Estimates of Capital Input index by Industries: The People's Republic of China (1980-2000)

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Abstract:

The purpose of this paper is to report estimates of capital input index classified by industries in the People's Republic of China (1980-2000). We estimated capital stock based on the perpetual inventory method, and then estimate the flow of capital service and capital service price consistently with the capital compensation in input-output table. The various assumptions and adjustments made on the data and estimation implementation in our study were discussed. Several issues remained to be dealt with in the further study were identified.

Keywords: Capital Stock, Capital Input, Capital Rental Price, Rate of Return

[1] The paper is based on the KLEMS project. This KLEMS project was funded by the Research Institute of Economy, Trade and Industry, Tokyo, Japan, National Natural Science Foundation of China (grant no. 70173029) and the U.S. Environmental Protection Agency (EPA Work Order 3W-0258-NASX). We thank Dale Jorgenson, Mun Ho, Masahiro Kuroda, Kazuyuk Motohashi, Kazushige Shimpo, Hiroki Kawai, Hak K. Pyo, Chi-yuan Liang and Marcel Timmer for their advice and comments.

1. Introduction:

Many interesting economic problems require measure of capital service. For example, how are we to understand the process of economic growth if we cannot agree on how to measure one of the potentially most important factors influencing that process? What can we say about such important issues as why growth rates differ across countries? The fields of study in which capital service estimates might play a key role seem to comprise four main areas. They are 1) the study of the processes of economic growth, including the role of investment in these process, the distribution of income between profits and wages, and the relationship between capital input and output in the different industrial sectors of the economy. 2) Methods of forecasting the future method for capital goods involving study of the relationship between output, desired capital stock and investment.3) Study of the distribution of wealth between and within institutional sectors. 4) Assess investment inventive policies or monitor their impacts on the relative capital intensities of specific industries.

Until recently the study of sources of economic growth in China has been based on the aggregate production function. At the same time the concept of an aggregate production function is highly problematical, requiring very stringent assumptions on production patterns at the level of individual sectors of the economy. Furthermore most researches have taken capital stock as a measure of capital input. This approach ignores the heterogeneity among components of capital input reflected in the growth of capital quality. The distinction between the concept of capital stock and capital flow is important. If we are concerned with factors contributing to gross product, including the using up of capital assets, then the appropriate measure of capital input would seem not to be gross capital stock but a measure of the capital service flow.

The flow of capital service is similar to the flow of labor hours but, unlike labor hours, usually can not be measured directly because companies own most of the capital assets that they use. Market data are thus inadequate for the task of directly estimating the price and quantity of capital services, and this has led to the development of indirect procedures for inferring the quantity of capital（like the PIM）, or to the acceptance of flawed measures（like book value）.

In this paper, we estimated China's capital service flow by sectors for 1980-2000 by KLEMS framework formulated in Jorgenson (1987), OECD productivity manual (OECD, 2001) and OECD capital measurement manual (OECD, 1999). We apply the resulting measures of capital input to the study of total factor productivity. Our approach of measuring capital input is to infer the level of capital stock and rental prices. Data on asset prices and rates of replacement together with data on investment are required for PIM estimates of capital stock. Measurement of capital services requires the same data as the PIM for measurement of capital stock together with data on total property compensation and the tax structure. The paper is structured as follows. Section 2 reports the measurement of capital stock in thirty three industries of Chinese economy during 1981-2000. Section 3 presents the rental price and tax structure. Section 4 gives the capital input by sector estimation result. The discussion about the implication of the capital input index was given in the concluding remarks.

2. The Measurement of Capital Stock

2.1 The perpetual inventory method

We have cross-classified the capital input of each industrial sector by 3 types of assets: structure, equipment, and auto. Our first task is to construct estimates of capital stock by type of asset for each sector.

Broadly there are two methods of measuring capital stock, through a survey or via perpetual inventory method(PIM)[2]. In practice, due to cost of surveys, the PIM is the only real alternative. For depreciable assets- structure, equipment, auto- we employ the PIM to estimate capital stocks from data on investment. PIM assumes that the capital stock is the weighted sum of past investments, with weights given by relative efficiencies of capital goods of different ages. Based on the concepts introduced above the perpetual inventory methods can be expressed by the following equation:

$$A_t = \sum_{\tau=0}^{\infty} d_\tau I_{t-\tau} \tag{1}$$

A_t : capital stock at time τ ; d_τ : the relative efficiencies of capital goods of age τ ; $I_{t-\tau}$: the investment at time $t-\tau$.

In the declining balance pattern[3], efficiency declines geometrically. PIM may be represented in the below form in discrete time:

$$A_t = A_{t-1} + I_t - \delta A_{t-1} \tag{2}$$

δ : depreciation rate , which is equal to rate of replacement in the declining balance pattern.

The data required for implementation of PIM are investment data, investment price deflator, capital stock benchmark, and rate of replacement for each capital type.

2.2 Investment data

In china statistical data, there are two kinds data series which can be used in the PIM(investment in fixed assets and the gross fixed capital formation).“Investment in fixed assets” excludes the value of land because land is an intangible asset, the purchase of second-hand capital goods, the small-scale investment. Prior to 1997, the value limit of investment in fixed assets was 50,000 Yuan; after 1997, the value limit becomes 500,000 Yuan. The published data of 1996 come according to both definitions, the new coverage eliminates 0.26% of the previous coverage.

But the value of “investment in fixed assets” and “gross fixed capital formation” are very similar. Between 2001 and 2003, the ratio of gross fixed capital formation to investment in fixed assets fell

[2] The perpetual inventory method is discussed by Goldsmith and employed extensively in his Study of Saving
[3] There are 3 kind of relative efficiency pattern: the declining balance pattern, the one-hoss shay, straight line pattern.

from 0.9892 to 0.9223, this follows a value of around unity before 2001. But there is only available investment in fixed asset by sector, so we used the investment in fixed assets to estimate capital stock.

Our main sources of investment data are “China statistical yearbook” and “China statistical yearbook on investment in fixed assets”. We compared the investment data from different data sources, and found the investment data from different sources are the same. Investment published in China before 1950 is null. And till now, statistics mainly focused on the investment data for state-owned firms.

We can obtain the aggregate investment time series for the whole economy, the state-owned firms from the “China statistical yearbook”. Chinese statistical investment data are generally divided into 3 categories: the investment in structure, the equipment and others. The investment in others refers to the expenses that are necessary to do the work with the relation to the structure and installation projects and to the purchase of equipment. We reallocated the investment in other into the investment in structure and in equipment according to the ratio of investment in structure to investment in equipment. Then we can obtain the aggregate investment in structure, equipment of the whole economy, the state-owned firms.

The investment data of auto vehicle data is not available. We use the annual domestic revenue of auto vehicle plus the net import value of auto vehicle as the domestic consumption value of auto vehicle. The value of domestic consumption of vehicle is obtained by sales Revenue of domestic vehicle industry plus the net imports value of vehicle industry(subtract exports value of vehicle from imports value of vehicle industry). But the domestic consumption value of auto vehicle is composed by two parts: auto consumption by household and auto consumption by businesses. From the economical perspective, the auto consumption by households isn’t the part of investment of auto vehicle. The problem isn’t too serious at the beginning of 80’s., but it become more and more important. So the annual auto volume increment ratio between the households and the whole economy is applied to set apart the consumption by households and by the whole economy. Then we subtract the auto consumption by households from the auto consumption by the whole economy, and obtain the annual auto vehicle investment.

As to the investment data by sector, there are only investment of state-owned firms by sector available. The investment data by sector for the non-state-owned enterprises are very limited. In the pre-reform economy, non state-owned firms may have been small, but now become more important. The total investment in the state-owned enterprises account for near 70% of the investment in the total economy in the early 1980s; the proportions have been declining since 1980 but never less than 50%. At first, we estimate the capital stock of state-owned firms by sector.

The KLEMS classification system[4] differs from the existing classification system used in China. So we have to do some adjustments. For example, in order to have the investment data for motor

[4] Our project divided the economy by 33 industries, we called KLEMS sector.

vehicle industry, we used the capital formation data from the input-output series of China.[5]

From 1996, there are investment data with disaggregated into structure and equipment by sector. Before 1996, there are only aggregate data with disaggregated into structure and equipment. We use 1996 composition for each industry to disaggregate investment before 1996 by sector into structure and equipment. In the adjustment, we applied Kuroda approach[6]to get the asset total correct. With the application of auto vehicle investment ratio for the economy into every sector, we estimated the annual auto vehicle investment by sector. At last, we obtained the investment in structure and investment in equipment by sector for state-owned firms, investment in auto for the whole economy by sector for 1980-1999.

2.3 Asset life and depreciation rate

Under the declining balance pattern, rate of depreciation is equal to the rate of replacement. The geometric form is widely used in theoretical research of capital theory because of its simplicity. Hulten and wykoff use vintage asset prices data for various categories of capital, find the depreciation form is closed to the geometric form. But, while it enjoys empirical support from searches of used capital prices, it is regarded by some as empirically implausible because of the rapid loss of efficiency in the early years of asset life. The geometric depreciation assumes that the asset is depreciated annually by a geometric rate, consequently, depreciation is higher in earlier than later years.

The geometric rate itself is usually derived from surveys where taxpayers are asked about their asset acquisition prices by age and data[7], or from used asset market prices surveys[8]. In China, there are no available surveys about depreciation rate. We derive the depreciation rate from the assumption of asset life.

The weighted average service life for manufacturing equipment ranges from 10 years in Japan, through 15 years in Germany and 17 years in both US and France to 24 years in UK. For manufacturing structures the figures range from 31 years in US, through 37 years for France, 41 years for Germany and 43 years for Japan to 60 years in the UK. The lack of reliable information about asset lives poses another obstacle (OECD 1993). In practice, the difficulty is often overcome by using the assumed service lives. Sources of asset life information include company accounts, other countries' estimates and expert advice. We assumed an asset life of 16 years for equipment, and 10 years for auto, 40 years for structure according to the experience in the study on estimation of capital stock in other countries.

Under geometrically declining relative efficiency pattern, let S to be the survival rate of capital, we

[5] The input-output series project has been conducting in a collaborative way including professional staffs from National Bureau of Statistics of China who have the high level expertise about the statistical methods and data for the study and the researchers from the academic community who have been working on the data issues for China for a long time (Szirmai, A.,and Ren Ruoen, 1995 , Szirmai, A., and Ren Ruoen 2000, Wing Thye Woo and Ren Ruoen, 2002.).
[6] The method is often used in the Input-Output research.
[7] see Hulten & Wykoff(1980).
[8] See Hulten & Wykoff(1981)

have:

$$S = (1-\delta)^T \tag{3}$$

where δ is depreciation rate, T is the life of capital. We assumed the value of S is 3~5% according to government setting, with our assumption of assets life, the depreciation rate of equipment is 17%, and structure is 8%, the auto is 26%.

2.4 Investment deflator

A deflator for investment in fixed asset is only available since 1992. The investment in fixed asset price index is collected by the urban survey team of National Bureau of Statistics(NBS), based on 600 enterprises. Since 1999, the survey covers 4500 enterprises. Investment price index for structure and equipment for 1992-2000 were given in ““China Statistics Yearbook”.

Before 1992, we employ other price index to replace the investment deflator. The price index for structure and equipment for 1953-1979 was the retail price index. The price index for equipment for 1979-1991 was the overall industries index from “China Statistics Yearbook, 1995”. The price index for structure for 1979-1980 was from "Statistics for the Chinese Construction, 1952-1985". In the study on the construction of input-output table time series, the estimates of price indices are part of the project. The index for structure for 1980-1991 was construction investment price index, which is from the I_O time series price index. There is no available price index of auto vehicle investment, so we use the auto ex-factory price index price index instead, which is also from the IO time series price index.

Table 1 The investment deflator of different asset type

	Price index of investment		
	structure	auto	equipment
1980	1.06	1.00	1.01
1981	1.05	1.00	1.00
1982	1.03	0.99	0.99
1983	1.05	1.00	1.00
1984	1.06	1.01	1.01
1985	1.08	1.09	1.09
1986	1.09	0.89	1.04
1987	1.08	1.09	1.08
1988	1.13	1.07	1.12

1989	1.07	1.15	1.12
1990	1.22	1.03	1.04
1991	1.107	1.09	1.06
1992	1.17	1.09	1.09
1993	1.31	1.21	1.20
1994	1.10	1.07	1.10
1995	1.05	1.05	1.06
1996	1.05	1.02	1.02
1996	1.03	0.99	1.02
1997	1.01	0.98	0.98
1998	1.00	0.99	0.98
1999	1.06	0.98	0.98

2.5 Capital benchmark:

2.5.1 The estimation of structure and equipment capital stock benchmark

According to our asset life assumption, we need the investment in equipment series since 1964 and the investment in structure series since 1940. Investment series for 1952 onwards are available, we estimate the investment data before 1952.

Based on the indices provided in Maddison's 1995 OECD study (Maddison, 1995), the GDP time series for 1940-1951 in the 1952 prices was estimated. A ratio between investment and GDP for 1933 was estimated in Kung-chia Yeh (1972), which is 0.05. On the other hand, based on his analysis, Feuerwerker(1977) believed in that the ratio between the investment and GDP had not been exceeded 0.05 before 1949. So we used the ratio of 0.05 to estimate the investment from GDP data for 1940-1951. The data for construction and investment for 1931-1936 provided in Yeh (1979) were used to estimate the investment on construction for 1940-1949. The war damage was allowed for by making reference to the assumption of war damage for Japan made in Maddison (1994).

The investment series for state owned firms for 1953-1979 was from “China statistical yearbook on investment in fixed assets 1950-1995”. We assumed that the investment for the state owned firms was the same with the investment for the whole economy before 1953. The 1950 and 1951 estimates of total investment, investment on structures and investment on equipment are derived by multiplying the corresponding figures for the state owned sector by the 1952 ratio of total investment to investment in new assets in the state sector. The investment for state owned firms for 1950-1979 was disaggregated into structure and equipment by the corresponding ratio of

investment on new assets. The ratios are from “China statistics yearbook on investment in fixed assets 1950-1995”. We checked the accuracy by data on 1980-1985, the structure investment ratio for the economy is about an average 10 percent lower than on new assets.

The following table gives the estimates of capital stock for state-owned firms in 1980. We compared these results with various assumptions of relative efficiency pattern, service life and replacement distribution. Despite of their different life assumptions the estimates are nearly the same when same replacement distribution is assumed. It seems that our estimates would be affected slightly by our quite simple assumptions on the data before 1949.

Table 2 Comparisons of the benchmark results with various assumptions

Asset	Asset life	Depreciation Rate		Capital Stock (100 Mill. RMB at 1980 prices)		
		Declining balance Model	Straight-line Declining	Declining balance Model	straight-line declining	one hoss shay pattern
structure	40	8%	2.5%	3201.22	4510.33	6033
equipment	16	17%	6.25%	1059.74	1525.22	2387.65
structure	48	7%	2.1%	3412.58	4804.76	6113.68
equipment	19	15%	5.26%	1153.05	1666.00	2465.95
Structure	32	10%	3.125%	3014.36	4137.98	5958.5
Equipment	13	20%	7.69%	938.10	1347.17	2132.45

2.5.2 Auto benchmark

Due to the few investment data on auto vehicle, we can’t obtain the initial capital stock of auto vehicle on PIM basis. Under the assumption that the gross value of fixed asset ratio is the same with the capital stock ratio between the auto vehicle industry and the state-owned firms, the initial capital stock is given by:
The initial capital stock for auto vehicle in 1980= the gross value of fixed asset of auto vehicle /the gross value of fixed of fixed asset of stated-owned firms *the initial capital stock for state-owned firms in 1980.

We have estimated the initial capital stock for stated-owned firms, which is 426.278 billion Yuan. “china statistical yearbook” gives us the gross value of fixed asset of stated-owned firms; the gross value of fixed asset for auto vehicle can’t be found in the official statistical sources ,we must estimate it. The total auto vehicle volume data in 1980 is 1782900, which is published in “china statistical yearbook”. The revenue of auto vehicle industry in 1980(860198 ten thousand Yuan) ,is divided by the sales volume of auto vehicle(222288) to obtain the average price of auto in 1980: 3.87 ten thousand Yuan. Then we approximately obtain the gross value of fixed asset of auto

vehicle, which is 3.87*1782900 ten thousand Yuan. At last, we have the initial capital stock is 553.6 a hundred million Yuan.

2.5.3 Estimate the benchmark capital stock by sector

The ratios of net valued fixed assets in 1980 for sectors from "Chinese industrial census data in 1985"were used to distribute the aggregate capital stock for state owned firms over sectors in 1980. However, we can not find the net valued of fixed assets for finance industry and insurance industry. So we used the Incremental capital output ratios[9] to estimate the capital stock of finance industry and insurance industry.

In summary, for each type of capital good we follow these steps: 1)a benchmark is obtained, 2) the investment series in current prices is deflated to obtain a real investment series. 3) a rate of replacement is chosen. 4) the stock series is computed using the PIM.

2.6 the estimation of capital stock by sector for the whole economy

We have estimated the capital stock for structure and equipment by sectors for the state owned enterprises. The eventual purpose of the study is to build the capital stock by sectors for the whole economy. For the investment data by sector for non-state-owned sectors, we can only find the investment data for the urban collective economy by a very rough sector classification. So we tried to estimate the capital stock of the urban collective economy by rough sector at first step.

In order to obtain the capital stock for the urban collective economy by KLEMS sector, we have made some assumptions. For example, we have estimated the capital stock of manufacture for the urban collective economy. We assumed that in the manufacture industry the capital stock structure by sector for the urban collective economy are the same with that for the state owned firms. So we obtain the capital stock for urban collective economy by KLEMS sector.

Now we have estimated the capital stock by sector for state owned firms and urban collective economy, we blown up the capital stock for state owned firms and urban collective economy to the whole economy using ratios of the aggregate capital stock for state owned firms and urban collective economy to the aggregate capital stock for the whole economy. Finally, we estimated the capital stock for structure and equipment by sector for the whole economy series for 1980-2000[10].

2.7 The estimation of land capital stock

Because land is an important capital input for agriculture, we estimated the land capital stock[11] for agriculture.

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[9] Increment capital output method assumes the ratio of increment capital to increment output is constant.
[10] We have not given the estimation result of capital stock for state-owned firms and urban collective economy, the whole economy by KLEMS sector. Any needed can email to the author.
[11] As a non-depreciable asset, land can not be estimated based on the PIM.

We can obtain the infield quantity data from “China statistical yearbook”, but there is no any land price data. The official data on area land are known to be inaccurate. Various new estimates indicate that official figures under report actual acreage by as much as 30-40%. However, it is difficult to judge how this under-reporting varies over time, so in this study we simply use the official data.

We must estimate the land price ourselves. The ordinary methods to estimate the price of land include: surplus method, market comparison method, shadow price method, and the profit discount method. We adopt the profit discount method, which denotes the price of land as: P=a/r P refers to the land price, a refers to the annual profit, that is subtracting annual cost (including production cost and human cost etc) from the annual revenue. r refers to the annual discount rate. From “china agriculture statistical yearbook”, we find the data about the data of profit and cost for land. As to the annual discount rate, we select the 1-year deposit interest rate. Moreover, the land with different uses has different profit. In order to obtain the China land price, we weight the land prices with different uses. The estimation results of land price are below:

Table 3 the land price（ten thousand yuan/thousand hektare）

1980	1983	1985	1986	1987	1988
1009.68	2348.37	3169.02	4156.63	3828.97	4897.57
1989	1991	1992	1993	1994	1995
5579.62	5208.89	5303.87	12836.4	14139.28	16958.24
1996	1997	1998	1999	2000	
12475.16	8500.361	8547.409	4612.291	4311.07	

Then the capital stock of land is equal to the land price multiplying the total sown area of farm crops. For some years (1981,1982,1984,1990), we can’t obtain the price of land, so we use the average value of price of land of the border upon years. At last, we estimate the capital stock of land for these years. We give the result below:

Table 4 the agriculture land capital stock (100 mill. RMB)

1980	1981	1982	1983	1984	1985	1986
14779.67	22422.07	22359.97	33814.92	32916.5	45515.42	59940.3
1987	1988	1989	1990	1991	1992	1993
55503.52	70950.55	81771.49	82780.28	77917.69	79031.33	189646.3
1994	1995	1996	1997	1998	1999	2000
209602.1	254168.4	190097.7	130879.2	133088.3	72123.78	67381.93

3. Capital service prices

Capital stock estimates are widely used in econometric and growth accounting analyses of production. However, the production function is conventionally interpreted as a relationship between the flow of output and the flow of input services. We have thus far ignored the distinction

between capital stock and flows. Now we must consider the problem of converting estimates of the capital stock into a flow.

3.1 the rental price

Our second task is to construct estimates of rental prices by type of asset for each sector. The product of the rental price and the quantity of the asset used is the capital service flow in current prices. For property with an active rental market the price of capital services may be observed directly as the rental price for the use of a capital asset. The main obstacle to broader application of this method of imputation is the scarcity of data on market rental values. But we can estimate the rental price based on the capital compensation. The rental price is formulated by Jorgenson(1963), and in an early form by Walras(1874). The rental price represent the amount of rent that would have been charged in order to cover costs of asset.(BLS, 1983). The rental price of capital services involves rates of return, depreciation, and capital gain or loss for each of asset. It incorporates the tax structure for property compensation. For an asset with a geometrically declining pattern, the rental price of capital services takes the form[12]:

$$p_t = r q_{t-1} + \delta q_t - (q_t - q_{t-1}) \tag{4}$$

q^t: is the acquisition price of one effective unit of capital, δ is the depreciation rate of asset, $q_t - q_{t-1}$ is the revaluation of asset, **r**: the rate of return.

Data on asset prices and rates of depreciation for all assets are required for the PIM described in preceding sections. The depreciation rate of asset should be consistent with the depreciation rate used in the estimation of capital stock. As to the capital gains, the most common approach consists in approximating expected asset price inflation by the observed change in the price index for assets. The implication is that the asset price changes have been perfectly anticipated by agents. Under the geometric efficiency decline pattern, depreciation rate is equal to the rate of replacement. We have obtained the depreciation rate of structure, which is 0.08, and the depreciation rate of equipment, which is 0.17, and the depreciation rate of auto, which is 0.26. The revaluation of assets can be derived from the investment deflator.

3.2 Rate of return and tax structure

Given the quantity of assets held by each sector, the price of each asset, and the rate of replacement for each asset, only the rate of return for all assets used in a given sector remains to be determined. Griliches and Jorgenson(1967) have proposed to measure the rate of return as the rate implicit in the total flow of property income.

For a sector not subject to direct or indirect taxes on property income, we can solve for the rate of return, given data on property compensation for the sector:

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[12] A detailed derivation of prices of capital services is given by Hall an Jorgenson(1962).

$$r = \frac{property\ \ compensation - \{\delta q_t - (q_t - q_{t-1})\} A_t}{q_{t-1} A_t} \tag{5}$$

The expression for the rental price of capital services can be modified to incorporate property taxes, the corporate income tax, value-added tax, the present value of capital consumption allowances[13].

$$p_t = \frac{[r q_{t-1} + \delta q_t - (q_t - q_{t-1})](1 + h - u(1+h)z)}{1-u} + q_l^t \tau^t \tag{6}$$

u^t: the corporate income tax rate, τ^t: is the property tax rate; h: is the value-added tax rate; z^t: the present discounted value of depreciation allowances of 1 Yuan investment.

Because the land is a important capital input for agriculture, we have estimated the land capital stock for agriculture. The capital rental price formula for land is simple for land is a non-depreciation capital:

$$p_t = [\frac{1}{1-u^t}][r q_{t-1} - (q_t - q_{t-1})] + q_l^t \tau^t \tag{7}$$

Our data source of sector property compensation is the input-output table time series. In the input-output table, there are value-added, and labor compensation, We subtract the labor compensation from sector value-added to obtain the capital property compensation. So the capital property compensation =depreciation of fixed assets + net taxes on production+ operating surplus. Adjustment has been done to the agriculture property compensation data for considering private household issue. From the unit land proceeds we estimated the capital input property and labor input property ratios for every year. The annually agriculture value-added is breakdown into property compensation and labor compensation.

In measuring the rate of return we begin by estimating the effective tax rate on corporate property rate. We assumed that the rate of property taxes allocated to capital asset, τ^t is equal across all types of assets for a particular industry and the rate is computed as the ratio of the value of indirect business taxes allocated to capital assets, to the value of capital stock. We obtain the data of property taxes from “The Tax Yearbook of China”.

To calculate the present value of depreciation deductions on one Yuan’s worth of investment, z^t, we should create a weighted average of the present values for depreciation under the different methods used for tax purposes. The present values of depreciation deductions on new investment, which depend on depreciation formulas allowable for tax purpose, the lifetimes of assets used in calculated depreciation, and the rate of return. But in China, before 1994, the only legal

[13] We adjusted the rental price formulation to consider the China tax structure.

depreciation method is straight-line depreciation. From 1994, only some sectors have adopted accelerate depreciation method. We believe that the weight of the present values under accelerate depreciation is rather small. A reasonable approximation to depreciation practice is provided by the assumption that the straight-line depreciation formula was the only one permitted. Then the present value of depreciation deductions on one Yuan's worth of investment is:

$$z^t = \int_0^{\tau} \frac{e^{-r\tau}}{\tau} d_s = \frac{1}{r\tau}(1 - e^{r\tau}) \qquad D_s = \begin{cases} \frac{1}{\tau} 0 \le s \le \tau 0 \\ 0 \quad others \end{cases} \qquad (8)$$

τ ; Asset life

To estimate average asset lifetimes for tax purposes we employ data from the tax rules. Before 1994, structure's legal life is 40;equipment's legal life is 18; auto's legal life is 12. After 1994, the number changed to 30; 13; 8. Given depreciation formulas and lifetimes for tax purposes, calculation of present values of depreciation deductions requires an estimate of the rate of return for discounting these deductions. As to the discount rate, we use the current deposit interest rate. Then, we can obtain the present value of depreciation deductions for asset at every year.

In China, firms must pay value-added taxes when they purchase fixed assets, and the value-added taxes can not be deductive because China uses the value-added taxes based on production rather than value-added taxes based on consumption. Gross fixed assets are used to calculate depreciations include VAT. We use the statutory value-added rate: before 1994 which is 16%, after 1994 which is about 17%. We calculated the actual income tax rate based on the tax paid and profit data to replace the legal income tax rate.

With the capital compensation and tax rate, we can solve for the rate of return by sector. With the results of rate of return , we can estimate the rental price of different asset type by sector with the formulation 6 and 7.

4. The measurement of capital input index.

We have outlined the development of data on capital stock and the rental price of capital services for each sector, cross-classified by asset class. To construct an index of capital input for each sector, we assume that capital input can be expressed as a translog function of its individual components.

When rental prices are proportional to marginal products and when the production function has the homogeneous translog form , the Tornqvist-translog index of capital is exact. The corresponding index of capital input k^t is a translog quantity index of individual capital inputs K_k^t.

$$\ln K^t - \ln K^{t-1} = \sum V_k (\ln K_k^t - \ln K_k^{t-1}) \qquad (9)$$

where weights are given by the average shares of each component in the value of property

compensation $V_k = \frac{1}{2}(V_k^t + V_k^{t-1})$, and $V_k^t = \frac{p_k^t k_k^t}{\sum_k p_k^t k_k^t}$, with p_k the rental price of capital services from asset type k.

Table5 gives the capital input results.

Table 5 Sectoral capital input: rates of growth.

	Agriculture	coal mining	metal and nonmetal mining	oil and gas extraction	construction	foods	textile	apparel
1981-1982	5.50%	-10.29%	8.31%	15.57%	0.19%	1.69%	3.56%	-14.52%
1982-1983	6.93%	-3.38%	10.22%	17.35%	4.06%	9.78%	11.36%	-12.99%
1983-1984	2.40%	3.14%	12.40%	17.55%	4.56%	7.70%	10.45%	-11.45%
1984-1985	0.77%	8.63%	14.42%	17.85%	5.26%	5.91%	6.32%	-9.38%
1985-1986	-1.28%	8.37%	9.80%	19.21%	12.83%	15.43%	4.29%	-6.58%
1986-1987	-0.47%	7.41%	10.18%	14.94%	8.45%	18.57%	8.36%	-0.77%
1987-1988	3.09%	6.29%	12.31%	14.61%	5.61%	16.84%	7.71%	2.63%
1988-1989	2.66%	4.85%	9.38%	12.98%	4.72%	14.16%	13.30%	4.20%
1989-1990	1.19%	3.86%	5.59%	12.08%	0.46%	2.64%	2.77%	-1.32%
1990-1991	2.16%	5.03%	3.37%	6.63%	-2.36%	1.21%	-1.57%	-2.35%
1991-1992	1.38%	6.01%	4.70%	7.13%	-1.68%	3.26%	-1.43%	-0.32%
1992-1993	0.25%	5.66%	6.58%	5.41%	1.03%	5.35%	1.52%	4.87%
1993-1994	0.10%	4.72%	3.42%	4.51%	20.96%	6.02%	1.80%	1.88%
1994-1995	1.75%	3.72%	4.45%	5.92%	13.65%	3.30%	-2.05%	-1.82%
1995-1996	7.05%	14.11%	12.27%	17.28%	25.36%	14.93%	7.59%	6.00%
1996-1997	0.17%	8.74%	0.94%	5.51%	14.30%	1.76%	-4.37%	-2.68%
1997-1998	11.07%	6.26%	1.75%	9.83%	11.68%	4.46%	-4.28%	5.81%
1998-1999	10.07%	1.39%	2.28%	9.98%	9.25%	3.41%	-4.27%	12.19%
1999-2000	5.14%	7.42%	8.33%	9.63%	19.91%	18.91%	8.87%	41.43%

Continue:

	Lumber and wood	Furniture and fixtures	Paper allied	Printing, andpublishing and allied	chemical	petroleum and coal products	leather	stone, clay ,glass
1981-1982	-6.61%	-9.67%	-3.27%	-7.12%	-2.31%	1.26%	-6.54%	5.55%
1982-1983	-5.56%	-7.27%	-9.72%	-1.87%	-7.66%	-2.29%	-2.95%	8.33%
1983-1984	-3.40%	-5.00%	-6.86%	0.79%	1.77%	4.61%	-7.54%	12.99%
1984-1985	6.56%	2.49%	-5.35%	3.27%	1.78%	9.97%	-2.67%	11.88%
1985-1986	-1.30%	-2.58%	5.54%	13.77%	8.75%	5.53%	-1.32%	18.03%
1986-1987	5.30%	-0.83%	13.11%	13.40%	12.47%	7.91%	3.33%	21.26%
1987-1988	0.73%	1.21%	11.53%	5.38%	14.36%	15.75%	10.39%	14.76%
1988-1989	3.86%	5.14%	14.17%	1.53%	15.87%	21.21%	18.41%	10.19%
1989-1990	4.04%	-2.83%	3.08%	-5.31%	7.17%	9.53%	1.56%	0.70%

1990-1991	1.43%	-5.25%	4.38%	-1.30%	5.19%	11.42%	-10.25%	-1.46%
1991-1992	-0.87%	-6.18%	3.64%	9.21%	5.99%	13.68%	3.01%	1.10%
1992-1993	-3.46%	-1.88%	6.08%	20.75%	4.62%	11.36%	21.08%	7.25%
1993-1994	0.94%	-5.51%	3.70%	13.40%	3.74%	13.45%	9.63%	12.55%
1994-1995	5.62%	-3.54%	1.28%	9.58%	6.51%	13.85%	-10.63%	8.47%
1995-1996	19.94%	8.27%	15.87%	8.60%	22.82%	15.88%	-3.91%	14.55%
1996-1997	6.54%	-3.33%	8.19%	-4.87%	12.93%	-0.02%	-15.57%	0.62%
1997-1998	5.07%	-0.14%	9.96%	0.75%	8.71%	11.21%	-8.53%	1.24%
1998-1999	61.91%	6.97%	5.20%	3.08%	5.68%	2.16%	10.70%	-0.88%
1999-2000	10.63%	29.42%	37.50%	23.53%	15.70%	6.81%	8.97%	14.56%

Continue:

	prim. metal	fab., metal	elc. machinery	machinery	mot. veh	trasp.（and ordiance）	pre, inst	rubber and misc plastic	misc mfg
1981-1982	-7.08%	-9.45%	-12.57%	0.63%	-3.20%	-5.95%	-5.06%	-17.43%	39.14%
1982-1983	-1.92%	2.89%	-5.84%	-9.81%	-8.94%	-11.31%	-1.49%	-18.13%	28.17%
1983-1984	0.27%	3.39%	-2.58%	-8.36%	-5.88%	-7.53%	-0.30%	-16.21%	-0.77%
1984-1985	2.38%	4.40%	0.54%	-5.15%	-4.40%	-5.36%	3.76%	-11.48%	-5.63%
1985-1986	6.20%	-3.14%	-0.54%	35.96%	3.68%	3.73%	1.64%	-6.11%	-1.14%
1986-1987	8.13%	-0.31%	0.71%	28.13%	0.56%	6.16%	1.64%	-2.42%	7.73%
1987-1988	10.73%	2.17%	1.21%	13.76%	4.21%	9.28%	1.36%	-4.87%	4.28%
1988-1989	12.05%	1.53%	1.90%	14.81%	5.15%	8.92%	5.24%	-3.01%	7.30%
1989-1990	4.77%	-1.56%	-2.80%	5.84%	0.88%	3.15%	-1.98%	-6.89%	1.69%
1990-1991	1.26%	-2.54%	-2.59%	7.31%	12.28%	-4.80%	-1.28%	-6.00%	2.29%
1991-1992	4.66%	-0.81%	-0.96%	4.48%	14.02%	-0.76%	-2.03%	-3.17%	6.15%
1992-1993	6.40%	0.56%	2.52%	7.82%	16.07%	2.76%	1.33%	0.75%	10.26%
1993-1994	10.00%	2.40%	0.64%	5.45%	17.55%	6.28%	2.95%	1.43%	16.77%
1994-1995	11.23%	1.29%	0.35%	-1.16%	10.57%	3.23%	-0.04%	-0.78%	13.98%
1995-1996	19.50%	10.07%	8.67%	7.77%	14.83%	17.32%	7.59%	4.41%	22.72%
1996-1997	5.28%	-3.15%	-3.93%	3.88%	5.45%	15.01%	-1.58%	0.38%	11.30%
1997-1998	4.29%	-0.70%	-0.38%	6.15%	10.20%	11.75%	-0.30%	3.62%	12.23%
1998-1999	0.62%	-0.26%	-0.50%	10.48%	4.72%	9.99%	-0.33%	-0.19%	14.31%
1999-2000	8.62%	22.89%	11.06%	40.85%	23.91%	21.88%	8.84%	32.08%	4.05%

Continue:

	Transportation	Communication	Electric utilities	Gas utilities	trade	finance insurance and estate	realother services	privatepublic services
1981-1982	-7.81%	-16.20%	-6.31%	0.39%	-4.76%	105.43%	46.42%	29.80%
1982-1983	-3.19%	-11.12%	-3.54%	2.12%	-1.53%	61.32%	28.59%	44.60%
1983-1984	2.16%	-3.59%	1.19%	6.28%	-0.49%	30.55%	23.59%	27.74%
1984-1985	7.13%	0.97%	5.04%	9.32%	3.29%	25.49%	23.26%	25.36%

1985-1986	9.44%	1.00%	8.63%	56.56%	6.18%	38.61%	28.31%	13.12%
1986-1987	7.33%	-2.04%	13.80%	38.60%	5.11%	54.26%	21.03%	8.80%
1987-1988	8.71%	4.66%	15.06%	19.63%	7.36%	35.78%	15.56%	10.44%
1988-1989	7.46%	3.87%	12.87%	14.82%	7.28%	34.38%	13.95%	9.75%
1989-1990	3.73%	8.91%	9.55%	9.82%	2.36%	20.10%	11.59%	2.76%
1990-1991	3.07%	10.65%	9.12%	21.08%	0.14%	8.74%	6.82%	1.47%
1991-1992	6.80%	11.28%	7.89%	21.58%	2.68%	11.39%	5.63%	4.43%
1992-1993	5.81%	20.04%	7.74%	20.18%	6.89%	22.85%	7.84%	6.99%
1993-1994	10.64%	33.47%	7.43%	14.05%	4.67%	27.75%	7.49%	15.04%
1994-1995	19.54%	16.41%	9.33%	4.43%	5.18%	25.05%	8.91%	16.10%
1995-1996	26.99%	45.55%	20.20%	10.61%	16.75%	30.29%	24.07%	28.22%
1996-1997	12.24%	28.22%	15.26%	6.31%	6.04%	-4.09%	11.26%	19.45%
1997-1998	17.98%	26.96%	17.11%	11.04%	5.00%	-1.74%	12.68%	14.94%
1998-1999	23.26%	32.71%	14.71%	13.31%	6.85%	-0.44%	17.33%	18.75%
1999-2000	26.65%	33.53%	31.01%	20.45%	13.31%	9.80%	27.70%	23.64%

In this section, we examine capital growth in the 33 industries over the 4 periods: 1981-84; 1984-88; 1988-94; and 1994-2000. The four periods are not chosen arbitrarily. The endpoints of each period are years in which a cyclical peak occurred. The capital input grew fast during the whole period. Considering the 4 periods in chronological order, 5; 6; 2 and 7 industries, respectively, experienced annual rates of growth of the capital input in excess of 15 percent. In 1981-1984, 22 industries had a negative capital input growth rate. The number of industries of negative capital input growth declined to 3, 4, 1 industries, respectively, during 1984-88, 1988-94, 1994-2000. Finance insurance and real estate, other private services, public services had an annual rate of capital growth in excess of 15% during 3 periods. In China service and extraction had a high capital accumulation speed during the past years. The average capital input growth across industries was 3.08%; 8.38%; 5.94% and 10.30%, respectively, during 1981-84; 1984-88; 1988-94 and 1994-2000.

Table 6 Classification of industries by annual rate of growth of capital input

Classification of growth rate(%)	Number of industry			
	1981-1984	1984-1988	1988-1994	1994-2000
<0	20	3	4	1
0—5	4	10	8	3
5—10	3	10	16	14
10—15	1	4	3	8
>15	5	6	2	7

5. Conclusion

We have made the estimates of capital stock and the flow of capital service by KLEMS sector classification time series for China for 1980-2000 based on KLEMS approach. The various assumptions and adjustments were made on the data were discussed. We tried to make the estimation procedure and data used as transparent as possible. We also limited ourselves to make our estimates based on the official published data. So everyone interested in our study can check our data sources and assess our estimation procedure, and challenge our assumptions and adjustment made.

Fully satisfactory estimates of real capital input will require much further research. Several issues remained to be dealt with in the further study. The predetermination of assets life and depreciation pattern might be the most important one. Reliable information about the expected service lives of different categories of asset, in particularly about the way in which average lives may have changed and changing over time. This is the issue that needs to be addressed and analyzed in the further study. It may need to initiate a separate study. The investment data may have more internal inconsistency than other data in China. Some reconciliation work may be needed before the data can be used to estimate the capital stock. The capital asset should include both depreciable and non-depreciable assets. In this study we only estimate the depreciable assets and agriculture land, which will influence our result on the internal interest rate. Capital rental prices of capital assets are seen to depend on such parameters such as tax structure. Our tax parameters are mainly from the statutory rate, which perhaps different from the actual tax rate. Substantive improvement can come from the collection of additional information and more reliable data. In our cases, capital utilization-defined as the ratio of the flow to the stock, is assumed to remain constant over the business cycle. In future research, the relative utilization adjustment for capital should be employed.

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