Sources of Growth in Mainland China: An Investigation Using the Dual Approach

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Abstract

This paper examines the sources of economic growth in mainland China using the *dual approach* to growth accounting This approach is useful because of numerous problems that continue to beset Chinese national income accounts data, despite attempts to rectify them. Almost all growth accounting studies conducted on China so far have followed the *primal approach*, which depends heavily on national income accounts data. The dual approach, by contrast, allows independent price information to play a role. Recent research on Chinese growth has revolved around the following two questions: (a) How significant has TFP's role been in post-reform Chinese growth? (b) Has TFP growth rate slowed down in more recent years? Examination of the Chinese growth using the dual approach provides the following answers to these questions: (a) In contrast to what Hseih (2002) found for Singapore, the rate of TFP growth for mainland China using the dual approach proves similar to the high TFP growth rates that have been obtained by many researchers using the primal approach. (b) The rate of TFP growth in China has slowed down a little, but still remains high. These results however need to be taken with a grain of salt, mainly because of the weak nature of the data on rate of return to capital in mainland China. (*JEL Classification:* O47; O53. *Keywords:* Economic Growth; Total Factor Productivity; China)

[1] This is a very preliminary version of the paper. Please do not quote. Your comments are welcome. Please send them to Nazrul Islam, the corresponding author, at nislam@icsead.or.jp .

Sources of Growth in Mainland China: An Investigation Using the Dual Approach

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1. Introduction

This paper examines the sources of economic growth in mainland China using the *dual approach*. This approach is useful because of numerous problems that continue to beset Chinese national income accounts data, despite attempts to rectify them. Almost all growth accounting studies conducted on China so far have followed the *primal approach*, which depends heavily on national income accounts data. The dual approach, by contrast, allows independent price information to play a role. Recent research on Chinese growth has revolved around the following two questions: (a) How significant has TFP's role been in post-reform Chinese growth? (b) Has TFP growth rate slowed down in more recent years? Examination of the Chinese growth using the dual approach provides the following answers to these questions: (a) In contrast to what Hseih (2002) found for Singapore, the rate of TFP growth for mainland China using the dual approach proves similar to the high TFP growth rates that have been obtained by many researchers using the primal approach. (b) The rate of TFP growth in China has slowed down a little, but still remains high. These results however need to be taken with a grain of salt, mainly because of the weak nature of the data on rate of return to capital in mainland China.

The discussion of the paper is organized as follows. Section-2 provides the background by reviewing the growth accounting exercises that have been conducted for China so far and by considering the problems of Chinese National Income Accounts (NIA) data. Section-3 presents the theory of the dual approach to growth accounting. Section-4 presents the implementation of the dual approach for China and discusses the results. Section-5 concludes.

2. Background

2.1 Very Different Estimates of TFP

By now a good number of researchers have examined the issue of sources of Chinese growth. One of the initial studies on this topic is by Chow (1993), who focuses on the period of 1952-1980. Chow's main finding for this pre-reform period is that growth was almost entirely capital accumulation driven and there was no TFP growth. Based on both graphical presentation and on estimation of aggregate production functions, Chow concludes that "technological change was absent in the growth of the Chinese economy from 1952 to 1980." (p. 841)

Chow and Li (2002) return to this issue, following a similar methodology as of Chow (1993), but updating the analysis to the more recent year of 1998. They find that in contrast to the pre-reform period, growth during the post-reform period was driven to a considerable degree by TFP growth. According to their estimation results, "there is an average increase in total factor productivity of about 2.6 percent per year from 1978 to 1998." (p. 249)

Borensztein and Ostry (1996) offer a starker contrast of the pre- and post reform periods. According to their computation, while TFP growth was negative, -0.7 percent during 1953-1978, it was an astounding positive, 3.8 percent during 1979-1994. Hu and Khan (1997) provide an even upbeat assessment of the role of TFP growth in the post-reform growth. They compute a translog productivity index taking the directly observed capital and labor income shares as the respective elasticities. According to their results, the TFP growth rate for the pre-reform 1953-78 period was 1.1 percent, while it rose to 3.9 percent during the post reform, 1979-94 period.[2]

There is not much debate about the relative absence of TFP growth in the pre-reform Chinese economy. Similarly there is not much debate that TFP growth played an important role in the post-reform growth. The debate rather concerns the following two questions: (i) *How much* has been TFP's role in the post-reform growth of China? (ii) Is TFP growth in China experiencing a *slow down* in recent years.

With regard to the second question, Hu and Khan (1997), for example, think that TFP growth is rather accelerating. According to their computation, TFP growth rate for the last few years of the sample period, namely for 1990-1994, was 5.8 percent, and during this sub period TFP growth surpassed growth in capital stock as a source of output growth.[3] The authors attribute the higher TFP growth of more recent years to further deepening of economic reforms.[4] Nogami and Li (19??) reach similar conclusions. Confining their analysis to the industrial sector, they divide the post-reform period into the following three sub-periods: 1977-1984, 1984-1988, and 1989-1992. According to their computation, TFP growth rate for these sub-periods was 2.06, 2.14, and 5.14, contributing 24.8, 19.6, and 44.2 percent of the overall growth, respectively. (The average growth rate of TFP for the whole period of 1977-1992 is 2.40 percent, accounting for 25.6 percent of the output growth.) Ezaki and Sun (1999) also agrees with a rising trend in TFP growth rate. Based on their analysis, these authors conclude that

[2] This also implies that while TFP contributed only 18 percent of the pre-reform growth, its contribution to the post reform growth was 41.6 percent.

[3] As they authors put it, during this sub period, "productivity changes for the first time overtook capital as the predominant source of China's economic growth." (Hu and Khan 1997, p. 124)

[4] In their words, "Instead of slowing down (as one might have expected), productivity growth reached stunning new highs as China moved forward on the reform path, albeit at an uneven pace." (Hu and Khan 1997, p. 124) They further add the following commentary in this regard: "Therefore, the evidence from this study points to a somewhat different conclusion from that reached by Sachs and Woo (1997). Even though the efficiency gains brought about by earlier agricultural reforms may have dissipated, the sharp growth in rural industry, the surge in foreign direct investment, the export boom, the further dismantling of the central planning system, and the increasing market orientation in the state-owned sector have combined to boost aggregate productivity growth in the 1985-94 period, and even more so during 1990-94." (Hu and Khan 1997, p. 124)

"The TFP growth has been fairly high at from 3 to 4 percent *with a slight tendency to increase* (italics added), and its contribution to GDP growth is around 40 percent." (p. 49)

Not every body however shares such upbeat assessments of the role of TFP growth in the recent Chinese growth. Skepticisms have been voiced with regard to both the extent of the role of TFP in general and the claimed increasing tendency of this role. Woo (1997), for example, suggests that Chinese TFP growth rates are not only lower in general, they are also declining as the post-reform period progresses. According to his computation, net TFP growth rate for the period of 1979-1993 ranges from only 1.1 to 1.3 percent.[5] He divides the post-reform period into two sub-periods, namely 1979-84 and 1985-93,[6] and shows that while TFP growth rate ranges from 2.76 to 3.76 (depending on the chosen value of labor share in income) during the first sub period, it ranges only from -0.11 to 1.58 during the second sub period. Woo interprets this slowdown as evidence that "the TFP growth unleashed by the 1978 reforms was a *one-time recovery in efficiency* (italics added) from the decade-long Cultural Revolution and from the overregulation of the economy by central planning." (p. 10)[7]

Young (2000) also concludes that China's TFP growth rates have been over reported. He adopts a skeptical view of the Chinese official data, and undertakes a laborious effort to reconstruct this data using information from both Chinese NIA and non-NIA sources. Young focuses on the period of 1978-1998 and considers only the industrial sector. He substitutes the official industrial output deflator by ex-factory price index.[8] He also uses the national income identity to derive a deflator for the investment series in a residual manner. He conducts a meticulous analysis of the demographic and labor force participation data to derive the labor force growth rate to be 2.2 percent.[9]

A major advance in Chinese growth accounting that Young accomplishes in his paper is incorporation of labor quality into the analysis. In this regard, he uses the Jorgenson et al. (1987) approach of using the income earned by a particular category of labor as indicator of its productivity. He uses various surveys to get data on income of labor of difference categories. Based on the exercise, he finds that "the growth of human

[5] Inclusive of labor reallocation (from agriculture to industry) effect, TFP growth rate for this period would range from 2.2 to 2.4 percent per annum. (p. 2)

[6] He provides the following reasoning for the choice of the sub periods: "The delineation of the sub-periods corresponds, one, to the policy regime change toward accelerating reforms in the non-agricultural sectors, and two, to the emergence of industry as the undisputed primary engine of growth. The growth performance of the 1985-93 subperiod may be a better guide (than that of the entire period) to understanding the future growth prospects of China. This is because future Chinese growth is likely to be led by the (non) agricultural sectors as in 1985-93 period." (p. 9)

[7] He further adds that "The agricultural reforms may have accounted for a large part of the initial high net TFP growth." (p. 10)

[8] He notes that the use of this alternative deflator brings down the growth of real GDP between 1978 and 1998 from the official 9.1 percent to 7.4 percent for the aggregate and from 10.6 to 8.1 for the non-agricultural sector.

[9] He thinks that "In sum working age population growth of 2.2 percent per annum, in excess of the 1.3 percent rate of population growth, is completely consistent with reasonable participation and demographic trends and may be deemed fairly accurate." (p. 22)

capital in the non-agricultural sector of the Chinese economy between 1978 and 1998 to be 1.1 percent per annum." (p. 31)[10]

On the basis of reconstruction of data along the above lines,[11] Young finds that the rate of TFP growth in the Chinese economy for the period was 1.4 percent per annum. He comments that this is "a respectable performance, but by no means extraordinary." (p. 1) Young does not consider explicitly the issue of slowdown of Chinese TFP growth rate with the progression of the post-reform period. However, the spirit of his analysis suggests that he would support such a view.

In a recent paper, Wang and Yao (2001) also allow for improvement in labor quality in growth accounting for China. However, they voice doubts regarding Young's (2000) data on income for specific categories of labor, and instead use the number of schooling years as indicative of labor quality. They follow the Barro-Lee (1997) approach of using enrolment rates in a perpetual inventory framework to derive the number of people belonging to different education categories. Changes in these numbers are taken to reflect changes in the quality of labor. On the basis of this exercise Wang and Yao find significant improvement in the quality of Chinese labor. However, they find that even after taking into account the role of labor quality improvement, the contribution of TFP remains high.[12] They offer results with alternative assumptions regarding labor share in income. For example for the pre-reform period of 1953-77, they assume the labor share to be 0.40, and find the output, physical capital, labor quantity, human capital stock, and TFP to grow over this period at an annual rate of 6.46, 6.11, 2.63, 5.30, and -0.57, respectively, and the contribution to output growth of physical capital, labor, human capital, and TFP to be 56.8, 16.3, 32.8, and -5.9 percent, respectively. For the reform period of 1978-99, they assume a labor share of income of 0.50, and find output, physical capital, labor quantity, human capital stock, and TFP to grow over this period at an annual rate of 9.72, 9.39, 2.73, 2.69, and 2.32, respectively, and the contribution to output growth of physical capital, labor, human capital, and TFP to be 48.3, 14.0, 13.8, and 23.9 percent, respectively. (Table-1, p. 15) Thus, while in the pre-reform period the TFP growth rate is negative, -.57, during the reform period it is 2.32 percent.[13] The results regarding TFP of Wang and Yao are therefore somewhere in between the very high

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[10] He however recognizes that "… both slightly lower and moderately higher estimates are plausible, but all estimates are tolerably concentrated around a value of 1.1 percent." (p. 31)

[11] So far as factor shares are concerned, Young accepts what is there in the official data, viewing that "…there is no reason to modify the reported Chinese estimates of the share of labor…In this paper I use the average share of labor reported in the Chinese national accounts, in preference over the more volatile figures of the input output tables." (p. 41)

[12] "We found that, first, the accumulation of human capital was quite rapid and it contributes significantly to growth and welfare. Second, after incorporating human capital, the growth of TFP still plays a positive and significant role during the reform period 1978-1999. In contrast, productivity growth was negative in the pre-reform period. Results are robust to changes in labor shares in GDP." (Wang and Yao 2001, p. 3)

[13] Wang and Yao (2001) present another Table (Table-2, p. 16) where they impose the same value of labor share for the pre- and post-reform period and computes TFP growth rates. The pre and post reform TFP growth rate prove to be -.87 and 2.98, -.74 and 2.72, and -.38 and 1.92 when labor income share is assumed to be 0.67, 0.60, and 0.40, respectively.

estimates of 4 to 5 percent per annum offered by Hu and Khan, Nagomi and Li, and others and the very low estimates of 1.1 to 1.4 percent of Woo and Young.[14]

This brief survey[15] of Chinese growth accounting exercises shows that results differ widely regarding the relative importance of accumulation versus assimilation (as represented by TFP growth) in the country's growth. Results also differ widely with regard to whether or not TFP growth rates are slowing down in recent years. More research is therefore necessary to settle these important questions. The answer to the second question has wider ramifications, as Sachs and Woo (1997) expound. The purpose of the paper is to use of the dual approach to answer the two questions mentioned above. However, before embarking on that exercise it is worthwhile to check on possible reasons why TFP estimates have differed so much.

2.2 Reasons for Divergent TFP Estimates

Referring to the wide range of TFP estimates, Sachs and Woo (1997, p. 21) offer the following observation: "The wide range of TFP estimates in the literature could be caused by a wide array of factors which include the choice of data set (e.g. geographical and sectoral representation, time period), the specification of the production function (e.g. Cobb-Douglas, Griliches-type), the assumption of technical change (e.g. Hicks-neutral, labor-augmenting), the estimation method (e.g. OLS, stochastic frontier), the selection of deflators for outputs and inputs, and ad hoc exclusion of observations." This is quite an apt description, and there is not much to add to this statement.

However, a particular source for differences in TFP estimates is the problems that beset the Chinese national income accounts (NIA) data. It may be noted that there are quite contrasting views regarding the merit of Chinese NIA statistics. At one extreme is probably Chow (1993, p. 810), who relies entirely on Chinese official statistics viewing that these are by and large "…internally consistent and accurate enough for empirical work." He also adds that "…official statistical reporting in China is by and large honest." At the other extreme is probably Young (2000). He notes that under the Chinese system, there are inbuilt tendencies for local officials to "…overstate the growth of output, while understating investment and births." (p. 4)[16] Young sarcastically comments that "… while the Chinese government has conducted laudable campaigns against statistical misrepresentation, recording no less than 70,000 such cases in 1994 and 60,000 cases in 1997, this information has difficulty in finding its way into revisions of the GDP estimates." (p. 6)

[14] In fact that is exactly how they themselves view their results. They think that "Regarding the on-going debate, this paper proposes a middle-road answer to the sources of growth, and that is, both productivity growth and factor accumulation are very significant in accounting for China's growth performance during the reform period." (Wang and Yao 2001, p.3)

[15] For more on diverse TFP results on China, see Sachs and Woo (1997).

[16] Young (2000, p. 5) observes that "Following a nationwide audit of statistical reports, the 1994 gross industrial output estimates were revised downwards by about 9 percent, with most of the adjustment falling on township and village enterprises, whose output was deemed to have been exaggerated by about a third."

In addition to the problems of honest reporting, Chinese national accounts data are also affected by several methodological problems. During the pre-reform period, China was following the Material Product-balances System (MPS) under which output of many service sectors was not included in the measured national income. From 1985, China began its shift to the international System of National Accounts (SNA), and this shift was completed only in 1992. Despite this shift, Wang and Yao (2001), for example, note the following three problems. The first is the problem of compatibility of national income (GDP) measure before and after reform. The second is the problem of absence of deflator for national income of the pre-reform period of 1952-77. And the third is the problem of absence of investment deflator for the period 1952-1990.[17] Attempts have been made to correct these statistical problems.[18] Hsueh and Li (1999) represent a significant contribution in this regard. Using historical data, they try to fill up for the missing service sector output in the national income data for the pre-reform period of 1952-77, so that these data are now more comparable with those of the reform period of 1978-95. Hsueh and Li also provide deflators for both GDP and investment, so that real values of these variables are now available for the period of 1952-1995.

Some researchers, such as Wang and Yao (2001), are very upbeat about the contribution of Hsueh and Li (1999) and think that with their work all the major methodological problems of Chinese national income accounts data have been resolved.[19] Others have however voiced doubts. For example, Young (2000) notes that the way missing service sector output was incorporated in the GDP is not proper, because it assumes that most of the service sector activities sprang up only during the post-reform period and almost nothing existed during the earlier years.[20]

Young also has serious reservations about the deflators. He thinks that "Despite …riders and exceptions, it is fair to say that, overall, the SSB remains heavily dependent upon enterprise-provided output-based implicit deflators to deflate nominal value added." Echoing views expressed earlier by Ruoen (1995) and Woo (1995), Young also thinks that "implicit deflators provided by Chinese enterprises are systematically biased." (p. 8)

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[17] State Statistical Board (SSB) of China began constructing fixed asset investment price index only in 1991.

[18] For example a Census of Services was conducted in 1991-1992 in order to gather data on the service sector, "which produced a dramatic revision of the national accounts." (Young 2000, p. 6)

[19] "With the support and cooperation of the SSB, Hsueh and Li (1999) have made significant progresses and published the most complete set of Chinese national income from 1952 to 1995 based on SNA in 1999 both at the national and provincial level." (Wang and Yao 2001, p. 5)

[20] "Beginning with the 1995 issue of the publication, the GDP estimates were revised on the basis of the data from the Census of Services. ….the estimated value of service sector output in 1993 was raised by about a third, while the estimates for 1978 were hardly changed at all. In other words, when the SSB improved its measure of the service sector, it concluded that virtually all the newly discovered, and hitherto unrecorded, value added had developed during the reform period. This assumption is retained, with minor revisions, in the most recent (1999) version of the national accounts. While the development of non-material sectors was neglected under the plan, so was their measurement. Consequently, the approach adopted by the SSB seems somewhat extreme, as it is likely that a fair amount of the newly discovered non-material output was present in 1978. As an alternative, one might assume that the ratio of unmeasured to measured activity found in 1993 existed in 1978 as well. If so, the SSB's adjustments overstate the growth of service sector nominal output between 1978 and 1993 by 1.6 percent per annum." (Young 2000, pp. 6-7)

He in fact formulates and estimates a sophisticated bi-factor latent variable model to prove this systematic bias. (pp. 11-18) Young laments that SSB uses implicit deflators provided by the enterprises themselves instead of using 'independent price indices,' on which it does collect data. This choice of deflator leads to the much discussed problem of *underdeflation* of the industrial output, particularly of the output of the TVEs. It is in view of this bias that Young uses for this own analysis the ex-factory price index as the deflator instead of the one provided by the national accounts data.[21]

Young is similarly unhappy with the official deflator for gross fixed capital formation (GFCF). He thinks that "The official deflator for GFCF is presumably an inappropriate choice, as it relies upon enterprise output deflators and is, consequently, likely to be characterized by the same understatement of inflation that plagues the People' Republic's production estimates." (p. 33) As mentioned earlier, Young resorts to an elaborate exercise to derive an investment deflator via the income expenditure identity.

The above discussion makes it clear that, despite efforts to improve, Chinese national income accounts data continue to be affected by several problems. Yet, growth accounting exercises using the *primal approach* generally depend heavily or entirely on national income accounts data. Almost all growth accounting exercises for China have been conducted so far using the primal approach. It is therefore difficult for these exercises to extricate themselves from the impact of these data problems. Growth accounting using the *dual approach*, on the other hand, provides more avenues for information other than of national income accounts source to play a role. It is therefore useful to find out what kind of answer this approach can provide to the two questions mentioned above.

3. The Dual Approach to Growth Accounting

The dual approach to growth accounting was proposed earlier by Jorgenson and Griliches (1967).[22] Having presented the expressions for TFP from the primal and dual approach they note that "These two definitions of total factor productivity are dual to each other and are equivalent. In general, any index of total factory productivity can be computed either from indexes of the quantity of total output and input or from the corresponding price indexes." (p. 252) There are many different ways in which the dual

[21] Following is how Young justifies his choice of deflator: "… the joint stochastic behavior of the implicit GDP deflators and alternative price indices lends substantial support to Ruoen and Woo's argument that the implicit GDP deflators systematically understate price movements. Various attempts to allow the data to select its own inflation rate return estimates close to, if not exceeding, the growth of the alternative price indices. On this basis, I follow the suggestion of Ruoen, substituting the SSB price indices he recommends for the implicit deflators of the national accounts." (Young 2000, p. 16) Young further mentions that "Ruoen (1995) argues that these independent price indices can credibly substitute for the existing implicit deflators in the estimation of the growth of real output," and himself concludes that "For all these reasons, the Ex-Factory price index is arguably a superior choice as a replacement deflator." (p. 10)

[22] For even earlier discussion of the basic duality for indexes of total factory productivity, they refer to Siegel (1952, 1969)

approach may be presented. A rather simple way is to proceed from the following national income accounting identity:[23]

(1) $$Y = r\,K + w\,L,$$

where Y is the aggregate output (or aggregate income), r is the real rental price of capital, w is the real wage, L is labor, and K is capital. Upon differentiation with respect to time and dividing by Y, we get

(2) $$\hat{Y} = s_K(\hat{r} + \hat{K}) + s_L(\hat{w} + \hat{L})$$

where $s_k \equiv rK/Y$ and $s_L = wL/Y$ are the factor income shares, and variables with "^" on top are the corresponding growth rates, so that $\hat{r} = dr/r$, and $\hat{w} = dw/w$. Rearranging equation (2), we get

(3) $$\hat{Y} - s_K\hat{K} - s_L\hat{L} = s_K\hat{r} + s_L\hat{w}\,.$$

The left hand side of equation (3) represents the usual, primal representation of the Solow residual, so that we can write

(4) $$SR_{primal} = \hat{Y} - s_K\hat{K} - s_L\hat{L}$$

However, equation (3) also shows that SR_{primal} is equal to the right hand side, which gives the dual representation of the Solow residual in terms of the share-weighted growth in factor prices, so that we can write

(5) $$SR_{dual} = s_K\hat{r} + s_L\hat{w}\,.$$

Note that this equality between SR_{primal} and SR_{dual} proceeds entirely from the national income identity and does not require any additional assumption.

Just as the SR_{primal} can be interpreted as a measure of shifts in the production frontier, provided the efficiency parameter is Hicks neutral and equality between marginal products and factor returns hold, SR_{dual} can also be interpreted under these assumptions as a measure of shifts in the corresponding factor price frontier. Samuelson (1962) provides an elaborate discussion of the relationship between the production frontier and factor price frontier. Diamond (1965) and Phelps and Phelps (1966) in fact use factor price frontier in defining changes in total factor productivity.[24]

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[23] This presentation of the dual approach follows Hseih (2002).

[24] As Hseih (2002, p. 503) explains, "In a simple model with two factors, say capital and labor, the outward shift of the factor price frontier is simply a share-weighted average of the growth rate of real wages and the rental rate of capital. According to the dual growth accounting formula, if real wage growth is entirely due

The equality shown by equation-3 also makes it clear that if one computes the SR_{dual} using *r* and *w* that can be obtained using capital and wage income data provided by the national income accounts, SR_{dual} should be exactly equal to the value of the SR_{primal}. Such an exercise would therefore be redundant. However, the usefulness of SR_{dual} lies in the fact that it can be computed based on factor price information from alternative sources, and such TFP estimates can then provide a useful check on the validity of SR_{primal} estimates and/or validity of the national income accounts data.

As is known, both the primal and the dual version of the Solow residual, as given by equation-4 and 5 above, are growth rates of continuous time Divisia-type indices. In order to compute Solow residual using discrete time data, Jorgenson and Griliches (1967) introduce a discrete time approximation to the Divisia derived from Tornqvist index. Under this approximation, the TFP growth rate (TFPGR) between time (*t-1*) and *t*, as measured by SR_{dual} is given by:

(5') $$TFPGR_t = SR_{dual} = s_{L\tau} \cdot \hat{w}_t + s_{K\tau} \cdot \hat{r}_t$$

where $\hat{w}_t$ and $\hat{r}_t$ are growth rates of *w* and *r*, respectively, between *t*-1 and *t*, and

(6a) $$s_{L\tau} = \frac{1}{2}\left[s_{L,t-1} + s_{L\,t}\right],$$

(6b) $$s_{K\tau} = \frac{1}{2}\left[s_{K,t-1} + s_{K\,t}\right].$$

In other words, continuous time (exponential) growth rates are replaced by growth rates between discrete time periods *t*-1 and *t*, and the continuous time shares (*s*) are replaced by averages of the shares of *t*-1 and *t*.[25]

Just as is the case with primal approach, the dual approach to growth accounting can also be extended to take into account improvements in quality of the inputs. As is known, this is usually done by allowing for different types of labor and capital.[26] The Divisia index framework facilitates the task. For example, assuming that there are *m* different types of labor, an aggregate growth rate of the wages, $\hat{w}$, can be derived as a share-weighted average of the growth rates of the individual labor types, using the following formula:

to capital accumulation, the return to capital must fall by the same magnitude as the rate of real wage growth."

[25] It is also known that the Tornqvist indices are not only good approximation of the corresponding Divisia indices. They are also the exact indices if the underlying production function has the translog specification. To the extent that translog function can serve as the second order approximation to any other production function, the validity of the Tornqvist index is quite general. See Hulten (2000) for an excellent recent discussion of various issues regarding the theory and computation of TFP.

[26] See Jorgenson, Gollop, and Fraumeni (1987, p. 2) for elaboration.

(7) $$\hat{w} = \sum_{j=1}^{m} s_{L_j} \hat{w}_j \ ,$$

where $\hat{w}_j$ is the growth rate of wages of a worker of type *j*, and s_{L_j} is the share of wage payments to the workers of type *j* in the total wage payments. Similarly, if there are *n* different types of capital, the aggregate rental price can be obtained as a weighted average of the rental price of these different types of capital, using the formula:

(8) $$\hat{r} = \sum_{i=1}^{n} s_{k_i} \hat{r}_i \ ,$$

where $\hat{r}_i$ is the growth rate of the rental price of type *i* capital, and s_{k_i} is the share of payments to capital type *i* in the total payments to capital. This property of Divisia index can be used to compute $\hat{w}_j$ and $\hat{r}_i$ based on sub-types into which labor of type *j* and capital of type *i* can be further disaggregated. In all cases the Tornqvist approximation helps in estimating the Divisia growth rates using discrete (annual) data.

The importance of accounting for input quality improvements while computing TFP can hardly be overemphasized. Note that TFP represents the *costless* part of the growth in output (in the primal approach) and returns to factors (in the dual approach).[27] For example, high educational attainments have been a key characteristic of East Asian growth. However, these societies however had to incur substantial costs in order to have these educational attainments. Unless improvement in the quality of labor arising from higher educational levels is accounted for, and instead the labor input is measured only by the number of bodies (or even hours), the TFPGR will be overestimated. From the dual point of view, wage growth achieved by having more people with higher education than before should not count as TFP growth. Only wage growth with unchanged labor quality (education) can be taken as reflective of TFP growth. Equation-7 allows us to capture that part of wage growth. If wages for workers of given levels of education do not increase, the value of $\hat{w}$ will be zero, even though the unweighted growth rate is positive. Similarly, the aggregate rental price of capital may be higher just because of relatively more productive capital goods being in place than before. However, the society has to incur costs in order to bring about the changed composition of its capital stock. Equation-8 allows us to capture the change in the rental rate for a constant quality (composition) of capital stock. Thus unless rental prices change for given types of capital, the value of $\hat{r}$ computed using equation-8 will be zero even though the unweighted average rate of change of the rental price may change.[28]

Although in terms of algebra the above framework is symmetric with respect to labor and capital, it differs in terms of actual capability to capture their quality changes.

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[27] See Abramovitz (1962, p. 764), Griliches and Jorgenson (1967, p. 250-51), and Hulten (2000) for further elaboration of this point.

[28] See Hseih (2002, p. 506) for further discussion.

This is because while there are independent physical measures of both quantity and quality of the labor input, such measures are generally absent for capital. For example, the quantity aspect of the labor input can be measured by the number of bodies or hours, and the quality aspect of the labor input can be measured by the number of schooling years. By contrast, given the heterogeneity of capital goods, there is no physical measure of aggregate capital, either at the national, sectoral, or even plant level. The Jorgenson-Griliches approach of taking the rate of return earned by a particular type of capital as a measure of its quality can ideally provide a way around the problem. However, data on such rates of return are often difficult to obtain. Second, and more importantly, this does not obviate the problem of absence of a physical measure of the quantity of capital. We will encounter these problems in our growth accounting for China too.

There have been several prominent applications of the dual approach growth accounting in recent years. For example, Shapiro (1987) uses this approach to show that TFP movements are not caused by demand side shocks. Hesih (1999, 2002) proves a more important recent application, which inspired and is closely related to the present study. Hsieh's work is a response to Young's (1992, 1995) earlier work showing that Singapore experienced negative TFP growth. Hsieh notes that constant capital share and spectacular capital stock growth suggested by Young's data (obtained from Singapore's national income accounts) would imply a significant fall in the rental rate of capital in Singapore.[29] Hence looking at the dynamics of factor prices can provide an additional check on the validity of the national accounts data on capital accumulation. Accordingly, Hsieh conducts a dual approach growth accounting exercise for the East Asian Tigers (namely Hong Kong, Korea, Singapore, and Taiwan) and produces TFP growth rates for these economies. He finds that while for Korea and Hong Kong the dual estimates of TFP growth are similar to the primal estimates, they exceed the primal estimates by more than 2 percentage point for Singapore. Hsieh shows that the reason for this large discrepancy lies in the fact while Singapore national income accounts data imply a large fall in the rate of return to capital, independent information on these return do not indicate any such fall.[30] He notes that such a fall is not likely given the openness of Singaporean economy to cross border capital mobility and given the already low level of the rate of return to capital at the beginning of the period.[31] This suggests that Singaporean national income accounts must have over reported capital accumulation.

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[29] "This evidence suggests that while the data on investment expenditures in the Korean national accounts are reasonable accurate, Singapore's national accounts significantly overstate the amount of investment spending." (p. 503) Note that

$$r = \frac{rK/Y}{K/Y} = \frac{s_K}{K/Y}.$$

If s_K remains constant, r has to fall in exactly the same rate as rise of the capital-output ratio (K/Y). As Hsieh puts it, "Since the share of payments to capital in Korea and Singapore has remained roughly constant, the marginal product of capital implied by Korea's and Singapore's national accounts must have fallen by 3.4 percent and 2.8 percent a year respectively, the same rate as the increase in the capital-output ratio." (pp. 502-3)

[30] "This discrepancy is not explained by financial market controls, capital income taxes, risk premium changes, and public investment subsidies." (Hseih 2002, p. 502)

[31] Actually, Hsieh's Figure-2 makes it clear that *r* did not have any further room to fall in Singapore. In 1962, *r*, as given by 'Average lending rate,' was already at the level of around 6-7 percent. In contrast,

Thus Hseih's use of the dual approach was prompted to a large extent by problems in the Singaporean national accounts data.[32] There is therefore a parallel with the Chinese situation in this regard. As seen in the discussion of Section 2.2 above, there are considerable problems with Chinese national accounts data too, though of different type and extent. Problems in national income accounts data are not uncommon, and it is not easy to completely eradicate these problems.[33] The use of the dual approach to growth accounting can therefore provide a useful alternative check on the results produced so far for China by the primal approach.

4. Implementing Dual Approach Growth Accounting for China

In conducting growth accounting exercise for China, this paper focuses entirely on the post reform period of 1978 to 2002. One question that is often asked is whether actual conditions of developing economies such as of China satisfy the neoclassical assumptions of competition and equality between factor prices and their marginal value products. While most authors of Chinese growth accounting studies do not discuss this question explicitly, some do. For example, Nagomi and Li (1999, p.1) note that "It has been a long controversy whether or not neo-classical model is applicable for the Chinese economy." They respond to the question by providing the following quote from Rawski and Zheng (1993, pp. 320-1):

> "…The absolutely complete market economy doesn't exist in reality….It can not be obstructed that we describe the basic trends of the Chinese economy with the simple theory model. The practice proves that the Chinese economy which is changing into a market economy can be described with such simple theory model to some extent, and the results are basically fitted the reality….and the practice also proved that the result is more sensitive to different data than to different methods. So we should pay more attention to data handling."

Be that as it may, the important point to note is that equality of prices with marginal products is required for the *interpretation* of the Solow residual as shifts of the production frontier (in the primary approach) and of the factor price frontier (in the dual approach). Even if this interpretation does not hold exactly because of departures from competitive equilibrium conditions, it is still possible to compute Solow residual and treat is as the *measured* productivity growth. Also, our choice of sample period (consisting entirely of post-reform years), makes it likely that competitive market equilibrium conditions will be satisfied to greater extent.

Hsieh's Figure-1 shows that *r* in Korea, as measured by curb loan rate was at the level of around 16-17 percent, and so there was considerable room to fall.

[32] As Hseih (2002, p. 503) suggests, "As one solution to this problem, this paper presents price-based (dual) estimates of TFPG that do not rely on data from national accounts."

[33] As Hseih (2002) notes, "Of course, this simply reinforces what anybody who has worked with national accounts data knows: that the task of computing reliable national income statistics is an impossibly difficult one and that, *even under the best of the circumstances, such statistics are riddled with large errors*." (p. 503)

4.1 Measuring Wage Growth

In implementing the dual approach, we first focus on the wage growth part of SR_{dual}. In other words, we want to obtain $s_L \hat{w}$, where we compute $\hat{w}$ using equation-6, in order to take into account different types of labor. We consider disaggregation in terms of both education level and residence (urban vs. rural). The disaggregation along these two lines for China turns out to be intertwined, as we shall see.

As noted in Section-2, very few studies on China's TFP have attempted to incorporate changes in quality of labor, with Young (2000) and Wang and Yao (2001) being exceptions. Both these studies have however conducted growth accounting following the primal approach. They both therefore needed to construct a *quantity index* for labor input. In our case, we do not need the quantity index. All we need is a measure of wage growth that is net of the impact of growth in quality (of labor). However, in order for that we need data on wages differentiated by quality types (education categories) and also the distribution of the labor force among these quality types (education categories).

Distribution of Labor into Different Education Types

The distribution data of educational attainment by levels of schooling in the total Chinese population or total labor are available only in the three recent censuses (1982, 1990, 2000) and in several small sample-based Surveys on Population Change in recent years. In order to get such distribution for all the years of the sample period, we follow the perpetual inventory method introduced by Barro and Lee (2000), and implemented recently for China by Wang and Yao (2001). We use enrolment rates (annual graduate flow data) from "Comprehensive Statistical Data and Materials on 50 Years of New China 1949-98" and China Statistical Yearbooks for this purpose. The formulas for such perpetual inventory computation are as follows.

(9) $$SP_{0,t} = (1-d_t)SP_{0,t-1} + (PRI\_ENROLLED_{0,t} - PRI\_GRADUATED_{0,t+6})$$

(10) $$SP_{1,t} = (1-d_t)SP_{1,t-1} + (PRI_t - JUNIOR_{t+3})$$

(11) $$SP_{2.t} = (1-d_t)SP_{2,t-1} + (JUNIOR_t - SENIOR_{t+3} - SPECIAL_{t+3})$$

(12) $$SP_{3,t} = (1-d_t)SP_{3,t-1} + (SENIOR_t - HIGHER_{t+3.5})$$

(13) $$SP_{4,t} = (1-d_t)SP_{4,t-1} + SPECIAL_t$$

(14) $$SP_{5,t} = (1-d_t)SP_{5,t-1} + HIGHER_t$$

where $SP_{j,t}$ is the number of persons in the population for whom *j* is the highest level of schooling attained; *j* = 0 for incomplete primary, 1 for primary, 2 for junior secondary school, 3 for senior secondary school, 4 for specialized secondary school, and 5 for higher education. If a person cannot complete the enrolled education level, we take that person as belonging to the schooling level he had before. The variable d_t is the annual mortality rate of the population, which is drawn from "Comprehensive Statistical Data and Materials on 50 years of New China 1949-1998" and China Statistical Yearbook 2003.

These equations are similar to those of Wang and Yao (2001). However there are a few differences. First, we allow for a different category for "incomplete primary education." In the classification of Wang and Yao, people with incomplete primary education are lumped with people with no schooling at all. Second, we take the number of years required to complete "specialized secondary school" to be three, instead of two, as assumed by Wang and Yao – an assumption that may not be correct.

Implementation of the above perpetual inventory method requires assumption or information regarding the distribution in the initial year. Following Wang and Yao, we also take India's distribution for 1960 to apply for China in 1951. According to this distribution, 16% had incomplete primary, 8.4% completed primary, 2.7% had incomplete secondary, 0.1% completed high school, 0.06% completed higher education, and the rest was illiterate. See Barro and Lee (1997, 2000). Although this assumed distribution may not be entirely accurate, the influence of the inaccuracy will wear off significantly by 1978, the beginning year of the sample period of this study.

After obtaining the education distribution of *population*, we compute the education distribution of *labor*, using the following formula:

$$SL_{jt} = TL_t * \left(SP_{jt} / TP_t\right), \tag{15}$$

where TL_t is the total size and TP_t are the total size of labor and population, respectively, in year *t*, and SL_{jt} and SP_{jt} are the size of labor and population, respectively, in that year for whom *j* is the highest level of schooling attained. This formula is based on the assumption that in a particular year education distribution of population (in percentage form) is the same as the education distribution of labor (in percentage form).

In view of absence of any other reliable source for relevant data, we rely on Chinese Statistical Yearbook (CSY) for the labor force data. However, we make a few adjustments to the pre-1990 labor force data. Based on the result of 2000 Population Census, the Chinese statistical authority has revised labor data for 1990-2000 significantly upwards, creating a huge jump (of 94.2 million) between the labor force figures of 1989 and 1990. Such a large increase in labor force in one year is unlikely. We therefore smooth out this jump by taking new 1990 labor data as the base and calculating backwards the labor force figures for 1978-1990 using the labor growth rates calculated from old data series for this period. This adjustment is made to total, urban, and rural labor figures.

Although this perpetual inventory exercise allows us to distinguish six different categories of education, corresponding data on wages are difficulty to get, as noted earlier by Young (2000) and Wang and Yao (2001). In view of this, we collapse the education categories into three broad categories, namely "junior secondary school and the below (Type-E1)," "high secondary school (including specialized secondary school and vocational school) (Type-E2)," and "higher education" (Type-E3).

The results of the above perpetual inventory calculation can be seen in Table-D1. Column-2 shows the total population, while column-3, 4, and 5 show population, P1, P2, and P3, belonging to the three education type E1, E2, and E3, respectively. Similarly column-7 shows the size of the total labor force, while column-8, 9, and 10 show labor force L1, L2, and L3 belonging to education type E1, E2, and E3, respectively.

Wage Data for Urban Labor

In order to proceed further we need information on wages distinguished by these three education types. There are some urban wage data by education level (for 1993-2001) reported in post 1994 issues of China Labor Statistical Yearbook (CLSY). However, these wage data are based on small sample surveys, covering usually only four to five cities. Examination of these wage data shows them difficult to explain and far from reliable. For example, these data show that in 1995 average wage rates for all education types are lower than those of 1994. This is highly unlikely. The probable reason for this anomaly is that while the 1994 survey included more of coastal cities, the 1995 survey included more of inland cities.

In view of these difficulties with CLSY data, we instead use CSY data to get education specific labor incomes. We first consider wage rates urban labor force. Let w_{L1}, w_{L2}, and w_{L3} be the wage rates of urban labor of education type E1, E2, and E3, respectively. To the extent that E3 represents higher education, we take the wage of state-owned science and technology research sector (institutes), which has the highest share of labor with completed higher education, as a measure of w_{L3}. By analogous reasoning, we use the average wage data of SOEs as a measure of w_{L2}. Since the end of 1970s, the labor growth in SOEs has been very slow. Usually only persons with completed senior secondary or special secondary education find employment in SOEs. On the other hand, except in some selected professional fields, SOEs do not attract and employ persons with completed higher education. Thus, employees of SOEs can be regarded as representing labor of education type E2. Finally, we use the average wage of Collectively Owned Enterprises (COE) as w_{L1}. In China's Statistical system, COE is a type of small scale cooperatively owned enterprises, which (particularly the ones in the service sector) generally employ less educated urban labor and some of migrant rural labor. Information on urban wages obtained as above is provided in Table-D2

With the above information in hand, we can now compute the weighted average urban wage growth rate. However, before going ahead with this computation, we need to take note of the situation in the rural areas.

Special situation with Rural Labor

The education distribution of population and labor force shown in Table-D1 apply to the nation as a whole, i.e. including both urban and rural areas. Ideally, both urban and rural population and labor should fall into different education categories. However, data from Surveys on Population Change (China Labor Statistical Yearbook 2003) show that less than five percent of rural labor has completed senior secondary school or above. This would put 95 percent of the rural labor into education type E1. Furthermore, the quality of high school education in rural areas is much lower than that in urban areas, so that rural labor nominally belonging to type E2 does actually belong to type E1, when quality of school education is taken into consideration. (As we shall soon see, the wage data for rural labor also validates this observation.) Also, though there are some official sample surveys on rural labor in China, none of these provide wage data distinguished by education categories. Thus even if we wanted to distinguish education type E2 and E3 in rural labor, we would not have corresponding data on wages. In view of this situation, we classify the entire rural labor (L_R) into education type E1.

Table-D3 shows information on rural labor and wages. It gives total nominal rural wage, rural labor, nominal rural wage, national CPI, and rural CPI. It would seem proper to deflate nominal rural wage using rural CPI. Unfortunately rural CPI is generally regarded very problematic, so that the use of the national CPI is preferred for this purpose. These average real rural wages (at 1978 prices), denoted by w_R, are given in column-8 of Table-D3. For comparison, we also compute average rural real wage using the rural CPI as the deflator. This series, denoted by w_{R2}, is given in column-9. The year-to-year growth rates of w_R, denoted as $\hat{w}_R$, are given in column-10. On the other hand, year-to-year growth rates of w_{R2}, denoted as $\hat{w}_{R2}$, are shown in column-11. By comparing w_R with w_{L1}, the urban wage of labor of education type E1, we see that indeed the former is much lower than the latter, supporting our earlier observation about inferior quality of rural education and the decision to classify all rural labor into education type E1. In fact, the rural labor can be thought to belong to a separate, lower education type, say E0. However, doing so would not affect the computation, because in either case we will be using the rural wage to construct the weight for rural labor. We therefore refrain from introducing E0 in order to minimize notations and also to reflect the fact that nominally the rural labor does belong to E1.

Aggregation over Education and Residence Types

We first subtract L_R from L1, the total labor of education type E1, in order to get $L1_U$, the urban labor belonging to education type E1. Column-5 of Table-D2 shows $L1_U$. The rest of the computation of the urban wage growth rate is shown in Table-D4, and is carried out using the following equation:

$$(16) \qquad \hat{w}_U = s_{L1} \cdot \hat{w}_{L1} + s_{L2} \cdot \hat{w}_{L2} + s_{L3} \cdot \hat{w}_{L3},$$

where $\hat{w}_{L1}$, $\hat{w}_{L2}$, and $\hat{w}_{L3}$ are the growth rates of w_{L1}, w_{L2}, and w_{L3}, respectively, and s_{L1}, s_{L2}, and s_{L3} are share of wage payments made to E1, E2, and E3 type labor in the total urban wage-payments. Column-2, 3, and 4 show $\hat{w}_{L1}$, $\hat{w}_{L2}$, and $\hat{w}_{L3}$, while column-5, 6, and 7 show the values of s_{L1}, s_{L2}, and s_{L3}, respectively. The values of $\hat{w}_U$ are presented in column-8. These values may be compared with unweighted average growth rate of urban wage shown in column-9.

We can now compute the weighted average of the wage growth rate for the economy as a whole ($\hat{w}$), using the formula:

$$\hat{w} = s_U \hat{w}_U + s_R \hat{w}_R . \tag{17}$$

The results are shown in Table-D5. Column-9 and 11 shows the values of $\hat{w}_U$ and $\hat{w}_R$, respectively from earlier Tables. Column-8 and 10 show the values of s_U and s_R, respectively. The values of $\hat{w}$ can be seen in column-12. These values may be compared with unweighted average growth rates shown in column-4 and 7.

4.2 Measuring Changes in the Capital Rental Rate

Measuring the capital rental rate in China is a challenging task. This is because capital markets were either non-existent or very weak until recently. In the following we therefore follow several routes in trying to have an idea about what has been happening to the capital rental rate during 1978-2002.

Estimating Capital Stock

The first task in measuring capital rental rate is to construct the capital stock figures. As noticed in Section-2, this remains a thorny issue. Our capital construction exercise is presented shown in Table-C1. It begins with the gross investment series in current prices, shown in column-2. To bring these to constant 1978 prices, we use the GDP deflator, shown in column-3. We saw earlier that the deflator to be used for this purpose has been a question, and we will comment on this later. The constant (1978) price investment figures are in column-4 of the Table. This investment series is then used to compute the capital stock using the perpetual inventory method using the following familiar equation:

$$K_t = (1-\delta) K_{t-1} + I_t \tag{18}$$

where notations are obvious. The capital stock for the initial year, K_0, is computed using the formula:

$$K_0 = I_0 / [g_0 + \delta_0] \tag{19}$$

where I_0 is the investment for the initial period, and δ_0 is the rate of depreciation applicable for the initial year, and g_0 is ideally the rate of growth of capital around the initial year. To the extent that value of capital stock is unknown, various proxies are used.

For example, in computing initial capital stock for 1960, Hall and Jones (1999, p. 89, ff 5) takes g_0 to be "the average geometric growth rate from 1960 to 1970 of the investment series." In our case, we take 1957 as the initial year, and g_0 is taken to be 0.13, the average growth rate of investment during 1952-1957. As for the depreciation rate, it ranges between 0.02 and 0.04 in the Chinese official documents. We therefore take δ_0 to be equal to 0.03, the mid-point of this range. Note that since the period analyzed in this paper is 1978-2002, the assumptions made in computing capital stock for 1957 will not have much influence in the capital stock data actually used.

It may be noted that the composition of the Chinese capital stock changed quite a bit over the last decades. In general, the share of "machinery and equipment," which depreciate faster, has increased relative to the share of "buildings and structures," which depreciate at a slower pace. This implies that the depreciation rate of the aggregate Chinese capital stock has increased over time. To reflect this process, we take the depreciation rate to be 0.03 for 1952-1978, 0.04 for 1979-1992, and 0.05 for 1993-2002. The rates assumed for the first two sub-periods are based on Chinese statistical authorities. (NBSC, 1997) The assumed rate for the more recent sub-period is based on the past rates and some recent literature. See, for example, Ezaki and Sun, (1999) and Hu and Khan (1997)

The estimated values of capital stock are influenced by the assumptions concerning deflators, initial capital stock, and depreciation rates. Table-C1 therefore also offers a comparison of our estimated values of capital stock with those offered recently by other researchers. The comparison shows our capital stock figures to be larger than those of Hu and Khan (1997) and Ezaki and Sun (1999). However, they prove smaller than those of Chow and Li (2002), who include land in their capital stock.

Rental Rate of Capital according to NIA Data

Before we compute capital rental rate using alternative sources information, we first check what these rates turn out to be when computed on the basis of NIA data. This exercise is presented in Table-C2. Column 2 gives the GDP in current prices, while column 3 gives total wage payments aggregated for the national economy from provincial data. (Note that in China's national income account, only provincial data of wage payments are reported.)[34] Payments to capital are shown in column 4, and are obtained by subtracting wage payments from GDP. The GDP deflator (shown in Table-C1) is used to convert the capital payments data in current prices into constant 1978 prices. These are then divided by the capital stock data to obtain the capital rental rate, shown in column-6 of Table C2. The year-to-year changes (as percentages of the base years' values) are shown in column-7.

The main feature of the results regarding NIA-based rental rate is its constancy, nay even an increasing trend. The rental rate seems to have gone up from around 14

[34] This data series from 1978 are available in "The Gross Domestic Product of China 1952-1995" and "China Statistical Yearbook" (various years)

percent to about 16 percent. Such an increasing trend contradicts the expectation that capital deepening will pull down the rental rate via diminishing returns. As data in Table-C1 show, between 1978 and 2002, the aggregate capital stock has increased 7.8 fold, and per labor capital stock has increased by 4.8 fold. It is remarkable that the capital rental rate has remained constant or even increased despite this enormous increase in capital.

Hsieh (2002) has argued in the context of Singapore that such an outcome is untenable if capital-output ratio has increased and the share of capital in national income has remained unchanged.[35] However, unlike Singapore, data for China does not show significant rise in the capital-output ratio. Based on our capital stock estimates, the capital-output ratio (*K/Y*) for 1978 and 2002 are 3.39 and 3.06 respectively. Thus, instead of increasing, the capital-output ratio has declined somewhat.[36] Similarly, based on national accounts data the value of capital share β has also remained almost constant. This would suggest that marginal product of capital, MP_K, has also remained constant. Thus unlike that of Singapore, the NIA data for China does not suggest any decline in the capital rental rate. We now check what evidence on capital rental rate can be obtained from alternative sources of information.

Rental Rate of Capital according to Industry Level Data

For one such alternative source of information, we turn to industrial level data to be found in "China Industry Economy Statistical Yearbook (CIESY)." These data also allow a two-level disaggregation. At the first level we distinguish two sectors, namely Manufacturing and Other. The latter consists mainly of agriculture and service sectors. At the second level, we distinguish capital by two ownership types, namely State Owned Enterprises (SOE) and Non-State Owned Enterprises (Non-SOE). Since 1978 the Chinese economy is undergoing a radical transformation of ownership type. The share of state-ownership of capital assets has considerably fallen. The share of various indigenous cooperative and individual ownerships has risen. In addition, there is now considerable intrusion of foreign ownership of various forms. It is often maintained that capital under these various types of ownership differ in quality, manifested in very different rates of return that they earn. A disaggregation in terms of ownership therefore will be helpful in netting out the impact of quality improvements in capital. Data limitations however restrict the second level disaggregation to the Manufacturing sector only.

Table-C3 shows the computation of the average rate of change in the rental rate of capital for the Manufacturing sector based on diaggregation into SOE and Non-SOE.

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[35] This can be clearly seen from the following expression of capital share, $\beta = MP_K * \left(K/Y\right)$. Clearly, if (*K/Y*) goes up while β remains unchanged, MP_K has to fall.

[36] This finding regarding lack of capital deepening is not new. Earlier researchers have also been struck by this. For example, Hu and Khan (1997, p. 3) make the following comment in this regard: "… although the capital stock grew by nearly 7 percent a year over 1979-94, the capital-output ratio has hardly budged. In other words, despite a huge expenditure on capital, production of goods and services per unit of capital remained about the same. This pronounced lack of capital deepening suggests a constrained role for capital."

Column-2 shows the rate of return for SOE part of the Manufacuring sector, denoted as r_{SOE}. These rates are also computed from CIESY with “profit plus tax” as the numerator and the value of the fixed assets as the denominator. We see that r_{SOE} displays a strong declining trend. It falls from 0.25 in 1978 to 0.10 in 2002. The year-to-year changes of this rental rate (denoted as $\hat{r}_{SOE}$) are shown in column-4. Column-3 shows the rate of return to industrial capital in non-state owned enterprises (non-SOE), denoted as r_{NSOE}. The capital stock (value of fixed assets) of the non-SOEs is calculated by subtracting the value of fixed assets of the SOEs from the value of the total fixed assets of the Manufacturing sector. Similarly, profit-plus-tax of the non-SOEs is computed by subtracting the “profit-plus-tax” of SOEs from the corresponding total for the industry. We see that r_{NSOE} also shows a strong declining trend. In fact, the declining trend is more pronounced for r_{NSOE} than for r_{SOE}. As column-3 shows, this rental rate has declined from a high of 0.44 in 1978 to 0.18 in 2002. The year-to-year changes in this rental rate (denoted as $\hat{r}_{NSOE}$) can be seen in column-5.

With this disaggregated data available, we can now calculate the rate of change in the rental rate in the Manufacturing sector as a weighted average using the formula:

$$\text{(20)} \qquad \hat{r}_M = s_{SOE,\tau} \cdot \hat{r}_{SOE,t} + s_{NSOE,\tau} \cdot \hat{r}_{NSOE,t} .$$

Column-6 and 7 show the share of SOEs and non-SOE capital, denoted by $s_{SOE,t}$ and $s_{NSOE,t}$, respectively, in the total payments to capital in the Manufacturing sector. We can see that $s_{NSOE,t}$ has steadily increased, from a mere eight percent in 1978 to thirty-one percent in 2002. The $s_{SOE,t}$, correspondingly, has decreased from 92 percent in 1978 to 69 percent in 2002. The weighted changes in the rental rate, $\hat{r}_M$, are shown in column-8.

As already mentioned, lack of data prevent disaggregation of the “Other” sector by ownership type. We therefore next consider aggregation over the Manufacturing and Other sector. The results from this exercise are provided in Table-C4. Column 2 shows the rental rate of capital in the “Manufacturing” sector, denoted as r_M. These rates are computed with “profit plus taxes paid” as the numerator and the value of the fixed assets as the denominator for the entire Manufacturing sector. We again see that this rate of return displays a clear declining trend, from a value of 0.26 in 1978 to 0.13 in 2002. The rental rate of “Other” sector, denoted by r_O, can be seen in column-3. The CIESY does not provide data on the capital stock of sectors other than the Manufacturing sector. Hence the value of fixed assets for the “Other” sector is calculated by subtracting the fixed asset of the Manufacturing sector from the total capital stock of the economy, computed earlier through the perpetual inventory method. Similarly, we get the value of profit and taxes for the “Other” sector by subtracting the profit and tax of the Manufacturing sector from the total value of profit and tax (in the economy). The figures of column-3 show that, in contrast to what we saw for the Manufacturing sector, the rental rate of capital for the “Other” sector shows an upward trend. The year-to-year changes in these rates (denoted as $\hat{r}_{Ot}$) are shown in column-5. Column-4 reproduces the values of $\hat{r}_M$ obtained earlier in Table-C3. Comparing, we see considerable differences between rental rates of capital in these two sectors, in terms of both level and trend.

We can now calculate the economy wide weighted average ($\hat{r}$) using the following formula:

$$(21) \qquad \hat{r}_t = s_{M\tau} \cdot \hat{r}_{Mt} + s_{O\tau} \cdot \hat{r}_{Ot}$$

where $\hat{r}_M$ and $\hat{r}_{Ot}$ are as before and $s_{M\tau}$ and $s_{O\tau}$ are the share of payments to capital of Manufacturing and Other sector, respectively, in the total payments to capital. Column-6 and 7 in Table-C4 show the values of s_{Mt} and s_{Ot}, respectively. Column-8 presents the computed values of $\hat{r}$. These may be compared with the unweighted rate of changes in the rate of return to capital, denoted by $\hat{r}^{UN}$ and shown in column-9. We note considerable differences between $\hat{r}$ and $\hat{r}^{UN}$, implying that disaggregation does influence the results.

Thus we see contrasting results regarding the rental rate of capital. The rental rate obtained on the basis of NIA data show that this rate has remained relatively unchanged, despite very significant capital deepening as measured by capital stock per labor. This relatively unchanged rate is about 15 percent. However, rental rate computed from industrial data show a clear and marked declining trend. For the Manufacturing sector as a whole this rate has come down from a high of 26 percent in 1978 to about 12 percent in 2002.[37]

4.3. Dual Estimates of TFP Growth Rates

We now collect the results to compute the SR_{dual}, or the dual approach TFPGR using equation-5'. This computation is presented in Table-T1. The first few columns provide the ingredients for computation of SR_{primal}, or the primal TFPGR. Thus column-2, 3, and 4 give the year-to-year growth rate in GDP, labor, and capital. Column-10 shows

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[37] What explains this discrepancy? The following observations by Hu and Khan (1997) are pertinent in this regard: "The Chinese authorities regularly undertake fixed asset surveys for the state-owned sector, obtaining information on (1) gross stock of fixed assets valued at the original acquisition prices of the respective assets; and (2) the stock of fixed assets valued at current prices in the survey years, net of depreciation. In comparing the net stock value series, as reported by the official asset surveys, with the capital stock estimated using cumulated investment flows and the official depreciation table for the state-owned sector, large discrepancies emerge. One possible explanation is that the state owned enterprises (SOEs) and other state entities fail to use consistent price deflators for those asset surveys. Another possible reason is that official surveys suffer from serious reporting errors and omissions. In any event such official surveys are not conducted for urban collective and rural agricultural sectors, and thus do not cover the economy as a whole." (p. 110) This difficulty was also mentioned in the shorter version of Hu and Khan (1999, p. 8): "Chinese asset surveys do not produce capital stock estimates consistent with the investment data in the national accounts. The difficulties of bridging this gap are considerable."

the share of labor income (α) in GDP, as per NIA data. These produce the primal TFPGR (TFP_p) shown in column-10.

The ingredients for computation of the dual TFPGR are in column-5 and 7, which show the weighted growth rate of wage and rental rate. The corresponding unweighted averages can be seen in column-6 and 8. Comparing, we find that the weighted average growth rate of wage ($\hat{w}$) does prove less than the corresponding unweighted average ($\hat{w}^{UN}_{CLSY}$), though not by that much. The simple arithmetic average of $\hat{w}$ for 1978-2002 is 5.6 percent, while analogous value for $\hat{w}^{UN}_{CLSY}$ is 5.8 percent. Accounting for labor quality as measured by educational attainment does have some effect. (Both these values are however much lower than the analogous average of $\hat{w}^{UN}_{NIA}$, the unweighted wage growth rate according to the NIA data. The latter has a value of 7.4 percent.)

The comparison of the weighted and unweighted average change in capital rental rate is more problematic, as noted earlier. The simple arithmetic average for 1978-2002 of $\hat{r}$ equals 1.05. Analogous average of $\hat{r}^{UN}_{CIESY}$, the unweighted rate of change of capital rental rate according to CIESY data equals 0.38. We may note that the analogous average of $\hat{r}^{UN}_{NIA}$ equals 0.84.

We compute two alternative values of dual TFPGR. Column-11 shows TFP_d the dual TFPGR based on the weighted growth rates $\hat{w}$ and $\hat{r}$. Column-12 shows the dual TFPGR (denoted as TFP_d^{UN}) based on the unweighted averages $\hat{w}^{UN}_{CLSY}$ and $\hat{w}^{UN}_{CLSY}$. To conduct a rough and ready comparison, we may again look at the long-term averages of TFP_p , TFP_d , and TFP_d^{UN} provided in the bottom rows of Table-T1. A simple arithmetic average of TFP_p equals 4.08, while those of TFP_d , and TFP_d^{UN} equal 3.45 and 3.23, respectively. Thus we find the dual TFPGR to be only about half a percentage point less than the primal TFPGR. Unlike that for Singapore, the dual TFPGR for China do not appear to be that different from the primal TFPGR.

It may therefore be concluded that even after taking account of improvements in labor quality (through higher educational attainments), TFPGR in mainland China for the post-reform period of 1978-2002 prove to be high, around 3 percent per annum. In other words, the answer to the first question is that TFPGR did play a very important role in the post-reform growth. In fact our dual estimate of TFPGR proves higher than of both Young (2000) and Woo (1997) and closer to that of Hu and Khan (1997) and Wang and Yao (2001).[38]

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[38] One thing that needs to be noted is that the contrast between the upbeat TFP growth rates of Hu and Khan and those of Young, Woo, and Wang and Yao may not be that great as it appears. This is because Hu and Khan's analysis does not take into account quality improvements of labor. Hence their estimates of TFP are inclusive of the contribution of human capital growth. On the other hand, both Young and Wang and Yao account for quality improvements in labor, and hence their TFP growth rates do not include the contribution of quality improvements in labor. As we can from the results of Wang and Yao, presented above, the total of human capital growth and TFP growth rates prove to 5.01 for the post reform period.

To answer the second question, we may look at the 1978-1984 and 1992-2002 averages of TFPGR. According to the primal measure, TFP_p, this average has *increased* from 4.23 in the first sub-period to 4.61 in the second sub-period. However, according to the dual TFPGRR, TFP_d, this average has decreased from 5.69 to 3.77. The other measure of dual TFPGR, TFP_d^{UN}, also shows an analogous decrease from 5.24 to 3.82. Thus according to the dual growth accounting, while the TFPGR still remains high, it has slowed down to some extent. In this regard, we see a contrast between the results based on dual TFPGR and those based on primal TFPGR.

5. Concluding Remarks

This paper shows that the dual approach to growth accounting can be applied to China, and such an application can help in answering thorny questions concerning sources of Chinese growth. However, there remain many weaknesses, which are particularly true with regard to the rental price of capital than to wages. This is not surprising. Rental rates of capital, particularly disaggregated by capital types, are very hard to get even for developed market economies. So we very much look forward to further improvement in this area. An alternative source of information regarding rate of return to capital in China is International Financial Statistics (IFS), which provide "deposit rate" and "lending rate." The former refers to "interest rates on institutional and individual deposits of one-year maturity." The latter refers to "rate on capital loans to state-owned industrial enterprises during 1980-1989 and to all enterprises thereafter." This information is much more independent of NIA than the rental rates that we used in our computation of dual TFPGR above. However, most researchers think that the sphere of application of the IFS rates is very limited, so that these rates cannot be taken as representing the rental rate of capital for the broader Chinese economy. With time, as capital market develops in coverage and depth in China, many other more representative rental rates will emerge. However, as of now, problems remain in getting capital rental rates that are completely independent of NIA. The situation with regard to wages is better in this respect. However, as we saw, there remain considerable problems in getting wages differentiated by education types, both for urban and particularly the rural sector.

The Chinese statistical authorities are making important progress in eliminating data deficiencies and weaknesses. Hopefully more of such improvements will take place soon as will help overcome many of the difficulties that were faced in this paper in applying the dual approach growth accounting to China.

(Analogous total for the pre-reform period proves to be 4.73 percent per annum) This is higher figure than even of Hu and Khan! Similarly, Young finds that while output per worker increases in the post-reform period by 3.6 percent, output per effective worker increases by 2.6 percent, suggesting a growth rate of human capital of about 1 percent. Adding this to his TFP growth rate would raise it to 2.4 percent, much higher than the measly 1.4 percent!

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Table D-1 Labor Stock by Education Level (10,000)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Total	Educated Population				Educated Labor			
	popu-								
Year	lation	E1	E2	E3	SUM	L	L1	L2	L3
1951	56300	10942	56	34	11032	—	—	—	—
1978	95617	42538	4014	288	46840	45820	41612	3927	281
1979	96901	45901	4694	294	50889	46815	42226	4318	271
1980	98124	48570	5298	307	54175	48340	43339	4728	274
1981	99389	51561	5791	319	57671	49897	44611	5010	276
1982	100863	54135	6085	363	60583	51689	46187	5192	310
1983	102331	56445	6291	394	63130	52991	47379	5281	331
1984	103683	58829	6449	420	65698	55000	49250	5399	351
1985	105104	60982	6630	449	68060	56913	50994	5544	375
1986	106679	63040	6856	485	70381	58521	52417	5701	403
1987	108404	64985	7128	535	72648	60233	53880	5910	443
1988	110163	66906	7411	586	74904	62003	55383	6135	485
1989	112704	68647	7693	640	76980	63139	56304	6310	525
1990	114333	70229	7970	697	78896	64749	57636	6540	572
1991	115823	71600	8235	754	80589	65491	58186	6693	613
1992	117171	72848	8496	810	82153	66152	58659	6841	652
1993	118517	73868	8764	861	83493	66808	59107	7012	689
1994	119850	74734	9014	919	84667	67455	59541	7181	732
1995	121121	75498	9280	994	85772	68065	59912	7364	789
1996	122389	76176	9576	1071	86823	68950	60495	7604	851
1997	123626	76960	9901	1147	88008	69820	61055	7855	910
1998	124761	77859	10262	1223	89344	70637	61557	8114	967
1999	125786	78755	10700	1300	90754	71394	61954	8417	1022
2000	126743	82391	11260	1386	95036	72085	62493	8540	1051
2001	127627	86100	11844	1481	99425	73025	63238	8699	1088
2002	128453	89952	12442	1605	103999	73740	63780	8822	1138

Source: China Labour Statistical Yearbook (various years), China Statistical Yearbook (various years)

Note 1: E1=SP0+SP1+SP2; E2=SP3+SP4; E3=SP5. SP5, SP4, SP3, SP2, SP1, SP0 is the number of educated population for whom the highest level of schooling attained is higher education (university and college), special secondary, senior secondary, junior secondary, primary, and incompletely primary, respectively.

Note 2: The percentage of population stock of each education level (SP5, SP4, SP3, SP2, SP1, SP0) to total population in 1951 is assumed as 0.06, 0.03, 0.07, 2.7, 8.4, and 16, respectively.

Note 3: L is the number of total national labor; L1 is the number of labors who received education lower than senior secondary school; L2 is the category of labors who completed senior secondary school education; L3 is the category of labors who completed higher education. L1= (E1/SUM)*L; L2= (E2/SUM)*L; L3=L - (L1+L2).

Table D-2 Urban wage by Education Level

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Nominal average wage			Composition of L1		Real average wage			Total real
Year	W_{L1}	W_{L2} (yuan)	W_{L3}	$L1_u$ (10,000)	L_R	W_{L1}	W_{L2} (yuan)	W_{L3}	wage (100 MY)
1978	506	644	670	6791	34794	506	644	670	615.4
1979	542	705	719	6971	35233	532	692	706	688.6
1980	623	803	853	7166	36154	569	733	779	775.5
1981	642	812	852	7492	37103	572	723	759	811.7
1982	671	836	860	7711	38461	586	730	751	854.0
1983	698	865	992	7968	39395	598	740	849	895.2
1984	811	1034	1074	8387	40846	676	862	895	1063.8
1985	967	1213	1268	8888	42092	737	925	967	1204.6
1986	1092	1414	1494	9263	43143	782	1013	1070	1344.7
1987	1207	1546	1624	9581	44290	805	1032	1084	1429.6
1988	1426	1853	1935	9874	45501	801	1041	1087	1482.3
1989	1557	2055	2123	9802	46492	741	978	1011	1396.8
1990	1681	2284	2411	9928	47708	776	1055	1113	1524.1
1991	1866	2477	2580	10160	48026	833	1106	1152	1657.5
1992	2109	2878	3130	10368	48291	885	1208	1314	1829.7
1993	2592	3532	3989	10561	48546	948	1292	1460	2008.4
1994	3245	4797	6212	10739	48802	957	1414	1832	2177.4
1995	3931	5625	6835	10887	49025	990	1416	1721	2256.3
1996	4302	6280	7984	11467	49028	1000	1460	1856	2415.1
1997	4512	6747	8974	12016	49039	1020	1526	2030	2609.5
1998	5331	7668	10146	12536	49021	1215	1748	2313	3165.6
1999	5774	8543	11543	12972	48982	1335	1975	2669	3667.5
2000	6262	9552	13221	13559	48934	1442	2200	3045	4154.3
2001	6867	11178	16218	14153	49085	1570	2556	3709	4850.1
2002	7667	12869	19006	14820	48960	1768	2967	4382	5735.6

Source: China Labour Statistical Yearbook(various year and Authors).

Note 1: $L1=L1_u+L_R$ (Total rural labor). Thus, $L1_u = L1-L_R$.

Note 2 : W_{L1} in the Table D-2 is the weighted average wage of $L1_u$. The average wage of Collective-Owned enterprises is used as proxy of W_{L1}.

Note 3: W_{L2} is the average wage of L2, using the average wage data of SOEs;

Note 4: W_{L3} is the average wage of L2. The average wage for labors of State-Owned science and research sector is used as proxy of W_{L3}.

Note 5: MY refers to Million Yuan.

Table D-3 Rural Wage Growth Rate

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Total rural nominal wage	Rural Labor	Nominal rural wage	CPI	Rural CPI	Total rural real wage	Average real wage		Wage growth rate	
							w_R	w_{R2}	$\hat{w}_R$	$\hat{w}_{R2}$
Year	(100 MY)	(10,000)	(yuan)	(1978=100)	(1978=100)	(100 MY)	(yuan)	(yuan)	(%)	(%)
1978	1055.4	34793.6	303.3	100.0	100.0	1055.4	303.3	303.3	—	—
1979	1266.1	35233.1	359.3	101.9	101.9	1242.5	352.6	352.6	16.3	16.3
1980	1522.3	36154.1	421.1	109.5	109.5	1389.7	384.4	384.5	9.0	9.0
1981	1785.3	37103.4	481.2	112.3	112.2	1590.0	428.5	428.9	11.5	11.5
1982	2165.6	38460.5	563.1	114.5	114.4	1890.9	491.6	492.2	14.7	14.8
1983	2500.9	39395.2	634.8	116.8	116.7	2140.9	543.4	544.0	10.5	10.5
1984	2854.7	40846.5	698.9	120.0	119.9	2379.5	582.5	582.9	7.2	7.2
1985	3210.9	42092.3	762.8	131.1	134.2	2448.7	581.7	568.4	-0.1	-2.5
1986	3438.4	43142.7	797.0	139.7	142.4	2462.1	570.7	559.7	-1.9	-1.5
1987	3775.6	44289.7	852.5	149.8	151.2	2519.7	568.9	563.6	-0.3	0.7
1988	4488.4	45501.5	986.4	178.0	177.7	2521.3	554.1	555.2	-2.6	-1.5
1989	5002.4	46491.7	1076.0	210.1	211.9	2381.4	512.2	507.8	-7.6	-8.5
1990	5774.5	47708.0	1210.4	216.6	221.6	2666.3	558.9	546.3	9.1	7.6
1991	5995.8	48026.0	1248.4	223.9	226.7	2677.4	557.5	550.8	-0.2	0.8
1992	6663.6	48291.0	1379.9	238.3	237.3	2796.7	579.1	581.6	3.9	5.6
1993	7865.5	48546.0	1620.2	273.3	269.7	2878.0	592.8	600.7	2.4	3.3
1994	10461.5	48802.0	2143.7	339.2	332.8	3084.5	632.1	644.1	6.6	7.2
1995	13560.2	49025.0	2766.0	397.2	391.1	3414.3	696.5	707.3	10.2	9.8
1996	16388.0	49028.0	3342.6	430.1	421.9	3810.1	777.1	792.2	11.6	12.0
1997	17594.1	49039.0	3587.8	442.2	432.5	3979.1	811.4	829.5	4.4	4.7
1998	17977.5	49021.0	3667.3	438.6	428.2	4098.6	836.1	856.4	3.0	3.2
1999	18133.2	48982.0	3702.0	432.5	421.8	4192.8	856.0	877.7	2.4	2.5
2000	18216.0	48934.0	3722.6	434.2	421.4	4195.2	857.3	883.4	0.2	0.7
2001	18827.8	49085.0	3835.8	437.3	424.7	4305.9	877.2	903.1	2.3	2.2
2002	19369.6	48960.0	3956.2	433.8	423.0	4465.6	912.1	935.3	4.0	3.6

Source: China statistical Yearbook (various years) for per capita income of rural population, rural population, rural labor, CPI, rural CPI.

Note: Total nominal rural wage = Rural population * Per capita income of rural population. MY refers to Million Yuan. Data in Column-7, 8 and 10 are calculated using CPI, and data in Column 9 and 11 are calculated using rural CPI, respectively.

Table D-4 Urban Wage Growth Rate

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year	Growth rate by education			Share in total wage			Urban growth rate	
	$\hat{w}_{L1}$ (%)	$\hat{w}_{L2}$ (%)	$\hat{w}_{L3}$ (%)	S_{L1}	S_{L2}	S_{L3}	$\hat{w}_{U}$ (%)	$\hat{w}_{U}^{UN}$ (%)
1978	—	—	—	0.56	0.41	0.03	—	—
1979	5.1	7.4	5.3	0.54	0.43	0.03	6.1	6.5
1980	6.9	6.0	10.4	0.53	0.45	0.03	6.6	7.0
1981	0.5	-1.3	-2.6	0.53	0.45	0.03	-0.4	-0.3
1982	2.5	0.9	-1.0	0.53	0.44	0.03	1.7	1.8
1983	2.0	1.4	13.1	0.53	0.44	0.03	2.1	2.0
1984	13.1	16.4	5.4	0.53	0.44	0.03	14.3	14.1
1985	9.1	7.3	8.0	0.54	0.43	0.03	8.3	8.1
1986	6.0	9.5	10.6	0.54	0.43	0.03	7.6	7.6
1987	3.0	1.9	1.3	0.54	0.43	0.03	2.5	2.5
1988	-0.6	0.9	0.3	0.53	0.43	0.04	0.1	0.2
1989	-7.5	-6.0	-7.0	0.52	0.44	0.04	-6.8	-6.6
1990	4.7	7.8	10.2	0.51	0.45	0.04	6.3	6.5
1991	7.4	4.9	3.5	0.51	0.45	0.04	6.1	6.1
1992	6.2	9.2	14.0	0.50	0.45	0.05	7.9	7.9
1993	7.2	7.0	11.1	0.50	0.45	0.05	7.3	7.4
1994	0.9	9.4	25.5	0.47	0.47	0.06	6.2	6.1
1995	3.5	0.1	-6.0	0.48	0.46	0.06	1.3	1.5
1996	1.1	3.1	7.9	0.47	0.46	0.07	2.4	2.3
1997	2.0	4.5	9.3	0.47	0.46	0.07	3.7	3.6
1998	19.1	14.6	14.0	0.48	0.45	0.07	16.7	16.6
1999	9.8	13.0	15.4	0.47	0.45	0.07	11.7	11.7
2000	8.0	11.4	14.1	0.47	0.45	0.08	10.0	9.7
2001	8.9	16.2	21.8	0.46	0.46	0.08	13.3	12.9
2002	12.6	16.1	18.1	0.46	0.46	0.09	14.6	14.2
1978-2002	5.5	6.7	8.4	0.53	0.46	0.05	6.2	6.2
1978-84	5.0	5.1	5.1	0.62	0.51	0.03	5.1	5.2
1985-91	3.2	3.7	3.8	0.53	0.44	0.04	3.4	3.5
1992-2002	7.2	9.5	13.2	0.48	0.46	0.07	8.6	8.5

Source: Authors

Note 1: $\hat{w}_{L1}$, $\hat{w}_{L2}$, and $\hat{w}_{L3}$ are wage growth rates of each labor category, L1, L2, L3, respectively. $\hat{w}_u$ is the weighted urban overall wage growth rate, while $\hat{w}_u^{UN}$ is an unweighted rate, which is calculated from the data of total urban labor and total real urban wage (column-10 of Table D-2).

Note2: Data for 1978-2002, 1978-84, 1985-91, and 1992-2002 are arithmetic average of wage growth rate for each period respectively.

Table D-5 Overall Wage Growth Rate

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	TW_{NIA} (100MY)	W_{NIA} (yuan)	$\hat{w}^{UN}_{NIA}$ (%)	TW_{CLSY} (100MY)	W_{CLSY} (yuan)	$\hat{w}^{UN}_{CLSY}$ (%)	S_u	$\hat{w}_U$	S_R	$\hat{w}_R$	$\hat{w}$ (%)
1978	1800	393	—	1671	365	—	0.37	—	0.63	—	—
1979	2004	428	9.0	1931	413	13.1	0.36	6.1	0.64	16.3	12.6
1980	2150	445	3.9	2165	448	8.6	0.36	6.6	0.64	9.0	8.1
1981	2331	467	5.0	2402	481	7.5	0.34	-0.4	0.66	11.5	7.4
1982	2584	500	7.0	2745	531	10.3	0.31	1.7	0.69	14.7	10.5
1983	2864	541	8.1	3036	573	7.9	0.29	2.1	0.71	10.5	8.0
1984	3301	600	11.0	3443	626	9.3	0.31	14.3	0.69	7.2	9.3
1985	3698	650	8.3	3653	642	2.5	0.33	8.3	0.67	-0.1	2.6
1986	4020	687	5.7	3807	651	1.3	0.35	7.6	0.65	-1.9	1.4
1987	4417	733	6.8	3949	656	0.8	0.36	2.5	0.64	-0.3	0.7
1988	4887	788	7.5	4004	646	-1.5	0.37	0.1	0.63	-2.6	-1.6
1989	5065	802	1.8	3778	598	-7.3	0.37	-6.8	0.63	-7.6	-7.3
1990	5454	842	5.0	4190	647	8.2	0.36	6.3	0.64	9.1	8.1
1991	5815	888	5.4	4335	662	2.3	0.38	6.1	0.62	-0.2	2.1
1992	6380	964	8.6	4626	699	5.7	0.40	7.9	0.60	3.9	5.4
1993	7323	1096	13.7	4886	731	4.6	0.41	7.3	0.59	2.4	4.3
1994	8337	1236	12.8	5262	780	6.7	0.41	6.2	0.59	6.6	6.4
1995	9508	1397	13.0	5671	833	6.8	0.40	1.3	0.60	10.2	6.6
1996	10529	1527	9.3	6225	903	8.4	0.39	2.4	0.61	11.6	8.0
1997	11331	1623	6.3	6589	944	4.5	0.40	3.7	0.60	4.4	4.1
1998	12296	1741	7.3	7264	1028	9.0	0.44	16.7	0.56	3.0	8.7
1999	12988	1819	4.5	7860	1101	7.1	0.47	11.7	0.53	2.4	6.6
2000	13757	1909	4.9	8350	1158	5.2	0.50	10.0	0.50	0.2	4.9
2001	14810	2028	6.3	9156	1254	8.2	0.53	13.3	0.47	2.3	7.9
2002	15823	2146	5.8	10201	1383	10.3	0.56	14.6	0.44	4.0	9.8
1978-2002			7.4			5.8	0.4	6.2	0.6	4.9	5.6
1978-84			7.3			9.4	0.3	5.1	0.7	11.5	9.3
1985-91			5.8			0.9	0.4	3.4	0.6	-0.5	0.8
1992-2002			8.4			6.9	0.4	8.6	0.6	4.6	6.6

Source: Authors.

Note1: TW_{NIA}(Total Labor compensation) and W_{NIA} are calculated from National Income Account data; TW_{CYSY} (Total National Wages) and W_{CYSY} are calculated from wage data for rural sector and urban sector in China Labour Statistical Yearbook. All of these wage data (in1978 price) are deflated from nominal data by CPI. $\hat{w}$ in column 12 is the weighted overall wage growth rate, and data in column –4 and 7 are two unweighted rates.

Note2: Data for 1978-2002, 1978-84, 1985-91, and 1992-2002 are arithematic average of wage growth rate for each period respectively.

Table C-1. Estimation of China's Capital Stock

(In hundreds of millions of yuan and 1978 price, unless otherwise indicated)

	Gross fixed investment (current prices)	GDP deflator (1978 =100)	Gross fixed investment	Capital stock	Comparison of several Estimations			
					Our estimation (Note 1)	Hu and Khan (1997) (Note 2)	Ezaki and Sun (1999) (Note 3)	Chow and Li (2002) (Note 4)
1978	1377.9	100.0	1377.9	12289.7	12289.7	8239.0	—	14112.0
1979	1474.2	103.6	1423.6	13221.7	13221.7	8850.0	—	15273.0
1980	1590.0	107.5	1479.5	14172.3	14172.3	9489.0	8324.6	16438.0
1981	1581.0	109.9	1438.8	15044.2	15044.2	9993.0	8948.3	17268.0
1982	1760.2	109.8	1603.6	16046.1	16046.1	10699.0	9680.6	18297.0
1983	2005.0	110.9	1807.2	17211.5	17211.5	11525.0	10606.2	19515.0
1984	2468.6	116.4	2120.9	18643.9	18643.9	12629.0	11752.6	20928.0
1985	3386.0	128.2	2640.6	20538.7	20538.7	13984.0	13252.6	22755.0
1986	3846.0	134.1	2869.0	22586.2	22586.2	15321.0	15079.4	24822.0
1987	4322.0	140.9	3067.9	24750.6	24750.6	16847.0	17154.8	27123.0
1988	5495.0	158.0	3477.8	27238.3	27238.3	18502.0	19466.2	30085.0
1989	6095.0	172.0	3544.1	29692.9	29692.9	19423.0	21507.1	33445.0
1990	6444.0	181.7	3546.9	32052.0	32052.0	20445.0	23090.2	36565.0
1991	7517.0	193.9	3876.3	34646.3	34646.3	21718.0	24725.8	39776.0
1992	9636.0	209.2	4606.8	37867.2	37867.2	23311.0	26823.1	43589.0
1993	14998.0	239.6	6258.7	42232.5	42232.5	25532.0	29700.0	48994.0
1994	19260.6	287.2	6707.1	46828.0	46828.0	28297.0	33372.6	55006.0
1995	23877.0	325.0	7346.9	51833.5	51833.5	—	37593.8	61856.0
1996	26867.2	344.3	7804.2	57046.1	57046.1	—	—	69304.0
1997	28457.6	347.0	8202.2	62395.9	62395.9	—	—	77218.0
1998	29545.9	338.6	8726.6	68002.8	68002.8	—	—	85692.0
1999	30701.6	331.0	9274.9	73877.5	73877.5	—	—	—
2000	32499.8	334.1	9726.1	79909.8	79909.8	—	—	—
2001	37460.8	338.1	11079.7	86994.0	86994.0	—	—	—
2002	42355.4	337.2	12559.4	95203.7	95203.7	—	—	—

Source: China Statistical Yearbook (various issues) and authors' calculation

Note 1: The gross fixed investment series is used to compute the capital stock using the perpetual inventory method, $K_t=(1-\delta)K_{t-1}+I_t$. The capital stock for the initial year(1957), K_0 , is computed using the formula $K_0 = I_0/(g_0+\delta_0)$, where I_0 is the investment for the initial period, and δ_0 is the rate of depreciation applicable for the initial year, and g_0 is ideally the rate of growth of capital around the initial year. In this study, g_0 is taken as 0.13, which is the average growth rate of investment during 1952-1957, and δ_0 is 0.03, which is the average value of rate of depreciation usually used by China government. After 1978, δ is taken as 0.04 for 1978-92, and 0.05 for 1993-2002.

Note 2: They take depreciation rate as 0.036 for 1978-94. Investment deflator they used are not shown in their paper, but seem to be obviously higher than those used in other paper.

Note 3: They use depreciation rate as 0.049 for 1980- 1995. For comparison, we converted the original data series of Ezaki and Sun's estimation, which is in 1995 price, into present data in 1978 price.

Note 4: They use depreciation rate as 0.04 for 1978- 1998. Land is included in stock.

Table C-2. Rate of Return to Capital (from National Income Account)

(In hundreds of millions of yuan, unless otherwise indicated)

	GDP (current prices)	Payments to wages (current prices)	Payments to capital (current prices)	Payments to capital (1978 prices)	Rate of return to capital (%)	Year to year change (%)
1978	3624.1	1799.6	1824.5	1824.5	14.8	—
1979	4038.2	2074.8	1963.4	1896.0	14.3	-3.41
1980	4517.8	2310.7	2207.1	2053.7	14.5	1.06
1981	4862.4	2561.7	2300.7	2093.8	13.9	-3.96
1982	5294.7	2836.2	2458.5	2239.8	14.0	0.30
1983	5934.5	3177.6	2756.9	2485.0	14.4	3.43
1984	7171.0	3841.6	3329.4	2860.5	15.3	6.26
1985	8964.4	4742.2	4222.2	3292.7	16.0	4.49
1986	10202.2	5388.9	4813.3	3590.6	15.9	-0.84
1987	11962.5	6223.0	5739.5	4074.0	16.5	3.54
1988	14928.3	7721.3	7207.0	4561.3	16.7	1.73
1989	16909.2	8710.4	8198.8	4767.4	16.1	-4.12
1990	18547.9	9908.1	8639.8	4755.5	14.8	-7.59
1991	21617.8	11276.0	10341.8	5333.0	15.4	3.75
1992	26638.1	13344.1	13294.0	6355.5	16.8	9.04
1993	34634.4	17548.3	17086.1	7130.0	16.9	0.59
1994	46759.4	23940.2	22819.2	7946.4	17.0	0.51
1995	58478.1	30900.4	27577.7	8485.6	16.4	-3.53
1996	67884.6	36248.6	31636.0	9189.4	16.1	-1.60
1997	74462.6	39311.6	35151.0	10131.4	16.2	0.80
1998	78345.2	41632.2	36713.0	10843.5	15.9	-1.80
1999	82067.5	42991.0	39076.5	11805.0	16.0	0.21
2000	89468.1	45970.5	43497.6	13017.4	16.3	1.95
2001	97314.8	50071.6	47243.2	13973.0	16.1	-1.40
2002	104790.6	53362.0	51428.6	15249.9	16.0	-0.27

Source: National Bureau of Statistics of China, *The Gross Domestic Product of China 1952-1995* and *China Statistical Yearbook* (various issues); Authors' calculation.

Note: Payments to wages is aggregated from provincial data in tables of National Income Account; Payments to capital (current price) = GDP(current price)-Payments to wages (current price); Rate of return to capital is calculated as payments to capital(1978 price) /capital stock(1978 price).

Table C-3 Rate of Return to Capital at Disaggregated Level (SOEs and NSOES)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year	By ownership type (in manufacturing sector)						Overall manufacturing sector (%)	
	Rate of return (%)		Year to year change (%		Capital share			
	State-owned-enterprises	Other enterprises	$\hat{r}_{SOE}$	$\hat{r}_{NSOE}$	State-owned-enterprises	Other enterprises	$\hat{r}_M$	$\hat{r}_M^{UN}$
1978	0.25	0.44	—	—	0.92	0.08	—	—
1979	0.25	0.38	0.70	-12.73	0.91	0.09	-0.44	-0.78
1980	0.24	0.38	-2.47	-1.09	0.90	0.10	-2.34	-1.81
1981	0.23	0.33	-5.84	-12.65	0.89	0.11	-6.53	-6.52
1982	0.22	0.31	-2.94	-7.69	0.89	0.11	-3.46	-3.40
1983	0.22	0.32	-2.53	4.84	0.88	0.12	-1.69	-1.21
1984	0.22	0.31	2.94	-2.71	0.87	0.13	2.25	2.37
1985	0.22	0.45	0.45	44.44	0.89	0.11	5.63	6.21
1986	0.20	0.28	-11.21	-39.15	0.85	0.15	-14.81	-15.54
1987	0.20	0.26	-0.84	-6.86	0.84	0.16	-1.78	-1.65
1988	0.20	0.28	2.33	8.65	0.83	0.17	3.39	4.04
1989	0.17	0.22	-13.53	-21.99	0.81	0.19	-15.05	-15.19
1990	0.13	0.16	-25.81	-26.65	0.81	0.19	-25.97	-25.87
1991	0.12	0.16	-5.35	-0.23	0.79	0.21	-4.32	-3.74
1992	0.12	0.20	1.06	26.31	0.79	0.21	6.40	7.75
1993	0.13	0.22	3.97	8.37	0.74	0.26	5.02	8.35
1994	0.12	0.20	-3.29	-8.47	0.69	0.31	-4.77	-2.89
1995	0.09	0.15	-25.38	-22.24	0.69	0.31	-24.40	-23.93
1996	0.08	0.14	-15.26	-9.83	0.67	0.33	-13.51	-11.87
1997	0.08	0.13	-3.72	-4.36	0.64	0.36	-3.94	-2.60
1998	0.07	0.13	-7.19	-4.79	0.74	0.26	-6.45	-11.62
1999	0.08	0.14	9.09	10.32	0.74	0.26	9.41	9.52
2000	0.10	0.17	33.69	21.35	0.73	0.27	30.41	29.67
2001	0.10	0.17	-4.60	2.06	0.72	0.28	-2.75	-1.27
2002	0.10	0.18	4.74	5.99	0.69	0.31	5.11	7.22
1978-2002	0.15	0.24	-2.96	-2.05	0.79	0.21	-2.69	-2.28
1978-84	0.23	0.34	-1.69	-5.34	0.89	0.11	-2.03	-1.89
1985-91	0.18	0.26	-7.71	-5.97	0.83	0.17	-7.56	-7.39
1992-2002	0.10	0.17	-0.63	2.25	0.71	0.29	0.05	0.76

Source: National Bureau of Statistics of China, China Industry Economy Statistical Yearbook (2003); Authors' calculation.

Note1: The fixed asset for other enterprises(non-SOEs) equals to gross fixed asset (of Manufacturing sector) minus that of SOEs, while profit and tax for non-SOEs equals to gross profit and tax (of Manufacturing sector) minus that of SOEs. $\hat{r}_M^{UN}$ is the unweighted growth rate of return rate to capital for 2 kinds of enterprises in Manufacturing sector, SOEs and Other, and $\hat{r}_M$ is the weighted growth rate.

Note2: The data for 1978-2002, 1978-84, 1985-91, and 1992-2002 are arithematic average value for each period respectively.

Table C-4 Rate of Return to Capital at Disaggregated Level (2 Sectors)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	By sector						Overall change rate (%)	
	Rate of return (%)		Year to year change (%)		Capital share			
	Manufac-turing sector	Other sector	$\hat{r}_M$	$\hat{r}_O$	Manufac-turing sector	Other sector	$\hat{r}$	$\hat{r}^{UN}$
1978	0.26	0.10	—	—	0.28	0.72	—	—
1979	0.26	0.10	-0.44	-4.92	0.28	0.72	-3.67	-3.41
1980	0.26	0.10	-2.34	5.38	0.27	0.73	3.26	1.06
1981	0.24	0.10	-6.53	-1.80	0.27	0.73	-3.09	-3.96
1982	0.23	0.10	-3.46	2.34	0.28	0.72	0.74	0.30
1983	0.23	0.11	-1.69	6.98	0.28	0.72	4.54	3.43
1984	0.23	0.12	2.25	10.85	0.27	0.73	8.46	6.26
1985	0.25	0.13	5.63	5.75	0.25	0.75	5.72	4.49
1986	0.21	0.14	-14.81	8.18	0.26	0.74	2.25	-0.84
1987	0.21	0.15	-1.78	6.23	0.26	0.74	4.13	3.54
1988	0.22	0.15	3.39	1.48	0.25	0.75	1.97	1.73
1989	0.18	0.15	-15.05	1.10	0.24	0.76	-2.86	-4.12
1990	0.14	0.15	-25.97	-0.53	0.25	0.75	-6.78	-7.59
1991	0.13	0.16	-4.32	6.15	0.26	0.74	3.52	3.75
1992	0.14	0.18	6.40	9.29	0.25	0.75	8.56	9.04
1993	0.15	0.17	5.02	-1.43	0.26	0.74	0.21	0.59
1994	0.15	0.18	-4.77	1.38	0.25	0.75	-0.17	0.51
1995	0.11	0.18	-24.40	3.08	0.27	0.73	-4.01	-3.53
1996	0.10	0.18	-13.51	0.56	0.26	0.74	-3.18	-1.60
1997	0.10	0.19	-3.94	2.15	0.28	0.72	0.50	0.80
1998	0.09	0.19	-6.45	0.61	0.28	0.72	-1.36	-1.80
1999	0.09	0.19	9.41	-0.59	0.29	0.71	2.29	0.21
2000	0.12	0.18	30.41	-3.76	0.29	0.71	6.29	1.95
2001	0.12	0.18	-2.75	-1.49	0.29	0.71	-1.86	-1.40
2002	0.13	0.17	5.11	-2.40	0.29	0.71	-0.20	-0.27
1978-2002	0.17	0.15	-2.69	2.27	0.27	0.73	1.05	0.38
1978-84	0.24	0.11	-2.03	3.14	0.28	0.72	1.71	0.61
1985-91	0.19	0.15	-7.56	4.05	0.25	0.75	1.14	0.14
1992-2002	0.12	0.18	0.05	0.67	0.27	0.73	0.64	0.41

Source: National Bureau of Statistics of China, China Industry Economy Statistical Yearbook (2003); Authors' calculation.

Note 1: Rate of return (to capital) =(gross profit and tax)/(fixed asset). Data of gross profit and tax, and fixed asset for Manufacturing sector are available in the *China Industry Economy Statistical Yearbook*. The value of fixed asset for Other sector equals to gross capital stock minus fixed asset of Manufacturing sector, while the value of profit and tax for other sector equals to gross capital income minus profit and tax of Manufacturing sector.;

Note 2: $\hat{r}^{UN}$ is the unweighted growth rate of return rate to capital for all two sectors, manufacturing and other, and $\hat{r}$ is the weighted growth rate.

Note 3: The data for 1978-2002, 1978-84, 1985-91, and 1992-2002 are arithematic average value for each period respectively.

Table T-1 TFP Calculated by Two Approaches

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Growth rate (%)							Labor share	TFP(%)		
Year	GDP	Labor	Capital	$\hat{w}$	$\hat{w}_{CLSY}^{UN}$	$\hat{r}$	$\hat{r}^{UN}$	(SL)	TFP_p	TFP_d	TFP_{d2}
1978	—	—	—	—	—	—	—	0.50	—	—	—
1979	7.60	2.17	7.58	12.58	13.1	-3.67	-3.41	0.51	2.83	4.68	5.09
1980	7.81	3.26	7.19	8.14	8.6	3.26	1.06	0.51	2.66	5.76	4.90
1981	5.26	3.22	6.15	7.35	7.5	-3.09	-3.96	0.53	0.63	2.41	2.06
1982	9.01	3.59	6.66	10.50	10.3	0.74	0.30	0.54	3.95	5.96	5.67
1983	10.89	2.52	7.26	7.97	7.9	4.54	3.43	0.54	6.10	6.38	5.82
1984	15.18	3.79	8.32	9.35	9.3	8.46	6.26	0.54	9.21	8.94	7.87
1985	13.47	3.48	10.16	2.56	2.5	5.72	4.49	0.53	6.78	4.04	3.45
1986	8.86	2.83	9.97	1.36	1.3	2.25	-0.84	0.53	2.61	1.78	0.31
1987	11.57	2.93	9.58	0.68	0.8	4.13	3.54	0.52	5.45	2.34	2.11
1988	11.27	2.94	10.05	-1.61	-1.5	1.97	1.73	0.52	4.92	0.12	0.05
1989	4.07	1.83	9.01	-7.29	-7.3	-2.86	-4.12	0.52	-1.21	-5.14	-5.77
1990	3.83	2.55	7.95	8.08	8.2	-6.78	-7.59	0.53	-1.31	1.16	0.82
1991	9.19	1.15	8.09	2.11	2.3	3.52	3.75	0.52	4.71	2.79	2.98
1992	14.24	1.01	9.30	5.45	5.7	8.56	9.04	0.50	9.25	7.00	7.34
1993	13.49	0.99	11.53	4.35	4.6	0.21	0.59	0.51	7.44	2.30	2.61
1994	12.66	0.97	10.88	6.44	6.7	-0.17	0.51	0.51	6.94	3.21	3.66
1995	10.51	0.90	10.69	6.59	6.8	-4.01	-3.53	0.53	4.90	1.59	1.93
1996	9.59	1.30	10.06	7.98	8.4	-3.18	-1.60	0.53	4.08	2.78	3.72
1997	8.84	1.26	9.38	4.12	4.5	0.50	0.80	0.53	3.68	2.41	2.76
1998	7.82	1.17	8.99	8.72	9.0	-1.36	-1.80	0.53	2.90	4.00	3.93
1999	7.14	1.07	8.64	6.57	7.1	2.29	0.21	0.52	2.44	4.53	3.80
2000	8.00	0.97	8.17	4.90	5.2	6.29	1.95	0.51	3.57	5.58	3.62
2001	7.50	1.30	8.87	7.94	8.2	-1.86	-1.40	0.51	2.57	3.18	3.56
2002	7.96	0.98	9.44	9.79	10.3	-0.20	-0.27	0.51	2.92	4.89	5.13
1978-2002	9.41	2.01	8.91	5.61	5.80	1.05	0.38	0.52	4.08	3.45	3.23
1978-84	9.29	3.09	7.20	9.31	9.44	1.71	0.61	0.53	4.23	5.69	5.24
1985-91	8.90	2.53	9.26	0.84	0.89	1.14	0.14	0.52	3.14	1.01	0.57
1992-2002	9.79	1.08	9.63	6.62	6.95	0.64	0.41	0.52	4.61	3.77	3.82

Source: Calculated by authors.

Note 1: TFP_p is calculated using the primal approach, while TFPd and TFPd2 is calculated using the dual approach. TFP_d is based on weighted wage growth rate and weighted growth rate of capital return rate (Column 5 and 7), and TFP_{d2} is based on two unweighted growth rates (Column 6 and 8).

Note 2: The data for 1978-2002, 1978-84, 1985-91, and 1992-2002 are arithematic average value for each period respectively.