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# The Impact of R&D on Software Firms' Performance and Efficiency

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**Abstract**

*The software industry is a typical knowledge-intensive business services and R&D profoundly affects the competitiveness of the software enterprises. According to the type of products or services provided by software companies, software enterprises are divided into system software companies, application software companies and service software companies. Taking software enterprises in top 1000 global research and development as the research sample, the influence factors of software companies performance are studied using Panel data model. After eliminating no significant influence factors, the efficiency of system software companies, application software companies and service software companies are measureed and compared based on the DEA method. Finally, the factors affecting efficiency are studied through the Tobit regression. The results show that R&D improve company performance mainly by promote production frontier, namely the technology progress. R&D can't improve the efficiency of system software companies and application software companies but can effectively improve the efficiency of service software companies.*

***Keywords:*** *Software industry; R&D efficiency; Panel data; DEA; Tobit*

## 1. Introduction

Software industry is a typical Knowledge Intensive Business Services (KIBS). Miles and others point out that companies belongs to the KIBS significantly rely on professional knowledge to provide users with service based on information and knowledge; KIBS innovation contains a large number of users knowledge and skilled user needs the product platform support for its innovation [1]. Software industry needs high intensity R&D input, R&D profoundly affects the competitiveness of the software enterprises. At present, software companies in the process of product development faces two challenges. One is the rapid expansion of the technology system and the range of technology for enterprises to choose is expanded. Companies can not and not necessary to master the knowledge required in product innovation. The second is the user's demand changes quickly and diversity is enhanced and so as the customization degree of software product. Companies need to shorten the innovation cycle and improve the efficiency of research and development. Under the background, companies are easy to fall into technical flood and hard to effectively match the technology and market demand, which requires the companies must achieve the optimal allocation of R&D resources. The main object of this study is to analyze the impact of corporate R&D activities on firm performance. To that end, we analyze a sample of 39 software enterprises, covering the period from 2005 to 2010. The database comes from industrial R&D Investment Scoreboard (from Eurostat).

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The influence of R&D on the companies can be divided into two aspects. From the perspective of productivity, R&D improves company performance mainly by promote production frontier, namely the technology progress. From the perspective of efficiency, R&D can reduce the input and avoid waste, thereby improving the technology efficiency of companies. Significant difference of production process was found between the software industry and the traditional manufacturing. Whether R&D can affect companies' performance through the above two ways remains to be verified. First, manufacturing company production function of input factors mainly include capital, personnel and intellectual investment. The capital investment and personnel input are the main factors that influence the performance of manufacturing while software companies rely mainly on professional knowledge to provide users with products and services. Whether plant, hardware equipment and personnel number input influence on the performance, and if they have, compared with the influence of R&D input, which one is bigger? Second, the software industry has late-developing advantage. Once technology is developed, it is often accomplished market success by companies which attaches great importance to the business model innovation and the R&D developing companies has failed to benefit from R&D. So it remains to be verified R&D efficiency is affected by the R&D density.

To answer the above two problems, the paper accomplished empirical research using the Panel data model, DEA method and Tobit regression by taking software enterprises in top 1000 global R&D scoreboard as the research sample. The effect of R&D on the performance and efficiency of software companies is analyzed so that to provide management support for the enterprise and government decision.

## 2. Literature Review

The literature of research and development (R&D) generally assumes that R&D has a positive impact on corporate performance, for example, the seminal article by Griliches [2] and more recent contributions by Klette and Kortum [3], Janz *et al.*, [4], Rogers [5], Lööf and Heshmati [6], and Heshmati and Kim [7]. All these authors point out that there are strong positive correlations between R&D (knowledge creation) and firm growth. The software industry is the quintessence of the knowledge-intensive industry. It is characterized by a high rate of product and process innovations, high knowledge intensity, rapidly shrinking product and technology life cycles, global market [8]. Romijn and Albaladejo found that in small hi-tech companies, specialized knowledge and experience in science and technology should be in place [9].

However, software development highly depends on skilled and creative employees rather than technology. Different from other industries, technology-orientation has a negative impact on the software industry [10]. Nowak and Grantham study California software industry, the California case illustrates clearly that human capital – attracting and retaining the right talent is the critical resources for software industry [11]. Ethiraj *et al.*, using a large sample of detailed project-level data from a leading firm in the global software services industry, find that two broad classes capabilities are significant, that are client-specific capabilities and project management capabilities[12]. Akman and Yilmaz found that customer-orientation is one of the important factors that significantly affects the innovation capability, and they also pointed out that inter-functional co-ordination is another factor that has a significant effect on innovative capability [9]. Software development team creativity is positive related to a creative climate, *e.g.*, challenging work, freedom and group support [13]. In the software industry, analysis and design has become the crucial phase in software development. A good software design can be reused in other projects, will shorten the development period and, ultimately, the costs as well [14].

 

The efficiency of research and development is the ability of an area or an enterprise to transform a variety of resources (such as funds, personnel etc.) through research into various output (such as new product sales, patent application), and it has a profound impact on enterprise performance. The methods for measuring the efficiency of R&D include data envelopment model (DEA) and stochastic frontier analysis (SFA) method etc. Golany and Shtub used BSC (balance score card) and DEA method combined to evaluate the efficiency of R&D projects with different life cycle, they chose a research laboratory which performed dozens of R&D projects per year as a case study object, and verified the feasibility of the method [15]; Lee *et al.*, pointed out that the DEA method allows DMU to select the optimal weights so as to maximize the efficiency of the input and output, so the DEA can reflect the unique characteristics of R&D plans in these countries through assigning higher weight to the dominate variables in different countries[16]; Zhong *et al.*, by using the DEA method to Chinese first economic census data, evaluate the R&D efficiency in 30 areas, showing that the eastern region have the advantage in terms of technical efficiency, the western region has advantages in scale efficiency, and the central region has no advantage in two aspects[17]; Liu Yuanyuan and Su Qin, using the DRF analysis method and DEA model, assessed the efficiency of 8 major national software park in China in 2006[18].

The study by Kumbhakar *et al.*, has searched the efficiency of Europe's top R&D enterprise's investment through SFA, showing that R&D plays an important role in high technology enterprise productivity, and has little effect on low technology enterprises, but increasing R&D density can result in improving the technical efficiency of all three types of enterprises [19]; Bos established the R & D density function that included the Technology Club and its associated parameters; this model has provided a framework for the study of each technical clubs output growth drivers, technology diffusion and catch potential problems [20]; Wang uses unbalanced panel data to study the effects of imports and FDI on domestic technical efficiency, the results show that the import and FDI has a significant positive impact on technology transfer, but need to have a good talent pool [21]; Bai Junhong use the panel date of 30 provinces from 1998 to 2007 in China, and conduct the empirical estimates of the efficiency of the innovation in each region using SFA, and based on a system perspective, examines the main elements of the regional innovation system of enterprises, universities, research institutions, local governments and financial institutions and the effects of innovation efficiency causing by the relationship of them [22].

In summary, the efficiency of R&D in companies has profound impact on the performance of software companies, and the relevant academia, research began to receive attention, has made meaningful progress. However, differences in the production process and manufacturing software are significant, and these factors have affected the performance of different software companies. Funds, personnel, knowledge capital investment are considered to be the main factors affecting the productivity of the manufacturing sector, but whether this model is suitable for the software industry still needs empirical research. In addition, it is necessary to classify the companies according to the characteristics of software enterprises, compare the R & D efficiency of different types of software companies, search the significant factors affecting the efficiency of different types of software research and development, and explore the software companies to improve the performance and efficiency of the conduct.

# 3. Research Design

## 3.1. Research Process

Research process is divided into three stages, first, to analyze the factors affecting the performance of software companies, we used the Cobb Douglas production function to create a function in which business sales revenue is used as the dependent variable, with R&D capital stock, capital stock, the number of personnel as independent variables, and use Panel data regression model to study the main factors affecting business performance.

To measure the efficiency of the software development industry, we need to identify elements of factor of inputs and outputs; input elements typically include capital, the number of personnel, and R&D capital and output elements typically corporate performance indicators. However, the software industry is a knowledge-intensive service industry, and need to support high-intensity R&D investment, equipment and other fixed assets have little impact on the output, the impact of the number of personnel on the output impact is also unknown. According to the regression results of Panel data model, we removed the non-significant input factors, used the significant elements in the regression results as inputs to estimate the R&D efficiency by DEA Method.

Finally, we used the R&D efficiency as the dependent variable, R&D intensity and capital intensity as independent variables to do the regression analysis; value of the dependent variable is between 0-1; therefore we used Tobit regression model to search the main factors affecting the efficiency of R&D.

## 3.2. The Classification of the Software Enterprises

The software industry is the production or manufacture of software enterprises collectively; the classification for the software industry has not yet formed a unified standard. According to the North American Industry Classification System (NAICS), the software industry includes System Software Publishing, Application Publishing and Other Services. The FTSE group and the Dow companies jointly established industry classification system Industry Classification Benchmark (ICB), dividing Software & Computer Services into "Computer Services", "Internet" and "Software" Subsectors. Chinese Ministry of industry and information technology published "software industry statistics system in 2010", dividing the software industry into software products, information system integration services, information technology consulting services, data processing and operation service industry, embedded system software industry and IC design industry.

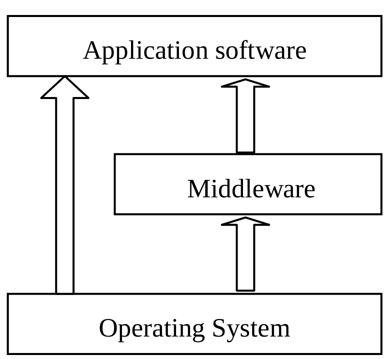


**Figure 1. Software System Architecture**

In fact, large and complex software system structures are operating system, database and middleware, and application software (as shown in Figure 1). Operating system platform is a software platform in the bottom, it operates to realize the interaction between application software and hardware platform; the database and Middleware are operating beyond the operating system; the database system is used to manage data resource, middleware is independent of operating system and database, provide the running and development environment for application software which is the upper application software; application software are used for specific business functions, such as enterprise resource planning (ERP), customer relationship management software (CRM), supply chain management (SCM) software, and financial management software. Service software enterprise mainly use the high technical ability of other enterprises to provide the operating system, database, middleware and other products, and, according to the user's actual business, construct the appropriate industry solution. Therefore, according to the products / services of software industry enterprises, the software industry is divided into three types: system software, application software and services business enterprise software companies.

### 3.3. Data Sources

The empirical analysis is based on the panel data consisting of 39 top software enterprises over the 6-year period 2005-2010. This unique dataset was collected from top R&D scoreboard data of European Commission's Joint Research Centre and Directorate General Research. This R&D scoreboard provides fiscal accounts of top global companies and top European ones. The data is abstracted from publicly available audited accounts, is timely and reliable, and provides evidence for R&D comparisons of different regions, industries and companies. We download data from web page of Joint Research Centre, clear up data manually, and obtain figures of sales, R&D investments, capital expenditures and employees.

**Table 1. Variable Descriptions**

| Viriables | Definitions |
|---|---|
| R&D investment | The cash investment funded by the companies themselves. |
| R&D intensity | The ratio between R&D investment and net sales of a given company or group of companies. |
| Capital expenditure | Expenditure used by a company to acquire or upgrade physical assets such as equipment, property, industrial buildings. |
| Capital intensity | The ratio between capital expenditure and net sales of a given company or group of companies. |
| Employees | The total consolidated average employees or year end employees if average not stated. |
| Sales | Follow the usual accounting definition of sales, excluding sales taxes and shares of sales of joint ventures & associates. |

In order to get representative sample and improve sample research validity, we select companies' consecutively entering scoreboard from 2006 to 2011, and get 42 companies totally. The companies publish annual report including last year's accounting data at the beginning of this year, so the sample range is actually from 2005 to 2010. After obtaining original data, we computed knowledge and physical capital stocks using the perpetual inventory method. Because the data through calculation of R&D capital stock of the Unisys and Tibco Software in 42 software enterprises is negative, we eliminated them. In addition, because the number of employees Nice Systems in 2008-2010 is absent, we also removed it. Finally there are 39 software enterprises as the research sample.

## 4. Study (I): The Key Factors Affecting Software Enterprises' Performance

### 4.1. Model

The software enterprises are divided into system software, application software and software services; we established the panel data model respectfully.

$$S_{k,it} = f(K_{k,it}, C_{k,it}, E_{k,it}; \beta)\exp\{\varepsilon_{k,it}\},\ k = 1,2,3,4;\ i = 1 \ldots 39;\ t = 2005, \ldots 2010$$

k=1 for the entire software industry; k=2 for the system software enterprises, k=3 for the application software enterprises, k=4 for the service software enterprises; i for the enterprises, t for time, in which $Y_{k,it}$ is the revenue of i in t year, $f(.)$ is the production function; input is the R&D stock( $K_{it}$ ), capital stock( $C_{it}$ )and the number of the employee( $E_{it}$ ), $\beta$ for the parameter, $\varepsilon_{it}$ for the random error term.

The production function is Cobb - Douglas log-linear equations, the logarithm equation shows as:

$$\ln(S_{k,it}/E_{k,it}) = \hat{\beta}_{0k} + \hat{\beta}_{1k}\ln(K_{k,it}/E_{k,it}) + \hat{\beta}_{2k}\ln(C_{k,it}/E_{k,it}) + \beta_{3k}\hat{\ln}(E_{k,it}) + \hat{\varepsilon}_{k,it}$$

This study selects the tangible capital stock per capita as a dependent variable. Capital expenditure is refers to the costs enterprises purchase or upgrade of fixed assets (such as equipment, property, plant, and outflow), it reflects the impact of fixed assets on corporate performance; in addition, the per capita stock of physical capital can eliminate the effect of enterprise scale. Hu and Wang argue that the capital stock (*i.e.*, tangible capital) as a measure of capital investment index is suitable [23]. Therefore, the perpetual inventory method to calculate the stock of tangible capital expenditure is needed.

$$C_{t0} = \frac{I_{t0}}{g_j + \varphi}$$

I for the capital expenditure, the average g growth for the rate of capital expenditure from 2005 to 2010, $\varphi$ for Depreciation rate, usually taken as 6%; j=1, 2,......39, ,T0=2005.

$C_t = C_{t-1}(1-\varphi) + I_t$ For t=2005,⋯⋯, 2010

 

This study chooses the capital stock per capita R&D as the dependent variable. R&D capital shows the influence of innovation performance on enterprise competitiveness, especially in high technology industry [24]. R&D capital stock is obtained through the perpetual inventory method for calculating annual R&D funds, R&D fund is refers to the R & D investment for enterprise itself, without R & D outsourcing funds, government grants, and cooperative R & D funds etc.

$$K_{t0} = \frac{R \& D_{t0}}{g_j + \delta}$$

R&D for the enterprise R & D funds, the average g growth for the rate of R&D funds from 2005 to 2010, $\varphi$ for Depreciation rate for R&D , usually taken as 15%; j=1, 2,......39, ,T0=2005.

$$K_t = K_{t-1}(1-\delta) + R \& D_t \quad \text{for } t=2005,\cdots\cdots,2010$$

This study chooses human capital, namely enterprise employees as the dependent variable. The number of employees reflects the scale of enterprises. According to Schumpeter's Hypotheses, the larger enterprise scale is, the stronger the corporate R & D strength and ability to resist market risk is [25]. Software industry is typical knowledge intensive service enterprises; in the process of software product development, system designers, programmers is the main input, rather than raw materials, plant and equipment required for manufacturing. Therefore, we select the number of employees as the main dependent variable; on one hand, it can be control variables to reflect the enterprise scale, on the other hand, combined with the actual production characteristics of software enterprises.

## 4.2. Estimation Results

Panel data model can be divided into constant parameter model, variable intercept model and varying parameter model; in this study we use the variable intercept model. Software companies are divided into system software, application software and software services, to analyze the overall characteristics of the various types of enterprises, it is not suitable to use the varying parameter model; while inside each type of enterprise, there are some difference in sales, research and development, capital investment and staff input, so it is also not suitable to use the constant parameters model. Thus, we used variable intercept model in all three types of the enterprises as a whole, and in individual differences of the three types of internal enterprises. After Hausman test, the model finally was adopted into variable intercept fixed effects model.

In order to avoid spurious regression, before building the model, we conducted the stationary test for all the factors, and chose the same root test methods LLC and different roots testing methods Fish-PP.

**Table 2. The Results of Unit Root Test**

| | Variables | Model (C,T,p) | LLC test | | PP test | |
|---|---|---|---|---|---|---|
| | | | Statistics | *p*-value | Statistics | *p*-value |
| Whole sample | ln(S/E) | (C,0,0) | -13.5769 | 0.0000 | 167.828 | 0.0000 |
| | ln (K/E) | (C,0,0) | -6.16773 | 0.0000 | 96.1365 | 0.0800 |
| | ln(C/E) | (C,0,0) | -6.46815 | 0.0000 | 104.758 | 0.0233 |

 

| | Variables | Model (C,T,p) | LLC test | | PP test | |
|---|---|---|---|---|---|---|
| | ln(E) | (C,0,0) | -16.6432 | 0.0000 | 141.457 | 0.0000 |
| | Variables | Model (C,T,p) | LLC test Statistics | LLC test *p*-value | PP test Statistics | PP test *p*-value |
| System software | ln(S/E) | (C,0,0) | -10.8163 | 0.0000 | 105.7590 | 0.0000 |
| | ln(K/E) | (C,0,0) | -7.3639 | 0.0000 | 69.8391 | 0.0499 |
| | ln(C/E) | (C,0,0) | -6.7714 | 0.0000 | 77.7316 | 0.0119 |
| | ln(E) | (C,0,0) | -16.5414 | 0.0000 | 97.1629 | 0.0001 |
| | Variables | Model (C,0,p) | LLC test Statistics | LLC test *p*-value | PP test Statistics | PP test *p*-value |
| Application software | ln(S/E) | (C,0,0) | -4.4007 | 0.0000 | 23.7367 | 0.0954 |
| | ln(K/E) | (C,0,0) | -19.8140 | 0.0000 | 26.7650 | 0.0442 |
| | ln(C/E) | (C,0,0) | -16.0242 | 0.0000 | 42.0403 | 0.0004 |
| | ln(E) | (C,0,0) | -5.4153 | 0.0000 | 32.1874 | 0.0095 |
| | Variables | Model (C,0,p) | LLC test Statistics | LLC test *p*-value | PP test Statistics | PP test *p*-value |
| Software service | ln(S/E) | (C,0,0) | -7.1317 | 0.0000 | 38.3325 | 0.0000 |
| | ln(K/E) | (C,0,0) | -6.9713 | 0.0000 | 53.0490 | 0.0000 |
| | ln(C/E) | (C,0,0) | -10.7675 | 0.0000 | 19.6308 | 0.0329 |
| | ln(E) | (C,0,0) | -3.1947 | 0.0007 | 12.1067 | 0.2780 |

In the model(C,T,p), C refers to intercept and T refers to trend. P refers to lag length in the difference equation. As C and T are both zero, intercept and trend are excluded. Lags selection criterion is AIC.

Unit root test results are shown in Table with all the variables stationary; therefore it can be regressed and the regression results are shown in Table 3.

**Table 3. The Parameter Estimation of Panel Data**

$$\ln(S_{k,it}/E_{k,it}) = \hat{\beta}_{0k} + \hat{\beta}_{1k}\ln(K_{k,it}/E_{k,it}) + \hat{\beta}_{2k}\ln(C_{k,it}/E_{k,it}) + \hat{\beta}_{3k}\ln(E_{k,it}) + \hat{\varepsilon}_{k,it}$$

| | Whole sample | System software | Application software | Software service |
|---|---|---|---|---|
| $\beta_0$ | 9.013***<br>(8.794) | 8.431***<br>(5.801) | 8.741***<br>(5.909) | 15.286***<br>(130.403) |
| $\beta_1$ | 0.340***<br>(5.250) | 0.396***<br>(5.134) | 0.331***<br>(3.370) | 0.122***<br>(8.214) |
| $\beta_2$ | 0.048<br>(1.338) | 0.063<br>(0.928) | 0.052<br>(1.156) | 0.015***<br>(5.315) |
| $\beta_3$ | -0.166***<br>(-3.371) | -0.162***<br>(-2.408) | -0.143***<br>(-2.132) | -0.491***<br>(-79.305) |
| $\tilde{R}^2$ | 0.83 | 0.94 | 0.72 | 0.99 |
| DW | 1.45 | 1.64 | 1.36 | 2.26 |
| Observations | 39 | 8 | 26 | 5 |

*** refers to significant at α 1%；**refers to significant at α 5%; * refers to significant at α 10%；the value in ( )is *t* statistics

 

### 4.3. Analysis

R&D capital were significant in the software industry as a whole, the system software companies, software companies and software services companies, the numbers are 0.340,0.396,0.331,0.122; R & D capital has the largest influence on the performance of system software enterprises, less on the application software enterprises, with least influence on the software services enterprises.

Software system enterprise products are mainly involved in operating system software, network software, database management software, development tools and programming language software etc... The main functions of the system software products lies in the control and coordination of external computer equipment, and the support of application software operation; technology and capital barriers are high with long development cycle and high risk of research, in which often require long-term, huge R & D funding support; therefore, effect of R&D capital on the productivity is highest.

Unlike system software enterprises which are involved in technique problems, application software enterprise products are mainly involved in commercial and domestic software, cross industry applications, vertical market application software and utility software. Compared with the system software, technology of application software is relatively low; application software products has paid more attention to develop the needs of the user than the system software product, but they also must master the core technology, in order to attract downstream software enterprises to use the products, and then expand the market scale.

Software services companies, as by the user of technology, emphases more on business model innovation; business model describes the basic principles of how companies create value, deliver value and get value. Software services companies usually use the system software and application software company's products, tailor to the actual business environment for business users, and provide total solutions; they are the user of technology rather than developers; therefore, their R & D investment has less influence on the enterprises' performance than the system software and application software companies.

Significantly different from the traditional manufacturing, the capital stock and the number of personnel had no significant effect on the business performance of software, or have a negative impact. Capital stock has a significant impact on the software services companies with the coefficient of 0.015, significantly lower than the impact of R & D capital for software services companies. The core competence of software service companies is the ability of project management, and obtaining this ability need enterprises to invest long-term, sustained for infrastructure and system of investment, so the physical capital has a significant positive effect on productivity. Capital stock has no significant effect on system software and application software companies, which indicates that, with the cost of the hardware devices in the computer gradually reduced, the main factors affecting the efficiency of the enterprises are not put in equipment and intangible assets.

Software companies are typical knowledge-intensive enterprises, relying on high-quality personnel to develop products or service; the quality of personnel is the key in the competition, rather than the number of staff. For system software and application software enterprises, products once were developed, copying costs and development costs were almost zero; therefore they do not need a lot of people for mass production. The effect of human capital on productivity of software service enterprises is negative, which contradicts our common sense; generally, we believe service enterprises is labor intensive, more staff should promote the productivity of enterprise. In fact, the leading performance software service enterprises usually develop user innovation toolbox, toolbox includes general function module, and special function module are developed by the enterprise, thus reduce the use of human capital and service enterprises, and improve the productivity.

## 5. Study (II): Estimates of Software Enterprise R&D Efficiency

### 5.1. DEA Model

Data Envelopment Analysis is one of the frontier theory models of efficiency evaluation analysis method, choosing the DEA model as a software enterprise efficiency evaluation method is the main setting function without the need for DEA, which avoids the clear relationship between the number of multiple variables, which simplifies the process of the research, and improves the efficiency. In addition, since it was advanced by DEA method, after years of theoretical exploration and application of DEA in different industry assessment, DEA method has formed a comparatively mature theory system, derived from a variety of models to solve the problem of efficiency evaluation in different areas.

According to the research target, we choose the DEA model of $C^2R$ and $BC^2$ model as the development efficiency of software enterprise evaluation. C2R model is a method based on linear programming and evaluation of multiple input and output of the relative efficiency of decision making units, first made by Charnes, Cooper and Rhode [26]. The model assumes n decision making unit (DMU), with each DMU, M input and s output, input vector is$x_j=(x_{1j}, x_{2j},\dots,x_{mj})^T$, the output vector is $y_j=(y_{1j}, y_{2j},\dots,y_{sj})^T$, j=1,⋯,n... By using Chames-cooper transform, N, linear programming model:

$$(P_{C^2R})\begin{cases} \max \quad u^T Y_0 = h_0 \\ \varpi^T x_j - \mu^T y_j \geq 0,\ j = 1,\cdots,n \\ \varpi^T x_0 = 1 \\ \varpi \geq 0, \mu \geq 0 \end{cases}$$

Based on the model of $C^2R$, Banker, Charnes and Cooper introduced $\sum_{j=1}^{n} \lambda = 1$ in 1984 as new constraints to establish the $BC^2$ model. The model discusses variable returns to scale assumptions technical efficiency and scale efficiency, taking into account the factors that cause DMU to exist economies of scale inefficiency [27]:

$$(P_{B^2C})\begin{cases} \max( \ u^T Y_0 - \mu_0) \\ \varpi^T X_j - \mu^T Y_j + \mu_0 \geq 0,\ j = 1,\cdots,n \\ \varpi^T X_0 = 1 \\ \varpi \geq 0, \mu \geq 0, \mu_0 \in E^1 \end{cases}$$

The DEA model contributes to deciding the relative effective DMU from input and output perspective. The efficiency evaluation model of DEA value is between 0 and 1, the closer to or equal to 1, the higher the efficiency is; conversely, the closer to or equal to 0, the lower the efficiency is. The overall efficiency is equal to the product of technical efficiency and scale efficiency, scale efficiency refers to the optimal allocation of the output unit has the function of industrial structure, technical efficiency reflects the gap between decision-making unit and the optimal production efficiency.

### 5.2. Model Calculation

The 39 software enterprises are as the research sample, the $C^2R$ and $BC^2$ model are used to measure the efficiency. Wherein, R & D investment, the number of employees, and capital investment of the sample enterprises in 2005 to 2010 are the input index, the number of patents and sales of the sample enterprises in 2005 to 2010 are the output index. DEAP2.1 is used to analyze the data, and calculate the sample enterprises overall efficiency, technical efficiency and scale efficiency.

Based on the calculation results, we compute the average overall efficiency, technical efficiency and scale efficiency of the average mean service in software enterprise, system software and application software enterprises in the sample from 2005 to 2010. By comparing the three types of enterprises in the average overall efficiency, technical efficiency and scale efficiency of the average mean, we summarized the development efficiency of service software enterprise, system software and application software enterprise.

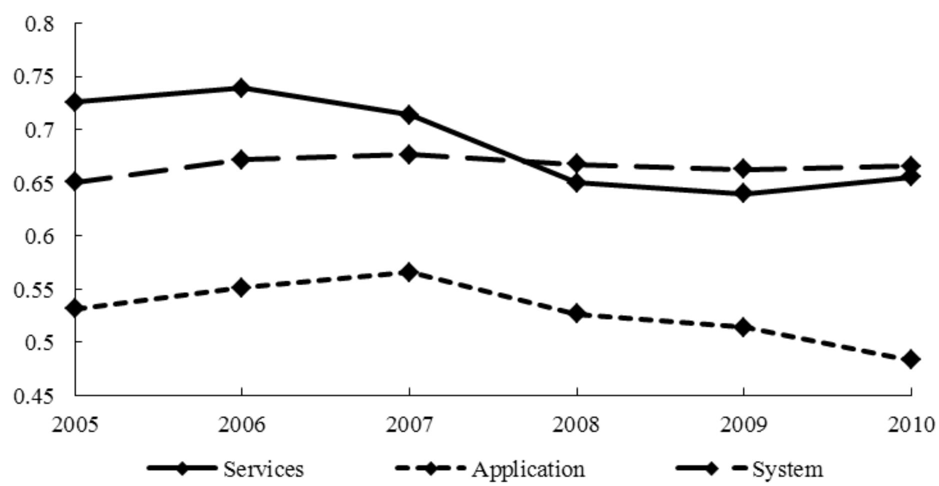


**Figure 2. The Average Overall Efficiency of Three Types of Companies from 2005 to 2010**

The results of the overall efficiency of the average show that, between 05 and 2010, the overall efficiency of the system software companies changed little, the efficiency of applications and service-oriented software companies overall decline.

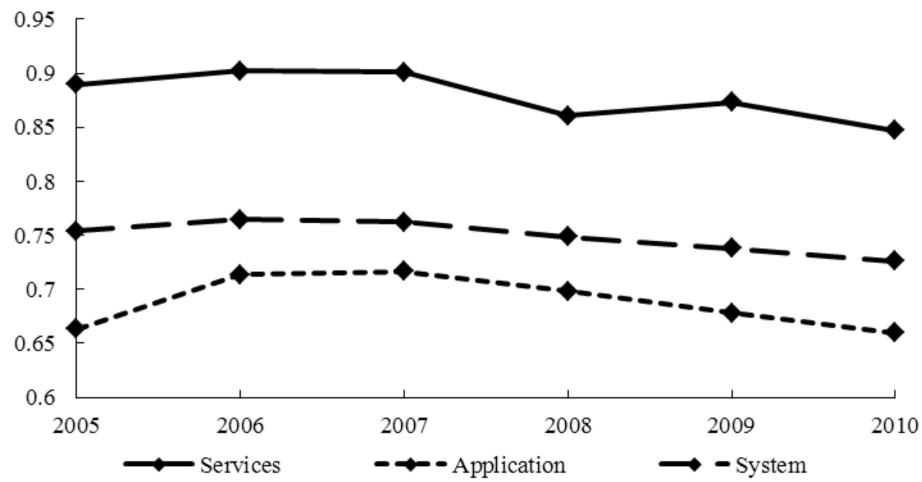


**Figure 3. The Average Technical Efficiency of Three Types of Companies from 2005 to 2010**

The results of the average technical efficiency show that, the average technical efficiency of the service-oriented software companies is the highest, system software companies are in the middle, and application software companies is the lowest.

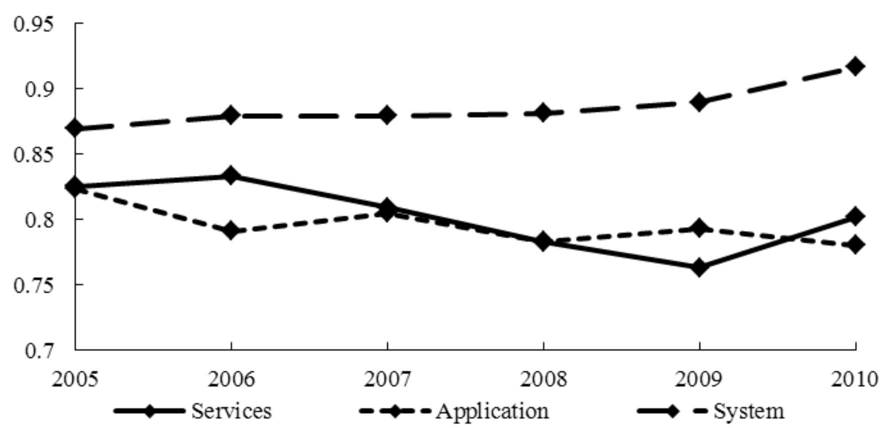


**Figure 4. The Average Scale Efficiency of Three Types of Companies from 2005 to 2010**

The results of the average scale efficiency show that, the average size efficiency of the system software companies is the highest, service-oriented software companies are in the middle, and application software companies are the lowest.

### 5.3. Analysis

Between 2005 to 2010, overall efficiency, technical efficiency and scale efficiency of the system software does not show a clear downward trend, which indicates that the economic crisis in the 2008 has little impact on system software companies. System software industry has long been monopolized by a few enterprises with few foreign enterprises to enter, the monopoly enterprise has prominent technical ability, great overall strength, and rich development experience, these skills and abilities is difficult to imitate by other enterprises. The economic crisis of 2008 has made a smaller impact on the software system enterprise, this is because they have devote huge investment for equipment and to improve the quality of personnel, then they has grasp the core technique in the supply chain, in which downstream enterprises must use their technology even in the economic crisis. The average size efficiency of the system software companies is the highest, that is because the system software products once were developed, the costs of copy was low, and profits were achieved mainly through large-scale application of system software, enabling the system software enterprise scale efficiency achieving outstanding performance.

The number of samples is 39, with application software companies occupying 26 of them, it is well grounded that the number of the application software enterprises is the largest. However, the overall efficiency, technical efficiency and scale efficiency of application software companies are the lowest. Application software is responsible for the implementation of specific business functions in the computer system, such as enterprise resource planning (ERP), customer relationship management software (CRM), supply chain management (SCM) software, financial management software, etc. Application software product varies, and is easier to develop than the system software; the enterprise should not only master the software development technology, but also need to have the knowledge and expertise, and industry knowledge localization. Local knowledge, the knowledge background of country or region where the enterprise is related with; industry knowledge means the knowledge of industry supply chain structure, production process, and the user; specialized knowledge is refers to the complete solution of products and services for the user. As for local knowledge, professional knowledge, and specialized knowledge, once they are applied to product development, it is easy for other enterprises to imitate, the pursuer can play the catch-up advantage to realize technology which means enterprises which have much R & D investment failed to benefit from advanced technology.

Technical efficiency of the software services enterprises is the highest, technical efficiency is the maximum output capacity given by fixed investment; the ability of software services companies to get profits from R & D investment is the best. In the software industry, cutting-edge technology is developed by the system software and application software companies, while software service enterprises timely monitor technology trends before competitors strive to identify and take advantage of technological opportunities; After following and identify the relevant technologies, the enterprises can approach the user-specific modification given the demand of the consumer, and integrated with the development of technology within the enterprise , and then the technology is eventually converted into new products or services, achieving effectively matching technology and the market. Based on R & D of services software enterprises process, the goal is very clear, and therefore they can achieve high technical efficiency.

## 6. Study (III): The Factors Affecting the Efficiency of Software Enterprise

### 6.1. Hypothesis and Model

After the estimates of the efficiency of software business, we need to analyze the factors that affect the efficiency level. This study focuses on the analysis of the influences of R & D on software enterprise performance and efficiency, research (a) has shown, R & D capital stock has a significant positive impact on the software business performance; based on this study, study (three) analyze the influences of R & D Density on the efficiency of software companies. Researches are based on the following assumptions:

 

H1: the higher the R & D density is, the higher the efficiency of software companies is;

H2: the higher the R & D density is, the higher the efficiency of the system software companies is;

H3: the higher the R & D density is, the higher the efficiency of application software enterprises is;

H4: the higher the R & D density is, the higher the efficiency of software services companies is.

The study (I) shows that the capital stock has no significant impact on system software enterprise performance and application software companies' performance, and has a positive impact on the software service companies. Study (III) further examines the effect of density on the capital efficiency of software companies. According to the conclusion of study (I), study (III) is based on the following assumptions:

H5: The higher capital intensity is, the lower the efficiency of software companies is;

H6: The higher capital intensity is, the lower the efficiency of the system software companies is;

H7: The higher capital intensity is, the lower the efficiency of application software enterprise is;

H8: The higher capital intensity is, the higher the efficiency of software services companies is.

To analyze the factors affecting the efficiency of software companies, we use TOBIT regression analysis, this is because the efficiency values are between 0 and 1, if we use the method of least squares regression coefficient, it will have a greater bias. TOBIT regression principle is as follows:

$$y_i^* = \alpha x_i + \varepsilon_i$$

$y_i^*$ for the Latent Variables, the relationship of $y$ and $y_i^*$ is as followed:

$$y_i = \begin{cases} 1 & if \quad y_i^* \geq 1 \\ y_i^* & if \quad y_i^* < 1 \end{cases}$$

The regression function:

$$Y_{k,it} = \hat{\alpha}_{0k} + \hat{\alpha}_{1k} Rd_{k,it} + \hat{\alpha}_{2k} Capex_{k,it} + \hat{\varepsilon}_{k,it}$$

k=1 for the whole software industry, k = 2 for the system software enterprises, k=3 for the application software enterprises, k=4 for the software service enterprises; i for the enterprise, t for time ; $Y_{k,it}$ for the technique efficiency, $Rd_{k,it}$ for the R&D Density, $Capex_{k,it}$ for the capital density.

### 6.2 Results

In order to avoid spurious regression, before building the model, we conducted the stationary test for all the factors, and chose the same root test methods LLC and different roots testing methods Fish-PP. The test results are shown in Table with all the variables stationary; therefore it can be regressed and the regression results are shown in Table 4.

 

**Table 4. The Results of Tobit Regression**

$$Y_{k,it} = \hat{\alpha}_{0k} + \hat{\alpha}_{1k} Rd_{k,it} + \hat{\alpha}_{2k} Capex_{k,it} + \hat{\varepsilon}_{k,it}$$

| | Whole sample | System software | Application software | Software service |
|---|---|---|---|---|
| $\alpha_0$ | 0.908*** (20.938) | 1.402*** (10.104) | 0.855*** (18.273) | 1.486*** (7.171) |
| $\alpha_1$ | -1.080*** (-5.585) | -4.409*** (-5.822) | -0.610*** (-2.794) | 1.694** (8.214) |
| $\alpha_2$ | 0. 719 (1.077) | 1.668* (1.690) | -1.202 (-1.512) | -12.584*** (-3.260) |
| Observations | 39 | 8 | 26 | 5 |

*** refers to significant at α 1% ; **refers to significant at α 5%; * refers to significant at α 10%; the value in ( )is *z* statistics

### 6.3. Analysis

R&D density has a negative impact on the efficiency of system and application software companies, namely, the higher the R&D density is, the lower the technical efficiency is. This shows that the software product companies spend huge sums of money for new technology and new product development, a large number of advanced techniques have been developed but did not achieve commercial application; software product companies do not attach importance to business model innovation, the blind pursuit of advanced technology has resulted in advanced technology wasted. R & D density has a positive impact on the technical efficiency of software services companies, they are the user of the technology, the key of the competition among enterprises is the how to integrate external technology and user needs; This requires that companies must have systems integration capabilities; internal R & D activity is an effective way to develop system integration capabilities. Therefore, the services software enterprises with high R & D density, have higher systems integration capabilities, stronger ability to integrate external technologies, and higher technical efficiency.

Capital intensity have a significant positive impact on system software companies, no significant impact on the application software companies, a significant negative impact on the software services enterprises. System software development is difficult with high industrial barriers to entry, competition is not very intense; system software industry has long been monopolized by a few companies, these monopolies have high technical ability and overall strength and rich experience in the development, and there are few new companies to enter the industry; the technology and capacity of existing enterprises is difficult to imitate by other companies, therefore, the higher the capital intensity is, the greater the technical efficiency is.

## 7. Conclusion

For the software industry, R&D improves company performance mainly by promote production frontier, namely the technology progress. R&D can't improve the efficiency of system software companies and application software companies but can effectively improve the efficiency of service software companies. R&D stock have significant positive influence on the performance of software enterprises. R&D stock has the most influence on system software enterprises, followed by the application software companies and service software companies, which is decided by the development difficulty of the products and services. R&D density has significant negative influence on the performance of system software enterprises and application software companies which suggests that although product enterprise attaches great importance to the R&D input, a lot of technology have been developed but does not accomplish market success. R&D density has significant positive influence on service software companies. Service software companies are users of technology and attaches great importance to the business model innovation. Companies with the more R&D input have a stronger ability to integrate the upstream enterprise technology which will have higher R&D efficiency.

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