Inspiration versus perspiration in economic development of the Former Soviet Union and China (ca. 1920–2010)[1]

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Abstract

Here we discuss the role of both perspiration factors (physical and human capital) and inspiration factors (Total Factor Productivity; TFP) in the economic development of the Former Soviet Union area (FSU) and China, ca. 1920–2010. Using a newly created dataset, we find that during the socialist central-planning period, economic growth in both countries was largely driven by physical capital accumulation. This finding follows logically from the development policies in place at that time. During their transition periods (i.e., starting from the late 1970s in China and the late 1980s in the FSU), China managed to keep technical inefficiency of production factors in check, largely by massively increasing its human capital, thereby lowering the physical-to-human capital ratio. In contrast, the FSU accomplished a similar outcome largely through reducing its stock of physical capital. As a result, although there was little difference in technical efficiency between these two economies, China's emphasis on human capital formation made it easier for this country to improve its general productivity and to increase per capita growth. This changed in the late 1990s and early 2000s, when the FSU began to recover economically, regaining its 1990 levels of output and productivity.

JEL classifications: N34, N35, O52, O53, P24

Keywords: Physical capital, human capital, productivity, technology, economic development, socialism, USSR, China

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1. Introduction

There is an on-going and lively debate on whether it is inspiration factors (here, Total Factor Productivity; TFP) or perspiration factors (factors of production; physical[2] and human capital) that drive economic development (see, for example, Krugman, 1994). For both China (Chow, 1993; Li *et al.*, 1993; Wang and Yao, 2003; Whalley and Zhao, 2010) and, to a lesser extent, Russia and the FSU[3] (Easterly and Fischer, 1995; Meliantsev, 2004) it has been argued that economic development in the period up to the 1980s was largely driven by perspiration factors, while the economic transitions experienced by both countries resulted in enhanced growth potential based on technical developments.[4]

A detailed quantitative analysis comparing these two vast socialist economies is still lacking. Therefore, in this paper we analyse economic development in both China and the FSU from a production-factor perspective. In Section 2 we provide a brief summary of estimates of human and physical capital, as well as an analysis of their role throughout the economic history of the FSU and China. We find that, until the reforms away from the existing socialist models were launched, both the FSU and China experienced a more rapid accumulation of physical capital than human capital, as well as less rapid economic growth in terms of per capita Gross Domestic Product (GDP). In hindsight, one might argue that this policy of physical capital accumulation was detrimental for both economies, and question why these countries chose such a path. This question is dealt with in Section 3 using a one-sector model developed by Foldvari *et al.* (2013), in which the government can strive to maximize material output, consumption, or a combination of both. Since material output generally requires more physical capital investment, the preference in socialist economies for material output requires a rise in the physical-to-human capital ratio. However, after their reforms, the focus in both countries shifted to more consumption goods (which were human-capital intensive), making growth in human capital increasingly important for an increase in per capita GDP. To succeed economically during the post-reform period, both China and the FSU had to change their methods of production, increasing their human capital relative to their physical capital.

It should be noted that the analysis in Section 3 only focuses on the direct effects of human and physical capital (perspiration factors), despite the fact that economic growth may also take place via TFP (inspiration) growth. Inspiration growth can raise the technological frontier, thereby increasing the maximum possible output given a certain amount of human and physical capital; alternatively, it can increase the efficiency of human and physical capital, bringing output closer to the maximum possible output given the existing technological frontier and limited physical and human capital. Therefore, in Section 4 we discuss the contribution of inspiration to growth. We find that the initial post-reform decline in technical efficiency was about equal in both countries, and that, in both countries, this drop was softened by a relative increase in the amount of human capital, which allowed these economies to make better use of existing physical capital. However, while China increased its human capital relative to its physical capital, in the FSU a drop in physical capital was largely responsible for the decrease in the physical-to-human capital ratio. In light of this information, it should come as no surprise that, with a decline in physical and, to a lesser extent, human capital, the technical frontier in the FSU regressed during the first few years following

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[2] We employ national accounts statistics for which *fixed capital* is the standard term. While *physical capital* is the preferred term in theoretical literature, both terms denote the same construct.

[3] The former Soviet Union (FSU or ex-USSR) is the mostly commonly used term for this area, and is therefore used throughout the present paper for all time periods and for all territorial makeups of both the USSR and the Newly Independent States (NIS) that followed the collapse of the USSR.

[4] There are also scholars (for example, Acemoglu and Robinson, 2012) who argue that, before the transition, economic growth in both countries was driven by movements of production factors from one economic sector to another.

reforms, a trend which only changed in the late 1990s and early 2000s. This offers a stark contrast to China, where the general technology frontier expanded considerably shortly after reforms.

In sum, China invested massively in both physical and human capital following the reforms. By increasing its human-to-physical capital ratio, China minimized the negative impact on technical efficiency. At the same time, China increased its productivity, both directly, via perspiration factors (physical and human capital), and indirectly, via inspiration (the attraction and development of new technologies). The FSU, on the other hand, limited declines in technical efficiency mainly through reducing its stock of physical capital, thereby reducing perspiration-driven growth and limiting the introduction of new technologies. These major strategy distinctions suggest significant differences between China and the FSU in the way they have dealt with their economic reforms.

2. Data

Over the past few years, more and more data have been made available regarding human and physical capital, and GDP for socialist countries in the twentieth century. Estimates of GDP for China are taken from Maddison (2007; updated data are available online http://www.ggdc.net/MADDISON/oriindex.htm) and from the National Statistical Bureau (1999) for individual Chinese provinces. For the USSR and Russia, per capita GDP is drawn from Didenko *et al.* (2013); these data are based on the official statistics, secondary literature, and, in the case of the other FSU countries, on information from the World Bank (2011).

Gross physical capital for China as a whole, as well as for its provinces, is taken from Wu (2004, 2009); for the USSR from Didenko *et al.* (2013) and CIS Stat (2011); and for the remainder of the FSU area from Extended Penn World Tables v. 4.0 (Marquetti and Foley, 2011). The cost-based human capital measure for China is taken from Van Leeuwen *et al.* (2011), and for the FSU up to 1989 from Didenko *et al.* (2013). For the period after 1970, the cost-based human-capital measure calculated in the present paper was based on data from UIS UNESCO (2012), UNSD (2012a), and CIS Stat (2011) (for more details please see the Appendix).

One important issue as regards to these data is the price deflator. For better comparability we took the national income data produced from a Western concept. This means that potentially the growth is a bit lower than the socialist alternative, Net Material Product. This has two reasons. First, because the concept is different as the Net Material Product excludes parts of the service sector. Secondly, because of the hidden inflation. This latter is also a problem for the capital series used. Hence, as pointed out by Gomulka (1988), dealing with data series on output and fixed capital, that are derived from different sources and therefore used different price deflators, is potentially misleading. For our calculations which combine capital and national income, it is thus important to get a handle on the hidden ('disguised' or 'concealed') inflation.

Hidden inflation is frequently discussed in the previous literature on the Soviet growth accounting. The consensus opinion is that official Soviet figures are irrelevant as they strongly underestimate inflation. 'Western' estimations of the Soviet national income real growth rates vary though not so much relative to the official figures (the latter are much higher than all of the 'Western' estimations), as it follows from their comparison for the most important period of 1927/28-1955 in Harrison (2000). In the case of China Maddison and Wu (2008) showed that the growth rates of official estimates were only for certain periods overestimated. Nevertheless, since for both countries we use the Western estimates, this causes no problems.

The question that remains is whether hidden inflation may affect the capital stock estimates. For China, the past studies mainly relied on semi-official series (e.g. Shi et al. 1984; Qin et al. 1986). Yet, the problem was that these studies combined deflated fixed capital over past years with current price capital in the present year, hence creating a mix of current and constant prices. Therefore, more recently researchers have constructed series based on the Western system (e.g. Chen et al. 1988; Wu 2009). Practically, they have deflated the capital stock using sector specific regional price indices back to 1978. Since before 1978 such data do not (abundantly) exists, region and sector specific GDP deflators are being used to bring the regional price indices further back in time. This is important, since it was only from the 1980s onwards that prices of consumer goods tended to rise much more than those of capital goods.

A similar method has been applied to the FSU area. In exploring the mechanisms of inflation generation under centralised price setting some authors (Kontorovich, 1989; Kushnirsky, 1989) stressed the leading role of the producers, primarily of capital goods. Indeed, in late Soviet Union prices for investment goods outperformed those for consumer goods. E.g., for the period 1955-1975 GDP deflator is estimated at 141.4% (Didenko et al., 2013) versus 129.5% in retail price index (Schroeder and Severin, 1976). However, this was not always the same case. In the 1930s-1940s the pattern was quite the opposite: from comparing the price indices derived in Didenko *et al.* (2013) from Moorsteen and Powell (1966) for capital goods and from Bergson (1961) for the whole economy (GNP) it follows that during that period prices for consumer goods grew more rapidly than for capital.[5] The problem lies in that we have insufficient information on capital goods price indices for each period. Therefore we deflated all the series employed with the same (GNP/GDP) price index from Didenko *et al.* (2013).

Our resulting estimates of human- and physical capital and GDP are reported in Table 1, below. They are given by region in both the FSU and in China. Both countries recorded a remarkable growth of per capita physical and human capital, although this growth was distributed unequally among

Table 1. Per capita GDP, human capital, and physical capital in the FSU and China in 1990 (Geary-Khamis dollars)

		1930s*			1980s**			2000s***		
		GDP/cap	K/cap	H/cap (cost-based)*****	GDP/cap	K/cap	H/cap (cost-based)	GDP/cap	K/cap	H/cap (cost-based)
Ex-USSR		1,247	1,547	1,649	6,753	30,432	12,337	6,013	19,894	12,305
Republic	Armenia			1,634	5,434	21,333	20,007	7,768	14,591	13,718
	Azerbaijan			1,856	4,942	17,793	10,063	4,168	17,422	7,545
	Belarus			1,298	5,554	27,216	10,763	8,969	22,441	25,517
	Estonia				10,630	40,003	27,826	16,065	55,840	44,458
	Georgia			1,930	9,355	22,933	16,004	4,484	10,037	6,696
	Kazakhstan			2,517	8,104	30,300	13,641	7,996	15,172	10,206
	Kyrgyzstan			1,730	3,184	16,114	12,496	2,439	7,573	4,845
	Latvia				9,278	35,690	21,841	11,374	39,959	29,856
	Lithuania				8,538	33,013	16,777	8,736	30,775	23,108
	Moldova				5,679	21,148	11,783	3,095	17,541	11,706
	Russia			1,931	7,308	36,218	12,761	6,943	23,384	12,304
	Tajikistan			1,563	3,214	12,830	7,804	1,228	1,912	1,428
	Turkmenistan			2,483	3,614	21,696	10,593	3,137	10,959	NA
	Ukraine			1,083	5,585	26,399	11,492	3,893	22,266	10,037
	Uzbekistan			1,111	4,124	15,498	7,863	4,151	5,383	25,183
China		570	515****	9.2	1,453	2,080	827	4,710	12,705	8,572
Province	Hebei			26.1	1,892	2,571	1,863	9,404	50,447	15,784
	Shanxi			53.9	1,349	1,693	1,511	5,941	20,971	7,371
	Inner Mongolia			2.9	1,456	1,884	2,153	7,279	14,316	12,339
	Liaoning			49.5	2,470	3,079	2,397	9,131	16,488	15,883

[5] In the 1930s the prices in the whole economy 2.31 times lagged behind the prices of capital goods, and 1.21 times in the 1940s.

	1930s*			1980s**			2000s***		
	GDP/cap	K/cap	H/cap (cost-based)*****	GDP/cap	K/cap	H/cap (cost-based)	GDP/cap	K/cap	H/cap (cost-based)
Jilin			25.9	1,583	1,753	1,833	6,667	9,455	12,423
Heilongjiang			21.8	1,897	3,026	1,741	6,960	12,552	11,765
Jiangsu			12.6	2,820	5,463	1,202	13,202	47,499	20,173
Zhejiang			6.2	1,804	1,917	899	12,014	23,315	15,928
Anhui			0.6	1,033	1,495	580	4,643	12,254	6,257
Fujian			3.4	1,299	1,708	827	9,612	17,978	10,201
Jiangxi			1.3	991	1,277	549	4,396	6,511	5,175
Shandong			5.8	1,420	1,729	827	9,111	15,952	11,322
Henan			0.7	910	1,279	793	5,588	9,008	6,907
Hubei			5.8	1,293	1,848	1,157	5,208	15,408	8,932
Hunan			2.9	1,101	1,477	901	4,303	7,987	8,363
Guangdong			5.7	1,810	1,923	1,866	11,498	6,184	18,891
Guangxi			7.0	831	1,009	1,202	4,053	4,311	6,359
Sichuan			3.2	956	1,216	905	4,109	4,347	7,365
Guizhou			0.7	688	706	499	2,238	3,003	3,060
Yunnan			5.0	858	912	720	3,412	4,111	4,772
Tibet			NA	1,299	2,316	436	3,780	30,719	1,152
Shaanxi			5.6	1,025	1,351	889	4,535	7,071	7,992
Gansu			2.1	1,026	1,161	2,442	3,332	4,223	3,522
Qinghai			10.7	1,375	1,618	1,013	4,812	4,697	4,844
Ningxia			5.4	1,266	1,424	1,251	4,746	4,571	7,130
Xinjiang			0.3	1,352	1,492	1,773	5,479	7,512	11,866

** For the USSR and its republics, H/cap (income-based) refers to 1940, H/cap (cost-based) to 1939, and other items to the 1930–1939 average.*
*** Average of 1980–1989 for the USSR and its republics; H/cap (cost-based) is an average of 1979 and 1989.*
**** Average of 2000–2008 for the republics of the former USSR.*
***** Capital stock in China prior to 1950 is taken from Wu (2012). Used with permission from the author.*
****** Human capital stock in China before 1950 only refers to modern education, as it was established at the end of the 19th century.*

their constituents (union republics in the USSR, provinces in China). These two countries also managed to initially converge with economically advanced countries (Western Europe and its offshoots in North America and Oceania, and, in recent decades, Japan), but fell behind again since the 1970s (see, for example, Van Leeuwen and Foldvari, 2008b). We can also observe that the USSR outperformed China in per capita GDP growth rates between the 1930s and 1990s, despite China's lower level of economic development. This could likely help to explain the longevity of the central-planning (also often referred to as the "command") system in the USSR, as well as the earlier start of market-oriented economic reforms in China. However, the situation changed after the collapse of the USSR: in the 2000s, most of the FSU had not recovered from the deep downturn that accompanied their systemic economic and political transformation in the 1990s, while China managed to substantially bridge the gap in per capita income with the FSU.

Table 1 also provides us with information on the causes of this pattern. We can see that, in the FSU before the reforms (from the 1930s to the 1980s) per capita physical capital growth outperformed that of human capital, which, in its turn, increased faster than GDP per capita in both countries. In the 1950s, the Chinese communist government adopted a policy of physical capital accumulation, similar to that of the FSU. However, in China this policy was already corrected by the 1960–1970s, after the failure of the Great Leap Forward. We clearly observe from Table 1 that, during the reform period, which started in China in the late 1970s, China's human capital rose faster than its physical capital, although its GDP/cap growth was still slower than either of these factors, implying negative TFP growth. In the FSU from the 1980s to the 2000s, while physical capital decreased dramatically (about halving), human capital appeared, on average, to be slightly better (in large part due to Russia, which, due to its large population, has a weight in the FSU of about half), although it did not recover in about half of the FSU countries. During this time, GDP per capita was close to recovery, although in some areas of the FSU it was far below its pre-reform level.

This development begs the question of why these countries clung to physical capital accumulation before the reforms, with all the associated positive and negative effects on growth before the reforms. We will discuss this in the following section. In addition, in both China and the FSU after the reforms there were regions that, relatively, or even absolutely, regressed in terms of human and physical capital. This increasing inequality affected both the efficiency of these factors in these regions, as well as the introduction of new technologies, a topic dealt with in Section 4.

3. The changing structure of factor accumulation (physical-to-human capital ratio)

Based on the information presented in the previous section, it is clear that physical capital before the reforms cannot be disregarded as a growth factor. Its excessive accumulation would eventually lead to a collapse of its value in the FSU when market reforms were launched, and slower growth in China after the Great Leap Forward (1958–1961). However, readers may wonder why this focus on physical capital existed if it had such adverse effects, and why these patterns eventually led to structural policy changes during the reform period.

The answers to these questions are probably best analysed based on the idea that state-socialist regimes, which follow a Marxist-influenced economic policy, have a tendency to value capital goods, which require relatively more material goods, above consumer goods, which require a different mix of material and immaterial goods. Since material goods are likely to be produced in a more physical, capital-intensive way than immaterial goods, this leads to a higher ratio of physical-to-human capital along the optimal growth path of the economy. This necessarily comes at the price of reduced consumption, of both tangible and intangible goods. Once a state-socialist regime starts to put more emphasis on the production of consumer goods relative to capital goods—likely thanks to growing social tensions arising from low consumption—its physical-to-human capital ratio should necessarily decrease.

These ideas were formalised in the model developed by Foldvari *et al.* (2013) based on an optimization approach taken from Barro and Sala-i-Martin (2004, Chapter 5, A.3.3 and A.3.5). In this model, there is neither endogenous growth nor exogenous productivity (TFP). Once the steady state is achieved, both per capita income and consumption will be constant. The social planner's problem is to maximize the utility value along the optimal path of economic development, given his preferences, as well as certain conditions and constraints. This optimal path is expressed by the following Hamiltonian function:

$$J = e^{-\rho t}\left(a \ln q_t^m + b \ln c_t\right) + \lambda_1\left(q_t^m + q_t^i - c_t - I_k^i - I_h^i - (\delta+n)k_m\right) + \lambda_2\left(I_k^i - (\delta+n)k_i\right) + \lambda_3\left(I_h^m - (\delta+n)h_m\right) + \lambda_4\left(I_h^i - (\delta+n)h_i\right) \quad (1)$$

where:
J = utility value along the optimal path of economic development;
ρ = discount factor;
t = point in time (assumed to be continuous with an infinite horizon);
a and b = parameters reflecting the preferences of the planner regarding material production and consumption (assumed to be positive);
q = per capita production;
c = per capita consumption;

m and i = super- and subscripts denoting the two sectors of production (material and immaterial);
λ = shadow prices[6];
I = gross investment during the period dt;
k = physical capital stock;
h = human capital stock;
δ = rate of depreciation; and
n = growth rate of the labour force.

With the above Hamiltonian function we arrive at the general formula of physical-to-human capital ratio when a planner derives utility both from consumption and material production:

$$\frac{k_t}{h_t} = \frac{\frac{\gamma}{1-\gamma} + \left(\frac{\rho+\delta+n-\left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}}{\rho+\delta+n-\left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}} \right) \frac{\beta(a+\alpha b)}{b(1-\gamma)(1-\alpha)}}{1+\left(\frac{\rho+\delta+n-\left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}}{\rho+\delta+n-\left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}} \right) \frac{(1-\beta)(a+\alpha b)}{b(1-\gamma)(1-\alpha)}} \tag{2}$$

where, in addition to the notation provided for Equation 1:
α = elasticity between material and immaterial consumption;
β = elasticity between physical and human capital in the material sectors of production; and
γ = elasticity between physical and human capital in the immaterial sectors of production.

Essentially, this is just the standard physical-capital to human-capital ratio in the model developed by Barro and Sala-i-Martin (2004),

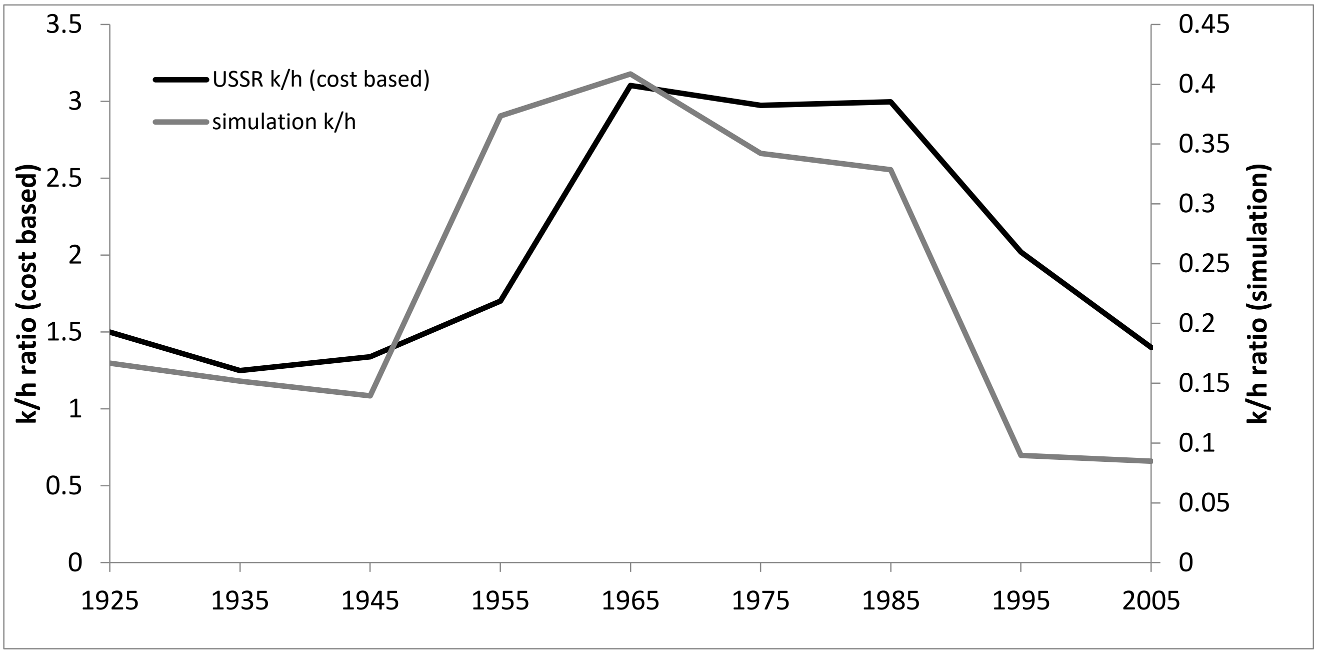
$$\frac{k_t}{h_t} = \frac{\theta}{1-\theta} \tag{3}$$

with θ being the weighted average of the elasticities between physical and human capital in the material and immaterial sectors. The only difference is that we allow for changing planner preferences. Hence, if we set the preferences of the planner (here, the coefficients of the model) in such a way that they resemble socialist and capitalist development policy, the model will theoretically return the approximate physical-to-human capital ratio in both economies.

We undertook this exercise in Figures 1 and 2, below. In the 1930s, the highest political leadership of the USSR spent more time focusing on consumption than on any other issue (Gregory, 2003, p. 94). The government expressed its interest in positive incentives for the labour force, who tended to abstain from working at their margin if their wage fell below the perceived fair level. The famine of 1932 also forced the authorities to temporarily allocate more resources to consumption at the expense of investments. Hence, for this period we set the coefficient values to account for that

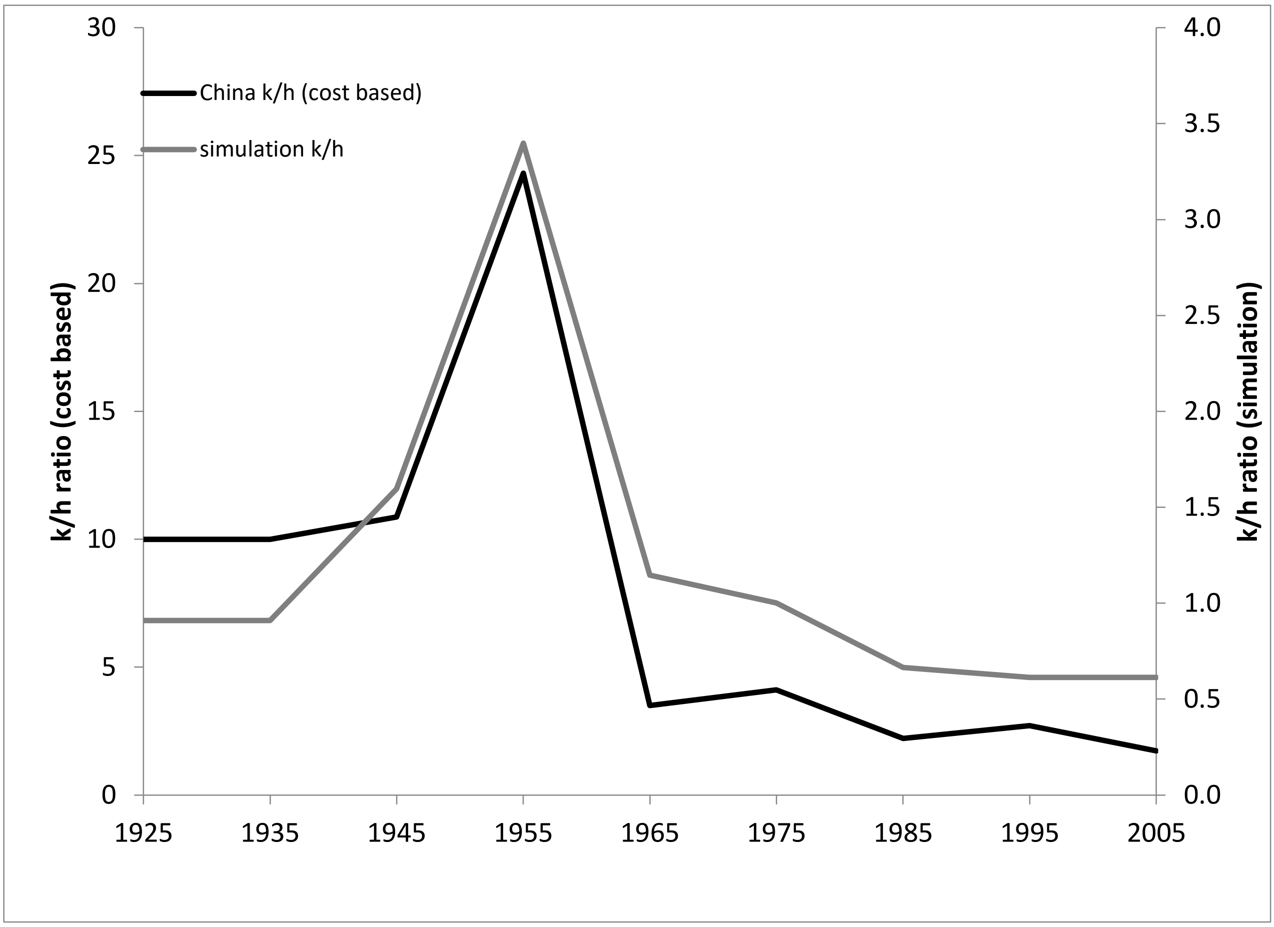
[6] The *shadow price* can be understood as the effect of an infinitesimally small change in the constraint on the value of the value function. Alternatively, it expresses how much the planner would be willing to pay, along the optimal path, for another unit of a production factor. Along the optimal path the effect of all factors of production on the value function should be equal, meaning that λ1–λ4 are equal.

Figure 1. Simulated and actual physical-to-human capital ratio in the FSU, 1925–2005



Notes. Assumptions: ρ = 0.02; δ = 0.07; n = 0.01;
1920–1940: a = 1; b = 3; α = 0.6; β = 0.3; γ = 0.2;
1950s: a = 2; b = 1; α = 0.6; β = 0.4, γ = 0.2;
1960s: a = 3; b = 1; α = 0.6; β = 0.4, γ = 0.2;
1970s and 1980s: a = 2; b = 1; α = 0.6; β = 0.4, γ = 0.2; and
1990s and 2000s: a = 1; b = 2; α = 0.5; β = 0.3, γ = 0.2.

Figure 2. Simulated and actual physical-to-human capital ratio in China, 1925–2005



Notes. Estimated for 1925 are made by multiplying the cost-based human-capital stock formed in modern education by 2.5 (to calculate total average years) and by 2 (to correct for more expensive traditional education; see Xu *et al.*, 2013).
Assumptions: $\rho = 0.02$; $\delta = 0.07$; $n = 0.01$;
1920s–1930s: $a = 2$; b = 3; $\alpha = 0.5$; $\beta = 0.3$; $\gamma = 0.2$;
1940s: $a = 3$; b = 2; $\alpha = 0.5$; $\beta = 0.3$; $\gamma = 0.2$;
1950s: $a = 3$; $b = 1$; $\alpha = 0.5$; $\beta = 0.5$, $\gamma = 0.2$;
1960s: $a = 2$; $b = 2$; $\alpha = 0.5$; $\beta = 0.5$, $\gamma = 0.2$;
1970s: $a = 2$; $b = 2$; $\alpha = 0.4$; $\beta = 0.4$, $\gamma = 0.2$;
1980s: $a = 2$; $b = 3$; $\alpha = 0.4$; $\beta = 0.4$, $\gamma = 0.2$; and
1990s and 2000s: $a = 1$; b = 3; $\alpha = 0.4$; $\beta = 0.3$, $\gamma = 0.2$.

policy. This changed, however, after the 1930s. We also assume that, after the 1980s, with the collapse of the centrally planned economy, the utility function maximized consumption. For China, the change towards a focus on consumption maximization started much earlier and was slower, beginning in the 1960s–1970s.[7] During the Cultural Revolution (1966–1976) China likely faced problems related to poor consumption, similar to those faced by the USSR during the forced industrialisation and collectivisation of the 1930s; the Chinese leadership addressed these problems in similar ways to the USSR.

It remains to be tested whether this focus on capital accumulation indeed led to higher GDP/cap for both countries (including their constituent parts). In principle, faster growth of physical capital per capita can, in one-sector growth models, lead to faster economic growth. For this reason, we expected to find that an increase in the *k/h* ratio led to a higher level of per capita GDP, as decreasing returns on capital should lead to zero growth in the long run (as in the case of all Solowian-type models), except when growth is driven by an exogenous process. Hence, the level

[7] The Great Leap Forward (1958–1961) is a symbol of a drive for massive physical capital accumulation in China; for this reason, it is considered an outlier and is not considered as a separate point in Figure 2.

of *k/h* affects the level of per capita income, but has only a transitory effect on growth. Since the material sector, which was stimulated during socialist planning, was also the most physical-capital intensive, it follows from the above model that, during the central-planning period, the effect of the *k/h* ratio on aggregate income level must exceed that of market-reform periods, which were characterised by higher levels of the non-material sector (other inputs being equal). Results are reported in Table 2, below. We find that, as expected, the *k/h* ratio had a positive, even though insignificant, effect on per capita GDP prior to the reforms in the case of China which was evidently at an earlier stage of industrialisation than the USSR in 1950-1990. Yet, after the reform period it turned negative as expected. That is, the increase in the *k/h* ratio dampened economic growth and vice versa – extending share of human capital had pro-growth effect.

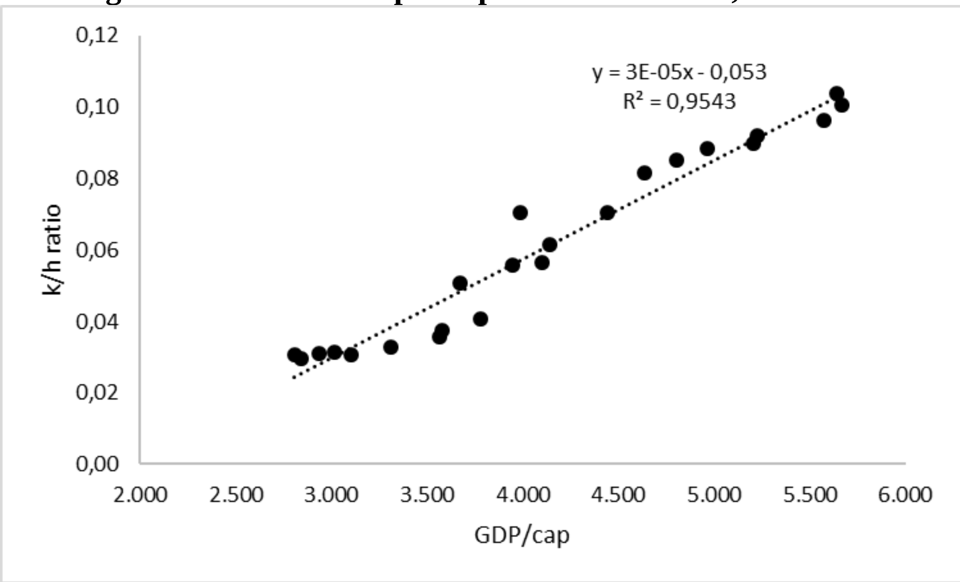
Also it was the case in the FSU but this effect was insignificant there during the immediate pre-reform period. This can be seen in Table 2 which uses panel data. However, since the data on the Republics are only available for the period after 1970, the period is biased to the immediate pre-reform period. This period is characterised by a basically completed transition to a modern industrial society and an economic growth slowdown while the period of 1950s – early 1970s appeared to be the zenith of industrialisation and rapid growth in material sector supported by fixed-capital accumulation and migration from rural to urban sector. Hence, we expect that, if we were to run the same regression for the FSU area between 1950 and 1970, we were to find a positive effect of the *k/h* ratio on per capita GDP turns out to be positive. Unfortunately, as pointed out, we only have estimates for the USSR as a whole which prevents us from doing a panel regression. Yet, Figure 3, reporting a scatterplot of the available data, indeed shows a strong positive relation between the *k/h* ratio and per capita GDP thus confirming our expectations. For the transition period (i.e. after 1990) we find, just as we did for China, that the effect of the *k/h* ratio on per capita GDP turns negative due to the increased importance of human capital for economic growth.

Table 2. Fixed effect panel regressions of per capita GDP on the log of *k/h* ratio

	(ex-)USSR		**China**	
	1950–1990	**1990–2010**	**1953–1979**	**1980–2000**
Constant	-23.1	-35.1	-65.3	-129.9
	(-3.04)	(-2.99)	(-14.0)	(-17.47)
year	0.016	0.022	0.036	0.069
	(4.19)	(3.70)	(15.4)	(18.5)
ln(k/h ratio)	**-0.066**	**-0.116**	**0.014**	**-0.157**
	(-0.66)	(-3.21)	(0.59)	(-3.11)
R^2	0.476	0.202	0.751	0.911
N	182	262	325	464

Note: Heteroscedasticity and serial correlation robust standard errors in parentheses.

Figure 3. k/h ratio and per capita GDP in USSR, 1950-1970



In both the FSU and China, the increase in physical, relative to human, capital in the central-planning period was based on economic models that aimed at rapidly stimulating industrialisation. Based on these models alone, there is no reason to assume that this growth path could not have been sustained. However, in both countries, the system ultimately failed. One of the reasons why such kinds of growth appear to be unsustainable is the difference in physical and human capital potential to produce external economic and social effects. Indeed, it is widely recognised that human capital preponderates over physical capital in this respect. Since the social returns on fixed capital are likely to be lower than those on human capital, the same amount of resources spent on increasing physical rather than human capital leads to a lower rate of economic growth.

Indeed, we find that just before the start of economic reforms in the FSU, when the physical-capital to human-capital ratio increased, per capita GDP growth decreased. During this period, human capital was necessary to increase GDP per capita due to the greater importance of the non-material (human-capital intensive) consumer sector. Therefore, when human-capital intensive, and physical-capital extensive, sectors were on the rise, an increase in the physical-to-human capital ratio became negative or insignificant. In other words, the negative coefficient after the transition to a market economy can be seen as the sign of the *k/h* ratio converging to a lower equilibrium value, caused by increased demand for human-capital intensive consumer products. These findings are consistent with other studies on this relationship (see, for example, Erk, Altan Cabuk, and Ates, 1998; Duczynski, 2002, 2003).

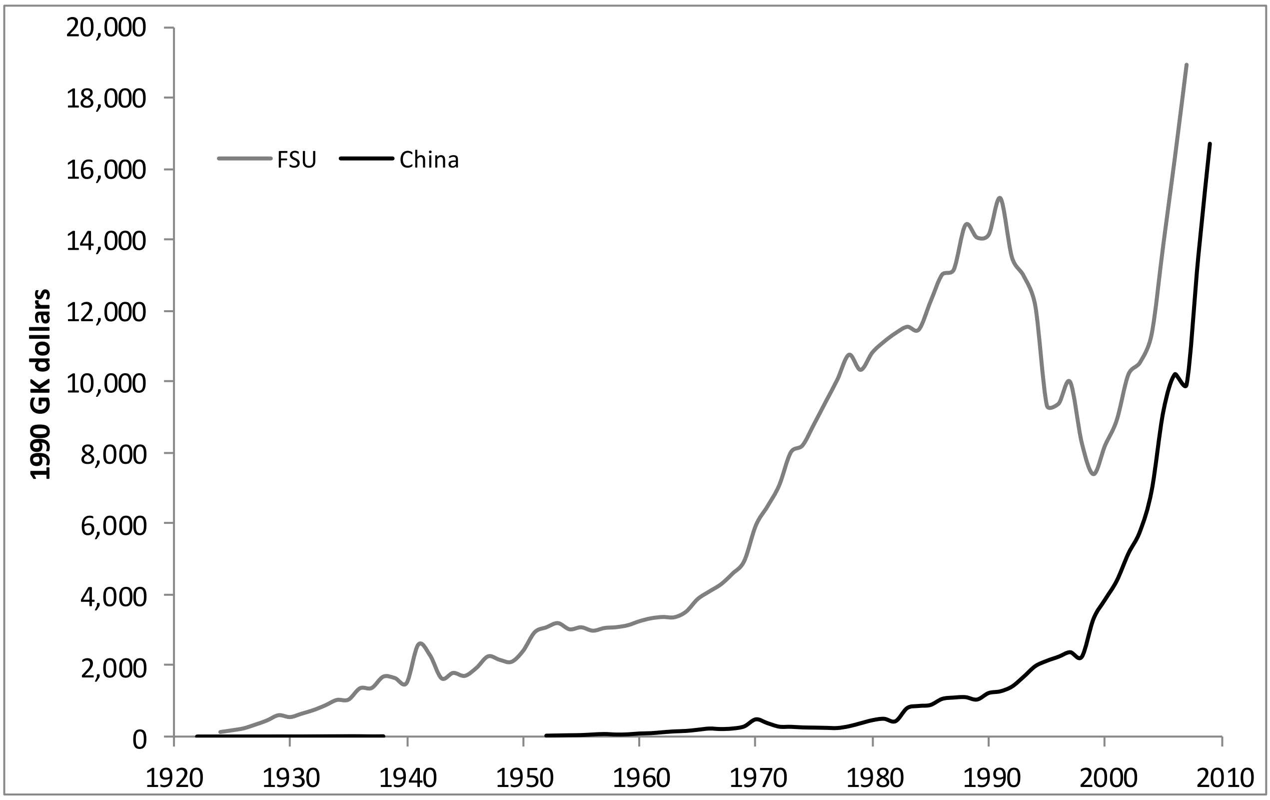
However, so far our interpretation has focused only on the perspiration factors; that is, how human- and physical capital could have opposite effects on economic growth due to different policy perspectives before and after reforms. Yet, economic growth may also stem from inspiration factors (here, TFP). This will be discussed in the upcoming section.

4. Growth in GDP, TFP, and factor accumulation in the FSU and in China: Walking different paths?

The previous section concluded on a potentially positive note: more human capital apparently increased GDP/cap after the reform period. Since human capital is assumed to also influence growth in the long run (here, TFP growth), this seems to be good news for both China and the FSU, since both countries were ultimately able to substantially increase their levels of human capital (see Figure 4).

Both the USSR and China started with a low-cost-based human-capital measure. However, while China started from almost nothing, the USSR more resembled Europe, as it already had a considerable human-capital base in the 1920s. Further, the USSR quickly caught up to Europe in

Figure 4. Cost-based human capital per capita in China and the (ex-)USSR (1990 Geary-Khamis dollars)



Note: In China prior to 1950, we included only modern education, excluding the traditional civil examination system.

average years of education, but not in cost- or income-based human capital. However, in recent years, Chinese human capital has grown much faster than it ever did in the USSR, thereby suggesting that China has succeeded in narrowing the gap with more advanced economies.

The higher initial stock of human capital in the FSU in the early twentieth century may be one of the reasons why the USSR outperformed China in GDP per capita growth from the 1930s to the mid-1970s. Indeed, while both China and the FSU experienced rapid capital accumulation, only the FSU had relatively large stocks of human capital ready. This suggests that human capital increased the efficient use of physical capital, increasing factor efficiency and moderating TFP negative change. Table 3 shows that while Chinese TFP growth was positive before the socialist period, during the height of the socialist period it was -10%, much more negative than in the FSU area around the same time.

Table 3. GDP per capita growth and TFP

	Factor share of human capital (HC)	Factor share of physical capital (FC)	Growth of GDP p.c.	Growth of HC p.c.	Growth of FC p.c.	TFP growth
			FSU			

	Factor share of human capital (HC)	Factor share of physical capital (FC)	Growth of GDP p.c.	Growth of HC p.c.	Growth of FC p.c.	TFP growth
1920–1940	40%	60%	6%	18%	8%	**-6%**
1950–1966	40%	60%	6%	4%	10%	**-2%**
1966–1977	40%	60%	3%	7%	5%	**-3%**
1978–1993	40%	60%	-1%	2%	3%	**-4%**
1994–2006	40%	60%	2%	7%	7%	**-5%**
			China			
1920–1940	53%	47%	0.1%	6%	-16%	**5%**
1950–1966	53%	47%	2%	16%	7%	**-10%**
1966–1977	44%	56%	2%	1%	5%	**-1%**
1978–1993	54%	46%	6%	12%	9%	**-5%**
1994–2006	54%	46%	8%	15%	11%	**-5%**

Note: Source factor shares for China: Chow (1993) and Li *et al.* (1993). Following Wang and Yao (2003), we assumed the factor share of labour to be the same for both periods under the market reforms.
Based on the growth accounting model presented in Equation 8.

After the reform period, however, we witness, after an initial collapse in the FSU, a rise in the growth of physical and human capital, combined with an increasingly negative TFP growth. This suggests that we have again entered a period of faster growth for factors of production, with decreasing growth rates due to diminishing returns. However, the important difference is that human capital now plays a more important role, which might also positively influence TFP changes. Hence, it is important to analyse the effect of increases in the factors of production on both components of TFP growth: technical efficiency[8] of human and physical capital and changes in the general productivity frontier[9].

To do this, we start by using the Cobb–Douglas production function for a national economy, within the framework of the neoclassical growth model from Solow (1956, 1957):

$$Y_t = K_t^{\eta}(A_t L_t)^{1-\eta} \tag{4}$$

where:
Y = output in monetary units (assumed to be GDP);
K = capital in monetary units (assumed by Solow to be only physical capital);
L = labour in natural units (number of workers in the labour force);
A = level of technology (assumed to be conventional TFP[10]); and
η = the elasticity of substitution (factor share) of physical capital.

[8] Indicates how far production is from the most efficiently used set of human and physical capital among the regions within a national economy.

[9] The maximum possible output given inputs of physical and human capital.

[10] As the literature agrees, *level of technology* refers not only to technology in its conventional sense (the processing capacity of technical equipment) but also to various aspects of social interaction in the production process (the institutional environment and its production- and growth-enhancing capacity), articulated by the concepts of *institutional* and *social capital*.

Augmented with human capital accumulation (for example, Mankiw, et al. 1992), this function can be modified as follows:

$$Y_t = K_t^{\eta} H_t^{\mu} (A_t L_t)^{1-\eta-\mu} \tag{5}$$

where (in addition, to the notation given for Equation 4):

H = human capital stock in monetary units;
μ = elasticity of substitution (factor/income share) of human capital.

However, instead of the natural proxies used by MRW, we prefer a human-capital, cost-based monetary measure, such as that proposed by Judson (2002) and updated by Van Leeuwen and Földvári (2008a). We then follow Mahadavan (2007) and Van Leeuwen *et al.* (2011) with the standard TFP analysis, expressing changes of the variables in per capita terms (denoted by lowercase letters; for example, *y* instead of *Y*, and so on):

$$\ln y_{it} = \hat{\eta} \ln k_{it} + \hat{\mu} \ln h_{it} + \ln A_t T_t + u_{it} \tag{6}$$

$$\ln y_{it} = (\eta_i - \hat{\eta}) \ln k_{it} + (\mu_i - \hat{\mu}) \ln h_{it} + \ln \theta_t T_t + \varepsilon_{it} \tag{7}$$

where (in addition, to the notation given for Equations 1, 4–5):
T = dummy variable (equal to "1" for the year in question and "0" for other years);
θ = a time-variant general (common for all the regions of a country) productivity factor; in other words, the general technological level of a national economy. Similar to A in the standard growth accounting in Equation (6), but free of the effect of technical-efficiency differences between the regions;
i = subscript denoting the province (in China) or the union republic (in the FSU);
$\hat{\eta}$ and $\hat{\mu}$ = elasticity (factor share) coefficients for the whole country;
η_i and μ_i = province- or republic-specific coefficients of elasticity between the factors of production;
u = residual, including the effect of technical-efficiency differences between the province or union republic and the whole country; and
ε = unexplained residual (error term).

The rate of change of the regression variables is expressed as:

$$\frac{\dot{y_{it}}}{y_{it}} = \frac{\dot{A_t}}{A_t} + \hat{\eta}\frac{\dot{k_{it}}}{k_{it}} + \hat{\mu}\frac{\dot{h_{it}}}{h_{it}} + \frac{\dot{u_{it}}}{u_{it}} \tag{8}$$

Clearly, it follows from Equations (4 and 5) that $\frac{A}{A_t}$ in Equation 8 is TFP growth.

Since we define technical efficiency as the differences among the provinces or republics in the input for the factors of production, econometrically, we can capture this in terms of the variables rates of change as follows:

$$\frac{\dot{y_{it}}}{y_{it}} = \frac{\dot{\theta_t}}{\theta_t} + \eta_i\frac{\dot{k_{it}}}{k_{it}} + \mu_i\frac{\dot{h_{it}}}{h_{it}} + \frac{\dot{\varepsilon_{it}}}{\varepsilon_{it}} = \frac{\dot{\theta_t}}{\theta_t} + \hat{\eta}\frac{\dot{k_{it}}}{k_{it}} + \hat{\mu}\frac{\dot{h_{it}}}{h_{it}} + (\eta_i - \hat{\eta})\frac{\dot{k_{it}}}{k_{it}} + (\mu_i - \hat{\mu})\frac{\dot{h_{it}}}{h_{it}} + \frac{\dot{\varepsilon_{it}}}{\varepsilon_{it}} \tag{9}$$

Combining Equations (8) and (9) we can show the relationships among TFP growth, general technology growth, and technical efficiency of physical and human capital:

$$\frac{\dot{A}_t}{A_t} = \frac{\dot{\theta}_t}{\theta_t} + (\eta_i - \hat{\eta})\frac{\dot{k}_{it}}{k_{it}} + (\mu_i - \hat{\mu})\frac{\dot{h}_{it}}{h_{it}} \tag{10}$$

Clearly, Equation 10 shows that TFP consists of a general production frontier and technical efficiency. Therefore, we arrive at the approximate change in technical efficiency of physical and human capital in the whole country by simply subtracting that country's general technology growth from that of the TFP. In Figure 5 we plot general productivity for both the FSU and China. It is clear that the productivity frontier moved less for FSU than for China. Technical efficiency dynamics, though, were slightly positive in the FSU from 1978 to 1993, unlike in China (Table 4). This is not surprising given that China had faster growth of both human and physical capital during this period, which reduced the efficient use of these inputs. This changed in the post-1994 period when in the FSU when human and physical capital started to grow again and their efficiency also turned negative.

Figure 5. General productivity index (1971 = 1)

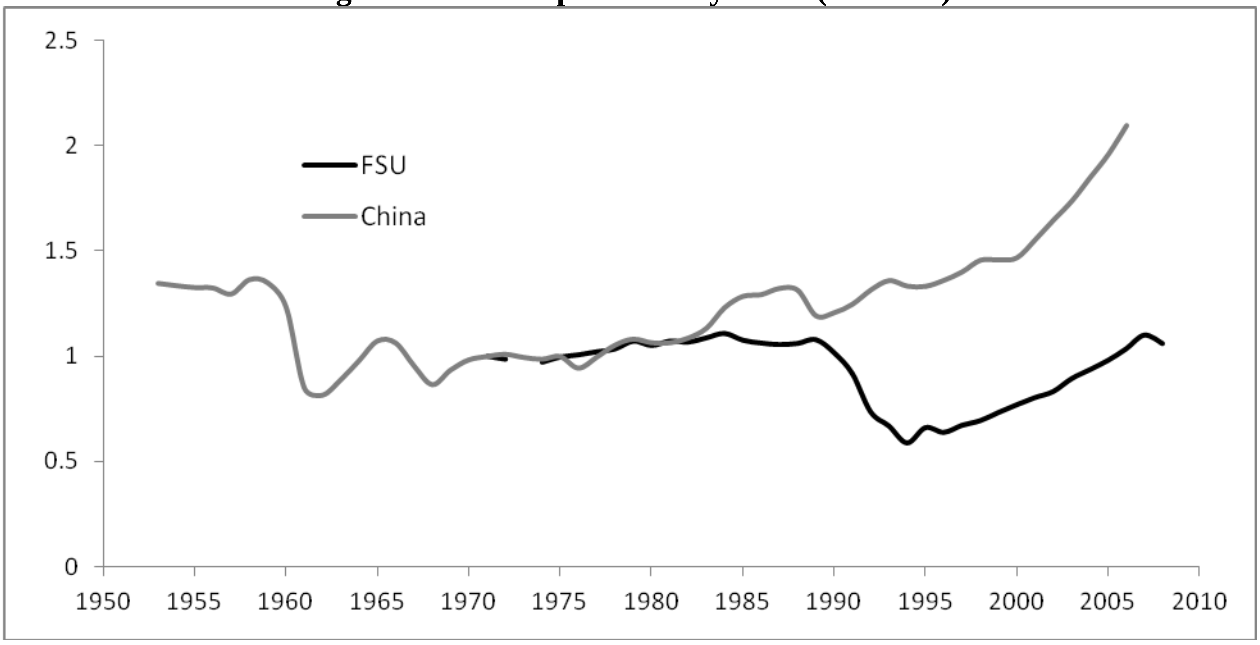


Table 4. Decomposition of TFP growth in growth of technical efficiency and general productivity growth

	1920–1940	1950–1966	1966–1977	1978–1993	1994–2006
			FSU		
TFP growth	-6.0%	-3.6%	-2.8%	-1.6%	-4.0%
Technical efficiency			-4.0%	0.8%	-7.6%
General productivity growth			1.2%	-2.4%	3.6%

	1920–1940	1950–1966	1966–1977	1978–1993	1994–2006
			China		
TFP growth	-4.7%	-9.8%	-1.2%	-4.6%	-5.2%
Technical efficiency		-8.6%	-0.7%	-6.6%	-8.6%
General technical growth		-1.2%	-0.5%	2.0%	3.4%

Figure 5 shows that the paths for the FSU and China diverged from the mid-1980s to the mid-1990s. However, during later periods, the difference was not in the direction of the trend of the general production frontier. The general production frontier increased in both countries, but China outperformed the FSU in both magnitude and sustainability. Another difference is that upward movement of this parameter barely constituted a recovery in the FSU: by the end of the 2000s, the general production frontier for this area was not far above its pre-reform level. One plausible explanation of this pattern is that increased openness[11] of the economies of China and the FSU, as well as their marked increase in the level of human capital relative to GDP, helped to extend active technological borrowing from abroad; however, China was able to benefit more due to its better institutional environment.[12] The borrowing, however, contributed to general technical development, rather than to other components of technological level, such as the technical efficiency of factors of production.

While both regions are currently experiencing an upturn in economic development, there are two major differences. First, the FSU is generally replenishing its lost physical, and, to a lesser extent, human capital. Due to its lower growth rates for capital stocks, this is being done with lower technical inefficiency. Nevertheless, it is to be expected that diminishing returns will soon set in, along with lower growth rates[13], unless the FSU area is able to modernise its stocks of human and physical capital in line with those of present-day more-developed economies. In China, in contrast, a very high physical- and human-capital accumulation is already taking place, accompanied by increasing technical inefficiency. Growth continues because China is so far behind with regard to technology that it is easier to import, thereby increasing its productivity frontier. However, in a couple of years China will likely face the same challenge as the FSU area, with a choice between radically changing its entire field of technology, or being trapped by low GDP per capita growth and diminishing return on capital. In other words, both China and the FSU have to extend their general production frontier (which is still far from a global one) and converge with advanced economies in the face of diminishing returns on physical and human capital.

5. Conclusion

[11] The source of the data (PWT 7.0) defined *openness* as exports and imports as a share of GDP. During the reform period (1977–2009) it increased in China from 19.5% to 58.6% (or from 10.8% to 61.2%, according to an alternative estimation); in Russia (1990–2009), which had about half of the FSU population and GDP following reforms, it increased from 11.9% to 54.6%, most sharply at the start of that period.

[12] Although conventional measures of institutional environment (such as 'ease of doing business', 'the rule of law', 'government effectiveness', 'index of economic freedom', 'corruption perceptions index', and so forth) are expressed quantitatively, they are based on expert assessments and therefore are consensuses of subjective opinions that may not be directly verified.

[13] Poor performance of the Russian economy in 2013, with estimated GDP growth rate slowing down to 1.3% from 3.4% in 2012 (Rosstat, 2014, p. 3) is in line with this analytical outlook based on the earlier data.

The Former Soviet Union (FSU) and China are two countries that moved onto a path of forced modernisation from a position of relative backwardness. Their strategy was one of catch-up: forced industrialisation, with a neglect of consumer production and wage development. This led to a rapid increase in physical capital, enabling relatively fast, capital-based growth. Put in terms of the perspiration–inspiration model, economic growth took place mostly due to the perspiration factors. However, this was not entirely unexpected since, from a socialist perspective, these economies maximized material output. Indeed, applying a one-sector model to both economies, we confirmed that policy motives were the driving force of this emphasis on physical capital accumulation. We also showed that this strategy initially increased per capita GDP, although it eventually slowed growth rates when the focus shifted more to the production of human-capital-intensive consumer goods.

Even though decreases in growth rates were expected based on the theoretical model, there was no specific reason to assume that the reforms would take place when they did, as they depended on the specific interplay of economic and social factors in both countries. There is, therefore, no direct reason why it was China that embarked earlier than the FSU on the path of increasing private consumption, which led to a decline in the physical-to-human capital ratio. While the FSU continued on the path of diminishing returns on physical capital, China slowly moved towards more human-capital-oriented industries, thereby avoiding the collapse experienced by the FSU and its economy in the 1990s.

After undergoing far-reaching reforms, China experienced an unprecedented rise in its human- and physical-capital stock. This initially led to decreasing technical efficiency. In the FSU, in contrast, physical capital collapsed and has not yet recovered, while human capital has had a better performance. As a result of these factors, the FSU's technical efficiency growth appeared to be positive in the early 1990s, with a relatively modest decrease thereafter. Since the FSU was closer to the global production frontier, from 1970 to the present it grew little, if at all, in this dimension, while growth in China continued. However, even in China, general productivity growth was limited until market reforms were extended in the 1990s and 2000s. This pattern can be explained, in part, by the fact that, in the FSU, wages are too low to make the use of modern technologies profitable, but too high to attract industries predicated on cheap labour. In China, which is further away from the global productivity frontier, productivity can continue to be increased, until it eventually faces the same problem as the FSU. Therefore, inspiration factors are yet to play their role in economic development of both China and the FSU which have to extend their general production frontier to overcome diminishing returns on perspiration factors.

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Appendix: Data and sources

1) GNP/GDP

Both the Soviet and Chinese official concept of national income (effectively Net Material Product – NMP) omitted most of services until mid-1980s after which both countries converted to standard national accounting based on Gross Domestic Product (GDP).

Contrary to China where the concept of GDP was used in the reconstructions, attempts to reconstruct the size of the Soviet economy were on the basis of Gross National Product (GNP). In the case of the USSR we assumed this concept to be comparable to GDP as capital flows to and from abroad were very limited. We chose to link together those series that had generally the same concepts and close values in neighbour time points.

The resulting GDP/GNP estimates in current prices were checked against monetary indicators that were originally expressed in current prices: total wage bill and the national budget total expenditures. We also used the series of both NMP and GNP in current prices as a cross check.

2) Gross fixed capital stock

Past Chinese official statistics on the capital stock combine the stock in fixed prices with current price addition of the present year hence creating an estimate consisting of fixed and current price components. Therefore, recent studies have tried to completely re-estimate the Chinese statistics.

Since, contrary to the FSU area, China cannot be considered a region with integrated prices, in constructing these series regional capital good prices were used back to 1978. Before 1978 the capital stock was deflated using a regional GDP deflator.

Estimates for the FSU were more challenging. Similar to GNP, we started to construct our annual series of fixed capital in current prices. Their estimation was based on gross fixed capital to GNP (at factor cost) ratio derived from Easterly and Fischer (1995).[14] We assumed that this relationship is correct for any particular year regardless of its monetary expression. To convert these series from current to constant prices we used the same price index as for the GNP.

We did some smoothing of the data for the early 1990s as under hyperinflation the original estimates were subject to frequent non-market revaluation of the books in compliance with the government regulations. Conversions of these series to constant prices were based on GNP/GDP deflators for the USSR (until 1991) and for the respective NIS (see below).

3) Price indices

As pointed out above, we used different sets of price indices for China. For the GDP and for the capital stock before 1978 we used the GDP deflator while, due to the massive difference between the GDP deflator and the prices of capital goods after 1978, we used the price of capital goods. Given the long period under consideration, we created several benchmarks for 1933, 1978, and 2008 to address the so-called 'Gerschenkron effect'.

For the FSU area, our preferred inflation indicator was GNP deflator as it is the most comprehensive price index that covers an entire economy. It includes not only consumer goods and services but also government consumption and capital assets. However, we used consumer price indices as a cross-check where it was possible. For most periods we constructed our Chain Deflator Index again to address the 'Gerschenkron effect'. After deriving the price indices with different year base (1928, 1937, 1950, 1958, 1964, 1973, 1982) we used them to make our synthetic deflator where weights (e.g. of 1928 and 1937) are to change when they approach or diverge from the

[14] *The Soviet Economic Decline Dataset* is enclosed to the World Bank electronic publication and contains the series with reference to Gomulka and Schaffer (1991) based on 'Western estimates' on GNP, labour input, and capital stock for the entire Soviet economy: Moorsteen and Powell (1966), Powell (1968), CIA (1982), CIA (various years), Kellogg (1989). The data from these underlying sources have much in common with those we use for our GNP values for the period prior to 1956.

respective year base.

Contrary to China, we preferred to apply the single price index for the USSR to all of its republics for the period before its dissolution (1991). This choice was based on our suggestion that a single country with centralised government price setting could not afford such an extreme difference in price index movement in its various parts in the long-run as it follows from the World Bank (1992, 2011).

4) Human capital stock

There are many ways to calculate the human capital stock. Yet, we need a method that is consistent with the calculation of physical capital in order to use it in economic analyses. As suggested by Judson (2002), the cost-based human capital indicator is similar to the measurement of physical capital stock. Therefore in calculating our cost-based estimation of the total accumulated stock of human capital per capita at its replacement cost, we follow Judson (2002), updated by Van Leeuwen and Foldvari (2008):

$$h_t = S_t \sum_j d_{jt} a_{jt}$$

where h_t denotes the average human capital stock per worker in year t, S_t is the average years of formal education in year t, d_{jt} is the public expenditure on education per level j in year t (per student enrolled), a_{jt} denotes the share of the labour force (population at the age of 15+ in the FSU and China cases) in year t with a certain level of education.

This method does not include foregone wages and non-government spending on education largely because these data are unavailable for many countries and adding them would make these series incomparable with other countries. However, as argued by Judson (2002), it is based on the key component of schooling costs, which normally defines their dynamics.

Table A1: Data sources for the FSU area

Category	Indicator	Period	Basic Sources and Literature	Notes
Size of the economy	GNP	1928-1955	Bergson (1961) for 1928, 1937, 1940, 1944, 1948-1955 with our interpolation for other years	For the entire USSR.
		1956-1957	Our interpolation based on Harrison (1998), Easterly and Fischer (1995)	
		1958-1964	Becker (1969) for 1958 and 1964 with our interpolation for 1959-1963 based on Harrison (1998), Easterly and Fischer (1995)	
		1965-1985	Steinberg (1990) series of his own calculation for 1965 and 1970-1985 with our interpolation for 1966-1969 based on Harrison (1998), Easterly and Fischer (1995)	For the entire USSR.
		1980-2010	World Bank (2011) as the primary source, also World Bank (1992)[15]	For the NIS; for Georgia and Latvia 1970-2010.

[15] Facing the two alternative estimates in World Bank (1992) we preferred to take their weighted average, with weights changing over time: we gave most possible weight to the optimistic estimate for 1980 and the most possible weight to the pessimistic estimate for 1990.

Category	Indicator	Period	Basic Sources and Literature	Notes
		1960-1979	Ponomarenko (2002)	For Russia.
	NMP	1928-1990	Khanin (1991), Steinberg (1990)	For the entire USSR.
Fixed (physical) capital	Stock	1928-1987	Our calculation based on Easterly and Fischer (1995)[16]	For the entire USSR. Gross stock, until ca. 1990 includes residential property.
		1970-1990	Easterly and Fischer (1995)[17]	For the NIS.
		1980-2010	CIS Stat (2011)[18]	For the NIS, except 3 Baltic countries (Estonia, Latvia and Lithuania).
		1991-2003	Our interpolation based on Easterly and Fischer (1995) and Marquetti and Foley (2011)	For 3 Baltic countries.
		2004-2008	Marquetti and Foley (2011)	For 3 Baltic countries.
	Annual investment	1928-1957	Moorsteen and Powell (1966)	For the entire USSR.
		1958-1961	Average between estimates from Moorsteen and Powell (1966), Becker (1969)	
		1962-1965	Becker (1969)	
		1966-1969	Our interpolation based on Steinberg (1990)	
		1970-1985	Steinberg (1990)	
		1986-1990	Our extrapolation based on Steinberg (1990)	
		1980-2010	CIS Stat (2011)	For the NIS, except 3 Baltic countries (Estonia, Latvia and Lithuania).

[16] In their turn, Easterly and Fischer (1995) employed the ‘Western estimates’ chain linked series of fixed capital using 1937 rubles for 1928-1960, 1970 rubles for 1960-1980 and 1982 rubles for the 1980s.

[17] For the period 1970-1979 expressed in 1973 prices. The data are taken from *The Soviet Economic Decline Dataset* in which they were compiled and rescaled with reference to the official data.

[18] For the period 1980-2009 expressed in current prices.

Category	Indicator	Period	Basic Sources and Literature	Notes
		1990-2010	World Bank (2011)	For the NIS; for some countries going back to 1980.
Prices	GNP/GDP deflator	1928-1955	Our derivation of the Laspeyres and Paasche price indices from the GNP data from Bergson (1961) expressed both in current and constant prices	For the entire USSR.
		1956-1957	Assumed zero inflation	
		1958-1964	Our derivation of the Laspeyres and Paasche price indices from the GNP data from Becker (1969) expressed both in current and constant prices	
		1966-1972	Steinberg (1990)	
		1973-1982	Our derivation of the Laspeyres and Paasche price indices from the GNP data from Steinberg (1990) expressed both in current and constant prices	
		1983-1985	Steinberg (1990)	
		1986-1990	World Bank (1992)	
		1991-2010	World Bank (2011)	For the NIS.
Human capital stock	Average years of education	1920-2010	Our calculation based on official publications of the censuses[19] and enrolment data.[20]	For the entire USSR since 1920, for the NIS since 1939.
	Government expenditure on education	1924-1990	Our calculation based on the Soviet Ministry of Finance (NarKomFin, MinFin) and secondary literature in Russian.	For the entire USSR since 1924, for the NIS since 1939.
		1991-2010	UIS UNESCO (2012) with our interpolation.	For the NIS, except Russia.
		1970-2010	Our calculation based on the Soviet and Russian Ministries of Finance (MinFin, Kaznacheistvo Rossii) and the derivative semi-official sources.	For Russia.

[19] 9 population censuses were conducted in the Soviet Union and 2 in post-Soviet Russia. Also, for the period after 1990 the census results in other FSU countries are available in UNSD (2012a) and CIS Stat (2011).

[20] For base years they are calculated based on the census data on age structure of the population and its educational attainment expressed in ISCED levels. To estimate educational attainment in years between censuses we use enrolment data by following Barro and Lee (2001) perpetual inventory method. However, contrary to Barro and Lee, we took the average of forward- and backward-flow estimates as proposed by Földvári and Van Leeuwen (2009).

Table A2: Data sources for China

Category	Indicator	Period	Basic Sources and Literature	Notes
Size of the economy	GDP	1922-1955	Maddison (2007), Maddison and Wu (2008)	For the entire country.
		1952-2010	National Statistical Bureau (1999)	For the provinces.
Fixed (physical) capital	Stock	1922-1949	Wu (2012)	For the entire country.
		1950-2010	Wu (2004, 2009)	National and regional estimates
	Annual investment	1922-1949	Wu (2012)	For the entire country.
		1950-2010	Wu (2004, 2009)	National and regional estimates
Prices	GDP deflator	1922-2010	Maddison (2007), Maddison and Wu (2008)	National and regional estimates.
	Capital goods price index	1922-1949	Wu (2012)	
		1950-2010	Wu (2004, 2009)	
Human capital stock	Average years of education	1920-2010	Our calculation (methodology is similar to the FSU). Data from population censuses were obtained for 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), and 2000 (National Bureau of Statistics of China 2011). Enrolment data 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 the entire country and the provinces since 1922.

Category	Indicator	Period	Basic Sources and Literature	Notes
	Government expenditure on education	1924-2010	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).	For the entire country and the provinces since 1922.

For the FSU comprehensive list of the sources is attached and the methodology is discussed in Didenko *et al.* (2013). For China the same is done in Van Leeuwen *et al.* (2011).

The per capita series are derivatives of the respective indicator values and the country population size. The latter are available in UNSD (2012a) and Maddison (2007) that basically use the official censuses data with some corrections and interpolations.

Initially all of the indicators were expressed in current prices. To convert them to constant prices we used the same price index as for GNP/GDP (except for fixed capital in China after 1978).

Values for all the indicators involved are denominated in constant 1990 Geary-Khamis (GK) dollars. For the USSR, Russia and China we converted from constant 1990 prices in national currencies into 1990 GK dollars (based on PPP) (Maddison 2007). For national currencies of the NIS conversion rates into 1990 GK dollars were derived by their GDP in national currencies in 1990 from the UNSD (2012b) divided by their GDP in 1990 GK dollars from updated Maddison's dataset[21].

[21] Available online http://www.ggdc.net/MADDISON/oriindex.htm.