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FIRM-LEVEL PRODUCTIVITY ANALYSIS FOR SOFTWARE-AS-A-SERVICE COMPANIES

Completed Research Paper

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Abstract

Software-as-a-service (SaaS) is a relatively new software delivery business model and has been one of the fastest growing segments of the information technology industry in recent years. In this study, we investigate the relationship between the SaaS software delivery model and the productivity of software vendors. We explore scale economies of pure-SaaS firms, non-SaaS firms, and mixed-SaaS firms (firms delivering products by dual models) by examining 179 publicly listed software companies in the United States. We use a Cobb- Douglas production function to model the functional relationship between inputs and outputs and employ the feasible generalized least squares method to evaluate the marginal product of each input factor. The input factors examined include capital, labor, R&D expenses, and marketing expenses. The most surprising result is the presence of significant diseconomies of scale in pure-SaaS firms. Also, SaaS firms are more productive only in utilizing capital assets.

Keywords: Firm performance, Production cost economics, Service-oriented enterprises (SOE)

Introduction

Software-as-a-service (SaaS) is a relatively new software delivery business model. Bill Gates of Microsoft calls it "the next sea change" while analysts call it a "tectonic shift" in the industry and trade publications hail it as "the next big thing" (The Economists 2006). SaaS has also been one of the fastest growing segments of the information technology (IT) industry in recent years. According to forecasts, the revenues of the worldwide SaaS market will grow from $4 billion USD in 2007 to $15 billion USD in 2011 at a 30% annual growth rate, whereas the total software market is expected to grow only 2% to 5% annually (TenWolde 2007).

In this paper, SaaS is defined as a model of software deployment via the Internet whereby the SaaS provider licenses an application to customers as a service based on usage or periodic subscription payments. SaaS software vendors typically host the application on their own web servers or enable customers to download the application to consumer devices via the Internet. In contrast, conventional software vendors charge buyers a one-time large fixed licensing fee and then install, maintain, and upgrade the software application on the customers' machines. The most successful pure-SaaS vendor to date is Salesforce.com, which delivers customer relationship management (CRM) solutions to businesses over the Internet. Salesforce.com was founded in 1999 and went public in June 2004. From 2004 to 2007, the revenues of Salesforce.com grew from 176.4 to 748.7 million, while its stock return was 364% during this period. Abundant success cases from other SaaS providers suggest that the surge of adoption of SaaS applications is not just another irrational technology fad.

The goal of this study is to investigate the influences of the SaaS business model on the Cobb-Douglas production function of software vendors based on the productivity analysis methodology rooted in economics. We classify software companies into three groups: pure-SaaS, non-SaaS, and mixed-SaaS firms.[1] There is a significant amount of evidence suggesting that the innovative SaaS business model provides real additional benefits (a complete discussion is provided in Section 2) to its enterprise clients in comparison to the traditional software business model. Part of the value created by the SaaS model will be reflected in the output (economic value-added) of SaaS vendors and the productivity of SaaS should be higher. Specifically, we are interested in investigating which component in the Cobb-Douglas production function generates the additional value and contributes to higher productivity in the pure-SaaS firms. The research questions of this paper are: (1) How do the productivity of input factors of pure- and mixed- SaaS firms differ from those of non-SaaS firms? (2) Do pure- and mixed- SaaS vendors exhibit larger or smaller economies of scale than non-SaaS firms? (3) Are the mixed-SaaS firms more or less efficient because of economies of scope from their dual-product line approach?

We compile an unbalanced panel dataset of 179 publicly listed software companies between 2002 and 2007 for our empirical task. In our analysis, we choose economic value-added (sales minus cost of goods sold in this study) as the output variable of the production function and analyze two different production functions. The first model's input factors include capital, total number of employees, and intangible assets while the second model uses cost-of-goods-sold, sales and marketing expenses, and R&D expenses as the input factors.

Our analysis shows that pure-SaaS firms exhibit smaller economies of scale than their conventional counterparts, a surprising result that contradicts most of the industry analysts' views. This is because pure-SaaS firms need to invest in the centralized hardware infrastructure so that they can provide applications-on-demand to all customers over the Internet. Those infrastructure related expenses may greatly reduce the "natural economies of scale" feature of the software business, which results from zero variable cost and unlimited capacity. That is, pure-SaaS firms do not

[1] Currently, several large software companies offer both SaaS applications and traditional packaged software applications. These firms may be skeptical about the prospect of SaaS and thus only experiment with the new SaaS model to test its profitability, fit of the SaaS model with their capabilities, customers' acceptance of SaaS, and competitors' responses. The mixed model could be the result of the long transition time for non-SaaS firms to completely migrate to the SaaS model. Another explanation could be that SaaS and non-SaaS applications may have different target customer groups and a software vendor can provide both services in order to increase its potential customer base. At the same time, the mixed-SaaS vendors may enjoy the economies of scope from selling two similar products in one firm. Therefore, in this study, we group sample companies into three categories: pure-SaaS firms, non-SaaS firms, and mixed-SaaS firms. Companies offering only SaaS solutions, such as Salesforce.com and DealerTrack, are categorized as pure-SaaS players. Companies offering both SaaS and packaged software products, such as Ariba and Oracle, are categorized as mixed-SaaS companies. Other conventional software vendors are grouped as non-SaaS firms. Formal definitions are provided in Section 4.

have zero variable cost anymore and may have difficulty in cost-efficiently managing a large server farm and a large IT management team (given the current technology in our sample period). The diseconomies of scale of pure-SaaS firms may also result from demand-side diseconomies of scale as well. Customers of SaaS vendors may suffer from processing power limitations (i.e., X servers can serve at most Y customers simultaneously, which is called congestion cost in the IS economics literature.) whereas non-SaaS firms do not have capacity limit in selling software applications. The analysis for marginal contribution of each input factor shows that at SaaS firms, the output elasticity for capital is larger and for labor is smaller than that of non-SaaS firms, a finding that could result from the lack of experience of SaaS vendors in performing R&D or inefficient sales and marketing activities due to low market acceptance of SaaS applications from 2002 to 2007. This conjecture is confirmed by our regression analysis in the second production function.

Our results also provide evidence that mixed-SaaS firms may enjoy benefits from economies of scope, and mixed-SaaS could be a better approach than either pure-SaaS or non-SaaS business models. Specifically, we find that mixed-SaaS firms have the largest economies of scale and are significantly more productive in utilizing both capital and labor resources, where the gain in labor productivity is mainly due to efficiency in marketing activities.

The current paper is organized as follows: Section 2 discusses the related literature while Section 3 presents the hypotheses. Section 4 reports the data sources, creation of variables, and the empirical model. The main results and related discussions are given in Section 5, with Section 6 concluding the paper.

Background and Literature

Comparison of SaaS and Conventional Software Business Models

There are three major differences between the SaaS and conventional software licensing models. First, SaaS offers web-based access to a commercial software application while conventional software is installed on customers' personal computer servers. Second, in the SaaS model, multiple clients typically access the same application based on a shared IT infrastructure (a multi-tenant architecture), and the servers and data centers are located and managed on the vendor side. Third, customers pay a recurring subscription fee based on usage and alienate the complete ownership of the software to its vendor: the vendor is responsible for all of the support, training, infrastructure operations, and security risks. In contrast, most of the conventional software vendors do not provide a subscription based pricing option.

The SaaS model brings several distinct benefits to its vendors compared with traditional software vendors (Dubey and Wagle 2007; SIIA 2001). First, the online access reduces the costs and efforts previously spent on distribution and implementation. This delivery method also restricts the possibility of customization and the associated debugging costs. Third, since all servers are located on the vendor side, compared with the traditional packaged software models, SaaS vendors do not need to send customer support staff to the customer to provide maintenance services. This not only reduces the maintenance costs but also increases revenue because clients of traditional enterprise software companies typically resort to third-party vendors for hardware and software maintenance. Fourth, the recurring payment model guarantees smoother revenue flow for the vendor company. Lastly, SaaS opens new markets in the small and medium business (SMEs) segment because SMEs may not be large enough to support the fixed costs of implementing expensive enterprise software applications and thus the SaaS application is the only option for them to access to those software features.

The benefits of the SaaS model to its clients are widely discussed in the news media due to the promotion of SaaS vendors (Carraro and Chong 2006; SIIA 2006). First, currently, small and medium-sized businesses are the most enthusiastic adopters of SaaS since it is cheaper and simpler than maintaining rooms of server computers and employing staff to keep them running. In other words, the software deployment, maintenance, and upgrading costs are all transferred to the SaaS vendors. Second, SaaS significantly reduces the time-to-deployment, which enhances greater business agility and enables the corporate customers to focus more on their core businesses. Third, SaaS allows vendors to introduce innovations to their entire installed base simultaneously. This reduces the cost of introducing new versions because developers do not have to worry about backward compatibility or migration paths, and all SaaS customers can enjoy the newest version at a low cost. Fourth, SaaS also minimizes the risk of replacement that normally arises when customers are left behind running old versions of the software. Lastly, the subscription-based pricing reduces the cash outflow of customers by shifting a large asset item (the traditional enterprise software perpetual licensing fee) to a much smaller income statement expense (the monthly SaaS subscription fee), increasing the predictability of corporate buyers' cash flows.

Like other new business models in the infancy stage, the SaaS model also has several shortcomings for vendors (Sääksjärvi et al. 2005). First, the inflexibility of customization makes SaaS unsuitable for innovative or highly specialized niche ecosystems and industries requiring higher customization of enterprise software applications. Second, the fact that the servers are located on the vendor side increases concerns of data security. Third, large companies worry about the reliability, archiving, and regulatory compliance of SaaS. Fourth, the recurring payment mode gives a smoother revenue flow but at the same time makes the break-even time much longer than those conventional software competitors. In terms of starting up a SaaS business, the initial investment is much higher due to buying servers and hosting applications for all customers. Longer break-even time and higher initial investment in hardware makes SaaS a riskier business model than the conventional counterparts. Lastly, SaaS may have lower lock-in effects on existing customers because customers do not need to invest in a huge fixed cost on software licensing (Shapiro and Varian 1999). Also, the staff training cost on a particular system is also lower. In exchange, SaaS vendors can increase the switching cost of clients only by contractual terms. The lower switching cost may make it difficult to keep existing customers, leading to fierce price competition and lower firm profits.

Application Service Provider, On-Demand Computing, and SaaS

There exist two frequently used similar terms in industry reports as well as in the academic literature: "Application Service Provider (ASP)" and "On-Demand Computing". IS researchers has examined various issues about ASP but less about on-demand computing. This section will provide a brief summary of the related literature.

Around 2000, ASP and SaaS were totally equivalent concepts (SIIA 2001) and ASP was more popular in terms of the number of citations in the academic literature and industry reports. Minor differences between ASP and SaaS started to emerge only recently. SaaS vendors typically develop and deliver a new software application based on a powerful shared computing infrastructure. In contrast, ASP is more like a third-party distributor of existing solutions between the target application vendors and customers. ASP vendors get authorization from the software developers and release the software to the end users as a service using subscription-based pricing plans. The underlying IT infrastructure of ASP is sometimes a dedicated one rather than a powerful grid computing infrastructure. To avoid confusion, we use only the SaaS term in the present paper.

IS researchers has examined the ASP business model from different perspectives. Walsh (2003) has provided an excellent overview of the technologies, economies, and strategies of ASP. Cheng and Koehler (2003) modeled the economic dynamics between ASP and its potential customers and derived the optimal pricing policy for ASP vendors. Susarla et al. (2003) developed a conceptual model of customer satisfaction of ASP based on the marketing literature to empirically show that expectations about ASP services have a significant impact on the performance evaluation of ASPs. Smith and Kumar (2004) developed a theory of ASP adoption from the client's perspective based on an analysis of primary and secondary data regarding ASP use. Through both quantitative and qualitative methods, Ma et al. (2005) identified seven dimensions (features, availability, reliability, assurance, empathy, conformance, and security) of service quality for ASP vendors to improve upon. Currie and Parikh (2006) developed an integrative (strategic) model for understanding value creation in web services from a provider's perspective. Demirkan and Cheng (2008) explored an application services supply chain by the analytical modeling approach.

On-demand computing service (also called utility computing) is a popular synonym of Software-as-a-Service. Some "SaaS" companies, such as Omniture Inc., use on-demand computing to describe their business model in its official annual reports. There exist scarce published academic papers dedicated to issues about on-demand computing or SaaS. Bhargava and Sundaresan (2005) studied various pricing mechanisms for on-demand computing with demand uncertainty by using an economic modeling approach. Choudhary (2007) analyzed an economic pricing model that contrasts SaaS and perpetual licensing, while Fan et al. (2009) used a game theoretical approach to examine short- and long-term competition between SaaS and conventional software providers.

To the best of our knowledge, none of the above studies examined the productivity of SaaS firms. Since most of the existing studies are theoretical papers, with the exception of Susarla et al. (2003), the present study could contribute to filling this gap by providing more empirical evidence about the performance of pure-SaaS firms.

IT and Productivity

The production function describes the relationship between a set of inputs and their maximum outputs within the existing technology and economy. The general mathematical form of a single-output production function is usually expressed as:

$$Y=f(X_1, X_2, X_3 \ldots X_n),$$

where Y stands for output, n is the number of inputs, and X_1 to X_n represent factor inputs such as capital, labor, and material. The most commonly adopted production function is the Cobb-Douglas function as follows

$$Y = A \times \prod_{i=1}^{n} X_i^{\beta_i}, \tag{1}$$

where A is a scale factor defined as total factor productivity (TFP) in the literature. TFP captures the impacts of production technology on the output Y. In our context, if SaaS vendors can create higher values than conventional software vendors with similar business process, then the value of SaaS may probably be captured by this term. By taking the logarithm of both sides of (1), we have

$$\ln Y = \ln A + \sum_{i=1}^{n} \beta_i \times \ln X_i, \tag{2}$$

which can be easily estimated by ordinary least squares or other advanced econometric models. Bear in mind that the intercept term of the right-hand side is the logarithm of the TFP, not TFP. In (2), the beta coefficients represent the output elasticities of each input factor: a 1% increase in input factor X_i may lead to β_i % increase in Y.[2]

In this study, we define economies of scale as the production functions in which "when all inputs are increased by a proportion, output will increase by a larger ratio". In an industry with economies of scale, firms will enjoy lower average costs when the firm size is larger, rewarding larger firms and leading to a monopoly or oligopoly in the end. In any Cobb-Douglas production function, it can be verified that the sum of the beta coefficients measures the economies of scale. Formally, in (2), production functions with $\sum_{i=1}^{n} \beta_i > 1$ exhibit increasing returns to scale. Production functions with $\sum_{i=1}^{n} \beta_i = 1$ exhibit constant returns to scale.

In the information systems literature, the most fruitful application of the productivity analysis by Cobb-Douglas function is IT productivity paradox: how expenditures on computers and IT workers may affect productivity at the firm, industry, or country level. In the early 1990s, researchers found that information technologies made no contribution to the production of firm output (Barua et al. 1991; Loveman 1994). Later, Brynjolfsson and Hitt (1996) documented how IS spending had made a substantial and statistically significant contribution to firm output. In a related paper (Hitt and Brynjolfsson 1996), the authors showed that IT increases productivity and creates substantial value for consumers but does not improve profitability for firms. There have been extensive studies following these two papers. A short list of examples includes the following papers. Dewan and Min (1997) extended earlier works to show that IT capital is a net substitute for both ordinary capital and labor, suggesting that the factor share of IT in production will grow to more significant levels over time. Dewan and Kraemer (2000) estimated an inter-country production function relating IT and non-IT inputs to GDP output. Kudyba and Diwan (2002) re-examined the productivity paradox with updated data, while Cheng and Nault (2007) estimated the effects of IT investments made upstream on downstream productivity. Mittal and Nault (2009) studied the indirect impact of IT on the production function at the industry level.

Similar productivity analysis methods have been applied to the study of other issues in the IT/MIS area. Banker and Slaughter (1997) investigated the relationship between project size and software maintenance productivity using

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[2] After differentiating both sides with respect to X_i, it follows that

$$\frac{dY}{Y} = \beta_i \times \frac{dX_i}{X_i} \Leftrightarrow \beta_i = \frac{dY}{Y} / \frac{dX_i}{X_i}.$$

Data Envelopment Analysis (DEA). Gurbaxani et al. (1997, 2000) conducted an empirical analysis of information systems budgeting for hardware and personnel to produce information services, based on the studies conducted by Gurbaxani and Mendelson (1987, 1990, 1992). Banker et al. (1994), Hu (1997), and Pendharkar (2006) studied software development at the project level.

Our study is different from the above two types of studies in that our focus is to compare the production of software at pure-SaaS, non-SaaS, and mixed-SaaS firms, which has not been investigated in the literature. Our research is related to the IT and productivity studies in that we apply very similar empirical methods: productivity analysis using a Cobb-Douglas function with similar input and output variables at the firm level. However, we do not focus on the role of IT hardware or IT workers expenses in production. Compared with the productivity analyses of software development and maintenance studies, the difference is that our analysis is at the firm level while those studies focused on production of software at the project level. As a result, most of the output and input variables are different. The findings of our paper can complement those studies to shed more light on the operations and performance of software vendors.

Theory and Hypotheses

Economies of Scale

> *"In addition to economies of scale, there's safety in numbers...so choosing an ASP with a long list of customers that haven't been prosecuted ensures something approaching best practices." (Information Week 2007)*
>
> *According to Nicholas Carr, "Electricity production, as do IT and computing, benefits from economies of scale." (USA Today 2008)*
>
> *"The sheer economies of scale achieved by public cloud providers will inevitably mean they dominate in future." (Computer Weekly 2009)*

Although economies of scale of software development and maintenance have been investigated at the project level, the existing studies have not addressed issues related to SaaS. As a result, we need to resort to anecdotal reports and economic intuitions to form our hypotheses. Trade magazine articles about SaaS generally refer to "economies of scale" as one of the major benefits over a traditional software delivery model. However, we will explain in detail in the following paragraphs that, in the framework of the current paper, SaaS firms actually have smaller economies of scale than traditional software firms.

There are two countervailing effects in the SaaS model: a centralized IT infrastructure, one of the three prominent features of SaaS, both increases and decreases economies of scale. First, in the SaaS model, vendors provide applications based on a powerful server farm, a large data center, and a professional IT management team at their sites. The fixed costs of the centralized IT infrastructure are indirectly shared among all customers and this cost-sharing is the main source of economies of scale mentioned in industry press articles. A shared IT infrastructure provides another source of economies of scale by increasing the utilization rate of computing resources. Studies have shown that the traditional software delivery model leads to overbuilding of IT assets (Carr 2005): the utilization rate of the computing power of servers is around 10% to 35% while that of desktop computers is only 5%. In a SaaS delivery model, because several firms operate on the same infrastructure, the under-utilization of processing power and storage can be alleviated. In sum, infrastructure cost-sharing and CPU time-sharing increases economies of scale of SaaS vendors and buyers as a group.

The second effect is that when the IT infrastructure and staff are centralized at the SaaS vendors, all costs are transferred to SaaS vendors from their clients. As a consequence, the cost function of SaaS vendors has a significant variable cost component because in order to serve more customers, the SaaS vendors need to install more servers, rent a larger space, and hire more IT workers. As a result, SaaS firms may not have zero variable cost anymore, eliminating the famous zero variable cost feature that makes conventional software companies enjoy huge (supply-side) economies of scale. At the same time, the centralized infrastructure also imposes capacity constraints on SaaS firms: there is a limit on the CPU processing power, memory or hard-disk storage space, and physical space for storing and cooling the hardware. The limited CPU processing power is an important source (it is the most expensive input) of congestion cost for the customers and is an example of demand-side diseconomies of scale.

Therefore, the centralized IT infrastructure destroys both supply-side and demand-side the economies of scale in the traditional software business.

We hypothesize that the second effect may dominate the first one. The reason is that the value of economies of scale created from the centralized IT infrastructure (first effect) will be distributed among a SaaS vendor and its clients, depending on the bargaining powers between the SaaS vendor and its clients. Our conjecture is that the values of the joint "economies of scale" may mostly go to the buyers because pure-SaaS vendors are generally newer, less reputable, and smaller than their traditional counterparts. For example, the earliest IPO case was in 2002, and the most successful firm, Salesforce.com, went public in 2004 and posted loss until 2006. This implies the following hypotheses.

> ***H1a.The production function of pure-SaaS vendors has smaller economies of scale than that of the traditional software vendors.***
>
> ***H1b.The production function of pure-SaaS vendors has smaller economies of scale than that of the mixed-SaaS software vendors.***

Output Elasticity of input factors

In the SaaS model, the IT infrastructure is centralized at SaaS vendors, so we expect that the productivity contribution (output elasticity) of capital in the SaaS production function is larger than that of the non-SaaS production function. This is because non-SaaS firms use capital or fixed assets mainly for R&D or administrative purposes, whereas part of the fixed assets of pure-SaaS firms are used to provide SaaS services to their customers.

There are two reasons that the productivity of labor is lower at SaaS vendors. Since SaaS vendors are younger, their employees enjoy smaller learning-by-doing effect in all functions. Second, since the technology is relatively new, customer acceptance is low and the marketing productivity will be lower.

> ***H2.The output elasticity of capital (i.e., marginal contribution of capital to output) is higher in delivering SaaS applications than non-SaaS applications.***
>
> ***H3.The output elasticity of labor (i.e., marginal contribution of labor to output) is lower in delivering SaaS applications than non-SaaS applications.***

Economies of Scope of Mixed-SaaS Firms

Economies of scope are conceptually similar to economies of scale. Whereas economies of scale primarily refer to the production efficiencies associated with selling more quantities of the same product, economies of scope refer to efficiencies primarily associated with selling through more marketing channels or selling a larger number of different products.

Compared with pure- and non-SaaS firms, mixed-SaaS firms are different in that they are able to deliver the same software application via two different business models. Intuitively, mixed-SaaS firms should be more efficient or productive in utilizing their capital and labor because of the economies of scope: they can provide customers two options with the same marketing team and probably a slightly larger R&D team. Also, the output elasticity for the capital dedicated to the delivery of SaaS applications should be higher than that for the capital used in non-SaaS firms for the same reason discussed in H2. This implies the following two hypotheses.

> ***H4.The output elasticity of capital (i.e., marginal contribution of capital to output) is higher in the production function of mixed-SaaS firms than in non-SaaS firms.***
>
> ***H5.The output elasticity of labor (i.e., marginal contribution of labor to output) is higher in the production function of mixed-SaaS firms than in non-SaaS firms.***

Data and Empirical Methods

The target industry of this study is the software industry, which is defined as the set of publicly listed firms with a Standard Industry Classification (SIC) code equal to 7372. As a consequence, we are forced to leave out some famous firms pioneering in SaaS, such as Amazon, Sun Microsystems, HP, and IBM. Samples with missing values in output or input variables are dropped. The data used for this analysis is comprised of an unbalanced panel of 179 unique firms over the period 2002-2007 with 770 data points overall. The first year that two pure-SaaS companies went public in the U.S. was 2002, and an ending point of 2007 was chosen because the complete financial statements of 2008 are still not available at the time when study was conducted.

This section explains in detail how we compile and construct the dependent and independent variables. A summary of the sources, construction procedures, and deflator for each variable is provided in Table 1, and sample statistics are reported in Table 2.

Table 1: Data Sources, Construction Procedures, and Deflators.

Variable Name	Construction Process	Source	Deflator	Notation
Output	Total Revenue (revt) minus Cost of Goods Sold (cogs), converted to constant 2002 dollars	Compustat	Producer Price Index for software (SIC code = 7372 or NAICS code = 511210) (Bureau of Labor Statistics 2009)	Y
Capital	Fix Assets (Total Assets (at) minus Total Current Assets (act) minus Intangible Asset (intan)), converted to constant 2002 dollars	Compustat	Producer Price Index for Intermediate Materials, Supplies and Components (Bureau of Labor Statistics 2009)	K
Labor	Total number of employees (emp)	Compustat	N/A	L
Intangible Assets	Intangible Assets (intan), converted to constant 2002 dollars	Compustat	Producer Price Index for Intermediate Materials, Supplies and Components (Bureau of Labor Statistics 2009)	I
Cost of Goods Sold	Cost of Goods Sold (cogs), converted to constant 2002 dollars	Compustat	Producer Price Index for Intermediate Materials, Supplies and Components (Bureau of Labor Statistics 2009)	C
SGA Expense	Sales and General Administrative Expenses (xsga) minus R&D Expense (xrd), converted to constant 2002 dollars	Compustat	Producer Price Index for Intermediate Materials, Supplies and Components (Bureau of Labor Statistics 2009)	S
R&D Expense	R&D Expenses (xrd), converted to constant 2002 dollars	Compustat	Producer Price Index for Intermediate Materials, Supplies and Components (Bureau of Labor Statistics 2009)	R

Dependent Variables

The standard output measure used in the literature is economic value added, which is defined as the additional value of the final product over the cost of input materials used to produce it from the previous stage of production (Brynjolfsson and Hitt 1996, Dewan and Min 1997, and Kudyba and Diwan 2002). The software business is unique in that the "input materials from the previous stage" are not well-defined. In this paper, we use a simple definition: output (equivalently, value-added) is operationalized as the total annual sales minus the cost-of-goods-sold (COGS) with total sales deflated by PPI in the software industry and COGS deflated by PPI for intermediate goods.

Independent Variables

This study considers two sets of three key input factors as the independent variables. One set of variables is obtained from the balance sheet and the other set is obtained from the income statement. The input factors from the balance sheet are fixed assets (a typical measure of "capital" in the literature), number of employees (a typical measure of "labor" in the literature), and intangible assets. The first two variables are standard inputs in the productivity analysis literature and the last input is important for the production of software products or services.

The input factors from the income statement are cost of goods sold (COGS), research and development expenses (R&D), and selling, general, and administrative expenses (SG&A). These three items together account for more than 95% of the total expenses of most software companies.

There are several reasons that we investigate the second model using input factors from the income statement. First, "labor" is clearly more important than capital inputs in conventional software companies and deserves deeper-level investigation. Also, employees working at software companies may have very different job functions. However, we do not have access to the subcategory of employees to differentiate between software developers and marketing managers. Therefore, we use R&D expense as the proxy variable for the number of R&D software developers and SG&A expenses as the proxy variable for the size of the marketing and sales team. With this approach, we can examine the source of efficiency differences in labor productivity between SaaS and non-SaaS firms.

Table 2: Descriptive Statistics

All Firms	Output	Capital	Labor	Intangible Assets	COGS	SGA Expenses	R&D Expense
Mean	340.333	335.327	1.664	237.247	87.712	192.302	60.529
Std.dev	1222.936	1491.793	5.642	1279.823	278.049	502.193	172.133
Max	19247.188	21835.308	84.233	19754.721	3528.538	6160.155	2070.105
Min	0.706	0.132	0.002	0.000	0.111	2.099	0.164

Sample Size (firm-year pair) = 770

Pure-SaaS	Output	Capital	Labor	Intangible Assets	COGS	SGA Expenses	R&D Expense
Mean	101.607	58.828	0.632	27.284	24.952	65.701	10.232
Std.dev	124.286	65.945	0.548	40.606	24.703	82.746	9.456
Max	644.377	261.127	2.606	137.485	115.863	416.866	47.775
Min	6.996	1.034	0.058	0.000	1.238	6.636	1.283

Sample Size =34

Mixed-SaaS	Output	Capital	Labor	Intangible Assets	COGS	SGA Expenses	R&D Expense
Mean	609.862	497.951	2.937	365.201	123.556	310.145	97.837
Std.dev	1968.238	2088.103	9.206	1837.595	401.280	747.465	253.695
Max	19247.188	21835.308	84.233	19754.721	3528.538	6160.155	2070.105
Min	3.412	1.689	0.047	0.000	1.060	6.146	0.183

Sample Size =250

Non-SaaS	Output	Capital	Labor	Intangible Assets	COGS	SGA Expenses	R&D Expense
Mean	218.388	271.017	1.082	186.116	73.664	140.540	44.856
Std.dev	570.120	1125.451	2.386	921.509	196.809	318.755	113.091
Max	5499.770	11622.539	17.600	10796.966	1515.151	2737.292	960.559
Min	0.706	0.132	0.002	0.000	0.111	2.099	0.164

Sample Size =486

Dummy Variable for Firm Categorization

The most critical independent variable of our research is the software company's business type: a pure-SaaS firm, a non-SaaS firm, or a mixed-SaaS firm. We use two dummy variables to measure this categorization. This study classifies software companies by the following approach. First, we download the annual reports (SEC form 10-K) of software vendors from 2002 to 2007 (calendar year). All software companies are required to submit annual reports to the Securities and Exchange Commission (SEC) and these reports are freely available online. In each report, the first section is the "business description". We use a Java program to identify the 10K reports that include a list of keywords related to SaaS.[3] Next, we coded each flagged 10K report to label the case as a pure-SaaS, a non-SaaS, or a mixed-SaaS firm. Our final list of pure-SaaS firms is consistent with an industry report from the Software Equity Group, and the results should be quite robust.

The coding of mixed-SaaS firms is less objective. For the flagged firms that are not pure-SaaS firms, we need decide it is a mixed- or non-SaaS firm. Since we do not have access to the proportion of SaaS revenue in a software company, we need to subjectively decide whether its SaaS operations are significant enough so that the target firm is coded as a mixed-SaaS firm. The other source of data limitations is that some firms do not mention their SaaS business in the annual report, or use a different name for SaaS services that is not captured by our Java program. However, we only underestimate but not overestimate the number of mixed-SaaS firms because of this problem. Therefore, our analysis is robust in that including those few missing mixed-SaaS cases strengthens, but does not invalidate, the findings of the present study.

Models

We base our empirical analysis on two augmented Cobb-Douglas production functions. In the first case, the independent variables are labor (L), capital (K), and intangible assets (I), while in the second case, the independent variables are cost-of-goods-sold (C), selling and general administrative expenses (S), and research and development expenses (R). We first perform fixed-effect panel-data regression models for our sample. As the standard fixed-effect regressions displayed significant levels of serial correlation based on Durbin-Watson tests and heteroskedasticity based on Breush-Pagan tests, we use Feasible Generalized Least Squares (FGLS) with within-panel corrections (AR1 error process) for heteroskedasticity and autocorrelation as the baseline econometric model for this paper. FGLS has been widely used in studying production functions by researchers in the IS literature (e.g., Dewan and Kraemer 2000, Cheng and Nault 2007, Mittal and Nault 2009).

Formally, we consider the two models presented below.

<u>**Model 1: Balance Sheet Model**</u>

$$\ln Y_{it} = \alpha_0 + \sum_{i=1}^{n} \alpha_i + \sum_t \beta_{0t}^N D_t + p_i \sum_t \beta_{0t}^P D_t + m_i \sum_t \beta_{0t}^M D_t + (\beta_K^N + \beta_K^P p_i + \beta_K^M m_i) \ln K_{it}$$
$$+ (\beta_L^N + \beta_L^P p_i + \beta_L^M m_i) \ln L_{it} + (\beta_I^N + \beta_I^P p_i + \beta_I^M m_i) \ln I_{it} + u_{it}, \qquad (3)$$

where the superscripts of the beta coefficients indicate that a firm is a non-SaaS firm (N), a pure-SaaS firm (P), or a mixed-SaaS firm (M), and p_i and m_i are dummy variables for indicating pure- or mixed-SaaS firms, respectively. We use the subscript *i* to indicate different firms and *t* to indicate different years. Intuitively, (3) is simply a standard regression equation with several dummy variables: including year and firm dummies of the intercept and dummies for three types of firms of all beta coefficient terms. Bear in mind that the coefficient of the multiplicative terms (e.g., $p_{it}K_{it}$) indicates the difference of the productivity of that input factor in a non-SaaS and SaaS firm. Also note that we allow the intercept term to vary across each category-year pair so that we can compare the time series of TFP (e.g., three categories of firms) from 2002 to 2007. Similarly, we have the following model using the inputs from the income statement.

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[3] This case-insensitive keyword list includes "on-demand", "SaaS", "Software-as-a-Service", "Application Service Provider", and variations with or without dashes.

Model 2: Income Statement Model

$$\ln Y_{it} = \alpha_0 + \sum_{i=1}^{n} \alpha_i + \sum_t \beta_{0t}^N D_t + p_i \sum_t \beta_{0t}^P D_t + m_i \sum_t \beta_{0t}^M D_t + (\beta_C^N + \beta_C^P p_i + \beta_C^M m_i) \ln C_{it}$$
$$+ (\beta_R^N + \beta_R^P p_i + \beta_R^M m_i) \ln R_{it} + (\beta_S^N + \beta_S^P p_i + \beta_S^M m_i) \ln S_{it} + u_{it}, \quad (4)$$

Both Models 1 and 2 are estimated by FGLS so that the autocorrelation and heteroskedasticity of u_{it} are appropriately modeled. In both Models 1 and 2, we report the results from two sub-cases with a different assumption about the autocorrelation: (1) the same autocorrelation coefficient of AR1 process applies to all samples; and (2) different firms have different autocorrelation coefficients (firm specific AR1). We have also examined the fixed-effect, random-effect, and panel corrected standard errors for robustness check but the results are omitted in this draft due to the space limitations.

Analysis

Economies of Scale

The results of our estimations are reported in Tables 3 and 4. Estimates of the intercept terms are reported separately in Table 7 for computing TFPs. At first look, Tables 3 and 4 suggest that most of the coefficients of the baseline case (non-SaaS firms) are significant at the 1% level, except for the coefficient of intangible asset which is significant at 10% for the AR(1) case. Note that the coefficients in Tables 3 and 4 for pure- and mixed-SaaS firms are incremental values. For example, the marginal product of capital for the pure-SaaS firm is the sum of two values, 0.130+0.0948. As a consequence, the p-value under 0.0948 indicates whether the coefficient of pure-SaaS firms is significantly greater than that of non-SaaS firms.

Based on Tables 3 and 4, we can calculate the economies of scale of three types of firms, defined as the sum of the output elasticities of the three input factors. The confidence intervals of those estimates are reported in Table 5, which shows that Hypothesis 1 is supported in both models: pure-SaaS firms indeed have (much) smaller economies of scale than the other two cases while mixed-SaaS firms have the largest economies of scale among the three types of firms. One explanation could be that the mixed-SaaS firms have much greater bargaining power than pure-SaaS firms and thus can appropriate more values created by the SaaS business model. It is also possible that the synergy of the mixed-SaaS firm dominates the diseconomies of scale in the SaaS model, leading to increased economies of scale. **Hypothesis 1 is supported.**

Table 3. FGLS Estimates of Model 1

Coefficient Est.	AR(1)	Panel Specific AR
K	0.130***	0.181***
	(0.000)	(0.000)
p*K	0.0948***	0.0672*
	(0.007)	(0.053)
m*K	0.0695***	0.0289***
	(0.005)	(0.000)
L	0.808***	0.786***
	(0.000)	(0.000)
p*L	-0.134**	-0.222***
	(0.026)	(0.000)
m*L	0.0443	0.0664***
	(0.250)	(0.000)
I	0.00711*	0.00823***

	(0.075)	(0.000)
p*I	-0.00810	-0.00321
	(0.541)	(0.865)
m*I	-0.0178**	-0.0159***
	(0.013)	(0.000)

p-values in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All intercept estimates are omitted for brevity

Table 4. FGLS Estimates of Model 2

Coefficient Est.	AR(1)	Panel Specific AR
C	0.0962***	0.112***
	(0.000)	(0.000)
p*C	0.0996**	0.0884**
	(0.044)	(0.021)
m*C	-0.0182	-0.0306***
	(0.301)	(0.004)
R	0.145***	0.113***
	(0.000)	(0.000)
p*R	-0.0778*	-0.0579**
	(0.097)	(0.013)
m*R	-0.0219	0.00120
	(0.465)	(0.945)
S	0.829***	0.880***
	(0.000)	(0.000)
p*S	-0.139***	-0.201***
	(0.001)	(0.000)
m*S	0.0782**	0.0349**
	(0.028)	(0.038)

p-values in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All intercept estimates are omitted for brevity

Table 5. Economies of Scale (Panel-Specific AR)

	Coef.	**Std. Err.**	**[95% Conf. Interval]**	
Model 1				
Non-SaaS	**0.9750**	**0.0074**	0.9605	0.9894
Pure-SaaS	**0.8168**	**0.0594**	0.7004	0.9332
Mixed-SaaS	**1.0544**	**0.0016**	1.0514	1.0575
Model 2				
Non-SaaS	**1.1053**	**0.0018**	1.1018	1.1089
Pure-SaaS	**0.9351**	**0.0214**	0.8932	0.9770
Mixed-SaaS	**1.1109**	**0.0031**	1.1048	1.1169

5.2 Productivity of Inputs

From Tables 3 and 4, we can examine the productivity contribution of each input factor. Note that the beta coefficient indicates the marginal contribution of productivity from that input factor. Specifically, the beta coefficient measures the percentage change in the output when the input is increased by one percent (output elasticity).

Capital: Both pure- and mixed-SaaS firms have significantly larger coefficients than those of non-SaaS firms. This finding is consistent with the conjecture that capital in non-SaaS firms contributes less to its output because fixed assets (such as computers or buildings) are used to support R&D and back office operations. The productivity difference is also economically significant, with a gain in productivity of at least 37% for pure-SaaS firms higher than non-SaaS firms (0.181 versus 0.181+0.0672 in the panel specific AR case) and 16% for the mixed-SaaS firms over non-SaaS firms (0.181 versus 0.181+0.0289 in the panel specific AR case). **Hypotheses 2 and 4 are supported.**

Labor: Our results suggest that the output elasticity for employees in pure-SaaS firms is lowest whereas the output elasticity for employees in mixed-SaaS firms is highest among the three types of firms. These comparisons are both statistically and economically significant. Due to the opposite sign of the results in the pure- and mixed-SaaS firms, we can conclude that the productivity gain of the mixed-SaaS firm is not a manifest of using SaaS business delivery model, but because of the economies of scope or other unidentified reasons. Otherwise, the labor productivity of the mixed-SaaS firms should be smaller than that in non-SaaS firms. As we have discussed in Section 3, we can examine the results of Model 2 to shed more light on the findings of Model 1 and can further delve into the cause of the differences in labor productivity.

Table 4 shows that pure-SaaS firms have lower productivity both in R&D and SG&A, which together contribute to the 22.5% lower labor productivity identified in Model 1.[4] There are several potential factors contributing to this observation. First, sales and marketing costs remain relatively high for SaaS firms as generally acceptable accounting principles (GAAP) force recognition of expenses in advance of subscription revenue, contributing to low SG&A productivity. Also, the SaaS model is relatively new and market acceptance among customers was still relatively low from 2002 to 2007, leading to lower marketing and sales productivity. As to the R&D productivity, in practice, SaaS firms typically have a lower R&D ratio (normalized by total revenue) because SaaS vendors support and manage only a single version of the software. This leads to significantly lower R&D costs because resources are not fragmented by supporting multiple versions or releases. However, our findings suggest that the output (value-added) could be hurt as well, leading to lower R&D productivity. Another explanation of this finding could be that SaaS firms are typically younger and smaller and their employees may lack experience in efficiently operating the SaaS model. That is, the learning-by-doing benefit in SaaS firms is much smaller than in non-SaaS firms. Lastly, a related potential cause is that SaaS firms are less reputable compared with well-established software companies. Therefore, they may not be able to attract talented staff from large companies such as Oracle or Adobe.

In contrast, the results of Model 2 suggest that mixed-SaaS firms have higher labor productivity mainly because of their SG&A activities. This evidence supports Hypothesis 5 that mixed-SaaS firms enjoy the synergy from selling two products via one channel. At the same time, there is no evidence that such synergy exists in R&D. Intuitively, it is convincing that the synergy of selling two products in one firm is larger than the synergy of R&D of two SaaS and non-SaaS applications in one firm: selling SaaS in addition to non-SaaS does not increase costs that much as R&D SaaS applications in addition to non-SaaS version of that application. **Hypothesis 3 and Hypothesis 5 are supported.**

5.3 Total Factor Productivity

In the Cobb-Douglas production function, the growth in the output variable may result from growth in the input factors and growth in total factor productivity, which is defined as the measure which accounts for effects in total output not caused by inputs in economics. A change in TFP is typically interpreted as a change in production technology. Clearly, the SaaS business model is an innovation in the production and delivery of software services. We can investigate the impacts of SaaS on TFP by examining the intercept terms in our regression models.

[4] 22.5% is derived by averaging the productivity loss in two cases: 0.134/0.808 and 0.222/0.786 in Table 3.

However, analysis in this section is more like a pilot study because the sample size of pure-SaaS firms is small: there are only 2 firms in 2002 and 9 firms in 2007. The estimated growth of TFP in our sample may result from the productivity difference among SaaS firms. As a result, investigating the growth pattern of TFP is just for completeness of the analysis. A rigorous and fruitful investigation is left for future research.

Recall that we have an intercept term for each type of firm in each sample year. The estimated intercept terms (logarithms of TFP) are reported in Table 6a. Table 6b presents the values of TFP and suggests that TFP of mixed- and non-SaaS firms are quite similar. Comparing the TFP of mixed-SaaS firms with the TFP of non-SaaS firms, we cannot conclude that the TFP of mixed-SaaS firms is consistently higher. One weakness of our research design is that we do not have the percentage of revenue from SaaS in mixed-SaaS firms. If the revenue contribution of SaaS was still small in mixed-SaaS firms from 2002 to 2007, then this result is obvious. In sum, we cannot conclude that using a dual channel approach in mixed-SaaS firms improves the TFP of software companies in this study.

Table 6b also shows sharply contrasting results about pure-SaaS firms in Models 1 and 2: the TFP of pure-SaaS firms is much smaller than that of the other two types of firms in Model 1, whereas the TFP of pure-SaaS firms is much larger than that of the other two types of firms in Model 2. This contradictory finding may imply that using input factors from the balance sheet (or income statement) for productivity analysis may underestimate (or overestimate) the productivity of SaaS firms. One potential explanation is that the subscription-based pricing together with the accounting rules about depreciation and expense recognition, a young pure-SaaS firm may exhibit that data pattern. The reason is that the book value of assets is relatively large in the earlier years of young firms when those assets haven't been depreciated. At the same time, part of the "real output" created this year will be realized in the future due to the subscription base pricing. Therefore, the TFP is underestimated. In order to perfectly measure the TFP of the pure-SaaS vendors, we need to design a new approach to aggregate the revenue across several years. However, this cannot be rigorously analyzed in the present study because we do not have the detailed sales contracts of pure-SaaS firms and it becomes infeasible to rigorously aggregate revenues across different years.

In Table 6c, we can observe the growth patterns of the TFP of the three types of firms. The growth patterns of pure-SaaS firms are quite unstable because of the limitation of our small sample size. Contrary to our expectation, our findings do not provide consistent evidence that the SaaS model improves the TFP of software firms because the TFP of non-SaaS firms is the highest in model 2 and not much smaller than pure-SaaS and mixed-SaaS firms in model.

Table 6a Original Intercept Coefficients Estimates (Panel-Specific AR)

	Model 1			Model 2		
	Non	PS	MS	Non	PS	MS
2002	4.177	3.649	4.155	-0.016	0.695	0.110
2003	4.304	4.131	4.217	0.251	0.918	0.248
2004	4.409	3.920	4.345	0.339	1.018	0.361
2005	4.440	4.008	4.425	0.449	1.136	0.488
2006	4.474	3.990	4.485	0.506	1.144	0.500
2007	4.552	4.135	4.554	0.620	1.246	0.562

Table 6b Total Factor Productivity Estimates (Panel-Specific AR)

	Model 1			Model 2		
	Non	PS	MS	Non	PS	MS
2002	65.170	38.436	63.739	0.984	2.004	1.116
2003	73.995	62.240	67.809	1.285	2.504	1.281
2004	82.187	50.400	77.092	1.404	2.768	1.435
2005	84.775	55.037	83.513	1.567	3.114	1.629
2006	87.707	54.055	88.677	1.659	3.139	1.649
2007	94.822	62.483	95.012	1.859	3.476	1.754

Table 6c Growth Rate of TFP Estimates (Panel-Specific AR)

	Model 1			Model 2		
	Non	PS	MS	Non	PS	MS
2002						
2003	13.54%	61.93%	6.39%	30.60%	24.98%	14.80%
2004	11.07%	-19.02%	13.69%	9.20%	10.52%	11.96%
2005	3.15%	9.20%	8.33%	11.63%	12.52%	13.54%
2006	3.46%	-1.78%	6.18%	5.87%	0.80%	1.21%
2007	8.11%	15.59%	7.14%	12.08%	10.74%	6.40%
Total	145.50%	162.56%	149.06%	188.89%	173.50%	157.15%

Conclusion

In this paper, we explore the relationship between the SaaS software delivery model and the productivity of software vendors using a Cobb-Douglas production function approach. Our results indicate the presence of significant scale economies in mixed-SaaS firms and significant diseconomies of scale in pure-SaaS software companies. This is because pure-SaaS vendors actually sell “two products”: a software application and the IT management service of that application. Software application is well-accepted as the typical example enjoying both supply- and demand-side economies of scale. However, the IT management service does not have zero variable cost, which reduces supply-side economies of scale. Also, the server farms at SaaS vendors are subject to high congestion costs, a classical example of demand-side diseconomies of scale. As a result, the production function of SaaS firms may have much lower economies of scale. The implication of this finding is that it might be difficult for pure-SaaS firms to compete with larger established software companies when they start to offer competing SaaS applications.

Our productivity analysis suggests that the capital of pure-SaaS firms contributes more to firm output compared with non-SaaS firms. At the same time, labor contributes significantly less to the output of pure-SaaS firms compared to non-SaaS firms. The low productivity results both from R&D and marketing activities. In contrast, our analysis also shows that employees of mixed-SaaS firms contribute much more to output, with the high labor productivity mainly resulting from the efficiency of marketing and sales activities. Overall, our analysis seems to imply that mixed-SaaS firms are more efficient than pure-SaaS firms in several aspects. In other words, a "hybrid" model combining traditional software with SaaS could be the most efficient organizational form of software companies in the future. Even if the traditional software delivery model’s eclipse by SaaS seems to be inevitable, it is too soon to write the obituary for traditional software companies as Microsoft, Oracle, and SAP, which are all belatedly moving into SaaS.

There are several possible extensions to this study. First, one major limitation is that we only have publicly available data from Compustat, so we do not have detailed contract-level revenue stream to calculate the exact output of SaaS firms in each year. Also, we cannot assess the proportion of revenue generated from SaaS in mixed-SaaS firms. With those proprietary data, researchers could shed more light on the differences between SaaS and non-SaaS production functions. Another possibility for further research is examining the overall business risk of pure-SaaS firms. From the perspective of licensing, the subscription-based pricing provides a smoother revenue spread over multiple years, on the one hand. On the other hand, it reduces the switching cost of buyers because of lower upfront large investments in software licenses and may increase the variability of the number of customers. It is not obvious whether the volatility of revenue from subscription-based pricing is smaller or larger than that from perpetual licensing plans. At the same time, since SaaS firms centralize the IT infrastructure and related IT management, the operation risks also become “centralized”. For example, Salesforce.com has had several outage events in the past, leaving thousands of businesses without access to their applications at the same time. The impact of the centralized risk on the valuation of SaaS firms or their products pricing is another important issue. Competition and product differentiation are clearly important traits of the software industry. Modeling the impacts of competition on the performance of SaaS firms could be another fruitful research direction.

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