

## Comparison of R&D Efficiency of System, Application and Service Software Companies

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### **Abstract**

*R&D efficiency has a profound impact on the competitiveness of software companies, which is the typical knowledge-intensive business service. The software companies is divided into system software companies, application software companies and service software companies according to the types of product or service of software companies. Using software companies in top 1000 R&D investment as the research sample, the R&D efficiency of system, application and service companies are measured and compared based on DEA. Through the comparison measurement of enterprises overall efficiency, technical efficiency and overall efficiency of three types, the research shows that the technical composition of system software products is complex and the product development is difficult. The system software company may take advantage of open source software or form industry alliances. The application software company may focus on the local market demand and satisfy it through introducing advanced technology from upstream companies. The service companies should improve system integration capabilities, thus providing customized software solutions for customers.*

**Keywords:** *System software companies; Application software companies; Service software companies; R&D efficiency; DEA*

### **1. Introduction**

Software industry is a basic, leading and strategic industry of national economy and social development, with additional high growth, high value-added and high drive characteristics; software industry is related to national security, economic security, and national security, and has positive effect in promoting and supporting the industrial structure, as well as changing the mode of development. At the same time, software enterprises are also the facilitator, carrier, and source of the technology innovation [1]; they not only disseminate knowledge, but also reengineer knowledge, therefore are an important part of national innovation system [2]; improving the software enterprise R & D efficiency plays an important role in promoting the construction of innovative country. However, the United States and Europe software enterprises stay in a monopoly position in the operating system, middleware, database, ERP and other basic software and application software, so software enterprises of our country are put behind the foreign software enterprises in the background of the basic technology and R & D, faced with severe challenges to narrow the technology gap, realize the independent innovation.

As Knowledge-intensive Business Services, the software industry needs to develop high intensity input to support the companies; R & D activities affect the competitiveness of software enterprises. Such as Microsoft Corp which monopolies operating system market, its

sales revenue in 2009 is \$58573000000, of which R&D investment business income accounted for 15.4%, about \$9020240000; IBM Company is famous for its software infrastructure platform products Websphere, DB2 and other products, its sales revenue in 2009 is \$95758000000, of which R&D investment business income accounted for 6.1%, about \$5841240000. With the development of technology's rapid development and the increasingly fierce market competition, more and more software enterprises seek to increase R & D investment intensity and to improve R & D output continuously, and the importance of the R&D development of software enterprises has become increasingly prominent to be carries out in-depth study.

## 2. Literature

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) through R & D to eventually multiple output (such as new product sales, patent application), a ability that has a profound impact on enterprise performance. Tsai and Wang, through the analysis of 1994-2000 years in the research and development efficiency of 156 Taiwan large enterprises, found that R & D investment and enterprise performance has a positive correlation [3]; An empirical study on Japanese industry of IT Sueyoshi and Goto shows that, the R & D investment helps to improve the business value [4]. Kumbhakar and Ortega-Argil é s, taking the Top 100 European R & D enterprises as the research object, proposed that increasing the R & D investment will promote the development of high-tech enterprises to improve the level of R & D investment but will have little influence to the increase in labor productivity of low technology enterprises [5]. Study proposed by the Zhu Youwei and Xu Kangning on the efficiency of 1995 to 2004 research and development of high-tech industry in China in 13 industries in large and medium-sized enterprises shows that the efficiency of Chinese high technology industry is relatively lower, that the differences of the R&D efficiency among industries are gradually narrowing, and that there is a significant positive correlation among trend, enterprise scale, the degree of market competition, foreign investment, and the efficiency of research and development. [6]

Measurement method of R & D activities mainly includes data envelopment analysis and stochastic frontier analysis method. Wang takes R & D expenditure and R & D personnel as input indicators, selects the number of patent applications and academic publications as output indicators, and studies 30 national research and development efficiency by stochastic frontier analysis to show that, if only considering the internal factors, each country's R & D efficiency index has improved in different scale. [7] Guo Bin divided our software enterprises into three parts including state-owned, foreign-funded and private three types, reached empirical research of whether the existence of scale effect can be observed on the Chinese software industry and whether the R & D activities have consistent positive impact on the performance, and proposed that the enterprise output rate has a certain scale, that scale effect of profit rate is not obvious, and that R & D intensity on the rate of profit is the negative effect [8]; Wang and Huang through data envelopment analysis (DEA) research and development efficiency of 30 national R & D activities, showed that less than 15 countries have effective R&D activities, most of these countries are in the stage of increasing scale income [9].Liu Yuanyuan and Su Qin, using the DRF analysis method and DEA model, assessed the input-output efficiency of Chinese 8 major national software park in 2006 [10].

In addition, research on R & D activities of software enterprises also includes measurement and evaluation of the models which take the software market, software industry park and industry cluster network software as the objects. Li Quan and Chen Hongmin applied the theory of two-sided markets, found the influence on industrial efficiency and welfare effects

of the software market, proved that open source operating system can partially solve the industrial efficiency, but still not socially optimal [11]; Chen Lei's study on the correlation between performance and patent application on China's top 100 software enterprises of the analysis shows that, there is positive relationship between the number of patent application and operating performance companies in Chinese top 100 software enterprises, especially for big-sized software enterprises ,however, in small and medium-sized software enterprises it shows a weak positive correlation; the fundamental reason lies in that the small and medium-sized enterprise R & D Performance conversion rate is very low [12]. Li Xiaogong and Hou Tieshan took the software industry cluster innovation network in 15 provinces and cities as the samples, and analyzed the operation efficiency of Chinese software industry cluster innovation network using data envelopment. [13]

Through the review of literature, we can see that the software enterprise R & D activities affect the software enterprise performance. Researches started by the academic circles, have made meaningful progress, but also have the following shortcomings: on the one hand, the existing studies focus on the software industry, software enterprise, the software market, the software Industry Park and the software industry cluster network, therefore lack the segmentation research on software enterprises; on the other hand, researches have mainly focused on the efficiency of research and development, lack the analysis of the development characteristics of software enterprises. Therefore, it is necessary to classify the different kinds of companies according to the characteristics of software enterprises, to estimate and compare R & D characteristics of different types of software enterprises, and to explore effective ways of different types of software enterprises to improve the efficiency of R & D.

### **3. Efficiency Evaluation Model**

#### **3.1. Classification of 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 company 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.

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.

### **3.2. Choosing Decision Making Unit**

To find appropriate Model, we must first determine the decision making unit. As the increasing attention to the research and development activities of enterprises, to encourage enterprises to the disclose of the R & D and R & D related intangible assets, the EU's Joint Research Centre and Directorate General Research, annually distributed Industry Research report that monitor R & D of EU and other countries since 2004. The report took "the industry classification benchmark" issued by the FTSE group and the Dow Company as the basis to divide the whole industry in the world. ICB is divided into four levels, including 10 industries, 18 supersectors, 39 sectors and 104 subsectors, except special notification, the data involved the subsectors, industry research report general involved industry.

In order to make the study sample has the typical representative, and improve the validity of the study, our study selects the software enterprises from 2006 to 2011 for 6 consecutive years entering the global top R & D 1000 software enterprise as decision making units, including a total of 42 software enterprises. According to ICB classification, we select all the companies in the "Computer Services" and "Software" industries reported by 'SCOREBOARD' which disclose TOP 1000 enterprises of research and development as samples, including 42 software enterprises. On this basis, according to the American industry classification code NAICS, we classify 6 enterprises which were classified to Computer Services industry as service software enterprises; according to the "2012 Software 500 Companies" released by the Software Magazine Online, we divide all the enterprises in the Software industry into 11 software enterprises and 25 application software enterprises, and then download data including all the enterprises described above from 2006 to 2011 from the "Monitoring industrial research: The EU Industrial R&D Investment Monitoring Industrial Research SCOREBOARD".

### **3.3. Establishing the Evaluation Index System**

Establishing a scientific and reasonable evaluation index system is the basis of the research efficiency evaluation of software enterprises in DEA model. Evaluation index system includes the input index and output index, input index refers to the investment factors affecting the development efficiency of software enterprises, output index refers to the development of the software industry generated by the R & D performance. In DEA model, when we select the input and output index, we take the cost index as input indicators, and take profitable index as output index [14]. Development involves the two aspects: research and development. "Research" means to gain or to understand new scientific or technical knowledge for the purpose of creative research and planning, the expenses occurred in research belongs to the R & D investment. "Development" refers to all the activities that put the knowledge or discovery made by research into use or that substantially improve materials, devices, products, processes, systems or services that meet specific criteria before the commercial production; when the development can reach specific criteria or can produce economic benefits in the future, the costs can be attributed to R & D investment. According to the definition of research and development, we select the following indicators to establish the evaluation system.

We select the R&D input for that year as input indicators of decision making units. Research and development funding reflects the year execution unit of the actual R & D funds

[15], and shows the influence of innovation performance in a company's competitiveness, especially in the high technology industry [16]. The success in the enterprises in the R & D investment will enable the future increase in R & D resources in the field of investment, which makes enterprise R & D investment's impact on innovation more far-reaching. Griliches study indicated that, in the high-tech industries, in the generation of new ideas, new blueprint and new models, some of them can be transformed into new patents and new products, which makes the R & D investment can be part of the company technical performance to reflect the future output [17]. This study uses the perpetual inventory method to calculate R & D capital stock,  $RD_{it} = E_{i(t-1)} + (1 - \delta) RD_{i(t-1)}$ , of which,  $RD_{it}$ ,  $RD_{i(t-1)}$  denote the I enterprise t years and t-1 years of R & D capital stock,  $E_{i(t-1)}$  said investment enterprise discount R & D funds.  $RD_{i0} = E_{i0} + (g + \delta) RD_{i0}$ , g is the average annual growth rate;  $\delta$  is the capital depreciation rate of R & D by 15%.

We select the number of employees as the inputs. The scale of the enterprise reflects the number of software enterprises owned by employees within the year. Effect of firm size on R & D performance is very complex. According to "Bear Pete hypothesis", the larger the enterprise scale is, the stronger the corporate R & D strength and ability to resist market risk will be [18]. An empirical study of Jaffe shows, small enterprises have the advantage in technological innovation, small businesses will research the market far faster than the big enterprise [19]. Inverted U theory thinks that, the enterprise scale poles have more efficient technology innovation [20]. Therefore, regardless of how the relationship between enterprise scale and technology innovation, enterprise scale is a core element of affecting the efficiency of software enterprises.

We select the capital expenditures as inputs. R & D activities need to be supplemented by the necessary R & D equipment and other fixed assets to enhance research and development efficiency and quality. Capital expenditure is acquired by the company to upgrade equipment, property, industrial buildings and other physical assets expenditure, namely, the asset account (or capital) increased, showing an increase in fixed assets, which reflects the fixed asset contribution to enterprise development. Hu and Wang argue that, using the stock of capital (material capital) as a measure of capital inputs index is suitable [21]. The study also uses the perpetual inventory method to calculate the capital expenditure of capital stock, stock calculated in accordance with the calculation method of R & D investment stock, capital depreciation rate is still 15%.

The number of authorized patents is selected as output indicators. Hagedoorn and Cloudt studies that, R & D performance measurement of enterprise indicators includes patent number, patent citation or new product launches [22]. Patent is R & D activities outputs, with private attributes, is able to produce economic benefits, and reacts more technical activities results; therefore, they are as from the view of output measure R & D index. The invention patent is on behalf of the output of a process, in particular may have commercial interests of the invention, and is the best index change from private and competitive angle measurement technology. Patent in most developed countries have basically covered quite a long time, all of the fields of innovation, which makes the series analysis with a large number of patent for a long time can be achieved [23]. In addition, the United States Patent, European Patent and other multi-national patent data can be obtained free of charge, a fact that also improve the feasibility of patents as a measure index.

We select the sales income as output indicators. In the research and development process, not all of the research has filed patent application, market application of enterprise is the extent to which the invention, such as new products, new processes or new tools is introduced, also can reflect the R & D output. Therefore, the choice of sales income as output indicators research efficiency measure is better to reflect the performance of R & D. Sale income as

output indicators mainly refers to net sales, namely the general definition of accounting in the sales, not including sales tax and joint venture enterprises and Associate Companies marketing company.

### 3.4. Select the 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 C2R and BC2 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 [24]. 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  $y_j = (y_{1j}, y_{2j}, \dots, y_{sj})^T$ ,  $j=1, \dots, n$ . By using Charnes-cooper transform,  $N$ , linear programming model:

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

Based on the model of C<sup>2</sup>R, Banker, Charnes and Cooper introduced  $\sum_{j=1}^n \lambda = 1$  in 1984 as new constraints to establish the BC<sup>2</sup> 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 [25]:

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

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.

## 4. Empirical Study

### 4.1. Data Acquisition

In this study, the R & D investment enterprise scale and capital input index data is mainly collected from Joint Research Centre and Directorate General Research issued by the "Monitoring industrial research: The EU Industrial R&D Investment Monitoring Industrial Research SCOREBOARD". We download the software industry R & D investment, enterprise scale and capital investment and other related data from 2006 to 2011 from the database, since companies earlier this year accounted and publish annual reports sales profits in last year, so the actual data is from 2005 to 2010, a total of 42 enterprises as sample data.

The number of output indicators patent relates to this study is collected from Derwent Innovations Index database, the database of patent information is from more than 40 patent agencies, detailed records of more than 11000000 basic invention patent information, with patent information about 2 million since 1966, which ensure the authority and integrity of the number collected. On the basis of the name of the 42 software enterprises for company code in DII, we collected the number of patents from 42 software enterprises. Sales of output indicators in this study are also taken from the "Monitoring industrial research: The EU Industrial R&D Investment Monitoring Industrial Research SCOREBOARD".

After obtaining the original data, we compute the R & D input and capital input stock according to the perpetual inventory method. Because the Unisys and Tibco Software have been found to have negative stock, we eliminated them. In addition, the Nice Systems is also removed due to its number of employees from 2008 to 2010 is empty. After data cleaning, we finally obtain 39 software enterprises as the research sample.

### 4.2. Model Calculation

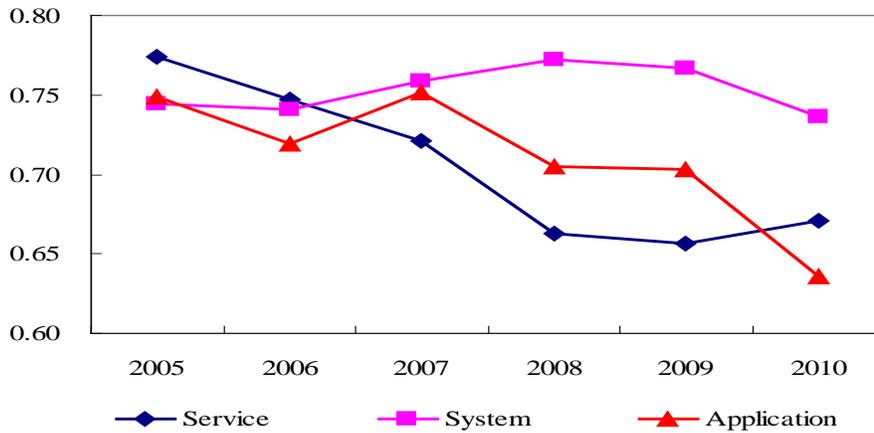
The 39 software enterprises are as the research sample, the C2R and BC2 model are used to measure the efficiency. Wherein, R & D investment, the number of employees, and capital investment of the sample enterprises in 2005 to 2010 are the input index, the number of patents and sales of the sample enterprises 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.

### 4.3. Analysis of the Results

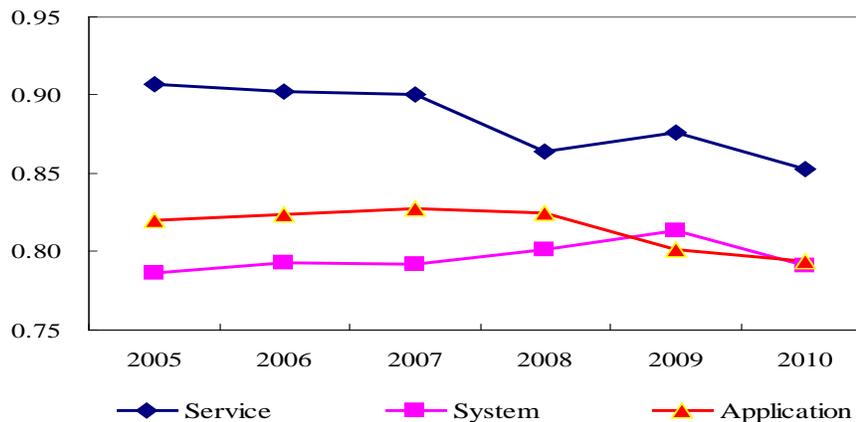
Based on the calculation of the average overall efficiency, service-oriented software enterprises, software enterprises and software enterprises from 2005 to 2010 the average overall efficiency was between 0.60 and 0.80, and showed a different trend. Among them, the average overall efficiency of software as a service enterprise from 2005 to 2009 decreased year by year, but started to rise since 2009, the general form of U type. On the contrary, the system software enterprises from 2005 to 2008 showed an upward trend year by year, but since 2008 they decreased year by year, showed inverted U type. The average overall efficiency of application software enterprises showed the tendency of changes of wave type,

the peak appeared in 2005 and 2007, 2006 and 2008 are at the bottom, especially after 2009, the average overall efficiency plummets.



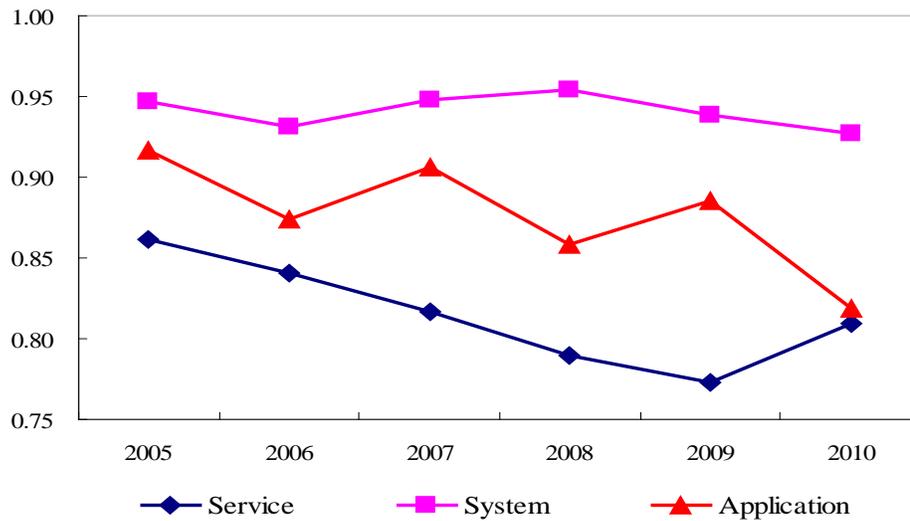
**Figure 2. The Average Overall Efficiency of Three Types of Companies from 2005 to 2010**

Based on the calculation of the average technical efficiency, service-oriented software enterprises, software enterprises and software enterprises from 2005 to 2010 the average technical efficiency was between 0.75-0.95. The average technical efficiency of service-oriented software enterprises from 2005 to 2008 showed a downward trend year by year, since 2008 they showed a wavy trend. The average technical efficiency of application software enterprise from 2005 to 2008 showed an upward trend, but since 2008 they were declining. The average technical efficiency of system software companies from 2005 to 2009 showed an upward trend, but in 2009 after declining. In a word, software as a service enterprises' average technical efficiency are the highest, software enterprise stand in the middle, software enterprises are the lowest.



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

Based on the calculation of the average scale efficiency, software as a service enterprise, system software and application software business enterprise from 2005 to 2010 the average scale efficiency was between 0.75-1.00. The average scale efficiency of system software enterprises move steadily, from 2005 to 2010 has ranged between 0.90-0.95. The average scale efficiency of application software enterprises from 2005 to 2010 was wavy, and forms the overall declining trend. The average scale efficiency of service-oriented software enterprises from 2005 to 2009 decreased year by year, after 2009 they were starting to increase. In a word, the system software enterprises' average scale efficiency is the highest, software enterprise stand in the middle, software as a service enterprise are the lowest.



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

## 5. Conclusions

The study of system software, application software and services software companies based on Data Envelopment Analysis (DEA) method shows that, system software enterprises are good and stable, application software enterprises stand in the middle, service enterprises are the lowest in the overall efficiency of enterprises; service enterprises' average technical efficiency are the highest, the one of application software enterprises is in the middle, the one of system software enterprises are the lowest; system software enterprise' average scale efficiency is the highest, the one of application software enterprises is in the middle, the one of service enterprises is the lowest, which reflects the characteristics of different efficiency innovation model of the different kinds of software enterprise.

System software enterprises' products are mainly involved in operating system software, network software, database management software, development tools and programming language software. The main functions of the system software products lies in the control and coordination of external computer equipment, and supporting application software running on the design, therefore their technology and capital barriers are high, and due to the long development cycle and the high risks of R & D, R & D process often requires long-term, huge funds support. However, the system software products are with high profit rate, namely, once

developed, the replication cost is low, so the software enterprise's profit is mainly realized by large-scale used system software.

Application software enterprises focus on the different technical level from that of system software, application software enterprise products are mainly involved in the general business and consumer software, across the industry application software, vertical market software applications and utilities application software. Application software products focus on the development of user demand more than the system software product, but they also have to master the core technology in order to attract downstream software enterprises to use the enterprise products and expand the size of the market. In fact, application software companies can often acquire advanced technology through close cooperation with the upstream enterprises, on the one hand, it improves the technical efficiency of the application of enterprise software, and on the other hand, it also limits the scope of application software products in a certain extent.

Service software enterprise mainly relates to the user application design and development, information technology consulting services and application services configuration, computer hardware and software sales, and information technology related training activities. Compared with the system software and application software business enterprise, requirement of R & D investment and technology base in service software enterprises is relatively low, and the innovation is mainly concentrated in business model innovation. It often provides products through the knowledge module integrated upstream enterprises, so the development risk is low and it has the most excellent technical efficiency. However, because the service software enterprise customization degree is high, so that it cannot be mass production application.

The software industry is the strategic industry relating to national security. However, the software enterprises of the United States and Europe are in a monopoly position in the system software, application software and other fields in the long time; the software industry of India is located in the international market, developing the software outsourcing services vigorously, by virtue of its labor advantage with low cost and high quality. In contrast, Chinese enterprises are less developed in software product technology and R & D investment, if we want to achieve rapid breakthrough in the software industry, we must adopt different strategies according to the development characteristics of different types of software enterprises. Among them, the product technology's form of system software enterprise is complex, and product development is difficult in itself. Due to the reason that it is not with a high level of technical ability of the background, the enterprise can use open source software in the development process, or build industry alliance to improve the efficiency of innovation; enterprise application software development model should pay attention to the local market demand, introduce advanced technology of the upstream enterprise, and match demand to technology effective ; service software enterprise development model should emphasize the clear positioning of enterprises in the industry value chain, focus on the integration development system, innovate the product launch platform to improve the quality of service, attract attention to customer needs, and provide customized solutions for client software.

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