.5$ and $d^*_{Ll} \geq 0.5$, which proves Lemma 2. Similarly, under the condition $(2\theta_l - \theta_h)\Delta q - 2S + I \leq \Delta c \leq (\theta_l - \theta_h)\Delta q$, the left-hand side inequality of $\theta_l \leq \frac{\Delta p}{\Delta q} \leq \theta_h$ is violated. So we need to rederive the equilibrium prices that make the constraint $\frac{\Delta p}{\Delta q} \geq \theta_l$ binding, namely, $\Delta p = \theta_l \Delta q$. The constrained equilibrium prices are $\{p_H = 0.5t + 0.5I + c_H + (\theta_h - \theta_l)\Delta q/2;\ p_L = 0.5t + 0.5I + c_H + (\theta_h - 3\theta_l)\Delta q/2\}$. The positions of the marginal clients are $d^*_{Hh} = 0.25 + S/2t + (\theta_h - \theta_l)\Delta q/t$ and $d^*_{Ll} = 0.25 + S/2t$. So when $S \geq 0.5t$, $d^*_{Hh} > 0.5$ and $d^*_{Ll} > 0.5$, which proves Lemma 2.

The other two equilibria are analyzed using the same method. The objective functions in the $(hH, lH) + Switch$ equilibrium are

$$\text{Vendor } H\text{: } \max_{p_H} (p_H - c_H)(2d^*_{Hh} + 2d^*_{Hl}) - 2I$$

$$\text{Vendor } L\text{: } \max_{p_L} (p_L - c_L - I)(1 - 2d^*_{Hh} + 1 - 2d^*_{Hl})$$

The objective functions in the $(hL, lL) + Switch$ equilibrium are

$$\text{Vendor } H\text{: } \max_{p_H} (p_H - c_H - I)(1 - 2d^*_{Lh} + 1 - 2d^*_{Ll})$$

$$\text{Vendor } L\text{: } \max_{p_L} (p_L - c_L)(2d^*_{Lh} + 2d^*_{Ll}) - 2I$$

For each one can also derive the equilibrium prices and the positions of the marginal clients. We can show that no clients will switch when their $S \geq 0.5t$ too. This is a proof for the Switching Cost Lemma 2. We omit the detailed proofs for the other two types of equilibria here due to space limitations. □

Proof of Proposition 1 (Opportunistic Pricing): When $\Delta c/\Delta q > \theta_l$, if Vendor *H* charges $p_H = c_L + \Delta q\theta_l < c_H$, then for any market share, Vendor *L* must reduce its price to c_L. This is because at any $p_L > c_L$, $\Delta p/\Delta q < \theta_l$. Lemma 1 states that no client will choose Vendor *L*. Vendor *H* is able to reduce its price further by some very small value ε so that Vendor *H* is still able to obtain a profit. Vendor *L* will go out of the market though. When $\Delta c/\Delta q > \theta_h$, a similar argument can be made. Vendor *L* will be able to use $p_L = c_H - \Delta q\theta_h$ to drive Vendor *H* out. □

Proof of Proposition 2 (Nonconfrontational Market Segmentation): The Vendor Coexistence Lemma 3 proves the market equilibrium. The statement that "*there is no direct competition between the SaaS vendors*" is proved based on the discussion in this article. □

Proof of Proposition 3 (Switching Cost Effects): Proving the Switching Cost Effects Proposition 3 is based on the proof for the Equilibrium Solutions Lemma 4 and the conditions for different types of market equilibria to appear. (See Table II.) □

Proof of Proposition 4 (Vendor's Service Quality Strategy): The proposition's conclusion comes directly from the discussions of Fig. 6. □

Acknowledgment

The authors benefitted from the helpful comments of the senior editor, associate editor, and the anonymous reviewers of this work, and the participants of the 2013 International Workshop on Grid Economics. Additional input from T. Weber, E. Clemons, the anonymous reviewers, and discussants of their 2013 Hawaii International Conference on Systems Science were invaluable. They also received useful comments from J. Huang, J. Liu, A. Seidmann, R. Shang, Y. Yang, and M. Yu.

References

[1] R. Aron, E. K. Clemons, and S. P. Reddi, "Just right outsourcing: Understanding and managing risk," *J. Manag. Inf. Syst.*, vol. 22, no. 2, pp. 37–55, 2005.

[2] P. Baake and A. Boom, "Vertical product differentiation, network externalities, and compatibility decisions," *Int. J. Ind. Org.*, vol. 19, nos. 1/2, pp. 267–284, 2001.

[3] Y. Bakos, "Reducing buyer search costs: Implications for electronic markets," *Manag. Sci.*, vol. 43, no. 12, pp. 1676–1682, 1997.

[4] S. Balasubramanian, S. Bhattacharya, and V. Krishnan, "Pricing information goods: A strategic analysis of the selling and pay-per-use mechanisms," INSEAD, Paris, France, 2008.

[5] J. A. Beath and Y. S. Katsoulocus, *The Economic Theory of Product Differentiation*. Cambridge, UK: Cambridge Univ. Press.

[6] A. Beggs and P. Klemperer, "Multi-period competition with switching costs," *Econometrica*, vol. 60, no. 3, pp. 651–666, 1992.

[7] M. Benaroch, Q. Dai, and R. J. Kauffman, "Should we go our own way? Backsourcing flexibility in IT services contracts," *J. Manag. Inf. Syst.*, vol. 26, no. 4, pp. 317–358, 2010.

[8] H. K. Bhargava and V. Choudhary, "Information goods and vertical differentiation," *J. Manag. Inf. Syst.*, vol. 18, no. 2, pp. 89–106, 2001.

[9] L. M. B. Cabral, "Switching costs and equilibrium prices," Working Paper, Stern School of Business, New York Univ., New York, NY, USA, 2012.

[10] H. K. Cheng and G. J. Koehler, "Optimal pricing policies of web-enabled application services," *Dec. Sup. Sys.*, vol. 35, no. 3, pp. 259–272, 2003.

[11] V. Choudhary, "Comparison of software quality under perpetual licensing and software-as-a-service," *J. Manag. Inf. Syst.*, vol. 24, no. 2, pp. 141–165, 2007.

[12] V. Choudhary, K. Tomak, and A. Chaturvedi, "Economics benefits of software renting," *J. Org. Comput. Electron. Commerce*, vol. 8, no. 4, pp. 277–305, 1998.

[13] E. K. Clemons and L. M Hitt, "Poaching and misappropriation of information: Transaction risks of information exchange," *J. Manag. Inf. Syst.*, vol. 21, no. 2, pp. 87–107, 2004.

[14] E. K. Clemons, S. P. Reddi, and M. C. Row, "The impact of information technology on the organization of economic activity: The 'move to the middle' hypothesis," *J. Manag. Inf. Syst.*, vol. 10, no. 2, pp. 9–36, 1993.

[15] B. Darrow, "Slide show: The top 25 tech breakthroughs of all time," CRN, Jun 27, 2007.

[16] C. D'Aspremont, J. J. Gabszewicz, and J. F. Thisse, "On Hotelling's stability in competition," *Econometrica*, vol. 47, no. 5, pp. 1145–1150, 1979.

[17] R. M. Dewan, B. Jing, and A. Seidmann, "Adoption of Internet-based product customization and pricing strategies," *J. Manag. Inf. Syst.*, vol. 17, no. 2, pp. 9–28, 2000.

[18] R. M. Dewan, B. Jing, and A. Seidmann, "Product customization and price completion on the Internet," *Manag. Sci.*, vol. 49, no. 8, pp. 1055–1070, 2003.

[19] J. P. Dubé, J. H. Gunter, and E. R. Peter, "Do switching costs make markets less competitive?" *J. Mktg. Res.*, vol. 46, no. 4, pp. 435–445, 2009.

[20] A. Dubey and D. Wagle, "Delivering software as a service," *McKinsey Quart.*, vol. 6, pp. 1–12, Jun. 2007.

[21] H. Erdogmus, "On-demand enterprise services: Where is the catch?" *IEEE Softw.*, vol. 24, no. 4, pp. 5–7, Jul./Aug. 2007.

[22] M. Fan, S. Kumar, and A. B. Whinston, "Short-term and long-term competition between providers of shrink-wrap software and software as a service," *Eur. J. Oper. Res.*, vol. 196, no. 2, pp. 661–671, 2009.

[23] J. Farrell and C. Shapiro, "Dynamic competition with switching costs," *RAND J. Econ.*, vol. 19, no. 1, pp. 123–137, 1988.

[24] P. Fishburn, A. Odlyzko, and R. Siders, "Fixed fee versus unit pricing for information goods: Competition, equilibria, and price wars," *First Monday*, vol. 2, no. 7, pp. 1–13, 1997.

[25] *Forecast: Public Cloud Services, Worldwide (2010–2016)*, Gartner, Stamford, CT, USA, 2012.

[26] K. Griva and N. Vettas, "Price competition in a differentiated products duopoly under network effects," *Inf. Econ. Policy*, vol. 23, no. 1, pp. 85–97, 2010.

[27] P. L. Guo, "A survey of software as a service delivery paradigm," Working Paper, Helsinki Inst. Technol., Helsinki, Finland, 2009.

[28] H. Gurnani and K. Karlapalem, "Optimal pricing strategies for Internet-based software dissemination," *J. Oper. Res. Soc.*, vol. 51, no. 1, pp. 64–70, 2001.

[29] J. Hickins, "Oracle: on-demand is now on the grid," Internet news, Quinstreet Enterprise, Sep. 2007.

[30] *Market Analysis Perspective: Worldwide SaaS and Cloud Services, 2011: New Models for Delivering Software*, IDC, Framingham, MA, USA, 2011.

[31] R. S. Kaplan and D. P. Norton, "Lock-in strategies: A new value proposition," *Harvard Bus. Rev.*, vol. 8, no. 8, 2003.

[32] P. Klemperer, "Markets with consumer switching costs," *Quart. J. Econ.*, vol. 102, no. 2, pp. 375–394, 1987.

[33] P. Klemperer, "The competitiveness of markets with switching costs," *RAND J. Econ.*, vol. 18, no. 1, pp. 138–150, 1987.

[34] P. Klemperer, "Price wars caused by switching costs," *Rev. Econ. Stud.*, vol. 56, no. 3, pp. 405–420, 1989.

[35] V. Kotelnikov, "Differentiation strategy: How to survive in the era of hypercompetition," White paper, Givis, Dover, DE, 2013.

[36] Y. Liu and H. K. Cheng, "Open source versus proprietary software: A case of fully covered market," in *Exploring the Grand Challenges for Next-Generation E-Business (Lecture Notes in Business Information Processing)*, vol. 52. Berlin, Germany: Springer-Verlag, 2011, pp. 279–288.

[37] D. Ma, "The business model of software-as-a-service," in Proc. IEEE Int. Conf. Serv. Comput., 2010, pp. 701–702.

[38] D. Ma and A. Seidmann, "Analyzing the price competition between SaaS and MOTS software business model," working paper, Singapore Mgmt. Univ., Univ. Rochester, 2014.

[39] N. Matsubayashi, "Price and quality competition: the effect of differentiation and vertical integration," *Eur. J. Oper. Res.*, vol. 180, no. 2, pp. 907–921, 2007.

[40] Z. Meng and S. T. Lee, "Open source vs. proprietary software: Competition and compatibility," Working paper, Nat. Univ. Singapore, Singapore, 2005.

[41] J. Muller, J. Kruger, S. Enderlein, H. Marco, and A. Zeier, "Customizing enterprise software as a service applications: Back-end extension in a multi-tenancy environment," in *Enterprise Information Systems (Lecture Notes in Business Information Processing)*, vol. 24. Berlin, Germany: Springer-Verlag, 2009, pp. 66–77.

[42] L. Murphy, "Average free trial conversion rates ... and why they don't matter," White Paper, SaaS Growth Strategies, Sixteen Ventures, Arlington, TX, USA, 2012.

[43] D. Park, "Differentiation: are product, brand and service still enough?" White Paper, B2B Int., Manchester, U.K., 2013.

[44] E. Ries, *The Lean Start-Up: How Today's Entrepreneur's Use Continuous Innovation to Create Radically Successful Businesses*. New York, NY, USA: Crown, 2011.

[45] *Company Milestones, 2012*, Salesforce.com, San Francisco, CA, USA, 2012.

[46] S. Salop, "Monopolistic competition with outside goods," *Bell J. Econ.*, vol. 10, no. 1, pp. 141–156, 1979.

[47] J. Shin and K. Sudhir, "Switching costs and market competitiveness: Deconstructing the relationship," *J. Mktg. Res.*, vol. 46, no. 4, pp. 446–449, 2011.

[48] A. Susarla, A. Barua, and A. B. Whinston, "Understanding the service component of application service provision: An empirical analysis of satisfaction with ASP services," *MIS Quart.*, vol. 27, no. 1, pp. 91–123, 2003.

[49] J. Sutton, "Vertical product differentiation: Some basic themes," *Am. Econ. Rev.*, vol. 76, no. 2, pp. 393–398, 1986.

[50] C. C. Von Weizsacker, "The costs of substitution," *Econometrica*, vol. 52, no. 5, pp. 1085–1116, 1984.

Dan Ma (M'14) received the Ph.D. degree in computers and information systems from the Simon School of Business, University of Rochester, Rochester, NY, USA, in 2006.

She is currently an Assistant Professor of Information Systems and Management at the School of Information Systems, Singapore Management University, Singapore. Her works have been presented in international workshops and conferences, including the International Conference on Information Systems, the Workshop on Information Systems and Economics, the Hawaii International Conference on System Science, the Annual Workshop on IT and Systems, and the IEEE International Conference on Services Computing, and appeared in the *Journal of Management Information Systems*, *Decision Support Systems*, and *Information Technology and Management*.

Robert J. Kauffman (M'93) received the M.A. degree in East Asian studies from Cornell University, Ithaca, NY, USA, in 1979, and the M.S. degree in system science and the Ph.D. degree in industrial administration from Carnegie Mellon University, Pittsburgh, PA, USA, in 1985 and 1988, respectively.

He is currently an Associate Dean (Research), Deputy Director of the Living Analytics Research Center, and Professor of IS at Singapore Management University, Singapore. His research has been published in *Information Systems Research, MIS Quarterly, Review of Economics and Statistics,* IEEE TRANSACTIONS ON SOFTWARE ENGINEERING, and *Management Science.* His article with X. Li, "Technology Competition and Optimal Investment Timing: A Real Options Perspective" (*IEEE Trans. Eng. Manag.*, 52, 1, 2005), received the 2005 IEEE International Society for Engineering Management Outstanding Research Contribution Award.