Does economic change really create inspiration? Inspiration versus perspiration in the former USSR area and China, ca. 1920-2010

Dmitry Didenko
Research Associate, Institute of Sociology, Russian Academy of Sciences.
ddidenko@bloomberg.net

Péter Földvári
Associate Professor, University of Debrecen (Hungary).
peter.foldvari@econ.unideb.hu

Bas van Leeuwen
Postdoc Researcher, Utrecht University (the Netherlands).
bas.vanleeuwen1@googlemail.com

Abstract

In this paper we extend our previous studies (Didenko et al., 2012; Foldvari et al., 2012; Van Leeuwen et al., 2011) on the role of conventional factors of production (fixed, or physical, and human forms of capital) and their productivity depending on their interrelations and economic development policies. Methodologically based on Solow (1956, 1957) and Mankiw, Romer and Weil (1992) we apply our theoretical models on the factors of economic growth to compare China with the republics of the former Soviet Union and, to this end, put together our new databases for both regions. Following Krugman (1994), we distinguish between perspiration (i.e. production factors) and inspiration (i.e. TFP, which consists in turn of technical efficiency of the production factors and a general production frontier) factors and find that in the socialist central-planning period economic growth was largely driven by physical and, to lesser extent, human capital accumulation. Moreover, at these times conventional TFP change was much more negative (1930s for the FSU, 1950s for China). This means that focusing mainly on physical capital increases the factors of production (hence increasing growth via perspiration) but reduces the technical efficiency of the factors of production strongly (hence lowers the growth via TFP, i.e. inspiration). After the economic transitions were launched (end 1970s in China and end 1980s in the FSU) the inspiration/perspiration pattern somewhat changed. China managed to keep technical inefficiency relatively moderate, largely by massively increasing its human capital (which made it easier to make use of physical capital). At the same time, they managed to increase their productivity frontier. In the FSU, however, the change in the human to physical capital ratio was primarily caused not by an increase of human-, but rather by a decrease of physical capital. This means that, even though technical efficiency relatively increased, the general productivity frontier remained stable or declined. This changed in the late 1990s and the start of the 21th century when the FSU started to recover somewhat, only to reach the 1990 level.

1. Introduction

There is a lively debate on whether it is inspiration (i.e. technological development) or perspiration factors (i.e. factors of production - physical[1]- and human capital) that drive economic development (i.e. Krugman, 1994). Both in China (e.g. Chow, 1993; Li et al., 1993; Wang and Yao, 2003;

[1] We employ national accounts statistics where 'fixed capital' is standard usage while in theoretical literature 'physical capital' is more preferred; we mean the same things using both.

Whalley and Zhao, 2010) and to, a lesser extent, Russia and the FSU[2] (e.g. Easterly and Fischer, 1995; Meliantsev, 2004) it has been argued that economic development in the period up to the 1980s has been largely driven by perspiration factors while their economic transitions have increased their growth potential based on technical development.

In this paper we try to analyze the development of modern economic growth from a production factor perspective. We are methodologically based on the growth model developed by Solow (1956, 1957), who introduced the level of technology into neoclassical production function, augmented with human capital accumulation by Mankiw, Romer and Weil (1992) – MRW hereinafter. However, instead of natural proxies used by MRW, we prefer a human capital cost-based monetary measure as proposed by Judson (2002), updated by Van Leeuwen and Földvári (2008). To this end, we put together our new databases on the factors of economic growth for both regions.

In Section 2 we provide with a brief summary of the estimation of human-and physical capital, as well as an analysis of its spread over the USSR and China respectively. We find that until the reforms were launched both in the FSU and China both countries experienced a faster accumulation of physical capital compared to human capital, combined with a less rapid economic growth in terms of GDP. This situation changed after the reforms, but the changes were different in the FSU area compared to China. In section 3 we test the focus of both China and the FSU on physical capital accumulation before the reforms. This is done by using a one-sector model from Foldvari et al. (2012) in which the government can either prefer to maximize material output or consumption (or a combination of both). Using this model, we show that the high physical- to human capital ratio in the pre-reform are was largely policy driven. Since more physical capital leads to higher productivity, this increased GDP per capita, i.e. a higher physical- to human capital ratio causes a higher GDP per capita. However, when after the reforms the focus shifted to more consumption goods (which were human capital intensive), the growth of human capital became increasingly important for an increase in GDP/cap, i.e. a lower physical- to human capital ratio leads to a higher GDP per capita. However, so far our focus has just been on the perspiration factors. Therefore, in section 4 we discuss the factor contributions to growth and analyse the development of total factor productivity (TFP), technical efficiency, and general technical development. We find that, whereas technical efficiency went down stronger in China (partly due to faster growth in physical and human capital), its production frontier increased stronger than in the FSU area. This suggests that technical inefficiency (the use of the factors of production) was somewhat different in China compared to the FSU. Therefore, section 5 deals with economic development and spatial growth of human capital in the FSU comparing it with China. The emphasis of this section is made on inequality issues between the republics of the FSU and the provinces of China. We end with a brief conclusion.

2. Data

This research topic requires data on both physical[3] and human capital as well as GDP per capita. Data on human- and physical capital as well as GDP for the socialist countries are being extended quite rapidly these past years. GDP estimates for China are taken from Maddison (2007) as updated

[2] 'The former Soviet Union' (the FSU or ex-USSR) is the mostly common term used hereinafter for all time periods and for all territorial coverage of both the USSR and the Newly Independent States (NIS) after its collapse. The terms 'USSR' or 'Soviet Union' are used for the period of 1922-1991 only when this state existed within its actual borders. The term 'Newly Independent States' (NIS) refers to multiple of existing states on the territory of the former USSR, both to the period after its dissolution and to the period when they were the Soviet republics, basically within their current borders. Russia refers to the territory basically within the borders of the contemporary Russian Federation, in various periods.

[3] This refers to the gross fixed capital stock.

on his website (http://www.ggdc.net/MADDISON/oriindex.htm) and for the individual provinces from the National Statistical Bureau (1999). For the USSR and Russia GDP per capita is drawn from Didenko et al. (2012) based on the official statistics, secondary literature[4] and, in the case of the other NIS, on the World Bank (2011).

Physical capital is taken from Wu (2004, 2009) for China as well as its provinces, from Didenko et al. (2012) for the USSR and from CIS Stat (2011) and Extended Penn World Tables v. 4.0 to make our estimations in this paper for the NIS. The cost-based human capital measure for China is taken from Van Leeuwen et al. (2011), for the FSU up to 1989 from Didenko et al. (2012) and for the period after 1990 calculated in this paper based on the data from the UIS UNESCO (2012), UNSD (2012) and CIS Stat (2011).

The results of our estimations are reported in below Table. They are reported by region in both the FSU and in China. Both

Table 1: Per capita GDP, human- and physical capital in the FSU and China in 1990 GK 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)**
USSR		1,787	1,547	1,649	6,753	30,432	10,127	6,013	20,319	12,866
of which	Armenia			1,634	5,434	21,333	16,226	7,768	14,703	13,718
	Azerbaijan			1,856	4,942	17,793	11,369	4,168	17,891	5,032
	Belarus			1,298	5,554	27,216	12,580	8,969	22,755	23,236
	Estonia				10,630	40,003	21,780	16,065	56,227	38,623
	Georgia			1,930	9,355	22,933	17,423	4,484	10,013	5,299
	Kazakhstan			2,517	8,104	30,300	15,670	7,996	15,873	8,857
	Kyrgyzstan			1,730	3,184	16,114	12,202	2,439	7,680	4,091
	Latvia				9,278	35,690	17,446	11,374	40,074	24,498
	Lithuania				8,538	33,013	16,931	8,736	30,796	21,181
	Moldova				5,679	21,148	12,747	3,095	17,503	8,959
	Russia			1,931	7,308	36,218	11,458	6,943	23,913	13,384
	Tajikistan			1,563	3,214	12,830	10,694	1,228	1,894	1,210
	Turkmenistan			2,483	3,614	21,696	11,180	3,137	10,932	NA
	Ukraine			1,083	5,585	26,399	10,924	3,893	23,019	8,912
	Uzbekistan			1,111	4,124	15,498	9,598	4,151	5,291	22,935
China		570		9.2	1,453	2,080	827	4,710	12,705	8,572
of which	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
	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

[4] Didenko et al. (2012) used GNP/cap., which they assumed comparable to GDP/cap, based on Bergson (1961), Becker (1969), Steinberg (1990); for Russia prior to 1991 GDP data are based on World Bank (1992, 1996).

	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)
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) is referred to 1940, H/cap (cost based) to 1939, other items to 1930-1939 average.*
*** Average of 1980-1989 for the USSR and its republics; H/cap (cost based) is average of 1979 and 1989.*
**** Average of 2000-2008 for the republics of the former USSR and CEE.*

the USSR and China recorded a remarkable growth of per capita physical and human capital, although this growth was distributed unequally among their constituents (union republics in the USSR, provinces in China). They also managed to converge with economically advanced countries (Western Europe and its offshoots in North America and Oceania, and in recent decades Japan). Also we can observe that the USSR outperformed China in per capita GDP growth rates between 1930s and 1990s, despite China's lower base. Probably, this could add to explanation of longevity of the central-planning (also often referred to as command) system survival in the USSR and earlier start of market-oriented economic reforms in China. However the situation turned different after the collapse of the USSR: in 2000s most of the NIS did not recover after deep downturn which went along their systemic transformation in economic and political spheres, while China managed to substantially bridge the gap with the FSU.

Table 1 also provides us with some information on the causes of this pattern. We can see that both in the FSU and in China before the reforms (from 1930s to 1980s) per capita physical capital growth outperformed that of human capital which, in its turn, increased faster than GDP per capita. This similar pattern in the two regions is caused by a policy of physical capital accumulation by the Chinese government in the post-WWII period, similar to the FSU policy which already started in the 1930s. This changed in the reform period, which started in China already in the end-1970s. We clearly observe that, during the reform period, China experienced outperforming rise of human capital relative to physical capital, although GDP per capita's impressive growth was slower than that of these factors. In the FSU from 1980s to 2000s physical capital decreased dramatically (about halving), human capital appeared to be slightly higher on average (in much due to Russia with its relatively large population) and did not recover in most of the NIS, while their GDP per capita was close to recovery (although in some of the NIS it was far below its pre-reform level). Such a pattern leads us to explore the role of these factors in economic growth with more scrutiny.

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

It is thus clear that physical capital as a factor of growth cannot be disregarded before the reforms.

This eventually would lead to a collapse of physical capital in the FSU and slower growth in terms of physical capital in China after the reform period. But why did this focus on physical capital exists, and why did these patterns changed after the reform period?

This answer is probably best analyzed by the idea that a state-socialist regime, following a Marxist-influenced economic policy, had a tendency to value capital goods (requiring relatively more material goods) above consumer goods (requiring 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, probably thanks to growing social tensions arising from low consumption, starts to put more emphasis on the production of consumer goods relative to capital goods, its physical to human capital ratio should necessarily decline.

These ideas were formalised in the model developed in Foldvari et al. (2012) based on optimization approach from Barro and Sala-i-Martin (2004, Chapter 5, A.3.3 and A.3.5). In this model there is no endogenous growth or any exogenous productivity (TFP). As once the steady state is achieved, both per capita income and consumption will be constant. The social planner's problem along the optimal path of economic development is to maximize the utility value given its preferences, certain conditions and constraints. This optimal path is expressed by the following Hamiltonian function:

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

where:
J - utility value along the optimal path of economic development;
ρ - the discount factor;
t - point in time (assumed to be continuous with infinite horizon);
a and b - parameters that reflect 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 - supers and subscripts that denote the two sectors of production (material and immaterial);
λ - the shadow-prices[5];
I - gross investment during period of dt;
k - physical capital stock;
h - human capital stock;
δ - the rate of depreciation;
n - the growth rate of 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:

[5] 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 at the optimal path for another unit of a production factor. What we here find is that at optimal path the effect of all factors of production on the value function should be equal, i.e. λ1-λ4 are equal.

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

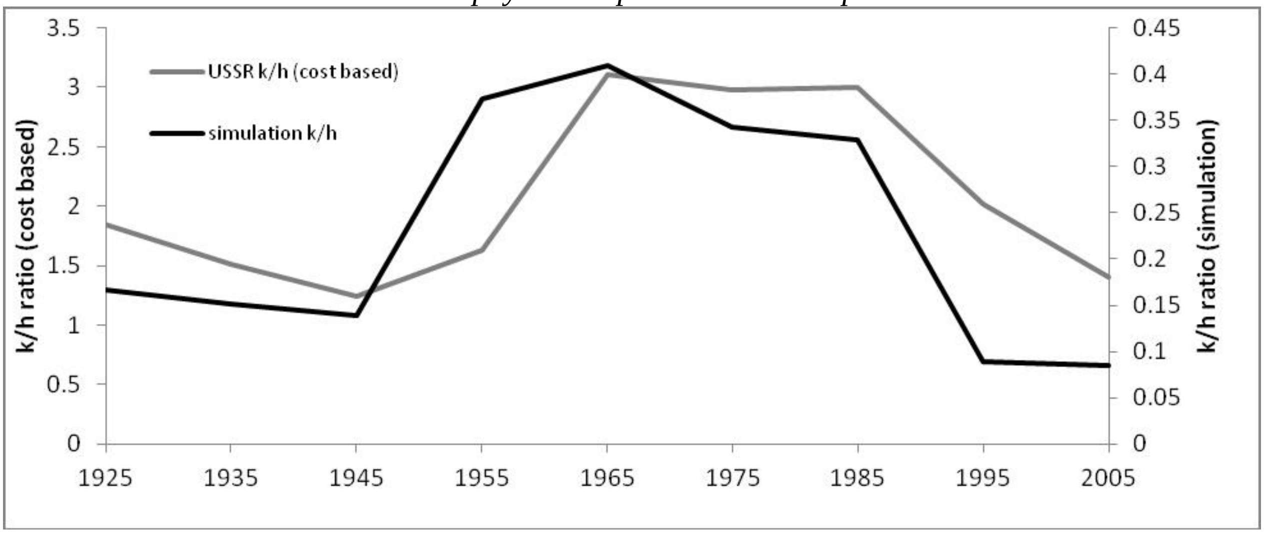
where (additionally to notations of equation 1):
α - the elasticity between material and immaterial consumption;
β - the elasticity between physical and human capital in material sectors of production;
γ - the elasticity between physical and human capital in immaterial sectors of production.

Essentially, this is just the standard physical capital to human capital ratio is shown in the model from Barro and Sala-i-Martin (2004), where we allow for changing preferences of the planner. Hence, if we set the preferences of the planner (i.e. the coefficients of the model) in such a way that they resemble socialist and capitalist development policy, the model will return the approximate physical/human capital ratio in both economies.

We did this exercise in Figure 2 below. Basically, as during the 1920s - 1930s the Soviet planner often had to give priority to consumption in its utility function[6] we set the coefficient values to capture this empirical evidence. We also assume that after the 1980s, with collapse of the centrally-planned economy, the utility function was maximizing consumption. For

Figure 2: Simulated and actual physical to human capital ratio

2a. Simulated and actual physical capital to human capital ratio in the FSU

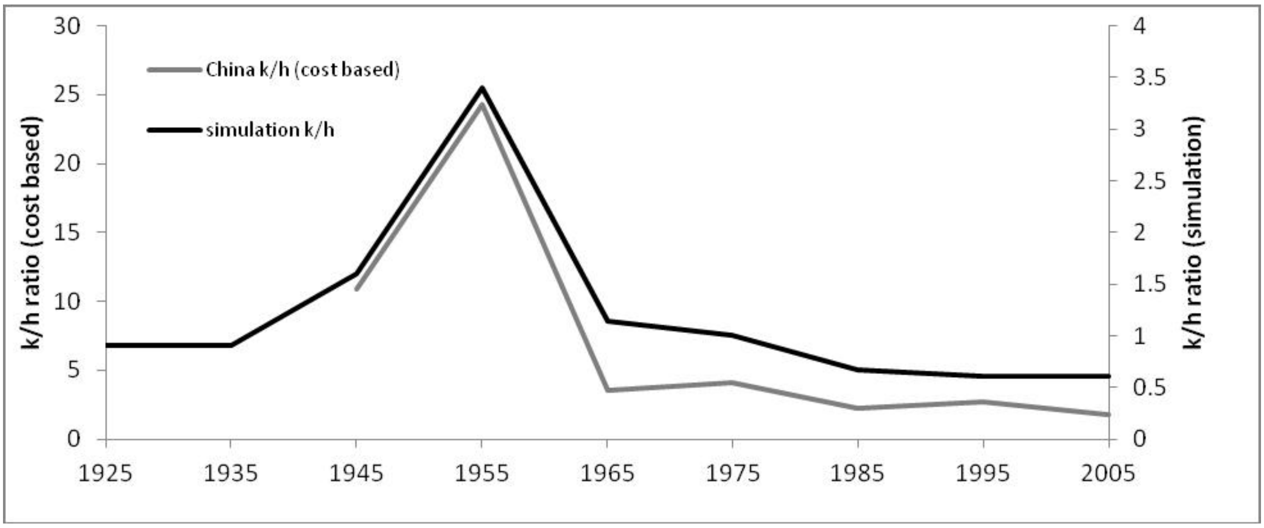


Notes: Assumptions: ρ=0.02; δ=0.07; n=0.01;

[6] In 1930s the highest political leadership of the USSR spent more time of their sessions on consumption than on any other issue (Gregory 2003, p. 94). The government expressed their interest in positive incentives for the labour force that 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 temporarily allocate more resources to consumption at the expense of investments in order not to aggravate the situation further.

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;
1990s and 2000s: a=1; b=2; α=0.5; β=0.3, γ=0.2.

2b. Simulated and actual physical capital to human capital ratio in China



Notes: Assumptions: ρ=0.02; δ=0.07; n=0.01;
1920s-1930s: a=2; b=3; α=0.5; β=0.3; γ=0.2;
1940s: a=3; b=2; α=0.5; β=0.3; γ=0.2;
1950s: a=3; b=1; α=0.5; β=0.5, γ=0.2;
1960s: a=2; b=2; α=0.5; β=0.5, γ=0.2;
1970s: a=2; b=2; α=0.4; β=0.4, γ=0.2;
1980s: a=2; b=3; α=0.4; β=0.4, γ=0.2;
and 1990s and 2000s: a=1; b=3; α=0.4; β=0.3, γ=0.2.

China the change towards a focus on consumption maximization started much earlier and slower, already from the 1960s-1970s.[7] Probably, during the 'Cultural Revolution' campaign of 1966-1976 China faced similar problems resulting from poor consumption as the USSR did during the forced industrialisation and collectivisation of 1930s, and the Chinese leadership addressed them in similar ways.

Does this focus on capital accumulation indeed lead to a higher GDP/cap for both countries? In principle, faster growth of physical capital per capita can lead in one-sector growth models to faster economic growth. Hence, we expect to find that an increase in the *k/h* ratio leads to a higher level of per capita GDP. This is the case because in our model in the long run growth must be zero (at least based on capital accumulation). Hence, the level of *k/h* must have effect on the level of per capita income, but not on its growth rate.

From our model, it follows that, during the central-planning period, we expect the effect of the *k/h* ratio to be bigger than in the market-reforms periods, i.e. after ca. 1980 in China and ca. 1990 in the NIS. The reason is that the material sector, which was stimulated during socialist planning, was also the most physical capital intensive. Therefore, an increase in the *k/h* ratio must have increased the level of per capita GDP more in centrally-planned economies than during market-reforms period which were characterised by higher levels of the non-material sector taking

[7] The 'Great Leap forward' campaign of 1958-1961, being a symbol of massive physical capital accumulation drive in China, is considered as an outlier and not taken as a separate point in Figure 2b.

other things equal.

The results are reported in Table 2 below. We find that the *k/h* ratio has a positive effect on per capita GDP prior to the reforms as expected, even though in the case of China it is insignificant. Looking at the FSU (USSR and Russia) and China, it becomes clear that this effect is biggest for the central-planning period (before 1990 for the FSU and before 1980 for China). Both in the FSU and China the increase of physical to human capital in the pre-reform period was based on economic models that were stimulating rapid industrialisation. Based on these models alone, there was no reason to assume this growth path could not be sustained. However, in both countries the system ultimately failed. One of the reasons why such kind of growth appears to be not sustained could be attributed to physical- and human capital potential to produce external economic and social effects. Indeed, it is widely recognised that human capital preponderates over physical one in this respect. Since the social returns to fixed capital are likely to be lower than that of human capital, the same amount of resources spent on increasing physical rather than human capital leads to a lower rate of economic growth.

Table 2: Instrumental variable regression with *k/h* ratio

	dependent variable: log of per capita GDP (NMP)					
	USSR		**Russia**		**China**	
	ln(GDP/cap)	**ln(GDP/cap)**	**ln(GDP/cap)**	**ln(GDP/cap)**	**ln(GDP/cap)**	**ln(GDP/cap)**
	1950-1990	**1990-2010**	**1970-1990**	**1990-2010**	**1950-1980**	**1980-2010**
constant	25.84	-32.753	-8.900	-32.510	-35.32	-107.00
	(3.79)	(-2.41)	(-1.02)	(-3.51)	(-5.71)	(-20.35)
year	-0.0083	0.021	0.009	0.021	0.021	0.058
	(-2.36)	(3.05)	(1.95)	(4.48)	(6.84)	(22.40)
ln(k/h ratio)	**0.87507**	**-0.316**	**0.334**	**-0.258**	**0.010**	**-0.560**
	(8.79)	(-4.51)	(1.23)	(-5.94)	(0.15)	(-2.90)
Cragg-Donald Wald F statistic (p-value)	36.162	1.503	2.640	2.062	5.797	1.816
Hansen J statistic (p-value)	0.353	0.771	0.455	0.583	0.670	0.485
N	38	17	17	19	24	26

Note: fixed effects; z-statistic in parentheses

Indeed, we find that just before the start of economic reforms in the FSU and China when the physical capital/human capital ratio increased, per capita GDP growth decreased. In this period it is human capital that was necessary to increase GDP per capita due to the bigger 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/human capital ratio became negative or insignificant.These findings are consistent with the other studies (e.g. Erk, Altan Cabuk, and Ates, 1998; Duczynski, 2002; 2003).

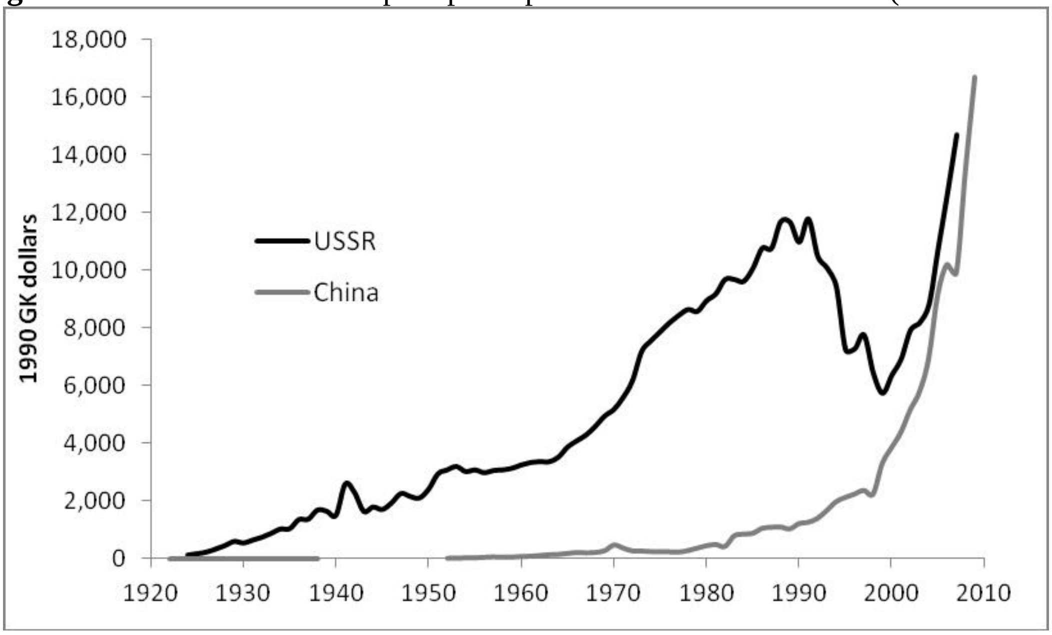
However, so far our interpretation has focused only on the perspiration factors: how human- and physical capital could have opposite effects on economic growth due to different policy perspectives before and after reforms. Yet, economic growth may also stem from inspiration factors (i.e. TFP). This will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

4. GDP growth, 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 long-run growth (i.e. TFP growth), this seems to be good news for both China and the FSU.

Indeed, both the USSR and China started with a low cost-based human capital measure. However, where China started from almost the absolute 0-level, the USSR already had quite a human capital base in the 1920s. In that respect the latter more represented Europe. In addition, it witnessed a fast growth by catching up to Europe in average years of education (but evidently not in cost- or income-based

Figure 3: Cost based human capital per capita in China and the USSR (1990 GK dollars)



human capital). However, the Chinese human capital in recent years grows much faster than it did in the USSR in the most part of the twentieth century. All the available evidence thus suggests that China has succeeded in narrowing the gap with the advanced economies.

Possibly, the higher initial stock of human capital in the FSU in the early twentieth century is one of the reasons that the USSR outperformed China in GDP per capita growth during later period of 1930s – mid-1970s. Indeed, whereas both China and the FSU experienced fast 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, hence increasing the factor efficiency, hence moderating TFP negative change. Indeed, we do find that, even though both in China and the FSU the TFP growth was most negative in these periods of rapid physical capital accumulation, it was stronger negative in China compared to the FSU (see Table 3).

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			
1920-1940	40%	60%	6%	18%	8%	**-6.0%**
1950-1966	40%	60%	4%	4%	10%	**-3.6%**
1966-1977	40%	60%	3%	7%	5%	**-2.8%**

	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
1978-1993	40%	60%	1%	2%	3%	**-1.6%**
1994-2006	40%	60%	3%	7%	7%	**-4.0%**
			China			
1920-1940	53%	47%	0.1%	10.7%	NA	**c.a. - 6.5%**
1950-1966	53%	47%	2%	16%	7%	**-9.8%**
1966-1977	44%	56%	2%	1%	5%	**-1.2%**
1978-1993	54%	46%	6%	12%	9%	**-4.6%**
1994-2006	54%	46%	8%	15%	11%	**-5.2%**

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 of the factors of production, with decreasing growth rates due to diminishing returns. However, there are some differences with the previous period. First, the TFP growth is less negative, and second, human capital plays a more important role, which might also positively influence TFP change. Hence, it is important to analyze the effect of increases in the factors of production (perspiration) and of the general productivity frontier on TFP growth.

We start by using the Cobb–Douglas production function for a national economy in the framework of the neoclassical growth model from Solow (1956, 1957):

$$Y_t = K_t^{\eta}(A_t L_t)^{1-\eta} \tag{3}$$

where:
Y - output in monetary units (assumed as GDP);
K - capital in monetary units (assumed to be only physical one by Solow);
L - labour in natural units (number of workers in the labour force);
A - level of technology (assumed as conventional TFP[8]);
η - the elasticity of substitution (income share) of physical capital.

Augmented with human capital accumulation by MRW this function turns out to be modified:

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

where (additionally to notations of equation 3):
H - human capital stock in natural units (number/percentage of literate workers or those with secondary education);
μ - the elasticity of substitution (income share) of human capital.

[8] As multiple literature suggests, level of technology refers not only to technology in its conventional sense (processing capacity of technical equipment) but to various aspects of social interaction in production process as well (institutional environment, its production- and growth-enhancing capacity) that were pronounced by the concepts of ‘institutional-’ and ‘social’ capital.

However, instead of natural proxies used by MRW, we prefer a human capital cost-based monetary measure as proposed by Judson (2002), updated by Van Leeuwen and Földvári (2008). Then we 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, e.g. *y* instead of *Y*, etc):

$$\frac{\dot{y}_{it}}{y_{it}} = \frac{\dot{A}_t}{A_t} + \hat{\eta}\frac{\dot{k}_{it}}{k_{it}} + \hat{\mu}\frac{\dot{h}_{it}}{h_{it}} + \frac{\dot{u}_{it}}{u_{it}} \tag{5}$$

where (additionally to notations of equations 1, 3-4):

i - subscript that denotes the province (in China) or the union republic (in the FSU);

$\hat{\eta}$ and $\hat{\mu}$ - the elasticity (income share) coefficients for the whole country;

u - effect of technical-efficiency differences between the province (or the union republic) and the whole country.

Clearly, it follows from equations (3 and 4) that $\frac{\dot{A}}{A_t}$ in equation 5 is TFP growth.

Since we define technical efficiency as the differences among the provinces/republics in the output/input ratio for the factors of productions, econometrically we can capture this as:

$$\frac{\dot{y}_{it}}{y_{it}} = \frac{\dot{\theta}_t}{\theta_t} + \eta_i\frac{\dot{k}_{it}}{k_{it}} + \mu_i\frac{\dot{h}_{it}}{h_{it}} + \frac{\dot{\varepsilon}_{it}}{\varepsilon_{it}} = \frac{\dot{\theta}_t}{\theta_t} + \hat{\eta}\frac{\dot{k}_{it}}{k_{it}} + \hat{\mu}\frac{\dot{h}_{it}}{h_{it}} + (\eta_i - \hat{\eta})\frac{\dot{k}_{it}}{k_{it}} + (\mu_i - \hat{\mu})\frac{\dot{h}_{it}}{h_{it}} + \frac{\dot{\varepsilon}_{it}}{\varepsilon_{it}} \tag{6}$$

where (additionally to notations of equations 1, 3-5):

θ - a time-variant general (common for all the regions of a country) productivity factor (similar to A in the standard growth accounting in equation (5) but free of the effect of technical-efficiency differences between the regions), i.e. general technological level of a national economy;

η_i and μ_i - the province (republic)- specific coefficients of elasticity between the factors of production;

ε - unexplained residual (error term).

Combining equation (5) and (6) we can show the relationships among TFP growth, general technology growth, and technical efficiency of physical and human capital:

$$\frac{\dot{A}_t}{A_t} = \frac{\dot{\theta}_t}{\theta_t} + (\eta_i - \hat{\eta})\frac{\dot{k}_{it}}{k_{it}} + (\mu_i - \hat{\mu})\frac{\dot{h}_{it}}{h_{it}} \tag{7}$$

Clearly equation 7 shows that TFP consists of a general production frontier (the maximum possible output given inputs of physical and human capital) and technical efficiency. In Figure 4 we plot general productivity for both the FSU and China. It is abundantly clear that the productivity frontier did move less in the case of the FSU compared to China. Technical efficiency dynamics, though, was less negative in the FSU in the period 1978-1993 than in China, as it can be seen from Table 4. This is not surprising given that China has faster growth of both human- and physical capital in this period. This changed in the post 1994 period when also the FSU had lower growth of technical efficiency.

Figure 4: General productivity index (1971=1)

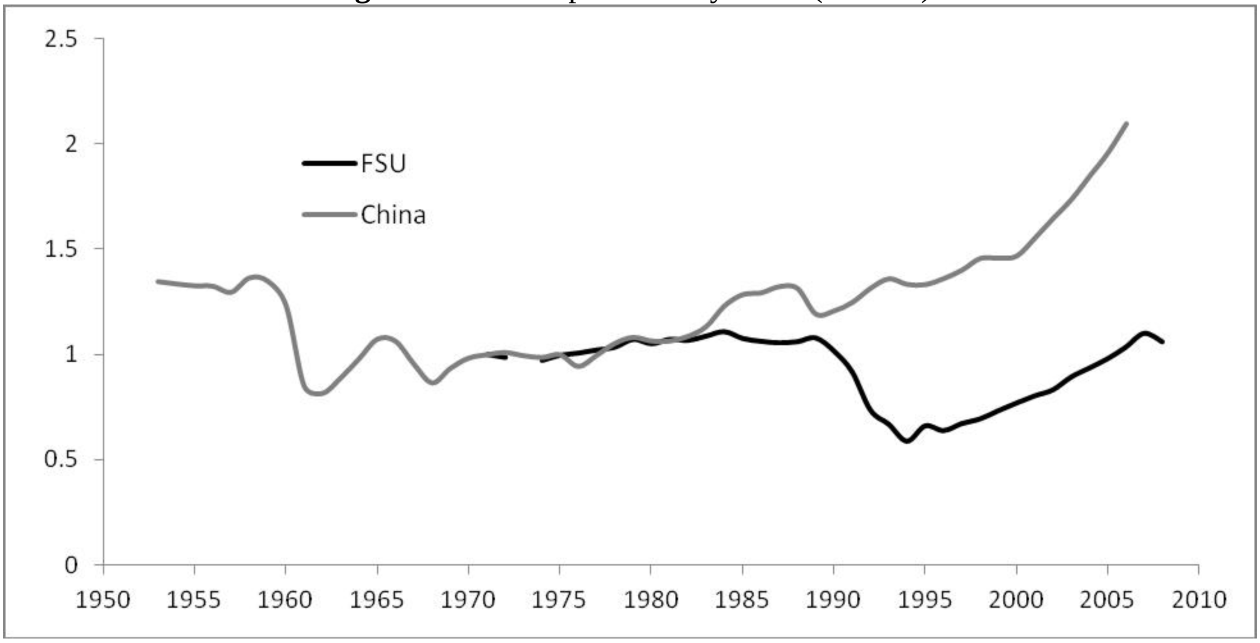


Table 4: Decomposition of TFP growth in growth technical efficiency and general productivity growth

	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%
			China		
TFP growth	-6.5%	-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 4 demonstrates that the FSU and China paths diverged from mid-1980s to mid-1990s. However, it also shows that during later period the difference was not in direction of the trend of general production frontier. The latter increased in both countries but China outperformed the FSU in its magnitude and sustainability during the crisis of 2008-2010. Another difference is that upward movement of the parameter was just its recovery in the FSU: by end 2000s general production frontier was not far above its pre-reform level. The plausible explanation of this pattern is that increased openness[9] of economies of China and the NIS, as well as their high level of human capital relative to GDP, helped to extend active technological borrowing from abroad but China managed

[9] In the source of the data (PWT 7.0) defined as exports and imports as a share of GDP. During the reform period it increased in China (1977-2009) from 19.5% to 58.6% (from 10.8% to 61.2% as of the alternative estimation); in Russia (which is keeping on about half the size of the NIS population and GDP) - from 11.9% to 54.6% (1990-2009), most sharply at the start of the period.

to benefit more due to its better institutional environment.[10] The latter is attributed rather to general technical development than to another component of technological level, namely technical efficiency of factors of production.

Both regions currently face an upturn in economic development, but there are two main differences. First, the FSU is rather replenishing the lost physical- and, partially, human capital. Due to its lower growth rates of the capital stocks, this is done using lower technical inefficiency. Nevertheless, it is to be expected that diminishing returns will soon set in and lower growth rates, unless the FSU area is able to modernise its stocks of human- and physical capital to that of present-day more developed economies. In China, however, a very high physical- and human capital accumulation takes place. This is already accompanied by increasing technical inefficiency. The reason why growth nevertheless continues, is that it is so far behind in technology that it is easier to import and, hence, increase in productivity frontier. Yet, in a couple of years China will likely face the same challenge as the FSU area: to radically change its entire technology, or to run into a trap with low GDP p.c. growth and diminishing return on capital.

In other words, both the China and the NIS have to extend their general production frontier (which is still distant to global one) and converge with advanced economies.

5. Spatial growth in the FSU and China

Above we noticed that the technical efficiency in the USSR is on average slightly higher than in China, while China having higher investments in physical and human capital in the reform period. Basically, this suggests that China had faster increasing inequality between regions than the FSU area: technical efficiency (i.e. the distance from the productivity frontier) did not go down that much in the FSU and the productivity frontier did not go so far up.

So the question is: why did virtually all countries of the FSU area not manage to accumulate so much physical- and human capital while growth patterns in China provinces were more different? The pattern is given in Table 5.

Table 5: Inequality in per capita GDP, human- and physical capital in the FSU and China*

			GDP/cap	Physical capital/cap	Average years of education	Cost based HC/cap
1929	Value	FSU	1,386	970	2.0	602
		China	563	NA	0.5	3.7
	Gini	**FSU**	**NA**	**NA**	**NA**	**NA**
		China	**NA**	**NA**	**25.3**	**58.7**
1939	Value	FSU	2,237	1,858	3.2	1,649
		China	562	NA	0.8	7.0
	Gini	**FSU**	**NA**	**NA**	**2.2**	**10.5**
		China	**NA**	**NA**	**31.6**	**NA**
1959	Value	FSU	3,669	7,539	5.1	3,140
		China	686	557	2.6	63
	Gini	**FSU**	**NA**	**NA**	**2.1**	**12.1**
		China	**28.1**	**26.4**	**15.8**	**28.2**
1979**	Value	FSU	6.427	25,315	8.1	8,580

[10] 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’ etc.) are expressed quantitatively, they are based on expert assessments and therefore are consensuses of subjective opinions that may not be verified themselves.

			GDP/cap	Physical capital/cap	Average years of education	Cost based HC/cap
		China	1,039	1,331	5.2	375
	Gini	**FSU**	**10.9**	**11.0**	**1.4**	**7.0**
		China	**25.3**	**24.0**	**7.8**	**25.5**
1989	Value	FSU	7,112	35,297	9.8	11,673
		China	1,834	3,085	5.9	1,044
	Gini	**FSU**	**10.6**	**13.6**	**1.1**	**7.5**
		China	**24.0**	**30.1**	**7.8**	**35.2**
2009	Value	FSU	7,940	24,142	12.5	18,952
		China	6,048	17,122	7.5	10,223
	Gini	**FSU**	**17.5**	**17.5**	**7.7**	**19.4**
		China	**25.3**	**39.4**	**8.2**	**29.7**

* Values are in 1990 GK dollars (except Average years of education)
** 1980 for physical capital in the FSU.

We see that inequality was rather high in both countries as a consequence of multi-ethnical and multi-cultural composition of these societies. In China the differences between the provinces were always higher than between the republics of the FSU. During central-planning period their political elites perceived the potential to the counties' disintegration arising from striking spatial differences and attempted to carry out equalizing policies as regards the factors of production. Such policies were targeted to accumulate them more rapidly in the low-developed periphery than in relatively developed regions. As result, the intra-country differences diminished somewhat during central-planning period but only modestly (only non-monetary indicator of 'average years of education' recorded remarkable convergence between the regions).

As regards GDP and fixed capital data, the observation period is rather short for the FSU republics to make generalised conclusions. But in terms of cost-based human capital we clearly see that the convergence between them appeared to be very limited for 50 years (1939-1989). Although it is highly probable that disparities were in much bridged during the earlier period of 1920s-1930s.

After 1989 the republics of the FSU clearly diverged from each other. This is no surprise as they ceased to comprise a united country and became independent states, of which three Baltic states (though not significant relative to the total of the NIS economies) joined the European Union. Break of previously established connections caused different outcomes for their economies that were exacerbated by large-scale armed conflicts on the territories of at least five of the NIS. There is also much other evidence (structure of foreign trade) that the trend to weakening economic integration between the NIS is still in force.

During the reform period inequality in China also increased but modestly comparing to the FSU. Moreover, it started to moderate as regards cost-based human capital since 1989.

6. Conclusion

The Former Soviet Union (FSU) and China are two countries that relative early moved onto a path of forced industrialisation, from a position of relative backwardness. Their strategy was one of catch-up: forced industrialisation, with a neglect of consumer production and wage development. 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 increased GDP per capita initially, even though it eventually caused deceleration in its growth rates.

However, China embarked earlier than the FSU on the path of increasing private consumption, which led to a decline in k/h ratio. This means that whereas the FSU continued on the path of diminishing returns to physical capital, China slowly moved towards more human capital oriented industries, thus avoiding the collapse of the FSU and its economy in the 1990s.

After the reforms China experienced outperforming rise of its human- and physical capital stock. This led to decreasing technical efficiency. In the FSU, however, physical capital collapsed and has not recovered so far while human capital had better performance. Hence, its technical efficiency growth was higher. On the other hand, since the FSU was closer to the global production frontier, its growth in this dimension was small to none while in China growth continued. Partially, this can be explained by the fact that wages are too low to make it profitable to use modern technologies while at the same time wages are too high to attract cheap labour industry. In China, which is further away from the global productivity frontier, still productivity can be increased until it has to face the same problem as the FSU.

The higher technical inefficiency in China also suggests greater inequality, since technical efficiency is essentially how far production is from the most efficiently used set of human and physical capital among the regions within a national economy. Indeed, we find that inequality in China is higher in both GDP, physical, and human capital. This suggests once more that productivity can increase, but will probably diminish as soon as China approaches the level of the FSU.

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