

**INFORMATION TECHNOLOGY, PRODUCTIVITY AND
ECONOMIC GROWTH IN CHINA**

by

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Information Technology, Productivity and Economic Growth in China

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Abstract This paper presents an empirical assessment of the “New Economy” in China, drawing upon the linkage between information technology (IT) and economic growth. The aim of this paper is to interpret China’s economic growth from a perspective which emphasizes IT as a factor in economic growth. While the explosive growth of IT investment in the developed economies and its contribution to GDP and labour productivity growth has already been extensively researched, there has been little research on China, which is one of the world’s largest IT markets. The primary objective of this paper is to examine the sources of China’s economic growth with particular emphasis on the contribution of IT capital for the period of 1984-2001. The paper addresses whether growth in China over this period can be explained by factor accumulation or technological progress. To account for the contribution from factor accumulation, the paper employs the neoclassical production function model that will segregate IT capital from other forms of capital as an input to production. With the introduction of IT capital, the paper attempts to reduce the possible “vagueness” and omission bias of total factor productivity (TFP) growth of the neoclassical model in analysing the sources of growth in China. In addition, a key contribution of this paper is the estimation of China’s IT capital stock, which has not been investigated previously. Preliminary empirical findings on the contribution of factor inputs to China’s economic growth in 1984-2001 suggest that IT capital contributes about 30% of the economic growth rate.

Keywords: *Information technology (IT), TFP, average labour productivity (ALP), IT capital, China*

JEL Classification Numbers: O40, O53

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1. INTRODUCTION

China's economy has been growing at an average rate of 7.6% annually in the past five years (1997-2002). Most studies attribute its rapid growth to various macro-economic factors, such as economic reform, including fiscal reform and exchange rate reform, the huge domestic market and active participation in globalisation, including increased international trade and inflow of foreign direct investment. However, few studies have paid attention to the role of information technology (IT) as a potential and increasingly significant source of economic and productivity growth for this economy. This is surprising as there is an increasing amount of literature describing studies of the high technology sector, in telecommunications, the computer industry and Internet development, for example.

As China is poised to become an economic powerhouse and a "global manufacturing centre", the importance of IT industry cannot be overlooked even though its contribution to the national gross domestic product (GDP) might still be relatively small by international standards. In addition, China's economy has been increasingly stimulated through development in its high-tech sector, since the 1990s in particular. Its Ministry of Information Industry reported in early 2002 that the contribution of the information industry to the country's GDP would increase from 4.2% in 2001 to 7% by 2005. IT is therefore expected to be a crucial driving force for China's economic growth in the 21st century.

The paper begins with an outline of evidence that shows how increasing IT investment in the developed countries such as the US has revived productivity growth in these countries. This is followed by a discussion of China's IT industry and the methodology used to measure the contribution of IT to economic and labour productivity growth, where IT capital is distinguished from other factor inputs in the growth modeling process. The empirical results showing the sources of China's economic growth are then presented, highlighting the contribution of IT capital.

2. LITERATURE REVIEW

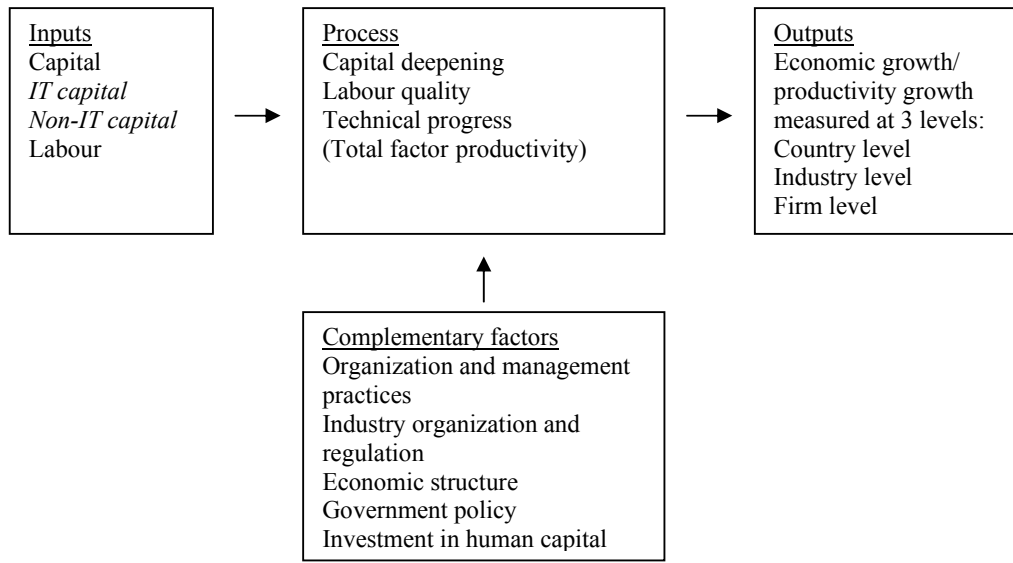
The positive relationship between IT and productivity in developed economies is well documented. Indeed, there is a general consensus is that IT is a key driver of factor productivity (Jorgenson, et al., 2003). This phenomenon has been observed in most

developed countries, although there has been found a lag in productivity growth attributed to IT between the US and the other developed countries. The resurgence of economic growth in the US is attributed to an acceleration of US average labour productivity (ALP) growth and total factor productivity (TFP) growth since the mid-1990s, driven by the semiconductor industry. Empirical studies comparing US and Europe have found the latter lagging behind in economic growth due to having lower levels of IT investment (Inklaar et al., 2003). This suggests a strong link between IT investment and growth. However, while the explosive growth of IT investment in the advanced economies and its rising contribution to GDP and labour productivity growth has already been extensively researched, there has been little research on China, although it has one of the world's largest IT markets and a rapidly growing IT infrastructure.

As this research focuses on the rising importance of IT to China's economy, it is necessary to conduct a review of studies related to this issue. This study is significant for its relevance to the developing countries. It will also contribute further to current literature related to the IT-productivity paradigm. This paper therefore aims to (i) identify the most recent empirical studies on the contribution of IT to the economic and productivity growth of various countries, covering the past five years or so; and (ii) to interpret China's economic growth from a perspective which emphasizes IT as a factor in economic growth. .

A typical framework pertaining to the relationship between IT, economic and productivity growth is illustrated in Figure 1 below. Traditionally, this is based on the production function model where output – a measure of economic and productivity growth – is a function of factor inputs, namely, capital and labour. In this literature, the emphasis is on the IT capital stock which is differentiated from all other forms of capital. The factor inputs are transformed into outputs through the processes of capital deepening, improvement in labour quality and technical progress (also known as total factor productivity, or TFP). During the transformation process, the production methods can be improved or enhanced by complementary factors such as investment in human capital or a more efficient organizational practice. Output can be measured at three levels, namely, country, industry and firm level. This paper will examine empirical findings at China's national level.

Figure 1 IT, economic and productivity growth



Source: Dedrick, Gurbaxani and Kraemer (2003), pp. 3.

IT capital is broadly defined as the part of capital stock which comprises investments in computer hardware, software and telecommunications (Dedrick et al., 2003). The story behind the relationship between IT and economic growth largely started with an input substitution between IT capital (mainly computers) and non-IT capital. In the US, for instance, there has been a dramatic decline in the price for computers in the US since the 1970s. According to McGuckin et al. (1997), the price of computers in the US decreased at more than 17% annually between 1975 and 1996. This in turn led to a massive investment in computers, resulting in the share of computers in the producers' durable equipment increasing from zero to more than 27% during the same period. Similarly, Jorgenson (2001), in accounting for the sharp acceleration in the level of economic activity since 1995, demonstrates that the decline in IT prices will continue for some time, which will in turn provide incentives for the ongoing substitution of IT for other productive inputs. He concludes that the accelerated IT price decline signals faster productivity growth in IT-producing industries, which have been the main source of aggregate productivity growth throughout the 1990s.

A positive correlation between growth in IT investment and GDP growth has been found by Kraemer and Dedrick (1999) in a study of 43 countries including China, from 1985 to 1995. They show that IT investment makes a significant contribution to

economic growth of the developed countries due to the existence of a “complementary system of IT infrastructure” but not to the developing countries which are obviously lacking in such investments. Interestingly, in that study, China is found to be an “outlier” with its exceptionally high correlation between growth in IT investment and GDP growth.² Therefore, one question is to what extent a cross-country analysis of developing countries is applicable to China, which has a low proportion of IT investment to output but has one of the world’s largest IT market and a rapidly-growing IT infrastructure such as the telecom network and Internet.

Current studies show an increase in the contribution of IT capital to the economic growth of the US and other OECD countries during the late 1990s. The empirical findings pertaining to the contribution of IT to economic growth is summarized in Table 1. For instance, empirical evidence for the acceleration of economic and productivity growth in the US during the 1990s due to IT investment is well established in Jorgenson (2001), Jorgenson et al. (2003), and Oliner and Sichel (2000, 2003). Empirical works on other countries which incorporate IT capital into the production function model include Colecchia and Schreyer (2002), Harchaoui et al. (2002), Javala and Pohjola (2001), Kim (2002), Lee and Khatri (2003), Parham et al. (2001), Robidoux and Wong (2003), Schreyer (2000), and Simon and Wardrop (2002). Among the studies pertaining to countries outside US and the G-7 countries, Parham et al. (2001) and Simon and Wardrop (2002) look at Australia specifically, Javala and Pohjola (2001) study Finland, Kim (2002) investigates Korea, and Lee and Khatri (2003) include several Asian developing countries, including China, in their model.

The empirical findings pertaining to the contribution of IT to average labour productivity (ALP) growth is summarized in Table 2. Most empirical findings reveal an increase in ALP growth in major economies around the world between the periods before and after the mid-1990s (Jorgenson and Stiroh, 2000; Jorgenson, 2001; Jorgenson et al., 2003; Oliner and Sichel, 2000, 2003; Parham et al., 2001; Harchaoui et al. 2003; Robidoux and Wong, 2003; Lee and Khatri, 2003). Corresponding to the

² China’s GDP and IT investment grew annually at 10% and 35% on average respectively. In that study, two other countries were shown to be “outliers” - India and Venezuela - but they had GDP growth rates of 2-4%, much lower than that of China. Several countries such as Hong Kong, Indonesia, Korea, Malaysia, Singapore and Thailand had high average annual GDP growth rates of more than 6%, but IT investment grew only by 15-20% (Kramer and Dedrick, 1999).

increase in productivity growth rate in the developed countries is a rise in the contribution of IT capital deepening. The increase in the contribution of IT relative to other factor inputs lends weight to the argument about IT being the predominant source of the productivity revival in the US, due to “an increase in TFP growth in the IT-producing sectors (computer hardware, software and telecom) and induced capital deepening in IT equipment” (Jorgenson et al., 2003).

So far, however, there have been very little empirical studies for the developing countries in this field of research, let alone China. Lee and Khatri (2003) of the International Monetary Fund (IMF) present some findings for selected Asian developing countries in the 1990s, most of which experienced declines in their GDP growth rates between the two halves of the 1990s, except for the Philippines and India, caused mainly by the Asian financial crisis which started in mid-1997. China’s economic growth decreased slightly from 10.6% in 1990-94 to 8.8% in 1995-99, but its economy still remained the strongest in the Asia-Pacific region. Yet, in spite of the economic downturn, the contribution from IT capital to economic growth in Asian countries has generally increased. According to Lee and Khatri (2003), the share of IT capital’s contribution to economic growth ranges from a mere 2-3% in China and India to more than 50% in Hong Kong during the period 1995-99. Overall, while one would expect the US to lead the world in IT investment, yet the highest contribution of IT capital to growth occurred in Hong Kong and Australia in the second half of the 1990s with shares of 56% and 33% respectively (Lee and Khatri, 2003; Simon and Wardrop, 2002).

Table 1 Contribution of IT to GDP Growth (Unit: %)

Author	Country	Period	GDP growth rate	K _{IT}	K _N	L	TFP	Other variable
Jorgenson and Stiroh (1999)	US	1990-96	2.36	0.12 <i>(5.1)</i>	0.51 <i>(21.6)</i>	1.22 <i>(51.7)</i>	0.23 <i>(9.7)</i>	Consumer durable 0.28 <i>(11.9)</i>
Jorgenson and Stiroh (2000)	US	1995-98	4.73	0.76 <i>(16.1)</i>	0.86 <i>(18.2)</i>	1.57 <i>(33.2)</i>	0.99 <i>(20.9)</i>	Consumer durable 0.56 <i>(11.8)</i>
Oliner and Sichel (2000)	US	1996-99	4.82	1.10 <i>(22.8)</i>	0.75 <i>(15.6)</i>	1.81 <i>(37.6)</i>	1.16 <i>(24.1)</i>	
Jorgenson (2001)	US	1995-99	4.08	0.99 <i>(24.3)</i>	1.07 <i>(26.2)</i>	1.27 <i>(31.1)</i>	0.75 <i>(18.4)</i>	
Jorgenson, Ho and Stiroh (2003)	US	1995-2000	4.07	0.98 <i>(24.1)</i>	1.10 <i>(27.0)</i>	1.37 <i>(33.7)</i>	0.62 <i>(15.2)</i>	
		1995-2001	3.55	0.93 <i>(26.2)</i>	1.10 <i>(31.0)</i>	1.12 <i>(31.5)</i>	0.40 <i>(11.3)</i>	
Parham et al (2001)	Australia	1995-2000	4.9	1.3 <i>(26.5)</i>	0.8 <i>(16.3)</i>	0.7 <i>(14.3)</i>	2.0 <i>(40.8)</i>	
Simon and Wardrop (2002)	Australia	1996-2001	3.86	1.26 <i>(32.6)</i>	0.60 <i>(15.5)</i>	0.57 <i>(14.8)</i>	1.43 <i>(37.0)</i>	
Harchaoui et al (2003)	Canada	1995-2000	4.9	0.7 <i>(14.3)</i>	1.0 <i>(20.4)</i>	2.2 <i>(44.9)</i>	1.0 <i>(20.4)</i>	
Jalava and Pohjola (2001)	Finland	1995-1999	6.0	0.7 <i>(11.7)</i>	-0.4 <i>(-6.7)</i>	1.6 <i>(26.7)</i>	4.2 <i>(70.0)</i>	
Kim (2002)	Korea	1996-2000	4.96	1.22 <i>(24.6)</i>	2.62 <i>(52.8)</i>	0.21 <i>(4.2)</i>	1.40 <i>(28.2)</i>	Business cycle -0.49 <i>(-9.9)</i>

Notes: Figures in italic parenthesis () are the weights of GDP growth.

K_{IT} = IT capital

K_N = Non-IT capital

L = Labour

TFP = Total factor productivity

Table 2 Contribution of IT to ALP Growth (Unit: %)

Author	Country	Period	ALP growth rate	K _{IT}	K _N	L	TFP	Other variable
Jorgenson and Stiroh (2000)	US	1995-98	2.37	Capital deepening (K _{IT} + K _N) 1.13 (47.7)		0.25 (10.5)	0.99 (41.8)	
Oliner and Sichel (2000)	US	1996-99	2.57	0.96 (37.4)	0.14 (5.4)	0.31 (12.1)	1.16 (45.1)	
Jorgenson (2001)	US	1995-99	2.11	0.89 (42.2)	0.35 (16.6)	0.12 (5.7)	0.75 (35.5)	
Jorgenson, Ho and Stiroh (2003)	US	1995-2000	2.07	0.87 (42.0)	0.37 (17.9)	0.21 (10.1)	0.62 (30.0)	
		1995-2001	2.02	0.85 (42.1)	0.54 (26.7)	0.22 (10.9)	0.40 (19.8)	
Oliner and Sichel (2003)	US	1996-2001	2.43	1.02 (42.0)	0.17 (7.0)	0.25 (10.3)	0.99 (40.7)	Semiconductors 0.42 (17.3)
Parham et al (2001)	Australia	1995-2000	3.7	1.3 (35.1)	0.4 (10.8)		2.0 (54.1)	
Jalava and Pohjola (2001)	Finland	1995-99	3.5	0.6 (17.1)	-1.4 (-40.0)	0.2 (5.7)	4.1 (117.1)	
Harchaoui et al (2002)	Canada	1995-2000	1.7	0.4 (23.5)	0.0 -	0.3 (17.6)	1.0 (58.8)	
Robidoux and Wong (2003)	Canada	1996-2001	1.8	0.6 (33.3)	0.3 (16.7)	-	1.0 (55.6)	

Note: Figures in italic parenthesis () are the weights of each factor growth.

3. DAWN OF THE “NEW ECONOMY” IN CHINA?

The world economy has undergone a transformation from the emphasis on manufacturing industry (known as an “industrial economy”) to a shift towards the greater investment and application of IT in broad sectors of the economy (dubbed the “new economy” or “information economy”). On top of that, many studies now explore a more recent concept of the “knowledge economy”. Simply, the knowledge economy is defined as one that has a “strong science and technology base and high technology (hereafter high-tech) industries” (Lan and Sheehan, 2002: 3). It is measured using a knowledge intensity factor, also referred to as investment in knowledge, which includes public and private expenditure on research and development (R&D), higher education as well as investment in software (OECD, 2001). The term therefore encompasses the characteristics which constitute the earlier concept of “information economy” as it measures investment in IT as well. The key difference lies in the inclusion of investment in higher education, or human capital.

Current discussions on China’s economic development tend to focus on its transition from an agriculture-based to an industrial economy that relies more on the manufacturing sector. Given that an “information economy” or a “knowledge economy” is normally associated with the tertiary or service sector, which has not attained a prominent place in China’s industrial share of total output, there is debate over whether it is too early to even discuss the relevance of knowledge economy to China (Lan and Sheehan, 2002).

China’s tertiary industry has maintained at more than 30% of its GDP since the late 1980s. The share of its primary industry, on the other hand, has declined to less than 20% since 1997 to about 15% in 2002, while the secondary industry (comprising mainly manufacturing and construction) made up about 50% of the GDP in 2002.³ At the same time, China’s economy is increasingly spurred on through development in the IT sector. As it propels into the 21st century, China is not only rapidly establishing its status as a global manufacturing centre in various sectors such as automobiles, textile and air-conditioning, but is also set “to become a research and

³ *China Statistical Yearbook 2003*, pp. 56.

development (R&D) base for technology and telecom multinationals,”⁴ and become “the world centre for IT products within the next decade.”⁵ China is said to hold economic advantage with an average manufacturing cost within its IT sector that accounts for only 70% and 80% of that in the US and South Korea respectively.⁶

As a matter of fact, China has become the world’s largest mobile phone market, overtaking the US in July 2001. For instance, by the end of 2003, China already had 269 million mobile subscribers, much far ahead of the US’ current 156 million.⁷ In 2001, the value-added output of China’s information industry accounted for 4.2% of the country’s US\$1.2 trillion (9.7 trillion RMB) GDP and 8% of its total industrial output. According to a Ministry of Information Industry (MII) report, China’s information industry grew more than 32% annually, outpacing industrial growth by almost 18%, and would contribute to 7% of the country’s GDP by 2005.⁸ China’s exports of high-tech products have steadily increased as a proportion of total exports, from 4% in 1991 to more than 24% in 2001 to reach US\$65 billion (Figure 2). Total value of China’s high-tech products, at US\$99.5 billion (823.7 billion RMB) in 2001, is expected to increase to US\$137 billion by 2005.⁹

In an outline of the development of the New Economy in China, Meng and Li (2001) illustrate how China is rapidly embracing the “third industrial revolution” through a rising contribution of the electronics industry as a share of GDP and increasing production of electronic products, namely, the computer (including hardware and software), communications equipment and electronic components. While they present a trend for the period of 1990-99, this paper uses data covering period of 1984-2001. In the paper, the IT sector is restricted to one that comprises the electronic device and communications equipment manufacturing industry as well as the computer hardware and software industry, and does not cover the entire

⁴ “Technology prospers under China’s new rules”, *International Financial Law Review* (London, July 2002).

⁵ “Local IT sector to be world force”, *China Daily* (22 November 2002).

⁶ *Ibid.*

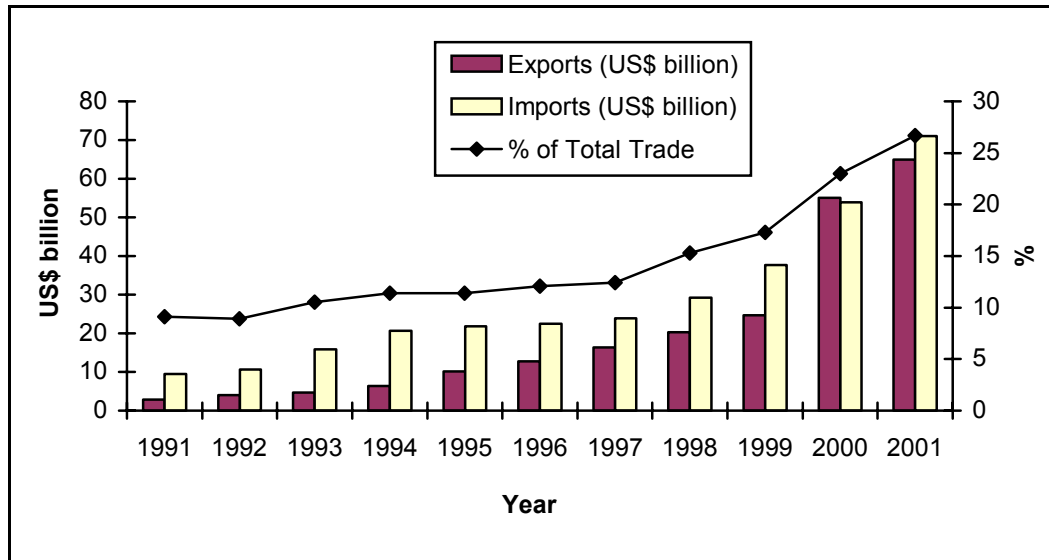
⁷ See Ministry of Information Industry (MII) website, <http://www.mii.gov.cn>, and Cellular Telecommunications & Internet Association website, <http://www.wow-com.com/internet/> (accessed on 26 February 2004).

⁸ See “Information industry sector rockets”, *HK-iMail News* (21 March 2002).

⁹ See “Information industry sector rockets”, *HK-iMail News* (21 March 2002) and “Mainland IT sector sets the pace”, *South China Morning Post* (23 January 2002).

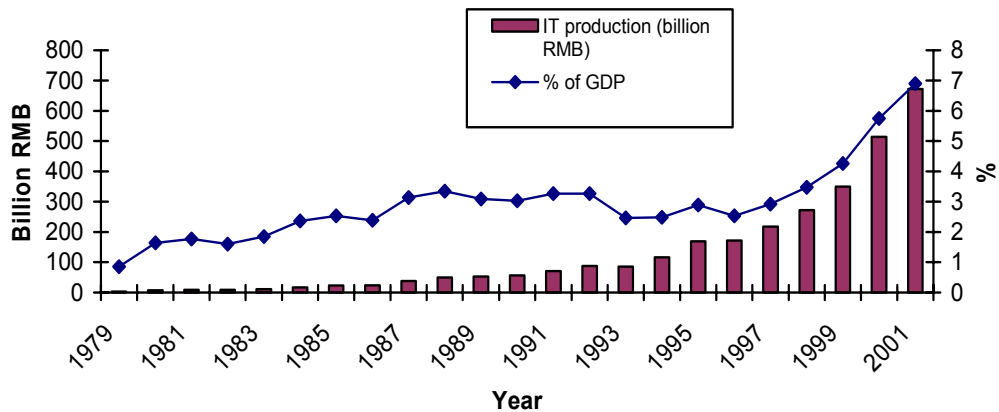
electronics industry as defined by the *Yearbook of China Electronics Industry*. It can be demonstrated that China has experienced a steady rise in its IT output since the beginning of reform, growing annually at about 32% from 1996-2001, with the share of GDP increasing from about 1% in 1979 to 7% in 2001 (Figure 3).

Figure 2 China's exports and imports of high-tech products, 1991-2001



Sources: Wong, J. and Wong, C. K. (2004), "China's Software Industry: Moving on the Fast Track", *Journal of Chinese Economic and Business Studies*, 2 (1), 73-95.

Figure 3 China's IT output and share of GDP, 1979-2001

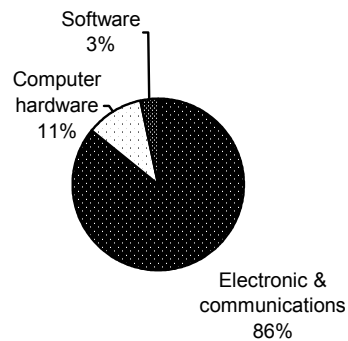


Source: *Yearbook of China Electronics Industry*, various issues.

The rapid growth of China's IT capital stock has stimulated a doubly fast-track growth of its IT industry. For instance, the real IT capital stock grew annually at 15% for the past five years from 1996-2001, which produced IT output growth of 26%

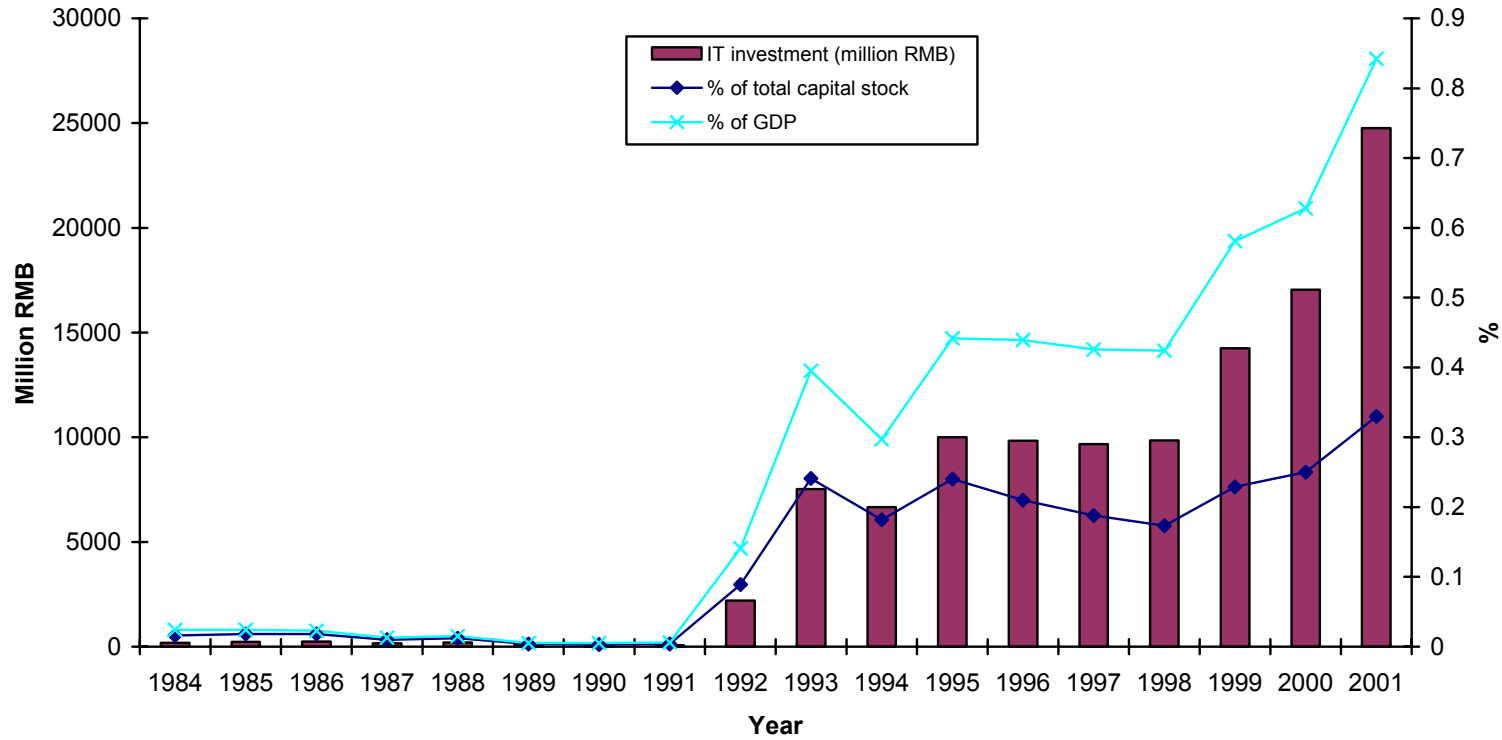
during the same period. Among the component sectors, investment in electronics and communications grew at about 25%, computer hardware at more than 35% but tended to fluctuate between 20% and more than 100%, whereas investment in software has been highest at more than 100% annually although its share of total IT investment is still miniscule – only 3% in 2001 (Figure 4). In 2001, China's IT capital stock made up merely 0.3% of its total capital stock (derived from total fixed asset investment), yet the growth rate of the former far outstripped that of the latter, which grew by about 10% on average annually from 1996 to 2001 (Figure 5). The growth rate of China's IT capital stock is comparable to that of OECD countries, which grew between 15% and 35% in 1999 (OECD, 2001). Although China's IT capital investment made up less than 1% of its GDP even in 2001 – compared with 4.7% in 1999 for OECD countries – it is nevertheless becoming an increasingly significant driver of growth in China's New Economy.

Figure 4 Composition of China's IT investment in 2001



Source: *Yearbook of China Electronics Industry*, various issues.

Figure 5 Growth of Real IT investment in China, 1984-2001



Source: *Yearbook of China Electronics Industry*, various issues.

The patterns of investment in China's IT capital can be explained from two factors. First, technological improvement in China in the 1980s came primarily from the transfer and import of foreign technology. Xu (1997) identifies three phases in China's introduction of technologies since the 1980s. There was a stagnation of technology import during the period 1988-91, followed by a surge in import from 1992 onwards. The period of stagnation coincides with this paper's data on IT capital growth rate which finds IT investment decreased by 7% annually on average from 1987-1991. This was due to "the implementation of a contractionary macroeconomic policy which saw a drop in the number of technology import contracts from 437 in 1988 to 232 in 1990" (Xu, 1997: 86).

China's investment in IT capital experienced a twenty-fold increase in 1992. This phenomenon occurred in parallel to China's new phase of high-speed economic growth since the "southern tour" (*nanxun*) by Deng Xiaoping in the spring of 1992. From 1993-2001, China's investment in IT capital grew by an average of almost 33% annually. Xu (1997) cites two main reasons for the surge in technology imports since 1992. The first is attributed to inward FDI which became "a strong force in the development of China's economy which created a new channel for the import of technology". Second is the increasing role given to private enterprises which now had greater autonomy to import technology, whereas the main task of government was simply "to set macro targets for technology imports but not to seek micro-control of the structure and content of such imports" (Xu, 1997: 88-9).

The second factor accounting for China's pattern of IT investment is related to the establishment of High Technology Development Zones (HTDZ) in the early 1990s, which was probably a major factor propelling a surge in IT capital investment. In 1992, the State Basic Policy for High-Tech Industrial Development Zones was issued which covered five areas of concern pertaining to high-tech industries, namely, taxation, finance, trade, pricing and personnel policy (Segal, 2003). These policies were favourable to new technology enterprises. By 1993, there were already 52 HTDZs throughout the country.

4. METHODOLOGY AND MODEL SPECIFICATION

There is ongoing debate about the choice of growth models which could explain China's sources of growth. It depends on the extent to which factor accumulation accounts for China's economic growth. Questioning the inadequacy of existing models in accounting for the sources of growth, Wu (2002: 133-5) asks "if growth can be totally explained by factor accumulation, then growth follows the neoclassical model. (However) if much of the growth is the result of technological change, further questions can be raised about how this is achieved... Large TFP residuals will simply show a failure of the assumptions of the (neoclassical) model and will be suggestive of an alternative."

The World Bank (1997) reports a substantial "unexplained share of economic growth" (i.e. TFP) which makes up 46%. Hence, to address this issue, the paper is designed to reduce possible omission bias of the neoclassical model in analysing the sources of growth in China. To account for the contribution from factor accumulation, the paper employs the input-output data model which segregates IT capital from other forms of physical capital inputs that produce output in the form of real GDP. Technological progress, or TFP, is derived as a residual of the production function.

A typical production function in its simplest form can be expressed as:

$$Y = A \cdot (K, L) \quad (1)$$

where A , which represents technological progress or TFP, is obtained by subtracting the combined growth of total factor inputs (K and L) from the growth of total output (Y). An extended form that explicitly distinguishes IT capital from non-IT capital is given by Jorgenson, Ho and Stiroh (2003) as:

$$Y(Y_n, I_{IT}) = A \cdot X(K_{IT}, K_n, L) \quad (2)$$

This paper applies the production function developed by Jorgenson et al. (2003), rewritten as

$$Y_t = A \cdot (K_{IT}^\alpha, K_N^\beta, L_t^\theta) \quad (3)$$

where Y represents real output, K_{IT} and K_n stand for the stock of IT and non-IT capital respectively, and L_t is employment. In order to decompose the growth rate of output Y_t , by differentiating both sides of Eq (2) and taking logs, one obtains

$$\Delta \ln Y_t = \alpha \Delta \ln K_{IT} + \beta \Delta \ln K_N + \theta (\Delta \ln L_t) + \Delta \ln A_t \quad (4)$$

where all lowercase variables denote the respective growth rate of the uppercase variables, while α , β and θ represent the weighted share of the respective inputs in the real GDP, and A_t measures TFP growth.

The estimation of factor contribution to the growth of average labour productivity (ALP) is derived from the production possibility frontier model outlined in Equation (3) above. ALP is defined as the ratio of output to employment such that $ALP = Y/L = y$, where y denotes output (Y) per labour (L). Based on Eq (3), the ALP function can be rewritten as follows, typically used by Jorgenson et al. (2003):

$$\Delta \ln y = \alpha \Delta \ln k_{IT} + \beta \Delta \ln k_n + \theta (\Delta \ln L + \Delta \ln H) + \Delta \ln A \quad (5)$$

where α , β and θ denote the respective factor shares of output, whereas k_{IT} and k_n reflect changes in the respective use of IT and non-IT capital per worker, or capital deepening, and H represents the number of hours worked, as explained below. Equation (5) indicates that ALP growth comprises three components: (i) capital deepening, which Jorgenson et al. (2003) define as “the contribution of capital services per hour and allocated between IT and non-IT components” ($\alpha_{IT} \Delta \ln k_{IT} + \beta \Delta \ln k_n$). It enhances the efficiency of labour by increasing capital per worker in proportion to the capital share (that is, increase in the capital-labour ratio); (ii) labour quality, which is defined as “the contribution of increases in labour input per hour worked” [$\theta (\Delta \ln L + \Delta \ln H)$]. It reflects changes in the composition of the workforce and raises labour productivity in proportion to the labour share; and (iii) TFP, which augments factor accumulation ($\Delta \ln A$) (Jorgenson et al., 2003).

5. DESCRIPTION OF DATA

Choice of variables

The variables for the model are as follows:

Y_t = real GDP

K_{IT} = real value of IT capital stock

K_N = real value of non-IT capital stock

L_t = total employment

Output

Output is defined as real GDP, which is derived from nominal GDP deflated by the constant price index. In determining the price deflator for China's real GDP values, Wu (2004) observes a few problems related to the price index. Firstly, prices hardly changed in China during the pre-reform period due to price control under the central planning system; and secondly, the volatility of price movement during the reform period as the Chinese economy was undergoing transformation to a market system. To address these problems, the following method for estimating the constant price index is adopted:

$$P_t^{con} = Y_t^{cur} / Y_t^{con}$$

where P_t^{con} , Y_t^{cur} and Y_t^{con} represent the price index in constant prices, GDP in current prices and GDP in constant prices at period t respectively. The Data for GDP and employment are obtained from *China Statistical Yearbook* for the period 1984-2001.

Capital stock

The capital stock is estimated using the perpetual inventory method employed in Wu (2004), which is based on the total fixed asset investment obtained from *China Statistical Yearbook*. Data for total fixed asset investment is available for the period 1985-2001. The estimation of capital stock can be expressed as

$$K_t = (1 - \delta)K_{t-1} + \Delta K_t \quad (5)$$

where K_t is the real value of capital stock in the t^{th} year, given the rate of depreciation, δ , and ΔK_t is the value of incremental capital stock. The same formula will be applied for the estimation of IT capital stock. Non-IT capital stock is derived from investment

in non-IT capital, which is estimated by first taking the difference between total fixed asset investment and investment in the IT sector. The real value of non-IT capital stock is then derived using the same formula expressed in Equation (5). Data for total fixed asset investment is available from 1980 to 2002.

IT-capital stock

Depending on data availability, two approaches are suggested for the estimation of IT-capital stock. Firstly, IT capital stock can be estimated based on the “investment in capital construction”¹⁰ and “investment in innovation”¹¹ from communications equipment, computer (hardware and software) and electronic component industries, obtained from *Yearbook of China’s Electronics Industry*, for the period 1984-2001. However, several problems arise pertaining to data on China’s investment in the IT sector. The data on investment in the communications equipment sector includes the broadcasting equipment sector for the years up to 1992. Data for software investment is only available from 1994. Furthermore, data for total IT capital investment in 1996 cannot be found in the *Yearbook of China’s Electronics Industry 1997*.

The second approach involves using data from “fixed asset investment by sector”, drawing statistics from investment in the “scientific and polytechnical services” found in the *China Statistical Yearbook*. This can be taken as a proxy for IT investment, excluding communications. However, the data concerned is only available from 1989 onwards. Data prior to 1989 includes investment in other sectors such as culture, education, health care and social welfare, together with scientific research.

In this paper, the former method of estimating IT capital stock is chosen. The estimation of initial IT capital stock for US and Japan has been carried out by Shinjo and Zhang (2003) who apply the following formula:

¹⁰ Investment in capital construction refers to “the new construction projects and related activities of enterprises, institutions or administrative units for the purpose of expanding production capacity or improving project efficiency covering only projects each with a total investment of 500,000 RMB or more.” See *China Statistical Yearbook 2002*, pp. 243.

¹¹ Investment in innovation refers to “the renewal of fixed assets and technological innovation of the original facilities by the enterprises and institutions as well as the corresponding supplementary projects and related activities covering only projects each with a total investment of 500,000 RMB or more.” See *China Statistical Yearbook 2002*, pp. 243.

$$K_t = \frac{I_{t+1}}{g+\theta}$$

where g is the average annual growth rate of IT capital investment (I) and θ is the weighted average rate of depreciation. The real IT capital stock is then derived as follows:

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

where the capital stock, K , at year t is dependent on the level of capital investment, I_t in the same year and capital stock level in the preceding year which is deflated by the rate of depreciation, θ .

6. ESTIMATION RESULTS AND INTERPRETATION

The paper begins with a simple regression of output (real GDP) against factor accumulation, that is, IT capital, non-IT capital and labour, expressed in the following equation:

$$\ln Y = \ln \beta_1 + \beta_2 \ln K_{IT} + \beta_3 \ln K_N + \beta_4 \ln L + u_i \quad (6)$$

where Y , K_{IT} , K_N and L stand for real output, IT capital stock, non-IT capital stock and employment respectively.

Figures for GDP and IT capital investment are deflated by the constant price index and the “fixed asset investment index” obtained from *China Statistical Yearbook* respectively. The choice of the capital depreciation rate, δ , is based on empirical studies of Kim (2002) and Wu (2004) for IT capital and non-IT capital stock respectively. Kim (2002) uses a depreciation rate of 14.2% for Korean IT capital stock in 1977-2000, whereas the rate of depreciation for non-IT capital stock is derived from the total capital stock used in Wu (2004), which stands at $\delta = 0.07$. Since IT equipment turns obsolete faster than other forms of capital, this study assumes 15% as a proxy depreciation rate for China in 1984-2001, i.e. $\delta = 0.15$ to derive the total IT capital stock. The sample has 18 observations for the period of

1984-2001.¹² The initial estimates of the parameters in Equation (6) are presented in Table 3.

All coefficients of the parameters are statistically significant at the correct sign, with intercept term (β_1) at 10% level of significance. The results show that the growths of IT capital as well as physical capital are positively related to China's economic growth from the mid-1980s till the beginning of the 21st century. The coefficients show there is an increasing returns to scale for China's production function.¹³

Table 3 Regression results of China's sources of economic growth, 1984-2001

<i>Regression Statistics</i>				
R Square	0.99386			
Adjusted R Square	0.99255			
Standard Error	0.036739			
Observations	18			
<i>Parameter</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>p-value</i>
β_1 (intercept)	-6.3375	3.6074	-1.7568	0.101
$\ln K_{IT}$	0.071594	0.025051	2.8579	0.013
$\ln K_N$	0.31259	0.10918	2.8630	0.013
$\ln L$	1.0952	0.43132	2.5391	0.024

Sensitivity analysis

The robustness of the estimation results can be examined with a sensitivity analysis by assuming different rates of depreciation for the IT capital stock. The estimated growth rates of IT capital stock show a similar trend of contribution under different depreciation rates (Table 4). It is interesting to note that the contribution from IT capital gets lower as δ increases.

¹² The only available source of time series data for this paper is the *Yearbook of China Electronics Industry*. The period of 1984-2001 was chosen as no data is available for years before 1984. At this stage of research, it is suffice to show that IT has a significant impact on China's economic growth.

¹³ A test of linear restriction on the factor inputs (i.e. constant returns to scale) has been carried out using the Wald test, which rejects the null hypothesis, $H_0: \beta_2 + \beta_3 + \beta_4 = 0$.

Table 4 Results of Sensitivity Analysis

Depreciation rate of IT capital (%)	Contribution to output growth (%)			
	K_{IT}	K_N	L	TFP
10	2.85 (34.5)	3.15 (38.2)	1.80 (21.8)	0.45 (5.5)
12	2.68 (32.4)	3.30 (40.0)	1.82 (22.0)	0.46 (5.6)
15	2.44 (29.5)	3.51 (42.5)	1.83 (22.2)	0.48 (5.8)
18	2.23 (26.9)	3.71 (44.9)	1.84 (22.2)	0.49 (6.0)
20	2.10 (25.4)	3.82 (46.3)	1.84 (22.2)	0.50 (6.1)
25	1.82 (22.0)	4.09 (49.5)	1.83 (22.1)	0.52 (6.3)

Decomposition of output growth

Using the estimates shown in Table 3, the sources of economic growth can be derived. The contributions of the factor accumulations and technical change (or technological progress) to real output growth in China for the period of 1984-2001 are shown in Table 5. The results differ from those of previous studies carried out by the IMF. For example, Lee and Khatri (2003) show the contribution from IT capital and TFP to be 3% and 43% respectively, while in Wang and Yao (2003), TFP contributes 25% to economic growth. Total capital accumulation (IT and non-IT capital) contributes to almost three quarters of economic growth.

This study shows that the contribution from the growth of IT capital has increased by 0.9 percentage points between the 1980s and 1990s, whereas that from TFP growth has declined by 1.2 percentage points. However, this phenomenon can be reconciled with the results from previous studies by questioning whether that the contribution from TFP has been distributed to the IT capital stock, which is yet to be proven. If this is the case, then China's IT sector can be said to be highly efficient and productive. As can be seen here, the contributions from IT capital and TFP sum

up to 36%. A difference in the measurement of IT capital stock between this study and that of Lee and Khatri (2003) is that this paper takes into account the investment in electronic components which is not included in the latter's work. This segment of the electronic industry can be described as the "IT-producing industry" which, in the literature on productivity growth, contributes to TFP growth.

Table 5 Contributions to Output Growth in China, 1984-2001 (unit: %)

	Period			Percentage point change (b)-(a)
	1984-2001	1984-1990 (a)	1991-2001 (b)	
Output growth rate	8.26 (100.0)	7.47 (100.0)	8.69 (100.0)	1.22
IT Capital	2.44 (29.5)	1.82 (24.3)	2.74 (31.5)	0.92
Other Capital	3.51 (42.5)	2.69 (36.0)	3.96 (45.6)	1.27
Labour	1.83 (22.2)	1.70 (22.8)	1.90 (21.9)	0.20
TFP	0.48 (5.8)	1.27 (17.0)	0.09 (1.0)	-1.18

Note: Figures in italic parenthesis () are the weights of each factor growth.

Finally, Table 5 also shows two remarkably contrasting results between the 1980s and 1990s. The former had a lower contribution from IT capital (24%) compared to the pooled period, but a much higher contribution from TFP growth (17%). The reverse is true for the latter period, which saw the contribution from IT capital shooting up to 32%, but that from TFP growth dropped to 1%. Therefore, what can be concluded here is that whether the larger share of TFP growth is attributed to IT capital or not, has so far been unaccounted for in existing literature.

7. CONCLUSION

The empirical results indicate that China's economic growth largely comes from factor accumulation, which shows that the neo-classical approach to growth accounting is still very much relevant today. China's economic growth is largely driven by the expansion of capital investment. Such expansion at a break-neck speed may explain the possible "overheating" of China's economy recently. From the fact that IT investment as a proportion of GDP is much lower than that of other forms of investment, and yet its contribution to economic growth is almost half of the latter, it can be ascertained that IT has become an important contributor to the growth of China's economy. Its rapid economic growth will in turn ensure a continued high demand for IT products and services.

This paper is meant to be a preliminary exercise setting the stage for further potential study in this field of research. The depreciation rate of China's IT capital stock is unknown. Therefore, my future research will focus on the formation of China's IT capital stock. This should shed new lights on the sources of China's economic growth in the late 1990s and the early 21st century. There is also a need for further empirical research on the sources of China's productivity growth that investigates whether there has been a capital reallocation between the IT sector (i.e., "IT-producing" and "IT-using" industries¹⁴) and the non-IT sectors.¹⁵ Lastly, it should be acknowledged that China's regional disparity in IT investment will be an issue for examination. This could bring up debate over whether China should focus its IT investment in the more developed eastern or coastal regions, or to invest more in the inward or western regions.

¹⁴ Dedrick et al. (2003) define IT-producing industries as "those which manufacture semiconductor, computer, or telecommunications hardware or provide software and services that enable these technologies to be used effectively in organizations", whereas IT-using industries are "all the other sectors of the economy that apply IT as part of their operations in order to achieve greater efficiency and effectiveness, and they include manufacturing (durable and nondurable), wholesale and retail trade, finance, insurance and real estate, business and professional services, etc."

¹⁵ On this issue, the study of industry productivity is exemplified in Stiroh (2001, 2002) who explains that productivity revival in the US can be proven by evidence that IT producers and the most intensive users experience the largest productivity acceleration in the late 1990s. Overall, he finds that IT-producing industries have shown the largest productivity gains when compared with IT-using and other industries. Evidence of a stronger contribution from IT capital deepening, that is, IT-using industries than that of IT-producing industries to labour productivity growth can also be found in Australia, as supported by Colecchia and Schreyer (2002) and Parham et al. (2001).

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