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Abstract: According to the consensus view it was physical capital accumulation that primarily drove economic growth during the early socialist period. Growth models incorporating both human and physical capital accumulation (Caballe and Santos 1993, Barro and Sala-i-Martin 2004) lead to the conclusion that a high physical/human capital ratio can cause a lower economic growth in the long-run. In this paper we show theoretically and empirically that according to the logic of the socialist planner, it was optimal to achieve a higher physical to human capital ratio in socialist countries than in the West. Using a VAR analysis, we find empirical confirmation that within the Material Product System of national accounting the relative dominance of investment in physical capital accumulation relative to human capital was indeed more efficient than under an SNA system of national accounts.

Keywords: central planning, capital accumulation, human capital, Soviet Union, national accounts.

JEL Codes: N14, P21, P24, P36.

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The findings, interpretations, and conclusions are the authors' own views which may not be shared by the institutions of their affiliation.

Introduction

The economic transition in the countries with centrally planned economies (those identified themselves as socialist and those were often referred to in political slang as the 'Eastern Block') has triggered many studies in its underlying sources of growth. Many of those make use of some sort of growth accounting framework in which they decompose GDP growth in physical (or fixed) capital, sometimes human capital, and some sort of residual factor, TFP, which is supposed to capture technological change. These studies often find that technical change was limited (and declining) during the socialist period when growth was mainly driven by physical capital accumulation (Kaplan 1968; Bergson 1978 [1971], pp. 166-168; Kontorovich 2001, p. 687). This is confirmed by Bob Allen (2003) whose simulation exercise indicates that without the massive capital accumulation of the 1930s, the USSR would have been worse off in the 1960s than it actually was. This follows logically from a simple neoclassical growth model (Solow 1956; 1957): an increase in physical capital stock per worker increases the steady state level per capita GDP in the long-run.

However, the problem with such a framework is that actual economic growth in the 'Eastern Block' turned out to be lower than in the Western world: whereas many of the Central and Eastern European countries (hereinafter referred to as CEE or Eastern Europe), and to a lesser extent the republics of the USSR, had been at par with the West in the 1920s, in the 1980s they lagged substantially behind in terms of per capita GDP. This would be consistent with studies arguing that the lack of technology hampered growth in these regions. Indeed, it is often found that, when physical capital/human capital ratio grows, per capita GDP growth decreases (e.g. Erk, Altan Cabuk, and Ates 1998; Duczynski 2002; 2003).

The different views on the role of physical capital accumulation in long run economic development are less surprising when seen from a policy perspective. Whereas the former centrally planned countries measured their aggregate economic activity (or aggregate income) in terms of Net Material Product (NMP), loosely described as the sum of material production[2], the West relied on the concept of GDP which also included immaterial production like services. In addition, material production required more physical capital than immaterial production. Hence, in order to achieve a growth in NMP, socialist governments were more inclined to maximize material production and hence prioritize physical capital accumulation. This was even strengthened by the theory of socialist reproduction embodied in the growth programme voiced by an early Soviet economist Grigory Feldman (1964 [1928]): the planning priorities were defined in the way that even among material goods productive capacities were expected to grow faster than consumer goods. In the West, on the other hand, where individual decisions to maximize utility (as a function of consumption) aggregate into some economy level policy, the immaterial sector also took a large share of GDP and, consequently, the optimal rate of physical capital accumulation was less. This is the reason why it has been found by the NBER in the 1950s and 60s that once Western GDP was converted into NMP (i.e. the majority of the service sector value added was subtracted), the West turned out poorly in terms of economic development compared to the socialist countries. From a socialist point of view, it was thus

[2] Datta (2007) discusses its concept in comparison with conventional measures of national accounting (SNA).

logical to maximize material output and physical capital accumulation.

In this paper we analyse economic development in Eastern Europe and the former USSR from the socialist policy perspective. In Section 2 we start by looking at the data. We find that most socialist countries knew a sharply rising physical/human capital ratio combined with lowering economic growth in terms of GDP. In Section 3 we provide our insights into theoretical background and practical implications of the socialist central planning policies. In Section 4 these insights are applied in a one-sector model in which the government can either prefer to maximize material output or consumption (or a combination of both). This model is an exogenous growth model, meaning the long-run (balanced growth) effect is zero. This model is tested in Section 5 where we discuss some effects of physical- and human capital on growth. We end with a brief conclusion.

Data

Our empirical analysis requires data on physical[3] and human capital as well as GDP per capita and its socialist equivalent the Net Material Product 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 Eastern Europe and the former USSR are taken from Maddison (2007) as updated on his website (http://www.ggdc.net/MADDISON/oriindex.htm) and, in the case of the republics of the former USSR, extended by Didenko et al. (2013b) based on the World Bank (2011).[4] Physical capital is taken from Van Leeuwen and Foldvari (2012) and Didenko et al. (2013b) based on Easterly and Fisher (2001). The income-based human capital measure is taken from Didenko et al. (2013b). For comparison we also added a cost-based human capital measure for the former USSR taken from Didenko et al. (2013b).[5] Finally, the Net Material Product is taken from Didenko et al. (2013b) which in its turn was based on the official figures from 1958 to 1990 and Khanin (1991) for the earlier period in current prices.

The results are reported in Table 1. The most interesting feature is that there

[3] This refers to the gross fixed capital stock.
[4] Didenko et al. (2013b) used GNP/cap., which they assumed comparable to GDP/cap, based on Bergson (1961), Becker (1969), Steinberg (1990).
[5] For this analysis, the cost-based analysis is the most appropriate. Not only does it compare better with the cost-based valuation of fixed capital, but also it remains a yet unanswered question if we can have income-based capital stock estimates for socialist economies as generally there was just a limited market for fixed capital under socialism while there was a quasi-market for human capital.

Table 1. **Per capita GDP, human- and physical capital in socialist Eastern Europe and ex-USSR in 1990 GK dollars**

	1930s*				1980s**				2000s***			
	GDP/cap	K/cap	H/cap (cost based)	H/cap (income based)	GDP/cap	K/cap	H/cap (cost based)	H/cap (income based)	GDP/cap	K/cap	H/cap (cost based)	H/cap (income based)
ex-USSR	1,247	1,547	1,649	78,849	6,753	30,432	12,337	197,217	6,013	19,894	12,305	167,592
Armenia			1,634	62,850	5,434	21,333	20,007	198,469	7,768	14,591	13,718	260,828
Azerbaijan			1,856	79,019	4,942	17,793	10,063	231,616	4,168	17,422	7,545	292,853
Belarus			1,298	37,177	5,554	27,216	10,763	128,692	8,969	22,441	25,517	260,659
Estonia					10,630	40,003	27,826	274,576	16,065	55,840	44,458	391,433
Georgia			1,930	79,604	9,355	22,933	16,004	240,516	4,484	10,037	6,696	171,572
Kazakhstan			2,517	116,635	8,104	30,300	13,641	364,441	7,996	15,172	10,206	144,413
Kyrgyzstan			1,730	53,756	3,184	16,114	12,496	154,778	2,439	7,573	4,845	183,101
Latvia					9,278	35,690	21,841	205,149	11,374	39,959	29,856	332,254
Lithuania					8,538	33,013	16,777	224,697	8,736	30,775	23,108	228,418
Moldova					5,679	21,148	11,783	155,135	3,095	17,541	11,706	120,229
Russia			1,931	78,597	7,308	36,218	12,761	200,059	6,943	23,384	12,304	148,561
Tajikistan			1,563	71,794	3,214	12,830	7,804	178,827	1,228	1,912	1,428	55,900
Turkmenistan			2,483	71,367	3,614	21,696	10,593	153,597	3,137	10,959	NA	148,709
Ukraine			1,083	53,466	5,585	26,399	11,492	145,588	3,893	22,266	10,037	88,555
Uzbekistan			1,111	70,944	4,124	15,498	7,863	204,320	4,151	5,383	25,183	242,894
Austria	3,221	4,135		87,274	14,753	30,683		419,171	21,435	43,278		485,662
Bulgaria	1,443	1,264		75,396	6,281	9,224		124,955	6,424	8,853		79,627
Czechoslovakia	2,662	2,981		109,313	8,329	15,770		176,107	9,897	14,188		233,175
Germany	4,206	4,275		64,571	15,044	31,165		401,016	19,291	25,813		553,817
Hungary	2,473	2,241		57,475	6,648	10,919		188,916	8,182	13,863		210,450
Poland	1,775	3,319		28,179	5,617	14,342		146,800	7,974	11,588		243,855
Romania	1,191				4,101	8,037		138,182	3,566	6,854		103,524

Source: Didenko et al. (2013a); Didenko et al. (2013b); Van Leeuwen and Foldvari (2013, forthcoming).
** 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.*
**** Average of 2000-2008 for the republics of the former USSR and CEE.*

seems to be little change in per capita GDP ranking over time. Indeed, Germany, Austria and Czechoslovakia, together with the Baltic states, were as much in the top ranks in 2000 as they had been in the 1930s. The same holds true for the physical capital stock, even though in the 1980s for a short time the countries of the former USSR area appeared to have caught up. In the income-based human capital stock we find some sort of reversal though: whereas before the World War II it was Czechoslovakia that topped the list, after the War their places were taken in by Germany, Austria. The Baltic states were the most developed among the republics of the USSR both in terms of per capita GDP and income-based human capital stock. Unfortunately we do not have comparable cost-based human capital data for Eastern Europe, but the limited

data that we have available in Table 1 show a similar pattern with the Central Asian republics and Russia dominating before the War and the Baltic states appeareing (although they might have been at the top of the list in the 1930s, but we unfortunately do not have any data) at the top of the list thereafter. A possible reason may be the USSR central government equalizing policy that was targeted to allow the low-developed national periphery catch-up with the European Soviet regions in terms of education spread, while allowing the more developed Baltic republics to sustain their relatively high level.

In maps 1a and 1b we report per capita GDP in 1940 and the 2000s (average of GDP per capita for the years 2000-2009). Even we only have GDP data for the USSR in 1940, we report it for the current borders of Russia (it should be born in mind that in 1940 Russia was better off than the USSR as a whole) because the other regions might have had considerably different per capita incomes. As one can see, both

Map 1a. **GDP/cap in 1940 (USSR=Russia, current borders) (1990 GK dollars)**

Note: Countries for which we do not have data are omitted.

Map 1b. **Average GDP/cap in the 2000s (1990 GK dollars)**

Note: Here and below the borders within the ex-USSR are as they were prior to its dissolution.

before and after World War 2, Austria and Germany were in the lead together with Czechoslovakia. However, Russia (USSR) made quite a recovery after the War.

These patterns may also be observed for physical capital per capita. As shown in Table

1, even though, just as in terms of per capita GDP, Germany and Austria remained the leading economies, Russia made up quite some ground in capital formation, especially up to the 1980s. However, the socialist collapse in the 1990s hit the former Soviet Union (FSU) area much harder than Eastern Europe and, consequently, the 1930s ranking seems to have been restored.

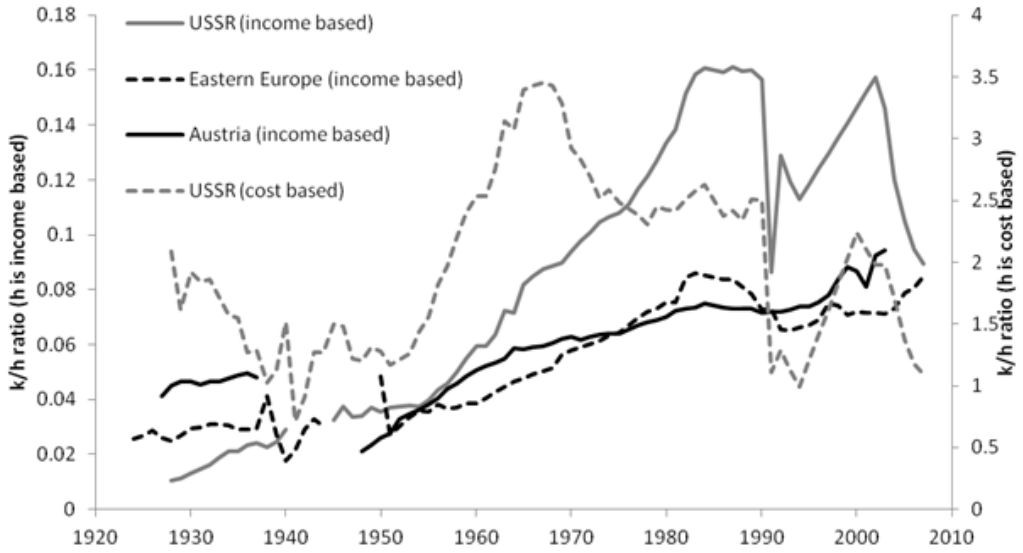
The human capital is measured in two ways. The cost-based method is based on Judson (2002), who estimates the public expenditure on a single year of education for each year. We introduce only a slight modification, namely, we multiply the replacement value of a single year of education by the average years of education to receive the replacement costs of the education of the average individual. The second method is the income-based measure suggested in Van Leeuwen and Foldvari (2011, 2013 forthcoming). The income-based measure of human capital equals the present value of all future income flows under some assumptions on the expected rate of growth of real incomes, incorpoating information on the average age of the population.

We report the estimates for the income-based human capital measure since wage data was available for all countries in the sample, while the cost-based estimation was only possible for the ex-USSR. As can be seen from Table 1, in terms of human capital endowment, the regional ranking differs from the physical capital accumulation. It was especially Czechoslovakia, Austria and the Central Asian republics that did well in the 1930s. This situation remained until the 1980s, with the only difference that Germany caught up in the meantime. Yet, the collapse of the socialist states completely changed this picture with Germany, Austria and the Baltic states at the head of the pack and the Central Asian republics falling far behind. This suggests that the human capital stock, when measured by the present value of earnings, especially in the Central Asian region, underwent a significant devaluation during the transition period.

In sum, whereas GDP/cap and physical capital/cap rankings were somewhat persistent over time, this was less true for human capital. Physical capital accumulation was especially rapid in the USSR and, to a lesser extent, in Eastern Europe, but much of this ambiguous advantage was lost during the transition period. Human capital accumulation was especially rapid in Germany and Austria and probably the Baltic states while the initial lead of the Central Asian republics was lost during the 1990s. In other words, it seems as if the massive fixed capital accumulation had contributed both to acceleration of growth initially (at early stages of industrialization) and also to its deceleration at advanced stages of development (when human capital intensive service sectors were on the rise) in the socialist countries. Hence, whereas initially the gap with the Western countries in terms of per capita income seemed to be declining, after the mid-20th century, with the increase of human capital intensive economic sectors, it increased once more.

The observed trends suggest that there was, in line with the dominant economic policy in the 'Eastern Block', an increased accumulation of physical capital relative to human capital up to the 1980s, but this gap was narrowed somewhat in the 1990s. This feature is plotted in Figure 1.

Figure 1. **Physical to human capital ratio in socialist Eastern Europe and the ex-USSR**



We can also observe that Eastern European dynamics is closer to the Austrian than to the Soviet one indicating that state-socialist countries in Central and Eastern Europe adopted the Soviet central planning model with some adaptations. Also we find a decline of this ratio in the 1990s when physical capital became valued closer to its actual market price. Another important point to note from the above Figure is that the cost-based human capital indicator seems to move quite well together with the income-based measure with the exception of the pre-1940 period. Nevertheless it is clear that both the cost- and income-based measures show a far faster growth in physical/human capital ratio in the USSR than elsewhere.

Socialist planners' preferences in theory and practice

The finding is that while the ranking in terms of GDP per capita did not change much the physical/human capital ratio increased considerably in Eastern Europe and even more in the USSR. Even though not unexpected, this observation warrants further analysis given that some growth theories incorporating an endogenous investment in both types of capital (Caballe and Santos 1993) predict that a more physical capital intensive development path should result in a lower growth rate. Obviously, from the perspective of a planner in a market economy this direction would be suboptimal. Can the rationality of the economic planner be squared with the overinvestment in physical capital accumulation? The most likely explanation lies in the different role of the state played in economic development in state-socialist countries and market economies, and, as a result, the difference in preferences of the social planner.

The idea to provide some insights into the 'socialist planners' preferences' to find some inner rationale, economic behaviour patterns and to assess efficiency of their decisions within the socialist system own context originally could be traced back to Bergson (1964). He examines to what extent their behaviour was rational to meet their ends while having expected the planners' welfare function to favour investment and defence. Indeed, in state-socialism,

initially the government takes full control of the resources and also makes the majority of allocation decisions. As such, we can use the government's priorities as those of the 'social planner'.

In a market economy, however, decisions regarding the allocation of resources are made by private agents as they make decisions about the size and allocation of their savings and consumption. But the decisive factor is not the role of the state: even if the state has a large redistributive power (in a mixed-economy or in a welfare state), as long as its primary concern is welfare maximization in the long-run (where welfare is modelled as some function of the discounted sum of present and future consumption), the final outcome should, at least theoretically, not be different than from a society where private agents make all decisions. The basic idea behind central planning is the elimination of transaction costs and reduction of informational asymmetry, which are inevitable in market economies. In the first half of the twentieth century this idea seemed quite rational and plausible to many left-wing economic and political theorists who contended to gain political power to put it into reality.

State-socialist governments were influenced by the Marxian theory of economic development and economic reproduction, based on Adam Smith's view on productive and unproductive labour. Marxism motivated economic policy inherited this distinction between material and immaterial production. The latter was simply not even included into the Material Product System (MPS), a system of national account widely used in European state-socialist countries until the 1980s and in the People's Republic of China until 1993. Of all the socialist countries, it was the ex-USSR which was the first in a row of socialist countries where new revolutionary elite after their victory in the civil war and subsequent economic recovery had got political tools to produce such a socio-economic experiment.

As the state-socialist system emerged, empirical studies became possible to explore its strong and weak points. It is pointed out in Harrison (1985) that two philosophies and practices of planning emerged during late 1920s. 1) The 'Balance school' whose basic idea was not to disrupt social and economic equilibrium, and adapt capital construction to the needs of household consumption and other determinants of social welfare and 2) the 'Mobilization school' which stressed primary role of political decisions to get things done regardless of attendant sacrifices, exertions and wastes by exercise of authority, i.e. for material production. The immediate winner in the dispute then was 'mobilization school' but the concepts of the 'balance school' were rather modified and incorporated than rejected. For example, as shown by Gregory (2003), the government was interested 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 archives provide numerous expressions of the Soviet leadership's belief in a strong link between consumption and work effort: more *Politburo*[6] time in 1930s was spent on consumption (especially emergency sessions) than on any other issue (Gregory 2003, p. 94). It was, for example, the famine of 1932 that made the authorities temporarily allocate more resources to consumption at the expense of investments. Hence, these two approaches (balance

[6] The highest political organ of the ruling Communist Party in the 1930s comprised of about ten persons that defined the political guidelines.

and mobilization) coexisted within the Soviet system as they both agreed on the need for capital accumulation to bring about rapid economic development. After each period of forced mobilization there was need to find a temporary adjustment phase when it was possible to voice the need for restored balance as a precondition of any further mobilization.

Two streams in the literature have argued about the practical implications of this policy. Even though they agree about the principle of the planner, they disagree about the practical implication of these plans. First, Ellman (1979) stresses the decisive role of production over distribution, exchange, and consumption as the starting point of socialist planning. He also summarizes that the planners considered material goods as the basis and condition of existence, and producer goods had higher priority over consumer goods. This was amplified under Stalin's rule where the balance between current needs and investments was strongly biased in favour of the latter based on general preference for 'tomorrow' over 'today' (Nove 1983).

The second branch of this literature, which agrees with the planner preferences but argues that these plans were much more poorly implemented, is headed by Kornai (1992) (but see also Zaleski 1980; Gregory and Stuart 2001, 7th edition; Gregory 2003 and Harrison 2005). Kornai sees the central planning system as some sort of principal-agent problem, where direct bureaucratic management is impeded by conflict of interest between principal (who has the authority to command) and agents (who are obliged to execute the orders) as well as by information distortions. Hence, Kornai is rather sceptical as regards planners' preferences strong influences on final output structure. He argues that priorities often changed over time depending on political sentiment but to some extent policy line may be traced ex-post in actual economic outcomes despite unintended consequences of major and minor management decisions might also arise. However, he does not distinguish between core preferences, sometimes not expressed systematically, that were shared implicitly by most of experts and decision-makers (e.g. 'current consumption is the residual of investment needs'), and particular preferences that could be campaigned but might be subject to change (e.g., whether to rely on domestic or imported technical equipment to modernize industry).

Hence, even though one may argue about the effectiveness of the plans, the core principles remained basically unchanged over time. Moreover, the planning system appeared to be rather sustained and reproduced itself for more than half a century. Gregory (2003) applies to its propagandistic significance in respect to long-term plans that served primarily motivational rather than resource-allocation functions. He also stresses that planners' preferences were basically expressed as the policy guidelines and were shared by them as well as by resource managers from the highest to the lowest levels. The planners' preferences were really expressed through the investment plan, which was the cornerstone of resource allocation. There were a number of priorities that were established under Stalin but survived until 1980s having remained remarkably constant over time and space: investment over consumption (referring to investment-maximizing mathematical growth model formulated in late 1920s by the above-mentioned economist G. Feldman); industry over agriculture while services were the least important and could be neglected; heavy industry (producer goods) over light industry (consumer goods); defence production over civilian production; domestic production over imports.

Indeed, the works by Nove (1977, 1983) confirmed that although the details of planning organization changed over time in the USSR, this process at its more advanced stages (with the exception of the period 1957-1965) inherited essential features noted by Gregory and the planners' priorities had not altered. Even though mathematical methods of optimization (linear programming etc) were applied to planning in 1960-1980s, the plans never became sufficiently balanced, what was softly recognized even at the very top level. What really did change were the growing producers' opportunism and their abilities to manipulate plan indicators and planners' expectations (Gregory 2003). Therefore the plans became less ambitious and 'balanced' approach dominated over 'mobilization' one in terms of Harrison (1985).

Both Gregory (2003) who explored the Soviet archetype and Kornai (1992) who generalized common features of socialist system performance agree on the assertion that implicit rules and practices were transmitted from the Soviet Union to other planned economies. However, we should note that other socialist countries basically adopted the Soviet planning system in its rather modest variant. Most of European satellites of the USSR entered 'socialism' at more advanced stage of development and they did not have such a strong aptitude to resort to mobilization drives accompanied by extremely brutal forms of command management in order to provide rapid factor accumulation. Not acting as self-sufficient actors in global politics, they also did not have vital needs to carry on too hard defence burden. Various countries' specific experience in planning is explored in Ellman (1979), Nove (1983) and much of other literature. Even before the collapse of the USSR they started to diverge from its central planning model: Yugoslavia did so almost from the start of the communist rule, Hungary after 1968, while China started reforms at the turn of 1970s-1980s (followed by Vietnam in late 1980s) gradually drifting to market-based government management of the national economy.

The model

Hence, no matter which branch of literature is followed, all agree that state-socialist planning combined with a focus on material production led to increased physical capital accumulation. In this section we will try to capture this policy in a formalized model. Nevertheless, the main results and mechanisms can be summarized in a quite succinct way. A state-socialist regime, following a Marxism-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 has consequences on the performance of the economy as well, but the conclusion strongly depends on the way of measurement: in terms of GDP per capita growth (SNA), since the social returns to fixed capital are likely to be lower than that of human capital (as it is usually found in the empirical literature), the same amount of resources spent on increasing physical rather than human capital leads to a lower rate of economic growth. It turns out, however, that if one measures performance within the MPS, the planned economy should produce a faster growth and outperform other economies. 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.

The optimization problem that we discuss below is basically the same as that in Caballe and Santos (1993) also discussed in Barro and Sala-i-Martin (2004, Chapter 5). We start with following Ellman (1973) in that the government makes the decisions like some sort of social planner and has a combination of per capita consumption (c) and per capita material production (q^m) in its utility function, which it seeks to maximize. The value function (V) equals the discounted sum of the utilities over an infinite horizon:

$$V(t, q^m, c_t) = \int_0^\infty e^{-\rho t}(a\ln q_t^m + b\ln c_t)dt \tag{1}$$

where ρ is the discount factor, a and b are parameters that reflect the preferences of the planner regarding material production and consumption which we discussed in the previous Section. The planner's problem is to maximize the value function.

Even though, as argued by Ellman (1973), the socialist government largely focuses on material production, we also include consumption in its utility function since the planner also wishes to prevent hunger or political instability (strong empirical evidence is provided in Gregory 2003). As such we assume that both a and b are positive.

The factor accumulation is governed by the following equations, where, without the loss on generality, we assume the same rate of depreciation in all sectors and for both types of capital. The super and subscripts m and i denote the two sectors (material and immaterial), while k and h denote physical and human capital, with δ and n being the rate of depreciation and the growth rate of labour force respectively. As usual $\dot{x} = dx/dt$, I is gross investment during period of dt.

$$\dot{k}_m = I_k^m - (\delta + n)k_m \tag{2}$$

$$\dot{k}_i = I_k^i - (\delta + n)k_i \tag{3}$$

$$\dot{h}_m = I_h^m - (\delta + n)h_m \tag{4}$$

$$\dot{h}_i = I_h^i - (\delta + n)h_i \tag{5}$$

We assume that the planner seeks to spend all of its income y (resources available for allocation) at time t what yields the following budget constraint:

$$y_t = c_t + I_k^m + I_h^m + I_k^i + I_h^i = k_m^\beta h_m^{1-\beta} + k_i^\gamma h_i^{1-\gamma} \tag{6}$$

where β is the elasticity between physical and human capital in material sectors and γ is the same elasticity in immaterial sector.

Consumption consists of material and immaterial goods which require a different mix of the two capitals to be produced:

$$q_t^m = k_t^{\beta} h_t^{1-\beta} \quad q_t^i = k_t^{\gamma} h_t^{1-\gamma} \tag{7}$$

In equation 7 we can assume that $\beta > \gamma$, that is, material goods are produced more physical capital intensively than immaterial goods.

Consumption is also modelled as a composite of the two types of goods and they are assumed to be imperfect substitutes. This is modelled as a Cobb-Douglas type function:

$$c_t = \left(q_t^m\right)^{\alpha} \left(q_t^i\right)^{1-\alpha} \tag{8}$$

where α is simply the elasticity between material and immaterial consumption.

Now we can write the following Hamiltonian:[7]

$$\begin{aligned} H = e^{-\rho t}\left(a \ln q_t^m + b \ln c_t\right) + \lambda_1 (q_t^m + q_t^i - c_t - I_h^m - I_k^i - I_h^i - (\delta + n)k_m) + \\ + \lambda_2 (I_k^i - (\delta + n)k_i) + \lambda_3 (I_h^m - (\delta + n)h_m) + \lambda_4 (I_h^i - (\delta + n)h_i) \end{aligned} \tag{9}$$

where H is utility value along the optimal path and λ is the shadow-price.[8]

The first order conditions for a maximum require:

$$H_c = e^{-\rho t} \frac{b}{c_t} - \lambda_1 = 0 \tag{10}$$

$$H_{I_k^i} = -\lambda_1 + \lambda_2 = 0 \; H_{I_h^m} = -\lambda_1 + \lambda_3 = 0 \; H_{I_h^i} = -\lambda_1 + \lambda_4 = 0 \tag{11}$$

or

$$\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda \tag{12}$$

The additional conditions of an optimal path are:

$$H_{k_m} = \frac{e^{-\rho t} \beta (a + \alpha b + \lambda q_t^m e^{\rho t})}{k_m} - \lambda(\delta + n) = -\dot{\lambda}\,) \tag{13}$$

$$H_{k_i} = \frac{e^{-\rho t} \gamma (b(1-\alpha) + \lambda q_t^i e^{\rho t})}{k_i} - \lambda(\delta + n) = -\dot{\lambda} \tag{14}$$

[7] For econometric application of the Hamiltonian function see Barro and Sala-i-Martin (2004, A.3.3 and A.3.5).

[8] 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.

$$H_{h_m} = \frac{e^{-\rho t}(1-\beta)(a+\alpha b+\lambda q_t^m e^{\rho t})}{h_m} - \lambda(\delta+n) = -\dot{\lambda} \tag{15}$$

$$H_{h_i} = \frac{e^{-\rho t}(1-\gamma)(b(1-\alpha)+\lambda q_t^i e^{\rho t})}{h_i} - \lambda(\delta+n) = -\dot{\lambda} \tag{16}$$

where we already incorporated the condition that the shadow-prices λ_1-λ_4 are equal along the optimal path. Making above expressions equal for the same sectors leads to the following physical to human capital ratios within each sector:

$$\frac{k_m}{h_m} = \frac{\beta}{1-\beta} \tag{17}$$

$$\frac{k_i}{h_i} = \frac{\gamma}{1-\gamma} \tag{18}$$

The optimal growth rate of consumption is given as follows:

$$\frac{\dot{c}}{c} = \frac{e^{-\rho t}\beta(a+\alpha b+\lambda q_t^m e^{\rho t})}{k_m \lambda} - (\rho+\delta+n) = \frac{\beta(a+\alpha b)c_t}{k_m b} + \left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t} - (\rho+\delta+n) \tag{19}$$

$$\frac{\dot{c}}{c} = \frac{e^{-\rho t}\gamma(b(1-\alpha)+\lambda q_t^i e^{\rho t})}{k_i \lambda} - (\rho+\delta+n) = \frac{\gamma(1-\alpha)c_t}{k_i} + \left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t} - (\rho+\delta+n) \tag{20}$$

where we made use of that:

$$q_t^m = \left(\frac{1-\beta}{\beta}\right)^{1-\beta} k_m \text{ and } q_t^i = \left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} k_i \tag{21}$$

Once the steady state is achieved, both per capita income and consumption will be constant. This gives us the following consumption level at steady state:

$$c_t = \left[\rho+\delta+n-\left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}\right]\frac{bk_m}{\beta(a+\alpha b)} \tag{22}$$

$$c_t = \left(\rho+\delta+n-\left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}\right)\frac{k_i}{\gamma(1-\alpha)} \tag{23}$$

So the steady state ratio of the physical capital in the two sectors is:

$$\frac{k_m}{k_i} = \frac{\rho + \delta + n - \left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}}{\rho + \delta + n - \left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}} \frac{\beta(a+\alpha b)}{b\gamma(1-\alpha)} \tag{24}$$

The same for human capital is:

$$\frac{h_m}{h_i} = \left[\frac{\rho + \delta + n - \left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}}{\rho + \delta + n - \left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}} \right] \frac{(1-\beta)(a+\alpha b)}{b(1-\gamma)(1-\alpha)} \tag{25}$$

In order to arrive to the economy-wide ratios of physical to human capital, we need to express the total amount of physical- and human capital in the economy:

$$k_t = k_m + k_i = \left(1 + \left(\frac{\rho + \delta + n - \left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}}{\rho + \delta + n - \left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}} \right) \frac{\beta(a+\alpha b)}{b\gamma(1-\alpha)} \right) k_i \tag{26}$$

Doing the same for human capital yields:

$$h_t = h_m + h_i = \left[1 + \left(\frac{\rho + \delta + n - \left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}}{\rho + \delta + n - \left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}} \right) \frac{(1-\beta)(a+\alpha b)}{b(1-\gamma)(1-\alpha)} \right] h_i \tag{27}$$

We can now simply divide above equations and arrive at the physical to human capital ratio:

$$\frac{k_t}{h_t} = \frac{\frac{\gamma}{1-\gamma} + \left(\frac{\rho + \delta + n - \left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}}{\rho + \delta + n - \left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}} \right) \frac{\beta(a+\alpha b)}{b(1-\gamma)(1-\alpha)}}{1 + \left(\frac{\rho + \delta + n - \left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}}{\rho + \delta + n - \left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}} \right) \frac{(1-\beta)(a+\alpha b)}{b(1-\gamma)(1-\alpha)}} \tag{28}$$

This is a general formula when a planner derives utility both from consumption and

material production. In the extreme case, when $a>0$ and $b=0$, that is the planner does not assign any value to consumption, investment will only be in the material production and

$$\frac{k_t}{h_t} = \frac{\beta}{1-\beta} \tag{29}$$

Since usually $\beta<0.5$, this means that $k/h<1$.[9]

In the other extreme case, when a=0, we have the case where consumption is all important (which will be approximately the case for capitalist/post-socialist countries), b cancels out and we get:

$$\frac{k_t}{h_t} = \frac{\frac{\gamma}{1-\gamma} + z\beta}{1+z(1-\beta)} = \frac{\frac{\gamma}{1-\gamma} + z\beta}{1+z-z\beta} \tag{30}$$

with: $z = \left(\frac{\rho+\delta+n-\left(\frac{1-\gamma}{\gamma}\right)^{1-\gamma} e^{\rho t}}{\rho+\delta+n-\left(\frac{1-\beta}{\beta}\right)^{1-\beta} e^{\rho t}} \right) \frac{\alpha}{(1-\gamma)(1-\alpha)} > 0$ and if $\beta>\gamma$, $z>1$. (31)

We take two additional special cases. If $\alpha=\beta=\theta$, that is if both material and immaterial goods were produced with the same factor intensity, the capital ratio at balanced path would be:

$$\frac{k_t}{h_t} = \frac{\frac{\theta}{1-\theta} + \frac{\theta(a+\alpha b)}{b(1-\theta)(1-\alpha)}}{1+\frac{a+\alpha b}{b(1-\alpha)}} \tag{32}$$

If additionally a=0, that is, the planner's utility includes only consumption:

$$\frac{k_t}{h_t} = \frac{\theta}{1-\theta} \tag{33}$$

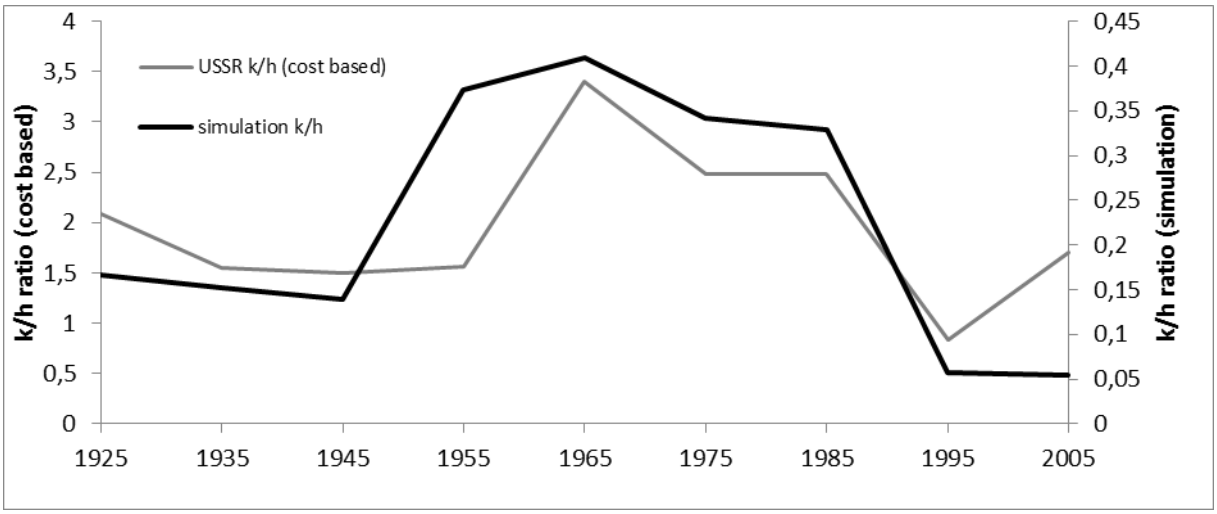
Which is the same result that Barro and Sala-i-Martin (2004, Chapter 5) obtained for a market economy. That is, (33) is a special case for the more general formula for the *k*/*h* ratio in equation (28) along a balanced growth path.

In the followings we choose different values of the parameters in accordance with the policy changes and simulate the physical to human capital ratios using equation (28). As we found that during the 1920s - 1930s the planner often had to give priority to consumption (Gregory 2003) in its utility function we set the coefficient values to capture this empirical

[9] That is, we assume here that the proportion of capital incomes in total income is smaller than that of labor incomes.

evidence. We also assume that after the 1980s, with collapse of the planned economy, the utility function of the social planner includes much less material production (i.e. a=1) since after the regime change material production less important while consumption rise in importance. During socialist times, however, there was a preference for material production. The result is given in below graph. We have to stress that above model incorporates human capital as direct expenditure into the model for which the closest empirical equivalent is the cost-based measure (see Judson 2002 or Van Leeuwen and Földvári 2008). The income-based measures reflect private and social returns to human capital so even though its trends should not deviate from the cost-based measurement for a very long period, it is much less appropriate to test the model.

Figure 2. **Simulated and actual physical to human capital ratio in the ex-USSR**



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;
1990s and 2000s: a=0; b=2; α=0.5; β=0.3, γ=0.2.

Effects on economic growth

The above simulations show that once we take differences in the objectives of the socialist planner relative to the market economy into account, the increased focus on physical capital accumulation can be placed within the framework of rational decision. But how does this policy affect economic growth? The empirical success of the strategy depends on how we measure economic growth: since the non-material sources of value added are excluded from the Net Material Product, state-socialist countries are more likely to appear successful if we measure their economic activity in terms of NMP rather than in GDP.

In principle, the growth of any types of capital should lead to a temporary increase in economic growth, but due to their decreasing marginal product this cannot be sustained unless

the other type of capital also increases. Just like in the original model by Cabale and Santos (1993) the optimal *k*/*h* ratio, unless the model parameters change fundamentally, should remain constant along the balanced growth path, but deviations from it are also possible (imbalanced growth) which should increase the growth rate relative to the balanced growth rate.[10] According to our model, when aggregate economic activities are measured in term of NMP, an increase in the *k*/*h* ratio should have a greater impact on output than when GDP is used.

In order to find an empirical confirmation for this, we use the data for the USSR, for which we have a good coverage of NMP data and also cost-based human capital estimates, which are more comparable with physical capital than income-based measures, and hence are more in line with the human capital concept applied in the theoretical model. We choose 1955-1989 as our sample period, which can be seen as a relatively stable period of the Soviet planned economy, after the forced industrialization of Stalin but before the transition to a market economy. The initial unit root tests suggest that all of our variables are stationary (Table 2).

Table 2. **Unit-root tests, USSR 1955-1989 (p-values in parentheses)**

	ADF (lag selection with MAIC)	Phillips-Perron
log of per capita GDP	-2.628 (0.097)	-3.636 (0.0099)
log of per capita NMP	-5.751 (0.000)	-7.267 (0.000)
log of *k*/*h*	-6.278 (0.000)	-5.779 (0.000)

We estimate two vector autoregressive (VAR) systems, one with per capita GDP and the other with per capita NMP. All lag-length selection criterion suggest a VAR(1) system, but the exclusion tests suggest that a second lag still had significant explanatory power, for this reason we estimated VAR(2) systems for both specifications. In both cases the residuals are normally distributed and have no serial correlation significant at 5%. Also, all the characteristic roots are found to be within the unit circle, hence the impulse-response functions (IRF) are meaningful (Figure 3).

[10] If the economy has the tendency to return to the balanced growth path, this growth bonus is only temporary.

Figure 3. **Impulse response function**

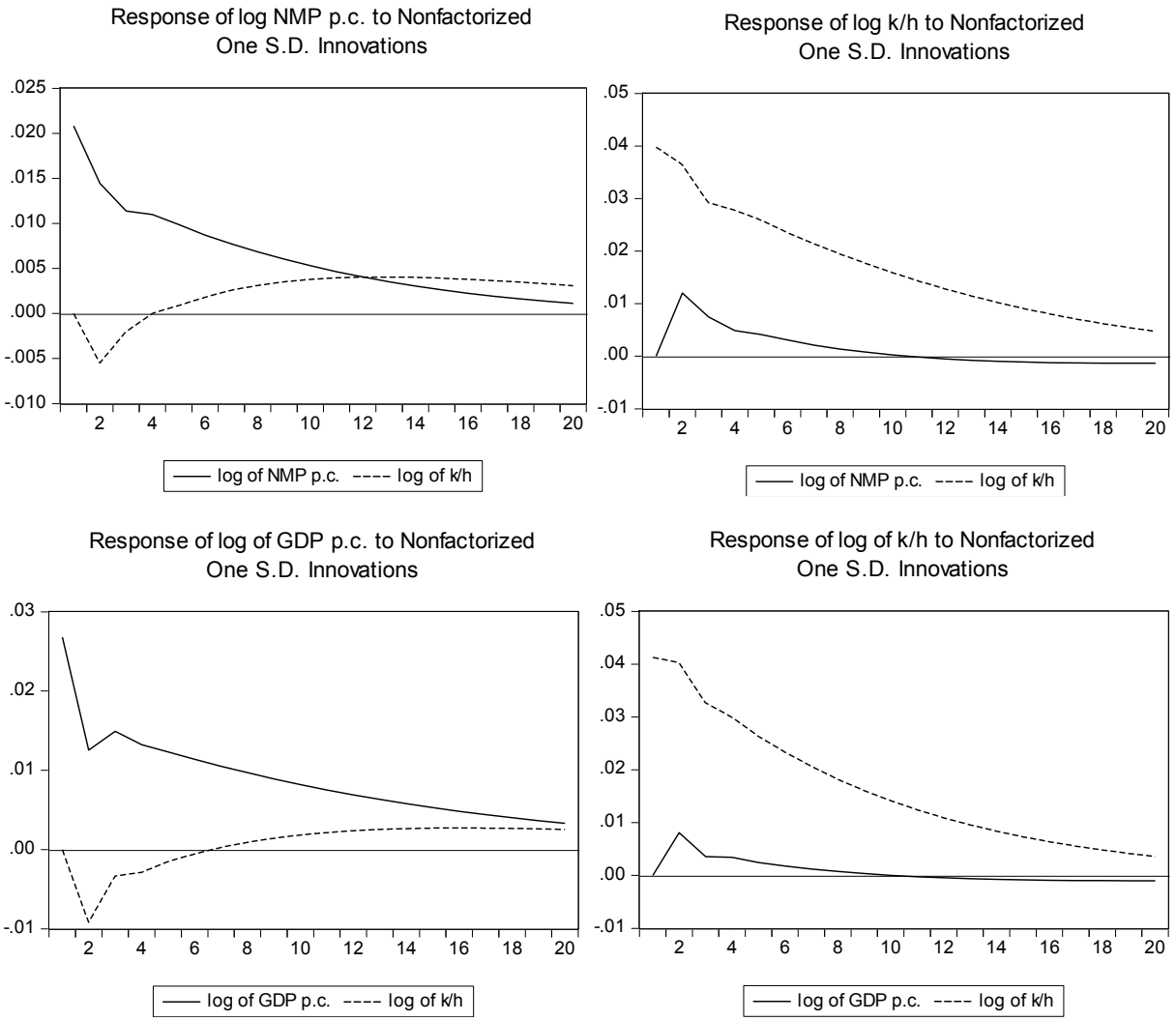


Figure 3 reflects the reaction of the endogenous variables of the system on an innovation of one standard deviation magnitude. An initial increase in the *k*/*h* ratio has an immediate negative impact on both the per capita GDP and NMP, but after 4 (NMP) or 6 (GDP) years a positive impact appears. The total effect can be estimated by looking at the accumulated responses: after 20 years a permanent one standard deviation increase in the log(*k*/*h*) (0.26, i.e. about 26% increase in *k*/*h*) had an impact of 1.17% on the NMP per capita, while only 0.3% on GDP per capita. We can hence conclude that the economic policy aiming at a higher physical to human capital ratio in the USSR proved to be more efficient within the Material Product System than from an SNA based point of view.

At the early stage of industrialization (1920s-1930s) in the USSR growth rates of NMP outperformed those of GNP. They went almost alongside in 1950s while in 1960s-1980s growth measured by GDP was a little bit faster than by NMP. However, both rates were declining significantly. Moreover, the Soviet immaterial sector remained subdued indicating the divergence with more advanced market economies. Clearly, GDP/GNP growth rates outperformed those of NMP at advanced stage of industrial development and during transition to post-industrial society when human capital intensive sectors were on the rise. In earlier stages

of economic development, dominated by physical capital intensive sectors, NMP growth outperformed GDP/GNP growth. Hence, after an initial head start for NMP, at the end of the century GDP growth had gone in the lead. One could expect the gap between GDP and NMP growth measures would be wider in state-socialist countries, should their social planners and economic policy makers had more preference towards consumption and lower physical to human capital ratio. The dynamics of these both measures during the start of transition to market economy exposed that NMP was more sensitive to adverse transformation shocks while GDP was somewhat supported by the service sector.

Conclusion

Two stories go round concerning centrally planned economies. On the one hand it is claimed that initially they experienced fast economic development due to strong capital accumulation while, on the other hand, it is argued that their growth rates declined due to a rising physical to human capital ratio (k/h).

In this paper we addressed this issue in the framework of a theoretical model which allows for differences in the objective function of the social planner. State-socialist governments had preferences for consumption and material production, while market economies, where a central planner does not even exists, it is only consumption that can affect utility. With socialist governments having a preference for material production (Ellman, 1973), due to their different understanding of value, our model predict that state-socialist countries must have had a higher k/h ratio along the optimal growth path. This is confirmed by our empirical observations: it is only after ca. 1990 that we find a reduction on the k/h ratio. Using a VAR analysis on the USSR data, we find that while a permanent increase in the k/h ratio did result in a very small, economically non-significant increase in terms of GDP per capita, once we measure value added in terms of net material product, the estimated effect increases by a factor of almost four.

These findings suggest that the underlying economic theory had a profound impact on the accumulation of production factors. Clearly, in Eastern Europe, and especially in the former USSR, the increase of physical to human capital was based on economic models that were stimulating rapid industrialization. This becomes even clearer when using NMP, being a different (more material production oriented) measure of per capita production. Only when human capital intensive (and physical capital extensive) sectors were on the rise, an increase in the physical/human capital ratio became negative and insignificant. The fact that this applies both to capitalist and (former) socialist countries again implies that the choice for a centrally planned economy at the start of the twentieth century may not have been so illogical with the knowledge of those days.

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