Economic effect of information technology in China

Qin Shen（s020310d@mbox.nagoya-u.ac.jp）
〔Nagoya University〕

中国における情報通信技術の経済効果

沈 勤
名古屋大学大学院 環境学研究科

要約

本研究は、新古典派の経済成長モデルによって、1990年から2001年まで中国の情報通信技術（IT）資本のGDP成長に対する寄与を測定し、国際比較研究の視点から中国のIT発展を実証的に研究した。1990年代に入って、GDPの高成長とともに、中国のIT投資が急速に伸びてきた。しかし、アメリカ、日本などの工業先進国と比べて、2001年まで中国IT資本投資の経済効果は大きくなかった。1990年から2001年にかけて、アメリカと日本のIT資本の経済成長に対する平均寄与率はそれぞれ22.8%と35.2%であった。それに対して、中国のIT資本の平均寄与率は7%にすぎなかった。その原因はIT資本ストックの総資本ストックに占めるシェアが非常に小さかったからである。中国のIT資本の中では、通信設備資本の成長寄与が一番大きく、ソフトウェア資本の寄与が一番小さかった。中国のIT発展はまだ遅れていたが、中国と先進国とのIT格差は年々縮小している。また、本論文は中国の「移行経済」の特徴に注目し、全要素生産性（TFP）のGDP成長に対する寄与が減少している現象を検討した。

Key words

IT capital, economic growth, China, international comparison

1. Introduction

The accelerating development of information technology (IT) all over the world since the early 1990's have generated considerable attention, with many studies examining the economic effect of the IT innovation, in particular, measuring the contribution from IT investment to the GDP growth. For example, using the neo-classical growth model, Oliner et al. (2000), Jorgenson et al. (1999, 2001), Bassanini et al. (2000), Motohashi (2002), and Shinozaki (2003) estimated the economic effect of IT investment in U.S., OECD countries and Japan respectively.

This study focuses on measuring the growth contribution from China's IT capital and TFP (total factor productivity) etc. by using the conventional neo-classical growth model. The results will be compared to other studies, such as Oliner et al. (2000), Jorgenson (2001), Motohashi (2002), and Shen (2004).

The study begins with constructing the China's IT capital stock data in 1990-2001, then turns to calculating the contribution of the IT capital to the GDP growth, and finally discusses the measurement errors and some characteristics of Chinese transition economy.

2. Methodology

The neo-classical model employed in this study is based on the following standard production function

$$Y = A \cdot F(K, L) \tag{1}$$

where Y is output, K is capital input, L is labor input, A is referred to Hick-neutral technical progress, or called as TFP. The capital K can be divided into computer capital K_C, software capital K_S, communications equipment capital K_M (K_C, K_S, and K_M are called as IT capital in this paper), and Non-IT capital K_N. Thus, the equation (1) becomes

$$Y = A \cdot F(K_C, K_S, K_M, K_N, L) \tag{2}$$

Under the assumption that product and factor markets are competitive, the following growth accounting equation can be given

$$\frac{\dot{Y}}{Y} = s_C \frac{\dot{K}_C}{K_C} + s_S \frac{\dot{K}_S}{K_S} + s_T \frac{\dot{K}_M}{K_M} + s_N \frac{\dot{K}_N}{K_N} + s_L \frac{\dot{L}}{L} + \frac{\dot{A}}{A} \tag{3}$$

where $\dot{Y}/Y$, $\dot{K}_C/K_C$, $\dot{K}_S/K_S$, $\dot{K}_M/K_M$, $\dot{K}_N/K_N$, $\dot{L}/L$, and $\dot{A}/A$ denotes the growth rate of output, computer capital, software capital, communications equipment capital, Non-IT capital, labor, and TFP respectively, and the weights s_C, s_S, s_M, s_N, and s_L denotes each factor's expenditure share ($s_i = \frac{p_i \cdot K_i}{Y}$ for $i = C, S, M, N$, under the assumption of perfect competitive). Under an additional assumption of constant returns to scale, $s_C + s_S + s_M + s_N + s_L = 1$.

As mentioned above, the important premises of this model are perfect competition and constant returns to scale. The two premises are not completely satisfied even in the market economy, such as in the United States (Hall, 1988,1990). For this reason, Basu et al. (2001) proposed a more exact measuring method. Because the Chinese economy is the transition economy (from a planned economy to a market economy), setting the prices for products or factors of production does not depend on the competitive markets completely. Thus, using this model to estimate the economic effect of China's IT may cause a measurement error.

The methodology of this study is very similar to that in Oliner et al. (2000), since we use the same production function and capital stock data. The difference between our methodologies is that Oliner et al. (2000) uses the productive capital stock data of IT goods, while I only use the general capital stock data. In addition, Jorgenson (2001) and Motohashi (2002) also use the neo-classical model, but they adopt the production possibility frontier and use the capital service data.

3. Data

3.1 IT capital stock

This study starts with constructing the time-series data of China's IT capital stock from 1989 to 2001 using the perpetual inventory method and annual IT investment data constructed in Shen (2004). If the relative efficiency of IT capital goods decreases geometrically at a constant exponential rate, the IT capital stock can be calculated as follows

$$K_t = I_t + (1-d)K_{t-1} \quad (4)$$

where K_t is the IT capital stock at a point of time t, I_t is the IT investment, and d is the depreciation rate. In this study, I suppose that all of the IT capital goods follow the exponential efficiency-declining pattern.

The first step in constructing IT capital stock data is measurement of the initial capital stock in a chosen base year. Chow (1993) estimated China's initial total capital stock in 1952 using the regression analysis in order to construct the time-series data on China's total capital stock from 1953 to 1980. Because there are not much sample data for using the regression analysis, I adopt the Geometric Series Method (1) in this study. This method is based on the assumption that the IT investments increase at the same growth rate before a base year. In this study, the base year is set to 1989. The initial IT capital stock in 1989 was calculated as shown in Table 1. The service life (T) of IT capital goods in China are assumed to be equal to that in U.S. (BEA, 1997), and the depreciation rates are calculated by the formula $d = 2/T$, which is often used to calculate the depreciation rate of fixed assets approximately.

Table 1: Service life, depreciation rate of IT capital goods and estimating of the initial IT capital stock in 1989

	Computer	Software	Communications
Service life (T)	7	5	11
Depreciation rate (d)	0.29	0.40	0.18
Average growth rate (g) before 1989	0.58	0.58	0.36
Investment in 1989	45	1.2	59
Capital stock in 1989	82	2	149

Note: The unit of service life is year, and the values of investment and stock are in one hundred million yuan in constant price (1990).

Using the estimated initial IT capital stock in 1989 and the China's IT investment data, I constructed the annual IT capital stock data from 1990 to 2001. The results are shown in Table 2.

Table 2: China's IT real investment and real capital stock

	Computer		Software		Communications	
Year	I	K	I	K	I	K
1989	45	82	1.2	2	59	149
1990	46	105	1.2	2	68	191
1991	59	133	1.7	3	89	245
1992	83	178	1.2	3	136	336
1993	113	240	1.8	4	184	460
1994	222	392	4	6	285	661
1995	193	471	4.3	8	493	1036
1996	332	667	4.3	9	683	1532
1997	299	772	4.4	10	762	2019
1998	657	1205	7.4	13	1298	2953
1999	806	1662	40.7	49	1426	3848
2000	1193	2373	122.9	152	1939	5094
2001	1318	3003	153.7	245	2069	6246

Notes: "I" stands for investment, and "K" for stock. The values of real investment and stock are in one hundred million yuan in constant price (1990). The investment data are constructed by using the statistics from China Electronic Industrial Yearbook (1990-2002).

3.2 Total capital stock

Mainly two methods were used for calculating the China's total capital stock. One is Chow (1993)'s method, the other is He (1992)'s. This study adopted Chow (1993)'s method, because the method is appropriate for the SNA (System of National Accounts) that has been employed in China since 1992. He (1992)'s method is suitable for the MPS (Material Product Balances), which was a national economy accounts system adopted for Chinese planned

Table 3: China's total real investment and real capital stock

	This study		Zhang (2002)
Year	Total investment	Total capital stock	Total capital stock
1989	6714	60699	59955
1990	6444	64715	64850
1991	6646	68772	70045
1992	7719	73740	76533
1993	10673	81464	84872
1994	12006	90211	94695
1995	13784	100386	105590
1996	15123	111494	117585
1997	16337	123371	130420
1998	17793	136230	145089
1999	19171	149951	NA
2000	20064	164017	NA
2001	23175	180631	NA

Note: The values are in one hundred million yuan (1990 price).

economy decades before.

Following Chow's method, at first, I convert the initial total capital stock of 3,344,500 million yuan in 1989 (1978 price) into 6,069,800 (1990 price). Then, I use the China's total investment data in 1990-2001 from China Statistical Yearbook, and the formula $K_t = I_t + (1-d)K_{t-1}$ (d=0.04) to obtain the total capital stock data as shown in Table 3. Zhang (2002) calculated the China's total capital stock by He (1992)'s method. It is interesting that the result of this study is close to Zhang (2002)'s.

3.3 Expenditure share of capital and labor

According to the neo-classical model demonstrated in section 2, the expenditure share of each type of capital is equal to $p_i \cdot K_i / Y$ (for $i = C, S, M, N$), where p_i is the user cost of the type of capital goods, K_i is the capital stock, $p_i \cdot K_i$ is the capital service. Under the assumption of perfect competition, a firm accumulates the capital stock to an optimal level at which marginal profit is equal to marginal cost. Thus, the formula for calculating the user cost of capital is given by [2]

$$p = \frac{(1-k-uz)(r+d-\dot{P}_I / P_I)}{(1-u)} \quad (5)$$

where r is the rate of return, d is the depreciation rate of capital goods, $\dot{P}_I / P_I$ is the change rate of acquisition price of capital goods, u is the corporation tax rate (including the corporate income tax and business taxes), and k is the rate of deduction of investment tax, z is the present value of depreciation allowances on one unit of investment. The z at point of time t is obtained by

$$z_t = \int_t^{\infty} d e^{-(r+d)s} ds = \frac{d}{r+d} \quad (6)$$

In China, the investment tax credit k is equal to zero. The tax rate u for the period 1990-1993 was 55%. The tax rate has been 33% since 1994. Thus, we obtain the following approximate formula for measuring the user cost of China's capital goods

$$p = \frac{\left(1 - \frac{ud}{r+d}\right) \cdot (r+d-\dot{P}_I / P_I)}{(1-u)} \quad (7)$$

As we know from the formula (7), because the depreciation rate of IT capital goods is larger than that of non-IT capital goods, and the price change rate of IT products is generally minus, the user cost of IT capital is several times as large as that of non-IT capital.

The capital service is obtained by multiplying the capital stock by the user cost. Table 4 presents the calculated China's nominal capital service and nominal capital stock from 1990 to 2001. Using the capital service data we can calculate the expenditure share of each type of capital.

The sum of expenditure shares of all factors calculated in this way is not equal to one, however, because the method for estimating the capital service in China's official statistics is different from that used above. For this reason I adjusted the measurement of expenditure share of each type of capital goods using the expenditure share of total capital denoted by s_{TC} and the calculated capital service for each type of capital. Particularly, I divide the expenditure share s_{TC} of total capital into four sub-shares for computer, software, communications equipment, and non-IT capital. The sub-shares are obtained by $s_i = \frac{p_i \cdot K_i}{\sum p_i \cdot K_i} \cdot s_{TC}$ for $i = C, S, M, N$.

According to the official statistics from China Input-Output Table (1992, 1995, 1997), the expenditure share s_{TC} of total capital for 1992, 1995, and 1997 was about 0.55, 0.53 and 0.45 respectively. Using these data and the interpolation and extrapolation method, I constructed the annual time-series data on the expenditure share of total capital from 1990 to 2001. Then I estimated all of sub-shares shown in Table 5.

Table 4: China's nominal capital stock and nominal capital service

	Computer		Software		Communication		Non-IT	
Year	Se	St	Se	St	Se	St	Se	St
1990	63	105	1.5	2	89	191	3414	64417
1991	72	122	1.8	3	103	230	3935	74950
1992	88	147	1.8	3	135	297	4633	92652
1993	116	178	1.7	4	189	379	6482	129648
1994	110	314	4.5	5	157	572	7439	158295
1995	205	273	7.9	10	236	961	19989	186350
1996	168	394	6.9	9	620	1223	30382	215058
1997	173	481	5.3	10	571	1518	34632	241834
1998	369	593	7.0	13	759	2046	36236	266067
1999	256	885	20.3	49	849	2492	36739	291177
2000	428	1327	77.8	150	949	3218	33376	321087
2001	536	1804	121.3	235	1226	3729	41082	354449

Note: "Se" stands for capital service, and "St" for capital stock. The values are in one hundred million yuan.

Table 5: Expenditure share of each factor

	IT capital stock			Non-IT	Labor
Year	Computer	Software	Communication		
1990	0.0097	0.00022	0.0137	0.526	0.45
1991	0.0096	0.00024	0.0138	0.526	0.45
1992	0.0100	0.00021	0.0153	0.525	0.45
1993	0.0094	0.00014	0.0153	0.525	0.45
1994	0.0077	0.00032	0.0110	0.521	0.46
1995	0.0053	0.00020	0.0061	0.518	0.47
1996	0.0026	0.00011	0.0097	0.478	0.51
1997	0.0022	0.00007	0.0073	0.440	0.55
1998	0.0044	0.00008	0.0091	0.436	0.55
1999	0.0030	0.00024	0.0101	0.437	0.55
2000	0.0055	0.00101	0.0123	0.431	0.55
2001	0.0056	0.00127	0.0128	0.430	0.55

Notes: The expenditure share of IT capital or Non-IT capital is estimated by using the nominal capital service.

4. Sources of GDP growth

By using the growth accounting formula (3) and the data in Table 5 and Table 6 the China's GDP growth in 1990-2001 is decomposed as shown in Table 7 and Table 8. Here I calculated both the growth contribution and the contribution rate of each factor. The contribution rate of a factor in percentage term is defined as a share of the growth contribution of the factor in the GDP growth. In order to examine the changes in contribution or contribution rate of IT capital stock over time, I calculate the average growth contributions of all factors for the sub-period of 1991-1995 and 1996-2001, excluding the questionable results for 1990 when Chinese central government carried out a series of macro-economic policies.

Table 6: Growth rate of each factor

Year	IT capital stock			Non-IT (%)	Labor (%)
	Computer (%)	Software (%)	Communication (%)		
1990	27.7	19.4	27.9	6.5	1.5
1991	27.4	29.9	28.5	6.2	1.1
1992	33.2	0.1	37.5	7.1	1.0
1993	34.9	18.7	36.6	10.3	1.0
1994	63.8	68.3	43.9	10.4	1.0
1995	20.1	30.0	56.6	10.9	0.9
1996	41.5	13.3	47.9	10.5	1.3
1997	15.8	8.6	31.8	10.3	1.3
1998	56.1	34.3	46.3	9.5	1.2
1999	37.9	265.4	30.3	9.3	1.1
2000	42.8	212.3	32.4	8.3	1.0
2001	26.6	61.0	22.6	9.4	1.3

Notes: The growth rate of each type of capital stock is calculated by using the real capital stock. According to *China Statistical Yearbook*, the growth rate of labor in 1990 was 17.1%. The data is unusual, because two different methods for labor statistics were adopted before and after 1990. The growth rate of labor 1.5% for 1990 in this table is adjusted by averaging 1.8% for 1989 and 1.1% for 1991.

Table 7: Sources of China's GDP growth

	IT capital				Non-IT	L	TFP	GDP growth rate
	C	S	M	Total				
1990	0.27	0.0043	0.38	0.65	3.44	0.68	-1.0	3.8
1991	0.26	0.0073	0.39	0.66	3.25	0.52	4.8	9.2
1992	0.33	0.00002	0.57	0.90	3.71	0.45	9.1	14.2
1993	0.33	0.0026	0.56	0.89	5.41	0.45	6.8	13.5
1994	0.49	0.0217	0.48	1.00	5.41	0.45	5.7	12.6
1995	0.11	0.0061	0.35	0.46	5.65	0.43	4.0	10.5
1996	0.11	0.0014	0.47	0.58	5.03	0.66	3.3	9.6
1997	0.03	0.0006	0.23	0.27	4.55	0.69	3.3	8.8
1998	0.25	0.0029	0.42	0.68	4.16	0.64	2.3	7.8
1999	0.12	0.0640	0.31	0.48	4.08	0.59	1.9	7.1
2000	0.24	0.2134	0.40	0.85	3.59	0.53	3.0	8.0
2001	0.15	0.0775	0.29	0.52	4.06	0.72	2.0	7.3
91-95	0.30	0.01	0.47	0.78	4.68	0.46	6.08	12.0
96-01	0.15	0.06	0.35	0.56	4.24	0.64	2.66	8.1

Notes: "C" = Computer; "S" = Software; "M" = Communications; "L" = Labor.

Table 8: Contribution rate of each factor and TFP

	IT capital				Non-IT (%)	L (%)	TFP (%)
	C (%)	S (%)	M (%)	Total (%)			
1990	7.1	0.114	10.0	17.2	90.5	17.8	-25.5
1991	2.8	0.079	4.3	7.2	35.3	5.6	51.9
1992	2.3	0.0002	4.0	6.4	26.1	3.2	64.3
1993	2.4	0.019	4.2	6.6	40.0	3.3	50.1
1994	3.9	0.172	3.8	7.9	43.0	3.5	45.6
1995	1.0	0.058	3.3	4.4	53.8	4.0	37.8
1996	1.1	0.015	4.9	6.0	52.4	6.9	34.7
1997	0.4	0.007	2.6	3.0	51.7	7.9	37.4
1998	3.2	0.037	5.4	8.7	53.3	8.3	29.8
1999	1.6	0.902	4.3	6.8	57.4	8.3	27.4
2000	3.0	2.668	5.0	10.6	44.8	6.7	37.9
2001	2.0	1.062	4.0	7.1	55.5	9.8	27.5
91-95	2.5	0.07	3.9	6.5	39.6	3.9	49.9
96-01	1.9	0.78	4.4	7.0	52.5	8.0	32.5

Notes: "C" = Computer; "S" = Software; "M" = Communications; "L" = Labor.

Table 7 and Table 8 present the following four important facts:

(1) The contribution of capital input to the GDP growth was far larger than that of labor input. The average contribution of capital for 1991-1995 was about 5.5%, and it was about 12 times as large as that of labor during the same period. For 1996-2001, the average value was about 4.8% and 8 times large. This result is similar to those of other studies (e.g. Zhang, 2002). The fact implies that Chinese economic growth was mainly depended on the capital deepening during the 1990s, like Asian Newly Industrializing Countries (NIC'S) during the 1970s. However, the contribution of China's labor input was increasing rapidly. The average contribution rate of labor was about 8% in 1996-2001, compared to about 3.9% in 1991-1995.

(2) During the period of 1991-1995, the contribution from traditional non-IT capital was about 4.7%, and it was about 6 times as large as that from IT capital. For 1996-2001, the contribution was 4.2% and about 7 times large. The average contribution rate of non-IT capital was about 39.6% for 1991-1995

and 52.5% for 1996-2001, while average contribution rate of IT capital was only about 6.5% and 7%. Therefore, it can be said that the economic effect of China's IT was still small in 1990-2001.

(3) Of the three types of IT capital, the communications equipment capital was the largest contributor. The average contribution rate of this capital was about 3.9% for 1991-1995 and 4.4% for 1996-2001, while that of computer capital was about 2.5% and 1.9% respectively; and that of software capital was only about 0.07% and 0.78%. However, the contribution of software capital has been increasing sharply. The average contribution of software capital increased about 11 times in 1996-2001, compared with 1991-1995. In addition, the Table 8 shows that there was an upward trend in the growth contribution of total IT capital during 1990-2001, but the contribution of computer capital decreased to some extent. The reason will be explained in next section.

(4) There is an important feature in the result shown in Table 8. The contribution from China's TFP growth was extremely large in 1991-2001. The average contribution rate was about 49.9% for 1991-1995 and 32.5% for 1996-2001. However, the TFP growth has been decreasing since 1993. This phenomenon may reflect one of the characteristics of the Chinese transition economy, which is examined in section 5.4.

5. Examination of the results

5.1 Measurement error

In this study, there may be at least two kinds of measurement errors or biases. The first kind of error exists in adopting the neoclassical model for accounting for Chinese economic growth, since Chinese economy was not under perfect competition in 1990-2001. Moreover, this kind of error also exists in calculating the expenditure share of IT capital, because estimating the user cost of capital is also based on the assumption of perfect competition. For example, the return rate r, which is treated as nominal interest rate, undoubtedly deviates from the real rate of return due to strong monetary control from Chinese government during the 1990s.

The second error is connected with the calculation of IT capital stock. For example, when I calculate the computer capital stock, the service life of computer is assumed to be seven years. The assumption is the same as that in some advanced nations, such as the United States. In fact, the service life of computer (particularly mainframe computer) in China is actually more than seven years, according to some government regulations or accounting reports from Chinese firms published on the Internet [(3)]. Therefore, there may be the underestimation of China's computer capital stock. The error may lead to the underestimation of growth contribution from computer capital and total IT capital. If the service life of computer is assumed to be nine years, the average growth contribution rate of computer capital or total IT will add 0.4 percentage points for the period 1991-1995 and 0.2 percentage points for 1996-2001. Furthermore, if the service life of computer is extended from seven years to eleven years, the average contribution rate will jump 0.7 percentage points for 1991-1995 and 0.4 for 1996-2001 (See Table 9). However, even if the service life of computer is eleven years, the contribution of computer capital was still small in 1991-2001, and the communications equipment capital remained the leading contributor to the economic growth.

Table 9: Service life of computer and average growth contribution

Period	Capital	Service Life (years)					
		7		9		11	
		C	Rate	C	Rate	C	Rate
1991-1995	Computer	0.30	2.5	0.35	2.9	0.38	3.2
	Total IT	0.78	6.5	0.83	6.9	0.86	7.1
1996-2001	Computer	0.15	1.9	0.17	2.1	0.18	2.3
	Total IT	0.56	7.0	0.58	7.2	0.59	7.4

Note: "C" stands for contribution of computer or total IT capital stock. Rate=C ＊ 100/GDP (%)

5.2 International comparison

Table 10 shows the results of four studies on the GDP growth accounting in China, Japan, and United States. All of these studies are based on the neo-classical model, but there are some differences among the methodologies of those studies as mentioned in section 2. Nevertheless, the difference from using different methodologies based on the same model is small. For example, Oliner et al. (2000)'s methodology is different from Jorgenson (2001)'s, but the two results are very similar. Because China's total IT capital stock was far smaller than that in U.S. and Japan in 1990-2001, the difference in methodologies and some assumptions of the neo-classical model used for estimating the contribution of China's IT capital is likely to be small.

Table 10: The comparison of growth contribution from IT capital among China, Japan and U.S.

	China		Japan		U.S.			
	This Study		Motohashi (2002)		Oliner et al. (2000)		Jorgenson (2001)	
	91-95	96-01	90-95	95-00	91-95	96-99	90-95	95-99
GDP growth	12.0	8.1	1.69	1.45	2.75	4.82	2.36	4.08
IT capital	0.78	0.56	0.15	0.51	0.57	1.10	0.48	0.99
Comp.	0.30	0.15	0.09	0.21	0.25	0.63	0.22	0.55
Software	0.01	0.06	0.02	0.11	0.25	0.32	0.16	0.29
Comm.	0.47	0.35	0.03	0.07	0.07	0.15	0.10	0.14
Non-IT	4.68	4.24	1.01	0.34	0.44	0.75	0.61	1.07
Labor	0.46	0.64	-0.04	-0.14	1.26	1.81	1.03	1.27
TFP	6.08	2.66	0.57	0.74	0.48	1.16	0.24	0.75

Note: Comp.=Computer; Comm.=Communications. This study and Oliner et al. (2000) are based on capital stock, while Motohashi (2003) and Jorgenson (2001) are based on capital service.

As seen from Table 10, the contributions of IT capital in U.S. and Japan increased more rapidly in the second half of the 1990s than in the first half of the 1990s. This strong upward trend was not shown in China. However, if we pay attention to the fact that China's GDP growth rate was quite large in the 1990s, the average contribution rate of China's IT capital was about 7%, compared to 35.2% for Japan's (Motohashi, 2003) and 22.8 % for U.S.'s (Oliner et al., 2000). Thus, the economic effect of IT investment in China was still far smaller in 1991-2001 than that for Japan or the United States.

Another phenomenon is that unlike in U.S. or Japan, the communications equipment capital, instead of the computer or software capital, played the most important role in China's IT development from 1991 through 2001. The phenomenon and its reason are explained in Shen (2004).

5.3 Comparison with the result of Shen (2004)

Shen (2004) estimates the contributions of IT investment to the economic growth using a simple approach based on the expenditure side of national accounting identity (called as NAI approach in this paper). This approach uses the following accounting identity: $Y = C_p + C_g + I_p + I_g + (E - M)$, where Y is GDP; C_p and C_g is private and government consumption expenditure; I_p and I_g is gross private and government investment; $(E - M)$ is net export of goods and services. From the identity above, the following growth accounting equation can be obtained:
$\frac{\Delta Y}{Y} = s_C \cdot \frac{\Delta I_C}{I_C} + s_S \cdot \frac{\Delta I_S}{I_S} + s_M \cdot \frac{\Delta I_M}{I_M} + s_N \cdot \frac{\Delta I_N}{I_N} + s_D \frac{\Delta D}{D}$, where I_C, I_S, I_M, and I_N is computer, software, communications equipment, and gross non-IT investment respectively; $D = C_p + C_g + (E - M)$, it stands for the other final demands. The contribution of IT investment is calculated by $s_i \cdot \frac{\Delta I_i}{I_i}$ for $i = C, S, M$, where $s_i = \frac{I_i}{Y}$ is the expenditure share of each type of IT investment; $\frac{\Delta I_i}{I_i}$ is the growth rate of each type of IT investment. Unlike the neo-classical model, the NAI approach cannot be employed for estimating the economic effect of the accumulated IT investment and the rise in productivity. However, there is an important advantage in the approach. There are no behavioral assumptions, such as perfect competition and constant returns to scale. Therefore, the NAI approach can be directly used for a transition economy like Chinese economy.

Table 11 shows a comparison between two sets of results of the neo-classical model and NAI approach. As seen from the table, there are four interesting facts.

(1) The two sets of results for IT capital is generally similar except for computer capital. The main reason is that the IT capital stock data used in the neo-classical model are closely correlated to the IT investment flow data used in the NAI approach. This is probably due to the fact that the service life of IT capital goods is relatively short.

(2) The upward trend in the contribution rate of total IT capital from 1991-1995 to 1996-2001 in this study is the same as that in Shen (2004). However, the increment of contribution rate of IT capital between two sub-periods in this study is far smaller. It is because this study uses capital stock data, instead of investment flow data as in Shen (2004).

(3) This study shows that only the growth contribution of computer capital decreased in 1991-2001. The reason is that the depreciation and the price change of computer capital goods are taken into account in this model. Therefore, it is possible that the growth of the computer capital stock is far smaller than that of two other types of IT capital stock, since the depreciation and the price change rate of computer capital is much larger. It is the slower growth in the computer capital stock that closely relates to the decrease in growth contribution of computer.

(4) There is an upward trend of the growth contribution from non-IT capital as shown in this study. In contrast, the result of Shen (2004) presents a downward trend. It is because the contribution of one type of capital goods is the product of expenditure share and growth rate of the type of capital goods. When the expenditure shares are close to the same value, the trend of contribution depends heavily on the trend of growth rate. In each of these two studies, the trend of growth rates of non-IT capital depends on the trend of the growth contribution of non-IT capital to a large extent.

These four facts confirm that the two studies are complementary. Shen (2004) measured the economic effect of China's IT investment flow, and showed the acceleration in China's IT investment and the rapidly increasing growth contribution from the IT investment. In contrast, this study measured the effect of IT capital stock which is seen as the accumulated IT investment, and presented that a substantial economic effect of IT on the GDP growth in China has not appeared yet, unlike in U.S. and Japan, due to the far smaller share of IT capital stock in the total capital stock. Moreover, because no additional assumptions are neces-

Table 11: Comparison for the sources of China's GDP growth

	This Study		Shen (2004)	
	1991-95	1996-01	1991-95	1996-01
GDP Growth	12.0	8.1	12.0	8.1
Contribution Rates to GDP Growth:				
Gross Capital	46.1	59.6	54.8	40.9
IT Capital	6.5	7.0	3.4	7.7
Computer	2.5	1.9	1.0	2.6
Software	0.07	0.78	0.03	1.21
Communications	3.9	4.4	2.4	3.9
Non-IT Capital	39.6	52.5	51.4	33.2
Labor	3.9	8.0	—	—
TFP	49.9	32.5	—	—
Others	—	—	50.8	56.0

Note: The values are in percentage (%).

sary for the NAI approach, the result of Shen (2004) can be used to examine that of this study to a certain extent. For example, the third fact above may correlate with price-formation for computer products in China, since the Chinese computer market was not a market under perfect competition in 1991-2001.

5.4 The characteristics of the Chinese transition economy

From Table 7, Table 8 and Table 10, we notice that the contribution of capital input was considerably larger than that of labor input, and that the contribution from TFP has been decreasing since 1993. These two phenomena reflect two major characteristics of the Chinese transition economy.

The first characteristic is similar to the finding of Kim et al. (1994) and Young (1994) on the rapid economic growth of East Asia NICs (Hong Kong, Singapore, South Korea, and Taiwan), which was mainly depended on the capital deepening during the period of 1960-1985. Like in the NICs, China's capital deepening was increasing rapidly in the 1990s. The high savings rate of Chinese economy and the rapid rise in the foreign direct investment (FDI) may be the main factors of the capital deepening. Moreover, according to Shu et al. (2002), the marginal productivity of China's capital was not diminishing in 1952-1998. This may be related to the fact that the growth contribution of capital input became larger with the rise in capital deepening.

The second has been already pointed out by Borensztein et al. (1996). The main economic effect on the GDP growth from Chinese economic reform began in 1978 was rearrangement of the factors of production such as capital and labor more efficiently. That is, the aggregate economy was forced to move near the production frontier. This economic effect was reflected in TFP (in generally, it is thought that TFP includes technical progress, system innovation, and rise in the management power). With the enhancement of the economic reform toward a market economy, this kind of effect is getting weak gradually. Thus, I think that if there is no real technical progress, like the IT innovation, China's TFP will decline further.

6. Conclusions

From the analysis above, I make the following conclusions. First, the China's IT capital stock increased steadily in 1990-2001, but the economic effect of IT capital in China was not substantial, unlike in U.S. and Japan. It is because the share of China's IT capital stock in the total capital stock, or the expenditure share of China's IT capital in the GDP was still considerably small. Specifically, the average contribution rate of China's IT capital in 1991-2001 was about 7%, compared to 35.2% for Japan and 22.8 % for U.S. Second, the upward trend of accelerating in growth contribution from IT capital has not emerged in China yet during the 1990s. Third, the communications equipment capital was the largest IT contributor to the economic growth in China, in contrast to the computer and software capital's leading roles in Japan and U.S. Finally, the growth contribution from TFP in China was extremely large in the 1990s, but the contribution has been decreasing since 1993. In brief, China's IT development still lagged behind some advanced countries such as U.S. and Japan in 1990-2001. However, the gap between China and the advanced countries was getting narrow.

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Notes

(1) Geometric Series Method is based on the assumption that capital investment increases at the same growth rate g before a chosen point of time t. Thus, the investment values for all of periods become a geometric series. Let I_t stand for the investment at t, K_t denote the capital stock, and d denote the depreciation rate of the capital goods. Then we have

$$K_t = I_t + \left(\frac{1-d}{1+g}\right) I_t + \left(\frac{1-d}{1+g}\right)^2 I_t + \left(\frac{1-d}{1+g}\right)^3 I_t + \cdots + \left(\frac{1-d}{1+g}\right)^n I_t$$

$$\therefore \quad K_t = I_t \cdot \frac{1+g}{g+d} \quad \text{or} \quad K_t = \frac{I_{t+1}}{g+d} \qquad \text{(i)}$$

Using the formula (i), we can estimate the initial capital stock approximately. Suzuki et al. (1986, pp.140-141) used the method for estimating the technical knowledge stock.

(2) See Jorgenson (1963), Christensen & Jorgenson (1973), and Suzuki et al. (1986, pp.76-77).

(3) See: http://zz-www.sd.cninfo.net/song/law/mainlaw/depart/law08/74.txt ; http://finance.sina.com.cn/stock/company/sh/600018/14/20031231F39_1040.html.

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