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# Analysis of Factors of High-tech Industries Growth: A Case Study of the Late USSR*

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## ABSTRACT

Explanation of the role high-tech industries play in ensuring sustainable economic growth is significant in the contemporary environment. Also, it is relevant in theoretical discourses of modernization, neo-industrialization, and industrial policy that are similar in their structure. The purpose of the study is to assess the factors of dynamics of the most high-tech industries and the entire Soviet industry when having faced economic growth slowdown, with emphasis on institutional and technological components. The key hypothesis is that in the high-tech industries in the 1960s and 1980s, the institutional environment appeared to be a more significant factor than the technological level. The variety of the sources utilized includes calculations and estimates from the research literature and selected indicators from the official statistics. The econometric analysis of the data is based on an exogenous growth model in the form of the Cobb-Douglas production function, augmented with human capital in Mankiw, Romer, Weil (1992), modified in Didenko, Grineva (2020) by introducing variables that proxy for institutional and general technological dynamics. In this paper, we test it using lagged variables in per capita and rate-of-change terms. The marginal rate of technical substitution of physical by human capital, measured in such a way and indicating the flexibility of management of factors of production, exposed a stable level both in the entire industry of the USSR and its high-tech branches. At the same time, our key hypothesis found weak support.

***Keywords:*** planned economy; industrial development; production function; human capital; institutional environment; technological level

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## INTRODUCTION

The issue of the role of high-technology sectors of the new economy in ensuring sustainable growth is particularly important in the context of contemporary challenges from the external environment and the need for the Russian economy to emerge from the stagnation trap. It has been updated in the closely structured theoretical discourses of modernization, neo-industrialization, and industrial policy [1], recognizing the need for active and proactive measures by the state to catch up with the economically developed countries. Interaction between the institutional and technological aspects of the modernization of the high-technology sectors of the Russian economy is important. [2]

In this regard, it is relevant to study the experience of the development of such industries in the USSR, which had successfully achieved catching-up industrial development by the beginning of the period under review, but in the 1970s lost the dynamism. Falling behind the developed countries in terms of key indicators of economic and social development had led to the systemic economic and political crisis towards the end of the period under study.

In the development economics paradigm, slowdown is seen as a phenomenon common to many countries as catching-up industrialization is completed and the "structural bonus" is exhausted. [3] This is associated with lower returns of production factors (physical, human capital) under the neoclassical approach. On the other hand, it is at this stage that high-technology industries and services are becoming increasingly important, using human capital intensively and creating the conditions for the transition to an innovative knowledge-based economy.[4]

In an institutional perspective, the slowdown in growth in the late Soviet period is due to, on the one hand, the initial drawbacks of the "extractive" institutions of state coercion, on the other hand, the deterioration of the "quality of institutions" that demonstrated comparative efficiency at the stage of catching-up development. [5–7] The monograph [8] shows the influence of the institutional environment specific to the planned economy of the USSR on the nature of the accumulation of physical capital (preference of new construction instead of replacement of the retiring elements of production capacities). However, while the neoclassical versions have been widely tested by econometric methods, the institutional ones are mostly based on narrative evidence, expert estimates using descriptive quantitative statistics.

In line with the approaches formulated by the authors for the econometric study of the economy of the USSR from a cross-country perspective [9], these phenomena are studied in the article on the Soviet chemicals and machinery. These industries, at the beginning of the period, were the closest to the world technological frontier, determined the competitiveness of the USSR economy and created the basis for the implementation of the geopolitical priorities of its leadership.

We test our *key hypothesis*: in the 1960–1980s, the institutional environment for industrial production in high-technology industries was more important than its technological level. Another hypothesis to be tested is that human capital was a more important growth factor in high-technology industries than in total industry.

## DATA AND METHODS OF ANALYSIS

The main *data sources* are as follows:

- Value added growth rates reconstructed in the literature for selected industries [10], calculation and estimation of the level of human capital and wages of workers and employees in total industry.[11]
- Official statistics on the labor force in the industrial branches of the USSR and wages of its categories, published by the

Soviet supreme statistical offices (generally in topical publications: "Industry of the USSR", "Labor in the USSR", and also in the annual and anniversary compilations "National economy of the USSR").

From the data set attached to the preprint of the article by S. N. Smirnov [10] we selected industrial value-added growth indices estimated by L. Kurzweg[1] and M. Suhara.[2] These data cover the longest period of time and have consistent estimates for the industrial sector as a whole and for individual industries. Industrial growth, according to the CIA analyst team leader L. Kurzweg, was much faster than as of M. Suhara's estimate. Criticisms of the former are to be found in [12] which states that, while the CIA analysts' estimates are positioned below the apparently inflated reports of the official statistics, they did not fully account for hidden inflation and deterioration of the quality of production in most branches of the Soviet economy in the second half of the 1970s — the first half of the 1980s. Comparison with alternative calculation results from the works [13–15] for the shorter period available and with the GDP dynamics shows that long series by M. Suchara are closer to them (*fig. 1*).

The amount of physical capital in constant prices (in Geary-Khamis international dollars of 1990 purchasing power parity) was calculated on the basis of data on its total value in the national economy of the USSR in the same units [11] and the share of the industry in fixed assets according to the Soviet official statistics.

A similar operation for human capital is problematic (due to the inconsistency of this theory with the methodology of the official statistics, there were no corresponding data in value units). Therefore, the volume was determined on the basis of the average duration of education in the system of its organized forms, which in turn can be calculated on the basis of official data on the number of industrial and productive personnel with a certain level of education and data on average duration of education for the USSR as a whole.[11] This indicator can be applied both directly (which is commonly practiced in econometric studies), and as indexes derived from the rate of return on education of different durations (that has recently been applied in intercountry comparisons).[3]

Institutional environment is proxied by industrial wage pay differentials: white-collar (office and technical personnel, including engineers) versus blue-collar workers. This differential is a proxy-indicator for a combination of public policies that promote the accumulation of human capital, the motivation of those employed in the industries and the redistribution of income. In econometric analysis, this differential can be applied both directly and in relation to the difference in duration of institutionalized education, i.e. in term of 1 year return.

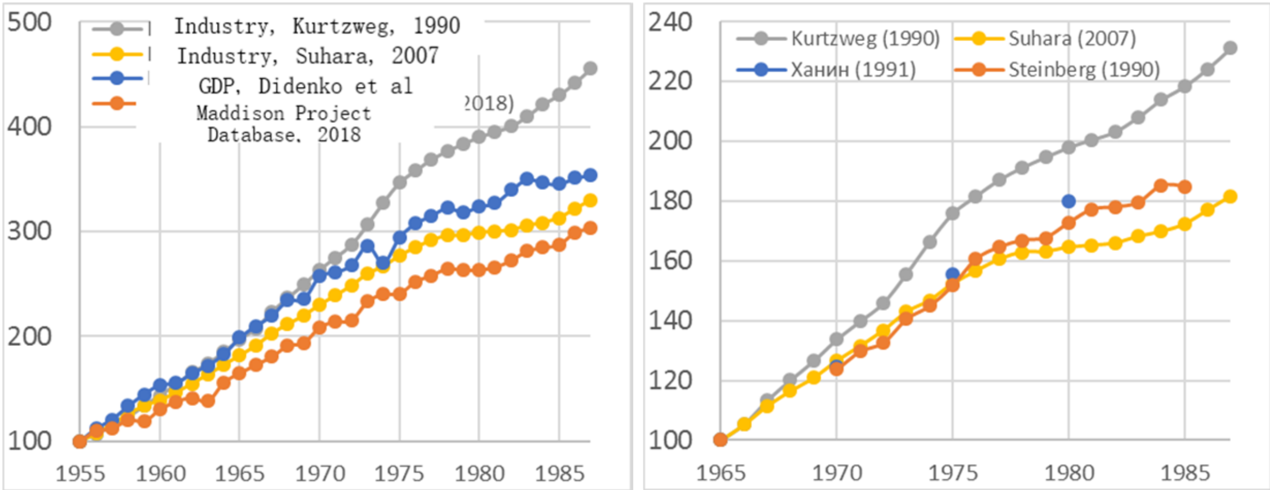
The results of the calculations by S. Y. Glaziev are used as proxy-indicator of technological level relevant for the industrial economy.[16] They are based on a cross-country analysis of the main directions of technological progress, reflecting the diffusion of the most important consolidated technologies, the aggregate of which forms the technological mode (then — TM) of individual branches and total industry. They reflect technological changes in the electric power[4] and chemical industries

[1] Measures of Soviet Gross National Product in 1982 Prices. A Study Prepared for the Use of the Joint Economic Committee. URL: https://www.jec.senate.gov/reports/101st%20Congress/Measures%20of%20Soviet%20Gross%20 National%20Product%20in%201982%20Prices%20(1530).pdf.

[2] An Estimation of Production Indexes for Soviet Industry: 1913–1990. URL: http://www.eco.nihon-u.ac.jp/center/economic/publication/pdf/07–01suhara.pdf.

[3] In particular, in Penn World Tables and based on them in [9].

[4] For total industry, we chose the overall level of development of the electric power branch, which determines the level of industrial development of an economy.




A) Industry and GDP (1955-1987 years; 1955 – 100%) B) Industry (1965-1987 years; 1965 – 100%)

*Fig. 1.* **Alternative estimates of the growth of value-added in the USSR industry and GDP**

*Source:* URL: https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2018; [10–12, 15].

resulting from the development of the second TM, and machinery — as a result of the development of the third TM related to the computerization of the economy.

As a reference base, measurement of the technological level takes into account the actual level achieved in the most technically advanced countries in the relevant field, which defined the world technological frontier (USA, West Germany, Japan). The actual distance is the number of years since, when the reference level of technological development was in line with the current level in the country — USSR. [16]

Thus, input data (other than physical capital) for the analysis in each industry had 2 series of alternative estimates. Their relative performance in the total industry is shown in *fig. 2*.

The period to be analysed is limited to 1961–1987 due to the lack of data from the above sources. Missing values[5] were reconstructed through inter-, retro- and extrapolation. To reconstruct wage differentials in industries through linear regression, a more complete series of the same indicator in industry was used. Between 1987 and 1988, the trend towards labor force growth reversed, making extrapolation irrelevant.

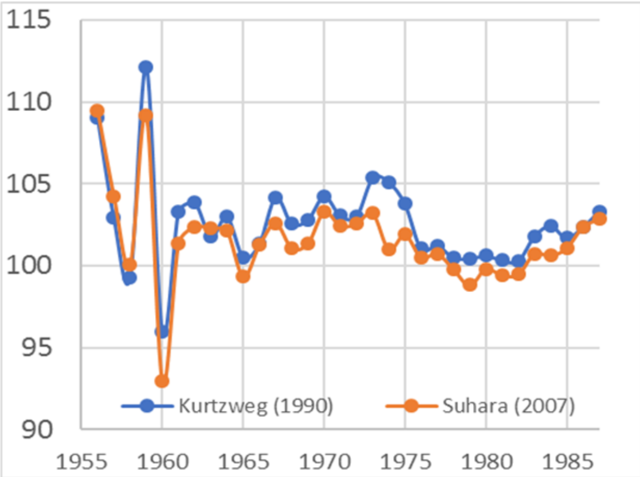
### Methodology for the analysis

The basis of the analysis in this article is the exogenous growth model in the form of a production function (then — PF), augmented with physical and human capital in [17, 18], modified by the introduction of variables proxying for institutional and general technological dynamics [9]. In the article it is applied per 1 employee, in terms of rate of change, also taking into account the delayed impact of independent variables on value added (lags).[6]

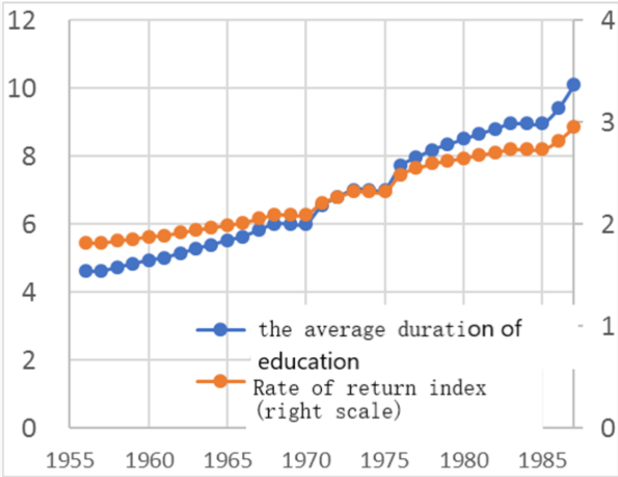
Among commonly cited works that used the PF methodological apparatus for the entire national economy of the USSR, some were dedicated separately to the Soviet industry. Most significant in this respect for the literature of the Soviet period were those published in the late 1960s by A.I. Anchishkin [19] and Y.V. Yaremenko. [20] In addition, for

[5] The largest gaps were in the indicators of wage differentials in industries; the actual distance of the USSR from the reference countries (the USA and Germany) by level of technological development in the electric power industry and the chemical industry.

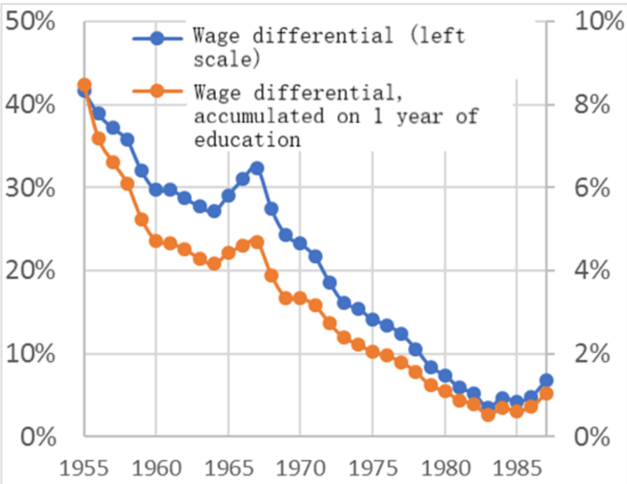
[6] Based on the cross-correlation function.



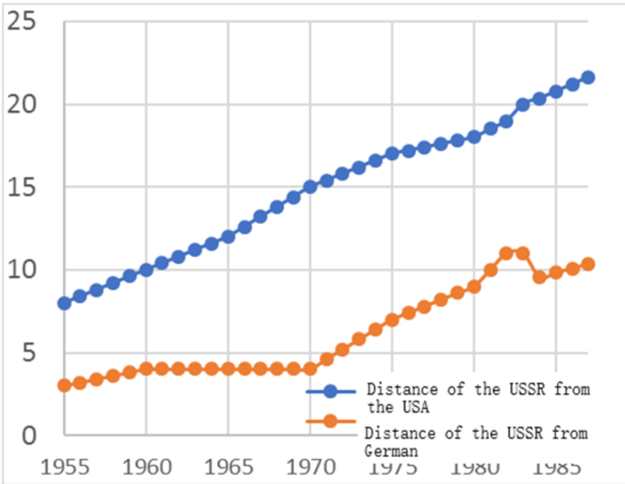

A) Dynamics of value added




B) Level of human capital




C) Wage differential




D) Summary of the actual distance of the USSR from the reference countries by level of technological development of the electric power industry

*Fig. 2.* **Alternative series of indicators in the Soviet industry**

*Source:* Authors' calculations based on [10, 11, 16].

Soviet literature, the key problem was the ratio of extensive ("accumulation of factors of production" in modern terminology) to intensive ("aggregate productivity") growth factors with consensus on the primary role of their first group.

In foreign literature most notable are the 1970–1980s works by M. Weitzman, A. Bergson, S. Gomulka, S. Rosefielde and C. Lovell, P. Desai. [21–27] After the collapse of the USSR, Soviet industrial growth was analyzed in a widely quoted paper by W. Easterly and S. Fischer [28] and in one of I.B. Voskoboynikov's recent works. [29] One of the most important issues in foreign literature was the elasticity of capital and labor substitution, which was assessed by consensus as low. For example, S. Gechert and coauthors noted that empirical studies in many countries have established ranges of substitution elasticity from 0 to 1.5. [30] The value of 0.3 is the average after a series of adjustments. Another problem was the relative importance of diminishing returns as physical capital was accumulating and technological progress was slowing down.

To our best knowledge, the works cited above were limited in using only traditional factors of production (capital and labor) and did not include the human capital variable (except [28, 31], where it was assigned to the national economy and was not distributed between its sectors and industries), leaving aside the institutional environment and the technological level.

The institutional environment as part of "institutional capital" was introduced into the PF by researcher works affiliated with the World Bank.[7] However, in the literature known to us attempts to quantify the institutional environment of the late Soviet economy [7, 8, 32] did not contain econometric analysis with application of the PF techniques.

### Model specification

The model argued by the authors of the article in work [9] is taken as the starting point:

$$Y_t = A_0 K_t^{\alpha} H_t^{\beta} I_t^{\mu 1} T_t^{\mu 2} + u(t), \qquad (1)$$

*where: Y* — value added; $A_0$ — free term; *K* – physical capital stock; *H* –human capital stock; *I* — proxy-indicator of institutional environment; *T* — proxy-indicator of technological level; α — coefficient of physical capital; β — coefficient of human capital; $\mu_1$ — coefficient of proxy-indicator of institutional environment; $\mu_2$ — coefficient of proxy-indicator of technological level; *u* — residuals.

[7] Hamilton K., Ruta G., Bolt K., Markandya A., Pedroso-Galinato S., Silva P., Ordoubadi M.S., Lange G.-M., Tajibaeva L. Where is the wealth of nations? Measuring capital for the 21st century. URL: http://documents.worldbank.org/curated/en/287171468323724180/Where-is-the-wealth-of-nations-measuring-capital-for-the-21st-century.

To achieve the research objective, it has been transformed into the following model variants:

A) Expressed in annual rates of change of linearized production factors and proxy-indicators *(differential model):*

$$\ln\frac{y_t}{y_{t-1}} = \ln A_0 + \alpha \ln\left(\frac{k_t^*}{k_{t-1}^*}\right) + \beta \ln\left(\frac{h_t^*}{h_{t-1}^*}\right) + \mu_1 \ln\left(\frac{I_t}{I_{t-1}}\right) + \mu_2 \ln\left(\frac{T_t}{T_{t-1}}\right) + u_t. \qquad (2)$$

B) Expressed in annual rates of change of linearized production factors and in levels of proxy-indicators (blended model):

$$\ln\frac{y_t}{y_{t-1}} = \ln A_0 + \alpha \ln\left(\frac{k_t^*}{k_{t-1}^*}\right) + \beta \ln\left(\frac{h_t^*}{h_{t-1}^*}\right) + \mu_1 \ln I_t + \mu_2 \ln T_t + u_t, \qquad (3)$$

*where: y* — value added per 1 employee (= labor productivity); *k* –physical capital stock at replacement cost per 1 employee (= capital intensity of labor); *h* –human capital stock per 1 employee (= average duration of institutionalized education, years).

After partial historical data reconstructions, more than 100 combinations of 4 independent variables were tested for significance in t-statistics, including both production factors (physical and human capital) and both proxy-indicators (institutional environment and one of two dimensions of technological distance in series levels or in their rate of change). In case when both production factors and only one proxy-indicator were significant (with other proxy-indicator insignificant), the model was additionally tested with 3 independent variables that appeared to be significant.

## RESULTS

Since variables *y, h, I, T* (i.e. all but *k*) had alternative historical series (see *fig. 2*), that testing was conducted for each series. As a result, in the area of human capital, the transfer of the education rate assumption from the global to the domestic level has not been adequately supported. Thus, wage differential rescaled to 1 year of education approximated the institutional environment to a lesser extent than without such conversion.

Twelve models with a sufficient set of 3 or 4 relevant variables were selected after testing (on a level no worse than 0.05): both production factors (physical and human capital) and at least 1 proxy-indicator (either institutions or technologies in any way). Their indicator assessments are provided in *table 1*.

The selected models were tested on the fulfilment of conditions of the Gauss-Markov theorem on the equality of the residuals expectation value to zero. The absence of heteroscedasticity is confirmed by the Goldfeld-Quandt tests. Since coefficients of correlation of independent variables in pairs did not in any case exceed module value 0.7, then it can be argued that there is no multicollinearity. As the regressions used lagged variables and key variables in terms of the rate of change, there was no autocorrelation of residuals.

Among the regressions selected, the number of blended (7 models) prevails over the number of differential (5 models). In the branches under consideration, the rate of growth is more related to the levels of proxy-indicators than to their rate of change. At the same time, in the total industry growth rates are more dependent on the rate of change of proxy-indicators.

The variables in the differential models assume a sufficient level of significance and a high coefficient of determination only at $A_0 = 0$ (if the coefficient is not significant). At the same time, blended models have a coefficient of determination above the average but significant set of key independent variables at $A_0 \neq 0$. Also, all constructed models have low (less than 1%) values of mean approximation error.

Of the 2 available series of the dependent variable, both are ($y_1$ and $y_2$) found in 2 types of models, but $y_1$ more often: in the differential models — in 3 out of 5; in blended — in 4 out of 7 models. While the accumulated total of industrial growth measured by $y_2$ (estimated by M. Suhara; 5 out of 12 were applied in our models) appears to be more consistent with GDP growth rates in the USSR (*fig. 1*), rate of growth $y_1$ (estimated by L. Kurzweg; 7 out of 12 were applied in our models) slightly more adequately reflects the annual fluctuations than $y_2$.

Of the 12 regressions selected, the institutional environment proxy-indicators are present in 4 models, the technology level in 10 models, with only 2 regressions including both proxy-indicators (institutions and technologies). The recent regressions relate to machinery and total industry.

Thus, proxy-indicators of technology-level were more likely to be a significant variable than proxy-indicators of institutional-level. The latter generally had a worse level of significance and never reached 0.01. They were in 1 out of 2 regressions in industry, 1 out of 2 in machinery and 2 out of 7 in the chemical industry.

The largest number of significant regressions were in the chemical industry, which was several times smaller in terms of value added and employment than the machinery.

To compare estimates of the influence of factors relative to each other and their contribution to the dynamics of a dependent variable, the regression coefficients from *table 1* (*a*) were used to calculate elasticities coefficient $Э_j$ and beta coefficients $\hat{\beta}_j$:

$$E_j = a_j \cdot \frac{\bar{x}_j}{\bar{y}},$$

*Table 1*

**Indicators of the models of production functions of the Soviet industry and its hi-tech branches (1961–1987)**

| | Source | $R^2$ | MAE | *F* Significance | $A_0$ | α | β | $\mu_1$ | $\mu_2$ | $\mu_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | y | | | | | ***k*** | ***h*** | ***l*** | $T_1$ | $T_2$ |
| ***Differential models*** | | | | | | | | | | |
| **Industry** | | | | | | | | | | |
| Coefficients | $y_1$ | 0.9999 | 0.304 | 5.0875E-53 | 0 | 0.3225*** | 0.4545*** | 0.0719** | | 0.1496** |
| Standard error | | | | | | 0.1025 | 0.1017 | 0.0332 | | 0.0644 |
| *t*-statistic | | | | | | 3.1469 | 4.4706 | 2.1669 | | 2.3245 |
| Coefficients | $y_2$ | 0.9999 | 0.257 | 3.1477E-57 | 0 | 0.3302*** | 0.5722*** | | | 0.0925* |
| Standard error | | | | | | 0.0781 | 0.0802 | | | 0.0508 |
| *t*- statistic | | | | | | 4.2256 | 7.1329 | | | 1.8234 |
| Chemical | | | | | | | | | | |
| Coefficients | $y_1$ | 0.9999 | 0.443 | 1.7631E-52 | 0 | 0.7697*** | −0.442** | | 0.6681*** | |
| Standard error | | | | | | 0.1774 | 0.1823 | | 0.1163 | |
| *t*– statistic | | | | | | 4.3402 | −2.4241 | | 5.7440 | |
| Coefficients | $y_1$ | 0.9999 | 0.577 | 2.4524E-49 | 0 | 0.9838*** | −0.5654* | | | 0.5749** |
| Standard error | | | | | | 0.2346 | 0.3040 | | | 0.2277 |
| *t*– statistic | | | | | | 4.1928 | −1.8603 | | | 2.5246 |
| Coefficients | $y_2$ | 0.9999 | 0.424 | 2.5218E-52 | 0 | 0.6731*** | −0.3295* | | 0.6528*** | |
| Standard error | | | | | | 0.1801 | 0.1851 | | 0.1181 | |
| *t*– statistic | | | | | | 3.7378 | −1.7799 | | 5.5271 | |
| ***Blended models (a number of independent variables – in series levels)*** | | | | | | | | | | |
| **Machinery** | | | | | | | | | | |
| Coefficients | $y_1$ | 0.9999 | 0.365 | 4.5520E-54 | 0 | 0.2287** | 0.7682*** | | 0.0023* | |

*Table 1 (continued)*

| | Source | $R^2$ | MAE | *F* Significance | $A_0$ | α | β | $\mu_1$ | $\mu_2$ | $\mu_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | y | | | | | ***k*** | ***h*** | ***l*** | $T_1$ | $T_2$ |
| Standard error | | | | | | 0.0953 | 0.0958 | | 0.0013 | |
| *t*– statistic | | | | | | 2.4002 | 8.0200 | | 1.7220 | |
| Coefficients | $y_1$ | 0.9999 | 0.312 | 1.1488E-52 | 0 | 0.2738*** | 0.7178*** | –0.0096** | | –0.0031*** |
| Standard error | | | | | | 0.0799 | 0.0804 | 0.0040 | | 0.0010 |
| *t*– statistic | | | | | | 3.4277 | 8.9311 | –2.3696 | | –3.0395 |
| Chemical | | | | | | | | | | |
| Coefficients | $y_1$ | 0.6156 | 0.483 | 5.3305E-05 | 10.5665*** | 0.6135** | –1.872*** | | | –0.0456* |
| Standard error | | | | | 2.1136 | 0.2509 | 0.4165 | | | 0.0258 |
| *t*– statistic | | | | | 4.9994 | 2.4451 | –4.4948 | | | –1.7676 |
| Coefficients | $y_1$ | 0.6376 | 0.471 | 2.7464E-05 | 10.839*** | 0.6016** | –1.937*** | 0.0278** | | |
| Standard error | | | | | 2.0407 | 0.2303 | 0.4067 | 0.0128 | | |
| *t*– statistic | | | | | 5.3114 | 2.6117 | –4.7623 | 2.1708 | | |
| Coefficients | $y_2$ | 0.6230 | 0.444 | 4.2905E-05 | 10.8451*** | 0.443** | –1.7444*** | | –0.0716** | |
| Standard error | | | | | 1.9232 | 0.2335 | 0.3879 | | 0.0309 | |
| *t*– statistic | | | | | 5.6391 | 1.8970 | –4.4975 | | –2.3183 | |
| Coefficients | $y_2$ | 0.6106 | 0.444 | 6.1665E-05 | 10.9528*** | 0.4674** | –1.8049*** | | | –0.0517** |
| Standard error | | | | | 2.0037 | 0.2379 | 0.3948 | | | 0.0245 |
| *t*– statistic | | | | | 5.4662 | 1.9652 | –4.5714 | | | –2.1148 |
| Coefficients | $y_2$ | 0.6070 | 0.449 | 6.8392E-05 | 10.6995*** | 0.5609** | –1.866*** | 0.0283* | | |
| Standard error | | | | | 1.9692 | 0.2135 | 0.3996 | 0.0138 | | |
| *t*– statistic | | | | | 5.4335 | 2.6269 | –4.6697 | 2.0543 | | |

*Notes:* Mean Approximation Error (%); *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$; $y_1$ – estimates of L. Kurtzweg (1990), $y_2$ – estimates of M. Suhara (2007).
*Source:* calculated by the authors.

*Table 2*

**Values of Standardized Coefficients of the Soviet Industry and its Branches (1961–1987)**

| Coefficient | Source | α | β | $\mu_1$ | $\mu_2$ | $\mu_3$ |
|---|---|---|---|---|---|---|
| | *y* | *k* | *h* | *l* | $T_1$ | $T_2$ |
| ***Differential models*** | | | | | | |
| **Industry** | | | | | | |
| $E_j$ | $y_1$ | **0.3245** | **0.4550** | **0.0704** | | 0.1501 |
| $\hat{\beta}_j$ | | 0.6828 | 0.8046 | 0.6147 | | 0.5905 |
| $\Delta_j$ | | 0.1626 | 0.1389 | 0.1505 | | –0.1025 |
| $E_j$ | $y_2$ | 0.3329 | 0.5741 | | | 0.0930 |
| $\hat{\beta}_j$ | | 0.8180 | 1.1687 | | | 0.4226 |
| $\Delta_j$ | | 0.1225 | 0.4981 | | | –0.0334 |
| **Chemicals** | | | | | | |
| $E_j$ | $y_1$ | 0.7738 | –0.4408 | | 0.6671 | |
| $\hat{\beta}_j$ | | 0.5529 | –0.1430 | | 0.5700 | |
| $\Delta_j$ | | 0.2709 | 0.0589 | | 0.3616 | |
| $E_j$ | $y_1$ | 0.9890 | –0.5640 | | | 0.5750 |
| $\hat{\beta}_j$ | | 0.7067 | –0.1829 | | | 0.3588 |
| $\Delta_j$ | | 0.3462 | 0.0753 | | | 0.0692 |
| $E_j$ | $y_2$ | 0.6768 | –0.3288 | | 0.6520 | |
| $\hat{\beta}_j$ | | 0.5133 | –0.1132 | | 0.5913 | |
| $\Delta_j$ | | 0.2289 | 0.0492 | | 0.3702 | |
| ***Blended models (l, $T_1$, $T_2$ – level in a number)*** | | | | | | |
| **Machinery** | | | | | | |
| $E_j$ | $y_1$ | 0.2304 | 0.7695 | | 0.0002 | |
| $\hat{\beta}_j$ | | 0.4291 | 0.5300 | | 0.3273 | |
| $\Delta_j$ | | 0.1803 | 0.1089 | | 0.0988 | |
| $E_j$ | $y_1$ | **0.2758** | **0.7190** | **0.0044** | | 0.0007 |
| $\hat{\beta}_j$ | | 0.5137 | 0.4953 | –0.3917 | | –0.5040 |
| $\Delta_j$ | | 0.2159 | 0.1018 | 0.0041 | | 0.2231 |
| **Chemical** | | | | | | |
| $E_j$ | $y_1$ | 0.6167 | –1.8671 | | | –0.0268 |

*Table 2 (continued)*

| Coefficient | Source | α | β | $\mu_1$ | $\mu_2$ | $\mu_3$ |
|---|---|---|---|---|---|---|
| | $y$ | $k$ | $h$ | $I$ | $T_1$ | $T_2$ |
| $\hat{\beta}_j$ | | 0.4406 | −0.6055 | | | −0.3147 |
| $\Delta_j$ | | 0.3507 | 0.4051 | | | 0.2442 |
| $E_j$ | $y_1$ | **0.6047** | **−1.9319** | **−0.0087** | | |
| $\hat{\beta}_j$ | | 0.4321 | −0.6265 | 0.3583 | | |
| $\Delta_j$ | | 0.3320 | 0.4047 | 0.2633 | | |
| $E_j$ | $y_2$ | 0.4454 | −1.7403 | | −0.0430 | |
| $\hat{\beta}_j$ | | 0.3378 | −0.5990 | | −0.4033 | |
| $\Delta_j$ | | 0.2418 | 0.4178 | | 0.3403 | |
| $E_j$ | $y_2$ | 0.4700 | −1.8007 | | | −0.0304 |
| $\hat{\beta}_j$ | | 0.3565 | −0.6198 | | | −0.3790 |
| $\Delta_j$ | | 0.3414 | 1.2846 | | | 0.0408 |
| $E_j$ | $y_2$ | 0.5640 | −1.8616 | −0.0089 | | |
| $\hat{\beta}_j$ | | 0.4278 | −0.6408 | 0.3336 | | |
| $\Delta_j$ | | 0.3143 | 0.4587 | 0.2270 | | |

*Note:* $y_1$ – estimates of L. Kurtzweg (1990); $y_2$ – estimates of M. Suhara (2007);
*The* authors' estimates are based on the variables under logarithms.
*Source:* calculated by the authors.

$$\hat{\beta}_j = \hat{a}_j \cdot \frac{S_{xj}}{S_y}.$$

The share of the factor in their total influence on the dependent variable was estimated by delta coefficients $\Delta_j$:

$$\Delta_j = r_{y,x_j} \cdot \frac{\hat{\beta}_j}{R^2}.$$

In the table 2 shows the results of the calculation of the respective standardized coefficients.

For the 3 most important models (shown in bold in *table 2*)[8] in *fig. 3* we present marginal rate of technical substitution in physical capital to human.[9] The downward trend identified in work [9] for the USSR economy, interpreted as diminishing flexibility in factor management, measured in this work in per capita and in rate of change terms was not observed in the branches analyzed or in the total industry.

[8] For 1 for each analyzed category; models for industry and machinery include all 4 independent variables, in the chemicals proxy-indicators of institutions is the most significant.

[9] Then — MRTS.

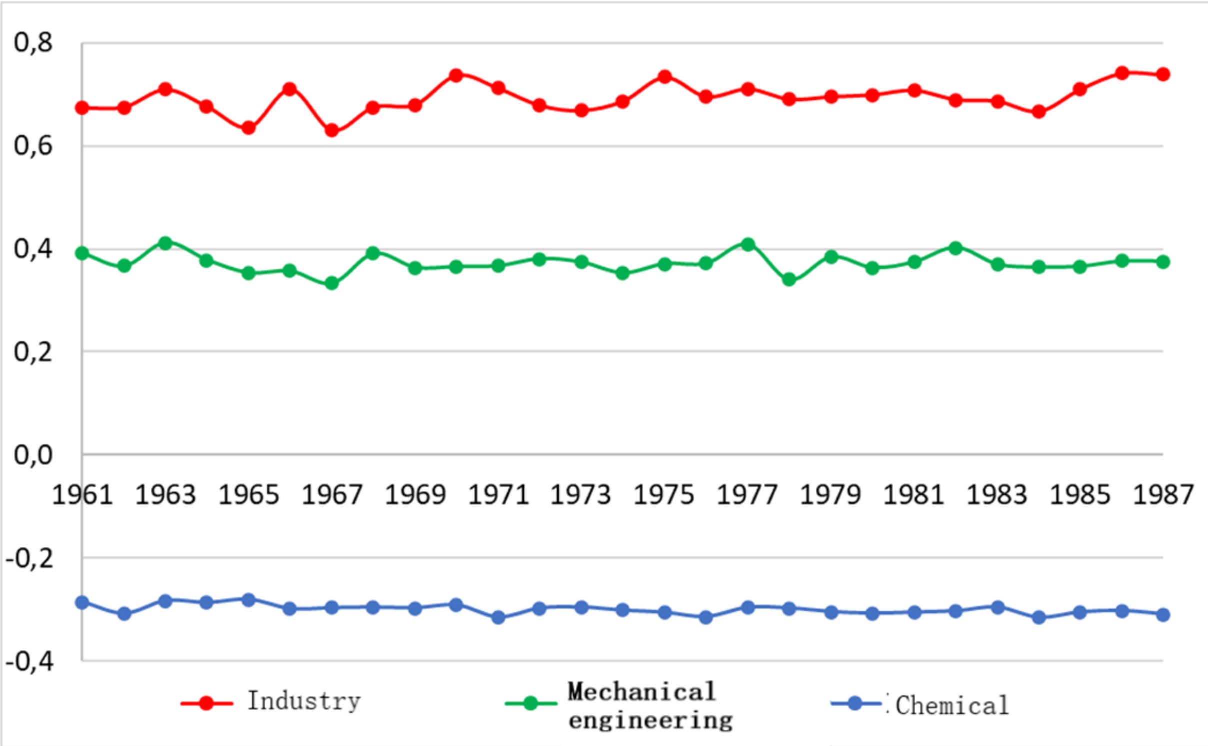



*Fig. 3.* **Dynamics of the marginal rate of substitution (MRTS) of physical capital by human capital in hi-tech industries of the USSR**

*Note:* Marginal Rate of Technical Substitution.

*Source:* calculated by the authors.

However, the cross-sectoral differences in this indicator cannot be interpreted as clearly as the dynamics in one industry. A negative value in the chemical industry follows from a negative correlation between the rate of growth of its value added and the rate of accumulation of its human capital.

## DISCUSSION OF RESULTS

The most important factor in the industrial growth of the late USSR was the accumulation of factors of production (physical and human capital).

The positive values of the coefficients of physical capital in all the selected models show the important role of its accumulation in the growth of the USSR industry and its most hi-tech branches. The effects of increases in physical capital were particularly strong in the chemical industry, where in one of the 3 differential models the value of the respective regression rate was close to 1.

The negative values of the coefficients of human capital index, which participates in our regressions, in the chemical industry are worthy of being noted[10] (versus positive values in machinery and total industry). This may be due to the effects of over-accumulation in some years (especially in mid-1960 years). It is likely that such process in a small (as compared to machinery) branch was reinforced by unbalanced impulses from the part of the state.[11] Consequently,

[10] As the lag y and h increase, the correlation ratio becomes positive, but its module drops and the coefficients of variables in all the tested regressions become insignificant.

[11] According to the official statistics, in 1965 employment in the chemical industry was about 4.6% of the total industry (compared to about 36.1% in machinery), and in 1985–5.2% and 43.0% respectively. According to data in [15], its share of industrial value added was between 3.0 and 3.7% in 1965 (compared with 24.6 to 26.3% in machinery), 6.6 to 7.9% and 33.5 to 34.3%, respectively, in 1985. Therefore, regular unbalanced fluctuations in the labor force (leading to the hiring of skilled personnel) could have a greater impact on the dynamics of the chemical industry.

the increase in the rate of growth of the educational level of the labor force was accompanied by a decline in the rate of growth of value added.

Predominance of positive values in the coefficients of the institution proxy-indicators used, which is interpreted as a slowdown in growth due to the narrowing of wage differentials while the higher growth is associated with them (blended models) or slower growth due to slowdown in narrowing wage differentials (differential models). The exception is machinery, where the wage differential was lower than in total industry, and the contribution of the differential to the growth rate was the least compared to total industry and the chemical branch.

Opposite signs of technology level proxy-indicators used in different models require more detailed discussion. On the one hand, the slowdown in industrial growth has been accompanied by a slowdown in the rate of technological catch-up even as it was widening. Positive coefficient values in differential models indicate just this. On the other hand, in blended models, signs at proxy-indicators of technological level are, in most cases, negative. This means that aggravation of the technological lagging behind (in years) was expected to have a negative impact on growth. The exception to this background (with a positive sign of a technology level proxy-indicator) is 1 out of 2 blended models in machinery that does not include proxy-indicator of institutions. However, the significance of proxy-indicators of the technology-level in this model (0.05) is worse than the significance of the physical (0.01) and human (0.001) capital measures used in the article. This relates to the actual distance of technological development of machinery in the USSR and Japan. The comments by the author of the relevant calculations, S. Y. Glaziev, should be taken into account [16]: source data of the Central Statistical Administration of the USSR and statistical services of reference countries are rated by him as least comparable relative to other industries. Consequently, the resulting assessments of the role of the technological level in the machinery are less reliable than others.

Among significant proxy-indicators of technological level $T_2$ (6 models) with the Western German reference point is somewhat more common, as compared to $T_1$ (4 models) with the United States and Japan as reference. In addition, a full set of variables proved relevant $T_2$, i.e, West Germany was a slightly more relevant base for comparison of technological level in machinery and in the total industry.

The values of the standardized coefficients show that the impact of the institutional environment and the technological level on industrial growth was relatively comparable.

Thus, the results of the econometric analysis do not strongly support the key hypothesis of the research: a more important factor in slowing the growth of high-technology industries was their technological level rather than their institutional environment.

Such results show that institutions "matter", but not just them and often — not the most important thing. They add empirical evidence to the critical understanding of the "pan-institutionalist" narrative, which has been widely disseminated in the historical and economic literature, and support the theoretical arguments given in the paper. [33]

While the importance of human capital accumulation in the industrial growth of the USSR was comparable to the accumulation of physical capital (in some regressions may even have exceeded), another hypothesis — is refuted, that human capital was a more important factor in the growth of high-tech industries than the Soviet industry as a whole.

## CONCLUSION

In the article we tested the hypothesis of the importance of the institutional environment and its contribution to slowing the growth of the Soviet industry and its most high-technology branches. This hypothesis is poorly confirmed: factor accumulation played a major role in the industrial growth of the late USSR; during the period under review, it slowed, leading to a slowdown in growth rates; widening technological gap with the advanced economies also played an important role in slowing growth. The institutional environment, proxied by wage differentials, played a comparable but generally less important role than the technological lagging behind.

In analyzing the role of institutions in economic growth, any study is limited by the availability of reliable data. We assume an explanatory power from other proxy-indicators of institutional environment. Reconstruction of relevant historical data (including as industry statistics are declassified) and testing them as alternative series using the proposed toolkit are promising areas for future research.

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