

Regional human capital in Republican and New China

Its spread, quality and effects on economic growth

Bas van Leeuwen, Jieli van Leeuwen-Li, and Peter Foldvari

Abstract

In recent decades there has been increasing attention for Chinese economic development. There has been a big debate though if its growth is caused by capital accumulation (perspiration factors) or driven by TFP growth (inspiration factors). The difference between both stances is quite substantial since, if the perspiration theory is correct, one expects the growth of the Chinese economy to slow down over time as the capital accumulation grows increasingly less efficient. However, so far this question is difficult to analyse for China since we lack information on one of the factors of production, human capital.

To analyse this question, in this paper we develop a new dataset on human capital for the provinces of China between 1922 and 2010. Using our new dataset together with physical capital and per capita GDP, allows us to do a TFP analysis for sub periods. We find a continuously negative TFP growth suggesting that reduction in productivity was a structural feature of the Chinese economy. If true, this was to lend support to the perspiration theory and would suggest a slowdown of the Chinese economy in the future. However, standard growth accounting allocates both technical efficiency of the factors of production and the general technical development to TFP. Subtracting technical efficiency from TFP growth, we find that general technological development turns increasingly positive in the 1990s and 2000s. This suggests that, whereas until the reform period China was largely driven by capital accumulation, afterwards general technical development got an increasingly prominent place giving hope for continued economic development in the future.

1. Introduction

Recently, China experiences remarkable economic growth. In terms of per capita growth China ranked 8th over-all between 2000 and 2008. At the same time, China ranked 76 in terms of its level of per capita GDP (Maddison (2007)). However, if we were to use the data from Barro and Lee (2010) on average years of education, China ranked 79th over-all, among

countries like Gabon, Iran, and Mongolia, while if we look at Nehru et al (2005) dataset China ranked 82nd in physical capital per capita, admittedly in 1989.

At first sight, these numbers suggest that growth in China was not excessively driven by factor accumulation since the level of the factors of production was not substantially more than average. As a result economic growth must have been driven by a combination of factor accumulation and productivity (Total Factor Productivity - TFP) growth (perspiration and inspiration factors as dubbed by Krugman, 1994). This does not, however, match with much of the current literature. Using improved measures of physical capital, several studies found large contribution of physical capital growth to GDP per capita growth in the order of magnitude of ca. 50% on average (e.g. Chow 1993; Wang and Yao 2003, 43), while TFP growth is found to be either small or even negative.

If these latter empirical results are correct, we can expect a reduction of economic growth in China since the fast growth of the perspiration factors cannot be sustained in the long-run because of diminishing returns to the factors of production (Young, 1995; Krugman, 1997), except if inspiration (TFP growth) increases in importance over time, a stance made by Collins and Bosworth (1996).¹ Such an increase in TFP growth indeed seems to exist when looking at standard TFP analysis: Wang and Yao (2003) find that TFP growth increased considerably during the late 1990s while Li (2009) also reports relatively high levels of TFP growth.

However, most studies finding a relatively high TFP growth during the late 1990s either did not include human capital or only used average years of education as a proxy. As Van Leeuwen and Foldvari (2009) argues, however, using average years of education in growth regressions is fraught with problems, largely because it does not take account of the value of human capital. Indeed, using an income based measure of human capital, Whalley and Zhao find a negative TFP growth for the late 1990s, even though there are significant differences on a provincial level of disaggregation. For example Li (2009, 219) estimates TFP growth for the four main regions in China, reaching the conclusion that TFP growth was highest in the Eastern provinces, while Bao et al (2002) argue that growth in the coastal provinces has been higher largely due to geographical factors.

In this paper, we combine the existing regional GDP and physical capital estimates with a new dataset on human capital by provinces going back to the 1920s to analyse the effects of the inspiration and perspiration factors of economic growth corrected for regional diversity. We find that including the contribution of human capital to economic growth leaves us with a negative growth of TFP. This result has to be further corrected for differences in technical efficiency, however, since the contribution of factors of production to economic growth may significantly differ by provinces. Neglecting these differences would lead to biased estimates of the change of productivity, causing it to look insignificant, or

¹ Although Bosworth and Collins (1996, 15*) find that TFP growth contributed about 50% to over-all growth in every period between 1960 and 1994 in China.

even negative. After correcting for provincial differences in technical efficiency, we find evidence for a positive rate of general technological development especially from the 1990s on.

This paper has the following structure: In the next section, we outline our estimation of the cost-based measure of human capital, which is a slightly modified version of the measure suggested by Judson (2002), as well as the underlying series of average years of education. Since technical efficiency of the factors of production may differ by province, in Section 3 we analyse the spread of human –and physical capital through China. In Section 4 we analyse the development of TFP, technical efficiency, and general technical development. We end with a brief conclusion.

2. A new dataset on provincial human capital in China, 1922-2010

As pointed out in the introduction, even though some growth accounting studies make use of average years of education in the recent decades, few studies include the value of human capital in their estimates and no studies make estimates of human capital by province.² Indeed, several studies on average years of education have been made for China: Barro and Lee (1993; 1996; 2001; 2010) reports average years of schooling for every fifth years beginning with 1950 in China. Likewise, Cohen and Soto (2007) do the same for every tenth year after 1960. Wang and Yao (2002) estimate annual series between 1952 and 1999, but, because of lack of data, they based their estimation on the Indian census of 1951 in combination with annual number of graduates by education level. Li (2009) estimates average years of education for several regions in China for the last few decades. Yet, long run, historical estimates similar to Morrisson and Murtin (2009) have not yet been made for China. Although Morrisson and Murtin did make one conjecture for early twentieth century China in their paper, they argue that since “there do not exist any satisfactory historical statistics for these countries [...] , the data [...] serve only an illustrative purpose [...] and shall be taken with caution (p. 29). This may also have been the reason that up to date no estimates of long-run human capital on a provincial level exist.

This lack of data becomes even more worrying when one seeks for a value measure of human capital, which is a crucial aspect in growth accounting. Only Whalley and Zhao (2010) calculated a human capital measure based on combining average years of education with an average wage rate in the population between 1979 and 2008, hence proxying for foregone earnings. However, as far as we are aware, no further information on cost-or income based measures of human capital for China are available.

² There is an obvious contradiction in using standard physical capital stock data together with educational attainment in regression analysis. While the first is measured by value (in order to avoid the problem of aggregation), the latter is simply the average of years spent by formal schooling. This is similar as if one wanted to measure physical capital by the average number of machines in the economy.

In this paper we therefore estimate a cost-based human capital stock for the 1922-2010 period. We started with the method as proposed by Judson (2002). She uses the following equation:

$$h_{it} = \sum_j d_{ijt} a_{ijt} \quad (1)$$

, where d_{ijt} is public expenditure on education and a_{ijt} is the percentage people who have attained level of education j in province i and year t . This results in the average educational expenditure in year t or the replacement value of a single year of education. Therefore, following Van Leeuwen and Foldvari (2008), we multiply this with average years of education, $educ_{it}$, to arrive at the total educational expenditure per capita in year t and province i , h_{it}^* :

$$h_{it}^* = h_{it} \cdot educ_{it} \quad (2)$$

We thus need information on both expenditure on education by level of education as well as average years of education. Starting with the latter, average years of education was calculated using an adapted Barro and Lee method proposed by Foldvari and Van Leeuwen (2009). They calculate the attainment between benchmark years using an average of forward and backward estimates. For the data before or after the census, we used the standard method of aggregating by age class and correcting for age specific mortality. The data on the attainment was taken from the 1964 (National Bureau of Statistics of China, Population Statistics Department and Ministry of Public Security, The Third Bureau, 1988), 1982, and 1990 (China National Bureau of Statistics 1982 and 1990 censuses) censuses. For Taiwan we use the data from Barro and Lee (2010). The educational enrolment from 1907 to 2009 was taken from Li, Qi, and Qian (1995), Education Department, Republic of China (1934), Chinese Education Compile Committee (1946), National Statistical Bureau (1999), and National Bureau of Statistics of China (accessed June 2011). For Taiwan enrolment was taken from Chinese Education Department (1946), Mitchell (1999), and National Statistics Republic of China (Taiwan) (accessed June 2011). Total population was obtained from Hou (2001), National Bureau of Statistics of China Population Statistics Department and Ministry of Public Security The Third Bureau (1988), and National Bureau of Statistics of China (accessed June 2011). For Taiwan the total population was obtained from Maddison (2007). The split up by age class was taken from the 1953, 1964, 1982, 1990 and 2000 censuses (the last one obtained from National Bureau of Statistics of China, accessed June 2011). For the pre-war period, the split up is derived from Yin and Qi (2009). For Taiwan the split up by age class was obtained from Taiwan Government Statistics Office (1946), and Directorate - General of Budget, Accounting and Statistics, Executive Yuan, R.O.C. (Taiwan) (2010).

Besides the data necessary to calculate average years of education, we also needed expenditure by level of education. These were obtained from Education Department, Republic of China (1934), Department of Planning Ministry of Education The People's Republic of China (1984), China Education Yearbook Editorial Department (1986), General

Planning Department of Ministry of Finance (1989), Financial Department of National Education Committee (1990-2010), Guangxi Education Committee Financial Department (1993), Hebei Education Department (2009), and Society Statistics Department, National Bureau of Statistics of China (1994).

The resulting estimates on average years of education, compared with some existing estimates, are presented in below table. As one can see, our estimates are closest to those of Barro and Lee (2010) who based their estimates on census data. We do find, however, that our estimates are much higher in the 1960s (1960-1969) than theirs and growth slowed down afterwards. This seems in correspondence with total enrolment which no less than doubled in the 1950s. Given that even profoundly poor people in local villages could at least attain around 3 years of basic education, we assume that 3.6 years of education is more plausible than 2.4 in the 60s.

	This text	Barro and Lee	Morrisson and Murtin
1920s	0.4		ca. 1
1930s	0.7		
1940s	1.2		
1950s	2.2	1.9	
1960s	3.6	2.4	2.7
1970s	4.4	4.0	3.5
1980s	5.7	5.2	4.4
1990s	6.2	6.4	5.3
2000s	7.3	7.6	6.0

Source: This text, Morrisson and Murtin (2009), and Barro and Lee (2010). Note: averages taken over decades.

Also, the estimate for from Morrisson and Murtin for the 1920s is largely a conjuncture as they also readily admit.

We can also report the figures for average years of education and our cost based human capital measure for several regions in the 1920s and 2000 (see Table 2). We can see that, even though all regions experienced rapid development in both human capital and

Table 2: **Human capital in China and Taiwan in the 1920s and 2000s**

	average years of education	educational inequality (Gini)	human capital/cap (1990 GK dollars)	physical capital/cap (1990 GK dollars)	GDP/cap (1990 GK dollars)
1920s					
North China	0.9	86.9	15.6	NA	NA
Northeast China	0.8	82	19.2	NA	NA
Southeast China	0.3	94.3	3.4	NA	NA
Central and Southern China	0.3	94.7	2.2	NA	NA
Western China	0.3	94.4	2.1	NA	NA
Total China	0.4	93.5	2	NA	562.5
Taiwan	1	86.5	NA	NA	799.5
2000s					
North China	8.6	15.7	16,029.9	13,691.9	8,853.9
Northeast China	8.2	22	13,601.0	13,323.6	8,348.7
Southeast China	7	20	11,993.1	23,227.6	9,956.6
Central and Southern China	7.6	15.3	10,817.8	8,505.9	7,191.4
Western China	6.3	24.4	6,386.3	4,946.2	4,132.4
Total China	7.3	16.8	8,609.6	12,704.8	5,111.0
Taiwan	10.4	20.1	34,318.1	NA	14,276.1

Source: This text; Maddison (2007)

Note: educational inequality calculated based on average years of education. For the method see Thomas, Wang and Fan (2000)

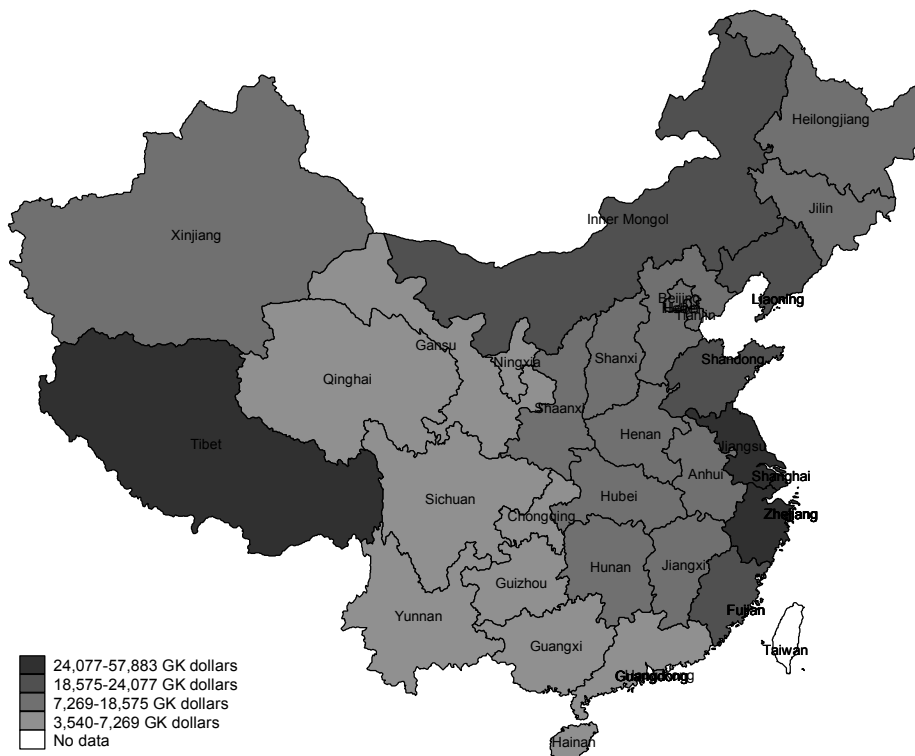
average years of education, North and Northeast China kept dominating. There was thus a strong regional persistency in human capital through China.

3. Regional spread of the factors of production

As pointed out in the introduction, many studies found TFP growth to be larger in the Eastern provinces. This may either be caused by the factors of production in these provinces (more specifically due to the omission of human capital from the growth accounting exercise which was more abundant in the Eastern provinces), or by higher technical efficiency in these provinces both of which enter as components of TFP in standard growth accounting exercises. Technical efficiency will be discussed in the next section, therefore we will focus our attention in this section on the spread of physical - and human capital in China.

If we look at the stock of physical capital per capita, we find that in the 1950s the per capita physical capital was the highest in the Northern provinces. Although the primacy of the North continued, also the East and some of the developing

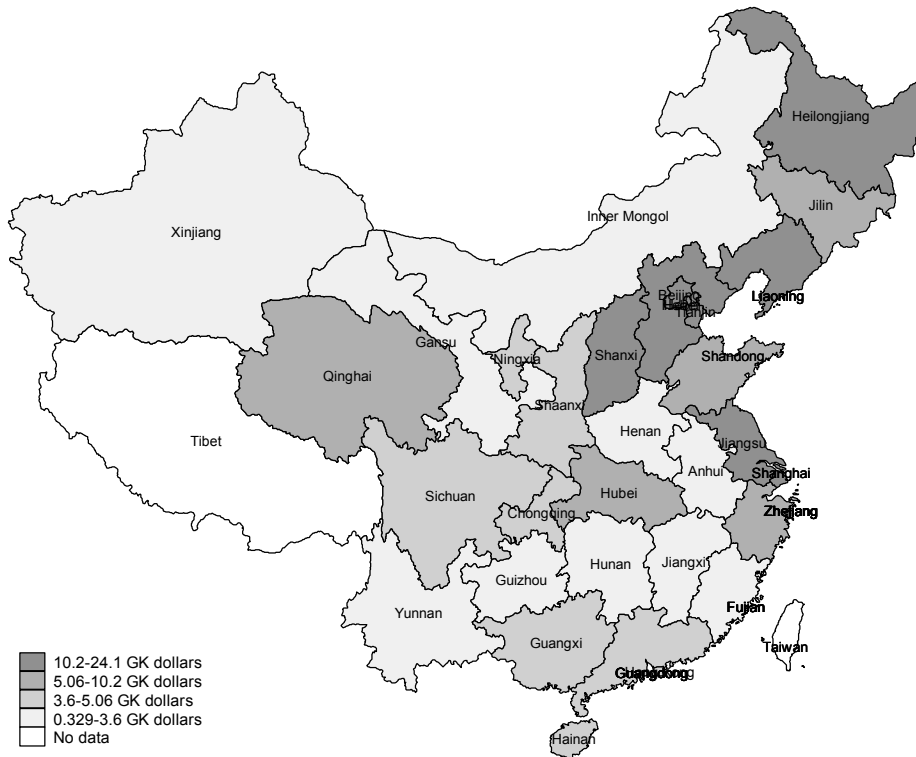
Map 1: Physical capital per capita in 2005 (1990 GK dollars)



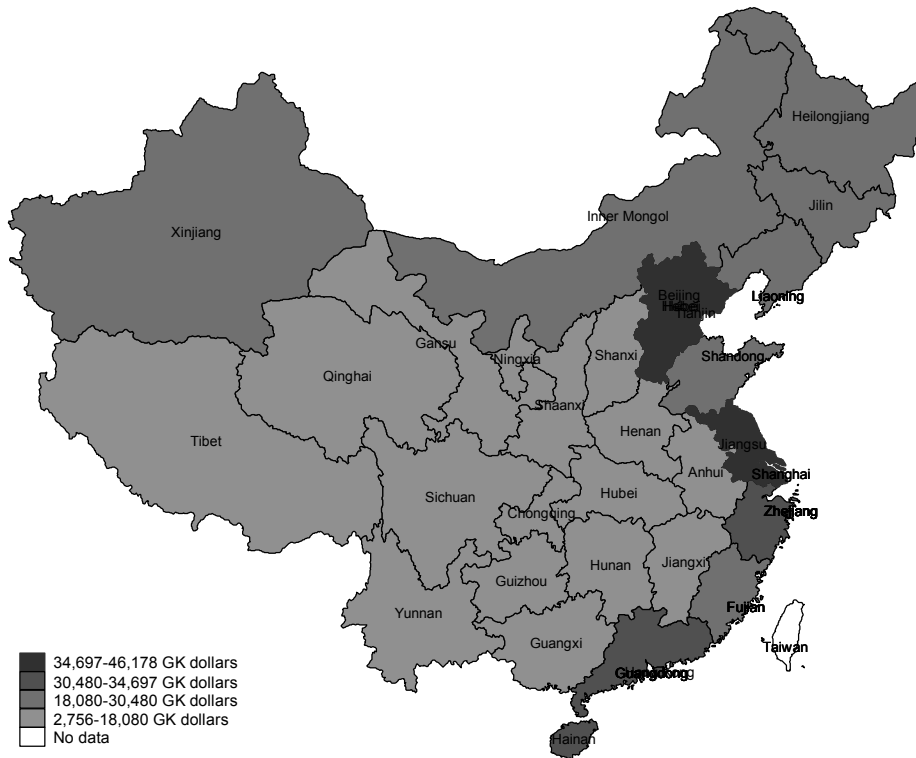
provinces, most notably Tibet, increased their levels of physical capital considerably (see Map 1 and Table 2). This suggests that average growth of physical capital was considerably higher in the Eastern Provinces and the developing provinces than elsewhere in China. Indeed, the average annual growth rate of physical capital in the Eastern provinces between 1990 and 2006 was 12.5% versus 10.6% for the whole of China.

A similar pattern can be detected for human capital. Table 2 shows that already in the 1920s the North of China was the most abundant in human capital, a fact that remained that way up to the present day, even though in relative terms the gap declined. Maps 2 and 3 show the development of the stock of human capital over time. Also here we can see that the Eastern Provinces gained on the North. The big difference with physical capital, though, is that in terms of human capital the

Map 2: cost-based human capital measure in 1925 (1990 GK dollars)



Map 2: cost-based human capital measure in 2005 (1990 GK dollars)



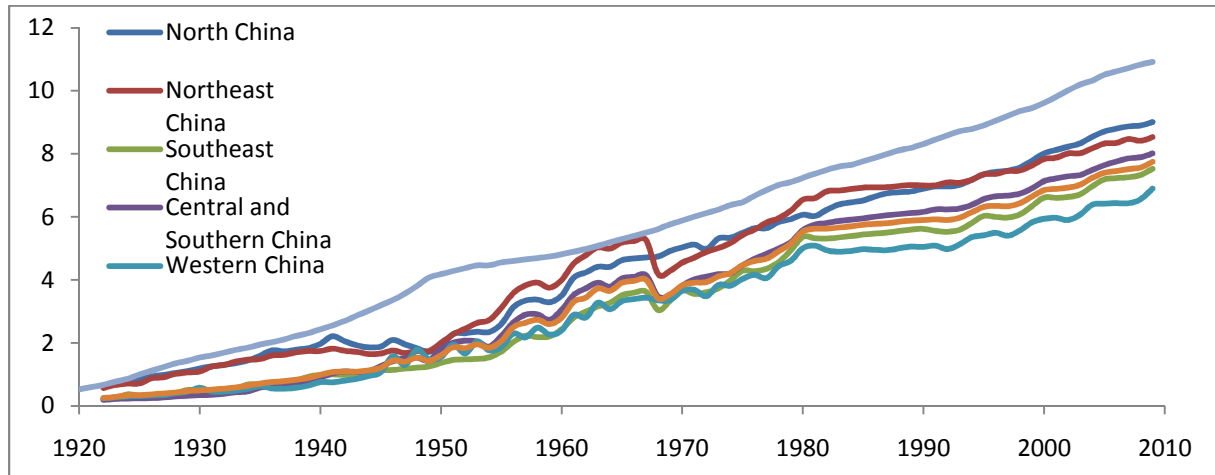
developing provinces did not improve as much as in physical capital.

This suggests that both human and physical capital show a large degree of regional consistency over time. We can arrive at a similar conclusion using Moran’s I, a spatial correlation measure which measures how related values of a variable are depending on the place where they are measured. The results for such an analysis are reported in Table 3. As can be seen, there is a strong and positive spatial correlation for human- and

Table 3: Spatial correlation, Moran's I			
	I	Z	p-value
1925			
average years of education	0.040	1.185	0.118
cost based human capital	0.136	2.590	0.005
K/cap	NA		
GDP/cap	NA		
1955			
average years of education	-0.048	-0.069	0.473
cost based human capital	NA		
K/cap	0.199	3.847	0.000
GDP/cap	0.151	2.828	0.002
2005			
average years of education	0.207	3.515	0.000
cost based human capital	0.108	2.163	0.015
K/cap	0.142	2.897	0.002
GDP/cap	0.206	3.535	0.000
Note: one tail test			

physical capital and GDP/cap. This suggests that the closer two provinces are, the higher their correlations in terms of both physical, and human capital and per capita GDP. This is once again confirming our previous suggestion that regional inequalities remained persistent in China in the twentieth century. However, this finding is not true for average years of education, its spatial correlation being insignificant in 1925 and 1955 only to turn positive in 2005. Since average years of education may be considered an indicator of the volume of human capital as outlined in the introduction, this suggests that the quantity of human capital spread through China evenly until after the Cultural Revolution while in terms of the value (expenditures on) of education the Northern and Eastern parts were in better position.

Figure 1: average years of education by region in China and Taiwan



Note: *Northeast China*= Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia; *Northeast China*= Liaoning, Jilin, Heilongjiang; *Southeast China*= Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong; *Central and Southern China*= Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan; *Western China*= Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang. Tibet is excluded.

This lack of spatial correlation in the volume, but the existence of spatial integration in the quality of human capital can be captured empirically by estimating an error correction model (ECM) in autoregressive distributed lag (ARDL) form. Let's start with the ECM:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta x_t + \gamma (y_{t-1} - \beta_0 - \beta_1 x_{t-1}) + u_t = \alpha_0 + \alpha_1 \Delta x_t + \gamma y_{t-1} - \gamma \beta_0 - \gamma \beta_1 x_{t-1} + u_t \quad (3)$$

Here γ is the adjustment parameter; its value is expected to be negative and shows how quickly the process returns to its long-run value. α_1 is the immediate effect of x on y , this effect is immediate and temporary (that is, it vanishes after one period). The beta coefficients are the elements of the cointegration vector. This is the long-run relationship between x and y to which the process should revert if cointegrated. The most serious econometric issue with such a specification is that in fixed effect dynamic panels the OLS leads to biased estimates. The standard solution is to use some instrumentation (or moment restrictions). The most popular techniques are by Arellano and Bond (dynamic panel GMM), and Blundell and Bond (GMM-SYS). The main difference between the two techniques is that the second utilizes additional moment restrictions. Since the variables are mostly nonstationary, their first differences would make weak instruments in the level equation. For this reason we use the Arellano-Bond approach with the third lag of the $\ln hc$ variable as instrument. Since average years of education is used to create the cost based human capital measure we need to take care of the simultaneity problem as well: we use the second lag of average years of education as additional instrument. The results of this regression are reported in Table 4 below.

Table 4: effects on human capital				
	Fixed effect panel		Fixed effect panel	
	OLS		Generalized Method of Moments (one step)	
	coefficient	t-value	coefficient	t-value
LNHC(-1)	-0.053	-4.979	-0.090	-1.736
C	0.032	1.525		
Δ LNHCWEIGHT	0.316	-1.752	0.423	8.424
LNHCWEIGHT(-1)	0.024	2.661	0.049	1.819
Δ AVYEARS	0.628	4.299	1.791	2.243
AVYEARS(-1)	0.029	2.749	0.034	0.663
Δ AVYEARSWEIGHT	-0.231	-3.892	-0.740	-2.301
AVYEARSWEIGHT(-1)	-0.017	-1.470	-0.030	-1.102
N	750		675	
Hansen-test p-value		NA	0.818	

The Hansen test cannot reject the null hypotheses that our instruments are indeed exogenous, suggesting that we have no problems with possible simultaneity. We can see that the short run effect of average years of education is 1.8, but that there is no long-run effect. That suggests that the relationship between education and human capital formation is not straightforward: in the short run more education may indeed increase the apparent value of human capital due to increased costs, but it is a quite weak policy tool to assure a stable growth of human capital in itself. Hence, there seems to be little correlation between the number of average years of education and the level of human capital.

If we look at the effect of human capital of the neighbouring provinces we indeed find that both the short and long-run effects are positive and significant. This suggests that when the human capital in a neighbouring province is higher, the higher will be the human capital in this province. Again, this suggests a strong clustering effect of expenditure on education as can be seen when comparing Map 2 and 3. This effect takes place in all periods and is corrected for province specific fixed effects. This is not strange since we already found that human capital per capita has a high degree of spatial consistency over time.

It is thus clear that the Northern, and especially the Eastern, provinces were considerably higher in the quality of human capital over time, but this was not necessarily the case for average years of education. Only in 2005 we find a positive spatial correlation for average years of education, suggesting that the level of education had increased so much that in all cases an extra year of education went hand in hand with a significant amount of educational expenditure. We can also see this in Table 5 below. Here we see that until the

reform period, with the exception of the Cultural Revolution, there is no long-run effect of average years of education on human capital. Only after 1978 we find an increasingly

	1920-1930	1950-1966	1966-1977	1978-1993	1994-2006
LNh(t-1)	-0.661 (-2.52)	-0.529 (-7.60)	-0.653 (-6.45)	-0.174 (-4.38)	-0.523 (-6.18)
Lnh(t-2)		-0.071 (-1.05)			0.211 (6.95)
Dlnvyears(t)	3.170 (2.06)	0.505 (4.17)	0.174 (1.68)	0.327 (4.39)	0.730 (3.88)
LNavyears(t-1)	1.182 (1.28)	0.487 (5.98)	0.084 (1.59)	0.236 (4.75)	0.426 (3.54)
N	150	156	132	293	398
Hansen test p-value	0.144	0.419	0.285	0.69	0.637

Note: robust t-value in parentheses

bigger long-run effect suggesting that each year of extra education lead to an increase in spending on education.

These observations warrant the conclusion that both in physical and human capital there was a spatial persistency over time: the Northern and Eastern provinces had already larger stocks of human and physical capital in the 1920s and 1950s and this continued up to the 2000s (and probably thereafter, Wei, 2008). For human capital, the feature may be attributed to a stronger amount of government expenditure on education: irrespective of their average years of education, Eastern provinces spent more on education than in the West. Hence, whereas there was a strong clustering of human capital in the North and East, this was less the case for average years of education. Only after the Cultural Revolution, we find that also average years of education became spatially correlated, suggested that increasing years of education above a certain level was costly and was only done in those provinces that also were able to spend more money on the quality of education. This is a similar observation as made by Heckman (2005) who noted that the richer provinces spent more on education than the poorer ones.

4. Technology, technical efficiency, and economic growth

It is clear from above analysis that physical- and human capital accumulation were always more pronounced in the Eastern, richer, provinces. Does this mean that these provinces were also the ones with more “perspiration”, or did they more dependent on inspiration

since the estimated TFP growth was higher there? And if perspiration factors in China indeed dominated economic growth, does this mean that we expect economic slowdown when the returns diminish, or is there a move over time towards technological growth?

In order to answer this question, we first estimate the effect of human - and physical capital accumulation on economic growth in a standard growth accounting framework. For our analysis we start with a standard TFP analysis:

$$\frac{\dot{y}_{it}}{y_{it}} = \frac{\dot{A}_t}{A_t} + \hat{\alpha} \frac{\dot{k}_{it}}{k_{it}} + \hat{\beta} \frac{\dot{h}_{it}}{h_{it}} + \frac{\dot{u}_{it}}{u_{it}} \quad (4)$$

, where $\frac{\dot{A}_t}{A_t}$ is TFP growth. This standard growth accounting is given in Table 6 for 4 periods: 1950-1966, 1966-1977 (the Cultural Revolution), 1978-1993 (the first part of the reform period) and 1994-2006 (the second part of the reform period). The first rows are the factor shares of labour and physical capital, then we have the growth of GDP/cap, K/cap, and

	1950- 1966	1966- 1977	1978- 1993	1994- 2006
Factor share labour	53%	44%	54%	54%
factor share physical capital	47%	56%	46%	46%
Growth y	2%	2%	6%	8%
Growth hc	16%	1%	12%	15%
Growth k	7%	5%	9%	11%
TFP growth	-10%	-1%	-5%	-5%
Technical efficiency	-9%	-1%	-7%	-8%
General technical growth	-1%	0%	2%	3%

Source: GDP: National Bureau of Statistics of China (accessed June 2011), National Statistical Bureau, 1999; Physical capital: Wu (2003; 2009); Human capital: This text.
Factor shares taken from Chow (1993), Li et al (1997) and, following Wang and Yao (2003) we assumed the factor share of labour the same for both periods of the reform period.

HC/cap. The third to last column gives the TFP growth. We find that in all cases the TFP growth is negative, especially during the period 1950-1966. This confirms the finding of Whalley and Zhao (2010) who found a negative TFP growth for the late 1990s. However, our

study suggests that negative or insignificant TFP growth was a structural feature of the Chinese economy during the 20th century.

At first sight, this seems to confirm the perspiration hypothesis: adding human capital to the growth accounting only lowers the effect of TFP growth. However, TFP growth consists of both general technological development and technical efficiency of both human- and physical capital. One might, for example, argue that due to diminishing returns the technical efficiency of both factors of production reduce, and hence that in the Eastern provinces with more human and physical capital, technical efficiency is low, basically meaning that the effects of human- and physical capital on growth are overestimated and the role of general technical development in TFP is underestimated. Technical efficiency is now defined as difference in the output/input ratio for the factors of productions across provinces. That is, an additional one percentage increase in a factor of production, unlike it is usually assumed in TFP exercises, may have different effect on income in different provinces. Econometrically this phenomenon is captured by province specific coefficients.

We can rewrite the standard TFP analysis while allowing for technical efficiency differences as follows:

$$\frac{\dot{y}_{it}}{y_{it}} = \frac{\dot{\theta}_t}{\theta_t} + \alpha_i \frac{\dot{k}_{it}}{k_{it}} + \beta_i \frac{\dot{h}_{it}}{h_{it}} + \frac{\dot{\varepsilon}_{it}}{\varepsilon_{it}} = \frac{\dot{\theta}_t}{\theta_t} + \hat{\alpha} \frac{\dot{k}_{it}}{k_{it}} + \hat{\beta} \frac{\dot{h}_{it}}{h_{it}} + (\alpha_i - \hat{\alpha}) \frac{\dot{k}_{it}}{k_{it}} + (\beta_i - \hat{\beta}) \frac{\dot{h}_{it}}{h_{it}} + \frac{\dot{\varepsilon}_{it}}{\varepsilon_{it}} \quad (5)$$

Where θ is a time-variant common productivity factor (similar to A in the standard growth accounting in equation (4) but free of the effect of technical efficiency differences, and α_i and β_i are the province specific coefficients. Combining equation (4) and (5) we can show the relationship between TFP growth, general technology growth, and technical efficiency of human- and physical capital:

$$\frac{\dot{A}_t}{A_t} = \frac{\dot{\theta}_t}{\theta_t} + (\alpha_i - \hat{\alpha}) \frac{\dot{k}_{it}}{k_{it}} + (\beta_i - \hat{\beta}) \frac{\dot{h}_{it}}{h_{it}} \quad (6)$$

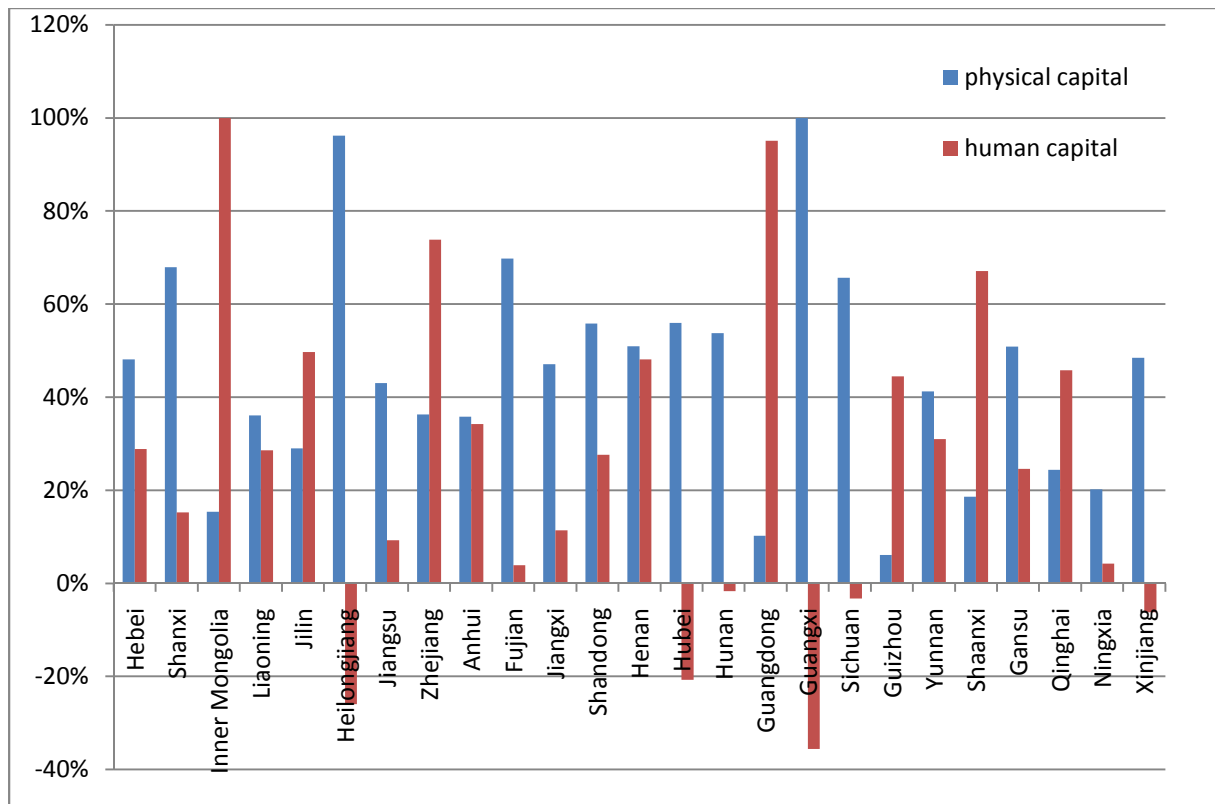
The TFP growth in (4) is not equal to the growth rate of θ (hence, it is not equal to standard TFP accounting) unless:

$$E \left[(\alpha_i - \hat{\alpha}) \frac{\dot{k}_{it}}{k_{it}} + (\beta_i - \hat{\beta}) \frac{\dot{h}_{it}}{h_{it}} \right] = 0 \quad (7)$$

They can be equal for example if the individual coefficient is uncorrelated with the growth of factor. This is very unlikely since higher human -or physical capital accumulation may lead to change in the coefficient (an obvious deviation from the Cobb-Douglas technology).

Using equation (5) allows us to estimate TFP growth without the effect of technical efficiency, which is included with the individual coefficients of each province for physical and

Figure 2: social returns to physical and human capital by province, 1953-2006.



human capital (see Figure 2). As one can see, the social returns to human- and physical vary a lot by province. However, there are two remarkable findings. First, there is a clear negative correlation between the social returns to human- and physical capital. Second, the social returns considerably outperform the private returns. In Table 7 one can see that the social returns on human capital in China changed from ca. 23% in 1950-66 to 0% during the Cultural Revolution, 35% during the reform period, and 7% during the period 1994-2006. These results are relatively high compared to the private returns which are rather in the order of magnitude of between 4 and 12% (Liu 1998; Wei, Tsang, Wu, and Chen 1999; Hossain 1997) for the reform period, a period when we found social returns in the order of 35%. This corresponds well with the finding of Heckman (2005) that the private returns to

Table 7: Effects on $Dlny$ using GMM

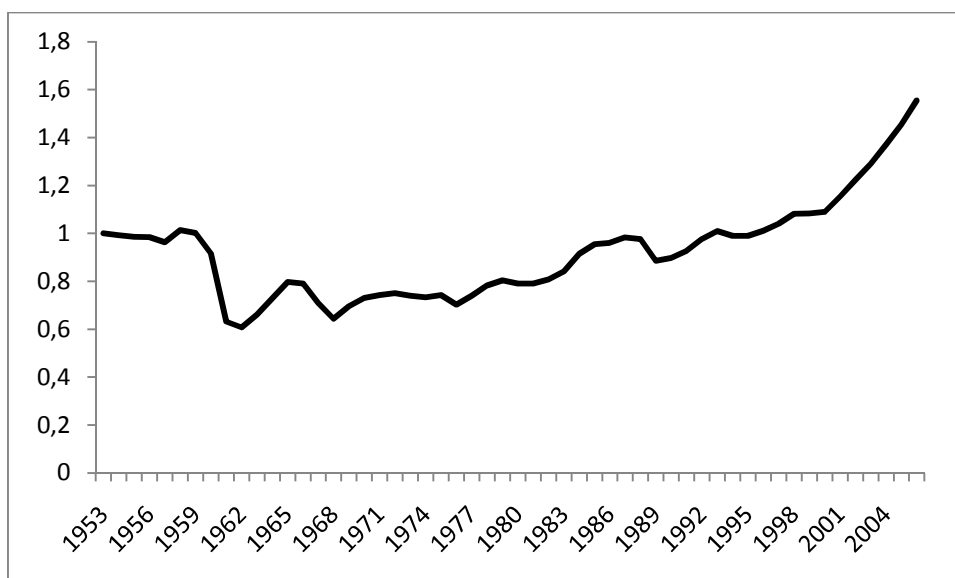
	1950-1966	1966-1977	1978-1993	1994-2006
$LNy(t-1)$	-0.964 (-6.99)	-0.793 (-5.33)	-0.993 (-4.00)	-0.499 (-2.01)
$Dlnh(t)$	0.372 (4.14)	0.068 (0.41)	0.411 (4.67)	-0.016 (-0.22)
$LNh(t-1)$	0.255 (2.97)	-0.226 (-1.39)	0.343 (3.40)	0.085 (1.64)
$DLNk(t)$	1.797 (4.93)	1.767 (3.56)	1.664 (3.08)	1.400 (4.18)
$LNk(t-1)$	0.017 (0.16)	0.383 (2.94)	0.159 (1.67)	0.274 (1.73)
N	127	132	280	325
Hansen test p-value	0.335	0.306	0.319	0.319

Note: robust t-values in parentheses

skills were lower than actual productivity. For physical capital, we find an average social return of around 50%, which is close to the figures reported by Heckman (2005).

We are now able to subtract technical efficiency from TFP growth. This is reported in the final two rows in Table 6. We can see that, whereas technical efficiency of human-and physical capital was continuously negative, countrywide productivity development grew over time from -1% in 1950-1966 to 3% in 1994-2006. The level of common productivity is reported in Figure 3. What is quite remarkable is that general technological development

Figure 3: index of common productivity factor (θ) (1953=1).



went clearly down in 1961 although also the previous years show a marked decline in general technology. This may be associated with the Great Famine, which was caused by the agricultural reorganisations during the Great Leap Forward. Another strong downturn took place during the first years of the Cultural Revolution. However, growth afterwards was clear.

5. Conclusion

In recent decades, especially with the fast growing economy, there has been much attention in the literature for Chinese economic development. There has been a big debate though if this growth is caused by capital accumulation (perspiration factors) or driven by TFP growth (inspiration factors). The difference between both stances is quite substantial since, if the perspiration theory is correct, one expects the growth of the Chinese economy to slow down over time as the capital accumulation grows increasingly less efficient. In many studies, however, the relatively fast Chinese growth is explained by both physical capital and TFP growth. However, most of these studies ignore human capital.

In this paper we develop a new dataset on human capital for the provinces of China between 1922 and 2009. We find that human capital was consistently biased towards the North-eastern and Eastern provinces already in the 1920s. The same applies to the stock of physical capital, suggesting a relatively fast capital accumulation in the East. However, there is no evidence that the social returns on either human-or physical capital were lower in the East than elsewhere.

Using our new dataset together with physical capital and per capita GDP, allows us to do a TFP analysis for sub periods. We find a continuously negative TFP growth suggesting that reduction in productivity was a structural feature of the Chinese economy. If true, this would lend support to the perspiration theory and suggest a slowdown of the Chinese economy in the future. However, standard growth accounting neglects differences in technical efficiency and leads to bias in the estimated growth rate of TFP, which we find to be significant in the case of China. After subtracting the effect of technical efficiency differences from TFP growth, we find that countrywide productivity development turns increasingly positive in the 1990s and 2000s. This suggests that, whereas until the reform period China was largely driven by capital accumulation, afterwards general technical development got an increasingly prominent place giving hope for continued economic development in the future. We still find a significant amount of technical inefficiencies across provinces in China however, that may undermine the efficient dissemination of new technologies.

References

- Bao, G. H. Chang, J. D. Sachs and W. T. Woo, 'Geographic factors and China's regional development under market reforms, 1978–1998', *China Economic Review* 13(1), (2002), pp. 89–111.
- 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. 2001. "International Comparisons of Educational Attainment: Updates and Implications." *Oxford Econ. Papers* 3:541–63.
- Barro, Robert J., and Jong-wha Lee. 2010. "A New Data Set of Educational Attainment in the World, 1950–2010," NBER Working Paper No. 15902, 2010.
- 《中国教育年鉴》编辑部编, 中国教育年鉴地方教育 (1949-1984), 湖南教育出版社 1986年12月 (China Education Yearbook Editorial Department, China Education Yearbook Local Education 1949-1984, Hunan Education Publishing House December 1986).
- China National Bureau of Statistics, *Census 1990*, Minnesota Population Center. *Integrated Public Use Microdata Series, International: Version 6.1* [Machine-readable database]. Minneapolis: University of Minnesota, 2011. China Census 1982 and 1990.
- 教育部教育年鉴编纂委员会, 第二次中国教育年鉴, 商务印书馆 (Chinese Education Compile Committee (1946), *The Second Chinese Education Yearbook*, The Commercial Press 1946).
- 教育部, 第三次中国教育年鉴, 台湾. (Chinese Education Department (1946), *The Third Chinese Education Yearbook*, Taiwan July 1946).
- Chow, G. (1993). Capital formation and economic growth in China. *Quarterly Journal of Economics*, 108(3), 809– 842.
- Cohen, Daniel, and Marcelo Soto (2007), "Growth and human capital: Good data, good results", *Journal of Economic Growth* 12(1), 2007, 51-76.
- Collins, S., & Bosworth, B. (1996). Economic growth in East Asia: Accumulation versus assimilation. *Brookings Papers on Economic Activity*, 2, 135–191.
- 中华人民共和国教育部计划财务司编, 中国教育成就统计资料1949-1983 和1986-1990, 人民教育出版社1984年六月 (Department of Planning Ministry of Education The people's republic of China, *Achievement of Education in China Statistics 1949 - 1983 and (1986 -1990)*, People's education press June 1984).
- Directorate - General of Budget, Accounting and Statistics, Executive Yuan, R.O.C.(Taiwan), *Republic of China Statistics Year book 2009*, Directorate - General of Budget, Accounting and Statistics, Executive Yuan, R.O.C.(Taiwan), 2010.
- 中国教育部, 第一次中国教育年鉴, 上海开明出版社 (Education Department, Republic of China (1934), *The First Chinese Education Yearbook*, Shanghai Kaiming Press 1934).
- 国家教育委员会财务司, 国家统计局社会和科技统计司, 中国教育经费统计年鉴, 中国统计出版社2001年, vol. 1989-2009, year 1990-2010. (Financial Department of National Education Committee, Department of Social Science and Technology Statistics, National Bureau of Statistics of China, *China educational Finance Statistical Yearbook 2000*, China Statistics Press 2001).

- Földvári, Péter and Bas van Leeuwen, 'Average years of education in Hungary: annual estimates 1920-2006,' *Eastern European Economics*, Vol. 47 (2) 2009, pp. 5-20.
- 财政部综合计划司编, 中国财政统计1950-1988, 中国财经经济出版社1989年10月。
(General Planning Department of Ministry of Finance, *China Finance Statistics 1950-1988*, China Financial and Economic Publishing House October 1989).
- 广西壮族自治区教育委员会财务处编, 广西教育经费统计资料1991,
广西民族出版社1993年7月 (Guangxi Education Committee Financial Department, *Guangxi educational Finance Statistical Data*, Guangxi Nationality Publishing House July 1993).
- 河北省教育厅 编, 河北省教育经费统计资料汇编1949-2008, 河北人民出版社
2009年12月 (Hebei Education Department, Hebei Province Educational Expenditure
Statistical Data Assembly 1949-2008, Hebei People Publishing House Dec 2009).
- Heckman, James (2005), 'China's human capital investment,' *China Economic Review*, 15, 50-70.
- Hossain, S.I. 1997. "Making Education in China Equitable and Efficient." Policy Research Working Paper No. 1814, Washington, DC, World Bank.
- 侯杨方, 中国人口史第六卷1910-1953, 复旦大学出版社2001年11月。 (Hou, Yangfang (2001), *China Population History The Sixth Volume 1910-1953*, Fudan University Press November 2001).
- Hu, Z. L., & Khan, M. S. (1997). Why is China growing so fast? IMF Staff Papers. Washington, DC: International Monetary Fund.
- Judson, R., 2002, Measuring Human Capital Like Physical Capital: What Does It Tell Us? *Bulletin of Economic Research*, 54, pp. 209-31.
- Krugman, P. (1994). The myth of Asia's miracle. *Foreign Affairs*, 73(6), 62-78.
- Krugman, P. (1997, August). 'What happened to the Asian miracle?' (see <http://www.pkarchive.org>).
- :李桂林, 戚名琇, 钱曼倩, 中国近代教育史料汇编, 上海教育出版社 (Li, Guilin, Mingxiu Qi, and Manqian Qian (1995), *Collection of Chinese Modern Education information*, Shanghai Education Press October 1995).
- Li, Kui-Whai (2009), 'China's total factor productivity estimates by region, investment sources and ownership,' *Economic Systems*, Vol. 33 (3), pp. 213-230.
- Li, J., et al. (1993). Productivity and economic growth in China, United States and Japan. Beijing: Chinese Social Science Press.
- Liu, Z. 1998. "Earning, Education and Economic Returns to Urban China." *Economic Development and Cultural Change* 46(4): 697-725.
- Maddison, Angus (2007), *Contours of the World Economy 1-2030AD*, Oxford, Oxford University Press.
- Mitchell, Brian R. (1999), *International historical statistics : Africa, Asia & Oceania, 1750-1993*, London [etc.] : Macmillan.
- Morrisson, Christiaan, and Fabrice Murtin (2009), 'The Century of Education,' *Journal of Human Capital*, Vol. 3 (1), 1-42.
- National Bureau of Statistics of China, *China Statistical yearbook 1996-2010*, <http://www.stats.gov.cn/english/statisticaldata/yearlydata/> (accessed June 2011).
- National Bureau of Statistics of China, *Census 2000*, <http://www.stats.gov.cn/tjsj/ndsj/renkoupucha/2000pucha/html/t0107.htm> (accessed June 2011).

- 国家统计局人口统计司 公安部三局编, 中华人民共和国人口统计资料汇编1949-1985, 中国财政经济出版社 1988年1月. (National Bureau of Statistics of China, Population Statistics Department and Ministry of Public Security, The Third Bureau (1988), *People of Republic of China Population Statistic Data Collection 1949-1985*, China Financial & Economy Publishing House January 1988).
- National Statistical Bureau, 1999. Comprehensive statistical data and materials on 50 years of New China 1949–1998. , Finance and Economic Publishing House, Beijing, China.
- National Statistics Republic of China (Taiwan), *Education at the primary, secondary and third level*, <http://eng.stat.gov.tw/lp.asp?ctNode=2268&CtUnit=1072&BaseDSD=36> (accessed June 2011).
- Nehru, Vikram, Eric Swanson, Ashutosh Dubey, 'A new database on human capital stock in developing and industrial countries: Sources, methodology, and results,' *Journal of Development Economics*, 46 (1995), 379-401.
- 国家统计局社会统计司, 中国社会统计资料1993, 新华书店北京发行所发行1994年3月 (Society Statistics Department, National Bureau of Statistics of China, China Social Statistics Data 1993, Xinhua Bookstore Beijing Publishing House March 1994).
- 台湾省行政长官公署统计室 编, 台湾省五十一年来统计提要, 进学书局1946年1月. (Taiwan Government Statistics Office (1946), 51 Years Data Collection in Taiwan Province, Jinxue Publishing House January 1946).
- Thomas, V., Wang Y. and Fan X. (2000) Measuring Education Inequality: Gini Coefficients of Education. Mimeo. The World Bank, http://econ.worldbank.org/files/1341_wps2525.pdf.
- Van Leeuwen, Bas, and Peter Foldvari (2009), 'Capital accumulation and growth in Central Europe, 1920-2006,' Paper presented at the World Economic History Congress, Utrecht 2009.
- Van Leeuwen, Bas, and Péter Földvári, 'Human Capital and Economic Growth in Asia 1890-2000: a time-series analysis,' *Asian Economic Journal* , Vol. 22 (3) 2008, pp. 225-240.
- Wang, Yan, and Yao, Yudong (2003), 'Sources of China's Economic Growth 1952-1999: incorporating human capital accumulation,' *China Economic Review*, Vol. 14, pp. 32-52.
- Wei, Chi (2008), 'The role of human capital in China's economic development: Review and new evidence,' *China Economic Review*, Vol. 19(3), 421-436.
- Wei, X., M.C. Tsang, W. Wu and L.-K. Chen. 1999. "Education and Earning in Rural China." *Education Economics* 7(2).
- Whalley, John, and Xiliang Zhao (2010), 'The Contribution of Human Capital to China's Economic Growth,' NBER Working Paper No. 16592, 2010.
- Wu, Yanrui (2009), 'China's Capital Stock Series by Region and Sector,' University of Western Australia Discussion Paper 09.02.
- Wu, Yanrui (2004), *China's Economic Growth: A Miracle with Chinese characteristics*, London and New York: RoutledgeCurzon Press Limited.
- 殷梦霞 田奇, 民国人口户籍史料汇编2, 国家图书馆出版社 2009年9月. (Yin, Mengxia, and Tian Qi (2009), *Republic of China Population and Household Historical Data Collection Volume 2*, National Library of China Publishing House September 2009).
- Young, A. (1995). The tyranny of numbers: Confronting the statistical realities of the East Asian growth experience. *Quarterly Journal of Economics*, 110(3), 641–680.