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An analysis on the macroscopic growth process and stage of information systems development in Chinese enterprises

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Abstract After thirty plus years of reform and opening up its markets to the global economy, China has sustained a rapid economic growth for many years, which provides an opportunity for the development of various industrial and social dimensions. In this process, the growth of information systems development in Chinese enterprises seems showing special characteristics which are different from the classical model proposed by Nolan. This paper discusses the macroscopic growth process of information systems development in Chinese enterprises. Based on the classical study by Nolan, the historical data for information systems development in 294 Chinese enterprises was collected for the period of 1982 through 2009. Using the annual expenditures on information systems as an index, the analysis shows that the information systems growth process in Chinese enterprises can be represented by five stages. A detailed discussion of the characteristics of each stage is provided in this paper which illustrates a macroscopic growth process of information systems development in Chinese enterprises.

Keywords Information system · Information systems management · Growth stage · Nolan's model

1 Introduction

In the discipline of Information Systems, it is of significance to explore the law of information systems (IS) growth. As such, it engages keen interest amongst IS scholars. At present, China's integration into the global economy is in an important historical period [19]. From a macroscopic level, to explore and to summarize the growth law of IS in China will not only enrich the theoretical system of the IS subject, but will also provide an important frame of reference to the policy-makers for making information technology development policy.

Information system research and development started in China in the 1950s since the Institute of Computing Technology of the Chinese Academy of Sciences was founded in 1956. Since then, information systems activity has been growing in China. Chinese researchers have developed information systems from transaction processing systems, management information systems, decision support systems, OLAP, to enterprise systems [44]. There are many different developments such as intelligent systems and business intelligence applications [4–6, 8, 25, 27, 38, 47, 56, 57], and manufacturing systems [9, 10, 20–22, 39, 41, 43, 45, 46, 60, 62, 68, 71]. For manufacturing systems, for example, Li et al. [20] discussed the usage of MRPII as a management tool in China a decade ago and whether indigenous firms benefitted from the streamlining of procurement, materials management and distribution, and inventory accuracy. Other researchers have analyzed the impact of using this technology in the development of the firm's knowledge management tools [17, 35, 40, 48, 61]. Specific applications have been developed for various industry sectors, such as agriculture, pharmaceuticals/health, transportation, and financial services [1, 3, 11, 16, 63, 65–67]. Some studies have been conducted on using information systems to assist human resource management such as modeling the firm's staffing flexibility [23, 52, 69]. E-business has become one of the most challenging areas for industry and research communities. In China, e-business has evolved from business-to-business,

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business-to-customer, customer-to-business, customer-to-customer, and business-to-government systems to the integrated and collaborative business services among various information systems and e-marketplaces [13, 18, 24, 26, 36, 37, 51]. Meanwhile, there are many other studies and applications as well [7, 28, 34, 42, 49, 50, 54, 55, 64, 70, 73].

For the IS development, one of the most classical empirical studies is Nolan model [12, 30–33]. According to the investment on information technology (IT), Nolan described IS growth process from the perspective of individual enterprise and proposed the "S" shaped cost curve model. Subsequently, Gurbaxani and Mendelson incorporated enterprises' total IT spending data (1960–1987), and proved that macroscopic growth of enterprises' IT spending expressed as "S" shaped curve [15]. These studies previously mentioned were conducted before 1990 in North America, and therefore the applicability of IS growth process has yet to be tested in China.

Some researchers made similar studies on Chinese enterprises based on the Nolan model. For example, the historical data of 27 enterprises in China were collected, and IS growth process, stage characteristics, and the pattern of IT expenditure were analyzed [2]. Guo [14] collected the IT expenditure data (1989–2001) of 94 enterprises in China, studied IS growth stages, and proved that Nolan focused on IS growth process of American enterprises in the 1970's, and neglected the differences between overall and individual enterprise.

Limited by both the place and time of the research, as well as sample size, sample distribution [2, 14], and so on, scholars actually could not comprehensively, completely summarize and interpret IS macroscopic growth law of Chinese enterprises from the very beginning. In this study, the historical data of IS construction from a large sample of Chinese enterprises was collected, the IS macroscopic growth process was studied using the method of orderly sample clustering, and the stage characteristics and development trend were empirically explored.

2 Data collection and method

2.1 Data collection

According to the definition of IT expenditures by Nolan [30], the IT expenditures typically include the expenditures on hardware, software, programming, systems analysis, management, etc. By means of an investigation we obtained the data including the expenses of hardware and software, training, IT personnel, development mode of IS construction, etc. In addition, we used the first time to acquire a computer counted as the starting time of IS construction in an enterprise.

With each enterprise's IT annual spending data, we processed the data by year, and then obtained the overall IT spending data. For the one-time investment projects, in order to avoid the overall spending causing the volatility of the curve effects, according to the construction period, the necessary average processing was conducted. Overall IT spending for each year contains the annual overall spending on software, hardware, IT training, and staffing, etc.

The questionnaires were completed by personal interview, mail, and email surveys. The respondents were the directors of IT departments or the high-level management for IT. Between November 2006 and November 2009, we randomly sent 987 questionnaires to enterprises, and received 355 responses, in which 294 were valid. The detailed description of the sampling is summarized in Table 1.

2.2 Sample

Based on the industry sectors classification by the National Bureau of Statistics of China [29], Table 2 shows the industry sectors represented in the samples. Table 3 provides the information regarding size of the enterprises covered in this study.

Table 1 Sample description

Research instrument	Total number of questionnaires	Valid questionnaires	Valid rate (%)	%
Interview	353	211	59.8	71.8
Mail survey	454	51	11.2	17.3
Email survey	180	32	17.8	10.9
Total	987	294		100

Table 2 Industry sectors represented in the sample

Industry sector	%
Agriculture, forestry, animal husbandry, fishery	1.51
Mining industry	3.77
Manufacturing	60.0
Electricity, gas and water production and supply	6.42
Building industry	3.02
Transportation, storage and postal services	2.64
Information processing, computing services and software industry	4.15
Wholesale and retail	8.68
Accommodation and catering industry	2.64
Financial industry	4.53
Real estate	2.64

Table 3 Size of the enterprises covered in the sample

Size of enterprise	%
Large-size	30
Medium-size	37
Small-size	33

2.3 The method

The optimal partition method [72] was used to divide stages in order to better analyze and study macroscopic growth process and stage characteristics of IS development in Chinese enterprises.

The optimal partition method is a clustering method for the orderly sample. It uses the sum of derivate square as division basis. Assuming samples are $x_1, x_2, \ldots, x_n$ (each is an m dimensional column vector) that are considered orderly. N samples are divided into k clusters. Assuming one of dividing results is: $P(n,k) : \{x_{i_1}, x_{i_1+1,}\ldots x_{i_2-1}\}, \{x_{i_2}, x_{i_2+1,}\ldots x_{i_3-1}\}, \ldots, \{x_{i_k}, x_{i_k+1,}\ldots x_n\}$.

The division points satisfy $1 = i_1 < i_2 < \cdots < i_k < n$, $D(i,j)$ that represents the diameter of the kind $\{x_i, x_{i+1}, \ldots, x_j\}(i<j)$, the common diameter is expressed by Eq. (1):

$$D(i,j) = \sum_{l=i}^{j} (x_l - \overline{x_{ij}})^T (x_l - \overline{x_{ij}}) \quad (1)$$

$$\text{And } \overline{x_{ij}} = \frac{1}{j-i+1} \sum_{l=i}^{j} x_l \quad (2)$$

The objective function of P (n, k) is defined as:

$$e[P(n,k)] = \sum_{j=1}^{k} D(i_j, i_{j+1} - 1) \quad (3)$$

The optimal partition method enables Eq. (3) to reach the minimum by selecting P (n, k) to find the optimal clustering result of k clusters.

Because the exact number of clusters could not be obtained by the optimal partition method, the following methods are commonly used for the purpose.

1. Drawing the change curve of the minimum objective function, and taking the cluster number corresponding to the inflection point of the curve or the point in which curve begins to be flat as optimal.
2. Calculating the ratio a :

$$a = e[P(n,k)]/e[P(n,k+1)] \quad (4)$$

when the value of a is relatively large, it indicates that the division of k+1 clusters is significantly better than k clusters. When the value of a is approximately equals to 1, the cluster number k is not suitable to enlarge.

3. F test. The optimal number of clusters must make the division result to pass F test, and the value of F should be as large as possible.

3 Macroscopic growth process and stage division of IS development

3.1 Results

We calculate the collected data according to Eqs. (1)–(3). The results about the stage division are shown in Table 4, in which the number of clusters exceed 10 are omissible because they have less significance.

According to the method of determining the optimal number of clusters mentioned above:

1. Figure 1 shows $e[P\ (n,\ k)]$ as a function of k. It is apparent that $e[P\ (n,\ k)]$ decreases over k, and the inflection point of curve is between 4 and 5 for the value of k. It shows that when the value of k exceeds 4 or 5, the decrease of the minimum objective function would not be significant. Thus 4 or 5 are better taken as the number of clusters.
2. Results from calculation of a in Eq. (4), $a(4) = 1.515$,$a(5) = 1.169$. The value of $a(4)$ is relatively large, which shows 5 is better than 4 as the number of clusters. The value of $a(5)$ is approximating to 1, it is not significant to go on for dividing. Thus 5 is the optimal number of clusters, and the division points are 11, 17, 20, and 23.
3. F test is carried out for the division result, $F = 480.91$, it is larger than the given significance level ($F_{0.005}$= 5.27). So it passes the F test, and the effect of this result is apparent.

Table 4 Calculating results by the optimal partition method

Number of clusters	Sum of diameter	Division points
2	41,966,556	17
3	8,150,935	17, 22
4	2,843,732	17, 19, 22
5	1,398,980	8, 17, 19, 22
6	908,032	8, 16, 17, 19, 22
7	504,606	8, 16, 17, 19, 20, 22
8	301,654	3, 11, 16, 17, 19, 20, 22
9	191,714	3, 5, 8, 16, 17, 19, 20, 22
10	139,777	3, 5, 8, 11, 16, 17, 19, 20, 22

According to the calculation results, preliminary division result is as follows: the first stage (1982–1989); the second stage (1990–1998); the third stage (1999–2000); the fourth stage (2001–2003); the fifth stage (2004–2009).

3.2 Stage division

On the basis of the results illustrated in Fig. 1, we analyze three IS growth characteristics which are IT spending growth curve, the distribution proportion of enterprises sizes, and IS application areas at each stage. Through this analysis we discovered that in the former two stages, IT spending growth curve shows similar characteristics. However, for the other two characteristics, the two stages show obvious differences. In the first stage, those organizations constructed IS mainly are a small number of large-size enterprises (Fig. 5). Besides, information systems are applied to individual offices, single-function departments and other primary business (Fig. 7). While, in the second stage, the distribution of enterprise size shows a balancing situation (Fig. 5), and information system application begins to show a cross-sector and integrated development tendency.

In the later three stages, the three IS growth characteristics are similar. First, IT spending growth curve shows a rapid increasing trend in general; second, on the distribution of enterprises size, the number of small and medium enterprises become the main part (Fig. 5); third, information system application begins to integrate information resources in the entire enterprise, even between enterprises, and comprehensively cover the enterprise's various functional areas (Fig. 7).

The IS growth process is mainly divided into three stages: initiation stage, diffusion stage and fast development stage. Although collected data indicates that Chinese enterprises apply IT technology to a certain extent from the beginning of 1980's (it is 1982 in the collected data), we found that the earliest user was in 1972. It means germination of informatization had appeared in early 1970's. So we regard the time of from 1970's to early 1980's as the germination stage of IT application in Chinese enterprises. Considering characteristics of fast development stage and the development trend, there will be a period of harmonious development of informatization in which different types of enterprises will participate in and the application areas will be highly diversified. This period can be called "harmonious development stage".

In summary, the macroscopic IS growth process in Chinese enterprises can be divided into five stages: germination stage (1970's–early 1980's); initiation stage (the middle of 1980's (1982–1992); diffusion stage (1993–1998); fast development stage (1999-present); harmonious development stage (in future). The IT spending growth curve and the result of stage division are shown in Fig. 2.

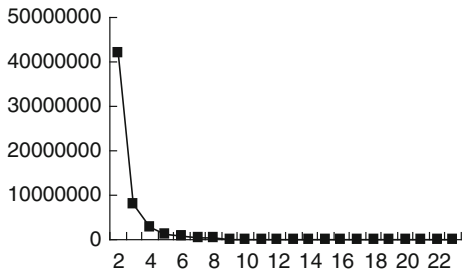

Fig. 1 $e[P(n, k)]$ as a function of k

4 Analysis of the stage characteristics

According to the results of stage division, we conducted a statistical analysis on the characteristics of each stage.

4.1 Germination stage (1970's–early 1980's)

At the germination stage only three samples involved with IT implementation, the involved organizations were large-sized enterprises. The computers acquired were mainly minicomputers, which were used for computing purpose

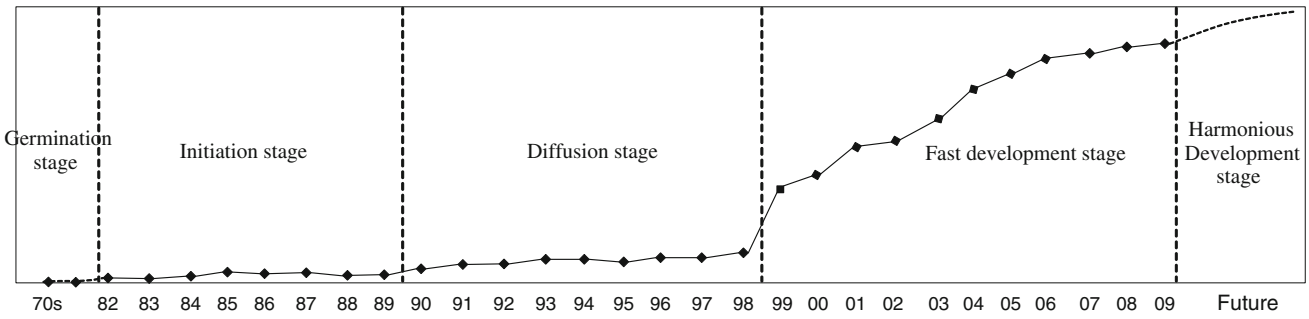

Fig. 2 Chinese enterprises' annual IT spending *curve* versus stages

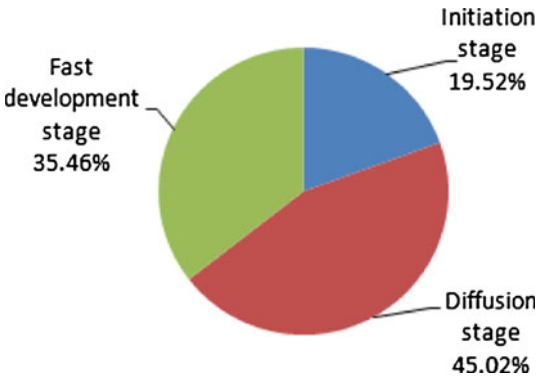

Fig. 3 Stages based on the percentage of enterprises acquiring the first computer

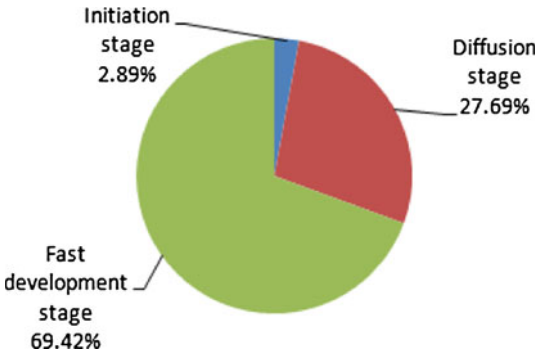

Fig. 4 Stages based on the percentage of enterprises to establish the first LAN

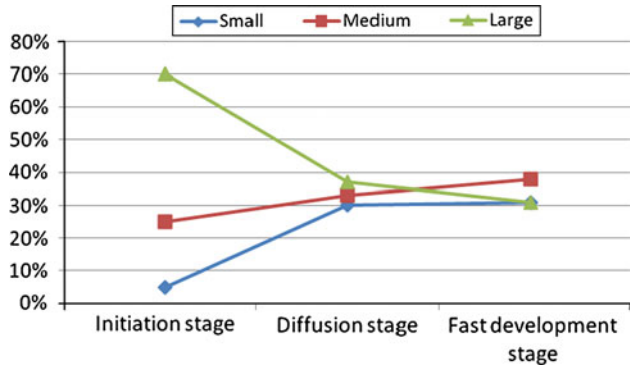

Fig. 5 Stages based on the percentage of IS constructed classified by enterprise size

for product design. The IT expenditures mostly were spent on hardware.

At this stage only a few large-sized enterprises which had economic strength introduced IT to meet the need of product design and R&D in the technical fields, while IT was not applied to managing the organization. According to the development history of IT in China, the IT

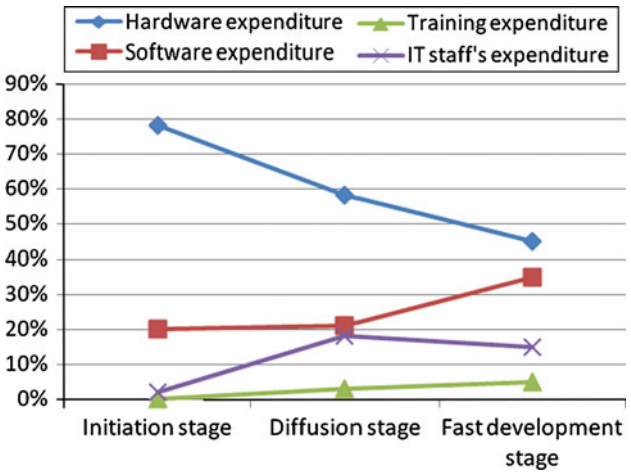

Fig. 6 Stages based on the percentage of IS constructed classified by investment content

application in Chinese enterprises was in its initial stage at this period.

4.2 Initiation stage (1982–1989)

At this stage, the number of enterprises started to implement IT is relatively small (Fig. 3). Most of the firms are large-sized enterprises (Fig. 5). In addition, very few enterprises had established local area networks (Fig. 4), and thus the scope of basic computer applications was limited to personal and individual business processing functions. Restricted by the technology of networks, software, database and the like, the application fields of IS were mainly in the single business functions which were in individual or single department and supported only basic functions such as office automation, finance, and personnel management (Fig. 7). Because the systems function was simple, training for users and systems maintenance was relatively simple as well. The expenditures on training and personnel were minimal. The hardware was the main focus of the expenditures (Fig. 6). The most preferred development mode was that IT personnel of enterprises developed applications by themselves (Fig. 8).

At this stage, IS of Chinese enterprises was at the primary stage for improving the office efficiency of individual or single department.

4.3 Diffusion stage (1990–1998)

At this stage, microcomputer had been popular, a large number of enterprises started to implement IS (Fig. 3), and the numbers of enterprises which began to build a LAN increased (Fig. 4). The number of small and medium-sized enterprises which started to implement IT increased (Fig. 5). Because of the development of software and

database, the application fields of IT extended to cross-department, integrated IS, such as OA, MRP, ERP, and Enterprise Systems (ES). The proportion of cross-department, integrated IS significantly increased, and the proportion of individual office application quickly decreased (Fig. 7). The proportion of expenditures on training and personnel management largely increased, and the system function became complex. The major development modes were acquiring software and customization as the functions of IS became complex (Fig. 8).

At this stage, IS in Chinese enterprises was at the transformation stage which was from single department application to cross-department ones.

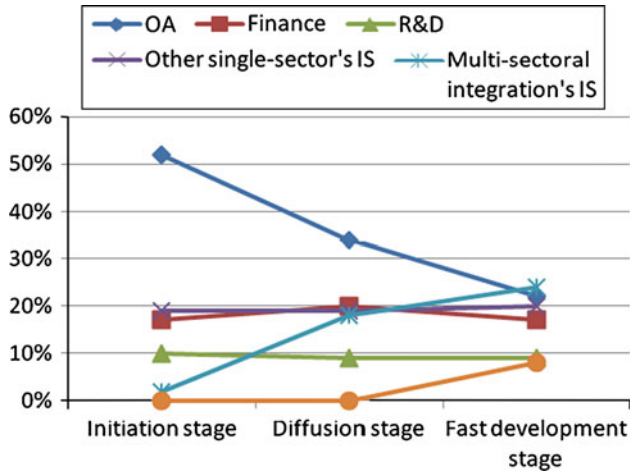

Fig. 7 Stages based on the percentage of IS constructed classified by application areas

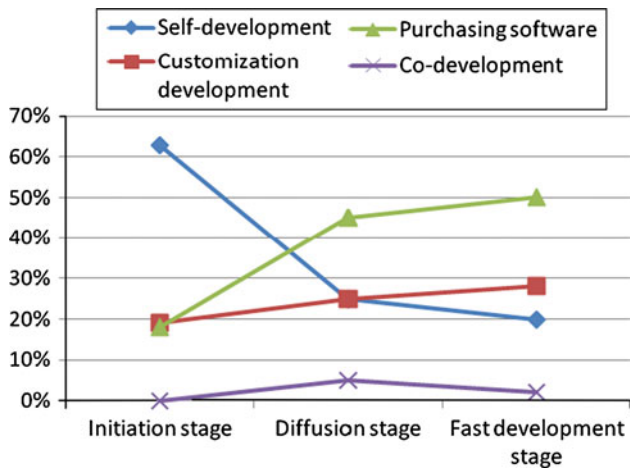

Fig. 8 Stages based on the percentage of IS constructed classified by system development methods

4.4 Fast development stage (1999-present)

At this stage there were many enterprises starting to implement IS. Because the network and Internet had been popular in China, the enterprises adopting LAN for the first time became popular at this stage (Fig. 4). The proportions of large, medium, and small-sized enterprises which implemented informatization had no significant differences; they were close in terms of the distribution proportions of different sizes of enterprises (Fig. 5).The trend that "all the people participate in informatization" appeared in Chinese enterprises (Fig. 6) [70]. The proportion of cross-department, integrated IS had surpassed that of individual office applications, and e-commerce reached a certain proportion (Fig. 7). Some enterprises started to integrate external information resource. Because of the improvement of the ratio of performance to the price of computer and the increase of the expenditures on software and relevant expenses, the proportion of expenditures on hardware decreased continuously, while that of software and training largely increased (Fig. 6). Acquiring software and customization development were the popular development modes (Fig. 8).

The IT spending growth curve shows a rapid growth trend in 1999, and during 2000–2003; it shows a solid growth trend. During 2004–2009, it shows a rational developmental growth tendency.

At this stage, the IS in Chinese enterprises was at multi-application coexistence stage in which single departmental application, cross-departmental application, and enterprise integrated application coexisted.

4.5 Harmonious development stage (in future)

By summarizing and comparing the growth curves and characteristics of each stage, we can see that the IT expenditure of Chinese enterprises shows an increasing tendency from year by year. It will grow in a more rational mode after fast development stage. IS construction will devote more resources to synergic development among systems, and the growth speed and connotation will be more reasonable. We can see from the trend of application fields, the integrated application of enterprise's entire set of resources will be the future development direction [53, 58, 59]. The proportions of the expenditures on training and staffing will increase annually. The cost of development, maintenance, and management will be higher, so many enterprises will execute IT outsourcing. The main development modes will be acquiring software and/or customization development. Meanwhile, IS will permeate into everywhere in business enterprises, and infuse into management and organization, and bring more changes. Because of the diversity of the time which enterprises start

to implement IS and the different informatization level, we will see that in Chinese enterprises, integrated IS applications will co-exist with many other applications.

5 Conclusion

In this study, we find that the macroscopic IS growth process in Chinese enterprises presents "S" shape, it reflects the general law of IS growth. But the development tendency of IS growth is slow until the late 90's, and subsequently accelerates and coincides with the Chinese economy development pace, which is proved by the description of each stage.

It is reasonable that the macroscopic IS growth process of Chinese enterprises is divided into the following five stages: germination stage (1970's–early 1980's); initiation stage (the middle of 1980's (1982)–1989); diffusion stage (1990–1998); fast development stage (1999-present); and harmonious development stage (in future).

In the view of information systems applications, Chinese enterprises go through the individual-based phase, single-sector business-oriented phase, multi-sector integration phase, and applications containing enterprise-wide integration of multiple application phase. In the macroscopic level, there is still much room for Chinese enterprises to improve the level of IT application, and within the next few years, overall IT spending will have a more substantial and sustained growth.

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