Contribution of ICT to the Chinese Economic Growth

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ABSTRACT

The view about systematic irrationality of investors and managers in investment with reference to information and communication technology (ICT) with no effects on productivity growth is called productivity paradox. Research suggests that ICT return in developed nations is significant and positive, but not in developing countries. This paper challenges the above conclusion by examining the contribution of ICT to the Chinese economic growth. We investigate the relationship between TFP growth and ICT capital and provide estimation of the returns to ICT investment. The contribution of ICT to economic growth has not been studied earlier for the developing countries like China. The empirical results suggest that China has reaped the benefits of ICT investment. The policy implications for the Chinese ICT investment and development are also discussed. The results add to our understanding of how ICT affects growth in the context of economic development.

Keywords: Productivity paradox, ICT, economic development, TFP growth, China

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1. INTRODUCTION

From the beginning of 1980s, when the information age was initiated, there has been a long-running debate in economic literatures on whether the information and communication technology (ICT) revolution is being paid off in productivity improvement. When Robert Solow, the Nobel Laureate Economist, commented that, “you can see the computer age everywhere but not in the productivity statistics”, the doubt of the fundamental economic principle that investors and managers are not systematically irrational rose among the business, organizations, government, and management researchers. This is the so called *productivity paradox* (Dedrick and Kraemer, 2001).

However, in recent year more evidences have converged in the similar conclusion that the return to ICT in developed nations is significant and positive, but not in developing countries. This paper will challenge this kind of proposition on the developing countries by examining the case of China. However, we do not claim that a single case study provides evidences of rejection of the productivity paradox, nor China represents the entire developing world. But in terms of size, economic development and investment in technology give China a stronger weight to the results presented here. It is believed in this paper that it is the lack of sufficient data with high quality, which lead to the paradox debate and the wrong interpretation of the ICT growth relationship in the analysis of developing countries.

While China has emerged as a large economy in the world, the empirical research in China has been scarce and neglected for its data availability, relatively low research capacity and lack of trust in the public register-based data quality. In 1990s, China developed its ICT sector with the average speed which is 4 times of the world average, and it is the largest telephone users and second largest Internet users in the world. But there are few papers that examine the contributions of ICT to Chinese economic growth. Meng and Li (2002) provide some evidences on China’s ICT industrial development and diffusion in recent years. And they mentioned that although there is still a huge gap between China and the developed countries in the development of ICT industry, yet the astonishing pace of its progress shows promise for the country’s New Economy. They also showed a clear digital divide among the nation’s three economic regions including East, West and Central. It is to be noted that, Meng and Li used no specific methodology in their analysis. In related research, the most frequently used methodology is growth accounting. Subsequently, it is not possible to conduct an international comparison of previous findings. With the exception of Meng and Li we have not been able to trace other studies that use Chinese data and relevant to our case.

This paper makes contribution to the growing literature on the impacts of ICT on economic growth by providing new results, which is based on data not published previously and an informative and up-to-date literature review. It challenges the productivity paradox conclusion by examining the contribution of ICT to Chinese economic growth. We provide some empirical evidences that China has reaped in ICT investment, specifically. The aim is firstly to investigate the relationship between TFP growth and ICT capital by using Chinese data. The contribution of ICT to economic growth has not been previously examined for developing country like China. Secondly, to provide estimation of returns or lack of returns to

ICT investment with sensitiveness analysis by using different depreciation rate and income shares of capital and labor. The ICT data is not published before. Thirdly, we introduce a capital share which unlike the existing approaches it is based on the development of the capital variable, time variant and reflect the development of capital-labor substitution patterns well. Fourthly, we will discuss the policy implications for the Chinese ICT development and investment patterns. Finally, we suggest guidelines for future research in general and also in the China case in particular. The results are of great interest by adding to our understanding of how ICT affects growth in the context of economic development.

The structure of the paper is as follows: Section 2 discusses ICT as infrastructure and a necessity to economic development. Section 3 will review the literature on the impacts of ICT on economic development at different levels of aggregation. The ICT sector in China and some data issues and challenges posed by the availability of data is discussed in Section 4 and Section 5. The growth accounting and regression analysis to measure the impacts of ICT on economic growth are introduced in Section 6. Section 7 presents the empirical results from the above methodologies to estimate the contribution of ICT investment on output growth in China at the national level. Suggestions to ICT development and investment at the central government level are provided. Section 8 concludes the paper and provides guidelines for future research.

2. ICT AS AN INFRASTRUCTURE TO ECONOMIC DEVELOPMENT

2.1 The scope of ICT

According to International Telecommunication Union (ITU), the type of ICT devices and services useful for improving the working efficiency and studying access to the information society includes radio, television, fixed telephone, mobile telephone, personal computer, and the Internet. The first three are often considered as *old* ICT devises while the latter three are considered as *new* ICT devises. In the manufacturing domain, computer aided manufacturing equipments are calculated in ICT. In addition to this, software sometimes considered separately from computer and Internet as an independent category to get more detailed implication.

Most international comparisons of ICT are based on the ICT capital stock available in the country. ICT capital stock is measured by estimated data based on ICT investment expenditure. This is usually not a very reliable or universally available statistic compared to those obtained through data surveys. In this research, the aggregate investment in ICT infrastructure (computer hardware, software and communication equipment) is considered in obtaining the ICT capital stock in China. Not surprisingly, this in similarity with many other measures will also underestimate the contribution of ICT. Among other measures, subject to same criticism, include software, personal expenditure in ICT and auto-manufacturing equipments which are not accounted for. At the same time, the low price of piratical software will underestimate the investment and the influence of ICT. So it will never be accurate if we limit the ICT measure to software expenditure to measure the software or ICT contribution to economic growth.

2.2 The ICT development in the world

The 1990s was the golden age for the world wide telecommunication development. The compound annual growth rate (CAGR) of telecom revenue was more than 8%. Figure 1 shows that the revenue for Telecommunication Service increased from US$400 billion in 1991 to more than $1 trillion in 2003. Correspondently, the market revenue of telecom equipment grows at the same rate which was US$120 billion in 1991 and up to US$300 billion. In 2003, the ratio of service and equipment keeps 10/3 in this period. This market is expected to increase continuously due to the growth in mobile telephone and personal computer markets.

After a close examination of the breakdown of increases in above, the fact that mobile telecommunication and Internet user occupies the top increases can be easily found. In 2003, the number of fixed telephone subscribers in the world was only 1,123 million, in contrast to this, the number of mobile telephone subscribers was 1,341 million which is 218 million more than former. In the Figure 2, the main telephone lines, mobile cellular subscribers, international telephone traffic in minutes, personal computers and internet users are shown from 1991 to 2003. The CAGR of main telephone lines is 6.4% and reached 1,147 million in 2003. However, with the CAGR of 40.9%, the increase in mobile cellular subscriber is far ahead than the growth rate of main telephone. In 1991, the number of mobile phone users was only 16 million because of the high subscription price. When the price of first generation and second generation cellular phones sharply declined due to new technology, people rushed to buy it, especially during 1994-1996. The above channels of growth rates are shown in Figure 3. Internet users have grown more dramatically with the CAGR of 47.1% during the same period. For example, in 1994, the growth rate of the number of users of internet doubled. The personal computer increased in the range 10-20% per year in 1990s. However, the development is not well balanced. For example, the phone subscribers of 100 inhabitants is 185.74 in Luxembourg, on the contrast, in Niger, it is only 0.33.

To evaluate the level of digital development, ITU uses the Digital Access Index (DAI) which is an overall measure of the level and diffusion of ICT technology. The DAI index is built around four fundamental factors that have an impact a country’s ability to access ICTs including: infrastructure, affordability, knowledge and quality. In addition to the developed countries, several Asian Tigers have achieved important success in digital society, but not in other areas.

Information age gave birth to the deeply unabridged divide between poor and rich countries. But, at the same time, it rises a question of whether ICT prompts economic growth? There are examples of the possibilities to leapfrog several generations of information and technology development. However, the success of such actions will depend on a country’s industrial technology and development policy and their implementations. The East Asian and South East Asian countries have been successful in taking advantage of ICT in their economic and social development (see Jussawalla and Taylor, 2003). The impact of ICT on economic growth is reviewed in the next section.

3. THE IMPACTS OF ICT ON ECONOMIC DEVELOPMENT

The first studies related to ICT contribution to national economic growth conducted at the country level in the late 1980s and early 1990s concluded that the contribution of IT to productivity and economic growth was nonexistent or slight. Oliner and Sichel (1994 and 2000) and 2002) by using the US data between 1970 and 1992 concluded that IT investment is too small to have substantial economic effects and ICT is only associated with 0.16–0.28 percent additional economic growth. In more recent studies Oliner and Sichel (2002) by using extended data covering until 2001 show that productivity growth in the U.S. economy jumped during the second half of the 1990s, which many be linked to the information technology. However, the fall in demand for IT products, lead to a debate about the connection between IT and productivity and sustainability of the faster growth. The new results reconfirmed their previous work that the acceleration in labor productivity after 1995 was driven largely by the greater use of IT capital goods and by the more rapid efficiency gains in the production of IT goods. The range of labor productivity growth is found to be in the interval of 2.0% and 2.75% per year and sustainable. Even much later Strassmann (1990) argued that there is no direct relation between spending on computers and profits or productivity. Moreover, Gordon (2000) argued that much of the productivity acceleration in 1990s is driven by the business cycle and concentrated in just a few sectors of the economy.

This *paradox* stimulated economists, management scientists, and the researcher of information systems to conduct more scientific analyses of the relationship between IT and productivity growth with larger datasets and more refined research methods. Given the continuous debate about whether IT investments pay off, this research reviews briefly but yet critically evaluates the large body of evidence-based research on the subject (for a more comprehensive review see Dedrick, Gurbaxani and Kraemer, 2003).

Jorgenson (2001) found that the IT investment contributed more than one-half of the recent increase in the US economic growth. Since 1995 about one-half the productivity growth has occurred in the IT-producing sector but growth has occurred in IT-using industries as well. Thus, there is a considerable agreement that IT investments have had a major impact on labor productivity and economic growth at the country level. Kraemer and Dedrick (2001) confirmed that the growth in IT investment is correlated with productivity growth by using the data from 43 countries. Melville (2001) checked 31 industries of US with the time span from 1965 to 1991 and found that IT returns were positive for US as a whole and the benefit of IT increased with time and higher IT returns accrued to the high growth industries (see also Stiroh, 2002). Plice and Kraemer (2001) also examined six industrial sectors for 38 countries and concluded that IT capital showed 5-8 times higher return on investment than non-IT capital for developed countries.

Except United States, for almost all developed countries began their similar researches from the late of 1990s. Niininen (2001) evaluated how large the impact of computer technology to economic growth in Finland. Oulton (2001) reported that the contribution of ICT on GDP growth in U.K. was 0.36% and 0.57% in the beginning and later of 1990s respectively. Kegels, van Overbeke and van Zandweghe, (2002) in their analysis of the ICT contribution to economic performance in Belgium found that the accumulation of ICT capital resulted in an increasing contribution of ICT capital on output growth and average labor productivity growth. Between the first and the second half of the 1990s, the contribution of ICT capital growth rose from 0.26% to 0.42%. In 2003, CEPII (2003) report that between the first and the second half of the 1990s, the contribution of ICT capital growth in France rose from 0.25% to 0.45%, and during the period 1996-2000, the ICT producer sector did indeed record very strong gains in output per hour worked (10.7% per year), stemming from total factor productivity (TFP) growth. Thus, all these studies come to similar conclusions suggesting that ICT showed a strong trend in the late 1990s compared to the beginning of 1990s. Several studies based on Korean data (e.g. Seo and Lee, 2000) also show such significant contribution from ICT investment. In 2003, Australia National Office of Information Economy found that ICT and services have become pervasive, general-purpose enablers of economic and social transformation. Given the right policy settings, they provide the platforms on which the growth in productivity, innovation and social well being can be constructed.

A lesser amount of related research is available in the developing countries on the ICT growth and its relationship with other factors. Only an Indian case study is reported by United Nation University (Joseph, 2002). Joseph concluded that India benefited more from ICT than harming other industries. The harm or reversal effect is associated with its impact on the reallocation of resources such as labor and affects input prices. India currently emphasize strongly on the role of ICT in its development and invest in ICT infrastructure and technology parks as a significant factor to attract FDI to enhance its economic development (see Naidu (2003). As pointed out previously, it might be rather difficult to reveal the truth when there is a lack of data with sufficient quantity and quality, especially in developing countries.

All cross country studies choose U.S. as comparison since U.S. has achieved highest ICT return in the late of 1990s. Kraemer and Dedrick (1994) demonstrated that IT investment is positively correlated with gross domestic product (GDP) and productivity growth by using 12 Asia-Pacific countries datasets from 1984 to 1990. Later, Dewan and Kraemer (1998 and 2000) claimed that IT capital is positively correlated with labor productivity in developed countries but not in the developing countries. Their result is based on a comparison of 36 countries with the data spanning from 1987 to 1993. Schreyer (2000) found that, in the case of G-7 countries, during 1990-1996, IT contributed significantly to the productivity growth in all seven countries, but the magnitude differs across countries.

Daveri (2000), by using 18 OECD and European Union (EU) countries data from 1992 to 1997, found that IT added to GDP growth in the 1990s for all countries studied, but the contribution in EU countries was smaller than in other industrialized countries. Within the EU, differences in the contribution of IT to the growth were also due to lower IT investment. Pohjola (2001) examined 39 countries, with the data from 1990 to 1995, and concluded that IT investment shows 80% gross returns for OECD countries, but developing countries did not experience significant returns. Kraemer and Dedrick (2001) concluded that the growth in IT investment is correlated with productivity growth but the level of IT investment (measured as % of GDP) did not correlated with productivity growth when compared 43 Countries in between 1985 and 1995.

Zhen-Wei Qiang, Pitt and Ayers (2003), in examining of the contribution of ICT to the growth concluded that various results obtained by different countries and regions fuel the debate over exactly how much influence ICT has on economic growth. In sum, the review by OECD study suggests that the US has enjoyed markedly better results from investment in ICT than most other countries. In Europe, ICT's contribution to growth has been more sporadic. In other regions except 4 Asian Tigers, there are few cross-country evidences on ICT's contribution to economic growth.

At the disaggregate industry or firm level, several studies confirmed that productivity growth remains high in IT-intensive industries and contributions to long-run productivity growth (1989-2001) of ICT are widely dispersed among industries (Ramirez, Kraemer and Lawler, 2001).

4. THE ICT SECTOR IN CHINA

From 2002, China became the first Nation in term of highest number of telephone users. This is not only a reflection of its population size but a direct result of improved connectivity in the recent years. Until September 2004, the total fixed phone users were 307 million, within which the city users occupied 2/3 and the remaining were rural users. Since a huge portion of its population living in rural China, the fixed phone usage rate of rural area is much lower than urban usage rate which is 36.9% (for national wide, it is 24.5%). Now the mobile phone user, which is mostly used by the residents of urban area are 320 million which is 13 million more than the users of fixed phone among which almost half of fixed phone is used for non-resident public and business purposes.[1]

The number of internet users also increased fast during the last 7 years. From 1997, China launched internet survey by the China Internet Network Information Center, after that they did it semiannually. In Figure 4, we show the development of the total users of internet in the country. From the beginning to the most recent survey which was conducted in July 2004, the number of users grows more than 100 times. China already becomes the second largest market with 87 million of internet just followed by United State with 170 million users. Even that, the usage in term of the whole population is very low, and is only 6.7%. Compared to Korea which has more than 70% internet users, China is taking extra effort to catch up with advanced countries in the internet connectivity. Recently, the semiannual growth rate of internet users in China decreased significantly. In the fourth survey in 1999, the users doubled just in half a year; but in fourteenth survey, the growth rate remains only 9% (Figure 5). If China keeps the same rate of increase at 9% every half year and United State has no increase of number of Users, China will surpass United States and become the largest Nation in term of internet users within only 4 years.

The Ministry of Information Industry announced that the average growth rate of China's ICT industry is forecasted to exceed 20% in the next five years. It also projects that software sales in China will reach US$30.8 billion by 2005. The demand for optical fiber is expected to

[1] If fit a simple regression between the total phones used and GDP per capita in every province, we find the coefficient (0.005) is strongly significant with the t-value 11.0. The result is interpreted as, when the GDP per capita increases with 200 RMB (US$25), 100 inhabitants will own one more phone.

reach 16 million kilometers by 2005, up from 6.6 million in 1999, a growth rate of more than 100%.

There is also digital dividing and inequality in access and usage in the internet world within and between regions in China. By looking at the domain name register under the .cn, Beijing occupies almost 25% of whole resource, and then Shanghai and Guandong which together occupy another 25% of resources. Other coast areas and oversea users register another 25%, the rest includes west and middle together only have less than remaining 25% domain name registered under .cn.

According to the recent rank by the new Digital Access Index of ITU, China has got the value of 0.43 which ranks 84 among 178 Nation or regions, and just followed by Fiji and Iran. It is not a surprising result because China's digital success has been concentrated in the areas like Beijing while in other areas the level of development is similar to that of least developed countries. The overall state of the economy determines the ICT development as we shown above, but does the counter question make sense too? Namely, whether the ICT will cause rapid economic development compared to other capital inputs?

5. THE DATA

Since the adoption of the comprehensive reform policy in 1978, China's statistical system has had to follow the international statistical norms under the assistance of the World Bank and the Asian Development Bank. The system of national accounts (SNA) was completely implemented with national coverage in 1992. Before that, China adopted the system of material product balances (MPS) in which national income is value-added and comparable with GDP in SNA system adopted by the countries with the market-economy.

Access to data, in sufficient quantity and with high quality is in general a limitation in research related to the Chinese economy. In particular data limitations related to information and communication technology, which is a problem not only to China but also a common problem to all developing countries. The data used in this study is not published and construction of the data series has required great amount of work, but it has resulted in a useful data and also guidelines to construct similar datasets for other developing countries.

5.1 Output

The official GDP is reported in the Chinese statistical year book (CSY), where the implicit GDP deflator is recovered from the reported nominal and real growth rates. The resulting annual series of aggregate data as expected matches closely to the data used by most researchers, as the source of the data is the same single source.

Table 1 shows that from 1977 to 2002, the real GDP in China grew 9.5 times and the compound annual growth rate is 9.4%. In 1985 when China launched its industrial reform program, the country achieved highest growth rate (15.2%) in its history. The second and third highest growth rates was in 1992 (14.2%) and 1993 (13.5%) respectively due to the Mr. Deng Xiaoping's emphasis on the market economy and its implementation. Because of political reason in the aftermath of the Tiananmen Square events and subsequent sanctions imposed by the Western countries, China suffered heavily from the low growth rates in 1989 and 1990. After 1995, Chinese government gradually managed to regulate the economic growth by the Macroeconomic policy instruments, so the annual growth rate in the economy has again increased and stabilized at the ranges of 7% to 10%.

5.2 Capital stock

Chow (1993) and several following studies made efforts to construct capital stock series for the Chinese economy. The standard perpetual inventory method for calculating Chinese capital stock is applied in most of other studies. The method is written as:

(1) $$K_t = I_t + (1-\delta)K_{t-1}$$

where K_t is the current real capital stock, I_t is the current period real investment, K_{t-1} is real capital stock at the beginning of current period, and δ is the depreciation rate. The calculation of gross fixed capital formation is based on the total social fixed asset investment which is referred to as gross fixed capital formation at the current price. But State Statistics Bureau of China (SSB) reported the price index of the fixed asset investment only from 1991. Hsueh and Li (1999) provided an implicit investment deflator for the period 1952-1995 and made measurement of capital stock by using this method possible.

In addition to fixed assets investment, the use of the perpetual inventory method requires two other crucial input variables. A first such variable is the initial capital stock and a second the annual investment rate. Most of growth studies on China have used the capital stock determined in Chow (1993) for the year 1952. Scheibe (2003) interestingly noted that based on the same 1952 initial value, Chow (1993) and Wang and Yao (2003,WY in short) came to different conclusions for the year 1977, where Chow's real capital stock is about 60% higher than the alternative series offered by WY (2003).

The third parameter relevant for the construction of the capital stock series is the deprecation rate. These deprecation rates listed in various issues of the CSY are very low compared to internationally used rates, and a depreciation rate of 15% is likely to be very high, the resulting in the fall in capital in the early 1980s seems implausible for a rapidly emerging economy (Scheibe, 2003). In this paper, 8 kinds of capital stock from combination of the Chow (1993) and WY (2003) initial capital and assuming 4 different depreciation rates (4%, 7%, 10% and 15%) based on Scheibe (2003) are used. Since replacement rate is lower in emerging economy, 7% must be a reasonable depreciation rate for capital stock construction, for the matter of sensitivity analysis we will use also 10% to check the consistency of the final result.[2]

[2] In order to conserve space the results for the growth rate of capital stock under assumption of different initial capital and depreciation rates described in above are not reported here. However, these can be obtained from the authors upon request.

5.3 Labor

There are several ways to construct Chinese labor variable for the estimation of a production function. Firstly, CSY reports labor data which are annual administrative and survey-based estimates and using the infrequently conducted population censuses. The employment data in the CSY shows a big jump from 1989 to 1990. Young (2000) explains that in 1997 the Statistics Bureau revised employment statistics from 1990 to 1996 according to a new method that was applied in the census definitions. The 'old' system would not recognize temporary employed people earning less than the minimum wage of qualified permanent employees. On the contrary, the census definitions would recognize anybody earning a wage or management income as employed. The 1990 to 1997 data reflect these changes in definition, while the official data of 1989 and before were left unchanged.

The second method of measuring labor is obtained from the working population multiplied by the participation rate and adjusted for unemployment rate which is assumed to be zero before 1997. WY (2003) display estimates derived from various issues of the CSY for the population aged 15 to 64, a series which closely represents the potential working population of China. We adopt WY data from 1977 to 1997 and complete it with the official data covering the last five years post 1997.

From Figure 6, one can find that Chinese labor grew faster in 1980s which was 3% annually than in 1990s with annual growth rate of 1%. The population increases due to the natural birth growth even if China adopted One-Child policy from late 1970s. In 1990s, China began to allow employers to fire labor or to make labor lay-off, so it offsets some effect of the growth in working population.

5.4 ICT capital stock

From the beginning of establishment of the People's Republic of China, Chinese government considered the telecommunication industry as an important component for national security. Consequently, China's investment in telecommunication area was significant even during the period with very low level of economic growth. The telecommunication investment share of total investment almost kept constant around 1%. However, during 1975-1980, the share of investment of ICT decreased to 0.6%. In the first five years of 1980s, it increased to 1.1% again. In the late 1980s, China started to invest more in ICT and reached the level of 1.62% of the total investment. Moreover, from 1990 to 1995, the share surprisingly reached the 6.6% level and remained constant at the 5% level in the late 1990s. After 2000, it still constitutes more than 5% of the total investment (see Figure 7). The data on ICT investment is provided by Statistics department of Ministry of Information Industry.

There is no deflator of ICT capital published separately. Scheibe (2003) estimated the deflator of ICT and transportation from 1978 to 2001. As an imputation measure, we assume that the year of 1977 was same as 1978 and the year of 2002 and 2003 decreased proportionally with the year of 2001 due to the declined information products' prices. After adjusted by ICT deflator, in most years, the annual growth rate of ICT investment is below 40% and it fluctuates over time. In some years, the ICT investment decreased, especially in 1996 and 2002. But in 1992 and 1993 and 1995, the ICT investment almost doubled.

In order to construct ICT capital stock from equation (1), information about the initial ICT capital stock is required. However, this data couldn't be available directly. By using the following formula, we calculate the initial ICT capital as:

(2) $$K_0 = \frac{I_0}{\delta + \bar{g}}$$

where I_0 is initial investment rate, δ is depreciation rate and $\bar{g}$ is the average growth rate of investment during the whole observation period. The average growth rate of ICT investment is 23% which is considered to be a high investment rate. But the depreciation rate is not easy to determine, because different ICT capital are depreciated differently: for computer, depreciation period is only 3 or 5 years, but for the communication equipments, it may be 15 years or more. The depreciation rate for ICT investment is around 22.4% in Korea. We will test the different depreciation rates which are 7%, 10%, 15% and 22.4% to get the different initial ICT capital stock and the growth rates of ICT capital stock. The ICT capital stock for remaining years can be calculated by using equation (1). The growth rate of ICT capital stock computed at different depreciation rates are reported in Figure 8.

6. GROWTH METHODOLOGIES

There are two methods used in this paper, the first involves the growth accounting and the other is regression analysis to analyse the impact of ICT on economic growth in China.

6.1 Growth accounting

Growth accounting essentially divides output growth into a component that can be explained by input growth, and a 'residual' which captures changes in productivity. Consider the following aggregate production function for the Chinese economy:

(3) $$Q = H(A, X, M) = A(t) \cdot F(X, M)$$

where the maximum quantity of gross output (*Q*) can be produced by all inputs including primary inputs (*X*), *i.e.* labor and capital, and intermediate inputs (*M*). The function also contains a parameter *A(t)* which captures disembodied technological shifts over time. Disembodied technical change can be the result of research and development that leads to improved production processes, or technical change can be the consequence of learning-by-doing, or imitation. This form of technical change is also called "Hicks-neutral" and is "output augmenting" when it raises the maximum output that can be produced with a given level of primary and intermediate inputs, and without changing the relationship between different inputs (OECD, 2001).

Since the technology parameter cannot be observed directly, total factor productivity (TFP) growth is derived as the difference between the rate of growth of a Divisia index of output and a Divisia index of inputs, as shown below. The Divisia index of inputs is made up of the logarithmic rates of change of primary and intermediate inputs, weighted with their respective share (S) in overall outlays for inputs:

(4) $$\dot{TFP} = \frac{\partial H}{\partial t} = \frac{\partial A}{\partial t} = \frac{dQ}{dt} - S_X \frac{d\ln X}{dt} - S_M \frac{d\ln M}{dt}$$

Productivity change also can be defined as a shift of the value-added function $G = (A(t), X, P_M, P)$, i.e. as the relative increase in value added that is associated with technical change which cannot be directly observed but it can be shown that it corresponds to the difference between the growth rates of the Divisia volume index of value added (V_A) and the growth rate of the Divisia index of primary inputs. The variables P and P_M are output and material input prices. The TFP growth is then written as:

(5) $$\dot{TFP} = \frac{\partial G}{\partial t} = \frac{d\ln VA}{dt} - \frac{d\ln X}{dt}$$

Under the assumption of Cobb-Douglas production function and constant return to scale, the input vector X can be written as $X = K^{\beta_K} \cdot L^{\beta_L}$ where $\beta_K + \beta_L = 1$. The parameters β_K and β_L are called the income share of capital and labor respectively. Then the equation (5) can be transformed to:

(6) $$\dot{TFP} = \frac{d\ln VA}{dt} - \beta_K \frac{d\ln K}{dt} - \beta_L \frac{d\ln L}{dt}$$

6.2 Regression analysis

In order to establish the relationship between ICT capital growth and TFP growth statistically, the following equation is estimated:

(7) $$\dot{TFP}_t = \alpha_0 + \alpha_{ICT} \dot{ICT}_t + v_t$$

where the coefficient α_{ICT} capture the impacts of ICT on economic growth. Additionally, in this paper, instead of assuming the income shares on an ad hoc basis, we try to use different income shares to compute the TFP growth. The income shares are obtained from the estimation of a Cobb-Douglas production function and are written as:

(8) $$\log(GDP_t) = \beta_0 + \beta_K \log(K_t) + \beta_L \log(L_t) + \varepsilon_t$$

Where by using the $\beta_K / (\beta_K + \beta_L)$, we estimate the income share of capital, and $\beta_L / (\beta_K + \beta_L)$ as income share of labor. It should be noted that constant returns to scale is assumed, i.e. $\beta_K + \beta_L = 1$.

7. EMPIRICAL RESULTS

During post 1978, China experienced average real growth of more than 9% per annum with fewer ups and less painful downs. Curious about why China has done so well, an IMF research team recently examined the sources of China's growth and arrived at a surprising conclusion (Fischer, 2002). Although capital accumulation, the growth of country's stock of capital assets, such as new factories, manufacturing machinery, and communications systems--was important, as were the number of workers, a sharp, sustained increase in productivity was the driving force behind the economic boom. During 1979-94 labor productivity gains accounted for more than 42% of China's growth and by the early 1990s had overtaken capital as the most significant source of that growth. This marks a departure from the traditional view of development in which capital investment takes the lead. This jump in productivity originated in the economic reforms begun in 1978 (Hu and Khan, 1997).

In addition to capital accumulation, labor force and labor productivity listed above, resource allocation is suggested as another source of productivity growth in China. Lin (2000) argued that the allocation of resources among enterprises of different types of ownership was important to economic growth. Other researchers argue that, until currently, the per capita GDP in China has been fairly low. Given China's abundant human resources, the average wages is about 2% to 3.3% of that in some industrialized countries. According to the findings from various growth studies when the per capita GDP is low the growth rate is high. A high growth rate upon a relatively low base will continue to be an important trend in China's economic development in the foreseeable future.

So many efforts have been made to try to trace the miracle of Chinese economy, but few of them mentioned the role of ICT capital. However, we can not deny the contribution of capital accumulation in China, in fact, especially in 1990s; the increase of capital stock in general played an important role to national economic growth. Among the various capital stock components, the ICT capital stock grew much faster than the physical capital stock. So this phenomenon drives us to ask whether the comprehensive ICT investment contribute more to the economic growth than other capital inputs.

7.1 TFP growth in China

There are several ways how researchers have obtained estimates of capital stocks by using different depreciation rates, different initial values of capital stock as well as different income shares of capital. For the reasons of sensitivity analysis, we computed a total number of 45 different alternative combinations of capital stock variables, variable input income share and capital depreciation rates where TFP growth is estimated based on the equation (6).[3]

Based on the patterns of TFP growth, the following could be concluded. First, the higher depreciation rate of capital will lead to lower capital growth in the beginning of the observation period as a result the TFP growth in the beginning will be higher. When a low depreciation rate is used, the TFP growth in the beginning will be lower. So the TFP growth

[3] Again these results are not reported here but can be obtained from the authors upon request.

in the beginning of the period is mostly determined by the rate of depreciation. Second, the income share of capital influences TFP growth differently in the beginning when TFP growth is highly affected by the depreciation rate, but income share has a major influence later when the capital growth is very high comparatively. The high income share of capital (i.e. more than 50%) will lead to negative TFP growth in the 1989 and 1990 when China suffered from low GDP growth due to Tiananmen Square events and very low (less than 1%) in the late 1990s and after 2000. The low income share of capital (i.e. less than 35%) will generate a high TFP growth rate (between 3% and 4%) during the end of this period compared to a high capital share. Thus, the rate of depreciation and the choice of initial capital stock affect the direction of over or underestimation of the TFP growth rate. The degree of differences among the alternatives is reflected in the level rather than in the temporal patterns of growth rates.

In our view, TFP growth is an indicator of technological change and efficiency improvement should not fluctuate too sharp during the post-reform period of China. After the significant growth of TFP in 1992 and 1993 when China adopted market economy, China's TFP growth cannot suddenly stop increasing in the late of 1990s. Furthermore, in the late 1990s, China already achieved high economic success, so the income share will be much closer to the developed countries in which the capital/labor income share is 35/65, especially for the East region which is considered as the engine of Chinese economy development.

As analyzed by some researchers (Scheibe, 2003), 7% and 10% depreciation rates is reasonable for Chinese capital, and when we chosen the 15% depreciation rate for ICT capital which is reasonable to China compared to other countries, the aggregate depreciation rate should be lower than 15%. Moreover, the depreciation rate of 7% or 10% will make the TFP growth to be around 4% to 8% in the beginning of the period and less volatile. Thus, we find the rate a reasonable level based on the arguments provided with preference for a low capital income share mentioned previously.

If we check the compound annual growth rate of these TFP which ranges from lower than 3% to above 6%, Wang and Yao's (2003) capital stock construction will lead to a lower TFP growth rate compared to Chow's (1993) approach. The high depreciation rate will result in a high TFP growth and the low income share of Capital also generates a high TFP growth rate. In China, during the successful economic transition period, it could be true that the reorganization of old system and reallocation of resource and the spillover of new technology due to the open-door policy played the most important role to the economic growth.

By using the model (7), where we assume 7% and 10% depreciation rate for capital and 15% depreciation rate for ICT, all regression results are reported in Table 2. From the regression result, for the 30% capital income share, all results are significant at the 5% level of significance. Some values of Durbin Watson (DW) are very low, after adjusting for the autocorrelation (ρ), the coefficients is still significant and it does not change much. For the 35% capital income share, all results are significant at 10% except the capital constructed by Chow method with the 10% depreciation rate. For 46% and 59% the income share of capital, the results of Chow's will not be significant even with 7% depreciation rate, but it is still significant for Wang and Yang's data. However, the coefficient drops a little. In the view of depreciation rate, the 7% rate will generate more significant and higher TFP growth results than 10% depreciation rate. In sum, the data constructed by Wang and Yang seems to lead to more robust results compared to Chow's method.

The ICT coefficients from the above regressions range from 0.064 to 0.084, after some adjustment, they converge to a value around 0.076. That means one percent ICT capital growth in China can generate 0.076% TFP growth. The average ICT capital growth rate in China of last two decades is 26.4%, so the TFP growth due to ICT is around 2%. For China average TFP growth rate is 5.3% according the capital data constructed by Wang and Yang with the 7% depreciation rate, so the contribution of ICT to TFP growth is around 38% and contribution to annual GDP growth rate of 9.4% is around 21.2%. It seems high, but when we recognize that it not only includes the capital deepening effect and technology improvement but also include the effects of resource reallocations, and reorganization effects in both ICT and non-ICT sectors, it is not so surprising.

7.2 TFP growth with estimated income share

In equation (8), by using the different capital stock variables we can obtain the estimated income shares of capital and labor, respectively. However, the sum of capital and labor coefficients may not be 1 which will violate the assumption of growth accounting. If we assume that the sum is 1 and divide the coefficient with real sum, we could get the normalized approximate income shares which equal to 1.

The coefficients of capital and labor listed in Table 3 show that no combination will yield constant return to scale. All cases where it is assumed that the sum of the coefficients of capital and labor equal to 1 are rejected based on Wald hypothesis. A non-constant returns to scale is expected given the Chinese growing economy with significant new investment, reallocation of resources, factor mobility, training and reorganizations. This is evidence of the fact that Chinese economic growth partly must be attributed to the increasing returns of scale (see results in Table 3). Even that, we get the income shares of capital and labor normalized to constant returns to scale. Results show that: (i) Chow's capital stock construction yields low capital income share compared to Wang and Yao's, and (ii) the higher depreciation rate for capital will generate lower capital income share. That is quite reasonable since when capital depreciates faster, the total capital will shrink faster, then its share will be low in total income. Previously calculated labor income shares, though some based on the wage share of total GDP bear some problem. The problem arises because many of welfare for the labor are not reflected in wage payments. These payments are basically in the form housing or heath care and other compensations which cannot be captured by wages, and several of which are not observable.

Since the income share is estimated from different capital stock, so it will be fixed for each capital stock in the calculation of the TFP growth. The average TFP growth rate of each alternative capital stock is shown in Figure 9. It ranges from 4% to 7%. Wang and Yao's construction of capital stock will lead to lower TFP growth compared to Chow's construction. And the high depreciation rate will have high TFP growth. The regression results are reported in Table 4. All estimated coefficients are statistically significant at the 5% level and the coefficient of ICT capital growth is around 0.076 to 0.083. So these results are consistent with the result where we directly assume the income share is around 30% or 35% for the capital and capital depreciation rate of 7%. Consequently, ICT growth contributes to TFP growth by around 2%, implying that around 21% of the GDP growth is due to growth in ICT capital investment.

7.3 Dynamic income share construction and ICT contribution

It is true that the income share of capital and labor inputs will change according to the temporal patterns of economic development. At the beginning of industrialization, the share of labor will be low; the most part of value added will be related to the capital input, however, then the late, labor will gain more. For the developed countries, the income share is set for 30% for capital and 70% for labor; we assume nowadays, the China's income shared is same as this level which was proved by the estimated results presented above. In Chinese Statistical year book, the compensation of labor account for 50%-55% of the cost in recent years. However, as discussed above, this compensation underestimates the welfare of labor. In China, even if new policy about the allocation of resident was adopted several years ago, most employees still access housing offered by their company or by the government. Furthermore, most company still provides non-salary benefits in the form of transportation, telecommunication, food as well as other benefits. Then, the total welfare enjoyed by labor will be more than 70% of total GDP.

In allowing the income shares to vary over time and to be consistent with empirical evidence we constructed new income share labeled as dynamic income shares. The construction of the new time variant shares involves a number of steps. First, we normalize the capital and labor inputs to the level in 2002. Capital is in constant price. As discussed above, Chow's 7% depreciation rate and Wang's 7% and 10% depreciation rate are reasonable for China economy growth, so we just normalize these three alternatives. Second, the difference between the normalized labor and capital is calculated. Third, the gap added to 1 multiplied with 0.30 which is the income share of capital (Table 5) will produce a time variant capital share. Since the labor growth slower than capital, so after normalization, the difference will be positive, and the income share of capital will be greater than 30% in the every year before 2002. In the last step, the TFP growth is reported in Figure 10.

The CAGR of TFP for Chow's 7% and Wang and Yang's 7% and 10% are 5.1%, 4.4% and 4.5%, respectively. Using these results, estimation of ICT growth on TFP growth is reported in Table 6. The coefficient and its level of significance are somewhat lower than the previous results based on time-invariant shares. The capital, constructed by Wang and Yang is more robust than Chow's. The lower coefficient is interpreted as if we use a constant income share, the contribution of ICT to economic growth will be somewhat overestimated, but not very much. Given the coefficient is 0.069 and CAGR of ICT, TFP and GDP are 26.4%, 4.4% and 9.4%. Out of the 4.4% TFP growth, 1.8% or 41% is due to ICT capital. For the GDP growth, ICT could explain around 19% which is 2% lower than former constant share based estimations.

8. SUMMARY AND CONCLUSION

ICT sector over time enjoy a growing importance in the Chinese economy. The contribution of ICT to the economic growth has not invoked much attention from economists. This paper employed three different methods to evaluate the contribution of ICT on the economic growth at the national level. The estimated results are then contrasted with those found in the literature. The following conclusion can be drawn from this research.

In similarity with the evidences from developed countries on the ICT and economic growth relationship, the results here suggest that ICT contributes significantly to the Chinese economic growth, rejecting the productivity growth paradox hypothesis, suggesting no positive effects. The contribution is in particular more evident in 1990s, but the contribution is lower in 1980s. Based in our calculations, ICT accounts for up to 20% of the GDP growth and about 38% for of the TFP Growth.

Different rates of depreciation have previously been suggested in relation to the construction of capital stock series. We find that a rate equivalent to 7% for Chinese aggregate capital stock is more reasonable than other commonly used rates of 4%, 10% or 15%. However, for ICT capital, the depreciation rate of 15% is more preferable. The TFP growth rate is positive and increasing function of the rate of depreciation of capital. Higher depreciation rate will generate higher TFP. Thus, over or underestimation of the depreciation rate biases the estimated rate of economic growth.

In the literature the Chinese economic growth is explained by contributions from capital accumulations, labor input, and increase labor productivity growth. In the beginning of Chinese post-reform period, the contribution from labor was significant, but not in the later period, even if the income shares of labor raised.

The average annual TFP growth in China from 1978 to 2002 is around 4% to 5%. It has played an important role to the economic development in China improving the welfare of millions of Chinese, reducing poverty, but also increasing inequality within and between regions. Implementation of new macroeconomic deregulation policy together with gained experience, skills, technology transfer, and capital accumulation has affected positively the TFP growth rate and its stability over time.

Concerning the income shares factor input, it is common to use 0.30 and 0.70 on an ad hoc basis for capital and labor. Our parametric estimated shares of 0.35 and 0.65, based on production function approach are reasonable and confirmed by different methods of estimation. At the same time, the income share of ICT capital increases gradually and amount to almost 2-3% in recent years.

This paper has pointed out a number of improvements concerning decomposition of capital stock into traditional physical capital and ICT capital inputs and the estimation of factor input shares used in the computation of TFP growth in China. Future research should attempt to improve our understanding of a number of issues as follows. First, advance could be made along with identification of some factors that influence ICT investment and its contribution to the economic growth. Second, construction of more accurately measured non-ICT capital to analyze the contribution of capital input will reduce biases in the estimated growth rate. Third, a further decomposition of ICT capital into telecommunication equipment, internet, hard and software components will contribute to our understanding of the deriving forces of economic growth and their individual contribution and policy options. Finally, the implications of the strong assumptions of constant returns to scale and time invariant factor input shares of production deserve further investigation.

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Figure 1. Development of the world telecom services and equipment, 1991-2003.

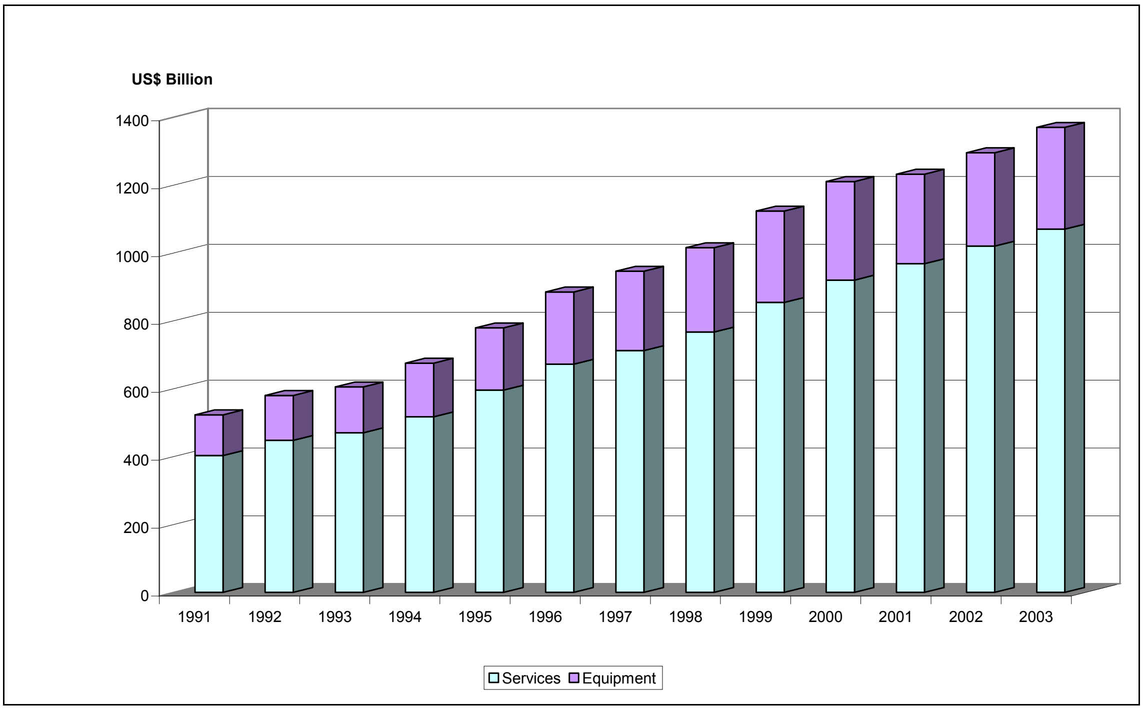

Figure 2. Development of worldwide telecom channels, 1991-2003.

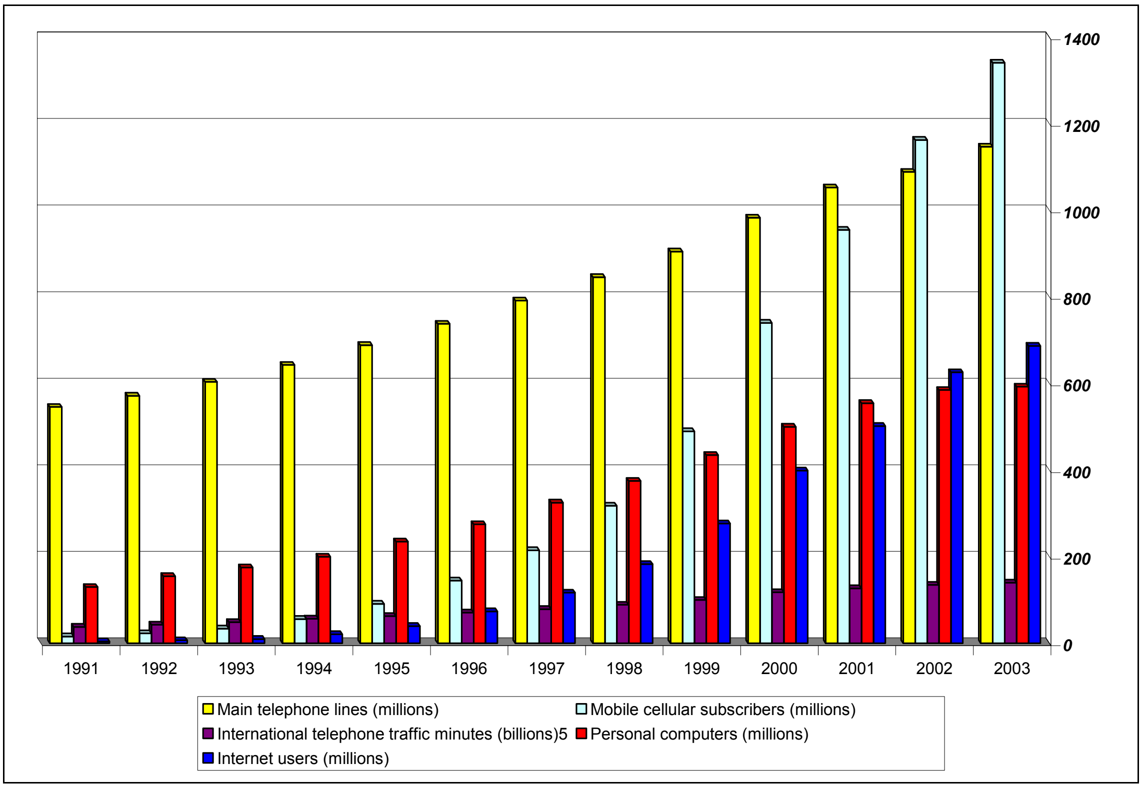

Figure 3. Development of worldwide growth rate of telecom channels, 1991-2003.

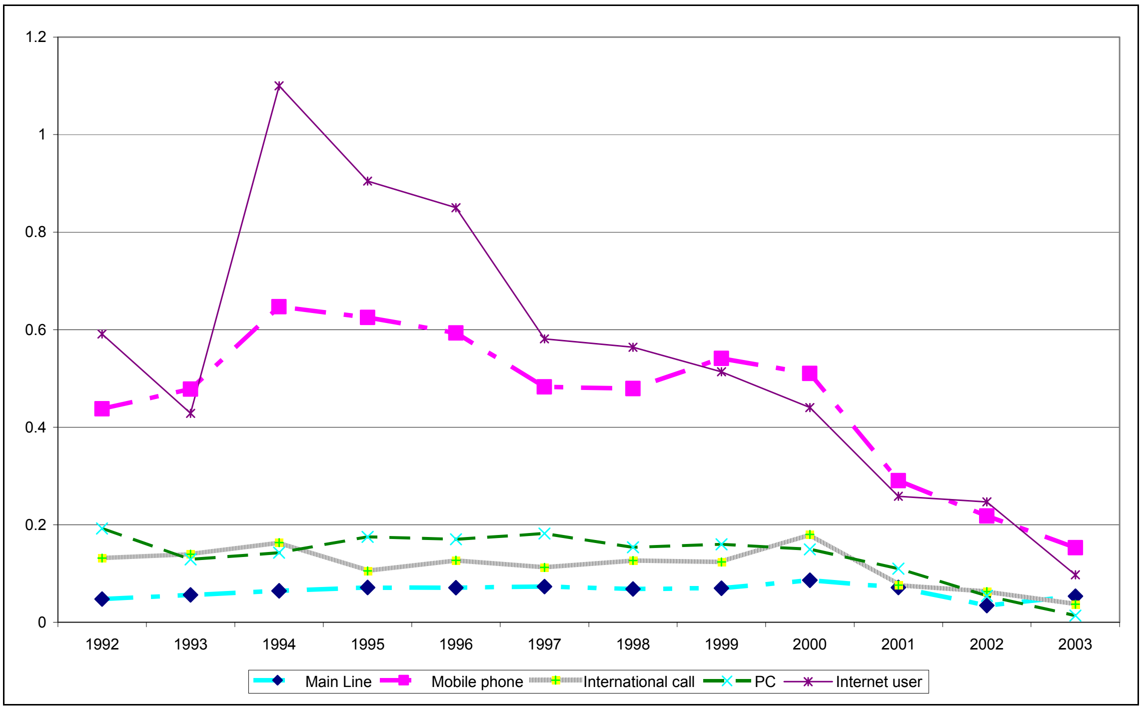

Figure 4. Development of Chinese internet user services, 1991-2004.

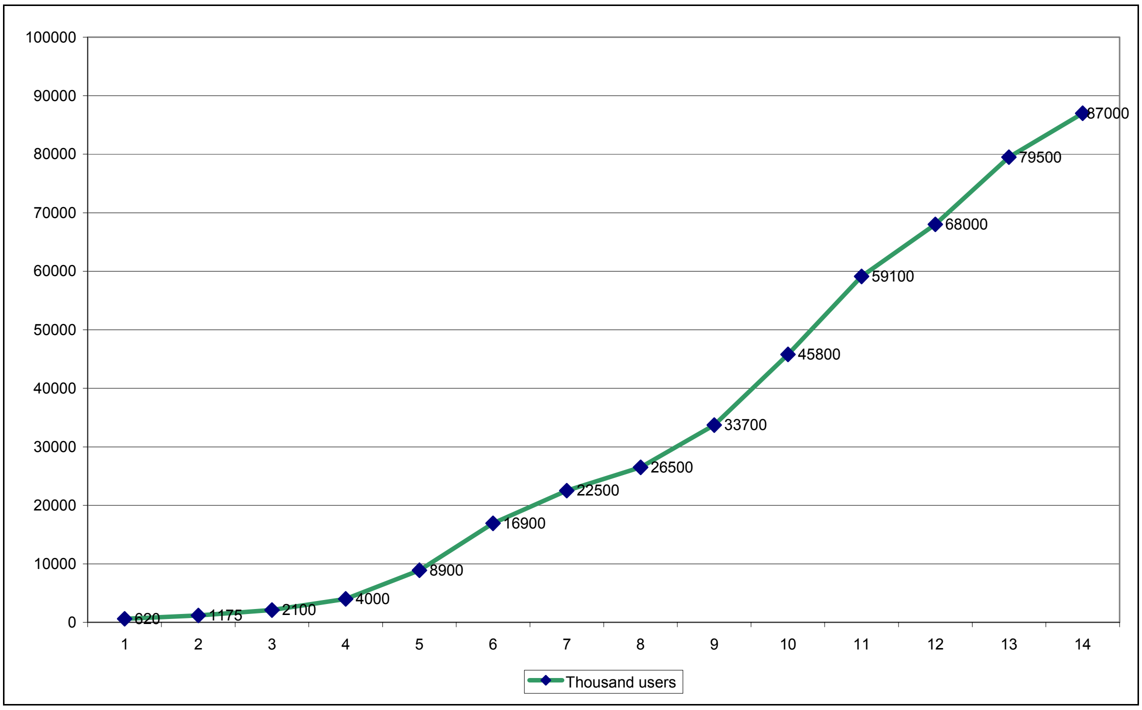

Figure 5. The growth rate of internet user in China, 1997-2004.

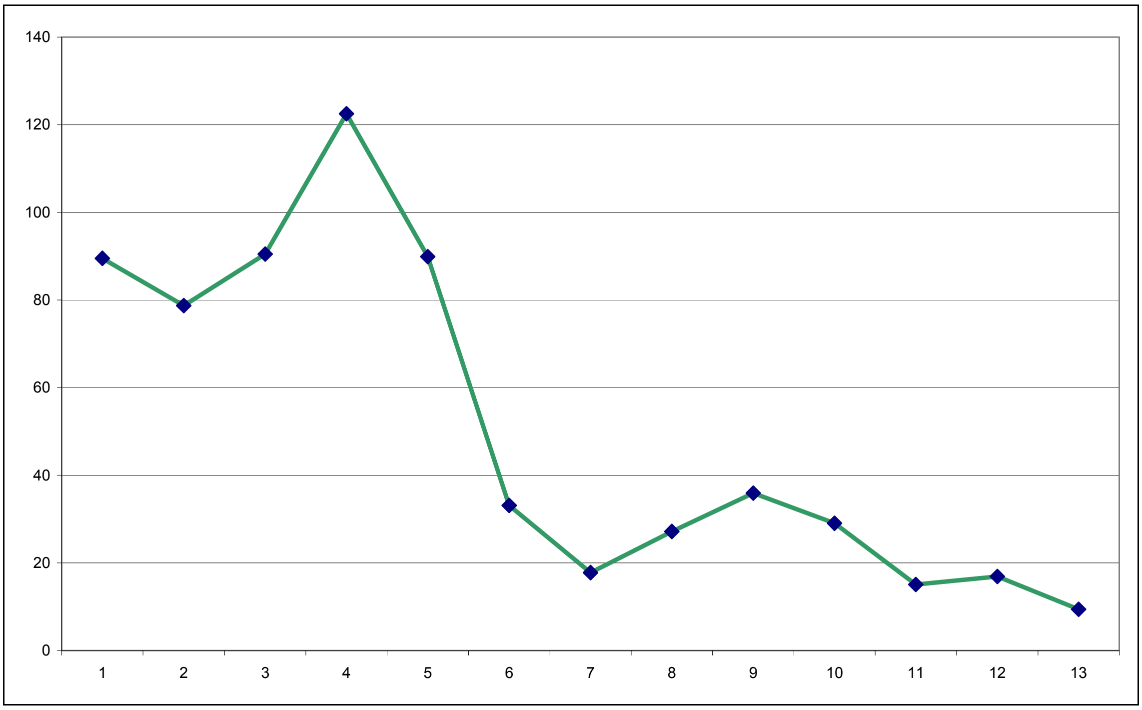

Figure 6. Growth rate of GDP, capital stock and labor in China, 1978-2003.

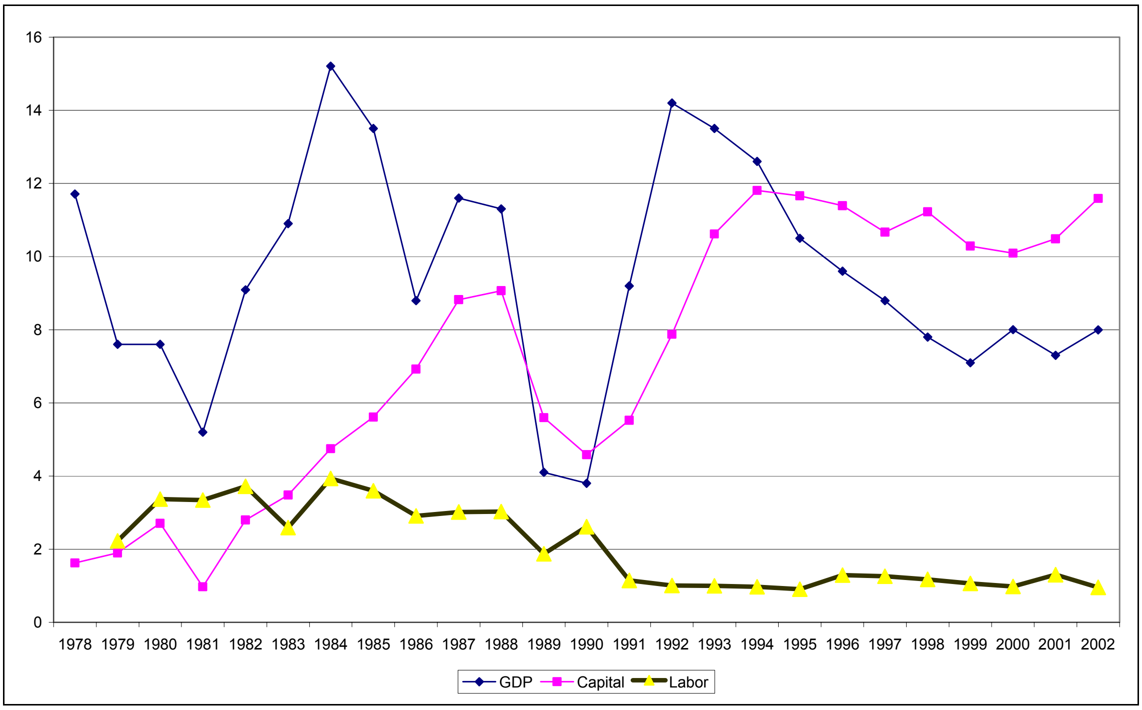

Figure 7. Development of the ratio of ICT to aggregate capital, 1978-2003.

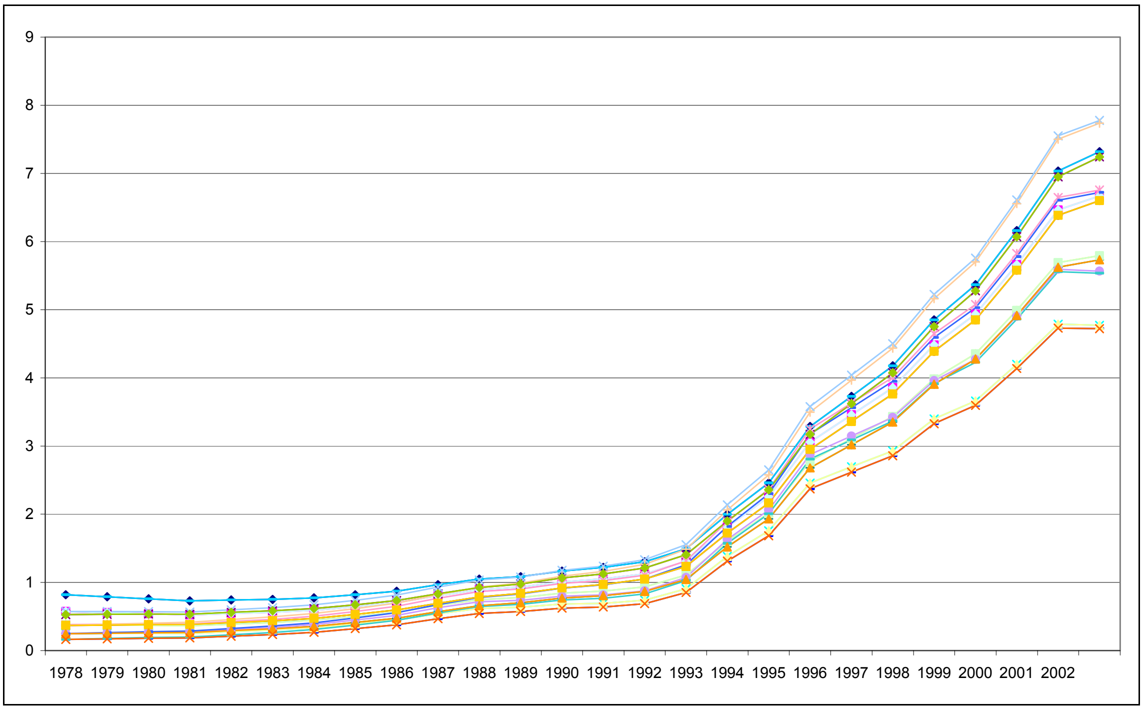

Figure 8. Growth rate of ICT capital estimated at different depreciation rates, 1977-2003.

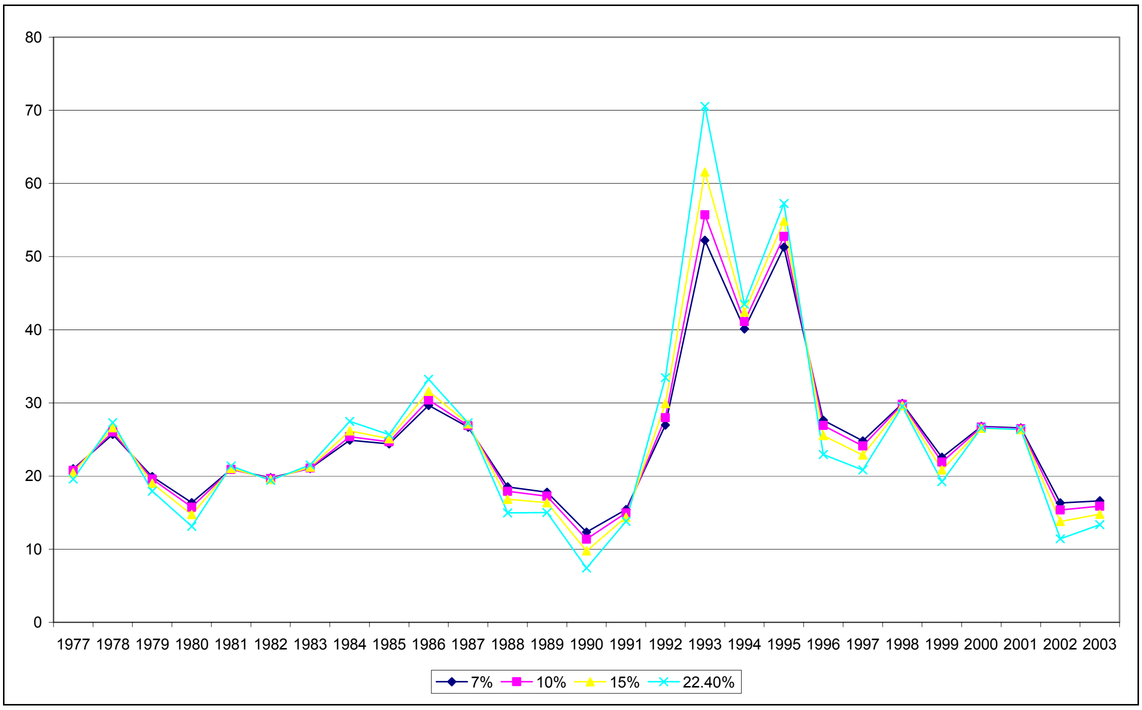

Figure 9. Average TFP growth rates based on different capital depreciation rate and estimated income shares.

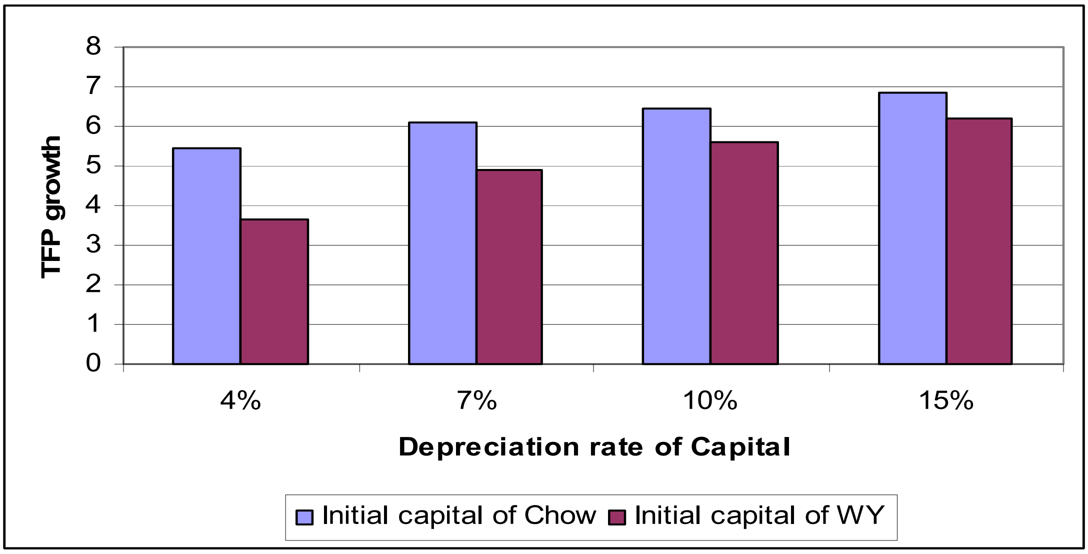

Figure 10. TFP growths with time variant input factor shares, 1978-2003.

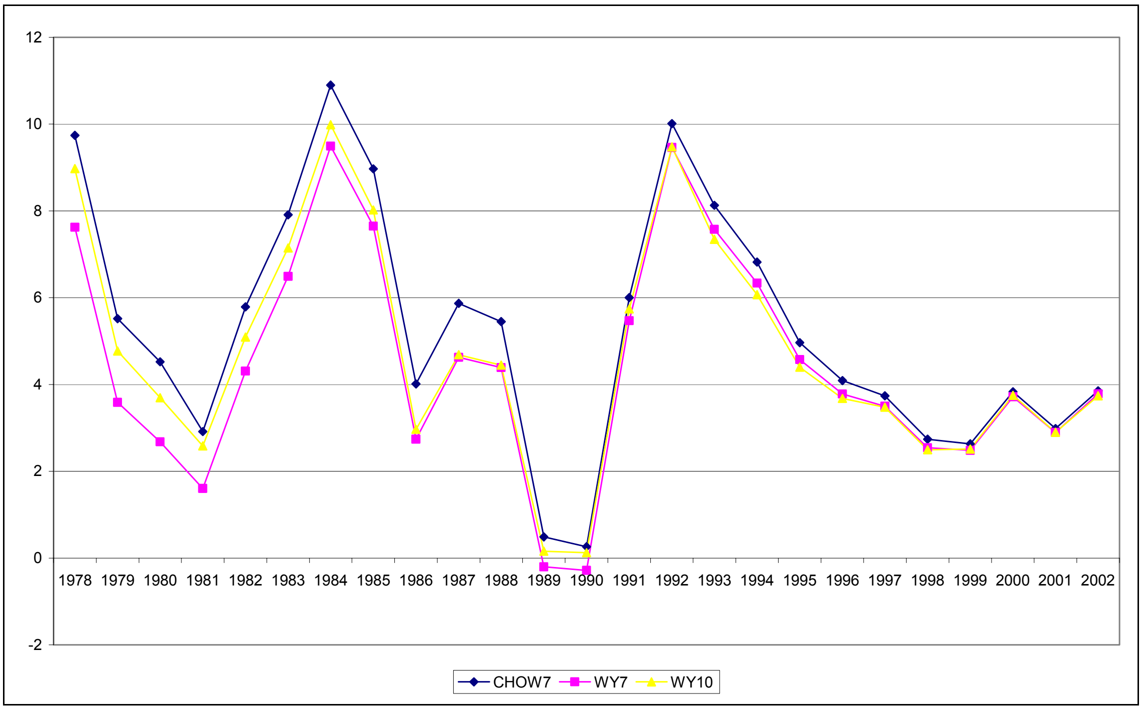

Table 1. China's GDP, capital stock and labor growth rates, 1977-2003.

year	GDP (10^8 yuan)	Capital (Chow 7%) (10^8 yuan)	Labor (10^6)	GDP growth (percentage)	capital growth (percentage)	labor growth (percentage)
1978	6592	23396	453.3	11.71	1.62	
1979	7093	23840	463.4	7.60	1.90	2.23
1980	7632	24485	479.0	7.60	2.71	3.37
1981	8029	24723	495.0	5.20	0.97	3.35
1982	8759	25415	513.4	9.09	2.80	3.72
1983	9714	26300	526.7	10.90	3.48	2.59
1984	11191	27549	547.4	15.20	4.75	3.93
1985	12702	29095	567.1	13.50	5.61	3.60
1986	13819	31109	583.6	8.79	6.92	2.91
1987	15422	33854	601.2	11.60	8.82	3.02
1988	17165	36924	619.4	11.30	9.07	3.03
1989	17869	38991	631.0	4.10	5.60	1.87
1990	18548	40779	647.5	3.80	4.59	2.61
1991	20254	43033	654.9	9.20	5.53	1.14
1992	23130	46421	661.5	14.20	7.87	1.01
1993	26253	51350	668.1	13.50	10.62	1.00
1994	29561	57413	674.6	12.60	11.81	0.97
1995	32665	64107	680.7	10.50	11.66	0.90
1996	35801	71410	689.5	9.60	11.39	1.29
1997	38951	79030	698.2	8.80	10.67	1.26
1998	41989	87899	706.4	7.80	11.22	1.17
1999	44970	96942	713.9	7.10	10.29	1.06
2000	48568	106728	720.9	8.00	10.09	0.98
2001	52114	117918	730.3	7.30	10.48	1.30
2002	56283	131583	737.3	8.00	11.59	0.96

Source: Scheibe (2003), GDP and Capital are in 1990 constant price.

Table 2. Regression results with fixed factor shares. Dependent variable is TFP and independent variable is growth of ICT capital stock.

income share	Depreciation rate	researcher	Coefficient	Std. error	t-value	p-value	R2
30	7	Chow	0.0734	0.0346	2.1364	0.0435	0.1656
30	10	Chow	0.0650	0.0357	1.8205	0.0817	0.1260
30	7	WY	0.0841	0.0321	2.6225	0.0152	0.2302
ρ =0.628, using $y'_t=(1-\rho)\, y_t$ $x'_t=(1-\rho)x_t$ to adjust			0.0762	0.0389	1.9561	0.0633	0.1482
30	10	WY	0.0766	0.0326	2.3540	0.0275	0.1942
ρ =0.52, using $y'_t=(1-\rho)\, y_t$ $x'_t=(1-\rho)x_t$ to adjust			0.0796	0.0364	2.1871	0.0397	0.1786
35	7	Chow	0.0688	0.0353	1.9465	0.0639	0.1414
35	10	Chow	0.0584	0.0370	1.5800	0.1278	0.0979
35	7	WY	0.0807	0.0321	2.5138	0.0194	0.2155
35	10	WY	0.0720	0.0329	2.1858	0.0393	0.1720
46	7	Chow	0.0571	0.0377	1.5136	0.1438	0.0906
46	7	WY	0.0730	0.0327	2.2322	0.0356	0.1781
59	7	Chow	0.0442	0.0413	1.0699	0.2958	0.0474
59	7	WY	0.0644	0.0341	1.8888	0.0716	0.1343

Table 3. Regression results to estimate factor shares, Dependent variable is log(GDP).

Coefficient	Chow 4	Chow 7	chow 10	chow 15	WY 4	WY 7	WY 10	WY 15
Log(Labor)	1.6181	2.0957	2.4687	2.8934	0.8874	1.3584	1.7551	2.2494
Log(capital)	0.7694	0.6974	0.6284	0.5324	0.8010	0.7438	0.6848	0.5966

Table 4. Regression results with estimated factor shares, Dependent variable is TFP and independent variable is ICT capital growth rate.

capital share	depreciation rate	Researcher	coefficient	std error	t-value	p-value	R2
32	4	Chow	0.0805	0.0338	2.3794	0.0260	0.1975
25	7	Chow	0.0790	0.0340	2.3206	0.0295	0.1897
20	10	Chow	0.0782	0.0340	2.2967	0.0311	0.1866
15.5	15	Chow	0.0781	0.0339	2.3074	0.0304	0.1880
47.5	4	WY	0.0833	0.0315	2.6419	0.0146	0.2328
35.4	7	WY	0.0805	0.0321	2.5047	0.0198	0.2143
28	10	WY	0.0785	0.0325	2.4181	0.0239	0.2027
21	15	WY	0.0761	0.0327	2.3270	0.0291	0.1906

Table 5. Development of time variant factor shares at different depreciations rates normalized at 2002 values, 1977-2004.

Year	Chow 7% capital	Chow 7% labor	WY 7% capital	WY 7% labor	WY 10% capital	WY 10% labor
1977	42.78	57.21	44.62	55.38	44.05	55.95
1978	43.11	56.89	44.81	55.19	44.32	55.68
1979	43.41	56.58	44.99	55.01	44.59	55.41
1980	43.90	56.09	45.37	54.63	45.03	54.97
1981	44.50	55.50	45.86	54.14	45.60	54.40
1982	45.09	54.90	46.35	53.65	46.15	53.85
1983	45.43	54.57	46.59	53.41	46.45	53.55
1984	45.99	54.01	47.06	52.94	46.96	53.04
1985	46.44	53.56	47.43	52.57	47.36	52.64
1986	46.65	53.35	47.56	52.44	47.52	52.48
1987	46.74	53.26	47.58	52.42	47.53	52.47
1988	46.78	53.22	47.55	52.45	47.50	52.50
1989	46.78	53.21	47.48	52.52	47.50	52.50
1990	47.04	52.95	47.69	52.31	47.77	52.23
1991	46.80	53.16	47.42	52.58	47.56	52.44
1992	46.33	53.67	46.86	53.14	47.02	52.98
1993	45.48	54.52	45.95	54.05	46.08	53.92
1994	44.36	55.64	44.77	55.23	44.86	55.14
1995	43.08	56.92	43.44	56.56	43.49	56.51
1996	41.77	58.23	42.08	57.92	42.10	57.90
1997	40.39	59.61	40.65	59.35	40.66	59.34
1998	38.70	61.30	38.91	61.09	38.90	61.10
1999	36.95	63.05	37.10	62.90	37.11	62.89
2000	35.00	65.00	35.11	64.89	35.13	64.87
2001	32.83	67.17	32.89	67.11	32.92	67.08
2002	30.00	70.00	30.00	70.00	30.00	70.00

Table 6. Regression results based on time variant factor shares. Dependent variable is TFP and independent variable is ICT capital growth rate.

	Coefficient	std error	t-value	p-value	R2
WY 7%	0.0689	0.0307	2.2419	0.0349	0.1793
WY 10%	0.0573	0.0321	1.7844	0.0875	0.1216
Chow 7%	0.0538	0.0350	1.5367	0.1380	0.0931