RIETI Discussion Paper Series 15-E-006

Constructing China's Net Capital and Measuring Capital Services in China, 1980-2010

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RIETI Discussion Paper Series 15-E-006

January 2015

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ABSTRACT

This paper documents the procedures of constructing industry-level net capital stock and measuring capital services in the Chinese economy. This work is based on our understanding of the major problems in the official investment statistics and follows the system of national accounts (SNA) principles. The main tasks accomplished include reconstruction of industry-level investment flows, estimation of the initial capital stock, measurement of industry-specific deflator and depreciation rate, and construction of net capital stock for 37 industries and estimation of their services. Our results show that China's rapid gross domestic product (GDP) growth has indeed been accompanied by a more rapid growth of capital input. The annual growth of China's net capital stock was 12% for the entire period 1980-2010. We find that despite institutional shocks and substantial restructuring in the early reform period of the 1980s, China managed to achieve an annual growth of over 10% in net capital stock. This was followed by an even faster growth in the 1990s (13%) and a further acceleration following China's World Trade Organization (WTO) entry (17%). Moreover, the unprecedented fiscal package in the wake of the global financial crisis drove up the growth of China's net capital stock to over 20% per annum. However, our estimated changes of capital services using the user-cost weights suggest that, since the late 1990s or early 2000s, there has been unusual substitution towards assets with relatively low rather than high marginal products. This may imply distortions in capital allocation and barriers to capital mobility in the economy.

Keywords: Economic depreciation, Investment flow, Net capital stock, Initial capital stock, Capital services

JEL Classification: C82, E22, L60, O47

* I am indebted to Abdul Erumban, Tomohiko Inui, Kyoji Fukao, Mun S. Ho and Ilya Voskoboynikov for constructive comments and suggestions. I also thank participants at 33rd IARIW and the World and Asia KLEMS Conferences for helpful discussions. What reported in this work are interim results of China Industry Productivity (CIP) Project under the RIETI (Research Institute of Economy, Trade and Industry, Japan) East Asian Industrial Productivity Project (http://www.rieti.go.jp/en/projects/program/pg-05/008.html). The earlier data work to construct historical investment and capital stock series are supported by Hong Kong UGC CERG Project B-Q293. I gratefully acknowledge financial supports from RIETI and Institute of Economic Research (IER) of Hitotsubashi University, as well as the Hong Kong UGC. I am responsible for all errors and omissions.

1. INTRODUCTION

A conceptually correct and empirically sound measure of capital input at industry level is essential for a standard and meaningful productivity analysis. However, data problems have long been the major obstacle to such a measure. The Chinese statistical authorities have never provided capital stock estimates in the SNA principles nor are available official statistics sufficient and qualified for the estimation of capital stock by the standard approach.

Basically, the available official fixed asset investment data are mixed up with inventories and official stock data suffer from an inappropriate treatment to aggregation by adding up investment at historical costs and mixing up industrial structures and equipment with dwellings. They also suffer from inconsistency in industrial classification, lack of information on investment prices and depreciation. Furthermore, the available investment data only cover enterprises in the state statistical reporting system that has changed criteria over time for qualified enterprises from the type of ownership, the level of administration to the size of firms. Since there is no investment matrix in the national accounts, it is very difficult to reconcile the reported fixed asset investment and capital stock data at industry level with the gross fixed capital formation (GFCF) statistics in the national accounts.

This study is based on the author's earlier estimates for the industrial sector at industry level (Wu and Xu 2002; Wu 2008) and for the national economy as a whole (2011 and 2014). It has two objectives. The first and major objective is to extend the industry-level estimates to all the non-industrial sectors of the economy, which will provide a data set of investment and net capital stock for 37 industries in 1980-2010. The second one is an attempt to establish some linkage between industry-level estimates and the GFCF statistics in the national accounts, which is exploratory in nature aiming to understand the underlying problems that may suggest proper solutions.

The work reported in this paper is heavily data-driven and measurement-oriented. For a large and complex economy like China whose official statistics has long suffered from conceptual flaws and methodological deficiencies, it is risky to propose any innovative method that imposes strong assumptions albeit "logical". In our view, fixing explicit inconsistencies in concept, classification and coverage is the top priority. Any methodological innovation in future has to work on a consistent series that coherently integrates industry-level investments with the national accounts.

This paper is organized as follows. The next session discusses major problems in the Chinese investment and capital stock statistics and how they were tackled in the previous studies. Section 3 introduces the theory of economic depreciation and capital services. Section 4 explains how annual investment flows are constructed for the industrial and nonindustrial sectors and decomposed into non-residential structures and equipment. Section 5 deals with the estimation of the initial capital stock and the adjustment of GFCF. Section 6 and Section 7 deal with industry-specific investment deflators and depreciation rates, respectively. Section 8 presents the estimates of net capital stock by industry and explores their relationship with the adjusted GFCF. Section 9 presents the estimates of capital services by industry. Finally, Section 10 concludes the paper with future research priorities.

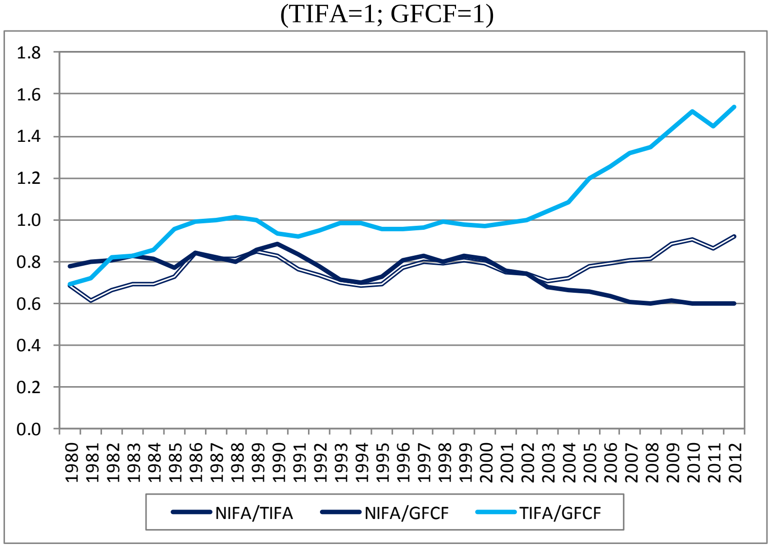
2. Problems in Measuring Capital Stock in China

Conceptual problems of the official investment statistics

The Chinese official investment statistics are constructed using data collected through the authorities planning and monitoring capital investment mechanism, consists of mainly two annual series, "total investment in fixed assets (TIFA)" (*quanshehui guding zichan touzi*) and "newly increased fixed assets (NIFA)" (*xinzeng guding zichan*), which are supposed to be the basis for the gross fixed capital formation (GFCF) item in the Chinese national accounts. However, these indicators do not appear to be consistent as shown in Figure 1, hence causing confusions to their users.[1]

An often made, significant mistake is the direct use of "investment in fixed assets" as the investment variable in estimating capital stock with the perpetual inventory method (Ho and Jorgenson, 2001; Young, 2000a; Huang et al., 2002; Hu and Khan, 1997; Li at el, 1992), which is conceptually inappropriate. By official definition, this indicator refers to the "workload" of activities in construction and purchases of fixed assets in money terms (NBS, 2001, p.220). As correctly noted in Chow (1993, p.816), the work performed in the "investment in fixed assets" may not produce results that meet standards for fixed assets in the current period. In fact, some of the work (investment projects) may take many years to become qualified for fixed assets and some may never meet the standards, hence be completely wasted, which is a typical phenomenon in all centrally planned economies.

Figure 1
Could the "Relationship" between TIFA, NIFA and GFCF be Gauged?
(TIFA=1; GFCF=1)



Sources: Wu (2014, Figure 5).

[1] Official statistics on the two series sometimes include two sub-categories: "investment in capital construction" and "investment in technical update and transformation" (of the existing capital assets). The latter is translated, inappropriately, as "investment in innovation" in recent volumes of China Statistical Yearbook, which causes some confusion. In this section, to simplify our discussion of conceptual issues we will temporarily ignore the distinction between the two subcategories.

The nature of the problem is the same as that commented by Xu (1999) on the item GFCF in China's newly adopted SNA-type national accounts, which is, as above mentioned, based on "total investment in fixed assets". Xu (1999, pp.62-63) points out that the key difference of the Chinese capital account in comparison with the 1993 SNA is that the former does not follow the SNA capital formation criterion of the sales contract-based, complete ownership transaction from producers or constructors to users (investors) of capital goods. For example, in SNA (CEC et al., 1993, p.230) a plant construction is counted as *inventory* if it cannot be sold to a buyer (investor), while in the Chinese national accounts it is included in the fixed capital formation.[2] This is a significant problem as it exaggerates the amount of capital stock in productive service.

Such a practice is rooted in the central planning period when the state was the dominant, if not sole, owner and player in the economy, and therefore a plant project was counted as (the state) investment once its structure was completed and equipment installed, no matter whether it could meet the standards for production. The problem is aggravated in the case of a large project because its investment "workload" is counted by stage of construction, but it cannot be used for production (hence should be counted as the increase in inventory) before all stages are completed and the operation actually commences. It can be sure that the official TIFA indicator and hence GFCF exaggerates the real level of fixed asset investment.

In fact, compared with the indicator TIFA, the series of NIFA is much more compatible with the SNA concept of fixed asset investment because it refers to the value of investment projects completed and put into production in the current year (NBS, 2001, p.222), hence reflecting the fixed assets formed in the current period as a result of those *effective* investment projects taking place in the current and previous periods. They are *effective* because they have been turned into new fixed assets for production services rather than wasted.

Let us reconcile the two Chinese concepts of fixed asset investment with the concept of investment used in the perpetual inventory method (PIM) (see Eq. 3.3). Now, if denote NIFA as N and TIFA as M (or the "workload" of investment projects), assuming no coverage problem and double counting (to be discussed later), then N in period t is the sum of M's in $\tau + 1$ periods (i = 0, 1, 2, …, τ) multiplied by their respective ratios θ ($\theta < 1$), defined as, in value terms, the proportion of actually completed investment in period t in the total "workload" of the investment projects taking place in period $t-i$,[3] that is,

$$(2.1) \qquad N_t = \sum_{i=0}^{\tau} \theta_{t-i} \cdot M_{t-i}, \; (i = 0, 1, 2, \ldots \tau).$$

It should be mentioned that there is little information available on θ and τ. Note that θ is not endogenous in the system.[4] Here it should be mentioned that an officially often used ratio,

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[2] The general SNA principles governing the time of recording and valuation of gross fixed capital formation is "when the ownership of the fixed assets is transferred to the institutional unit that intends to use them in production" (CEC *et al.*, 1993, p.223).

[3] Therefore, (1-θ) indicates the proportion of the value of investment projects that is unfinished or wasted or both in a given period.

[4] However, the ratio may be somewhat useful for gauging the possible wastage in China's capital investment projects. If the composite of projects with different construction periods in value is similar over time and there is no wastage, the ratio should have remained stable over time. If we believe that the reform-led marketization have

namely, "the rate of fixed assets turned over to use", defined as $N_t / M_t = \left(\sum_{i=0}^{\tau} \theta_{t-i} \cdot M_{t-i}\right) / M_t$, is misleading because it compares two concepts that are virtually incompatible (see figures on the ratio, NBS, 2001, p.174).[5]

However, N is not yet ready to be a good proxy for the investment variable, denoted as I, used in PIM. Two adjustments have to be made to transfer N to I. The first one is a downward adjustment to remove the investment in residential buildings, a prerequisite for conducting any production function analysis.[6] The second one is an upward adjustment to include the projects less than half million yuan by non-state firms that are not reported in official investment statistics, plus the value of likely underreporting (Young, 2000). Suppose that the two effects on N can be captured by η (residential structures and double counting) and λ (missing and/or underreported investment), respectively, we can have the following definition for I in line with the standard concept:

$$I_t = N_t \frac{1-\eta_t}{1-\lambda_t}, \; (\eta < 1; \lambda < 1) \tag{2.2}$$

If both η and λ are stable over time, N could be a good proxy for the growth of I, but not for the level of I. Yet, neither η nor λ has been stable. Also, it is conceptually wrong to substitute M for I as practiced in many studies and it is not appropriate to derive I based on the misleading N/M ratio for the current year (e.g. Li et al, 1992). So far, to our best knowledge only Chow (1993) adopted N as investment flow to construct capital stock in his growth accounting exercise for the period 1952-85, but without any adjustment.

Problems of deflation

All official fixed assets data are published in values at acquisition prices or historical costs. In fact, N is recorded at historical prices over the period $t-i$ (Eq. 2.1) which means it is valued at different prices over time. How to deflate fixed assets so that it can be valued at constant prices is a difficult task for researchers. Information on the prices of capital goods for the pre-reform period is scant. The official producer price indices for capital goods only became available after 1985. From 1992, the statistical authority began to publish investment price index (IPI).

Previous studies often use official retail price indices (RPI) (e.g. Huang, Ren and Liu, 2002) or implicit GDP deflator as a proxy (e.g. Chow, 1993; Hu and Khan, 1997; Wu Y., 1999 and 2000), which is conceptually incorrect. Since official GDP estimates may be exaggerated

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shortened the average construction period (note that the post-reform correction to the over-investment in heavy industrial projects should have shortened the period of an average project) and reduced wastage (at least for industrial projects), the ratio should have increased since the 1980s. Nevertheless, the official statistics show that the ratio dropped from 80.2% in 1953-57 to 62.7% in 1991-95 with sharp fluctuations over the periods in between (DFAIS, 1997, pp. 186-189).

[5] This ratio is mistakenly used in Li *et al*. to derive actual investment (1992, p.348).

[6] A few studies have so far attempted to tackle the problem (e.g. Maddison, 1998; Li *et al*., 1993; Chen *et al*., 1988a and 1988b), but all adjustments are inevitably rough.

partially due to the underestimation of price changes (Wu, 2002; Young 2000; Maddison, 1998; Woo, 1998; Ren, 1997),[7] using GDP deflator may also exaggerate the real investment.

Problems of depreciation

The published official depreciation rates are unusually low from an international perspective. For example, in 1990 the fixed assets depreciation rate (a comprehensive one including all types of fixed assets) is 4.8 percent for all state enterprises and 5.1 percent for state industrial enterprises, increased from 2.9 and 3.7 in 1952, respectively (NBS, 1992, p.28), compared with the empirical evidence of 13.3 percent for equipment and 3.7 percent for structures for the US economy in 1977 found by Hulten and Wykoff (1981b). The low depreciation was, not surprisingly, in line with the overestimated service life of fixed assets in the absence of property market in the central planning period. Furthermore, the official depreciation method assumes a straight-line depreciation function that is different from the geometric depreciation function supported by established empirical studies.

Due to the lack of empirical evidence of the service lives of equipment and structures and their depreciation patterns in China, many studies simply adopt the official depreciation rates (Chen et al., 1988a; Chow, 1993; Hu and Khan, 1997), whereas a few set their depreciation rates based on the experience of market economies (Huang et al., 2002; Li et al., 1993) or arbitrary assumptions (Young, 2000). Nonetheless, researchers' choices of different depreciation rates together with different deflators, *ceteris paribus*, could significantly affect the estimated growth rate of capital stock.

Problems of official "capital stock"

Official statistics also include two capital stock series that are constructed using data collected at the firm level through routine accounting reports (unfortunately the national aggregates are kept by NBS), that is, "original value of fixed assets" (OVFA) (*guding zichan yuanzhi*) and "net value of fixed assets" (NVFA) (*guding zichan jingzhi*). OVFA is current year's gross capital stock and NVFA is defined as OVFA minus the accumulated value of depreciation (NBS, 2001, pp.461-462). The NBS way of calculating OVFA is to add the value of investment in fixed assets in current year embodying a mix of buildings (factories, offices and dwellings), equipment and machinery, with the value of the existing stock at historical or acquisition prices. Assuming the official depreciation method can be accepted, NVFA cannot be used because it ignores two problems: inaccurate valuation and improper coverage. Firstly, there is not a proper deflator that can deflate a capital stock mixed with different types of assets purchased at different prices and in different periods. Secondly, like the official data on investment the stock series also include residential structures that cannot be easily separated.

The study by Chen et al. (1988a) is a pioneering one to reconstruct both the gross and net capital stock series for the state industrial sector in 1952-85 based on the official capital stock data.[8] This widely cited study makes important efforts in three areas. Firstly, it derived annual

[7] For a critical review on this deflator problem see Wu (2000).

[8] Rawski (1980) and Field (1980) made some earlier attempts but with less sufficient and less reliable information compared with Chen et al. (1988a).

investment flow from the official stock data so that the problems in the official investment data, i.e. the *M* series of Eq. 2.1, could be bypassed. Secondly, it decomposed the so-derived investment flow into four types of assets, namely, "equipment", "industrial construction", "housing" and "others" so that residential buildings could be separated from non-residential fixed assets. Lastly, it constructed four price indices to deflate each type of the assets.

However, the work by Chen *et al*. (1988a) is still questionable. Apart from their unconditional acceptation of the official depreciation method, there are other problems yet to be solved. Firstly, the scrapping problem was not carefully tackled in their estimation of investment flow. By the logic of the official definition, the end-year stock data, either OVFA or NVFA, have already excluded the assets that had retired during the current year, hence the so-derived investment flow might have underestimated the actual new investment.[9]

Secondly, the decomposition was largely based on the investment composite of the entire state sector rather than the state industrial sector, which might have underestimated the proportion of industrial assets and hence overestimated the proportion of housing.

Lastly, there are also problems in constructing price indices. For example, it is clearly that the official implicit output deflator heavily influenced the construction of the price index for equipment, hence the level of inflation might have been underestimated. The construction of the price indices for industrial and residential structures was based on the scattered official statistics on construction costs, but no details were given on how the cost data were used. It is also believed that using construction cost data to derive investment deflator could understate the productivity improvement in construction, an issue that is worth further investigating (Hulten, 1990). Besides, it is inappropriate to assume, as in Chen et al. (1988a), that changes in the investment outlay under "others" could have been a pure price effect (i.e. the real value has no change at all). This is because the data are already recorded as "stock" rather than investment.

3. ECONOMIC DEPRECIATION AND NET CAPITAL STOCK

Capital stock estimates can be derived either using data based on a direct measurement of the stock or using investment data and the perpetual inventory method. As we have seen, even if for countries like China with a long history of central planning that made it easy to monitor and record the process of production, the available official data on the direct measurement of capital stock do not provide detailed information about the vintages of the assets that is necessary to derive stock estimates in the current cost and constant cost valuations.

The perpetual inventory method of estimating capital stock has been developed since Goldsmith (1951). Following Hulten (1990), we can start by assuming that researchers can observe the quantity of new capital added to the stock via investment in each year, I_t, but not the amount of capital stock or accumulated productive asset itself, A_t. The problem is to develop a reasonable procedure for adding up the individual *I*'s into an estimate of *A*, recognizing that part or all of past additions to the stock may have been retired from service and the services yielded

[9] This was confirmed by some SOE factory accountants in Beijing in the author's field work accompanied by NBS statisticians in 2003.

to the stock may be less productive. The perpetual inventory method is one attempt at solving this problem.

In the perpetual inventory method, investment from all surviving vintages is weighted by a relative *efficiency* parameter, Φ_{t-v}, between zero and one to allow for the possibility that older capital is less productive than its newer counterparts, and the weighted investment series is then added up to form a total capital measure, expressed by the following equation:

$$(3.1) \qquad A_t = \Phi_0 I_t + \Phi_1 I_{t-1} + ... + \Phi_T I_{t-T}\ , \ (0 \le \Phi \le 1)$$

where $\Phi_0 = 1$ and $v = t - T$ is the date when the oldest surviving vintage was added into the stock, hence *T* is the age of the oldest vintage and *t*, as the convention, denotes the current time (or prime period). Since one unit of vintage *v* capital is treated as the equivalent of only Φ_{t-v} units of new capital, the stock A_t has the natural interpretation as the number of units of new investment needed to be equal to the productive capacity of past investment (Hulten, 1990).

There has been a vast of literature on the behavior or the pattern of Φ and the approach of estimating Φ. By far three typical efficiency patterns have been explored, namely, one-hoss shay, straight-line and geometric. In the one-hoss shay form, assets remain full efficiency until they completely fall apart. In the straight-line form, efficiency decays in equal increment every year, following the convention of the depreciation approach in accounting. The geometric form, which is now most popular and followed in this study, suggests that efficiency decays at a constant rate, δ, that is,

$$(3.2) \qquad (\Phi_{\tau-1} - \Phi_\tau)/\Phi_{\tau-1} = \delta\ , (\tau = 0, 1, 2, \ldots)$$

implying that $\Phi_0 = 1$, $\Phi_1 = (1-\delta)$, $\Phi_2 = (1-\delta)^2$, …, $\Phi_\tau = (1-\delta)^\tau$, …, and hence the perpetual inventory method (Equation 3.3) that follows the geometric depreciation function can be expressed as:

$$(3.3) \qquad A_t = I_t + (1-\delta)A_{t-1}\,.$$

Here it is important to note that the efficiency variable δ is in fact the Hicksian rate of economic depreciation as explained by Hulten (1990). Hicks (1946) defines income as the maximum amount that can be spent during a period while maintaining capital values intact; then it follows that economic depreciation is the sum of money, in constant dollars, that needs to be set aside in order to maintain that capital value in real terms.

How a capital asset is valued? Assuming that rental markets exist for capital assets of all vintages, the cost minimization behavior of producers implies that capital of each vintage will be rented up to the point that the value of its marginal product $(\partial Q/\partial I)$ is equal to its rental price P^K, which implies that

(3.4) $$\Phi_s = \frac{\partial Q / \partial I_v}{\partial Q / \partial I_t} = \frac{P^K_{t,s}}{P^K_{t,0}},$$

where $s = t - v$ denoted asset age. With this relationship, we can then, following Hulten (1990), define the asset price P^I in terms of the relative efficiency sequence and the rental price of new assets:

(3.5) $$P^I_{t,s} = \sum_{\tau=0}^{\infty} \frac{\Phi_{s+\tau} P^K_{t+\tau,0}}{(1+r)^{\tau+1}}.$$

Importantly, in the absence of rental markets, this expression is also valid for the case in which capital is utilized by its owner (Hulten, 1990, p.128). This can be seen clearly by solving (Eq. 3.5) to obtain:

(3.6) $$P^K_{t,s} = \left[r - \rho_{t,s} + (1+\rho_{t,s})\delta_{t,s}\right] P^I_{t,s},$$

where

(3.7) $$\rho_{t,s} = \frac{P^I_{t+1,s+1}}{P^I_{t,s+1}} - 1,$$

is the expected "inflation rate" in the vintage asset price occurring between years *t* and $t+1$, and

(3.8) $$\delta_{t,s} = -\left[\frac{P^I_{t,s+1}}{P^I_{t,s}} - 1\right],$$

is the rate of decline in the asset price with age *s*. Therefore, Equation 3.6 has a straightforward interpretation: when capital is used by its owner, the equilibrium value of the *implicit* rental must cover the real opportunity cost of an investment of value of P^I as well as the loss in capital value as the capital asset ages (Jorgenson, 1963; Hall and Jorgenson, 1967).

As discussed in Jorgenson (1973), equation (3.8) can be rearranged to link economic depreciation to changes in asset efficiency:

(3.9) $$\delta_{t,s} P^I_{t,s} = P^I_{t,s} - P^I_{t,s+1} = \sum_{\tau=0}^{\infty} \frac{(\Phi_{s+\tau} - \Phi_{s+\tau+1}) P^K_{t+\tau,0}}{(1+r)^{\tau+1}},$$

which states clearly that Hicksian economic depreciation is the present value of the rental income loss due to the efficiency decay $\Phi_{s+\tau} - \Phi_{s+\tau+1}$ taking place in each year in the future (τ = 0, 1, 2, …).

As emphasized by Hulten, Equation 3.9 "shows that economic depreciation (a price effect) and efficiency decay (a quantity effect) are not independent concepts. One cannot select an efficiency pattern independently of the depreciation pattern and maintain the assumption of competitive equilibrium at the same time." More importantly, "this framework is useful for revealing what economic efficiency is, but it is also useful for revealing what it is *not*. Depreciation is not the replacement cost of the efficiency units used up in any year, that is, $\sum(\Phi_s - \Phi_{s+1})P^I_{t,0}$, because $P^I_{t,s}$ is not generally equal to $\Phi_s P^I_{t,0}$ unless decay is geometric (Hulten, 1990, p.129)."

In conclusion, it is theoretically justifiable to adopt a constant parameter δ or geometric pattern of depreciation in the perpetual inventory method (PIM) as expressed in Equation 3.3 should the economic theory of depreciation be followed. This methodology is also justified by empirical studies conducted by Hulten and Wykoff (1981a and 1981b), Koumanakos and Hwang (1988) and Coen (1972).

Strictly speaking, depreciation rate of assets should be calculated from the estimated geometric age-price profiles of assets based on the information obtained from equipment rental markets. Hulten and Wykoff (1981b) apply a Box-Cox power transformation model to their samples of used assets classified by prices and ages, with censored sample biases adjusted by the Winfrey retirement distribution. Then they assign the so-estimated depreciation rates (in average) to those NIPA (the US National Income and Product Accounts) asset classes that contain their asset types. As for those NIPA asset classes that do not contain the Hulten-Wykoff asset samples, an indirect approach is used by following the relationship:

$$\delta \equiv R / T, \tag{3.10}$$

where T is mean asset life and R is a declining balance rate. Firstly, with the age-price profile-estimated δ's for equipment and non-residential structures, Hulten and Wykoff derive an average R ($R = \delta T$) for the two categories, respectively, that is, R = 1.65 for the former and R = 0.91 for the latter. Then, based on the estimated R's and the information on the mean life of NIPA assets, they calculate δ's for those NIPA assets that do not contain their samples (Hulten and Wykoff 1981b, p.94). The Hulten-Wykoff estimates were used as the basis for the new depreciation methodology of the Bureau of Economic Analysis (BEA) in 1997 (Fraumeni, 1997).[10]

4. Reconstruction of Annual Investment Flows

First of all, or before any serious estimation jobs can be carried out, a conceptually simple but practically difficult issue is how to make the industrial classification of the official data consistent over time, a problem that has been ignored by many researchers because there is limited information that can be used for reclassification. Our classification problem here is the same as the CIP program that in principle follows the method used in Wu and Yue (2012) to restore classification consistency in the official labor statistics. The reconciliation between CIP and CSIC (China Standard Industrial Classification) is constructed in Wu and Ito (2014). The Wu-Ito reconciliation table is presented in the Appendix.

Sources of the basic data

[10] There is a detailed list of the depreciation rates in Fraumeni (1997). The new estimates of capital stock using these depreciation rates are described in Kaze and Herman (1997).

The basic data used in this study are mainly from the official statistical publications. For the official investment statistics, there are two official sources that are related but not necessarily the same. One is national accounts and the other is total investment in fixed asset (TIFA) (see Section 2). The national accounts data are annual investment in fixed assets published as cumulated national income (*guomin shouru jilei*) under the traditional material product system (MPS) before 1993 and as the SNA concept of gross fixed capital formation (GFCF) afterwards. The regular publication is *China Statistical Yearbook* (DNEA, NBS) and Historical GDP Estimates Volumes (DNEA, NBS). However, the national accounts do not provide investment statistics at industry or sector level. Various investment indicators at sector or industry level are available from China *Fixed Asset Investment Statistics Yearbook* (DFAIS, NBS) including TIFA and NIFA as well as investment in asset types (see Section 2).

The official statistics on capital stock, as mentioned in Section 2, are available as end-year "original value of fixed assets" (OVFA) (*nianmo guding zichan yuanzhi*) and "net value of fixed assets" (NVFA) (*nianmo guding zichan jingzhi*). Both cover enterprises and their investments by the official designated criteria that have changed over time. Historical statistics can be found in industrial statistics published in *China Industrial Economy Statistical Yearbook* (DITS, NBS; DIS, NBS, various issues). Besides, the national industrial censuses for 1985 and 1995 and the national economic censuses for 2004 and 2008 also provide OVFA and NVFA with a higher level of details than the yearbooks.

Deriving the value of annual investment spending

In the previously discussion (Section 2.1) we have clarified the relationship between the investment concept in PIM (I) and the official statistics on total investment in fixed assets or TIFA denoted as M in Eq. 2.1 and newly increased fixed assets or NIFA denoted as N in Eq. 2.2. Ideally, we should follow Eq. 2.2 to construct the investment series for individual industries. However, since NIFA lacks industry details especially for the period prior to the mid 1990s, we have to rely on the official stock data, that is, the end-year "original value of fixed assets" or OVFA.

Conceptually, a *gross* capital stock of the j^{th} industry at historical prices A^G in the current period t, is a result of accumulated investment, or assets of all vintages, minus accumulated scrapings (S) which should also be at historical prices, that is,

$$A^G_{j,t} = \sum\nolimits_{\tau=0}^{T} I_{j,t-\tau} - \sum\nolimits_{\tau=0}^{T} S_{j,t-\tau} \quad (\tau = 0, 1, 2, \ldots T) \tag{4.1}$$

where T stands for the full "standard" service life of vintage-specific assets and τ for the number of years a vintage in service. Hence, the current period investment is given as:

$$I_{j,t} = A^G_{j,t} - A^G_{j,t-1} + S_{j,t}\,. \tag{4.2}$$

Now, if substituting OVFA for A^G in Eq. 4.2, taking into account the improper inclusion of residential structure in the investment statistics and assuming no underreporting problem, we can therefore obtain an estimate of the value of investment in the j^{th} industry by the following relationship:

(4.3) $$I_{j,t} = \frac{(1-\eta_{j,t})}{(1-\lambda_{j,t})}(OVFA_{j,t} - OVFA_{j,t-1} + S_{j,t})$$

where following Equation 2.2 $\eta_{j,t}$ (< 1) is the proportion of non-productive assets, mainly residential structures, and $\lambda_{j,t}$ (<1) is the proportion of productive assets not covered by the official industry investment statistics, mainly investment projects that are below the official threshold for investment statistics.[11]

However, one of the main problems in calculating Eq. 4.3 is that there is little information on scrapings. In both Chen *et al*. (1988a) and Li *et al*. (1993),[12] the scraping factor is simply ignored, which underestimates the value of investment. Li *et al*. (1993, p.97) argue that scrapings may be insignificant in China, especially for the central planning period, because the official standard of service lives of fixed assets was much longer than the accounting "standard" and the delayed retirement or over-service of fixed assets was a norm. Empirical evidence is called to justify such a conjecture and a treatment to the underlying scrapings. Besides, one has to take into account the effect of market-oriented reforms because increasing market competitions naturally tend to induce the earlier retirement of fixed assets.

In practice, OVFA is calculated at the end of each accounting period, thus it should exclude any asset that had already retired before that time point. In exercising Eq. 4.3, to avoid underestimating annual investment flows, it is conceptually correct to add back the value of retired assets (*S*). This is however difficult without necessary information. We need to know how fixed assets retire in each industry over time in general and under different policy regimes in particular. In the absence of any empirical evidence for the retirement function of assets across industries, we have to rely on assumptions. We assume that assets of the same vintage follow a normally distributed retirement function to leave production services and the retirement function is centered at the end of the standard service lives of assets. For simplicity, we also assume that the time span for a vintage to completely retire is seven years. That is, the function is maximized in the fourth year, and over this retirement time span some assets may retire three years earlier than their full service lives whereas some may retire three years later. The results are used to adjust the investment flows as the first difference of OVFA derived based on Eq. 4.3.

Decomposing assets and handling non-productive assets and missing assets

The official statistics on OVFA is in total value at historical prices. It is mixed with all types of assets. Without a proper decomposition of this total value, it is not only impossible to remove residential structures that were included in industrial assets but also inappropriate to conduct the standard deflation and depreciation procedures.

[11] Small investment projects are not recorded in the Chinese official investment statistics. The threshold was 50 thousand yuan prior to 1997. It was raised ten times to half million yuan in 1997 except for real estate investment and investment projects by rural collectives and individuals (NBS, 2011, p.144).

[12] There is an earlier study that is also led by Li *et al*. assuming mistakenly that OVFA does not exclude the value of scrapings, and hence it is no need to do the adjustment (Li *et al*., 1992, p.348). This is incorrect as shown by evidence obtained by the author in some Beijing factories arranged by NBS in 2003.

There are limited investment data by asset type especially at industry level. In the official investment statistics, under the subcategories of TIFA "capital construction" (*jiben jianshe touzi*) and "technical update and transformation" (*gengxin gaizao touzi*) there are data for "equipment" and "structures". The "structures" indicator also distinguishes "housing" or "non-productive" constructions. But they are only available for the aggregate economy without sector or industry breakdowns.

Any attempt to directly decompose OVFA in the official investment statistics is difficult to justify its results. This is not only because the decomposition should be industry-specific but also because TIFA, denoted as M in Equations 2.1 and 2.2, is incompatible with the actually invested assets N (I) or exaggerates the latter that is in fact the foundation for OVFA.

In this study, our decomposition mainly relies on industry-level investment statistics in various annual statistical bulletins available in the NBS Archives (DITS, various years). The bulletin data are still far from systematic, complete and consistent. For the period prior to 1974 there are only 1954 data are available, and for the period since 1974, on which we focus, data for 1983, 1986-88 are missing. However, they provide valuable industry-specific information though some industrial classification problems need to be fixed and also provide industry information for non-productive assets such as housing. Also importantly, the bulletin data refer to the existing stock, therefore they are compatible with OVFA.

This decomposition exercise produces four categories of industry-specific fixed assets for the industrial sector, namely, "equipment", "residential structures", "non-residential structures" and "others". Based on this, we first remove "residential structures" and then redistribute "others" into "equipment" and "non-residential structures" by a ratio of 3:7.[13]

Investment flows of the nonindustrial sectors

There are, however, no data on OVFA for the nonindustrial sectors (agriculture, construction and all services) that allow us to do the same exercise as we have done for the industrial sector. Before more information is available and better methodology is developed, we have to carry out our estimation based on strong assumptions. We assume that the sector-specific investment flows (I), as expressed in Eq. 3.3, is equal to the official newly increased fixed assets or NIFA (and NIFA is equal to N in Eq. 2.1). Also due to the lack of necessary information we use the share of productive structures given by the economy-wide TIFA to decompose the total investment into non-residential structures and equipment.[14]

5. Estimation of the Initial Stock & Annual "Control Totals"

[13] According to the author's discussion with NBS, most of the spending under the item of "others" incurred in structure construction-related land acquisition. The results are insensitive to ratios from 5:5, 4:6 to 2:8.

[14] The universal treatment to all non-industrial sectors is by no means realistic. But it is less strong than arbitrary treatments to individual sectors.

This section deals with aggregates, the estimation of the initial level of capital stock and annual net capital stock as "control totals".[15]

The initial capital stock

Despite many efforts which have been made in estimating China's aggregate capital stock,[16] the estimation of its initial (post-war) stock has been left ambiguous. Existing studies have made or adopted very different estimates for the initial capital stock (usually referring to 1952) ranging greatly from less than 50 to over 250 billion yuan in 1952 prices which imply a capital-output ratio (K/Y) ranging from below 0.45 to a level as high as over 2 if based on the official GDP for 1952. Some may argue that the initial stock in the early 1950s does not really matter if the main interest is in the reform period and in growth accounting (Young, 2003, p.1253). But it is however important if we are interested in examining changes in capital-labor ratio, capital-output ratio and the trend of return on capital in the Chinese economy in the long run.

Few of the studies have discussed how their estimates are made. Maddison (1998, pp.64-65) relied on a hypothetical capital-output ratio of 0.9 for 1952 that was empirically justified by the lower bound of the international standard and pre-war estimates by Yeh (1968 and 1979). This will be used as a reasonable starting point in the following discussion. Our research on the initial capital stock follows two lines: one is theoretical which assumes a steady state situation for China in the early 1950s using an approach as explained in King and Levine (1994), and the other one is empirical which uses the data of China's first asset census in 1951 (SETC, 2000, Vol. 1).

The estimation of the initial capital stock follows the steady-state method as in King and Levine (1994). Let us assume that physical capital stock and the real output grow at the same rate φ*, that is,

$$\varphi_t^* = \frac{dA_t}{A_t} = \frac{dY_t}{Y_t} \tag{5.1}$$

where A_t is the capital stock and Y_t is real GDP at time *t*. Since $dA_t = I_t - \delta A_t$ then $\frac{dA_t}{A_t} = \frac{I_t}{A_t} - \delta$ where I_t is gross investment and δ is the depreciation rate of physical capital. Letting *i* be the investment rate, i.e. $i_t = \frac{I_t}{Y_t}$, thus $\varphi_t^* = \frac{dA_t}{A_t} = \frac{i_t Y_t}{A_t} - \delta$, then the steady-state capital-output ratio is derived as follows:

[15] This section is based on Wu (2014).

[16] For studies in English see, e.g. Chow (1993), Chow and Li (2002), Field (1980), Holz (2006), Hu and Khan (1997), Maddison (1998), Wang and Szirmai (2012), Wang and Yao (2002), and Young (2003). For studies in Chinese see e.g. Bai *et al.* (2007), He (1992), He *et al.* (2003), Ren and Liu (1997), Tang (1999), Wang and Fan (2000), and Zhang and Zhang (2003).

(5.2) $$\kappa_t^* = \frac{i_t^*}{\delta + \varphi_t^*} \text{ that is, } A_t^* = \frac{I_t}{\delta + \varphi_t^*}.$$

To estimate physical capital stock at time *t* by the standard perpetual inventory method (PIM), the following equation is applied:

(5.3) $$A_{t+1} = I_t + (1-\delta)A_t$$

Then, based on 5.3 we can generate a function of initial capital stock and investment flows as follows:

(5.4) $$A_t = \sum_{i=0}^{t-1}(1-\delta)^i I_{t-i} + (1-\delta)^t A_0$$

where $A_0 = \kappa_t^* Y_0$

To solve for A_0 of Equation 5.4, we need data on investment flows, an average GDP growth rate and a depreciation rate for the initial period. The national accounts GFCF in 1952 can be used for I_0, official and our alternative measures of the average GDP growth for the period 1952-56 are used for $\bar{g}$, and δ_0 is assumed to be 2 percent based on the information from the 1951 national asset census (explained below).

Directly using the unadjusted official GFCF, GDP and the expenditure accounts implicit GFCF deflators, plus the 2-percent depreciation rate as revealed by the 1951 asset census, we obtain an initial capital stock of 166.7 billion in 1990 yuan for the midpoint time of 1952-57 (e.g. 1955) based on which the average GDP growth rate is calculated. However, if using our alternative estimates of GFCF, GDP and GFCF deflator, and choosing a 5-percent depreciation rate, the result would be 208.3 billion 1990 yuan. On the other hand, if following Maddison's assumption of a K/Y ratio of 0.9 and using our new estimate of GDP, we can obtain an estimate of 286.5 billion 1990 yuan for 1952.

We can evaluate the above estimates by examining the seldom used information from the aforementioned 1951 national asset census that verified and evaluated China's stock of fixed assets, only available for publication in 2000 as a collection of archived planning documents and papers by SETC (2000, Vol. 1, pp.1543-4). It shows that by the end of 1951, the total market replacement value of fixed assets was 128.4 billion in 1952 yuan. Taking off the accumulated depreciation value of 39.2 billion, the net stock would be 89.2 billion 1952 yuan, equivalent to 169.6 billion 1990 yuan (based on 1990/1952 investment price ratio 1.901 by the NBS deflator).

However, one should not take this asset census data for granted. Two political economy factors have to be taken into account when evaluating this census results. On the one hand, the private owners of fixed assets had strong incentives to hide some assets in a state-run survey because of a high fear of confiscation or nationalization. On the other hand, the authorities also tended to undervalue private assets in order to reduce the purchase cost of the assets should the sate decide to buy rather than to confiscate them.

There is clear evidence in the census data that the fixed asset in the agricultural sector, dominated by private farmers, is implausibly low – only 0.04 percent of the total net stock. Land is certainly not included. But that is not our problem, at least for the current work as land is also not included. However, we can show that this census result is absolutely implausible only using the information from state-owned farms. In 1952, the land area of state-owned farms, inherited from the old government after the 1949 revolution, accounted for 3.5 percent of the national arable areas. Since state farms were operated with more machinery, draught animals and productive structures than private and household farms, it is reasonable to assume that the fixed assets owned by the state farms may account for at least 10 percent of the total assets in agriculture. Chow (1993) also conjectures that the initial agricultural capital stock should account for 30 percent of the national total excluding land.

As a starting point, we may make an estimation based on the following (still conservative) assumptions: 10 percent of the fixed assets in industry and services were underestimated.[17] After an adjustment for the 10 percent underestimation, the value of non-agricultural fixed assets accounted for 70 percent of the national total. The residual estimate from this calculation refers to the fixed assets in agriculture. The so-estimated total value of fixed assets is 140.1 billion 1952 yuan for 1951, of which agriculture accounted for 30 percent, industry 8 percent and service 62 percent. After depreciation and an adjustment to the price change between 1952 and 1990, it would be 287.2 billion 1990 yuan. Next, based on the real growth of fixed asset investment of 14.3 percent between 1951 and 1952 (CASS and CA, 1998, pp.1138-42), the comparable value for 1952 is estimated at 328.3 billion 1990 yuan, which is not too far away from the estimate of 286.5 billion 1990 yuan based on Maddison's assumption. This result is used as the initial capital stock for 1952 in our PIM exercise.

Aggregate depreciation rate

Based on Equation 5.4 two sets of net capital stock series are constructed, each using the same alternative depreciation rates proposed in this study based on my earlier work on an industry-level estimation of capital stock (Wu, 2008).

Following the empirical findings in Hulten and Wykoff (1981b), we assume that industry-specific depreciation rate, $\delta_i \equiv R_i / T_i$, where T stands for the service life of an industry and function-specific asset which is based on official accounting regulations (State Council, 1985; Ministry of Finance, 1992), and R is the asset's declining balance rate. The estimated depreciation rates for 39 two-digit level industries are on average ranged from 7 to 8.5 percent for equipment and 2.5 to 3.5 percent for structures over three available time points, i.e. 1963, 1985 and 1993 (Wu, 2008). Considering the likelihood of a market-induced faster depreciation process following the reform, as well as the underlying faster economic depreciation before the reform, it is reasonable to increase these estimates to 10 percent for equipment and 4 percent for structures in industry. This is a basis for us to gauge an average general depreciation rate for the economy as a whole. In Chinese industry, as evidenced in Wu (2008) equipment accounts for 70 percent of the fixed assets and structures for 30 percent. This is reversed when focusing on the asset structure of the national economy based on investment, that is, approximately 35 percent

[17] We are looking for further justifications for the assumption and evidence for better adjustment.

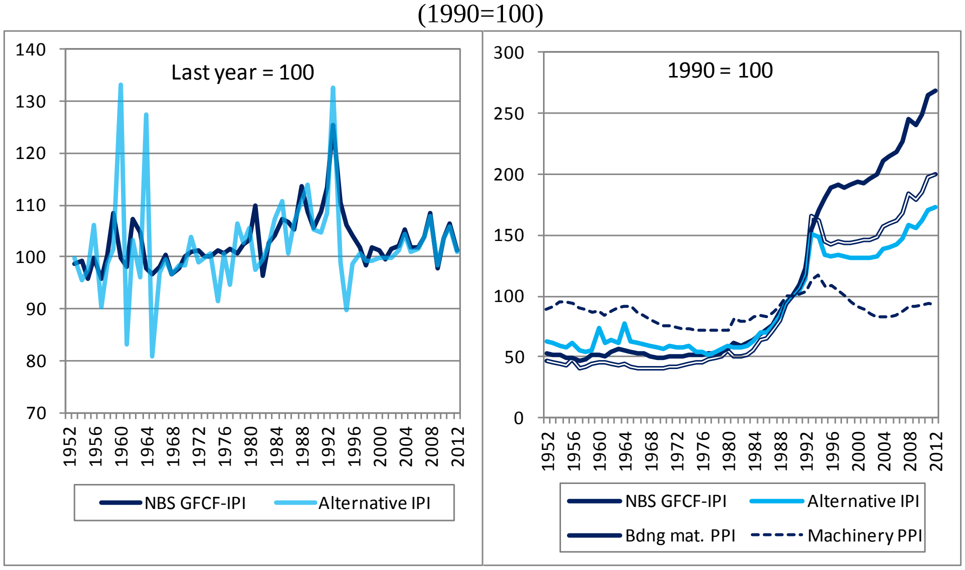
for equipment and 65 percent for structures excluding housing, based on official investment statistics. Therefore, an average depreciation rate for the whole economy is about 6 percent (6.1%=10%*0.35+4%*0.65).

Therefore, the present study sets a depreciation rate of 6 percent (δ=0.06) as the baseline with 5 and 7 percent as the lower and upper bound, respectively. These are alternative depreciation rates for the entire period in question assuming that the depreciation process in the Chinese economy follows a geometric function.

An alternative investment deflator

We can construct an alternative investment deflator to the official GFCF deflator that is implicitly given by the expenditure accounts based on two reasons. First, the implicit GFCF-IPI may have overstated the price changes in the period 1995-2004 in which China experienced an unprecedented long deflation in investment goods, much longer than that experienced by the general economy in 1998-2002. Second, the implicit GFCF-IPI is highly likely to be influenced by the rapidly rising prices of land transactions along with China's property boom in the 2000s. As Figure 2 shows, since the mid-1990s, the implicit GFCF-IPI has mainly followed the PPI (producer price index) of building materials rather than the PPI of equipment industries. However, the PPI of building materials better reflects the effect of the long deflation in the Chinese economy than the GFCF-IPI. This justifies the use of a PPI weighted by the PPI of building materials and the PPI of equipment industries.[18]

FIGURE 2
WHICH INVESTMENT DEFLATOR IS MORE REASONABLE?
(1990=100)



Sources: NBS (2012, Tables 2-17, 9-11, 9-12 and other issues), DNEA (2004 and 2007) and ECNH (2002).

[18] The estimated alternative IPI may be still too high in the case of information technology-related industries as Tomohiko Inui suggested using the Japanese experience, which certainly deserves further investigations.

TABLE 1

OFFICIAL AND ALTERNATIVE ESTIMATES OF ANNUAL INVESTMENT GROWTH, AND THE SHARE INVESTMENT IN CHINA'S GDP

(Annual compound growth in percent in nominal or 1990 prices, unless specified)

			GFCF in Nominal Prices		Price Change of GFCF		GFCF(B) in 1990 Prices		GFCF(C)[5] in 1990 Prices	
	TIFA[1]	NIFA[1]	GFCF(A)[2]	GFCF(B)[2]	Official IPI[3]	Alternative IPI[4]	Official IPI	Alternative IPI	Alternative IPI	Share[6] (GDP=1)
1952-57	28.3	13.1	18.3	17.7	-2.1	-2.3	20.3	20.5	19.9	0.09
1957-65	4.6	5.9	8.2	8.2	1.6	1.6	6.5	6.4	7.3	0.16
1965-71	11.5	10.9	9.5	9.0	-1.1	-1.1	10.1	10.2	9.9	0.17
1971-77	4.7	4.5	7.1	7.1	0.8	-2.3	6.3	9.7	9.1	0.23
1952-77	*10.7*	*7.9*	*10.2*	*10.0*	*0.0*	*-0.8*	*9.9*	*10.8*	*10.8*	*0.16*
1977-84	16.7	13.4	13.0	12.1	2.7	3.1	9.2	8.8	7.4	0.25
1984-91	17.3	17.6	16.0	16.8	8.0	7.5	8.2	8.7	5.2	0.27
1991-01	20.9	19.7	20.1	19.3	5.9	2.3	12.7	16.7	13.3	0.41
2001-07	24.3	19.8	18.4	15.0	2.7	2.0	11.9	12.7	11.4	0.52
2007-12	22.2	21.8	18.5	19.5	3.4	3.2	15.6	15.8	12.9	0.62
1977-12	*20.1*	*18.3*	*17.3*	*16.6*	*4.8*	*3.5*	*11.3*	*12.7*	*10.1*	*0.40*

Sources: Author's estimates. For the basic data, see Figure 5.

Notes: 1) TIFA and NIFA are as defined in text. 2) GFCF(A) includes residential housing and GFCF(B) removes residential housing. 3) The official investment price index (IPI) is the expenditure accounts implicit deflator. 4) The alternative IPI is constructed based on PPI of investment goods industries, see text for details. 5) GFCF(C) is alternative GDP-adjusted GFCF(B). 6) The share of GFCF is estimated as GFCF(C)/alternative GDP in 1990 prices.

In the construction of the alternative IPI, we first construct two weighted PPIs: one PPI is based on the PPIs of construction materials industries, namely, non-metallic materials and basic and fabricated metals, and the other PPI is based on the PPIs of machinery and equipment industries including ordinary and special purpose machinery, transportation equipment, electrical and electronic equipment and office equipment (Figure 2). We then further weight the two so-constructed PPIs into one IPI, the alternative IPI as depicted in Figure 2.

Table 1 includes a comparison of the implicit GFCF-IPI with the alternative IPI. For the planning period, the GFCF-IPI shows that there was no change in investment prices but our alternative deflator suggests a decline by 0.8 percent in investment prices. For the reform period, however, the alternative IPI also implies a slower change of investment prices than the official IPI does, i.e. 3.5 compared with 4.8 percent per annum. Consequently, using the alternative IPI will raise the growth of GFCF from 9.9 to 10.8 percent per annum for the planning period and from 11.3 to 12.7 percent for the reform period.

6. CONSTRUCTION OF INDUSTRY-SPECIFIC INVESTMENT PRICE INDEX (IPI)

This section deals with industry-level deflators. As indicated by Hulten (1990), there are mainly two potential sources of errors introduced in the process of deflation: the application of a single deflator to goods that are in fact heterogeneous and the lack of adjustment for quality change. In this study, an initial attempt is made to construct price indices for individual industries, which can significantly reduce the degree of the first type of errors. As for the second type of errors, we have to wait until better data become available. However, for the central planning period, this should not introduce a significant bias into the result as it can reasonably be assumed that there was generally no significant quality improvement under central planning.

Detailed information on prices is scant in the official statistics in general and for the prices of investment in particular. We rely on four sources of investment price statistics, directly or indirectly. The first one is implicit price deflator for GFCF that can be derived from the national accounts available in *China Statistical Yearbook*, but there is no explanation about how the nominal GFCF is deflated. The second source is investment prices for equipment and structures at the aggregate level in the official price statistics since the 1990s, also available in *China Statistical Yearbook*. The next source is 6-digit level industry-specific asset price indices for state owned enterprises (SOEs) based on an asset survey by Ministry of Finance, but it only covered for the period 1985-1998 (ECNH, 2002). The last source of data that can be used for the construction of investment deflators are the PPIs of investment goods, available from the official price statistics in *China Statistical Yearbook*.

Construction of industrial IPIs

Since much of the available price information is for the industrial sector, let us concentrate on the equipment of the industrial sector first. Using the available price statistics as summarized above, we take the following procedures to construct investment price index (IPI) for each of the 39 industries of the industrial sector (equivalent to the CIP Industry Code 2-25, see Table A1 of the Appendix). First, we rely on the MoF (2003) asset survey data for SOEs to construct industry-specific IPI for the period 1985-1998. In this part of the data work, we first group the 6-digit-level equipment price indices in line with the CIP classification (Table A1) and then adjust the results by the aggregate IPI for equipment (published by another source as indicated earlier) that is supposed to have covered both SOEs and non-SOEs. For the period 1980-84, we estimate industry-specific IPI based on the "relationship" between aggregate IPI for equipment and industry-specific IPI for 1985, assuming strongly though that the "relationship" could be held for the period prior to 1985. Finally, for the period 1999-2010 we estimate industry-specific IPI based on the "relationship" between the industry-specific IPI for 1998 and weighted PPIs of industries mainly producing for investment equipment, CIP coded from 19 to 22 (Table A1). Besides, given that the share of SOEs has declined particularly since the 1990s and also assuming that the aggregate IPI for equipment covered economy-wide investment in equipment, i.e. including both SOEs and non-SOEs, the above constructed industry-specific IPIs are further adjusted by changes in the aggregate IPI for equipment.

TABLE 2

RECONSTRUCTED INDUSTRY-SPECIFIC INVESTMENT PRICE INDICES OF THE CHINESE ECONOMY

(1990 = 100)

	1985	1992	1997	2002	2008	2010
Non-residential Structures						
Total economy	*64.7*	*130.1*	*137.9*	*128.7*	*193.4*	*200.0*
Equipment						
Total economy	*67.1*	*113.7*	*154.3*	*146.2*	*142.3*	*139.3*
Agriculture	67.2	113.8	155.4	147.9	144.0	141.0
Coal mining	68.5	112.8	165.8	161.1	156.8	153.5
Oil & gas extraction	71.1	117.6	168.6	165.7	161.2	157.8
Metal mining	66.8	115.0	161.2	158.0	151.4	149.4
Non-metal mining	66.3	119.0	170.5	162.5	158.2	154.8
Food products	67.0	111.4	143.1	135.6	134.0	131.8
						107.9
Tobacco products	65.7	108.6	120.9	113.3	110.2	
Textile products	65.8	110.0	144.5	138.8	135.0	132.2
Apparels	68.3	105.8	135.0	132.7	129.2	126.4
Leather products	65.5	113.3	138.3	129.1	125.6	122.9
Saw mill & furniture	70.8	115.5	165.9	146.7	144.3	140.9
Paper, printing & publishing	67.7	111.1	147.2	139.8	136.8	133.7
Petroleum & products	64.1	109.2	168.7	160.2	155.9	152.6
Chemicals	59.5	109.4	166.9	163.9	155.4	152.7
Rubber & plastics	65.9	113.6	159.8	151.4	150.0	146.5
Building materials	69.7	114.3	151.6	141.1	137.3	134.4
Basic metals	66.7	113.6	164.2	152.8	148.8	145.7
Metal products	65.7	114.7	158.4	149.5	145.4	142.4
Machinery	65.9	115.4	159.7	150.9	146.9	143.8
Electric equipment	70.2	111.9	144.0	136.0	132.3	129.5
Electronic equipment	73.1	125.5	141.0	127.8	124.4	121.8
Instruments & office equip.	69.1	119.7	151.3	140.6	136.8	133.9
Transport equipment	65.9	115.6	160.1	151.3	147.2	144.1
Other manufactures	65.1	111.9	154.4	142.7	135.3	132.5
Utilities	65.9	115.1	159.4	150.7	146.7	143.6
Construction	67.2	113.8	155.4	147.9	144.0	141.0
All services*	67.2	113.8	155.4	147.9	144.0	141.0

Source: Author's estimates. See text for more information.

Note:*Assuming all services face the same investment prices.

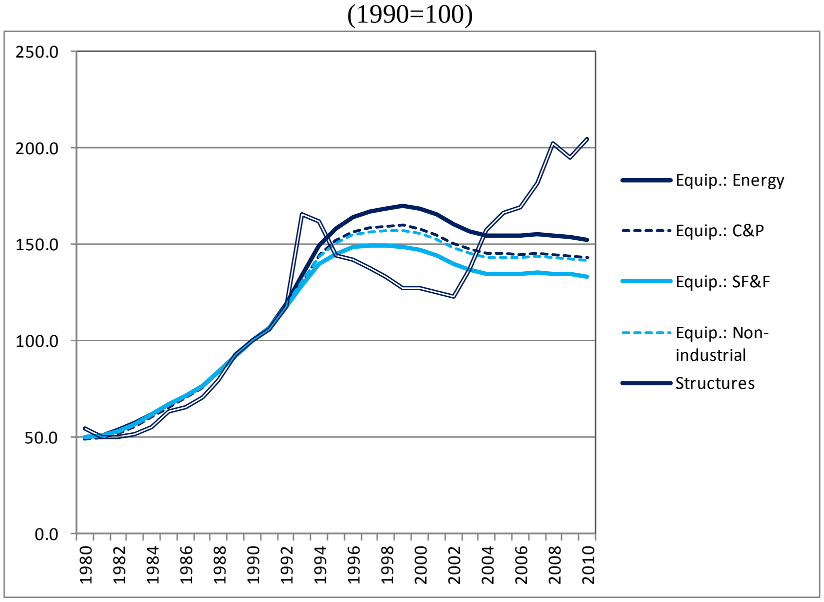
Construction of non-industrial IPIs

Constrained by little information on investment prices in non-industrial industries, especially services, we have no choice by assuming that the investment price changes for equipment in these industries have followed those of industrial sectors.[19] For the period before 1990, we use the national aggregate price index for investment in structures, unfortunately not yet able to separate residential from productive structures, and for the period since 1990 we use the official IPI for "construction and installation works". The constructed industry-specific IPIs for equipment and non-residential structures and for total investment are reported as 1990-based indices for selected benchmark years in Table 2. These benchmark years are used to capture the time of policy regime shifts or external shocks, namely the double-track price reform in 1984-85, Deng's southern China trip to promote deeper reforms in 1992, the Asian financial crisis in 1997-98, and the global financial crisis in 2008.

FIGURE 3

INVESTMENT PRICE INDICES OF THE CHINESE ECONOMY

(1990=100)



Source: Author's estimates.

Despite insufficient price information especially for services, our estimates appear to be plausible. Figure 3 shows that after a rapid increase in investment prices in general in the 1980s the increase in the investment price of structures suddenly turned in a sharp decline in the early 1990s. Meanwhile the rise in the investment prices of equipment substantially slowed down and finally began to decline in the wake of Asian financial crisis in 1997-98. These changes largely reflect increasing surplus capacity caused by the over-investment following Deng's southern China trip in 1992 to promote deeper reforms and the official adoption of the "socialist market economy". China entered a long period of deflation for 3-4 years in the case of the investment in equipment and for 7-8 years in the case of the investment in infrastructures. It was China's WTO

[19] We are still searching for more information to relax this strong assumption. Comments and suggestions are most welcome.

entry that stopped the deflation. However, while the investment price of structures turned into a rapid rise—thanks to the property bubble, the investment price of equipment stood still through China's post-WTO period.

7. INDUSTRY-SPECIFIC DEPRECIATION RATES

The last step of constructing the net capital stock is to depreciate the estimated gross capital stock series in equipment and structures of each industry. As defined in Equation 3.10, in this work we need declining-balance rates (R) and service-life assumptions (T) for equipment and structures of each industry.

We focus on the industrial sector first. For asset lives of different industries, given that lack of survey data we have to rely on state policies that regulate state firms in depreciation practice. Three sources of information are used for gauging the service lives of assets in Chinese industry. The first source is the depreciation rates used in the accounting practice since 1963 by the Ministry of Finance that refer to types of the fixed assets across industries under their responsible ministries. We gauge the service lives of different assets by Equation 3.10 assuming a straight-line function. The second source is based on the State Council No. 63 Circular in 1985 that gives a detailed list of the "regulated service lives" by major equipment and structures across state industries. The last source is based on the Ministry of Finance No. 574 Document in 1992 that provides updated asset service life regulations from those issued in 1985.

To reflect changes in economic efficiency rather than simply accepting the official arbitrary estimates of asset lives of different Chinese industries for accounting purpose, we feel justified to adopt the BEA estimates of declining-balance rates for major industrial equipment and structures (Kaze and Herman, 1997, pp.72-3), mainly based on the empirical work by Hulten and Wykoff (1981b).

We have two choices in deciding the standard of asset service lives. Firstly, we could use the estimates for 1963 for the period 1980-84 because of strict central planning controls lasting till the late 1980s; then, for the period 1985-92, we could use the regulated service lives adopted in 1985, and the regulated service lives adopted in 1992 for the period from 1993 onwards. In doing so, we actually adopt variant depreciation rates for the three periods (Table 3), which means that we introduce breaks into the depreciation process that is theoretically supposed to follow a geometric depreciation function with a constant depreciation rate as given in Equation 5.4. However, the significant shifts in industrial policy regimes that affected resource allocation through investment and depreciation systems over these periods may justify for such a treatment.

Alternatively, we could use the average of the three standards as a consistent depreciation rate over the entire period by assuming that the authorities constantly searched for some balance between their needs for a faster depreciation to stimulate technological advancement and needs for saving money when there is shortage of fund for investment. In this study, we divide the full period in 1993 when the economy began to respond to Deng's push for deeper and bolder reforms especially on SOEs. Table 3 reports the estimated depreciation rates for industry-specific non-residential structures and equipment as well as for total capital stock.

TABLE 3
ESTIMATED INDUSTRY-SPECIFIC DEPRECIATION RATES OF THE CHINESE ECONOMY
(Percent change per annum)

	Non-residential Structures		Equipment		Total Stock	
	1980-1992	1993-2010	1980-1992	1993-2010	1980-1992	1993-2010
Total economy	*2.5*	*2.7*	*7.5*	*8.3*	*5.5*	*5.2*
Agriculture	2.5	2.7	7.5	8.3	5.5	5.2
Coal mining	3.4	3.6	7.7	8.1	7.0	7.1
Oil & gas extraction	4.5	3.6	9.7	7.7	6.6	7.0
Metal mining	3.5	3.6	7.6	7.7	6.8	6.7
Non-metal mining	3.5	3.6	7.6	7.7	6.3	6.4
Food products	2.3	2.4	7.6	8.1	5.6	5.8
Tobacco products	2.3	2.4	7.6	8.1	5.5	6.7
Textile products	2.1	2.4	6.9	8.1	5.8	6.4
Apparels	2.1	2.4	6.9	8.1	5.3	5.0
Leather products	2.1	2.4	6.9	8.1	5.5	5.0
Saw mill & furniture	2.1	2.3	7.6	8.1	5.4	5.8
Paper, printing & publ.	2.3	2.4	7.6	8.1	5.8	6.3
Petroleum & products	2.3	2.4	7.6	8.1	6.7	7.3
Chemicals	2.3	2.4	7.8	8.1	6.7	6.8
Rubber & plastics	4.7	4.9	7.8	8.1	7.1	7.1
Building materials	4.7	4.9	7.8	8.1	6.8	7.0
Basic metals	2.0	2.4	7.3	9.0	7.4	7.6
Metal products	2.2	2.4	8.4	9.2	7.2	6.2
Machinery	2.2	2.4	8.7	9.8	7.3	7.2
Electric equipment	1.9	2.4	6.9	9.0	6.6	6.8
Electronic equipment	1.9	2.4	6.9	9.0	6.9	7.1
Instruments & office eq.	1.9	2.4	6.9	9.0	6.1	6.4
Transport equipment	2.0	2.4	8.2	9.9	7.5	7.5
Other manufactures	2.0	2.4	8.2	9.9	7.5	7.0
Utilities	2.4	2.4	5.3	5.5	4.9	5.0
Construction	2.5	2.7	7.5	8.3	5.5	5.2
All services*	2.5	2.7	7.5	8.3	5.5	5.2

Source: Author's estimates. See text for the methodology.
Note:*Assuming all services face the same depreciation rate.

Unfortunately, we have no information on the service lives of capital assets of any non-industrial sector, i.e. agriculture, construction and services. We assume that the capital stock of each non-industrial sector depreciates at a constant rate that is the same as the average of the industrial sectors over the period 1980-92 and 1993-2010 as reported in Table 3. In fact, this industrial sector-based average depreciation rate is also used for the total economy.[20]

8. ESTIMATED INDUSTRY-SPECIFIC NET CAPITAL STOCK

The industrial sector

[20] One sensible exploration is perhaps to compare our estimates to those using industry-specific depreciation rates from other countries, e.g. the US or Japan where detailed depreciation rates are available. This may also give us an indication of Chinese investment moving away from/close to competitive market principles as suggested by Abdul Erumban. Besides, we could also consider adjusting service lives to conduct some sensitivity tests of the current results.

Our final net capital stock estimates for each industry are made up by two parts: "formal" and "informal" components (including small private business and small-sized investment projects that are not included in the official investment statistics). For the formal component, the annual estimate of industry-specific net capital stock is obtained by Equation 3.3 using the reconstructed investment flows following Eq. 4.3 and the geometric depreciation rate given by Eq. 3.10. The initial level of net capital stock for 1980 is estimated using Equation 5.2 with adjustment. For the informal component, however, the annual estimate of industry-specific net capital stock is obtained by using the capital-labor ratio of labor-intensive industries and their employment reconstructed in Wu, Yue and Zhang (2014) for the CIP project. The labor-intensive industries are defined by the mean capital-labor ratio with an arbitrary measure of the standard deviation from the mean. This approach is applied to both non-residential structures and equipment.

The non-industrial sectors

The final net capital stock estimates for each non-industrial sector are also made up by two parts: formal and informal components. For the formal component, the annual estimate of industry-specific net capital stock is obtained by Eq. 3.3 using the official NIFA, defined as *N* in Equation 2.2. The initial level of net capital stock for 1980 is also estimated with Equation 5.2 with adjustment. For the informal component, we take two steps to estimate it. First, we calculate the "informal" employment of each sector by subtracting the "formal" employment as reported by the labor registration system from the total employment as constructed in Wu, Yue and Zhang (2014). Second, based on the K/L ratio of the most labor-intensive sectors, excluding agriculture assuming that agriculture was still in labor surplus status during this period, we estimate capital stock for the "informal" employment. However, this estimation does not distinct asset types.

The "residual"

We have noticed that the so-estimated total net capital stock is always smaller than that is simply based on GFCF (adjusted to exclude housing) which is defined as the national "control total" for the investment in fixed assets (we cannot make the comparison at sector or industry level because GFCF provides no disaggregated data for any level of classification. This persistent and positive "residual" means that the discrepancy is not random. That is, it cannot be mainly caused by measurement errors. The underlying factors may have opposite effects. On the one hand, our approach may not have fully covered the investment by the "informal sector", which underestimated the investment and capital stock. On the other hand, the investment may be exaggerated by improperly including some inventories (incomplete investment projects), but they are not captured by the end-year fixed assets based on which we derive industry-specific investment flows (discussed in Section 2). Furthermore the investment could also be exaggerated by growth-motivated local governments always racing for a better GDP performance, but it may not have a strong impact on the recorded fixed assets.

There may be three ways to deal with the "residual". If one is fully convinced by our reasoning and with data constraints he/she should accept our results without considering any further adjustment to GFCF. This is Scenario I (Table 4) which is adopted by the CIP program. Alternatively, one could propose two mechanical "reconciliations" to fully absorb the "residual". The first "reconciliation" or Scenario II can be based on an assumption that the "residual" is proportional to the investment of all industries as estimated without taking into account that individual industries could have different capital/labor ratios and different formal-to-informal ratios. The second "reconciliation" or Scenario III can be based on another assumption that our approach of reconstructing the investment flows for the industrial sector (Eq. 4.3) may be more reliable than directly accepting the official investment statistics for the non-industrial sectors (Eq. 3.3), hence leaving little room for further adjustment. Thus, the "residual" should exclude the former and focus on the latter also by the proportional distribution approach. A comparison of the three scenarios-based annual growth rates and industrial structures is presented in Table 4.

TABLE 4

ESTIMATED NET CAPITAL STOCK GROWTH AND INDUSTRIAL STRUCTURE FOR THE CHINESE ECONOMY: THREE ALTERNATIVE SCENARIOS

Industry group*	1991-2001 (% change p.a.)			2001-07 (% change p.a.)			2007-10 (% change p.a.)		
	I	II	III	I	II	III	I	II	III
Total	*13.0*	*14.4*	*14.4*	*16.8*	*13.0*	*13.0*	*20.4*	*14.4*	*14.4*
Agriculture	8.8	10.1	8.6	12.2	8.5	6.1	21.3	15.3	12.3
Energy	13.7	15.0	13.7	14.9	11.1	14.8	14.5	8.8	14.6
C&P	8.1	9.4	8.2	13.8	10.1	13.8	20.4	14.9	21.0
SF&F	9.6	10.8	9.5	14.9	11.1	14.9	22.9	17.4	23.6
Construction	14.4	15.8	14.2	14.5	10.7	8.2	15.8	10.0	7.1
Services I	19.3	20.2	18.5	14.7	10.9	8.3	16.1	9.3	6.4
Services II	19.7	21.1	19.4	21.5	17.5	14.8	22.7	16.6	13.5
Services III	14.2	15.5	13.9	23.3	19.3	16.6	25.3	19.1	16.0
	1992			2002			2008		
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Agriculture	7.4	7.4	12.2	5.4	5.4	7.6	4.1	4.1	5.1
Energy	18.6	18.6	11.4	18.9	18.6	10.2	17.1	16.8	11.9
C&P	24.9	23.9	14.7	15.4	14.7	8.0	14.6	14.1	10.0
SF&F	20.7	20.2	12.4	14.8	14.1	7.7	15.1	14.6	10.4
Construction	1.3	1.3	2.1	1.6	1.6	2.3	1.3	1.3	1.6
Services I	7.8	9.3	15.3	13.3	15.2	21.4	10.7	12.1	15.0
Services II	12.9	12.9	21.4	23.1	23.0	32.3	27.2	27.1	33.7
Services III	6.4	6.4	10.6	7.5	7.4	10.5	9.9	9.9	12.3

Source: Author's estimates. See text for the methodology. See text for the three scenarios I, II and III. The CIP program is currently uses the net capital stock of Scenario I.

Note: See Table A1 for the definition of industry groups.

In the comparison of the results based on the three scenarios, we focus on three periods marked by China's adoption of the "socialist market economy" in 1993 followed Deng's famous southern China trip in 1992 to promote bolder reforms, China's WTO entry at the end of 2001 and the global financial crisis in 2008-09. We use the previous year of the major event as the base for the growth rate estimation for that period. Besides, we also divide the economy into eight industry groups which is to make the results more readable and more importantly to help understand the economy against the background of significant changes or shocks alongside the course of development such as resources being "reallocated" from agriculture to manufacturing and services, the growth of export-oriented industries to reap China's comparative advantage and demand for energy.

For the annual growth rate over the three periods, Scenario I appears to be more plausible than other scenarios given acceleration of investment across board and also in the wake of the global financial crisis. For the benchmark structural shares, Scenarios I and II are similar or charges in similar patterns but not in the case of Scenario III. Apart from what have been discussed we are unable to have more reasoning to judge the alternative results in the table. While preliminarily adopting the results of Scenario I, how to treat the "residual" is still our top priority in the CIP program.

9. Measuring Capital Services

The capital input in a production function is not net capital stock but its services. In theory, the capital services can be measured by the user-cost weighted productive assets for a given point of time. Following our discussion in Section 3, we know that in the absence of the rental market or when capital is used by its owner, the equilibrium value of the *implicit* rental must cover the real opportunity cost of an investment of value of P^I as well as the loss in capital value as the capital asset ages (Equation 3.6). In what follows, we first estimate the nominal rate of returns of all capital assets and the rental prices of non-residential structures and equipment, and then estimate the growth of capita input in the Chinese economy. Our discussion will focus on the results by industry groups presented in the summary tables. The industry-level estimates for benchmark years are reported in the Appendix.

Nominal rate of returns and rental prices of capital

A summary of our estimated nominal rate of returns for the total economy and each industry group is reported in Table 5. The report focuses on some benchmark years to facilitate the reading and understanding of the results against the background of major reforms or external shocks. The table shows that the nominal rate of returns on capital for the total economy declined from 0.51 to 0.29 over the entire period or by -2.0 percent per annum (not shown in the table).[21] Agriculture experienced the most rapid decline from 1.04 to 0.03 or by -11.7 percent per annum, followed by the energy group declining from 0.64 to 1.42 or by -3.2 percent per annum (Figure 4). It appears that construction showed an unusual high and increasing nominal rate of returns from 0.64 to 1.42 or an annual growth of 2.8 percent (Figure 4). This was arguably attributable to China's premature property bubble caused by local governments' heavy reliance on the sales of "land use rights" to finance public spending on infrastructure. China's most export-oriented and perhaps also most competitive "semi-finished and finished industry" group showed a fairly stable nominal rate of returns over the past three decades.

The best sub-period for the returns on capital appears to be the early 1980s which is understandable because China suffered a severe shortage of capital. As it shows, the nominal rate of returns rose by 3.4 percent per annum in 1980-84. We also see an increase in the rate of returns following China's post WTO entry by 1.5 percent per annum from 2001 to 2007. A strong demand by manufacturing for energy and intermediate inputs in this period could be the key driver to the rise of the nominal rate of returns on capital in the energy and "commodity and input materials (C&P)" groups. However, this was followed by a substantial decline of -12.3 percent per annum in the wake of the global financial crisis and the unprecedented fiscal rescue measures.

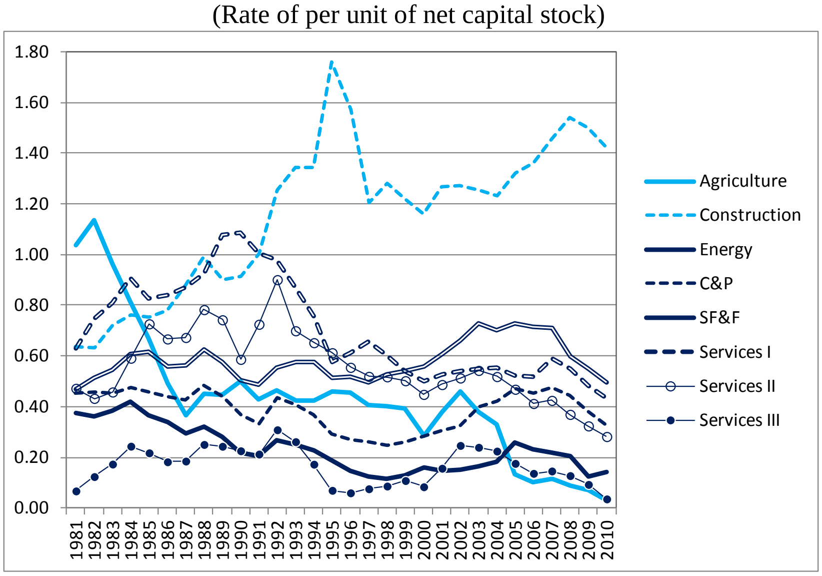
[21] All period annual growth rates in this section are calculated as annual compound growth rates based on the value of the year prior to the beginning benchmark shown in the table.

TABLE 5
ESTIMATED NOMINAL RATE OF RETURNS ON CAPITAL IN THE CHINESE ECONOMY
(Rate of per unit of net capital stock)

	1981	1985	1992	1997	2002	2008	2010
Total	*0.51*	*0.55*	*0.54*	*0.37*	*0.43*	*0.39*	*0.29*
Agriculture	1.04	0.67	0.46	0.40	0.46	0.09	0.03
Construction	0.64	0.75	1.25	1.21	1.27	1.54	1.42
Energy	0.37	0.37	0.27	0.12	0.15	0.20	0.14
C&P	0.46	0.46	0.43	0.26	0.32	0.45	0.33
SF&F	0.47	0.62	0.55	0.50	0.66	0.60	0.50
Services I	0.63	0.83	0.98	0.66	0.54	0.55	0.43
Services II	0.47	0.73	0.90	0.52	0.51	0.37	0.28
Services III	0.07	0.22	0.31	0.08	0.25	0.13	0.04

Source: Author's estimates. See Equation 3.5
Note: See Table A1 for industry grouping.

FIGURE 4
ESTIMATED NOMINAL RATE OF RETURNS OF CAPITAL IN THE CHINESE ECONOMY
(Rate of per unit of net capital stock)



Source: Author's estimates.
Note: See Table A1 for industry grouping.

Table 6 and Table 7 summarize our estimated rental price of net non-residential structures and equipment stock, respectively, for the total economy and each industry group of the same benchmark years. Figure 5 depicts the annual changes of individual groups. For the economy as a whole, the results show that the rental price of structures rose from 0.29 to 0.64 yuan or by 2.7 percent per annum whereas the rental price of equipment rose from 0.29 to 0.53 yuan or by 2.1 percent per annum over the entire period. Not surprisingly, industry groups faced very different user costs of capital.

TABLE 6

ESTIMATED RENTAL PRICE OF NET NON-RESIDENTIAL STRUCTURES IN THE CHINESE ECONOMY

(Current yuan)

	1981	1985	1992	1997	2002	2008	2010
Total	*0.29*	*0.31*	*0.47*	*0.58*	*0.54*	*0.71*	*0.64*
Agriculture	0.56	0.39	0.38	0.63	0.52	0.14	0.12
Construction	0.36	0.45	1.40	1.74	1.64	2.95	2.91
Energy	0.23	0.20	0.12	0.25	0.24	0.37	0.36
C&P	0.27	0.26	0.34	0.43	0.43	0.83	0.73
SF&F	0.27	0.36	0.49	0.76	0.81	1.12	1.06
Services I	0.35	0.50	1.05	0.98	0.71	1.03	0.93
Services II	0.27	0.43	0.95	0.79	0.66	0.68	0.63
Services III	0.07	0.10	0.18	0.18	0.25	0.21	0.14

Source: Author's estimates. See Equation 3.5

Note: See Table A1 for industry grouping.

In terms of the annual growth rate of the rental prices over the full period, which can be calculated based on the results reported in Tables 6 and 7, in the case of construction, the rental price of non-residential structures and equipment experienced the most rapid growth by 7.5 and 6.4 percent per annum, respectively. This was followed by the "SF&F" group by 4.8 and 3.7 percent per annum, and "Services I" by 3.4 and 2.6 percent per annum, respectively. It is however opposite in the case of agriculture, the rental prices of the two types of assets declined by -5.1 and -4.0 percent per annum, respectively. The over time changes are intuitively presented in Figure 5.

TABLE 7

ESTIMATED RENTAL PRICE OF NET EQUIPMENT STOCK IN THE CHINESE ECONOMY

(Current yuan)

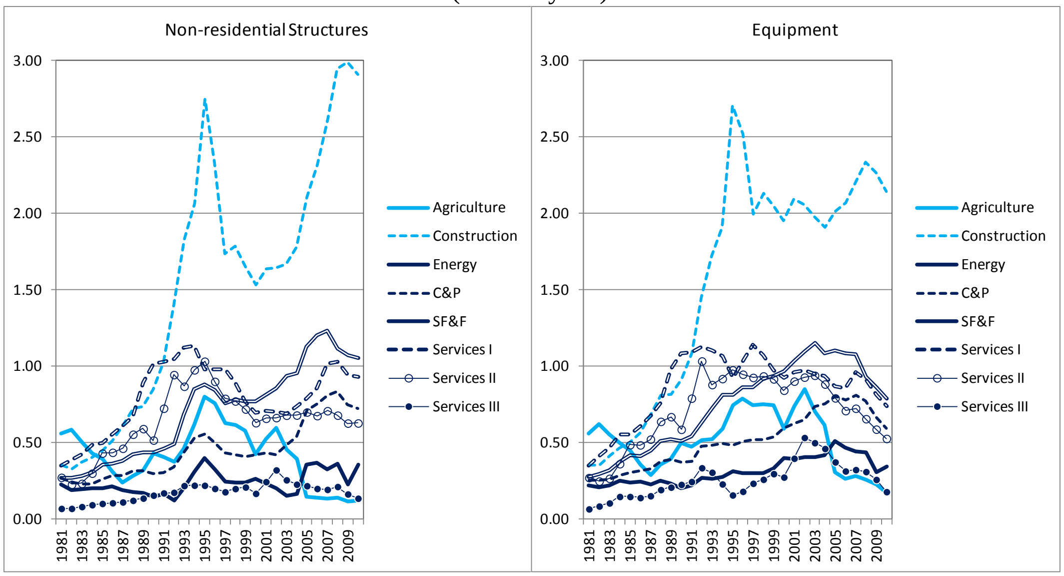
	1981	1985	1992	1997	2002	2008	2010
Total	*0.29*	*0.37*	*0.61*	*0.68*	*0.75*	*0.67*	*0.53*
Agriculture	0.56	0.45	0.52	0.75	0.74	0.26	0.17
Construction	0.35	0.50	1.45	2.00	2.10	2.34	2.14
Energy	0.22	0.24	0.27	0.30	0.40	0.44	0.34
C&P	0.26	0.30	0.48	0.52	0.62	0.77	0.60
SF&F	0.27	0.42	0.63	0.87	1.04	0.93	0.79
Services I	0.35	0.55	1.13	1.14	0.96	0.92	0.74
Services II	0.27	0.49	1.03	0.93	0.90	0.66	0.53
Services III	0.07	0.15	0.34	0.23	0.40	0.31	0.18

Source: Author's estimates. See Equation 3.5

Note: See Table A1 for industry grouping.

By 2010, construction faced the highest rental prices of non-residential structures and equipment, 2.91 and 2.14 yuan, compared to the economy's average of 0.64 and 0.53 yuan, respectively. By contrast, agriculture and the non-market services (III) faced the lowest rental prices. On the other hand, the "semi-finished and finished" (SF&F) group, China's most dynamic, export-oriented sector stayed in the middle – thanks to the reform and opening up policies, 1.06 and 0.79 yuan, respectively. State-monopolized services or Services I (including transportation, telecommunication and financial services) are very close to SF&F (0.93 and 0.79, respectively), whereas non-market services or Services III (including government, health care and education) appear to be very low (only 0.14 and 0.18, respectively).

FIGURE 5
ESTIMATED RENTAL PRICES OF NON-RESIDENTIAL STRUCTURES AND EQUIPMENT IN THE CHINESE ECONOMY, 1981-2010
(Current yuan)



Source: Author's estimates.
Note: See Table A1 for industry grouping.

Capital services

We are primarily interested in the flow of capital services of each capital asset in each industry ($K_{k,j,t}$ where the subscript k denotes for asset type) from the installed net capital stock ($A_{k,j,t}$, Equation 3.3) over a given period, rather than the capital stock itself. This is an important distinction when we aggregate heterogeneous assets with widely different marginal products to construct an industry or economy-wide aggregate.

Following Jorgenson, Ho and Stiroh (2005), when transforming capital stocks into capital service flows for each asset of an industry, we make an additional assumption that it takes some time for new investment to provide productive services. In practice, we assume that the capital service flow from individual assets is proportional to the arithmetic average of the current and one-period lagged capital stock:

$$K_{k,j,t} = Q^K_{k,j} \frac{(A_{k,j,t} + A_{k,j,t-1})}{2} = Q^K_{k,j} \cdot Z_{k,j,t} \qquad (9.1)$$

where $Z_{k,j,t}$ is the two-period average of the installed capital stock and $Q^K_{k,j}$ is the proportionality factor or the "quality of capital of type k" following Jorgenson and Griliches (1967).

Equation 9.1 implies that a given quantity of capital stock of each asset in any two-year period provides the same capital service flow. This is a direct implication of the efficiency unit concept discussed earlier where all changes in capital characteristics across vintages are captured in the price index and translated into increases in the quantity of investment Jorgenson, Ho and Stiroh (2005).

As defined in Equation 3.6, the quantity of the capital services is priced by the *user cost of capital*, which can be rewritten to specify asset type *k* and industry *j* as:

(9.2) $$P^K_{k,j,t} = r_{k,j,t} \cdot P^I_{k,j,t-1} + \delta_k P^I_{k,j,t}$$

where *r* and *δ* are defined as they are in Equation 3.6. Given problems and limited data on taxes, we assume that there is no tax effect albeit a strong assumption. However, we still maintain a joint estimation of the rate of return and capital service prices to satisfy the following restriction:

(9.3) $$\sum_k P^K_{k,j,t} K_{k,j,t} = P^V_{j,t} V_{j,t} - P^L_{j,t} L_{j,t}$$

which means that the value of capital services in industry *j* summed over all assets (*k*) must equal the value of total capital compensation in that industry. The capital compensation is defined as nominal industry value-added, $P^V_{j,t} V_{j,t}$, less total labor compensation, $P^L_{j,t} L_{j,t}$. It is important to emphasize that what defined in Equation 9.3 are coherent part of, as well as controlled by, the national accounts.

We use a Törnqvist quantity formula to aggregate capital assets where the quantity index of capital services in industry *j* is defined as an aggregate of the service flows from different capital assets.

(9.4) $$\Delta \ln K_{j,t} = \sum_k \bar{v}_{k,j,t} \Delta \ln K_{k,j,t}$$

where the value share of each type of capital services is defined as:

(9.5) $$v_{k,j,t} = \frac{P^K_{k,j,t} K_{k,j,t}}{\sum_k P^K_{k,j,t} K_{k,j,t}} \text{ and } \bar{v}_{k,j,t} = \frac{(v_{k,j,t} + v_{k,j,t-1})}{2}.$$

It should be noted that using capital service prices as weights to aggregate capital service flows within an industry satisfies production theory that the weights should reflect marginal products of capital assets.

By substituting Equation 9.4 into Equation 9.1 we show that the growth of industry capital services can be simply defined as:

(9.6) $$\Delta \ln K_{j,t} = \sum_k \bar{v}_{k,j,t} \Delta \ln(Q^K_{k,j} \cdot Z_{k,j,t}) = \sum_k \bar{v}_{k,j,t} \Delta \ln Z_{k,j,t}$$

Since the quality factor or proportionality constant $Q_{k,j}^{K}$ is assumed independent of time, it can be dropped out. Therefore, the industry aggregate capital services can be derived from two-period average stocks and capital service weights for each asset.

The economy-wide index of capital service price of each asset can be defined implicitly as the average service price through the following identity:

$$P_{k,t}^{K}K_{k,t}=\sum_{k}P_{k,j,t}^{K}K_{k,j,t} \tag{9.7}$$

Therefore, the economy-wide index of capital services can be constructed as the Törnqvist aggregate of capital services from all assets:

$$\Delta \ln K_{t}=\sum_{k}\bar{v}_{k,t}\Delta \ln K_{k,t} \tag{9.8}$$

where the value share of each type of capital services is defined as:

$$v_{k,t}=\frac{P_{k,t}^{K}K_{k,t}}{\sum_{k}P_{k,t}^{K}K_{k,t}} \text{ and } \bar{v}_{k,t}=\frac{(v_{k,t}+v_{k,t-1})}{2} \tag{9.9}$$

Our estimated annual growth rates of capital services for the economy as a whole and for each industry group and for each sub-period are reported in Table 8. Besides, Figure 6 depicts the economy-wide index and annual changes of capital services. On average and for the entire period in question, China's total capital services grew by 12.4 percent per annum (also see Figure 5). It accelerated from 7.3 percent per annum in the early 1980s to 12.0 percent in the 1990s and further to 15.4 percent in the post WTO period, and reached 18.6 percent in the wake of the global financial crisis. This clearly reflects the capital input-driven nature of the post-reform Chinese economy. Annual changes appear to be volatile with earlier external shocks as shown in Figure 5 but not during the global financial crisis, reflecting the unprecedented fiscal support to the economy in 2008-09.

TABLE 8

ESTIMATED COMPOUND ANNUAL GROWTH OF CAPITAL SERVICES IN THE CHINESE ECONOMY

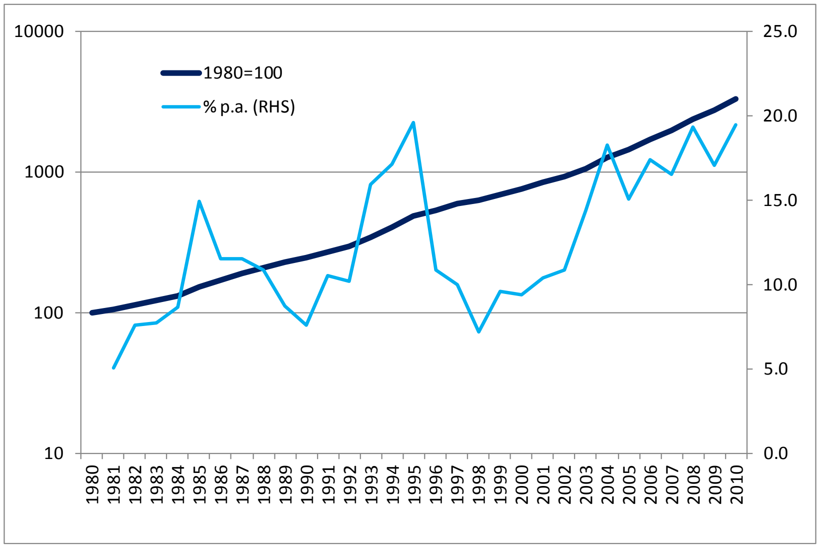
(Percent per annum)

	1980-1984	1984-1991	1991-2001	2001-2007	2007-2010	*1980-2010*
Total	*7.3*	*10.8*	*12.0*	*15.4*	*18.6*	*12.4*
Agriculture	6.6	4.3	8.4	11.5	19.3	*8.9*
Construction	10.8	6.9	13.4	13.4	14.6	*11.6*
Energy	5.7	12.7	12.9	14.1	13.5	*12.2*
C&P	7.4	11.5	7.6	13.0	18.4	*10.6*
SF&F	5.7	11.2	8.9	13.9	20.4	*11.1*
Services I	7.6	11.2	17.6	13.7	14.9	*13.7*
Services II	9.5	11.1	17.9	19.4	20.5	*15.7*
Services III	12.8	10.7	13.2	20.9	22.6	*15.0*

Source: Author's estimates.

Note: See Table A1 for industry grouping.

FIGURE 6
ESTIMATED INDEX AND ANNUAL CHANGES OF CAPITAL SERVICES IN THE CHINESE ECONOMY



Source: Author's estimates.

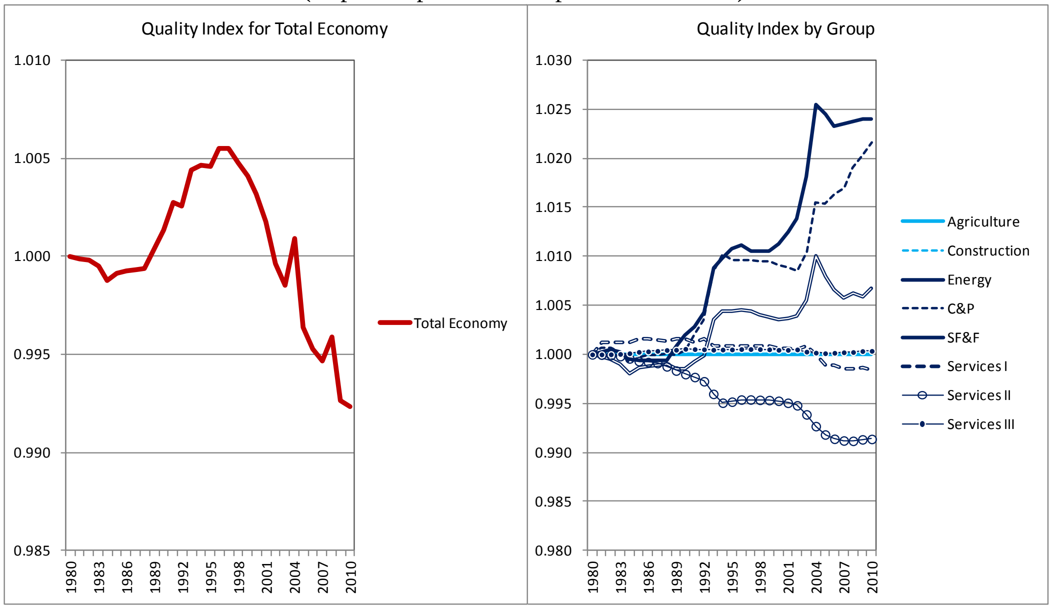
Group performances do vary greatly over different sub-periods. The reforms in the late 1980s were accompanied by a similar capital service growth rate in most groups. However, this changed in the 1990s with a substantial slowdown in the "C&P" and "SF&F" groups and a more rapid capital service growth in most of services (I and II). While China's WTO entry brought about a more rapid growth of capital services in the "C&P" and "SF&F" groups (13 to 14 percent per annum), services (II and III) accelerated further to 19 to 20 percent per annum. The post-GFC fiscal injection effect is also uneven, which appears to be especially benefiting the "C&P" and "SF&F" groups.

The *user cost* or service prices-based weighting approach for different types of assets across industries implies larger weights on assets with high marginal products so that growth in capital quality reflects *substitution* towards assets with relatively high service prices and marginal products. However, as emphasized in Jorgenson, Ho and Stiroh (2005), such quality changes do not refer to *improvements across vintages within a specific type of asset* which is captured and incorporated into the quantity component of each asset type by the use of constant-quality price deflators. It is of great interest to see if the substitution in the Chinese economy indeed happens towards assets with relatively high marginal products. Nevertheless, based on our estimation this does not seem to be the case especially since the mid 1990s on average (Left Panel of Figure 7). At group level (Right Panel), it seems that this unusual "quality decline" is attributed to the decline in the "C&P" and "SF&F" groups in the late 1990s, in "SF&F" in the mid 2000s, and in market services (I and II) since the 2000s. The most likely reason for such a behavior of the quality index is distortions in capital allocation and barriers to capital mobility, which should be further explored in more analytical studies using the newly constructed data.

FIGURE 7

QUALITY INDEX OF CAPITAL IN THE CHINESE ECONOMY, 1981-2010

(Capital Input Index/Capital Stock Index)



Source: Author's estimates.

10. CONCLUDING REMARKS

Based on our understanding of the major problems in the official investment statistics and following the SNA principles, we have reconstructed industry level investment flows, estimated initial capital stock, and measured investment price changes and depreciation rates. Based pm these works we have established capital stock series for 37 Chinese industries and estimated their services for 1980-2010. Our results show that China's rapid GDP growth has been indeed accompanied by a more rapid growth of capital input. Besides, our estimated changes of capital services using the user-cost weights also suggest that in the most recent decade there was unusual substitution towards assets with relatively low rather than high marginal products, which may imply distortions in capital allocation and barriers to capital mobility in the economy.

This effort has also discovered problems that cannot be easily tackled with the available information. Almost at each major step of the data construction we have to use somewhat strong assumptions to bypass difficulties that are caused by the lack of information. However, these compromises are by no means to ignore the underlying problems but to set up reasonable starting points to explore the direction of the likely biases and the possible solutions in future.

While searching for a better way to reconcile GFCF with the OVFA and NIFA-based estimation and conducting sensitivity tests for alternative depreciation rates and deflators, the top priority is to improve the national income accounts by estimating the contribution of natural capital (land) and self-employed. Moreover, given the increasing importance of information technology and on-going technological progress that inevitable relies on the further advancement in information technology, we will make effort to separate IT assets from other equipment and to construct knowledge-based capital stock such as R&D.

APPENDIX
TABLE A1
CIP INDUSTRIAL CLASSIFICATION AND CODE

This paper	This paper	CIP (China KLEMs)	EU-KLEMS	Group	Sector
01	AGR	01	AtB	Agriculture	Agriculture, forestry, animal husbandry & fishery
02	CLM	02	10	Energy	Coal mining
03	PTM	03	11	Energy	Oil & gas excavation
04	FMM	04	13	C&P	Mining and processing of ferrous metal ores
05	NFM	04	13	C&P	Mining and processing of non-ferrous metal ores
06	NMM	05	14	C&P	Non-metallic minerals mining
07	OMN	04	13	C&P	Other mining
08	FDP	06	15	SF&F	Food processing
09	FDM	06	15	SF&F	Food manufacturing
10	BEV	06	15	SF&F	Beverage manufacturing
11	TOB	07	16	SF&F	Tobacco products
12	TEX	08	17	C&P	Textile mill products
13	WEA	09	18	SF&F	Apparel and other textile products
14	LEA	10	19	SF&F	Leather and leather products
15	WOO	11	20	C&P	Saw mill products
16	FNT	11	20	SF&F	Furniture, fixtures
17	PAP	12	21	C&P	Paper
18	PRN	12	22	SF&F	Printing & publishing
19	CUL	24	36t37	SF&F	Culture, school and sport products for daily use
20	PET	13	23	Energy	Petroleum and coal products
21	CHE	14	24	C&P	Basic chemicals
22	MED	14	24	SF&F	Medicine manufacturing
23	SYN	14	24	C&P	Chemical fibers
24	RUB	15	25	SF&F	Rubber products
25	PLA	15	25	SF&F	Plastic products
26	BUI	16	26	C&P	Stone, clay, and glass products
27	FMF	17	27t28	C&P	Primary & fabricated metal industries, ferrous
28	NMF	17	27t28	C&P	Primary & fabricated metal industries, non-ferrous
29	MET	18	27t28	C&P	Metal products (excluding rolling products)
30	MAC	19	29	SF&F	Industrial machinery and equipment, general purposed
31	SMC	19	29	SF&F	Industrial machinery and equipment, special
32	TRS	23	34t35	SF&F	Motor vehicles & other transportation equipment
33	ELE	20	31	SF&F	Electric equipment
34	TEL	21	32	SF&F	Electronic and telecommunication equipment
35	INS	22	30t33	SF&F	Instruments and office equipment
36	OTH	24	36t37	SF&F	Miscellaneous manufacturing industries
37	POW	25	E	Energy	Power generation and supply, steam
38	GAS	25	E	Energy	Gas supply
39	WAT	25	E	Energy	Tap water supply
40	CON	26	F	Construction	Construction
41	TRD	27	G	Services II	Wholesale and retail trades
42	HOT	28	H	Services II	Hotels and restaurants
43	TRA	29	I	Services I	Transport, storage & post services
44	INF	30	71t74	Services I	Information & computer services
45	FIN	31	J	Services I	Financial Intermediations
46	REA	32	K	Services II	Real estate activities
47	BUS	33	71t74	Services II	Leasing, technical, science & business services
48	PUB	34	L	Non-market	Public administration and defense
49	EDU	35	M	Non-market	Education
50	HEA	36	N	Non-market	Health and social security services
51	SER	37	O&P	Services II	Other services

Sources and Notes: See the text.

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