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

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SUMMARY

The Software-as-a-Service (SaaS) business model is that, the vendors host their software application on their own servers, release it to several customers at one time through the internet using a multi-tenant architecture, and charge the customers by a recurring monthly subscription model. This new software management model has been place great expectation on as a more efficient software business model and as a future trend of the industry.

This research uses firm level financial data of software vendors from 2002 to 2007. We categorize software vendors into three groups: pure-SaaS vendor, mixed-SaaS vendor, and non-SaaS vendor. This categorization is used as the most critical dummy variable of the following analysis. We first build a performance model for SaaS business and study the effect of different business model on firm performance. Then we analyze how these three models affect the productivity of the vendor company. We build two Cobb-Douglas production models – balance sheet model and income statement model – using different combination of inputs and output. The productivity of software companies is evaluated from three aspects: economies of scale, marginal product of input factors and total factor productivity. Our results indicate that SaaS model has significant differences to conventional model in all three aspects. Especially, we find out that pure-SaaS companies have less scale economy than traditional packaged software companies, which breaks the existing common expectation of large economies of scale on SaaS model.

Keywords: Software-as-a-Service, Economies of Scale

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1. Introduction

Software-as-a-Service (SaaS) is a newly emerged software delivery business model. It is expected to be a growing trend for enterprise software vendors in the future. As early as in 2000, it was predicted that there would be a brand-new landscape for the future of software, in which a development called "servicization" would be a great revolution (Hock et al. 2000). After that, the Application Service Provider (ASP, a similar term to SaaS) model emerged and the favor of IT outsourcing market gradually transmits from on-premise software packages towards on-demand software services (Sääksjärvi et al. 2005). It was expected by the industry that the SaaS model would cause "a sea change" in the software industry (Software & Information Industry Association (SIIA) 2001). In the following years, this prediction was proved by the market both from the vendor side and from the client side. From the vendor side, the SaaS suppliers won highly appreciation from venture capital investments (Akella and Kanakamedala 2007). In a survey about SaaS, it was discovered that companies with SaaS as their main business had a revenues rise by 18% from 2002 to 2005, which was from $295 million to $485 million (Dubey and Wagle 2007). In another report about SaaS business, it was forecasted that the revenue of worldwide software-on-demand (a similar term to SaaS) would grow from $4,000 million USD in 2007 to $15,000 million USD in 2011, which would be a growth from 2% to 5% in total software market revenue (TenWolde 2007). In terms of annual growth rate, it was indicated that the annual growth rate of SaaS would be 22.1% through 2011 for the aggregate enterprise application software markets, which would be higher than twice of the growth rate of the total enterprise software (Mertz et al. 2007). Also, around 10% of the enterprise software vendors expected to transform into pure-playing SaaS vendors by 2009 (Traudl and Konary 2005). From the client side, SaaS is a demand-centric software delivery model received great acceptance across various different industries. In October 2006, 64% of 72 senior IT executives claimed in a survey that they were planning to implement service-oriented architectures in 2007 (Akella and Kanakamedala 2007). And this intension was proved to be common among these potential clients of SaaS by another industry research report (Traudl and Konary 2005).

Software as a service is a model of internet-based software deployment in which the vendors provide their application to customers as a service based on usage. The application is usually hosted in the vendors' own hardware, and they take up the maintenance and security of these devices as well. In contrast, the conventional software vendors sell the software to customers at a one-time large fixed licensing fee, and next install, maintain, upgrade the software application on the buyer's machine. Salesforce.com, a vendor of online Customer Relationship Management (CRM) application, is regarded to be the most successful SaaS adopter. Since 1999, it started their CRM business. After its IPO in 2004, their revenue stride up from 176.4 million to 748.7 million while its stock return increased by 364%. Client successes of Salesforce.com include the following stories (from Salesforce.com): Cisco implemented Salesforce.com to 15000 users and significantly improved their centralized information management; Prestitempo Division of Deutsche Bank deployed Salesforce.com in only one month and a half and found it to be better than their previous inhouse platform; Salesforce.com enabled Starburks to millions of customer feedbacks which shaped the company to who it is today; Allianz Insurance benefit from Salesforce.com with a 17.5 increase in opportunity conversation rate. Abundant success cases from other SaaS providers suggest that the boom of adopting SaaS software is not just another crazy technology fad.

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. This taxonomy is an innovation of this research and is used as a critical input factor in the following studies. We compile an unbalanced panel dataset of 212 publicly listed software companies between 2002 and 2007 for our empirical task. For each firm, we mark it with dummy variables for firm categorization based on their business description in annual reports. Formal definitions and detailed categorization results are provided in Section 3.

Software-as-a-Service business model has become a hot spot in both academic research and market research companies' works. There have been a lot of academic literatures about the technology to realize SaaS, the concept of SaaS model, and the competition between SaaS and non-SaaS business. Beyond the academic world, market research companies and writers from trade magazines put their interests into the market size, potential to growth, sales, and investments of SaaS markets. The SaaS vendors themselves released a lot of publications to promote their products by analyzing SaaS model from their clients' angle. Different from all these mentioned, this research will focus the attention on the software vendor side. The goal of this study is to investigate the impacts of this SaaS innovation on the performance and productivity of software vendors. Most of the existing studies are theoretical studies except Susarla et al. (2003). As a result, the present study could contribute to fill this gap and provide more empirical findings about the performance of SaaS firms. We present the performance analysis and productivity analysis separately in Section 4 and Section 5.

In performance analysis, we look into whether the business model of a software company would affect its financial performance. Abundant researches have been done into the benefits of SaaS model to its vendors (see details in Section 2), and we would like to see whether these benefits are reflected financially. We use four typical financial ratios to measure performance: price to book ratio (P/B ratio), return on asset (ROA), return on equity (ROE), and debt ratio. And our research questions for this section are: Do pure- and mixed-SaaS models exhibit better or worth 1) P/B ratio, 2) ROA, 3) ROE, and 4) Debt Ratio? These four ratios are used as output of our econometric model. The inputs in this model are dummy variables for firm categories and control variables for time and firm size. Our results show that pure-SaaS firms have significantly better performance in P/B ratio, ROA, ROE and Debt Ratio. Mixed-SaaS also exhibit positive performance results but is not significant. Specifically, pure-SaaS firms have extremely large value in P/B ratio than the other two groups. This means pure-SaaS firm is greatly over-valued in the equity market than their real book value. This finding is consistent with the observation of a market research company named SoftwareEquity Group. They discovered that in mergers & acquisitions cases with a pure-SaaS firm as target, the acquirer usually paid around 7.5 times higher than the targets revenue. Although the unique pricing model of pure-SaaS firms (see the details in Section 2) contribute to the high performance, this surprising finding is just a result of the excellent financial performance of pure-SaaS firms and great growth potential of this model.

We run a productivity analysis section as an in-depth research into the mechanism of how SaaS model could succeed. Also telling from the various benefits of SaaS model to its vendors, it is natural for us to assume that these benefits would be realized in the productivity of the company. As a unique property of SaaS, if the SaaS model creates new value, the increased value will be shared between SaaS vendors and clients. It is interesting to investigate which component of the production function of SaaS vendors has different productivity from the conventional software vendors so that

SaaS vendors can succeed. Especially, we doubt about the assumption in previous works that SaaS vendors will exhibit larger economies of scale (see details in Section 2). Our research questions for this section are: (1) Do pure- and mixed-SaaS vendors exhibit larger or smaller economies of scale? (2) How does SaaS affect the marginal product of various input factors of software vendors? (3) Do pure- and mixed-SaaS vendor exhibit larger or smaller total factor productivity? We adopt the production function analysis methodology from classical economics theory. We build two Cobb-Douglas production function models using different combinations production of inputs and output. We use capital, labour and intangible asset to build the balance sheet model, and build the income statement model with cost of goods sold, expenses on research and development (R&D), and expenses on selling, general and administrative activities. The econometric model we used to test the hypothesis is OLS with panel-corrected standard error (PCSE). The results support our suspicion on economies of scale of pure-SaaS firms: pure-SaaS firms demonstrate weaker economies of scale than non-SaaS firms. For mixed-SaaS firms, they are proved to be of stronger economies of scale by our finding. Our results on marginal product of input factors are also brand-new to the literature: Comparing to non-SaaS firms, pure-SaaS firms have larger marginal product of capital input while smaller marginal product of labor, especially for R&D staff and SG&A staff. Mixed-SaaS firms generally over perform non-SaaS firms although the results are less stable and significant. Our examination on total factor productivity is seriously limited by our small sample size and short sampling period. We cannot give a stable conclusion on TFP and may leave it to future research.

The paper is organized as follows: Section 2 discusses the related literature. Section 3 presents our data collection and firm categorization methods. Section 4 is about firm performance analysis, including research model, data analysis, discussion and implications. Section 5 presents the firm productivity analysis, including research model, data analysis, discussion and implications. Section 6 concludes the paper.

2. Background and Literature

2.1. The Software-as-a-Service Business Model

There are three major differences between SaaS and conventional packaged software business model: (1) SaaS is web-based access to a commercial software application, while conventional software is installed on the vendor's hardware. (2) SaaS is realized by a multi-tenant architecture, which enables multiple clients to use the software at the same time. Conventional packaged software is built on a single-tenant architecture. Clients could only use their own software instance through their own servers. (3) Customers pay a recurring subscription fee to SaaS vendor based on usage to the vendors and alienate the complete ownership of the software to its vendor. In exchange for these, the vendor takes up all the support, training, infrastructure and security risks. In contrast, conventional software developers sell software license to the clients, together with that, they have full ownership to their copy of software and need to ensure the security and on-going maintenance and management of the applications by themselves. We will elaborate these features in the next following paragraphs.

Internet Access

Internet Access to a software application is a revolution to the developer as well as to the clients. So to speak, a SaaS user accesses his ERP account like his email account: nothing is installed and stored locally except for an interface and an account. To the users, they get rid of the heavy load and long kickoff time of software installation in their local computer. To the vendor, the challenge is bigger that they need to take up responsibilities which were not supposed to be theirs in conventional software model: they need to develop new technology, run the servers, and market new concept – SaaS.

Multi-tenant Architecture

A tenant in SaaS architecture is a client who uses the application through the internet. SaaS vendors install their application in their own server and distribute it through the internet to the clients. One server, one data center, and one management team in the vendor side could support several different clients at the same time, using multi-tenancy architecture (Sääksjärvi et al. 2005; SaaS Executive Council of SIIA 2006). Comparing to traditional model, clients host their own servers in-house and run the application only for themselves. Viewing the clients and the vendor as a whole, this architecture improved the utilization rate and efficiency of servers. However, it also brings problems, one of which is customization.

The level of customization is an important factor of software quality. Since SaaS vendors use the same set of software to support different clients at the same time, it is not possible for them to maintain customized version for each customer. System integration to the customer's business model will be the major challenge to them (Seltsikas and Currie 2008). Also, it strongly affects the competency of the application (Sun et al. 2008) and the trust from service consumers (Tan et al. 2008). Smaller and more frequent upgrades are released in SaaS models than in traditional software model and mostly will be initiated by the vendor (Choudhary 2007; Dubey and Wagle 2007). To fix this problem, software engineers are still innovating for technologies to solve this problem. Special techniques, such as variability descriptor (Mietzner and Leymann 2008a; Mietzner and Leymann 2008b), has been proposed to highly enhance the level of customization of SaaS applications. And there have been a lot of successful cases of well-customized SaaS applications in areas like Invoice Management System (Kwok et al. 2008a) and Electronic Contract Management System (Kwok et al. 2008b).

Recurring Subscription Fee Model

The main stream pricing model for SaaS business is a subscription-based recurring payment model. It is like renting the application to clients. The vendor charges the customer a monthly subscription fee based on actually used software and a commitment to the number of users (SIIA 2001). For example, Salseforce.com charges a starting monthly subscription fee at $65 per user per month (Choudhary 2007). This model changes the cost allocation of software deployment and makes 80% to 90% of the total cost happened during the actual in-use time of the application, while in the traditional model, the biggest amount of cost will be the initial licensing fee (SaaS EC of SIIA 2006). Also, this model changes the competition between traditional software and SaaS software. It allows SaaS firms and traditional packaged software firms to coexist in a competitive market (Ma and Seidmann 2008) and segments the market in a way that small and medium size business with low transaction volume will choose SaaS while large firms prefer traditional software model (Fan et al. 2008; Ma and Seidmann 2008). The short term competition will reach equilibrium at a higher price. And the long term competition will be influenced majorly by software quality (Fan et al. 2008). Also, this recurring subscription fee model will increase the incentive of SaaS firms to invest more into software quality and finally reach greater profits and social welfare (Choudhary 2007).

2.2. Benefits and Shortcomings of SaaS

Software-as-a-Service model brings a lot of benefits to its vendors. Firstly, the online access saves a lot of costs and efforts which are previously spent on distribution (Dubey and Wagle 2007) and implementation (Dubey and Wagle 2007; SIIA 2001). This delivery method also restricts the possibility for customization and potential debugging which will also be great time and efforts saving for vendors (Dubey and Wagle 2007; SIIA 2001). Third, since all the servers are located in the vendor side, comparing to the traditional packaged software models, SaaS vendors do not need to send customer support staff to the customer to do maintenance work (SIIA 2001). After wider acceptance of the model, the efficiency of online delivery (Dubey and Wagle 2007; Wikipedia.org) and multi-tenant model (SaaS EC of SIIA 2006) will give large economies of scale for SaaS vendor companies. The recurring payment model guarantees smoother revenue flow for the vendor company (Dubey and Wagle 2007; SIIA 2001). The web-based service model opens new markets in small and medium business segment and the enlarged installed base could generate positive feedback and bring greater value (Shapiro and Varian 1999; SIIA 2001).

The benefits of SaaS model to its clients are widely discussed in the media in promoting their own business. The jobs of software application deployment, maintenance, upgrading will be done by the vendor as if corporate IT staff were migrated from supporting developers to users. This provides valuable human resources and great business agility to other areas and enables the customers to focus more on core businesses (Carraro and Chong 2006; SaaS EC of SIIA 2006). SaaS saves costs and efforts in installing and maintaining software applications and hardware infrastructures. Software maintenance took up over 75% of the Fortune 1000's IS spending (Eastwood 1993), which means that SaaS model will help save these money for the Fortune 1000 customers. At the same time, the professional IT staff from the vendor will initiatively provide better and faster support as an improvement of quality of SaaS applications (NetReturn Pty Ltd. 2007; SaaS EC of SIIA 2006). SaaS significantly reduces the initial financial risks of software adoption by reducing the implementation fee (Carraro and Chong 2006), shortening the time-to-production, and simplifying the deployment process (NetReturn Pty Ltd. 2007). SaaS reduce the Total Cost of Ownership (TCO) of the application (NetReturn Pty Ltd. 2007; SaaS EC of SIIA 2006) which means SaaS is cheaper than licensed software in almost every aspect. Also, SaaS was expected to make great saving in total cost ownership in various cost drivers like initial capital expenses, design and deployment costs, ongoing operations, training and support costs, and intangible costs (SaaS EC of SIIA 2006).

As other new business models at their infancy stage, Software-as-a-Service model has several shortcomings as well. First of all, the low-level customization makes SaaS not suitable for innovative or highly specialized niche ecosystems industries (Sääksjärvi et al. 2005; SIIA 2001, SaaS EC of SIIA 2006; Wikipedia.org). The fact that the servers are located in the vendor side is also double-edge swords. It increases concerns of data security, and application performance restrictions (Sääksjärvi et al. 2005). For the vendors, the recurring payment mode gives a smoother revenue flow but at the same time makes the initial turnover of selling the application much lower comparing to traditional packaged software's high license fee. Also, SaaS seems to have lower effect of lock-in, which may cause difficulties in maintaining existing customers (SaaS EC of SIIA 2006; Wikipedia.org). In terms of starting up a SaaS business, it cost higher initial investment on buying servers and running applications for all the customers (Sääksjärvi et al. 2005). The higher initial investment and longer breakeven time makes the SaaS model more risky. Lastly, SaaS seems to have lower lock-in effect because of lower migration cost for clients.

2.3. ASP, On-Demand Computing, and SaaS

There exist a lot of similar terms in the industry as well as in the academic literature. Application Service Provider and On-Demand software are the most common two.

Application Service Provider

In the early years of the 21st century, ASP and SaaS were totally equivalent concepts (SIIA 2001) and ASP was more popular in terms of times of appearance in the literature and industry reports (such as Demirkan and Cheng 2008; Kim and Kim 2008; Ma and Seidmann 2005; Seltsikas and Currie 2002; Susalia et al. 2003). Also, the term Application Service Providers described almost the same characteristics with what we mentioned about SaaS. Minor differences between these two terms started to emerge since recent years. ASP as "earlier attempts as Internet-delivered software" were regarded to be more similar to traditional on-premise software applications than to SaaS applications (Carraro and Chong, 2006). Actually, ASP was more like a third party outsourcing vendor between the software developer and the customer (SaaS EC of SIIA 2006). They got authorization from the software developers and release the software to the end users as a service. However, these two terms are not strictly differentiated in the industry and these claims of differences have very limited influence, and a lot of firms still use ASP to describe their SaaS business. Besides, the key characteristics of these two are still the same (or the differences will not influence the result of our results). Normally ASP also provides internet access through the internet and maintains the servers and data centers for their clients. They also get recurring payment from their customers (Wikipedia.org). So to avoid confusion and to ensure the validity of our next step sampling, we do not separate the two terms and will use Software-as-a-Service, or SaaS, in the following discussion.

IS researchers has examined the ASP business model via different perspectives. Walsh (2003) provides an excellent overview about the technologies, economies, and strategies of ASP. They found that ASP promised a lower cost per user and at the same time redistributed responsibilities and risks among organizations. Cheng and Koehler (2003) model the economic dynamics between the ASP and its potential customers. Under a realistic economies-of-scale assumption, they showed that there exist equilibrium of optimal pricing policy and firm capacity. Under this situation, they found that the optimal number of subscribers remained the same while the profit of the company increased with market demand. Susarlia et al. (2003) develop a conceptual model of customer satisfaction of ASP based on the marketing literature to empirically show that expectations about ASP service have a significant impact on the performance evaluation of ASPs. They showed that the user's disconfirmation effects negatively affected their satisfaction with an ASP, while user's perceived provider performance and prior systems integration could positively influence their satisfaction on ASP. They further analysed that the functional capability and quality assurance of the ASP could positively improve user's perceived provider performance, thus increase their ASP satisfaction. Smith and Kumar (2004) developed a theory of ASP adoption from the client's perspective through ground theory methodology based on analysis of primary and secondary data on ASP use. And they compared and contrasted the similarities and differences among IS outsourcing, ASP, and electronic data interchange (EDI). Through both quantitative and qualitative methods, Ma et al. (2005) identify seven dimensions (features, availability, reliability, assurance, empathy, conformance, and security) of service quality for the ASP vendors to improve. Currie and Parikh (2006) develop a generic strategic model for understanding value creation in web services from a provider's perspective. They identified market leadership, strategic differentiation, and revenue generation as three critical success factors of web service based on literatures from strategic management, e-business and IT management. Demirkan and Cheng (2008) study an application services supply chain by the analytical modelling approach. They separated application infrastructure provider (AIP) and application service provider (ASP) and built a supply chain model composited by AIPs, ASPs and end user. Their findings indicated that the ASPs always determined their capacity at the maximum level of market demand and simply passed the risk of over- and under capacity costs to the end-users.

On-Demand Software

Basically, on-demand software has the same meaning with Software-as-a-Service. On-demand software (also called utility computing) is a popular synonym of Software-as-a-Service. Some "SaaS" companies, such as Omniture Inc., use this term to describe their business model in their official annual reports. There exist scarce academic papers that are dedicated to discuss issues about on-demand computing or SaaS. Bhargava and Sundaresan (2005) study various pricing mechanisms for on-demand computing with demand uncertainty by using economics modelling approach. They build a contingent bid auction pricing model related to the availability-utility commitment tradeoffs. Choudhary (2007) analyses an economic pricing model that contrasts SaaS and perpetual licensing. They found that the unique subscription pricing model of SaaS would give more incentive to software vendors' investment in product development, thus lead to higher software quality and social welfare in equilibrium. Fan et al. (2009) uses a game theoretical approach to examine short- and long-term competition between SaaS and conventional software providers. Different from Choudhary, their results claimed that in the long run equilibrium, the price of SaaS would increase together with the operation cost of SaaS, which might affect SaaS vendor's R&D incentive.

Other Similar Terms

There were some less popular terms in use, such as Application Infrastructure Providers (AIPs), Internet Business Service (IBS), Business Service Provider (BSP), Solutions Service Provider (SSP). They were also given similar definitions to software as a service (or else, some of their businesses are integrated into today's SaaS or ASPs, like AIP) (SIIA 2001). Nowadays these terms are not widely used any more. So they will not affect our usage of the term SaaS as well.

2.4. *IT and Productivity*

We adopt production theory, Cobb-Douglas Function, and theory of economies of scale from microeconomics into our productivity research.

Production Theory and Cobb-Douglas Production Function

Production function describes the relationship between a set of inputs and their maximum outputs in an economy within existing technology and economy (Baye 2009). The general mathematic 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, 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. Initially it was developed using labor and capital as two inputs and production quantity as output. The relationship between inputs and output was derived from the manufacturing industry data in the US from 1899 to 1922 (Cobb and Douglas 1928). The commonly used expression of Cobb-Douglas function is:

$$Y=AL^{\alpha}K^{\beta},$$

where:

Y = Total Production Yield,

L = Labor Input,

K = Capital Input,

A = Total Factor Productivity,

α and β are elasticity of L and K respectively.

The input and output factors used in Cobb-Douglas function develop over time. Originally in Cobb-Douglas function's applications, researchers used dollar values of production yield, capital input and labor input (Cobb and Douglas 1928). In Cobb-Douglas function's factor measurement, output was measured as the net value of product in dollar values, capital input was expressed in dollar values of both fixed and working capital, while labor input was measure by average numbers of waged employees including all kinds of employment contracts (Douglas 1948). Although the function included both quantities and prices, it was still consistent with the marginal production theory since marginal productivity could also be measured by both quantity and value (Douglas 1948). Later, for practical reasons (Chung 1994; Walter 1963), researchers added different factors according to the nature of the industry under investigated or the needs of the research. Generally, we can also interpret Cobb-Douglas function as follows:

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

where A is a scale factor and X represents the input to the production process. By taking logarithm of both sides of the equation, we have

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

which can be easily estimated by ordinary least square or other advanced econometrics models. The scale factor A in Cobb-Douglas function also represents the total factor productivity (TFP) in the literature. TFP captures the impacts of factors on the output *Y* which could not be covered by the inputs, such as technology innovation, macro economy, etc. Bear in mind that the intercept term of the right hand side is the logarithm of the TFP. From this expression, it is obvious that the beta coefficients represent the output elasticity of each input factor: a 1% increase in input factor *i* lead to β_i % increase in *Y*. The Cobb-

Douglas production has several nice properties: first, the optimal budget share of each input factor is invariant in input factor prices. That is, if the computer hardware prices drop, the software vendor will use more computers so that the proportion of budget spent on hardware is the same. Second, the sum of beta coefficients represents a measure of economies of scale. Formally, if $\sum_{i=1}^{n} \beta_i > 1,$ then there exists increasing return to scale. If $\sum_{i=1}^{n} \beta_i = 1,$ this production function has constant return to scale.

Application of Production Theory in IS Literature

In the information systems literature, the most fruitful application of production function analysis is the studies about how spending on computers and IT workers can boost the productivity at the firm level. In the early 90s, researchers first found that information technologies had no contribution to the production firms' outputs (Barua et al. 1991; Loveman 1994) or the marginal benefits could not cover marginal cost (Morrison and Roberts 1990). Later, the seminal paper by Brynjolfsson and Hitt (1996) documents how IS spending had made a substantial and statistically significant contribution to firm output. In a related paper (Hitt and Brynjolfsson 1996), the authors show that IT has increased productivity and created substantial value for consumers but does not improve profitability for firms. There exist extensive studies in this area. A short list of examples includes the following papers. Dewan and Min (1997) extends 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) estimate 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. Cheng and Nault (2007) estimate the effects to downstream productivity from information technology (IT) investments made upstream. Mittal and Nault (2009) studies the indirect impact of IT on the production function at the industry level.

Cobb-Douglas function is an effective measure in IT production and information systems services (Gurbaxani and Mendelson 1987; Gurbaxani and Mendelson 1992). In the production process of information system services, expenses on software and hardware were used to represent inputs to the system (personnel cost was enclosed in software expenses according to a proved ratio). Applying Cobb-Douglas function to this production, the model showed that the budget spent on software and hardware remained constant overtime while project size increased (Gurbaxani and Mendelson 1987). Empirical tests to this model showed that software and hardware expenditures growed together with time exponentially at the same rate (Gurbaxani and Mendelson 1992). Another research about software development productivity also adopted the Cobb-Douglas function. They defined output as software development effort in forms of man-hours of the software developing process. Their inputs were software development team size as the number of team members and software size as the number of function points of the software (Pendharkar et al. 2008). The application of Cobb-Douglas function in firm-level evidence on information systems' return to spending showed that IS spending had made significant contribution to firm output (Brynjolfsson and Hitt 1996). In this famous research, they used firm's total sales as output and computer capital, non-computer capital, IS staff labor and other labor and expenses as four inputs (Brynjolfsson and Hitt 1996). Some other production functions were also used in the IS field. A research into information system budgets using Constant Elasticity of Substitution (CES) production function used hardware and personnel expenses as inputs and information system services as output (Gurbaxani et al. 2000). Their findings were consistent with the Cobb-Douglas model that the ratio of factor shares stayed constant over time and was independent of scale (Gurbaxani et al. 2000). In a research about software maintenance projects production, a Data Envelopment Analysis (DEA) was used to capture the relationship between inputs, measured by project team labors' working hours and contextual variable used, and output, measured by function points of the enhancement in the project (Banker and Slaughter 1997). The production function in software development process was also used to estimate future project size (Pendharkar et al. 2008). In these researches, the production inputs were usually programming language, development tools and environment, and developers' labor inputs. Outputs were usually software size, software efforts, and software productivity (Banker et al. 1991; Banker and Kemerer 1989; Banker and Slaughter 1997). Similar productivity analysis methods have been applied to study various issues in the IT/MIS area. Banker and Slaughter (1997) investigate the relationship between project size and software maintenance productivity by using Data Envelopment Analysis (DEA). Gurbaxani et al. (1997, 2000) conducts 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) study the production function of software development at project level.

Economies of Scale

The most important application of Cobb-Douglas production function is in studying economies of scale. When Cobb-Douglas function was firstly derived, they assumed unity elasticity of substitution, which means $\alpha+\beta=1$. With empirical economic data gathered from the US, Australia, Canada, South Africa, Norwegian, etc., this assumption was proved to be applicable at that time (Douglas 1948; Griliches 1965; Griliches 1980, Moroney 1967; Walters 1963). This unity elasticity of substitution revealed constant returns to scale in these industries at that time. Later critiques were raised that the exponents of Labor and Capital should be independent to each other rather than unity substitution (Durand 1937). And if $\alpha+\beta>1$, it means there exist economies of scale in the industry. Similarly, $\alpha+\beta<1$ means diseconomies of scale (Wikipedia.org). And this improvement makes Cobb-Douglas a measurement of scale economies (Griliches and Ringstad 1971). Economies of scale could be defined in two dimensions: The first dimension is to interpret it as a relationship between cost and size: Economies of scale mean the condition that at optimal size, firm will produce with lowest technical cost (Marshall 1997). Economies of scale are reductions of long-term average cost which are attributable to increases in scale (Pratten 1971). The other explanation is from the angle of inputs and output. Economies of scale are: when inputs are increased by a proportion, output will increase by a larger ratio (Baye 2009). And it is a theory of the relationship between "the scale of use of a properly chosen combination of all productive factors and services and the rate of output of the enterprise" (Stigler 1958). Economies of scale are affected by the size of firms, the scale of industry, the scale of a national economy, and of course the nature of the production process (Pratten 1971). Economies of scale stay consistent over time (Pratten 1971; Williamson 1968). What's more, the magnitude of the economies of scales is expected to be increasing as the industry grows more mature (Pratten 1971).

Economies of scales have many implications in firm management and government policy. Evaluation of economies of scale would provide important insights for cost control, management, and marketing (Pratten 1971). It could be used to estimate the optimal production size of an economy in varies industries (Stigler 1958) such as manufacturing industry (Pratten 1971), retailing industry (Tilley and Hicks 1970; Tucker 1972), and banking industry (Hughes et al. 2001; Wheelock and Wilson 2001). It could also be used to evaluate the development of an economy (Griliches and Ringstad 1971) and to estimate the total cost function and minimum cost output level (Turker 1975). It is also an important instrument in measuring of the performance and efficiency of particular economy activities (Turker 1975) such as R&D investment in drug industry (Henderson and Cockburn 1996; Macher and Boerner 2006). Investments in scale expansion could bring lower costs and lower prices for firms (Motta 2007). It is also a structural instrument of industrial organization when analyzing entry barriers, concentration of industry, natural monopoly, etc. (Motta 2007; Pratten 1971; Samuelson and Nordhaus 1998; Turker 1975; Williamson 1968). Firms who reach integration may decrease their costs because of economies of scale and scope (Motta 2007).

Applications of Economies of Scale

In software industry, research in scale economy is also widely used. Pendharkar (2006) used economies of scale to forecast software size in development projects. Both economies and diseconomies of scale were discovered in an empirical analysis in software development (Banker and Kemerer1989). And spreading fix cost of project management, specialized personnel and development tools in software development projects would increase productivity of large scale development projects (Boehm 1981). However, average project productivity declined over the optimal software development project size was also disclosed in some research (Banker 1984; Banker et al. 1991). Possible explanation to this might be the increased technical complexity and the more frequent inter- and intra-project communication of large projects (Brooks 1995; Conte et al. 1986). Some researchers took a more microscopic view into the software development projects with output as software size measured by lines of codes (Pendharkar 2006) or functional points (Banker and Kemerer 1989; Banker et al. 1991) and inputs as software labor measured by man-month (Boehm 1981) or software components (Pendharkar 2006). They concluded that non-linear variable returns to scale existed (Pendharkar 2006). In software maintenance projects, if batching smaller modifications into larger releases to utilize the scale economies of maintenance, the IT maintenance cost at a large financial services organization would be reduced by 36%, investigated using Data Envelop Analysis (Banker et al. 1991; Banker and Slaughter 1997). In the information economics research, they called these above economic efficiency earned from firm scale supply-side economies of scale. Besides of supply-side economies of scale, demand-side economies of scale also play an important role in enhancing the positive feedback in the network economy. Demand-side economies of scale are the customer value of an IT product because it is widely used and becomes an industry standard. This attribute is a special norm of the information economy and is crucial in enlarging the customer base of the IT product (Shapiro and Varian 1999). Demand-side economies of scale and network externalities would increase the market share of software vendors, support a more profitable pricing of the software (Gallaugher and Wang 2002) and influence the customers' choice of software adoptions (Au and Kauffman 2001).

Economies of Scale and SaaS Business Model

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 the company as a whole rather than from the development or maintenance unit's view. Even few researches looked into the production process of the new Software-as-a-Service business model. A lot of literatures about SaaS model's multi-tenancy architecture claimed that this architecture would bring economies of scale to software companies (Carraro and Chong 2006; Kwok et al. 2008; Mietzner and Leymann 2008a; Mietzner and Leymann 2008b; Pinhenez

2008; Sääksjärvi et al. 2005; Sun et al. 2008; Walsh 2003). As SaaS is a bundle of both software application and hardware infrastructure renting service and other services (Fan et al. 2009; Ma and Seidmann 2008), this multi-tenancy feature spreads the cost of servers over the clients who share this server (Sääksjärvi et al. 2005; SaaS EC of SIIA 2006; Wikipedia.org). So this relationship between cost and size gives great economies of scales for SaaS vendors. However, all of these findings in previous researches remain in descriptive level. And we will empirically test whether SaaS model really brings greater economies of scale to software vendors.

3. Data Collection and Firm Categorization

3.1. Data Collection

The target industry in this study is the software industry, which is defined as the set of US firms with a Standard Industry Classification (SIC) code equal to 7372[1] and publicly listed in New York Stock Exchange and NASDAQ. However as a consequence, we have to leave out some famous SaaS pioneers, such as Amazon, Sun Microsystems, HP, and IBM, whose SIC code is not 7372. Samples with missing values in important input and output variables are dropped. Microsoft is also dropped from the sample as a common practice in IS empirical research. Finally we get an unbalanced panel of 212 firms over the period 2002-2007 with 803 data points overall. The number of firms increases with time. Multiple

[1] SIC code 7372 stands for Prepackaged Software. It is used by US Securities and Exchange Commission (SEC) and appears in a company's Electronic Data-Gathering, Analysis and Retrieval filing submitted to SEC, such as its Annual Reports (file 10-K). SIC code 7372 is consistent with NAICS code 511210, which stands for Software Publisher in the new NAICS codes system.

occurrences of the same firm during the investigation period are accounted using year dummies in the regression formula. An ending point 2007 was chosen because the complete financial statements of 2008 are still not completely available by the time of this research.

3.2. Dummy Variable for Firm Categorization

The most critical and unique independent variable of this research model is the business model of software companies: a pure-SaaS firm, a non-SaaS firm, or a mixed-SaaS firm. In our sample, we have 11 pure-SaaS firms, 57 mixed-SaaS firms, and 144 non-SaaS firms. We use two dummy variables in the model to measure this categorization.

In this research, we identify SaaS companies by the following approach. First, we download annual reports (SEC form 10-K) of the 212 firms from 2002 to 2007 (calendar year). All publicly listed software companies in the USA are required to submit annual reports to the Securities and Exchange Commission (SEC) and these reports are freely available from the website of SEC. We use a Java program to pick the reports that include a list of keywords that are related to SaaS[2]. The firms with zero key word in their annual reports are identified as non-SaaS firms. Next, researchers read and code each flagged 10K report to label that case as a pure-play SaaS, mixed-SaaS, or non-SaaS firm. General rules for this step are as follows: in the first section of annual report, firms describe their main business and details of every product of them. If they use the key words to describe their

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

main business and all of their products, they are labeled as pure-SaaS firms. If some of their products are SaaS product while the rest of them are non-SaaS products, they will be labeled as mixed-SaaS firms. Not all firms with key words in their annual reports are of SaaS business. In some cases our key words appear in some unexpected descriptions which are not related to the firm's own business[3], thus these firms will be labeled as non-SaaS firms and they composite our non-SaaS group together with the firms not picked by the java program. Our result of pure-play SaaS firms is consistent with an industry report from the Software Equity Group and the result should be quite robust. A complete list of firm names is provided in Appendix 1 and short introductions to pure-SaaS firms are provided in Appendix 2. The controversial case is the definition of mixed-SaaS firms because we do not have access to the proportion of SaaS revenue in a software company. As a result, the categorization of mixed-SaaS firms is subjectively created. 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 keywords list. And we may underestimate the number of pure-SaaS firms because some of them report themselves to SEC with SIC code other than 7372[4]. Also, we may underestimate the number of firms that are mixed-SaaS when those firms do not mention it in their annual reports. In both

[3] For example, some firms said SaaS firms are their competitor, or their newly named CIO previously worked for an application service provider, or they planned to have SaaS business in the future beyond our sample period, etc.

[4] For example, SIC code of NetSuite Inc. is 7373, which stands for Computer Integrated System Design. SIC code for SoundBite Communications Inc. is 4899, which stands for Communication Services. SIC code for Salary.com Inc. and Athenahealth Inc. is 7370, which stands for Computer Programming, Data Processing etc. In concern of the consistency of our sample and work load to get complete data with various SIC code, we didn't include them in our sample as well although they are pure-SaaS firms from the nature of their business.

cases we may only underestimate but not overestimate the number of firms because of this problem. As a consequence, our analysis is robust in the sense that including those few missing pure- and mixed-SaaS cases strengthens, but does not invalidate, the findings of the present study.

4. Analysis of Firm Performance

As we mentioned previously, lots of academic researchers and industry analysts suggest Software-as-a-Service to be a more advanced business model. It implies that firms with this new business model will demonstrate superiority over their conventional counterpart. We hypothesize that this superiority will be realized in financial performance. And we expect mixed-SaaS firms also benefit from their SaaS business. Previous research has devoted a lot into IT values and company performance for non-IT industry. Here in this research we build regression models with firm categorization as independent variable, time and firm size as control variables, and four performance indicators as output variables. We test our hypothesis using ordinary least square with unequal variance. Then we conclude with implications of our findings.

4.1. Research Model

To measure the performance of IT firms, we adopt four commonly used performance ratios as our dependent variables: (1) Price to Book Ratio (PBR), (2) Return on Asset (ROA), (3) Return on Equity (ROE), and (4) Debt Ratio (DR). These measures are well developed in finance and are widely used in investment evaluation. Also, IS researchers adopt them in measuring IT values (Alpar and

Kim 1990; Cron and Sobol 1983; Hitt and Brynjolfsson 1994; Strassmann 1990; Weill 1992).

To estimate the impact of SaaS business model on these ratios, we develop the following regression model:

$$PBR_{it} = \sum_t \sigma_t D_t + \alpha p_i + \beta \mathrm{m_i} + \gamma \ln \mathrm{TA_{it}} + \mathrm{u_{it}} \qquad (1)$$

$$ROA_{it} = \sum_t \sigma_t D_t + \alpha p_i + \beta \mathrm{m_i} + \gamma \ln \mathrm{TA_{it}} + \mathrm{u_{it}} \qquad (2)$$

$$ROE_{it} = \sum_t \sigma_t D_t + \alpha p_i + \beta \mathrm{m_i} + \gamma \ln \mathrm{TA_{it}} + \mathrm{u_{it}} \qquad (3)$$

$$DR_{it} = \sum_t \sigma_t D_t + \alpha p_i + \beta \mathrm{m_i} + \gamma \ln \mathrm{TA_{it}} + \mathrm{u_{it}} \qquad (4)$$

Where D_t are dummy variables used to control for years; p_i and m_i are dummy variables indicating pure- or mixed-SaaS firms respectively; and $\ln TA_{it}$ is the logarithm of total asset of firm i at time t, which is also a control variable. As firm size has a relationship with IT investment (Harris and Katz 1991), in empirical research it is a common practice analyzing the relationship between accounting variables and financial ratios (Banz 1981; Dimson and Marsh 1986).

We get p_i and m_i for each company in each year according to Section 3. Our time range from fiscal year 2002 to 2007 and we mark year 2002 as year 1. And we get all the financial ratios and firm information from the Compustat database of WRDS. Table 1 summarizes the definition and calculation of the rest variables. Table 2 illustrates summary statistics of our sample.

Table 1. Data Sources, Construction Procedures and Deflators for Performance Analysis

Variable Name	Source	Construction Process	Deflator	Notation
Price to Book Ratio	Compustat	Market Value at the End of Fiscal Year (mkvalt_f) divided by Book Value per Share (bkvlps)	N/A*	PBR
Return on Asset	Compustat	Net Income (ni) divided by Total Asset (at)	N/A*	ROA
Return on Equity	Compustat	Total Stockholders' Equity (seq) divided by Total Asset (at)	N/A*	ROE
Debt Ratio	Compustat	Total Liabilities (lt) divided by Total Asset (at)	N/A*	DR
Firm Size	Compustat	Logarithm of deflated Total Asset (at) (converted to constant 2002 dollars)	Producer Price Index for Intermediate Materials, Supplies and Components (Bureau of Labor Statistics 2009)	lnTA

*: These are ratios with numerator and denominator using the same deflator

Table 2. Summary Statistics for Performance Analysis[5]

All Firms	**Total Asset**	**PBR**	**ROA**	**ROE**	**DR**
Mean	673.07	3.69	-0.13	0.54	0.46
Std.Dev	2408.45	12.00	0.63	0.33	0.33
Min	4.39	-104.15	-13.09	-2.72	0.04
Max	35388.19	196.30	1.06	0.96	3.72
Sample size =770[6]					
Pure-SaaS	**Total Asset**	**PBR**	**ROA**	**ROE**	**DR**
Mean	156.96	8.78	0.00	0.62	0.38
Std.Dev	166.84	5.41	0.14	0.18	0.18
Min	10.84	1.62	-0.62	0.22	0.09
Max	815.75	23.10	0.19	0.91	0.78
Sample size = 34					
Mixed-SaaS	**Total Asset**	**PBR**	**ROA**	**ROE**	**DR**
Mean	1040.35	3.52	-0.07	0.56	0.44
Std.Dev	3559.88	4.12	0.34	0.24	0.24

[5] To make the data easier to understand, we still run summary statistics on Total Asset rather than logarithm of Total Asset.
[6] 33 data items only exist in one year and is automatically dropped from the regression model.

Min	6.30	-11.50	-3.26	-0.69	0.04
Max	35388.19	36.13	0.43	0.96	1.69
Sample size =250					
Non-SaaS	**Total Asset**	**PBR**	**ROA**	**ROE**	**DR**
Mean	520.24	3.41	-0.18	0.53	0.47
Std.Dev	1605.49	14.69	0.75	0.38	0.38
Min	4.39	-104.15	-13.09	-2.72	0.05
Max	14865.71	196.30	1.06	0.95	3.72
Sample size =486					

4.2. Data Analysis

We use ordinary least square (OLS) assuming unequal variance to perform data analysis. The results are illustrated in Table 3.

Table 3. Results of OLS Assuming Unequal Variance

	PBR	ROA	ROE	DR
p	5.505***	0.125***	0.116***	-0.116***
	(0.000)	(0.001)	(0.003)	(0.002)
m	0.200	0.056*	0.001	-0.002
	(0.706)	(0.079)	(0.972)	(0.939)
lnTA	-0.094	0.074***	0.058***	-0.058***
	(0.816)	(0.001)	(0.000)	(0.000)
_cons	2.293	-0.742***	0.255***	0.745***
	(0.276)	(0.000)	(0.000)	(0.000)
N	770	770	770	770

p-values in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All results on year dummy variables are omitted for brevity.

As shown in Table 3, pure-SaaS business model has significant advantage over non-SaaS firms in all four ratios. Mixed-SaaS firms also demonstrate better performance than conventional non-SaaS firms but it's only significant to the 10% level in terms of return on asset.

We also run another regression with standard OLS (assuming equal variance) as robustness check. The results are provided in Table 4.

Table 4. Robust Check of Standard OLS Assuming Equal Variance				
	PBR	ROA	ROE	DR
p	5.505**	0.125	0.116**	-0.116**
	(0.011)	(0.254)	(0.044)	(0.044)
m	0.200	0.056	0.001	-0.002
	(0.832)	(0.243)	(0.977)	(0.949)
lnTA	-0.094	0.074***	0.058***	-0.058***
	(0.729)	(0.000)	(0.000)	(0.000)
_cons	2.293	-0.742***	0.255***	0.745***
	(0.159)	(0.000)	(0.000)	(0.000)
N	770	770	770	770

p-values in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All results on year dummy variables are omitted for brevity.

This equal variance assumption makes the relationship between pure-SaaS model and return on asset and the relationship between mixed-SaaS model and return on asset not significant anymore. And it also reduced the significant level positive relationship between pure-SaaS and return on equity from 1% to 5%, and negative relationship between pure-SaaS and debt ratio from 1% to 5%.

Based on the regressions we did, we can conclude with the same results as the original model: pure-SaaS firms have significant superiority over non-SaaS firms in Price to Book Ratio, Return on Asset, Return on Equity and Debt Ratio. Also, Mixed-SaaS firms have significant better financial performance than non-SaaS firms in Return on Asset.

4.3. Discussion and Implications

4.3.1. Discussion

As a conclusion from the data analysis, Software-as-a-Service business model does lead to better financial performance. One of the most significant findings is the advantage of SaaS in price to book ratio. Referring to Table 2, the cross-sectional average price to book ratio of pure-SaaS firm is 8.78, while it is 3.52 for mixed-SaaS firm and 3.41 for non-SaaS firm. This result is consistent with the software equity annual report published by Software Equity Group LLC. They disclosed in their 2007 annual report[7] that investors favor SaaS firms with remarkably higher valuations on an enterprise value to revenue (7.5×) and enterprise value to EBITDA (65.2×), while the same measurements for shrink-wrap software providers are 2.3× and 15.2× respectively. Also in mergers and acquisition cases involving pure-SaaS firms as target firms, the acquirer would pay averagely 5.2 times higher than the firm's revenue as exit valuation. Similar results could also be found in their reports of 2006 and 2008.

There are various explanations for SaaS firms to have better operation performance. Higher price to book ratio of pure-SaaS firms generally results from the equity market. As for the stock market, the stock price of some leading SaaS firms, like Salesforce.com, Taleo, kept growing in a fast pace before the big market failure on November 17, 2008. Even after November 17, in a weak global economy, the firms' stock prices are gradually climbing up (Source of stock prices are from Yahoo!Finance). Investors' positive attitude to SaaS is mainly because of the firms' steady increase in revenue growth and bullish prospect. Customers' convince in future adoption of SaaS guarantees board space for market growth (Akella et al. 2007). What's more, with the development of technology and the participation of big names in the

[7] The annual reports on software equity of SoftwareEquity Group LLC are publicly available upon registration through their website: http://www.softwareequity.com/

software industry such as Microsoft, Google, SAP, etc., large clients also open their gate wide to SaaS, which creates another source of confidence for the investors. And higher stock price will definitely lead to higher PB ratio.

The higher ROA and ROE and the lower debt of pure-SaaS firms could be generally explained from within the firms. Investigating into the SaaS business model itself, we may find an answer from its innovation in software delivery and payment model. Internet delivery with thin-client architecture raises the passion of small and medium size businesses who cannot afford the high investment for purchasing conventional packaged software, so these SMEs choose to "rent" the software through SaaS providers. Specially, for mixed-SaaS firms, they could cover both large and small clients with different models at the same time. So a continually growing customer base gives SaaS companies enduring revenue boosts and ability of debt coverage. Payment model might be another important contributor. The way how clients make payment to SaaS is at the same time how SaaS vendors realize their revenue. Although the recurring fee model reduces the initial turnover for SaaS vendors, it promises smoother cash flow for a longer time. In another word, it moves today's revenue to the future which is worth more. So it is easy to understand that under the generally acceptable accounting principles (GAAP), the ROA and ROE is higher for SaaS.

4.3.2. Implications

Previously, profound achievements have been reached in how IT affects their clients' business model and business performance. Nevertheless, this research is among the pioneer of studies into how a technology innovation (SaaS) affects the vendor's business model and business performance. Also, we use academic models to test performance ratios, which is more reliable and rigorous than simple statistics used in commercial market research firms. Therefore, our findings on the better performance of SaaS business model would contribute to the academic research in SaaS and introduce a new angle of view to this field.

Also, we are expecting the industry could find inspiration and enlightenment in their practice of Software-as-a-Service. For those who intend to start SaaS business or transform their conventional software business to this new model, they may find positive message through our findings.

5. Analysis of Firm Productivity

Besides studying the performance of Software-as-a-Service business, we also go in-depth with the inside mechanism of SaaS by investigating the productivity of the three groups of firms. In this section, we will analyze the productivity of pure-, mixed-, and non-SaaS firms from three aspects: economies of scale, marginal product of input factors, and total factor productivity. We use two augmented Cobb-Douglas production functions to run the productivity analysis. In the first model, we use capital (K), labor (L), and intangible asset (I) as production inputs. In the second case, our independent variables include cost-of-goods-sold (C), research and development expenses (R), and selling and general administrative expenses (S). In both case, we use economic value added as production output. Our baseline regression method is ordinary least square (OLS) with panel-corrected standard error (PCSE). Then we run several robustness tests with a reduced sample with lower average firm size and also three other regression models: Feasible Generalized Least Square (FGLS), fix effect and random effect panel-data regressions. Finally we present the discussion and implications of our findings.

5.1. Research Model

5.1.1. Empirical Models

In section 4, we test the superiority of SaaS model in firm performance. Now in this section, we are implying that the superiority of SaaS model will also be realized in firm productivity. To prove this, we apply production theory and build empirical analysis based on our firm categorization. We would like to find out the contribution of SaaS business model to the productivity of different firms and the relationship between production input and output variables. We intend to evaluate productivity from aspects of economies of scale, marginal product of input factors and total factor productivity.

Typical production theory composes a production output and several inputs. Usually inputs will cover capital input and labor input and other important factors. Formally, we consider the two models using same output variable and different sets of input variables. The two sets of input variables are composed of capital and labor measurement derived from balance sheet and income statement respectively. In the first one, we abstract data from balance sheet:

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

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

(5)

Similarly, we have the following model using the inputs from the income statement.

<u>Model 2: Income Statement Model</u>

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

(6)

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), p_i and m_i are dummy variables for indicating pure- or mixed-SaaS firms respectively from our results in section 3, and α_i is a dummy variable for each company, D_t is a dummy variable for fiscal year. Intuitively, (5) and (6) are simply standard regression equations with two dummy variables on the intercept and all coefficient terms of the three independent variables. Bear in mind that the coefficient of the multiplicative terms (e.g., $p_i \ln K_{it}$) indicates the difference of the productivity of that input factor between 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. The explanations to dependent and independent variables will be covered in the next section.

5.1.2. Variable Constructions

Dependent Variables

The standard output measurement 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. The software business is unique in that the "input materials from the previous stage" are not really 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 asset. 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). The construction of the three variables as indicated in their annual reports are: Cost of goods sold for pure-SaaS firms usually composite of the expenses on hosting service and providing support, the costs of maintaining infrastructures used for on-demand applications, and other related costs and allocated overhead. For non-SaaS firms, cost of goods sold includes the cost happened in manufacturing, packaging, shipping, and storage of products and other related costs and allocated overhead. And COGS in mixed-SaaS firms is a combination of these two. The construction of COGS makes it similar to the fix asset concept as we used in balance sheet model. So it is also regarded as a capital input in Cobb-Douglas production function. R&D expenses and SG&A expenses in all the three types of firms are indifference. R&D expenses are consisted by salaries and expenses on R&D staffs and costs of infrastructures used in R&D function. SG&A expenses are the expenses on the salaries and benefits of staff in sales, marketing, finance, human resources, and other functions, as well as expenses for their job functions such as promotion and branding activities. As both are expenses on functional staff, we could regard them as measures of labor input in terms of dollar value.

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. In balance sheet model, employees from all functions are treated as a whole measured by headcount. Although we do not have access to the subcategory of employees to differentiate between software developers and marketing managers, expenses generated by each function could be regarded as the proxy variable for the staff in that function. With this approach, we can examine the source of efficiency differences in labor productivity between SaaS and non-SaaS firms.

The data source used in this section is also Compustat. The variable construction process is provided in Table 5 and Table 6 and summary statistics to variables are in Table 7.

Table 5. Data Sources, Construction Procedures, and Deflators for Productivity Analysis

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 Asset (Total Asset (at) minus Total Current Asset (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 Asset (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

Table 6. Model Constructions for Productivity Analysis

Inputs	**Balance Sheet Model**	**Income Statement Model**
Capital	Fixed Asset	Cost of Goods Sold
Labor	Number of Employees	R&D Expenses; Selling, General and Administrative Expenses

Other	Intangible Asset	-

Table 7. Summary Statistics for Productivity Analysis

All Firms	**Output**	**Capital**	**Labor**	**Intangible Asset**	**COGS**	**SGA Expense**	**R&D Expenses**
Mean	314.38	323.13	1.62	228.25	85.21	186.87	58.74
Std.Dev	1141.74	1462.06	5.53	1254.00	272.86	492.81	168.85
Min	0.37	0.10	0.00	0.00	0.11	2.10	0.16
Max	17990.08	21835.31	84.23	19754.72	3528.54	6160.16	2070.11
Sample Size=803							
Pure-SaaS	**Output**	**Capital**	**Labor**	**Intangible Asset**	**COGS**	**SGA Expense**	**R&D Expenses**
Mean	91.62	56.24	0.62	25.96	24.44	65.23	10.48
Std.Dev	113.67	64.94	0.54	39.83	24.09	80.56	9.25
Min	7.00	1.03	0.06	0.00	1.24	6.64	1.28
Max	603.10	261.13	2.61	137.49	115.86	416.87	47.77
Sample Size=36							
Mixed-SaaS	**Output**	**Capital**	**Labor**	**Intangible Asset**	**COGS**	**SGA Expense**	**R&D Expenses**
Mean	576.13	487.76	2.89	356.95	122.36	305.69	96.33
Std.Dev	1852.59	2064.50	9.11	1816.64	397.07	739.64	250.98
Min	2.89	1.69	0.05	0.00	1.06	6.15	0.18
Max	17990.08	21835.31	84.23	19754.72	3528.54	6160.16	2070.11
Sample Size=256							
Non-SaaS	**Output**	**Capital**	**Labor**	**Intangible Asset**	**COGS**	**SGA Expense**	**R&D Expenses**
Mean	198.94	259.46	1.05	178.03	70.88	135.91	43.30
Std.Dev	530.80	1098.84	2.34	899.41	192.47	311.77	110.55
Min	0.37	0.10	0.00	0.00	0.11	2.10	0.16
Max	5334.04	11622.54	17.60	10796.97	1515.15	2737.29	960.56
Sample Size=511							

5.2. Data Analysis

To find a proper regression model for the production estimation, we consider heteroskedasticity and autocorrelation in our cross-sectional time-series data set. The reasons to consider heteroskedasticity are that our firms different in size.

And because of their different business model, they have differences in production cycle as well. These variances are likely to cause panel-level heteroskedasticity. According to a Breusch-Pagan test for panel-level heteroskedasticity of our sample, the null hypothesis that errors are homoskedastic could be rejected (For balance sheet model, χ^2=3.1e+31, p<0.001; for income statement model, χ^2 = 2.0e+31, p<0.001). Autocorrelation is common in any industry section with business cycles because one year's output is highly correlated with previous year's output. It will be more significant in SaaS business model because of its recurring payment model. Therefore, our data set might have heteroskedasticity across firm categories and autocorrelation across time periods. We ran Wooldridge test and proved that autocorrelation did exist in our panel data (For balance sheet model, F=19.171, p<0.001; for income statement data, F=21.832, p<0.001). In this case, *pooled OLS* may be problematic that the standard errors will not be correct although the estimators would still be unbiased and consistent. And Beck and Katz (1995)'s Monte Carlo analysis shows that PCSE may work well with heteroskedasticity and autocorrelation. So we choose PCSE with heteroskedasticity and a cross-categories common autocorrelation coefficient. Also, PCSE has been widely used in studying production function by researchers in the IS literature (e.g., Han 2006).

The results of our estimations on economies of scale comparison are reported in Table 8. Detailed coefficient of each variable are presented in Table 9 and 10.

Estimates of the intercept terms are reported separately in Table 11 for computing total factor productivities.

5.2.1. *Economies of Scale*

Based on Table 9 and 10, we can calculate the economies of scale of three types of firms, defined as the sum of the coefficients of the three input factors. The results are as follows:

Table 8. Economies of Scale (PCSE)

	Coef.	Std. Err.	[95% Conf. Interval]	
BS Model				
Non-SaaS	0.935	0.041	0.855	1.015
Pure-SaaS	0.844	0.068	0.712	0.977
Mixed-SaaS	1.058	0.029	1.000	1.115
IN Model				
Non-SaaS	1.101	0.021	1.060	1.143
Pure-SaaS	0.917	0.043	0.833	1.001
Mixed-SaaS	1.113	0.018	1.079	1.148

Telling from the coefficients and 95% confidence intervals in Table 8, we find that pure-SaaS firms generally have smaller economies of scales than the other two cases while mixed-SaaS firms have the largest economies of scale among the three types of firms.

5.2.2. *Marginal Product of Input Factors*

Table 9. PCSE Estimates of BS Model

Coefficient Est.	Full Sample
K	0.186^{***}
	(0.000)
p*K	0.124
	(0.111)
m*K	0.005

	(0.937)
L	0.744***
	(0.000)
p*L	-0.253*
	(0.061)
m*L	0.121
	(0.235)
I	0.005
	(0.654)
p*I	0.038
	(0.255)
m*I	-0.003
	(0.850)
N	803

p-values in parentheses:
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10. PCSE Estimates of IN Model

Coefficient Est.	Full Sample
C	0.124***
	(0.000)
p*C	0.249*
	(0.084)
m*C	-0.018
	(0.650)
R	0.092*
	(0.098)
p*R	-0.083
	(0.335)
m*R	0.027
	(0.669)
S	0.885***
	(0.000)
p*S	-0.350**
	(0.012)
m*S	0.004
	(0.962)
N	803

p-values in parentheses:
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In original Cobb-Douglas function, marginal product is the coefficient of input factors. Here in our model with dummy variables, the coefficients in Tables 9 and 10 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, 0.186+0.124. As a consequence, the p-value under 0.124 indicates whether the coefficient of pure-SaaS firms is significantly 0.124 greater than that of non-SaaS firms. Specifically, the beta coefficient measures the percentage change in the output when the input is increased by one percent (output elasticity). Most of coefficients of the base line case (non-SaaS firms) are significant at 1% level, except for the coefficient of R&D expenses which is significant at 10% and for the intangible asset which is not statistically significant.

Capital: Both pure- and mixed-SaaS firms have larger coefficients than those of non-SaaS firms but neither of them is statistically significant. The result in Table 9 indicates that fix assets used in SaaS model contribute more to output for pure-SaaS firms. And it is consistent with the marginal product of cost-of-goods-sold in Table 10. As we mentioned, cost-of-goods-sold could be regarded as a measurement of capital in income statement. The marginal product of COGS for pure-SaaS is 200% higher than non-SaaS firms (0.124 versus 0.124+0.249) and it is significant at the 10% level. Also, the capital productivity of pure-SaaS firms is higher in the case of pure-SaaS with p value 0.111. Although the numbers are still not significant here, they still make sense because the limitations of our pure-SaaS sample will only underestimate these effects as we mentioned in section 3. Marginal product of capital gains in productivity at least 67% for pure-SaaS firms higher than non-SaaS firms (0.186 versus 0.186+0.124).

For mixed-SaaS, neither the capital productivity in Table 9 nor COGS productivity in Table 10 is significant. They two also lead to different directions (2.6% higher for capital productivity of mixed-SaaS firms over non-SaaS firms (0.186 versus 0.181+0.005 in full sample) but 14.8% lower for COGS productivity (0.124 versus 0.124-0.018)). So we cannot make a concrete conclusion about the capital productivity in mixed-SaaS firms here.

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. And the pure-SaaS case is significant at 10% level. 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. Otherwise, the labor productivity of the mixed-SaaS firms should be smaller than non-SaaS firms.

As the elements used in our income statement describe expenses on different functional staff, we can examine the results of income statement model to shed more light on the findings of Model 1 and can further delve into the cause of the differences in labor productivity.

Table 10 shows that pure-SaaS firms have lower productivity both in R&D and SG&A, which together contribute to the 36.9% lower labor productivity identified in balance sheet model (36.9% is derived by the productivity loss of 0.253/0.744 in Table 8). The differences in R&D are not significant while the differences in SG&A coefficients are significant at 5% level.

For mixed-SaaS firms, none of the figures is significant. The results of income statement model suggest that their higher $&D and SG&A productivity contribute to their higher labor productivity. So it may be a sign that in our observations, most of the Mixed-SaaS firms easily keep two business models.

Intangible asset: Our estimation of intangible asset here is not rigorous because none of the input coefficients is significant. Based on what we have, pure-SaaS firms have 860% advantages in marginal product of intangible asset over non-SaaS firms (0.005 versus 0.005+0.038) while mixed-SaaS firms have 60% less marginal product of intangible asset than non-SaaS firms (0.005 versus 0.005-0.003).

5.2.3. Total Factor Productivity

Cobb-Douglas function captures two source of production growth: one from the growth of each factor, and another from the growth of total factor productivity (TFP). Total factor productivity is defined as the measure of effects other than the input variables, such as the growth of technology, the macro economy etc. Undoubtedly, Software-as-a-Service is a great technology innovation and may affect every aspect of the production. So we can figure out the impacts of SaaS on factors beyond our production inputs by examining the total factor productivity of our production function. However, restricted by the relatively smaller sample size, shorter time period and younger stage of SaaS development, analysis in this section is more like a pilot study for completeness of the research. In the future with the maturity of the SaaS industry, researchers could conduct more rigorous investigations with larger sample size and detailed data.

The intercept term in our regression formula is just the logarithms of TFP in Cobb-Douglas function. We present the estimated intercept terms, calculated TFP and the annual growth rate of TFP in Table 11 as follows:

Table 11. Total Factor Productivity (PCSE)

Original Intercept Coefficients						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	4.096	3.321	4.175	-0.032	0.817	0.055
2003	4.249	3.822	4.225	0.241	1.038	0.229
2004	4.343	3.704	4.365	0.322	1.131	0.367
2005	4.380	3.727	4.434	0.402	1.208	0.534
2006	4.452	3.623	4.480	0.490	1.218	0.518
2007	4.534	3.750	4.546	0.595	1.277	0.578
Total Factor Productivity						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	60.10	27.69	65.02	0.969	2.264	1.057
2003	70.04	45.70	68.38	1.273	2.824	1.258
2004	76.94	40.61	78.65	1.380	3.100	1.444
2005	79.84	41.55	84.27	1.495	3.348	1.706
2006	85.80	37.45	88.24	1.633	3.381	1.679
2007	93.13	42.52	94.26	1.814	3.587	1.783
Growth Rate of TFP						
	BS Model			**IN Model**		

	Non	PS	MS	Non	PS	MS
2003	16.53%	65.04%	5.16%	31.39%	24.73%	19.04%
2004	9.86%	-11.13%	15.03%	8.44%	9.75%	14.80%
2005	3.77%	2.33%	7.14%	8.33%	8.00%	18.18%
2006	7.47%	-9.88%	4.71%	9.20%	1.01%	-1.59%
2007	8.55%	13.54%	6.82%	11.07%	6.08%	6.18%

Firstly we compare the total factor productivity of non-SaaS firms and mixed-SaaS firms. In both model in most of years, mixed-SaaS firms have larger TFP than non-SaaS firms (except in 2003 in both model and in 2007 in income statement model). However it is not proper for us to make a conclusion here because the disparities are not very salient and consistent, and we do not know the proportional revenue contribution of SaaS and non-SaaS sectors within mixed-SaaS firms. In sum, in this study we cannot conclude that using a dual-model approach in mixed-SaaS firms improves their TFP.

Then we come to the total factor productivity of pure-SaaS firms. It shows sharply contrasting results in the two models: in balance sheet model, pure-SaaS firms obviously have least TFP among the three categories; while in income statement model, pure-SaaS firms exhibit largest TFP. 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 pure-SaaS firms.

We also calculate the annual growth rate of TFP for each category. Because of the limitation of our smaller sample size and shorter time period, we do not find stable result about the growth pattern of pure-SaaS firms. And the horizontal and vertical comparison of these numbers also cannot give consistent results about cross-category comparison and growth pattern of each category.

5.3. Discussion and Implications

5.3.1. Discussion

We analyze the productivity of SaaS business from three aspects: economies of scale, marginal product of input factors and total factor productivity. Based on our findings, we conclude that SaaS model does influence the productivity in varies aspects. Below are a summary of all the significant findings we get and some possible explanations:

Economies of Scale:

Mixed-SaaS firms have the largest economies of scale among the three categories, and pure-SaaS firms perform worst in economies of scale. The result is consistent in both balance sheet model and income statement model.

For mixed-SaaS firms, a possible 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. Also, most of the mixed-SaaS firms are initially non-SaaS firms. They have been exist and well operating for a long time. They have already set up a good status in the market and obtained positive word of mouth of their product. When they start a new SaaS business, their new business will also benefit from these operating experiences and market advantages. So it is possible for them to manage their inputs and output more efficiently.

For pure-SaaS firms, it proves that hosting servers and data centers for clients indeed gives SaaS vendors non-negligible variable cost as well as capacity constrains to the scale of the company. This finding is contradicted to the description in previous research and non-academic articles. Comparing to mixed- and non-SaaS firms, pure-SaaS firms are young firms with less operating experience and market awareness. And it is understandable for them to be less efficient in their early stage of growth. Also, there are two countervailing effects of the multi-tenant model as one of the three prominent features of SaaS, both increases and decreases economies of scale. First, in the SaaS model, 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. Infrastructure cost-sharing and CPU time-sharing increase 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. As a result, SaaS firms may not have zero variable cost anymore, eliminating the famous zero variable cost feature that makes conventional software companies have 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. Telling from our empirical result, the second effect dominates the first one and leads to smaller economies of scale for pure-SaaS firms.

Marginal Product:

Capital: Pure-SaaS firms have 66.7% larger marginal product of capital than non-SaaS firms in balance sheet model to a p value equal to 0.111, and 201% to a 10% significant level larger marginal product of cost of goods sold than non-SaaS firms.

The composition of COGS is different among pure-, mixed- and non-SaaS firms. In pure-SaaS firms it composites the expenses on hosting service and infrastructures, while in non-SaaS firms it composites of the cost of computer infrastructures, manufacturing, packaging, delivery and storage of the packaged product. The most important capital, or fix asset in software companies are computer infrastructures. In conventional non-SaaS business, the devices are mostly used to support R&D and back office functions.

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 contrast in a SaaS delivery model, because several firms operate on the same infrastructure, the under-utilization of processing power and storage can be alleviated. What's more, some of the devices used as SaaS application servers directly serve the clients and generate revenue. So pure-SaaS firms improve the utilization rate of infrastructures and will have larger capital productivity.

Labor: Our two models give consistent results about labor productivity: pure-SaaS firms have the smallest marginal product of labor in balance sheet model and R&D and SG&A in income statement model. The result of labor productivity in balance sheet model and the result of SG&A expenses productivity in income statement model are both significant to an acceptable level.

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. 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.

Intangible Asset: Neither observation is significant.

As described in the annual reports of the sample companies, typical intangible asset includes copyrights and patent rights. SaaS is a survivability in pure-SaaS firms so the patent right is crucial to them, while in mixes-SaaS firms, the SaaS product may not be in a dominant position and contribute less to their revenue comparing to other products in their product range. We hope future research could find a better way to evaluate intangible asset for SaaS firms.

Total Factor Productivity

Limited by our smaller sample size and shorter time period, we do not get stable results on total factor productivity and annual growth rate of TFP of these three groups. However one phenomenon is obvious: balance sheet model and income statement model give different ranking of pure-SaaS firms in TFP: the TFP of pure-SaaS firms is lowest in balance sheet model while highest in income statement model.

One potential explanation is from the accounting rules about depreciation and expense recognition: with a recurring subscription fee model, a young pure-SaaS company may exhibit that data pattern in comparison of balance sheet and income statement. In the early years of new firms, the book value of assets is relatively larger before they depreciated. However, part of the revenue generated in this year will only be realized in the future and distributed to the following several years due to the pricing model. Therefore, the TFP is underestimated in balance sheet model.

5.3.2. Implications

Our results have several contributions to the literature of Software-as-a-Service. First, this is a first academic work to the productivity of SaaS vendors with empirical analysis. Previous research works either remain as simple description of good market performance of SaaS companies, or describe the benefits of SaaS from client’s view, or do theoretical modeling without empirical support. Second, our firm categorization model is an innovation to the literature. Previously works only separate SaaS and non-SaaS but never look into firms with dual models. Our categorization methodology and results will also benefit future research. Last but not least, our finding about relatively lower economies of scale of pure-SaaS firm refreshes the existing misunderstanding to the scale economy of SaaS business. And our research about input factors’ marginal product and total factor productivity provide comprehensive evaluation to SaaS business model.

Practically, from our research findings SaaS firms may get a good understanding of the advantage and disadvantage of their business model and make improvements accordingly. The findings on economies of scale indicate that mixed-SaaS could grow larger while pure-SaaS firms are most probably to stay in a niche market. So for pure-SaaS vendors, it may be good for them to consider how to improve their efficiency of using production inputs, especially improve the efficiency of R&D and SG&A expenses. Also, our findings could be reference for those who want to start SaaS business and survive in the competition.

5.4. Robustness Check

5.4.1. A Reduced Sample

We dropped more items with extremely large firm size as measured by total asset. After that, we get a smaller sample size of 664 observations of 180 distinct firms, including 11 pure-SaaS firms, 47 mixed-SaaS firms and 122 non-SaaS firms. Coincidently, this control does not influent our pure-SaaS sample but only affects the mixed- and non-SaaS groups. As shown in Table 12, we narrow the gap in total asset between different firm groups: the mean and variance of total asset of the three groups become similar.

Table 12. Comparison of Total Asset

Full Sample	**All Firms**	**Pure-SaaS**	**Mixed- SaaS**	**Non- SaaS**
No. of Obs.	803	36	256	511
Mean	763.84	196.63	1210.48	580.04
Std. Dev.	2923.46	214.73	4411.07	1884.49
Min	5.49	10.84	6.59	5.49
Max	47268	1089.59	47268	18092.09

Reduced Sample	All Firms	Pure- SaaS	Mixed- SaaS	Non- SaaS
No. of Obs.	664	36	205	423
Mean	217.83	196.63	250.30	203.89
Std. Dev.	266.46	214.73	294.75	254.91
Min	6	11	7	6
Max	1549	1090	1511	1549

Based on this reduced sample, we build exactly the same two models and do PCSE regression. The results on economies of scale, marginal product of input factors and total factor productivity are listed in the following tables.

Table 13. Reduced Sample Economies of Scales (PCSE)

	Coef.	Std. Err.	[95% Conf. Interval]	
BS Model				
Non-SaaS	0.857	0.056	0.748	0.966
Pure-SaaS	0.842	0.071	0.703	0.981
Mixed-SaaS	0.956	0.046	0.867	1.046
IN Model				
Non-SaaS	1.1217780	0.045	1.033	1.211
Pure-SaaS	0.9201651	0.047	0.829	1.012
Mixed-SaaS	1.0674780	0.029	1.011	1.124

Table 14. Marginal Product of Reduced Sample

BS Model	Small Sample	IN Model	Small Sample
K	0.153***	**C**	0.075*
	(0.000)		(0.075)
p*K	0.157*	**p*C**	0.258
	(0.058)		(0.114)
m*K	0.014	**m*C**	0.018
	(0.827)		(0.734)
L	0.692***	**R**	0.157*
	(0.000)		(0.078)
p*L	-0.206	**p*R**	-0.135
	(0.160)		(0.246)
m*L	0.087	**m*R**	-0.053
	(0.478)		(0.569)
I	0.011	**S**	0.890***

	(0.317)		(0.000)
p*I	0.035	**p*S**	-0.325*
	(0.335)		(0.054)
m*I	-0.001	**m*S**	-0.019
	(0.940)		(0.870)
N	664		664

p-values in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 15. Total Factor Productivity (Reduced Sample, PCSE)

	BS Model			IN Model		
Original Intercept Coefficients						
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	4.132	3.311	4.123	-0.108	0.789	0.187
2003	4.221	3.796	4.129	0.134	0.997	0.331
2004	4.287	3.658	4.235	0.194	1.068	0.439
2005	4.258	3.659	4.286	0.236	1.128	0.584
2006	4.324	3.527	4.309	0.298	1.113	0.536
2007	4.383	3.642	4.391	0.394	1.159	0.605
Total Factor Productivity						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	62.30	27.41	61.74	0.898	2.201	1.206
2003	68.11	44.52	62.10	1.143	2.710	1.392
2004	72.75	38.78	69.06	1.214	2.910	1.551
2005	70.67	38.82	72.68	1.266	3.089	1.793
2006	75.49	34.02	74.37	1.347	3.043	1.709
2007	80.08	38.17	80.72	1.483	3.187	1.831
Growth Rate of TFP						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2003	9.32%	62.42%	0.59%	27.38%	23.12%	15.49%
2004	6.81%	-12.89%	11.21%	6.18%	7.36%	11.40%
2005	-2.86%	0.10%	5.23%	4.29%	6.18%	15.60%
2006	6.82%	-12.37%	2.33%	6.40%	-1.49%	-4.69%
2007	6.08%	12.19%	8.55%	10.08%	4.71%	7.14%

Economies of Scale

Our estimation about economies of scale is still consistent with a reduced sample. Pure-SaaS firms have smaller economies of scale than non-SaaS firms. Mixed-SaaS firms again demonstrate largest economies of scale among the three categories in balance sheet model. However, in the income statement model, mixed-SaaS firms demonstrate smaller economies of scale than non-SaaS firms.

Then we do a cross-sample comparison between Table 8 and Table 13. Note that in our new sample with averagely smaller firm size, the economies of scale in non- and mixed-SaaS groups also become smaller in balance sheet model, which means those large firms we dropped might have larger economies of scales in balance sheet model. However for income statement model, non-SaaS firms in the reduced sample have smaller economies of scale than those of full sample while mixed-SaaS firms' economies of scale become larger.

Productivity of Inputs

In Table 14, we find that most of the coefficients of the base line case (non-SaaS firms) are at the same significant level as full sample's, except for the coefficient of cost of goods sold which is less significant and is at 10% level.

Capital: In balance sheet model, both pure- and mixed-SaaS firms have larger coefficients than those of non-SaaS firms, and the coefficient difference for pure-SaaS firms is significant at 10% level. The numbers of this finding are also consistent with the coefficient of COGS in income statement model: pure- and mixed-SaaS firms have larger marginal product of COGS, but none of them is statistically significant.

Labor: Our results also 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. However none of these coefficients is significant.

Intangible asset: Our results are completely the same with the full sample results: pure-SaaS group is the largest and mixed-SaaS group is the smallest in intangible asset marginal product, and still none of the coefficients is significant.

Total Factor Productivity

The data about TFP demonstrate exactly the same pattern with full sample's results in income statement model: pure-SaaS firms have largest TFP, then come mixed-SaaS firms, then non-SaaS firms at last. For balance sheet model, the rank of mixed-SaaS group and non-SaaS group is different from full sample's results: for most of time mixed-SaaS firms have smaller TFP than non-SaaS firms. Another difference from full sample's result is that for most years in both models, the number value of TFP of reduced sample is smaller than that of full sample except for mixed-SaaS firms in income statement: reduced sample has larger TFP while full sample have smaller TFP. For TFP annual growth rate, most of the results in the reduced sample are also of smaller value than their counterparts in full sample. As mentioned previously, our results about TFP is not rigorous because of the sample size and time period. So we will not give a conclusion here as well.

5.4.2. Using Other Regression Methods

We first perform fixed-effect and random-effect panel-data regression models for our sample. As the presence of the serial correlation and heteroskedasticity of our sample, we could use Feasible Generalized Least Squares (FGLS) with within-panel corrections as robustness check model. 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). However, researchers also point out that FGLS may underestimate standard errors for panel data with heteroskedasticity and autocorrelation (Beck and Katz 1995; Han 2006). So we just do this for robustness check but will still hold our previous research results from PCSE.

Economies of Scale

The results of economies of scale derived from FGLS, FE and RE are presented in Table 16 and 17.

Table 16. Economies of Scale (FGLS, FE, and RE) of BS Model

		Coef.	Std. Err.	[95% Conf. Interval]	
FGLS					
Non-SaaS	*Full Sample*	0.945	0.016	0.913	0.977
	Reduced Sample	0.820	0.020	0.781	0.859
Pure-SaaS	*Full Sample*	0.898	0.061	0.778	1.017
	Reduced Sample	0.888	0.065	0.761	1.015
Mixed-SaaS	*Full Sample*	1.041	0.015	1.012	1.069
	Reduced Sample	0.871	0.024	0.823	0.918
FE					
Non-SaaS	*Full Sample*	0.634	0.061	0.514	0.754
	Reduced Sample	0.635	0.078	0.482	0.789

Pure-SaaS	*Full Sample*	0.438	0.201	0.044	0.832
	Reduced Sample	0.426	0.216	0.002	0.849
Mixed-SaaS	*Full Sample*	0.745	0.072	0.604	0.885
	Reduced Sample	0.716	0.079	0.561	0.871
RE					
Non-SaaS	*Full Sample*	0.855	0.026	0.805	0.906
	Reduced Sample	0.815	0.032	0.752	0.878
Pure-SaaS	*Full Sample*	0.799	0.159	0.487	1.110
	Reduced Sample	0.817	0.163	0.498	1.137
Mixed-SaaS	*Full Sample*	0.963	0.036	0.892	1.034
	Reduced Sample	0.872	0.047	0.780	0.964

Table 17. Economies of Scale (FGLS, FE, and RE) of IN Model

		Coef.	**Std. Err.**	**[95% Conf. Interval]**	
FGLS					
Non-SaaS	*Full Sample*	1.071	0.009	1.054	1.088
	Reduced Sample	1.068	0.014	1.041	1.096
Pure-SaaS	*Full Sample*	0.954	0.014	0.926	0.982
	Reduced Sample	0.958	0.015	0.930	0.987
Mixed-SaaS	*Full Sample*	1.109	0.008	1.094	1.124
	Reduced Sample	1.051	0.016	1.020	1.082
FE					
Non-SaaS	*Full Sample*	0.765	0.072	0.062	0.906
	Reduced Sample	0.784	0.099	0.589	0.979
Pure-SaaS	*Full Sample*	0.849	0.180	0.496	1.202
	Reduced Sample	0.902	0.181	0.547	1.257
Mixed-SaaS	*Full Sample*	0.987	0.069	0.851	1.123
	Reduced Sample	1.059	0.071	0.920	1.198
RE					
Non-SaaS	*Full Sample*	1.022	0.025	0.973	1.072
	Reduced Sample	1.030	0.037	0.958	1.102
Pure-SaaS	*Full Sample*	0.912	0.152	0.615	1.209
	Reduced Sample	0.923	0.164	0.601	1.245
Mixed-SaaS	*Full Sample*	1.082	0.032	1.019	1.146
	Reduced Sample	1.071	0.048	0.976	1.166

Reviewing Table 16 and Table 17, we get that the economies of scale of the three categories are mostly the same with our baseline case (full sample under PCSE regression): mixed-SaaS firms have the largest economies of scale and pure-SaaS firms have the smallest economies of scale. Only one exception is that in FGLS regression of reduced sample under income statement model, non-SaaS firms have slightly bigger economies of scale than mixed-SaaS. Also, in balance sheet model in Table 16, reduced sample has smaller coefficients in almost every regression model and every firm category. This comparison between full sample and reduced sample is just in the opposite direction for most cases in income statement model although it is not that obvious as balances sheet model.

Productivity of Inputs

We present the results of marginal product in Table 18 and 19. Based on the explanatory power of regression methods and to make the paper to be concise, we will only give short description on FGLS results.

Table 18. FGLS, FE, and RE estimation of BS Model

Coefficient Est.	FGLS		FE		RE	
	Full Sample	*Reduced Sample*	*Full Sample*	*Reduced Sample*	*Full Sample*	*Reduced Sample*
K	0.130***	0.105***	0.104***	0.122**	0.144***	0.138***
	(0.000)	(0.000)	(0.010)	(0.010)	(0.000)	(0.000)
p*K	0.095***	0.123***	-0.109	-0.135	0.027	0.050
	(0.007)	(0.002)	(0.220)	(0.170)	(0.807)	(0.671)
m*K	0.070***	0.107***	0.079	0.086	0.032	0.0385
	(0.005)	(0.000)	(0.156)	(0.187)	(0.436)	(0.416)
L	0.808***	0.704***	0.508***	0.485***	0.700***	0.658***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
p*L	-0.134**	-0.042	-0.126	-0.115	-0.115	-0.078

	(0.026)	(0.532)	(0.475)	(0.557)	(0.560)	(0.708)
m*L	0.044	-0.045	0.043	-0.007	0.081	0.008
	(0.250)	(0.330)	(0.713)	(0.959)	(0.235)	(0.918)
I	0.007^{*}	0.011^{***}	0.022^{**}	0.028^{**}	0.012	0.019^{*}
	(0.075)	(0.002)	(0.043)	(0.022)	(0.212)	(0.068)
p*I	-0.008	-0.012	0.038	0.041	0.032	0.031
	(0.541)	(0.416)	(0.154)	(0.189)	(0.519)	(0.552)
m*I	-0.018^{**}	-0.012	-0.011	0.002	-0.004	0.011
	(0.013)	(0.262)	(0.393)	(0.928)	(0.775)	(0.611)
N	770	634	803	664	803	664

p-values in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 19. FGLS, FE, and RE estimation of IN Model

Coefficient Est.	**FGLS**		**FE**		**RE**	
	Full Sample	*Reduced Sample*	*Full Sample*	*Reduced Sample*	*Full Sample*	*Reduced Sample*
C	0.096^{***}	0.046^{***}	0.007	0.001	0.088^{***}	0.059^{**}
	(0.000)	(0.002)	(0.897)	(0.987)	(0.000)	(0.033)
p*C	0.100^{**}	0.090	-0.224^{**}	-0.295^{***}	0.106	0.100
	(0.044)	(0.117)	(0.024)	(0.005)	(0.655)	(0.701)
m*C	-0.018	-0.018	0.038	0.013	-0.022	-0.006
	(0.301)	(0.420)	(0.570)	(0.876)	(0.627)	(0.913)
R	0.145^{***}	0.224^{***}	0.086	0.145	0.098^{**}	0.158^{***}
	(0.000)	(0.000)	(0.366)	(0.227)	(0.015)	(0.004)
p*R	-0.078^{*}	-0.132^{**}	0.186	0.153	-0.042	-0.083
	(0.097)	(0.011)	(0.210)	(0.350)	(0.832)	(0.705)
m*R	-0.022	-0.122^{***}	0.018	-0.027	0.008	-0.052
	(0.465)	(0.000)	(0.878)	(0.846)	(0.900)	(0.520)
S	0.829^{***}	0.799^{***}	0.673^{***}	0.637^{***}	0.836^{***}	0.813^{***}
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
p*S	-0.139^{***}	-0.068	0.121	0.259	-0.174	-0.124
	(0.001)	(0.164)	(0.668)	(0.399)	(0.469)	(0.638)
m*S	0.078^{**}	0.124^{***}	0.166	0.290	0.074	0.099
	(0.028)	(0.004)	(0.294)	(0.137)	(0.381)	(0.354)
N	770	634	803	664	803	664

p-values in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Under FGLS regression, more coefficients of become significant than PCSE referring to Table 9 and 10. Comparing the coefficients which are significant, FGLS gives same direction of changes in both full and reduced sample. That is:

Capital: In balance sheet model, pure- and mixed-SaaS firms both have larger marginal product of Capital. In income statement model, the productivity of COGS is better than non-SaaS firms for pure-SaaS firms.

Labor: In balance sheet model, pure-SaaS firms have smaller productivity of Labor than non-SaaS firms. In income statement model, the productivity of R&D staff and SG&A staff in pure-SaaS firms are both worse than non-SaaS firms. Mixed-SaaS firms also have lower productivity of R&D staff. However, SG&A productivity of mixed-SaaS firms are better than non-SaaS firms.

Intangible Asset: Only one coefficient is significant under FGLS and it shows that mixed-SaaS firms in the full sample have significantly (5% level) lower productivity in intangible asset.

Total Factor Productivity

Our results about total factor productivity are illustrated in Table 20 to Table 25. To keep the brevity of the paper, we will not express our results one by one. Due to the limitation of our sample size and time period, we still fail to get a consistent growth pattern of SaaS business. And we hope future research could find a proper way to analyze the total factor productivity of SaaS business.

Table 20. Total Factor Productivity (Full Sample, FGLS)

	BS Model			IN Model		
Original Intercept Coefficients						
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	4.347	3.790	4.263	0.179	0.660	0.113
2003	4.445	4.250	4.308	0.403	0.865	0.248
2004	4.546	4.082	4.427	0.515	0.960	0.362
2005	4.615	4.124	4.503	0.621	1.070	0.502
2006	4.661	4.145	4.563	0.697	1.079	0.508
2007	4.723	4.269	4.638	0.774	1.186	0.574
Total Factor Productivity						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	77.25	44.26	71.02	1.196	1.935	1.120
2003	85.16	70.08	74.32	1.496	2.375	1.281
2004	94.26	59.26	83.66	1.674	2.612	1.436
2005	101.0	61.81	90.29	1.861	2.915	1.652
2006	105.7	63.12	95.87	2.008	2.942	1.662
2007	112.5	71.47	103.3	2.168	3.274	1.775
Growth Rate of TFP						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2003	10.24%	58.36%	4.66%	25.11%	22.75%	14.41%
2004	10.68%	-15.44%	12.57%	11.85%	9.970%	12.09%
2005	7.14%	4.29%	7.920%	11.18%	11.63%	15.03%
2006	4.71%	2.120%	6.18%	7.90%	0.90%	0.60%
2007	6.400%	13.24%	7.790%	8.0%	11.29%	6.820%

Table 21. Total Factor Productivity (Reduced Sample, FGLS)

	BS Model			IN Model		
Original Intercept Coefficients						
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	4.318	3.769	3.985	0.190	0.611	0.286
2003	4.380	4.207	4.002	0.382	0.803	0.401
2004	4.461	4.026	4.088	0.488	0.889	0.502
2005	4.498	4.042	4.151	0.562	0.982	0.611
2006	4.540	4.046	4.199	0.603	0.973	0.596
2007	4.578	4.167	4.274	0.663	1.071	0.658
Total Factor Productivity						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	75.04	43.34	53.79	1.209	1.842	1.331
2003	79.81	67.16	54.71	1.465	2.232	1.493

2004	86.57	56.04	59.62	1.629	2.433	1.652
2005	89.84	56.94	63.50	1.754	2.670	1.842
2006	93.69	57.17	66.62	1.828	2.646	1.815
2007	97.32	64.52	71.79	1.941	2.918	1.931
Growth Rate of TFP						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2003	6.35%	54.96%	1.71%	21.17%	21.17%	12.15%
2004	8.48%	-16.56%	8.98%	11.18%	8.98%	10.63%
2005	3.77%	1.61%	6.50%	7.68%	9.75%	11.52%
2006	4.29%	0.40%	4.92%	4.19%	-0.90%	-1.49%
2007	3.87%	12.86%	7.77%	6.18%	10.30%	6.40%

Table 22. Total Factor Productivity (Full Sample, FE)

Original Intercept Coefficients						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	4.224	3.838	3.785	1.142	0.283	1.191
2003	4.333	4.224	3.837	1.339	1.166	1.247
2004	4.420	4.311	3.954	1.442	1.091	1.369
2005	4.494	4.498	4.065	1.545	1.115	1.452
2006	4.564	4.607	4.138	1.614	1.081	1.504
2007	4.687	4.847	4.224	1.739	1.221	1.569
Total Factor Productivity						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	68.31	46.43	44.04	3.133	1.327	3.292
2003	76.17	68.31	46.39	3.815	3.209	3.480
2004	83.10	74.55	52.14	4.229	2.976	3.931
2005	89.48	89.84	58.27	4.688	3.050	4.272
2006	95.97	100.2	62.70	5.023	2.947	4.500
2007	108.5	127.4	68.31	5.692	3.390	4.802
Growth Rate of TFP						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2003	11.52%	47.11%	5.34%	21.77%	141.8%	5.72%
2004	9.09%	9.13%	12.41%	10.85%	-7.27%	12.98%
2005	7.68%	20.51%	11.74%	10.85%	2.49%	8.65%
2006	7.25%	11.52%	7.61%	7.14%	-3.37%	5.34%
2007	13.09%	27.12%	8.95%	13.31%	15.03%	6.72%

Table 23. Total Factor Productivity (Reduced Sample, FE)						
Original Intercept Coefficients						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	4.032	3.113	3.726	0.937	0.190	0.518
2003	4.099	3.478	3.741	1.105	0.504	0.680
2004	4.173	3.550	3.824	1.191	0.682	0.748
2005	4.199	3.724	3.902	1.263	0.814	0.898
2006	4.267	3.802	3.937	1.316	0.843	0.848
2007	4.355	4.032	4.032	1.431	0.937	0.937
Total Factor Productivity						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	56.37	22.49	41.51	2.552	1.209	1.679
2003	60.27	32.40	42.14	3.019	1.655	1.974
2004	64.91	34.81	45.79	3.290	1.978	2.113
2005	66.62	41.43	49.50	3.536	2.257	2.454
2006	71.31	44.79	51.29	3.728	2.324	2.336
2007	77.87	56.37	56.37	4.183	2.552	2.552
Growth Rate of TFP						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2003	6.92%	44.05%	1.51%	18.29%	36.89%	17.59%
2004	7.69%	7.47%	8.65%	8.98%	19.48%	7.04%
2005	2.63%	19.01%	8.11%	7.47%	14.11%	16.14%
2006	7.04%	8.11%	3.60%	5.44%	2.98%	-4.81%
2007	9.20%	25.86%	9.92%	12.19%	9.81%	9.28%

Table 24. Total Factor Productivity (Full Sample, RE)						
Original Intercept Coefficients						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	4.124	3.686	4.173	0.222	0.634	0.138
2003	4.264	4.148	4.229	0.471	0.875	0.310
2004	4.348	4.073	4.351	0.560	1.008	0.426
2005	4.403	4.097	4.434	0.650	1.117	0.594
2006	4.464	4.063	4.486	0.713	1.153	0.581
2007	4.567	4.203	4.551	0.815	1.234	0.660
Total Factor Productivity						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	61.81	39.89	64.94	1.249	1.885	1.148

2003	71.09	63.31	68.65	1.602	2.399	1.363
2004	77.32	58.70	77.56	1.751	2.740	1.531
2005	81.70	60.17	84.27	1.916	3.056	1.811
2006	86.83	58.14	88.77	2.040	3.168	1.788
2007	96.26	66.87	94.73	2.259	3.435	1.935
Growth Rate of TFP						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2003	15.03%	58.72%	5.72%	28.27%	27.25%	18.82%
2004	8.76%	-7.27%	12.98%	9.31%	14.22%	12.30%
2005	5.65%	2.49%	8.65%	9.42%	11.52%	18.29%
2006	6.29%	-3.37%	5.34%	6.50%	3.67%	-1.29%
2007	10.85%	15.03%	6.72%	10.74%	8.44%	8.22%

Table 25. Total Factor Productivity (Reduced Sample, RE)

Original Intercept Coefficients						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	4.095	3.656	3.979	0.193	0.592	0.151
2003	4.181	4.108	3.988	0.412	0.818	0.304
2004	4.252	3.998	4.072	0.489	0.933	0.381
2005	4.249	3.994	4.128	0.546	1.025	0.526
2006	4.312	3.914	4.150	0.592	1.035	0.471
2007	4.386	4.035	4.232	0.688	1.097	0.560
Total Factor Productivity						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2002	60.04	38.71	53.46	1.213	1.808	1.162
2003	65.43	60.85	53.95	1.510	2.266	1.355
2004	70.25	54.49	58.66	1.631	2.542	1.464
2005	70.04	54.27	62.05	1.726	2.787	1.692
2006	74.59	50.10	63.46	1.808	2.815	1.602
2007	80.32	56.53	68.86	1.990	2.995	1.751
Growth Rate of TFP						
	BS Model			**IN Model**		
	Non	**PS**	**MS**	**Non**	**PS**	**MS**
2003	8.97%	57.21%	0.90%	24.48%	25.36%	16.59%
2004	7.37%	-10.45%	8.73%	8.00%	12.19%	8.00%
2005	-0.30%	-0.40%	5.78%	5.87%	9.64%	15.60%
2006	6.50%	-7.69%	2.28%	4.71%	1.01%	-5.35%
2007	7.68%	12.84%	8.50%	10.08%	6.40%	9.31%

6. Conclusion

In this paper, we first evaluate how SaaS model influences the financial performance of the firm. We adopt four commonly used financial ratios to measure firm performance: price to book ratio, return on asset, return on equity, and debt ratio. Price to book ratio reflects the market's expectation on the firm's stock and the rest three are signals of the firm's real business performance. Our result reveals that pure-SaaS firms have significantly better performance in all the four ratios than non-SaaS firms. Mixed-SaaS firms also win non-SaaS slightly in the four ratios but the results are not that significant as pure-SaaS firms. The advantage of pure-SaaS firms in price to book ratio is extraordinarily outstanding. It is almost 3 times larger than the same ratio of mixed- and non-SaaS firms as well as the industry average. Practically, the excellent performance of pure-SaaS firms proves that the SaaS model is indeed an outstanding technology innovation as well as business innovation. Investors and entrepreneurs may get some inspirations and software providers may consider join this trend.

We explore the relationship between the SaaS 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 result is an overthrow to prior studies. Conventional software application is well-accepted as they enjoy both supply- and demand-side economies of scale. However, pure-SaaS vendors actually sell "two products": a software application and the IT management service of that application, while 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 has much lower economies of scale. In the reality, most pure-SaaS firms are still in their rising stage during our sampling period. Gradually they will get more experience and enlarge customer base and might be of more economies of scale in the future. For mixed-SaaS firms, they have been long existing veteran non-SaaS players before they start their SaaS business segment. Their well-run packaged software business, established customer word-of-mouth, and economies of scope from dual-model may offset the shortage of SaaS business. The implication of this finding is that it is more 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 to 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 labor productivity results from both R&D and marketing categories. In contrast, our analysis also shows that employees of mixed-SaaS firms contribute much more to output, with efficient labor productivity in both R&D and marketing and sales activities. These differences are partially due to the different stage of development as well as experience accumulation of pure- and mixed-SaaS firms. 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. For pure-SaaS players, our results imply that they would better to improve their labor efficiency especially in R&D and marketing functions.

For our performance analysis, there remain a lot of spaces to improve. Firstly, we have a limited sample of pure-SaaS firms. And the number of firms is even restricted by our sampling method as we mentioned in section 3. As currently the SaaS market is still in its early phase, when the market becomes more mature, researcher could get more samples and the findings will be more stable and reliable. Future researchers could collect more data with the development of this market to fertilize the sample. Also, with the limitation of information provided in the annual report, we cannot tell the specific time when the mixed-SaaS firms start to run another business model. Comparison of effects of different models on the same company may bring about extremely meaningful findings. Researchers may try some direct methods like survey to collect more detailed information. Lastly, our hypothesis could also be tested using more advanced financial ratios such as Tobin's q if necessary data could be obtained.

There are several possible extensions to the productivity analysis as well. 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 and may increase the variability of the number of customers. It is not obvious whether the variability/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. Furthermore, since most mixed-SaaS firms transit from non-SaaS firms, it will be of value to investigate how their performance and productivity will change after their SaaS launch. Will more and more non-SaaS firms become mixed-SaaS firms? What is the difference in the firm's productivity before and after its SaaS initiative? Will pure-SaaS firms also start non-SaaS business and become mixed-SaaS from another direction? And if so, what will happen to their productivity? So researchers may keep watching whether pure-SaaS firms would transit to mixed-SaaS firms by starting conventional packaged software business as well. Last but not least, future research could seek for more detailed financial data to spilt the currently used input factors to the production, which will help find out what on earth is the shortest board of SaaS firms that leads to their lower labor productivity.

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Appendix 1

Pure SaaS (11)	Mix SaaS (57)	Non SaaS (144)
CONCUR TECHNOLOGIES INC	ADOBE SYSTEMS INC	724 SOLUTIONS INC
DEALERTRACK HOLDINGS INC	AMERICAN SOFTWARE - CL A	ACCLAIM ENTERTAINMENT INC
DEMANDTEC INC	ARIBA INC	ACTIVISION INC
KENEXA CORP	ART TECHNOLOGY GROUP INC	ACTUATE CORP
LIVEPERSON INC	AUTODESK INC	AGILE SOFTWARE CORP
OMNITURE INC	BLACKBAUD INC	ALTIRIS INC
RIGHTNOW TECHNOLOGIES INC	BLACKBOARD INC	APROPOS TECHNOLOGY INC
SALESFORCE.COM INC	BOTTOMLINE TECHNOLOGIES INC	ARTEMIS INTL SOLUTIONS CORP
SUCCESSFACTORS INC	CADENCE DESIGN SYSTEMS INC	ARTISTDIRECT INC
TALEO CORP	CALLIDUS SOFTWARE INC	ASCENTIAL SOFTWARE CORP
VOCUS INC	CARESCIENCE INC	ASIAINFO HOLDINGS INC
	CENTRA SOFTWARE INC	BACKWEB TECHNOLOGIES LTD
	CITRIX SYSTEMS INC	BAM ENTERTAINMENT INC
	CLICK COMMERCE INC	BINDVIEW DEVELOPMENT CORP
	COGNOS INC	BLADELOGIC INC
	DOCENT INC	BLUE MARTINI SOFTWARE INC
	DOCUCORP INTERNATIONAL INC	BMC SOFTWARE INC
	DOUBLECLICK INC	BORLAND SOFTWARE CORP
	EBIX INC	BRIO SOFTWARE INC
	EDWARDS J D & CO	BSQUARE CORP
	EGAIN COMMUNICATIONS	CA INC
	GOLDLEAF FINANCIAL SOLUTIONS	CAMINUS CORP
	I2 TECHNOLOGIES INC	CARREKER CORP
	I-MANY INC	CHORDIANT SOFTWARE INC
	IMPAC MEDICAL SYSTEMS INC	CLICKSOFTWARE TECHNOLOGIES
	INDUS INTERNATIONAL INC	COMMERCE ONE INC
	INFORMATICA CORP	COMMVAULT SYSTEMS INC
	INKTOMI CORP	COMSHARE INC
	INTERWOVEN INC	CONCERTO SOFTWARE INC

	INTUIT INC	CONCORD COMMUNICATIONS INC
	KRONOS INC	CONVERA CORP
	LANDACORP INC	COREL CORP
	LAWSON SOFTWARE INC	CORILLIAN CORP
	LIONBRIDGE TECHNOLOGIES INC	COVER-ALL TECHNOLOGIES INC
	MADE2MANAGE SYSTEMS INC	DALEEN TECHNOLOGIES INC
	MCAFEE INC	DIGIMARC CORP -OLD
	MOLDFLOW CORP	DIJJI CORP
	NOVADIGM INC	DOUBLE-TAKE SOFTWARE INC
	ONYX SOFTWARE CORP	E.PIPHANY INC
	ORACLE CORP	ELECTRONIC ARTS INC
	PARAMETRIC TECHNOLOGY CORP	EMAGEON INC
	PEOPLESOFT INC	ENGAGE INC
	PROGRESS SOFTWARE CORP	ENTRUST INC
	QAD INC	EVOLVE SOFTWARE INC
	QUOVADX INC	EXE TECHNOLOGIES INC
	SABA SOFTWARE INC	EXTENDED SYSTEMS INC
	SCIQUEST INC	FILENET CORP
	SELECTICA INC	FIREPOND INC
	SIEBEL SYSTEMS INC	GLOBALSCAPE INC
	SMITH MICRO SOFTWARE INC	GOREMOTE INTERNET COMM INC
	SONIC FOUNDRY INC	GROUP 1 SOFTWARE INC
	SS&C TECHNOLOGIES INC	GUIDANCE SOFTWARE INC
	SUMTOTAL SYSTEMS INC	HPL TECHNOLOGIES INC
	UNICA CORP	IMANAGE INC
	VISUAL SCIENCES INC/DE	INET TECHNOLOGIES INC
	WEBSENSE INC	INTERACTIVE INTELLIGENCE INC
	WORKSTREAM INC	INTERGRAPH CORP
		INTERNET SECURITY SYSTEMS
		INTERPLAY ENTERTAINMENT CORP
		INTERVIDEO INC
		KANA SOFTWARE INC
		KNOVA SOFTWARE INC
		LIBERATE TECHNOLOGIES
		LIGHTSPAN INC
		LYRIS INC

	MAGMA DESIGN AUTOMATION INC
	MAJESCO ENTERTAINMENT CO
	MARIMBA INC
	MATRIXONE INC
	METASOLV INC
	MICROMUSE INC
	MICROSTRATEGY INC
	MOBIUS MGMT SYSTEMS INC
	MSC SOFTWARE CORP
	NASSDA CORP
	NEON SYSTEMS INC
	NETEGRITY INC
	NETIQ CORP
	NEXPRISE INC
	NEXTWAVE WIRELESS INC
	NIKU CORP
	NUANCE COMMUNICATIONS-OLD
	OASYS MOBILE INC
	ON2 TECHNOLOGIES INC
	OPEN SOLUTIONS INC
	OPEN TV CORP
	OPENWAVE SYSTEMS INC
	OPNET TECHNOLOGIES INC
	OPSWARE INC
	OPTIO SOFTWARE INC
	PALMSOURCE INC
	PERSISTENCE SOFTWARE INC
	PHARSIGHT CORP
	PHASE FORWARD INC
	PHOENIX TECHNOLOGIES LTD
	PIVOTAL CORP
	PLUMTREE SOFTWARE INC
	PORTAL SOFTWARE INC
	PRECISE SOFTWARE SOLUTIONS
	PRIMUS KNOWLEDGE SOLUTIONS
	PRINTCAFE SOFTWARE INC
	QUEST SOFTWARE INC

		RADVISION LTD
		REALNETWORKS INC
		RED HAT INC
		RETEK INC
		SAGENT TECHNOLOGY INC
		SCIENTIFIC LEARNING CORP
		SCO GROUP INC
		SEEBEYOND TECHNOLOGY CORP
		SERENA SOFTWARE INC
		SIBONEY CORP
		SOFTBRANDS INC
		SOFTECH INC
		SSA GLOBAL TECHNOLOGIES
		SUNGARD DATA SYSTEMS INC
		SUPPORTSOFT INC
		SYMANTEC CORP
		SYNPLICITY INC
		SYSTEMS & COMPUTER TECH CORP
		T/R SYSTEMS INC
		TANGRAM ENTP SOLUTIONS
		TELECOMMUNICATION SYS INC
		TENFOLD CORP
		TENGTU INTL CORP
		TIBCO SOFTWARE INC
		TIMBERLINE SOFTWARE CORP
		TRIZETTO GROUP INC
		TUMBLEWEED COMMUNICATIONS CO
		ULTICOM INC
		ULTIMATE SOFTWARE GROUP INC
		VANTAGEMED CORP
		VASTERA INC
		VERISIGN INC
		VERISITY LTD
		VERSATA INC
		VERTICALNET INC
		VIEWLOCITY INC

		VIGNETTE CORP
		VIRAGE INC
		VITRIA TECHNOLOGY INC
		WATCHGUARD TECHNOLOGIES INC
		WEBMETHODS INC
		WITNESS SYSTEMS INC

Appendix 2

Pure SaaS firms:

Name of Company	**Found Time**	**IPO Time**	**Business Description***
CONCUR TECHNOLOGIES INC	1993	1999	Accounting & Finance
DEALERTRACK HOLDINGS INC	2001	2005	Sales and finance software for automotive retail industry
DEMANDTEC INC	1999	2007	SCM
KENEXA CORP	1987	2005	Workforce management
LIVEPERSON INC	1995	2000	CRM
OMNITURE INC	1996	2006	Web analytics
RIGHTNOW TECHNOLOGIES INC	1997	2004	CRM
SALESFORCE.COM INC	1999	2004	CRM
SUCCESSFACTORS INC	2001	2007	Workforce management
TALEO CORP	1996	2005	Workforce management
VOCUS INC	1992	2005	CRM

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