

NBER WORKING PAPER SERIES

THE CONTRIBUTION OF HUMAN CAPITAL TO CHINA'S ECONOMIC GROWTH

John Whalley
Xiliang Zhao

Working Paper 16592
<http://www.nber.org/papers/w16592>

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
December 2010

We are grateful to a seminar group at University of Western Ontario for comments, and to Chunbing Xing, Chris Robinson, Chunding Li, Jim MacGee and Xiaojun Shi for discussions. We acknowledge support from the Ontario Research Fund. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 16592
December 2010
JEL No. O0,O10,O4,O47

ABSTRACT

This paper develops a human capital measure in the sense of Schultz (1960) and then reevaluates the contribution of human capital to China's economic growth. The results indicate that human capital plays a much more important role in China's economic growth than available literature suggests, 38.1% of economic growth over 1978-2008, and even higher for 1999-2008. In addition, because human capital formation accelerated following the major educational expansion increases after 1999 (college enrollment in China increased nearly fivefold between 1997 and 2007) while growth rates of GDP are little changed over the period after 1999, total factor productivity increases fall if human capital is used in growth accounting as we suggest. TFP, by our calculations, contributes 16.92% of growth between 1978 and 2008, but this contribution is -7.03% between 1999 and 2008. Negative TFP growth along with the high contribution of physical and human capital to economic growth seem to suggest that there have been decreased in the efficiency of inputs usage in China or worsened misallocation of physical and human capital in recent years. These results underscore the importance of efficient use of human capital, as well as the volume of human capital creation, in China's growth strategy.

John Whalley
Department of Economics
Social Science Centre
University of Western Ontario
London, ON N6A 5C2
CANADA
and NBER
jwhalley@uwo.ca

Xiliang Zhao
Department of Economics
Xiamen University
zhaoxiliang@tsinghua.org.cn

1. Introduction

We reevaluate the role of human capital in economic growth in China relative to recent growth accounting literature (Chow and Li, 2002; Wang and Yao, 2003; Bosworth and Collins, 2008) which seemingly concludes that human capital has been relatively unimportant for China's growth. China maintained high growth rate for more than three decades after the 1978 reforms. The average real GDP growth rate was 9.82% between 1978 and 2008. But since 1999 there has been a major transformation in higher education in China as documented by Li et al. (2008). Existing growth accounting literature concludes that despite this physical capital growth rather than growth of human capital which is central to China's growth.

Following Barro and Lee (1993) which uses changes in the years of schooling over time as a proxy for human capital growth human capital is the relatively slow growing input in growth accounting for China and contributes little to growth. We use an alternative measure of human capital constructed from the opportunity cost side and reevaluate the contribution of human capital to China's growth. We treat human capital in its original Schultz (1960) sense as the opportunity cost foregone when individuals acquire human capital. This focuses on the earnings foregone when obtaining schooling, and the time and cost involved. We modify the procedure used by Barro and Lee (1993, 2000) and use the flow of graduates from different levels of education as the estimate of the volume increase in human capital, and then use the real average wage over time to value the time input into human capital formation for different levels of education. Under this treatment the human capital stock for the whole of China is much faster growing than in previous literature because wages change significantly over time.

Using this measure of the human capital stock, we recalculate the role of physical capital accumulation in China's economic growth along with labor, and human capital stock. Our results

suggest that human capital is much more important for China's growth than in existing growth accounting literature. During the period 1978-2008, our calculations suggest that China's human capital stock increased by 7.6% annually, and contributed 33.2% to growth, even though physical capital still contributes to economic growth in a major way (45.1%, between 1978 and 2008). Human capital's contribution is almost the same in recent decades at nearly 40%. The contribution of physical capital in the last decade accounts for more than 68% of economic growth, but equally human capital is important for China's economic growth, reflecting the transformation in higher education since 1999 (See Li et al., 2008). Our growth accounting results suggest that China's growth reflects input growth, physical capital as well as human capital, rather than exogenous technical changes as in Solow's (1957) original growth accounting study of the U.S.. In China's case, in the most recent decade, TFP growth becomes negative in the calculations we report.

There are several implications which follow from our analysis. As the contribution of TFP to growth in growth accounting is calculated as a residual, when we both separately identify and appropriately measure human capital accumulation, TFP growth in China is small to negative. This implies China's economic growth is mainly driven by capital accumulation, of both physical and human capital. But negative TFP growth suggests that there may well be inefficient use of human capital in recent decades, and this is particularly manifest in increased unemployment of college graduates. This misallocation of human capital and physical capital means that the Chinese economy may operate significantly inside the production frontier despite achieving high rates of growth. These findings suggest that there are substantial returns to raising employment of those with higher education and deploying human capital more efficiently. The paper is organized as follows. Section 2 is a brief review of previous growth accounting literature

on China and the role that human capital formation plays in it, and sets out the basic growth accounting framework. Section 3 discusses how human capital can best be incorporated into a growth accounting framework, and highlights critical issues in the measurement of human capital in the Chinese case given China's high growth rate. Section 4 provides a series of growth decompositions using growth accounting methods for China which stress the revision we offer to existing analysis of the role of human capital in China's growth. A final section, concludes.

2. Earlier Analyses of Sources of Chinese Growth

Positions on the sources of growth in China today are critical in framing an overall policy stance towards maintaining high growth in the future. The 11th five year plan in 2005, for instance, reported growth accounting calculations in which total factor productivity (TFP) growth accounted for around 40% of growth and argued for a target to raise this to 60% of growth (Fan, 2006). This in turn was to be achieved by large increases in educational expenditures with a stress on a knowledge based economy with both upgrading of quality of products and development of new products. This view of the Chinese growth process finds its echo in the sharp rise in information technology product exports from around 7% in the early 1990s to around 30% today (Xing, 2010).

The view that TFP growth increases are the way to sustain high Chinese growth is, however, one which can be challenged following debate over the main sources of growth in China over the last two decades. The view in the 1990s was that China's growth was driven primarily by growth of total factor productivity (TFP) as in Solow's (1957) analysis of US long term growth. Later empirical analysis for China by Maddison (1999) and the World Bank (1997) showed, however, that TFP growth accounted for over 30-58% of China's growth during 1978-1995. Hu and Khan (1997) calculated an average Chinese TFP growth of 3.9% over this period which they claimed accounted for more than 40% of China's growth in the early reform years. However, other economists have argued that China's growth in this period was mainly driven by the growth of inputs rather than TFP growth. Chow and Li (2002) found that the main contribution to China's economic growth in the post reform period of 1978-1998 was from capital accumulation rather than TFP increases in productivity. In their analysis capital accumulation accounted for 54% of growth while TFP increases accounted for only 32% of

growth, and labor input growth 13%. Li et al. (2005) reported an even higher contribution of capital accumulation to growth of 63.2% in the post reform period 1978-2003. The contribution of labor input growth was only 10.6%, total factor productivity contributed the 26.2% residual.

At the same time related work raised doubts concerning China's growth rate reflecting what was seen as poor quality of Chinese data. Krugman (1994), for instance, argued it is difficult to account for China's growth because of poor quality of data in China. Young (2003) also questioned the quality of Chinese data and after making adjustments to public Chinese data, found nonagricultural labor productivity growth of 2.6% and TFP growth of 1.4 per year. Holz (2006) further explored Chinese data issues.

Another strand of literature examines the role of human capital in understanding China's high growth, also our focus here. At analytical level, Lucas (1988) stressed human capital as an engine for economic growth and Romer (1990) developed a model in which growth was driven by human capital accumulation, with no special analysis of the Chinese case. However, later empirical analysis by Wang and Yao (2003) decomposes China's growth sources into physical and human capital accumulation, as well as labor force growth. For the post reform period 1978-1999, the contribution of physical capital accumulation, labor, and human capital accumulation are 47.7%, 15.9%, 11%, respectively with total factor productivity growth in the post reform period contribution is 25.4% of China's growth. Their results suggest that the human capital contributes in a major way to Chinese economic growth before reform, when TFP growth is negative, but after reform, the contribution of human capital is minor. The results seem counterintuitive since formal human capital formation increases sharply after the reforms. For example, according to their data, average years of schooling in China increase from 3.6 in 1978 to 5.9 in 1999.

A more recent paper, Bosworth and Collins (2008) also analyses sources of China's growth over the period 1978-2004. They decompose the growth of per capita output into growth of capital and education per worker. Their result shows that 3.2% of the 7.3% per capita output growth over this period is contributed by physical capital growth per worker, i.e., 44% of per capita output growth is due to physical capital accumulation. Only 0.3% of the 7.3% output per capita growth is from education, that is to say, 4.1% of growth is contributed by education. The residual 3.6% or 49% of growth is from total factor productivity growth.

The literature view thus seems to be that human capital formation is of little consequence in understanding China's high growth since reform in 1978. This is despite large increases in educational spending and participation since 1999.

3. Growth Accounting and Human Capital

Most growth accounting work builds on Solow's (1957) paper. He showed how to use an aggregate production function to decompose overall growth rates into growth of Hicks-neutral disembodied technical change and a weighted sum of rates of growth of factor inputs, coming to the conclusion that for the U.S. using data back to the 1870's the majority of U.S. growth arose from disembodied technical change. Later work challenged this conclusion using embodied technical change and quality adjustments over time for inputs.

This framework is well known using a CRS production function with capital and labor as inputs, and assuming factors are paid their values marginal products,

$$Y_t = A_t F(K_t, N_t), \quad (1)$$

where Y_t is output, K_t is capital. N_t is the work force, A_t is the Hicksian Neutral technology factor, then after a simple transformation of a time derivative, one can obtain the well known Solow growth accounting equation:

$$g_Y = g_A + s_K g_K + s_N g_N, \quad (2)$$

where $g_x = \dot{x}/x$ is the growth rate of x , where x refers to Y , A , K , and N alternately. s_K and s_N are shares of capital and labor in national income.

In principle it is easy to extend Solow's formulation to include human capital as well as the work force in the aggregate production function and extend it to a three-factor formulation. Human capital is then the increment which improves unimproved (or uneducated) labor through the educational process.

Early growth accounting literature, including Solow (1957) and Denison (1962), decomposed the overall growth rate into contributions from capital and labor service growth, and

computed the so-called Solow residual to capture the rate of technological change. Jorgenson and Griliches (1967) later noted that changes in the quality of factor inputs and particularly labor can play a major role in the decomposition of growth performance, and sharply reduce the contribution of Hicksian neutral technical change to growth. They did not explicitly refer to or emphasize human capital as well, but discussed education as something which improves labor quality over time. Increases in educational participation were therefore important in raising labor quality and raising growth rates. In this paper, we highlight that how human capital is measured in growth accounting is also important.

3.1 Barro and Lee's (1993; 2000) Approach to Measuring Human Capital

In recent literature and following Barro and Lee (1993, 2000), school enrollment rates, or adult literacy rates are frequently used as proxies for human capital because of the inadequacy of measures for human capital, Barro and Lee (1993; 2000) also used a perpetual inventory approach in estimating their human capital proxies. In constructing a measure of human capital for use in growth accounting, Barro and Lee (1993) use information which comes from census and survey estimates of educational attainment from UNESCO Statistical Yearbooks, U.N. Demographic Yearbooks, and other sources to first construct a data set on educational attainment for 129 countries over five-year periods from 1960 to 1985. They then use a perpetual inventory method to construct a human capital measure for each country that starts with census/survey figures as benchmark stocks and then uses school enrollment ratios to estimate changes from the benchmarks to get an estimate of education attainment for missing values. Barro and Lee (1996; 2000) update their data to 1990 and 1995 to provide a data set for international comparison and growth analysis.

Since we build on their method, we will first briefly review Barro and Lee's (1993; 2000) method. They consider country populations aged 25 and over in their 1993 paper, and later extended it to consider the population aged 15 and over in their 2000 paper. If L_t is the population aged 25 and over at time t , and H_{jt} is the number of people within this adult population for whom j is the highest level of education attainment, and $j=0$ for no schooling, $j=1$ for completed primary, $j=2$ for completed secondary, and $j=3$ for completed higher education, then $h_{jt}=H_{jt}/L_t$ is the proportion of the adult population for whom j is the highest educational level attained. $PRI_{t-\tau}$ is the gross enrollment ratio for primary school, $SEC_{t-\tau}$ the ratio for secondary school, and $HIGH_{t-\tau}$ the ratio for higher education, all observed at time $t-\tau$. $L25_t$ is the population aged 25-29 at time t who entered into L_t during the previous five years. Barro and Lee assume that these new entrants would have received primary education 15 years earlier (if they attend primary school), secondary education 10 years earlier (if they attended secondary school), and higher education 5 years earlier (if they received higher education).

Taking the no-schooling category as an example, the estimated number of people aged 25 and over who have no educational attainment at time t is given by

$$H_{0,t} = H_{0,t-5} \cdot (1 - \delta_t) + L25_t \cdot (1 - PRI_{t-15}), \quad (3)$$

where δ_t is the proportion of people aged 25 and over in year $t-5$ who did not survive to year t . This is estimated as $\delta_t \approx (L25_t + L_{t-5} - L_t)/L_{t-5}$. They assume that the fraction of the population aged 25 to 29 who have no elementary education equals the fraction, $1 - PRI_{t-15}$, who were not enrolled in primary school 15 years before. Substituting δ_t into (3), gives the fraction of the population with no schooling,

$$h_{0t} \equiv H_{0t}/L_t - [1 - (L25_t/L_t)] \cdot h_{0,t-5} + (L25_t/L_t) \cdot (1 - PRI_{t-15}), \quad (4)$$

The procedures they use for other levels of educational attainment are analogous. The resulting formulas are

$$h_{1t} \equiv H_{1t}/L_t = [1 - (L25_t/L_t)] \cdot h_{1,t-5} + (L25_t/L_t) \cdot (PRI_{t-15} - SEC_{t-10}), \quad (5)$$

$$h_{2t} \equiv H_{2t}/L_t = [1 - (L25_t/L_t)] \cdot h_{2,t-5} + (L25_t/L_t) \cdot (SEC_{t-10} - HIGH_{t-5}), \quad (6)$$

$$h_{3t} \equiv H_{3t}/L_t = [1 - (L25_t/L_t)] \cdot h_{3,t-5} + (L25_t/L_t) \cdot HIGH_{t-5}. \quad (7)$$

Using these ratios, they get an estimate of average years of schooling for different countries for every year.

3.2 Gemmell's (1996) Adjustment of Barro and Lee

Later, Gemmell (1996) made a significant adjustment to Barro and Lee's procedure. The Barro and Lee's (1993; 2000) method allows stock/accumulation effects to be investigated, but their dataset also includes adults not in the labor. Gemmell argues that only human capital in the labor force contributes to economic growth so that Barro and Lee's method exaggerates the size of the human capital stock. He constructed a stock-flow measure of human capital in the labor force,

$$H_t = H_{t-1} + \alpha_t N_t - \beta_t R_t \quad (8)$$

where H_t is the stock of human capital at time t , α_t is the proportion of new labor force entrants, and N_t , and β_t is the proportion of retirees with embodied human capital skills, R_t . He used 1960 schooling enrollment ratios as a proxy for the proportion of the 1960 labor force with relevant levels of education, combining it with the working age population in 1960 to estimate the initial

stock of human capital for different levels of education, and then used eq. (8) to estimate human capital stock over time.

3.3 Opportunity Time Cost Based Human Capital Measures

For growth accounting analyses of China, the Barro and Lee procedure produces a measure of human capital which is only slowly growing since increases in wage rates over time reflecting the opportunity cost of time involved in educational participation do not enter, as would be suggested by a Schultz (1960) formulation of human capital. We therefore combine the methods of Barro and Lee (1993; 2000) and Gemmell (1996), also using a perpetual inventory approach to estimate human capital stock in labor force. But we also treat human capital in its original Schultz (1960) senses as the opportunity cost foregone when individuals acquire human capital. Thus if a person with higher education spends sixteen years of formal education to accumulate his human capital, the total cost of time spent plus fees for the sixteen years would be the value of his human capital. Human capital would thus include foregone earnings over these sixteen years, including the direct cost of education, such as tuition and fees. If we assume w_t are counterfactual earnings in year t during education, total forgone earnings for these sixteen years are $h_i = \sum_t w_t$, $t \in [t_0, t_1]$, $t_1 - t_0 = 16$. For all people who finish higher education in a year, the additional human capital for the level of higher education would be the aggregate foregone earnings for that education group, i.e., $F_t^l = \sum_i h_i^l = \sum_i \sum_s w_s$, where h_i^l denotes human capital in that year for individual i in category l . F_t^l is the incremental or flow of human capital for category l in that year. Using a perpetual inventory method applied to these measures gives

$$H_t^l = (1 - \delta_t) H_{t-1}^l + F_t^l, \quad (9)$$

where H_t^l denotes the human capital stock in year t for category l , and δ_t is the depreciation rate for human capital in year t . The aggregate level of human capital would be the human capital stock for the economy, i.e., $H_t = \sum_l H_t^l$.

Instead of using enrollments as the flow measure of human capital formation, we use graduates as the flow of human capital as in Wang and Yao (2003). In China, there are usually six years for primary school education, three years for junior secondary school education, three years for senior secondary school education, and three or four years for tertiary education. Special secondary here mainly refers to vocational or technical schools, which are usually two or more years of education after junior secondary education. Tertiary graduates usually have 16 years of education, special secondary graduates, 11 years, senior secondary school graduates, 12 years, junior secondary graduates, 9 years, and primary school graduates, 6 years.

Specifically, human capital stocks in year t for different levels of education are

$$\begin{aligned}
H_{1t} &= (1 - \delta_t) H_{1t-1} + (PRI_t - JUNIOR_{t+3}) \cdot \sum_{s=t-5}^t w_s \\
H_{2t} &= (1 - \delta_t) H_{2t-1} + (JUNIOR_t - SENIOR_{t+3} - SPECIAL_{t+2}) \cdot \sum_{s=t-8}^t w_s \\
H_{3t} &= (1 - \delta_t) H_{3t-1} + (SENIOR_t - HIGH_{t+3.5}) \cdot \sum_{s=t-11}^t w_s \\
H_{4t} &= (1 - \delta_t) H_{4t-1} + SPECIAL_t \cdot \sum_{s=t-10}^t w_s \\
H_{5t} &= (1 - \delta_t) H_{5t-1} + HIGH_t \cdot \sum_{s=t-15}^t w_s
\end{aligned} \tag{10}$$

where H_{jt} stands for human capital stock for j level of education attained in year t , 1 for primary, 2 for junior secondary, 3 for senior secondary, 4 for specialized secondary, and 5 for tertiary education. δ_t denotes the depreciation rate for human capital, which is proxied by mortality rates for the population in t . PRI_t , $JUNIOR_t$, $SENIOR_t$, $SPECIAL_t$, $HIGH_t$ denote the number of new

graduates for primary, junior secondary, senior secondary, special secondary, and higher education. w_t are real average wages in year t .

Ideally, we should use average wage data for different levels of education in constructing our human capital estimate. These kinds of wage data are not available and so we use the same average wage for employees in China for all educational time valuations. The major impact of the adjustments we make in our human capital estimation is to capture changes in wages over time in the valuation of human capital inputs, and this effect is still preserved by this use of data.

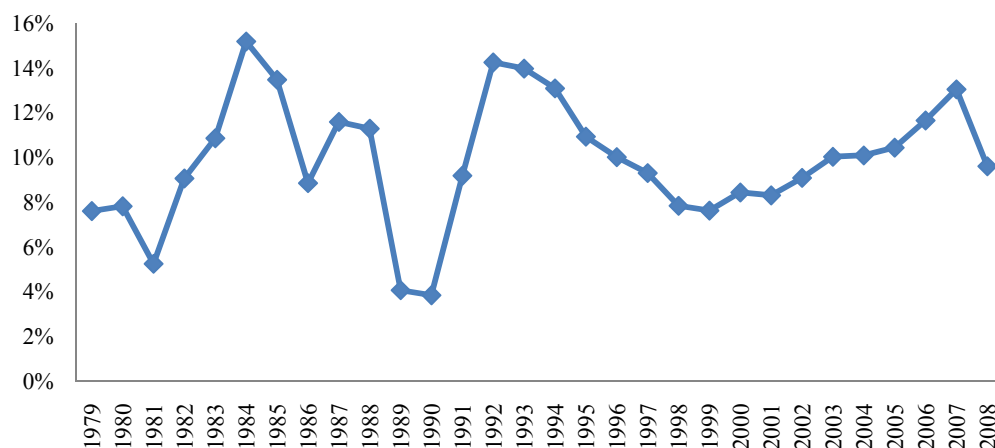
4. Measurement and Chinese Growth Accounting

This section discusses the measurement of the variables used for our growth accounting. The variables involved are output, the physical capital stock, labor, and the human capital stock.

4.1 Output

Our output data, GDP, covers 31-year period (1978-2008), and are taken from the China Statistical Yearbook (hereafter CSY, 2009). We use the CSY constant price index to transform nominal output into real output. Fig 1 shows that real GDP growth rates were more than 8% in most years, only except in 1981, 1989 and 1990. We divide our data into two sub periods before and after 1999 to capture the impact of major educational reforms in China which sharply raised both tertiary educational expenditures and student enrollments (see Li et al. 2008). The average growth rate during the period 1978-2008 was 9.82%. The average growth rates during the sub periods 1978-1999 and 1999-2008 were 9.7% and 10.1%, respectively. It can be seen that the growth rates from 1999 continue at high levels until the Financial Crisis 2008, when they drop back to 9.6%.

Figure 1. Real GDP Growth Rate in China, 1979-2008



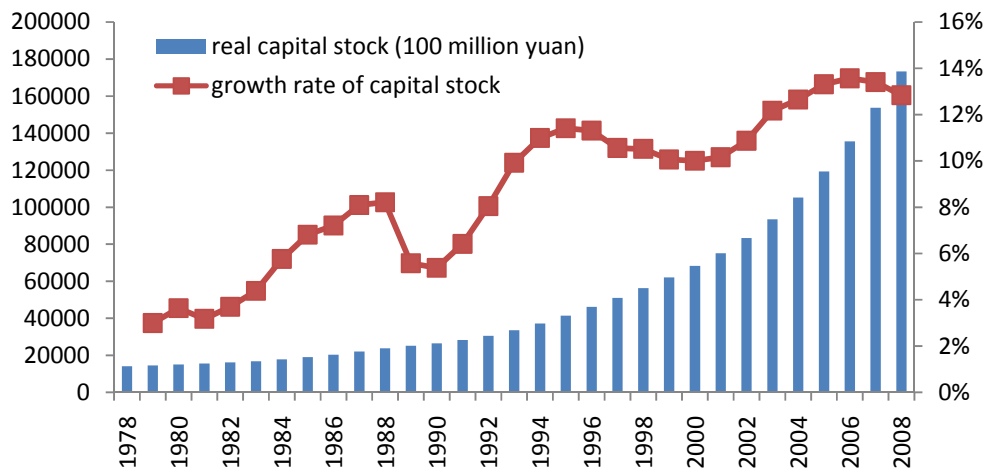
4.2 Physical Capital Stock

We use a perpetual inventory approach to estimate the physical capital stock over the same period. We take the 1978 capital stock estimate from Chow (1993) and Chow and Li (2002) of 1 411.2 billion yuan as our initial physical capital stock estimate at the end of 1978. CSY (2009) provides a fixed capital price index (1991=100) after 1991. Hsueh and Li (1999) provide an implicit investment deflator for the period 1952-1995, based on data from the *Annual Report of Statistics on Investment in Fixed Assets*. We combine Hsueh and Li (1999) and CSY (2009) together to get investment deflator from 1978-2008 and use gross fixed capital formation at current prices from CSY (2009), and the investment deflator above to estimate real investment. Our capital stock series is calculated as,

$$K_t = (1 - \delta) K_{t-1} + I_t, \quad (11)$$

where δ is the depreciation rate.

Figure 2. Real Capital Stock and its Growth Rate, 1978-2008



Chow (1993) assumes that the depreciation rate is 4%, while Perkins (1988), Wang and Yao (2003) assume the depreciation rate is 5%, Chow and Li (2002) first assume the depreciation rate is 4% in 1978-1992, then use equation (3) to estimate the implied depreciation rates for 1993-1998, giving an average implied depreciation rate of 5.4% which they then take 5.4% as the depreciation rate for the period of 1978-1998. We assume an average depreciation rate of 5% between 1978 and 2008. Figure 2 reports our estimate of real capital stock and its growth rate. The accumulation of physical capital increases at high rates with three growth rate declines in 1988, 1998, 2008, reflecting a downturn of economic activity in China in these years. The long-term trend growth rate for the capital stock growth rate is around 13% annually in recent years.

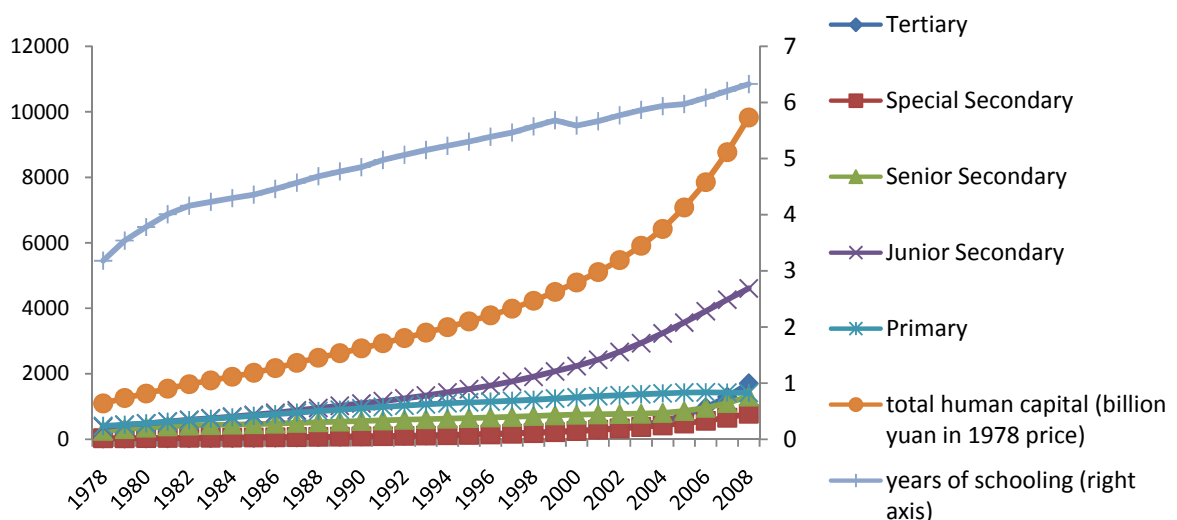
4.3 Labor

CSY provides employment data from 1952-2008. There was a revision after 1990 according to the 1990 population census data, and another revision according to 2000 population census data in 2002. Holz (2006) explores this issue in detail and adjusts the labor data before 1990, so that the labor data is consistent before and after 1990. We use his adjusted employment data as our labor data from 1978 to 1990, and use the employment data from CSY (2009) from 1990 onwards.

4.4. Human Capital

In our growth accounting analysis, our measure of human capital follows Barro and Lee's (1993; 2000) method to estimate average years of schooling as a proxy for human capital stock, but we estimate the human capital stock using the Schultz (1960) motivated modification set out earlier. Figure 3 reports average years of schooling (following Barro and Lee), rising from 3.18 years in 1978 to 6.33 years in 2008, an increase of 2.3% annually. However, our measure of the human capital stock suggests a much more rapid increase. The human capital stock was 1095 billion yuan in 1978, and reached 9826 billion yuan in 2008, increasing by 7.6% annually. The increase of human capital from tertiary education is even larger, from 27 billion yuan in 1978 to 1712 billion yuan in 2008, an increase of 14.8% annually. There is an increased rate of human capital formation for tertiary education after 2002 which is consistent with China's higher education expansion after 1999 (see Li et al., 2008). Using average years of schooling as in

Figure 3. Human Capital Stock in China (Left Scale Billion Yuan, Right Scale Years)



Barro and Lee significantly understates the changes in China's human capital stock and downplays its role in China's growth.

To implement our growth accounting, we also need the share of physical capital in national income, s_K . Usually, in growth accounting literature, s_K is assumed to be a specific number. For example, Chow (1993) uses 0.6 as the share of capital over 1952-1980. Young (2003) and Bosworth and Collins (2008) use 0.4 as the share of capital. Wang and Yao (2003) assume 0.5 for the share of capital over 1978-1999. Chow and Li (2002) estimate a Cobb-Douglas production function using data over 1952-1998, and this yields a coefficient for capital between 0.61 and 0.63. Qian (2008), however, studied data on the share of capital in GDP in China and shows that the capital share in GDP to be continuously increasing after 1995. Before 1995, the capital share was less than 0.5 in most years, but after 1995, the share of capital increased rapidly, and reached 0.6 in 2007 (see Figure 4).

Figure 4. Share of Capital in Chinese GDP

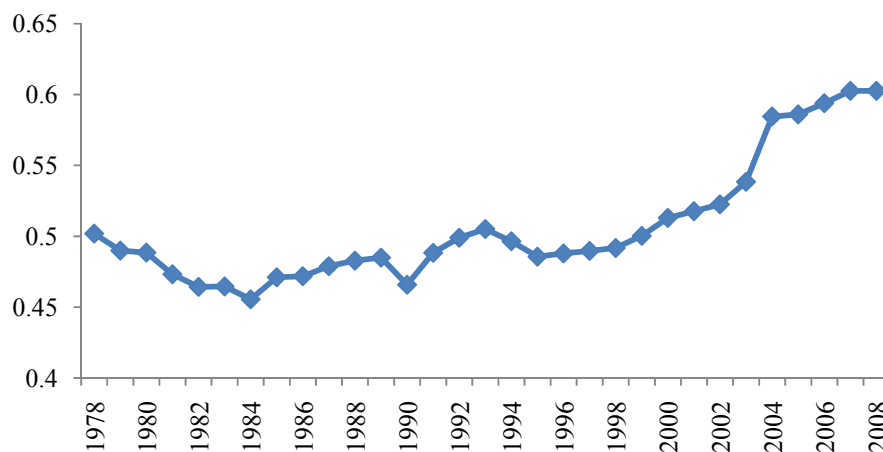


Table 1 reports the average capital and labor share in GDP for different sub periods. The average share of capital for the whole period 1978-2008 is 0.5064. Before 1999, the share of capital is 0.4835, and after 1999, the average share of capital is 0.5623.

Table 1
Average share of capital and labor in GDP¹

	share of capital	share of labor
1978-2008	0.5064	0.4936
1978-1999	0.4835	0.5165
1999-2008	0.5623	0.4377

¹ The Chinese Statistical Yearbook does not provide aggregate labor share data, but divides regional GDP into compensation of employees, net taxes on production, depreciation of fixed assets and operating surplus. We aggregate this regional data to get Chinese GDP and the share of aggregate labor is calculated as the ratio of compensation of employees to GDP.

5. New Growth Accounting Analysis of Human Capital's Role in China's Economic Growth

This section reports our growth accounting analyses of China's economic growth using the modified human capital measures we set out above. We first evaluate the sources of growth in the original sense of Solow (1957), which only considers the role of physical capital and labor. Then we contrast results using Barro and Lee's (1993; 2000) human capital measure in evaluating the role of human capital in growth and then our modified human capital measures in the sense of Schultz (1960).

5.1 Sources of Growth in the Sense of Solow (1957) and Excluding Human Capital

As in Solow (1957), we first decompose the sources of China's economic growth into growth of capital and labor and TFP. Table 2 reports the results. During the period 1978-2008, the average GDP growth rate is 9.82%, the growth rate of capital is 8.72%, labor increases by 1.67% annually, and TFP growth is 4.57% annually. Thus, in this analysis capital contributes nearly 45%, and labor only contributes 8.5% of growth, the rest, 46.5%, is contributed by TFP. If TFP is interpreted as technological change, then China's economic growth is mainly driven by capital input growth and technological improvement. The growth rate of capital is 7.3% over 1978-1999, and 12.1% over 1999-2008, which results in a large increase in the contribution of physical capital to growth, from 36.4% to 67.6%.

The reasons for the large increase in capital's role in growth are the combine effects of a higher growth rate for capital and an increased share of capital in output in recent decades (see Figure 4). Because the growth of labor and the share of labor in output were both decreasing, the contribution of labor is less, only 4% in recent decades. TFP growth decreases from 5.1% to

2.8%, which is reflected in a sharp decrease of TFP contribution to growth from 52.9% to 28.4%. Therefore, if TFP growth is interpreted as technological change, Solow based growth accounting results indicate that the growth of technology advances slows in recent decades. This result is consistent with literature which emphasizes the role of physical capital input and TFP. However, this result underestimates the role of quality improvement in labor or human capital.

Table 2
Sources of China's Economic Growth Using Simple Solow Growth Accounting

	1978-2008	1978-1999	1999-2008
<i>Growth rate (% per year)</i>			
Output	9.82%	9.72%	10.06%
Physical capital stock	8.72%	7.30%	12.10%
Labor	1.69%	2.03%	0.91%
TFP	4.57%	5.14%	2.86%
<i>Contribution to GDP growth (%)</i>			
Physical capital stock	44.96%	36.35%	67.62%
Labor	8.50%	10.78%	3.97%
TFP	46.54%	52.87%	28.41%

5.2 Sources of Growth with Human Capital in the Sense of Barro and Lee (1993; 2000)

Next we take human capital into account in our growth accounting approach using Barro and Lee's approach. We use years of schooling as a proxy for human capital which is estimated

combining the approaches in Barro and Lee (1993; 2000) and Gemmell (1996). Table 3 indicates that human capital contributes 11.7% to economic growth over the entire period 1978-2008, and that it contributes 9.6% in the most recent decade and contributes 15% before 1999. This result

Table 3

Sources of Economic Growth in China Incorporating Human Capital Using Barro-Lee Approach

	1978- 2008	1978- 1999	1999- 2008
<i>Growth rate (% per year)</i>			
Output	9.82%	9.72%	10.06%
Physical capital stock	8.72%	7.30%	12.10%
Labor	1.69%	2.03%	0.91%
Human capital stock*	2.34%	2.81%	2.21%
TFP	3.45%	3.64%	2.45%
<i>Contribution to GDP growth (%)</i>			
Physical capital stock	44.96%	36.35%	67.62%
Labor	8.50%	10.78%	3.97%
Human capital stock*	11.74%	14.95%	9.60%
TFP	34.80%	37.93%	18.81%

*average years of schooling as the proxy for human capital stock

reflects a declining and only small contribution to growth from human capital formation and seems counterintuitive, since educational participation in China in recent decades is rising and

substantively higher in recent years. One reason for this result is that years of schooling treats the productivity of different levels of education the same over time and as such undervalues the role of human capital. The contribution to growth of TFP declines comparing with the simple Solow case.

5.3 Sources of Growth with Human Capital in the Sense of Schultz (1960)

Average years of schooling is not a reliable proxy for human capital in implementing of growth accounting for China since it takes the productivity for different levels of education as the same through time, even though growth is occurring and wage rates are rising. Using years of schooling alone as a proxy for human capital thus underestimates the role of human capital in growth accounting and for China, and given her high growth rates the effect is large. Schultz's (1960) opportunity cost measure of education of inputs to human capital formation takes productivity into account, and seemingly provides a more appealing proxy for human capital formation.

Table 4 shows the results of growth accounting which uses a proxy for human capital in the sense of Schultz (1960). Under this approach, human capital in China grew at 7.6% annually over 1978-2008; slightly less than the growth rate of physical capital. The contribution of human capital to growth is 38.1%, which is large although still smaller than the contribution of physical capital, 44.96%. TFP growth is 1.66% annually, and contributes the remaining 16.9% of economic growth. The growth of human capital increases from 6.96% during 1978-1999 to 9.1% during 1999-2008. The contribution of human capital increases from 37% to 39.7% and TFP growth rate decreases from 2.59% to -0.52%. It contributes 26.65% of growth over 1978-1999 and -7.03% over 1999-2008.

Table 4**Source of China's Economic Growth, Including Human Capital in the Sense of Schultz**

	1978-2008	1978-1999	1999-2008
<i>Growth rate (% per year)</i>			
Output	9.82%	9.72%	10.06%
Physical capital stock	8.72%	7.30%	12.10%
Human capital stock	7.59%	6.96%	9.06%
TFP	1.66%	2.59%	-0.52%
<i>Contribution to GDP growth (%)</i>			
Physical capital stock	44.96%	36.35%	67.62%
Human capital stock	38.12%	37.00%	39.41%
TFP	16.92%	26.65%	-7.03%

We can also calculate the contributions of different inputs for the sub-period 2003-2008, when new graduates enter the job market after graduation. For this sub-period, economic growth is 10.95% annually, and the annual growth rates of human capital and physical capital are 10.7% and 13.2%, separately. The growth rate of human capital increases rapidly, but still lags behind the growth rate of physical capital. The contributions of human capital and physical capital are 40.6% and 70.2%, respectively. The contribution of human capital does increase, but only moderately.

5.4 Summary and Further Interpretation

The last set of growth accounting results above indicate that human capital plays an important role in China's growth, and contributes 20%-40% to growth. Without improvement of labor quality and accumulation of human capital, China's economic growth rate would be lower. There are several channels through which human capital contributes to economic growth. One is as an input like physical capital since more human capital inputs increase output. In this sense, it is effectively a quantitative increment to labor. Another channel may be human capital as an improvement to productivity. New growth theory indicates that the accumulation of human capital can increase the production of new ideas and innovation so that technology levels will improve, and increase productivity. Under this view, human capital is more than an input, and it should be thought as other input enhancing. The more human capital is accumulated, the more the chance of technology improvement and innovation, the higher the productivity of production, and more output results from the same inputs. In this sense, human capital is a source of productivity improvement. The reason why the contribution of TFP becomes negative when we include human capital in our growth accounting may be this.

Our growth accounting results also suggest that China's economic growth still relies heavily on capital input growth, although human capital play a more and more important role in economic growth over time. Despite this, the contribution of human capital still lags physical capital. The reasons why physical capital contributes so much to growth are a reflection in the share of physical capital and growth rate of physical capital. Figure 4 shows that the share of physical capital in GDP continues to increase, and exceeds 60% of GDP in recent years. The recent share of labor in GDP is only 40%. There is a debate as to whether the share of labor in

Table 5
Growth Accounting Where the Share of Capital is 0.4 and the Share of
Human Capital is 0.6

	1978-2008	1978-1999	1999-2008	2003-2008
<i>Growth rate (% per year)</i>				
Output	9.82%	9.72%	10.06%	10.95%
Physical capital stock	8.72%	7.30%	12.10%	13.15%
Human capital stock	7.59%	6.96%	9.06%	10.71%
TFP	1.78%	2.62%	-0.21%	-0.73%
<i>Contribution to GDP growth (%)</i>				
Physical capital stock	35.51%	30.07%	48.10%	48.03%
Human capital stock	46.34%	42.98%	54.03%	58.65%
TFP	18.15%	26.95%	-2.13%	-6.68%

GDP is underestimated in China. Gollin (2002) adjusts for self-employment and the sectoral composition of output, and found that the labor shares for most developing countries are in the range of 0.65-0.80.

If we adjust our growth accounting analysis for this effect, the contribution of physical capital is smaller and contribution of human capital larger. We cannot easily separate all these effects, but we can perform sensitivity analysis. Table 5 reports calculation that assumes the share of capital in GDP is 40%. Under this treatment the contribution of physical capital in growth decreases to 35.5% over 1978-2008, and the contribution of human capital increases to

46.3%, and the contributions of physical capital and human capital are 30.1% and 43% respectively over the period 1978-1999. For the most recent decade, the contribution of physical capital is 48.1%, and the contribution of human capital is 54%. For the period 2003-2008, after the increased educational participation, the contribution of human capital is even higher, 58.7%, which is a larger increase than earlier. Thus, under these assumptions, the contribution of human capital is larger, and the contribution of physical capital is smaller and less than that of human capital.

6. Conclusion

This paper reexamines the sources of China's economic growth, emphasizing the role of human capital. We first evaluate the sources of growth in the sense of Solow (1957), and find under this analysis China's economic growth is mainly driven by capital accumulation and TFP growth, which is consistent with the results in other Chinese growth accounting literature. Since Solow's framework does not consider quality improvements of labor and human capital, we first reevaluate the sources of growth taking human capital in the sense of Barro and Lee (1993; 2000) into account. The contribution of human capital in the sense of Barro and Lee is minor, only 11.7% between 1978 and 2008. Barro and Lee's measure of human capital is average years of schooling which does not distinguish productivity differences among different levels of education nor take wage rate changes into account over time.

We then construct an alternative human capital measure in the sense of Schultz (1960) taking productivity differences into account. Using this human capital measure, we find that human capital plays a much more important role in China's economic growth. The contribution of human capital to growth is 38%, and even higher for the most recent decade. If we allow for adjustment for self-employment and sectoral composition of outputs as Gollin (2002) suggests, the contribution of human capital is higher. Under an assumption that the share of capital in China in GDP is only 0.4 shows that the contribution of human capital to growth is 43% during 1978-1999, and accounts for 54% during 1999-2008. Human capital contributes 59% of growth over 2003-2008 when graduates enrolled during China's educational transformation enter job markets. In addition, since human capital growth accelerated following the major educational expansion after 1999 (college enrolment in China increase fivefold between 1997 and 2007), while growth rates of GDP are little changed, total factor productivity decreases. TFP, by our

calculations, contributes 16.9 of growth between 1978 and 2008, but this contribution is -7% between 1999 and 2008 taking human capital into account in the way we suggest.

These results suggest that economic growth in China may still be driven by growth in both capital inputs (physical and human), but TFP growth may have been negative in recent decades. Negative TFP growth along with a high contribution of physical and human capital to economic growth seems to suggest that there has been a decrease in the efficiency of input usage in China and misallocation of physical and human capital. This view is consistent with increased education expansion and has been accompanied by increased urban young skilled worker unemployment. These findings suggest that there are substantial returns to raising employment of those with higher education and deploying human capital more efficiently.

References

- Barro, Robert J., and Jong-Wha Lee, 1993, International comparisons of educational attainment, *Journal of Monetary Economics*, 32, 363-394.
- Barro, Robert J., and Jong-Wha Lee, 1996, International measures of schooling years and schooling quality, *American Economic Review*, 86, 219-223.
- Barro, Robert J., and Jong-Wha Lee, 2000, International data on education attainment: Updates and implications, NBER Working Papers 7911.
- Becker, G., 1964, *Human Capital* (Columbia University Press, New York).
- Ben-Porath, Yoram, 1967, The production of human capital and the life cycle of earnings, *The Journal of Political Economy*, 75, 352-365.
- Bosworth, Barry, and Susan M. Collins, 2008, Accounting for growth: Comparing China and India, *Journal of Economic Perspectives*, 22, 45-66.
- Chinese Statistical Bureau, 2009, *Chinese Statistical Yearbook*.
- Chow, Gregory C., 1993, Capital formation and economic growth in China, *The Quarterly Journal of Economics*, 108, 809-842.
- Chow, Gregory C., and Kui-Wai Li, 2002, China's economic growth: 1952-2010, *Economic Development and Cultural Change*, 51, 247-256.
- Fan, C. Cindy, 2006, China's Eleventh Five-Year Plan (2006-2010): From "Getting Rich First" to "Common Prosperity", *Eurasian Geography and Economics*, 47(6) 708-723.
- Gemmell, Norman, 1996,. Evaluating the Impacts of Human Capital Stocks and Accumulation on Economic Growth: Some New Evidence, *Oxford Bulletin of Economics and Statistics*, 58(1) 9-28.

- Gollin, Douglas, 2002, Getting Income Shares Right, *Journal of Political Economy*, 110(2), 458-474.
- Holz, Carsten A., 2006, Measuring Chinese productivity growth, 1952-2005, Hong Kong University of Science and Technology Working Paper.
- Hsueh, T. and Q. Li (eds), 1999. China's National Income, 1952–1995, Boulder, CO: Westview Press.
- Hu, X. F., and M. S. Khan, 1997, Why is China growing so fast? IMF Staff Papers 44, 103.
- Jorgenson, Dale W., and Z. Criliches, 1967, The explanation of productivity change, *The Review of Economic Studies*, 34(3), 249-283.
- Krugman, P., 1994, The myth of Asia's miracle, *Foreign Affairs*, 73, 62-78.
- Li, Shantong, Yongzhi Hou, Yunzhong Liu, and Jianwu He, 2005, China's economic growth potential and prospect analysis, *Management World* 9 (in Chinese).
- Li, Yao , John Whalley, Shunming Zhang, and Xiliang Zhao, The Higher Educational Transformation of China and its Global Implications (March 2008). NBER Working Paper No. W13849. Available at SSRN: <http://ssrn.com/abstract=1106576>
- Lucas, Robert E., 1988, On the mechanics of economic development, *Journal of Monetary Economics*, 22, 1988.
- Maddison, A., 1998, Chinese economic performance in the long run (Organization for Economic Co-operation and Development, Paris and Washington, DC).
- Perkins, D. H., 1988, Reforming China's economic system, *Journal of Economic Literature*, 26, 601-645.
- Qian, Zhenjie, 2008, Research on Chinese Factor Shares, PhD Dissertation submitted to Tsinghua University (in Chinese).

- Romer, Paul M., 1990, Endogenous technological change, *The Journal of Political Economy*, 98, S71-S102.
- Schultz, Theodore W., 1960, Capital Formation by Education, *Journal of Political Economy*, University of Chicago Press, vol. 68, 571.
- Solow, R.M., 1957, Technical changes and the aggregate production function, *Review of Economics and Statistics*, vol. 39(3), 312-320.
- Wang, Yan, and Yudong Yao, 2003, Sources of China's economic growth 1952-1999: Incorporating human capital accumulation, *China Economic Review*, 14, 32-52.
- World Bank, 1997, China 2020: Development challenges in the new century (The World Bank).
- Xing, Yuqing, 2010, China's High-Tech Exports: Myth and Reality, EAI Background Brief No. 506.
- Young, A., 2003, Gold into base metals: Productivity growth in the People's Republic of China during the reform period, *Journal of Political Economy*, 111, 1220-1261.