MPRA
Munich Personal RePEc Archive

Regional human capital in Republican and New China: Its spread, quality and effects on economic growth

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

Utrecht University Faculty of Humanities Research Institute for History and Culture

11. April 2011

Online at http://mpra.ub.uni-muenchen.de/43582/
MPRA Paper No. 43582, posted 5. January 2013 21:00 UTC

Regional human capital in Republican and New China:

Its spread, quality and effects on economic growth

Bas van Leeuwen (Utrecht University) (bas.vanleeuwen1@googlemail.com); Jieli Van leeuwen-Li (Utrecht University); Peter Foldvari (Utrecht University)

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 Total Factor Productivity (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.

JEL classification: N15, O11, P23

Keywords: China, economic development, human capital, technology

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, according to the Extended Penn World Tables, China ranked 73th in per capita physical capital with countries like the Dominican Republic, Venezuela, and Romania (Marquetti and Foley, 2011).

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 in the world economy. 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 China in the order of magnitude of ca. 50% on average (e.g. Chow, 1993), 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] Some studies have indeed argued that such an increase in TFP growth 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 (2011) argue, 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

[1] 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.

and Zhao (2010) find a negative TFP growth for the late 1990s, even though there are significant differences on a provincial level. For example Li (2009: 219) estimates TFP growth for 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 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 onwards.

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.

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

[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.

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.

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 on 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). Following Barro and Lee (2001), they started from benchmark years with census data on educational attainment. For the inbetween years, they calculate the attainment using an average of forward and backward estimates (from the preceding and following census). For the data before the first, or after the last, census, we used the standard method of aggregating by age class and correcting for age specific mortality (e.g. Van Leeuwen and Foldvari, forthcoming). 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

Table 1. Average years of education in China

	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.

plausible than 2.4 in the 1960s. Also, the estimate for from Morrisson and Murtin for the 1920s is largely a conjuncture as they also readily admit.

Table 2. Human –and physical 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

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

Source: This text; Maddison (2007)

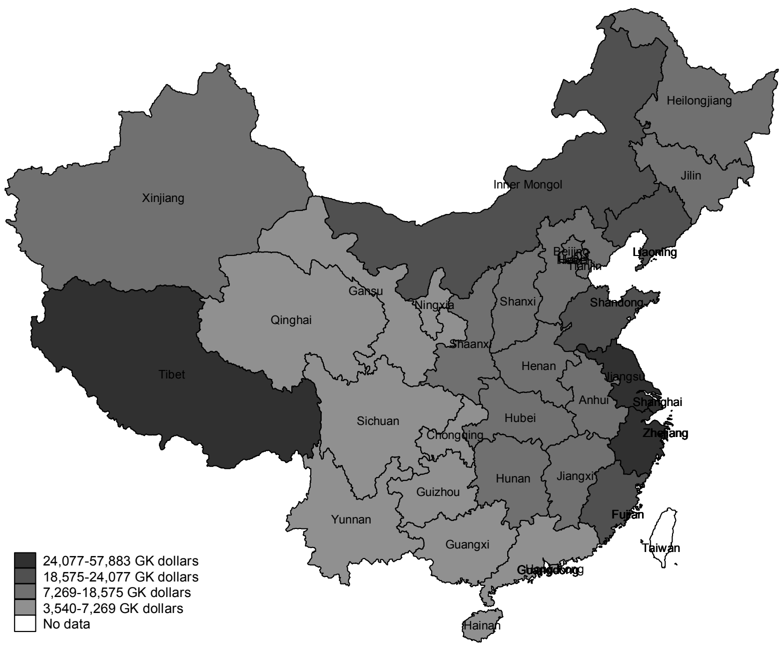
We can also report the figures for average years of education and our cost based human capital measure for several regions in the 1920s and 2000 (see Table 2). We can see that, even though all regions experienced rapid development in both human capital and average years of education, North and Northeast China kept dominating. There was thus a strong regional persistency in human capital in China.

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 provinces, most notably

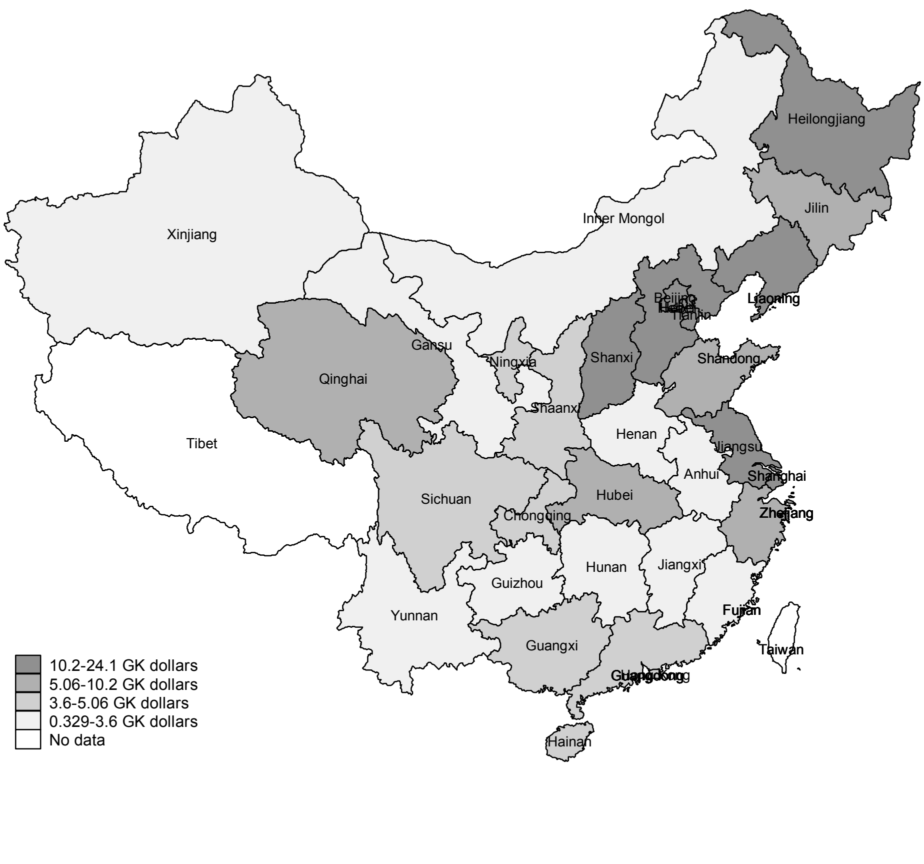
Map 1. Physical capital per capita in 2005 (1990 GK dollars)



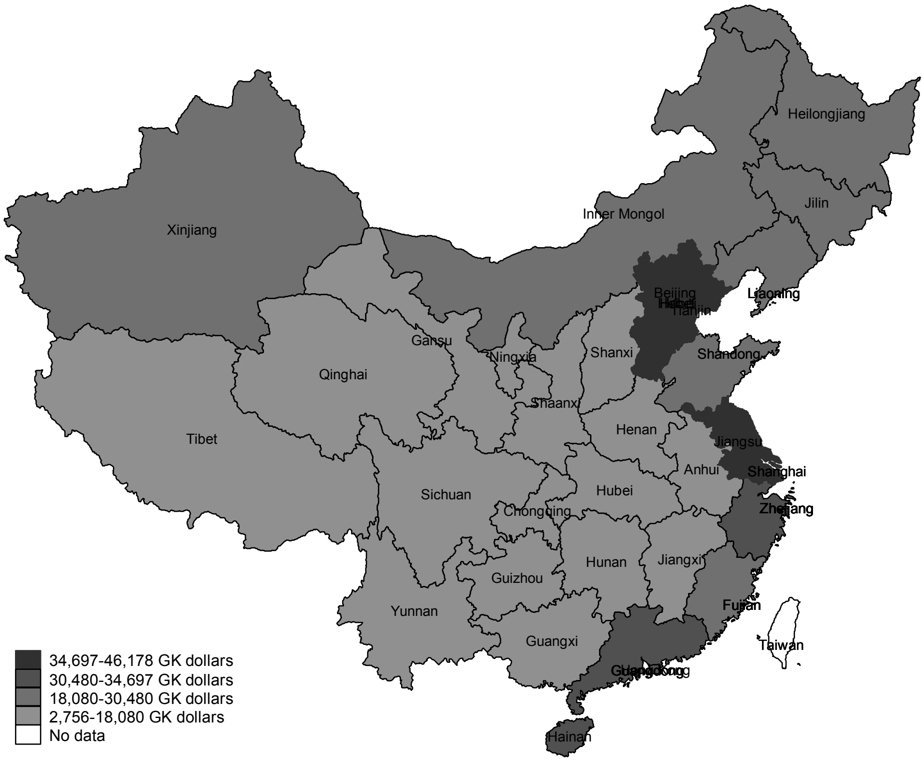
Tibet, increased their levels of physical capital considerably (see Map 1 and Table 2). This suggests that average growth of physical capital was considerably higher in the Eastern Provinces and the developing provinces than elsewhere in China. Indeed, the average annual growth rate of physical capital 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 average years of education, a situation that remained that way up to the present day, even though in relative terms the gap declined. The same basically applies to the cost-based human capital measure. 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

Map 2. Cost-based human capital measure in 1925 (1990 GK dollars)



Map 3. Cost-based human capital measure in 2005 (1990 GK dollars)



terms of human capital the 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 persistency over time, but that especially the East benefitted in terms of the growth of both human-and physical capital. 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 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

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

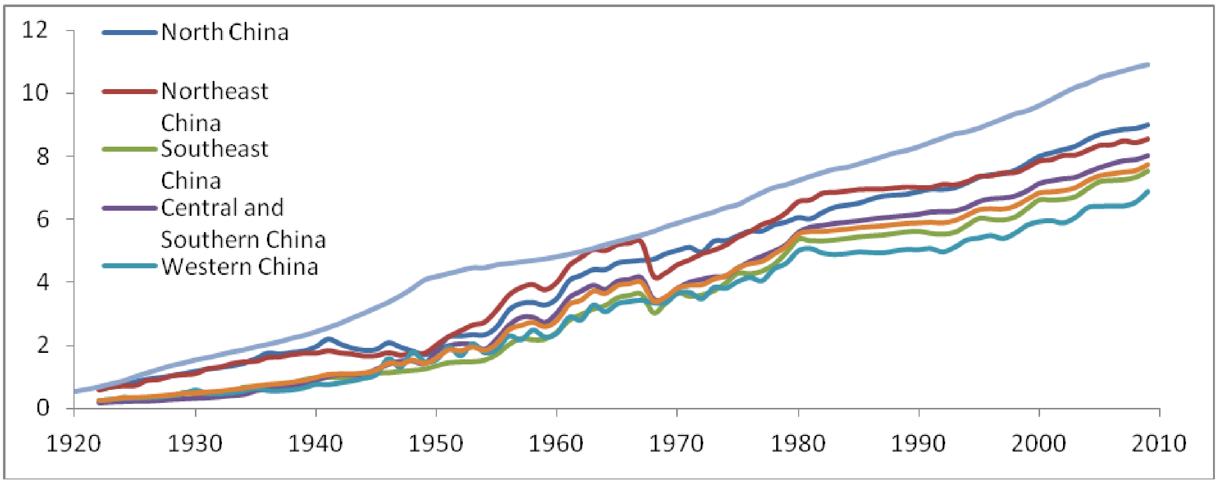
Note: one tail test

China in the twentieth century while, given our previous discussion, clearly the East was gaining.

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 and significant in 2005. One explanation, as pointed out in the introduction, is that, since average years of education may be considered an indicator of the volume of human rather than of its value, this suggests that the quantity of human capital spread through China evenly until after the Cultural Revolution while in terms of the value of (i.e. expenditures on) education the Northern and Eastern parts were in better position.

This lack of spatial correlation in the volume, but the existence of spatial integration in the value of human capital can be captured empirically by estimating an error correction

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.

model (ECM) in autoregressive distributed lag (ARDL) form. Lets' start with the ECM:

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

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 Arrelano 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 log of the value of human capital (i.e. lnhc) 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 OLS		Fixed effect panel 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		
ΔLNHCWEIGHT	0.316	-1.752	0.423	8.424
LNHCWEIGHT(-1)	0.024	2.661	0.049	1.819
ΔAVYEARS	0.628	4.299	1.791	2.243
AVYEARS(-1)	0.029	2.749	0.034	0.663
ΔAVYEARSWEIGHT	-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. 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 physical capital, GDP per capita, and in the quality of human capital over time. This suggests that the accumulation of the factors of production as such did not change much over time across China. This does not mean that there was no policy change, however. For example, average years of education became much more equal across provinces over time. 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

Table 5. Effects on Dlnh using GMM

	1920-1930	1950-1966	1966-1977	1978-1993	1994-2006
LNh(t-1)	-0.661	-0.529	-0.653	-0.174	-0.523
	(-2.52)	(-7.60)	(-6.45)	(-4.38)	(-6.18)
Lnh(t-2)		-0.071			0.211
		(-1.05)			(6.95)
Dlnavyears(t)	3.170	0.505	0.174	0.327	0.730
	(2.06)	(4.17)	(1.68)	(4.39)	(3.88)
LNavyears(t-1)	1.182	0.487	0.084	0.236	0.426
	(1.28)	(5.98)	(1.59)	(4.75)	(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

capital. Only after 1978 we find an increasingly 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 (cost-based) 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. This is a similar observation as made by Heckman (2005) who noted that the richer provinces spent more on education than the poorer ones. Hence, even though the government policy was directed at educating people across the whole of China, human capital as indicated by its value was strongly clustered in the North and East.

On first sight, the finding of a higher level of both factors of production in the East (and North) also implies a lower efficiency of these factors of production. Yet, Li (2009, 219) found that TFP growth was actually highest in the Eastern provinces. Since standard TFP growth includes both technical efficiency and general technical development, it is important to take a closer look of these factors in the next Section.

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 general technological growth?

In order to attempt to answer these questions, 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 $\frac{A}{A_t}$ 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 per capita, human capital per capita, and physical capital per capita. The third to last row 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

Table 6. Factor shares and TFP

	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%

Note: 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.
Source: GDP: National Bureau of Statistics of China (accessed June 2011), National Statistical Bureau, 1999; Physical capital: Wu (2003; 2009); Human capital: This text.

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. This is also what we found in the previous section: economic growth was strongest in those regions where also physical-and human capital was strongest, i.e. the North and East of China. 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 thus rewrite the standard TFP analysis while allowing for technical efficiency differences as follows:

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

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:

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

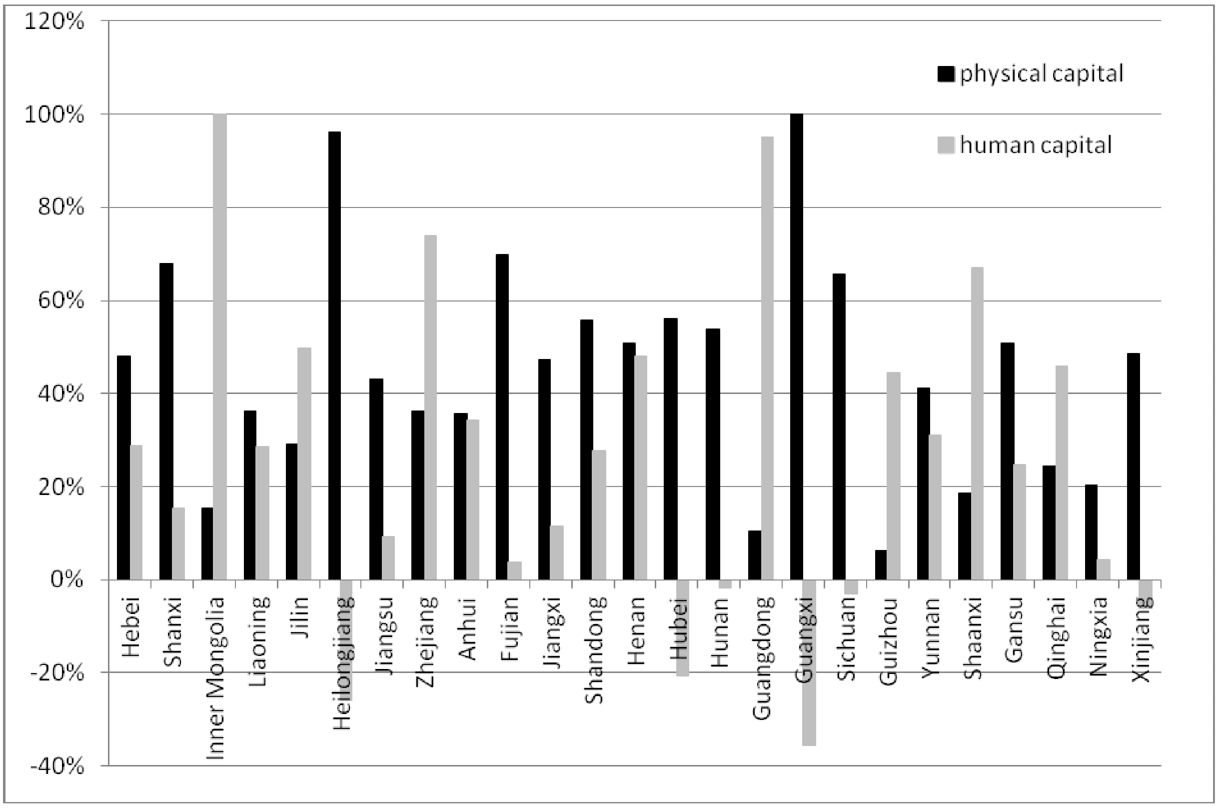
The TFP growth in (4) is not equal to the growth rate of θ (hence, it is not equal to standard TFP accounting) unless:

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

They can be equal for example if the individual coefficient is uncorrelated with the growth of the 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 human capital (see Figure 2). As one can see, the social returns to human- and physical vary a lot by province. However, there are three remarkable findings. First, there is a clear negative correlation between the social returns to human- and physical capital. Indeed, the

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



social rate of returns are highly regional: in the richer areas of the Northeast, Southeast, and Central China the social returns to physical capital are by far the highest, while those of human capital are low. In the West and North of China, with much lower social returns to physical capital, the returns to human capital are much higher. This is remarkable, since levels of per capita human capital are highest in the North and lowest in the West (see Table 2), suggesting it has little to do with diminishing returns to capital. It seems to be clear that the most physical capital intensive (and less human capital intensive sectors caused the main growth spurts, which largely took place in the Northeast and Southwest.

The second interesting finding from Figure 2 is that 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

Table 7. Effects on Dlny using GMM

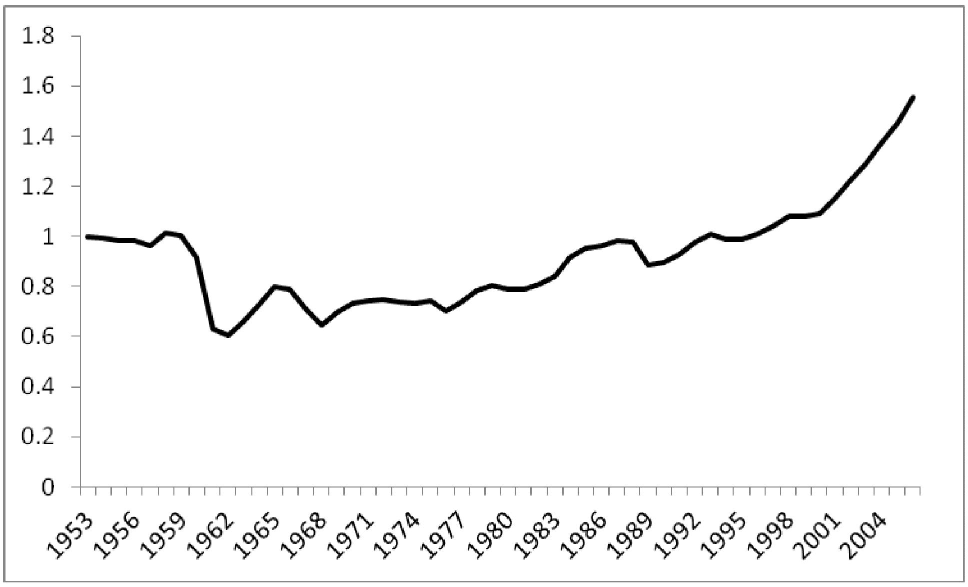
	1950-1966	1966-1977	1978-1993	1994-2006
LNy(t-1)	-0.964	-0.793	-0.993	-0.499
	(-6.99)	(-5.33)	(-4.00)	(-2.01)
Dlnh(t)	0.372	0.068	0.411	-0.016
	(4.14)	(0.41)	(4.67)	(-0.22)
LNh(t-1)	0.255	-0.226	0.343	0.085
	(2.97)	(-1.39)	(3.40)	(1.64)
DLNk(t)	1.797	1.767	1.664	1.400
	(4.93)	(3.56)	(3.08)	(4.18)
LNk(t-1)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

finding of Heckman (2005) that the private returns to 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

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



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 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.

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 empirical studies, however, the relatively fast Chinese growth is explained by both physical capital and TFP growth. Yet, 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. Interestingly, exactly in these regions the social returns to physical capital are also high compared to the Western provinces. In the Western provinces, however, with much less human capital and physical capital, it is the social returns to human capital that are relatively high. This points at a very diverse economic structure in China which is mainly driven by physical capital in the fast growing regions in the East, and by human capital in the slower growing regions in the West.

Using our new dataset on human capital, 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, Shuming, Gene Chang, Jeffrey Sachs and Wing Woo (2002) 'Geographic factors and China's regional development under market reforms, 1978–1998', *China Economic Review* 13: 89–111.

Barro, Robert Jong-Wa Lee (1993) 'International comparisons of educational attainment', *Journal of Monetary Economics* 32(3): 363-394.

Barro, Robert and Jong-Wa Lee (1996) 'International measures of schooling years and schooling quality', *American Economic Review* 86(2): 219-223.

Barro, Robert and Jong-Wa Lee (2001) 'International Comparisons of Educational Attainment: Updates and Implications', *Oxford Economics Papers* 53(3): 541–63.

Barro, Robert and Jong-Wha Lee (2010) 'A New Data Set of Educational Attainment in the World, 1950–2010', *NBER Working Paper No. 15902*.

China Education Yearbook Editorial Department (1986) *Zhong Guo Jiao yu Nian Jian Di Fang Jiao Yu* (*China Education Yearbook Local Education 1949-1984*). Hunan: Hunan Education Publishing House.

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.

Chinese Education Compile Committee (1946) *Di Er Ci Zhong Guo Jiao Yu Nian Jian (The Second Chinese Education Yearbook)*. The Commercial Press.

Chinese Education Department (1946) *Di San ci Zhong Guo Jiao Yu Nian Jian, Taiwan (The Third Chinese Education Yearbook)*. Taiwan.

Chow, G. (1993). Capital formation and economic growth in China. *Quarterly Journal of Economics 108*, 809– 842.

Cohen, Daniel and Marcelo Soto (2007) 'Growth and human capital: Good data, good results', *Journal of Economic Growth* 12(1): 51-76.

Collins, Susan and Barry Bosworth (1996) 'Economic growth in East Asia: Accumulation versus assimilation', *Brookings Papers on Economic Activity, 2*, 135–191.

Department of Planning Ministry of Education The people's republic of China (1984) *Zhong Guo Jiao Yu Cheng Jiu Tong Ji Zi Liao 1949 – 1983 He 1986 – 1990 (Achievement of Education in China Statistics 1949 - 1983 and (1986 -1990)).* China: People's education press.

Directorate - General of Budget, Accounting and Statistics, Executive Yuan, R.O.C.(Taiwan) (2010) *Republic of China Statistics Year book 2009*. Directorate - General of Budget, Accounting and Statistics, Executive Yuan, R.O.C.(Taiwan).

Education Department, Republic of China (1934) *Di Yi Ci Zhong Guo Jiao Yu Nian Jian (The First Chinese Education Yearbook).* Shanghai: Kaiming Press.

Financial Department of National Education Committee, Department of Social Science and Technology Statistics, National Bureau of Statistics of China (2001) *Zhong Guo Jiao Yu Jing Fei Tong Ji Nian Jian 1989 -2010 (China educational Finance Statistical Yearbook 2000)*. China Statistics Press.

Földvári, Peter and Bas van Leeuwen (2009) 'Average years of education in Hungary: annual estimates 1920-2006', *Eastern European Economics* 47(2): 5-20.

General Planning Department of Ministry of Finance (1989) *Zhong Guo Cai ZhengTong Ji 1950 -1988 (China Finance Statistics1950-1988)*. China: China Financial and Economic Publishing House.

Guangxi Education Committee Financial Department (1993) *Guang Xi Jiao Yu Jing Fei Tong Ji Zi Liao (Guangxi educational Finance Statistical Data).* Guangxi: Guangxi Nationality Publishing House.

Hebei Education Department (2009) *He Bei Sheng Jiao Yu Jing Fei Tong Ji Zi Liao Hui Bian 1949 – 2008 (Hebei Province Educational Expenditure Statistical Data Assembly 1949-2008).* Hebei: Hebei People Publishing House.

Heckman, James (2005) 'China's human capital investment', *China Economic Review* 16(1): 50-70.

Hossain, Shaikh (1997) 'Making Education in China Equitable and Efficient', *Policy Research Working Paper No. 1814*, Washington, DC, World Bank.

Hou, Yangfang (2001) *Zhong Guo Ren Kou Shi Di Liu Juan 1910 -1953 (China Population History The Sixth Volume 1910-1953)*. Fudan: Fudan University Press.

Hu, Zuliu and Mohsin Khan (1997) 'Why is China growing so fast?' *IMF Staff Papers*. Washington, DC: International Monetary Fund.

Judson, Ruth (2002) 'Measuring Human Capital Like Physical Capital: What Does It Tell Us?' *Bulletin of Economic Research* 54: 209-31.

Krugman, Paul (1994) 'The myth of Asia's miracle', *Foreign Affairs* 73: 62–78.

Krugman, Paul (1997, August). What happened to the Asian miracle? (see http://www.pkarchive.org).

Li, Guilin, Mingxiu Qi, and Manqian Qian (1995) *Zhong Guo Jin Dai Jiao Yu Shi Liao Hui Bian (Collection of Chinese Modern Education information).* Shanghai: Shanghai Education Press.

Li, Kui-Whai (2009) 'China's total factor productivity estimates by region, investment sources and ownership', *Economic Systems* 33(3): 213-230.

Li Jingwen, Dale Jorgenson, Zheng Youjing, and Masahiro Kuroda (1993) *Productivity and economic growth in China, United States and Japan*. Beijing: Chinese Social Science Press.

Liu, Zhiqiang (1998) 'Earnings, Education and Economic Reforms in 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.

Marquetti, Adalmir and Duncan Foley (2011) 'Extended Penn World Tables: Economic Growth Data on 166 Countries', http://homepage.newschool.edu/~foleyd/epwt/
Mitchell, Brian (1999) *International historical statistics: Africa, Asia & Oceania, 1750-1993*. London [etc.]: Macmillan.
Morrisson, Christiaan and Fabrice (2009) 'The Century of Education', *Journal of Human Capital* 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).
National Bureau of Statistics of China, Population Statistics Department and Ministry of Public Security, The Third Bureau (1988) *Zhong Hua Ren Min Gong He Guo Ren Kou Tong Ji Zi Liao Hui Bian 1949 -1985 (People of Republic of China Population Statistic Data Collection 1949-1985).* China Financial & Economy Publishing House.
National Statistical Bureau (1999) *Comprehensive statistical data and materials on 50 years of New China 1949–1998*. Beijing: Finance and Economic Publishing House.
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).
Society Statistics Department, National Bureau of Statistics of China (1994) *Zhong Guo She Hui Tong Ji Zi Liao 1993 (China Social Statistics Data 1993)*. Beijing: Xinhua Bookstore Beijing Publishing House.
Taiwan Government Statistics Office (1946) *Tai Wan Sheng Wu Shi Yi Nian Lai Tong Ji Ti Yao (51 Years Data Collection in Taiwan Province).* Jinxue Publishing House.
Thomas, Vinod, Yan Wang and Xibo Fan (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 (2012, forthcoming) 'Capital accumulation and growth in Central Europe, 1920-2006', *Eastern European Economics* (forthcoming).
Van Leeuwen, Bas and Peter Földvári (2008) 'Human Capital and Economic Growth in Asia 1890-2000: a time-series analysis', *Asian Economic Journal* 22(3): 225-240.
Wang, Yan and Yao, Yudong (2003) 'Sources of China's Economic Growth 1952-1999: incorporating human capital accumulation', *China Economic Review* 14(1): 32-52.
Wei, Chi (2008) 'The role of human capital in China's economic development: Review and new evidence', *China Economic Review* 19(3): 421-436.
Wei, Xin, Mun Tsang, Weibin Xu and Liang-Kun Chen (1999) 'Education and Earning in Rural China', *Education Economics* 7(2): 167-187.
Whalley, John and Xiliang Zhao (2010) 'The Contribution of Human Capital to China's Economic Growth', *NBER Working Paper No. 16592*.
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: Routledge Curzon Press Limited.
Yin, Mengxia, and Tian Qi (2009) *Min Guo Ren Kou Hu Ji Shi Liao Hui Bian 2 (Republic of China Population and Household Historical Data Collection Volume 2)*. National Library of China Publishing House.
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.