# Modeling the Social and Human Capital Factors Effect On the Cross-Country Income Differences

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**Abstract.** The paper is devoted to the investigation the effect of social and human capital factors on the cross-country income differences among countries that have similar with Ukraine income levels based on the economic and mathematical models construction. It was constructed four panel data models to estimate the effect of human capital accumulation on cross-country income differences. To study the influence of social factors on the dynamics of gross national income per capita of the countries and the causes of its volatility it was constructed the panel vector autoregression model.

**Keywords.** Social infrastructure, human capital, cross-country income differences, VAR model, panel data model.



## 1 Introduction

Dynamic development of the national economy is impossible without ensuring its social competitiveness as an important element of the overall competitiveness of the country and raising the population standard of living.

National social competitiveness is determined both by economic and socio-political factors, as well as by the infrastructure of the country, its scientific potential, the level of education of the population [1].

Quantitative and qualitative assessment of the potential of social competitiveness helps to determine the existing and potential competitive advantages and competitive status of the country in international comparisons.

In the context of the countries' social competitiveness research, the attention should be paid to the investigation of cross-country income differences determinants. Besides physical capital and labor, it should be considered indicators that characterize investment in human capital and social aspects in particular, health care and R&D expenditures, etc. As known, human capital represents an additional production factor along with labor and physical capital, which includes education, work experience and other aspects. According to some macroeconomists, only by investing in human capital poor countries may converge to wealthy ones. Some economists focus on cross-country income differences that explained by social infrastructure [2]. The aspects of so-

cial infrastructure include features of fiscal policy conducted by the governments, environment that surrounds the private agents in economy, etc.

The one of the most prevalent method of investigation of social aspects and human capital effects on cross-country income differences is the regression framework.

The purpose of the paper is to determine the influence of social and human capital factors on the cross-country income differences among countries that have similar with Ukraine income level based on the economic and mathematical models construction.

## 2 Analysis of Recent Research and Publications

The importance of social infrastructure and human capital in explaining the cross-country output differences is empirically tested by using regression techniques.

Research on importance of human capital and social infrastructure using the regression toolkit is devoted to the works of many scientists. Among them, we can emphasize works of Hall and Jones [2], Klenow and Rodrigues-Clare [3], Acemoglu, Johnson and Robinson [4, 5], Sachs and Warner [6] etc.

These papers explores measuring differences in human capital accumulation and social infrastructure aspects and estimation its influence on income differences with the regression framework based on the use of production functions, for example Cobb-Douglas production function [2, 3]. The authors also estimated the proportion of cross-country volatility in income due to volatility of these factors.

For example, Hall and Jones [2] propose to estimate social infrastructure influence on cross-country income differences using OLS regression. According to results of their research, the influence of social infrastructure on income is significant. Above all, volatility of social infrastructure cause a great volatility of cross-country income differences. To measure the social infrastructure Hall and Jones use two indexes: an index of government anti-diversion policies and index of openness or market-orientation (proposed by Sachs and Warner [6]).

Klenow and Rodrigues-Clare [3] suggest estimating the effect of human capital accumulation on income given the Cobb-Douglas production function with two factors: physical capital and effective labor services. The results of estimation show that the gap between poorest and wealthiest countries due to differences in human capital accumulation is less than 25%.

## 3 Research Methods

For the investigation of human capital and social aspects influence on the cross-country income differences, we propose to use panel data models and vector auto-regression models toolkits.

To measure the social aspects we suggest using the group of social aspects indicators mentioned in p.4.

Thus, in the research we suggest construction following panel data models:

$$y_{it} = \alpha_i + \beta_1 x_{1it} + ... + \beta_k x_{kit} + \varepsilon_{it} \quad (1)$$

where $y_{it}$ - the resulting variable, $x_{it}$ - k- dimensional vector of explanatory variables that does not include a constant [7]. The social aspects indicators are observed for N (i=1…N) observation units (countries) during T periods (t=1…T). In turn, the effects of change in $x$ are the same for all units of observation. At the same time, the average levels for each unit of observation are different. Elements $\alpha_i$ characterize the influence of individual factors for a i-th observation unit that is constant throughout the time period; perturbations $\varepsilon_{it}$ are independent, equally distributed random variables with mean 0 and variance $\sigma_\varepsilon^2$. If $\alpha_i$ are fixed, the model is called a fixed-effect panel model. And if $\alpha_i$ are random variables with mean μ and variance $\sigma_\alpha^2$, we have the panel model with random effects. Consequently, the error in this model has two components: independent of time $\alpha_i$ and residual components - $\varepsilon_{it}$.

So, the model with random effects can be written as follows:

$$y_{it} = \mu + \alpha_i + \beta_1 x_{1it} + ... + \beta_k x_{kit} + \varepsilon_{it} \quad (2)$$

where $\mu$ - free term or intercept [7].

To analyze the influence of human capital and social aspects on the countries' income dynamics and investigating its volatility we propose to use the vector autoregression models toolkit.

Thus, the p-th order vector autoregression model or VAR(p) has the following form:

$$Y_t = C_0 + C_1 Y_{t-1} + ... + C_p Y_{t-p} + v_t, \quad (3)$$

where $Y_t$ is the k-dimensional vector of the endogenous variables of the model, $C_0$ - k-dimensional vector of constants, $Cj$ - the matrix of coefficients of kxk (j=1…p) dimension, $v_t$ - is the k-dimensional perturbation vector with the covariance matrix Σ [7].

The stability or stationary of the vector autoregression model is the decay of external shocks over time. So, the VAR(p) model to be stationary the characteristic roots that are found by solving the equation

$$\left| \lambda^p I - \lambda^{p-1} C_1 - ... - \lambda C_{p-1} - C_p = 0 \right| \quad (4)$$

in absolute value must be less than one or lie within a single circle.

If there is a shock to the system (one of the vector $v_t$ element changes), model variables should deviate from their equilibrium state and eventually return to it. The trajectory of returning variables to its equilibrium state is an impulse response.

Impulse response functions are calculated by finding partial derivatives

$$\Theta_i = \partial Y_t / \partial v_{t-i}. \quad (5)$$

The (m,s)-th element of this matrix shows how the error in the m-th equation of the system affects the S-dependent variable in the presence of a lag in i periods.

The analysis of the decomposition of the predictions errors variances of the model variables allows determining the sources of their volatility.

## 4 Results

The indicator that characterizes cross-country income is the gross national income per capita. As regressors that influence the gross national income per capita, we selected such indicators as gross capital formation, labor force share in the total population over 15 years, health care and education expenditures, education level of the population that measured as the proportion of the population entering the higher education institutions.

Thus, as variables measuring investment in human capital, along with physical capital (gross capital formation) and labor (the share of labor force in the total population over 15 years) the model includes the expenditures on education and health care. Moreover, the proportion of the population enrolled in higher education reflects the level of countries' human capital. For example, according to S. Kuznets [8], advanced technology is only a necessary but not sufficient condition for economic growth. The production of own innovations is based on the institutional transformations that are stimulated only by the accumulated amount of human capital. Therefore, the main source of economic growth is "breakthroughs" in raising the level of human capital ("epochal innovations").

The data source of the research is the World Bank data during 2000-2015 for 14 countries: Armenia, Belarus, Bulgaria, Estonia, Indonesia, Kosovo, Mongolia, Paraguay, Poland, Russia, Samoa, Serbia, Ukraine and Chile [9]. We selected these countries according to their gross national income per capita similar to Ukraine's one and due to interest in the context of comparing the results of the research. The selection of indicators and time period also was limited by the availability of the data. As a further way of research it will be of interest to model the influence of human capital and social factors on economic growth of low-income and high-income countries and due to measure the level of human capital to include such indicators as labor force with basic, intermediate and advanced education.

All variables are modeled in logarithms. Moreover, the variables were tested for a unit root with tests for models with panel data such as Lewin, Lina, and Chu and Breitung criteria for the existence of common process of a unit root and Ima, Pesaran, and Tina criteria, criteria based on the use of ADF and PP statistics that include individual processes of unit root.

The results of the tests showed that all variables are first order integrated (Table 1). Therefore, we include the variables in the models in the first differences.

To verify the robustness of obtained results the proportion of research spending due to GDP, fertility rate and the proportion of population aged 15-64 were added to the model.

The results of estimation of panel data models are presented in Table 2. All coefficients presented in Table 2 are the coefficients of elasticity of gross national income per capita with respect to the regressors of the models.

**Table 1.** The results of unit root testing of panel data model variables

| Variable | Name of variable in the model | Order of integration |
|---|---|---|
| Gross national income per person | GNI_PER_CAPITA_LN | I(1) |
| Gross fixed capital formation | GFCF_LN | I(1) |
| Share of labor force in the total population over 15 years | LF_PART_RATE_LN | I(1) |
| Health care expenditures | HEALTH_EXP_LN | I(1) |
| Education expenditures | EDU_SPEN_LN | I(1) |
| Population enrolled in higher education | ENROL_SCHOOL_LN | I(1) |
| Ratio of R&D spending to GDP | RD_GDP_LN | I(1) |
| Fertility rate | FERTILITY_RATE_LN | I(1) |
| Proportion of population aged 15-64 | POP_15_64_LN | I(1) |

The choice of models with fixed effects is based on the verification of Redundant Fixed Effect-Likelihood Ratio test. It should be noted that all evaluated models are significant with sufficiently high values of R-squared, the residuals of which have a normal distribution and are characterized by the absence of auto-correlation.

Thus, as seen from the table 2, the gross fixed capital formation, the share of labor force, health care and education expenditures and the level of population education (measured by the indicator of the proportion of the population admitted to higher educational institutions) do explain the increase of gross national income per capita. In three of four models, all indicators are significant. In the last model, the gross fixed capital formation is not significant.

Due to results of the estimation, the increase in expenditures on research contributes to the growth of national income with a lag of 3 years. However, the addition of population aged 15-64 years to the model leads to the insignificance of gross fixed capital formation and fertility rate.

Analyzing the values of the elasticity coefficients, the largest impact on the gross national income per capita of the countries has the proportion of the population enrolling the higher education and the share of labor force in the total population over 15 years.

**Table 2.** The results of estimation of fixed effects panel data models

| **Regressors** | **Dependent variable ΔGNI_PER_CAPITA_LN** | | | |
|---|---|---|---|---|
| ΔEDU_SPEN_LN(-3) | 0.105576* | 0.121558* | 0.130035* | 0.127586* |
| ΔENROL_SCHOOL_LN | 0.783125* | 0.994216* | 0.776312* | 0.711054* |
| ΔHEALTH_EXP_LN | 0.555596* | 0.574627* | 0.533300* | 0.520187* |
| ΔLF_PART_RATE_LN | -1.320736** | -0.804834** | -1.584307** | -1.482774* |
| ΔGFCF_LN | 0.115139** | 0.093158** | 0.073278** | 0.062377 |

| | | * | | |
|---|---|---|---|---|
| Intercept | 0.038660** | 0.026281* | 0.036353** | 0.031539 |
| ΔRD_GDP_LN(-3) | | 0.083733* | | |
| ΔFERTILITY_RATE_LN | | | 0.593319*** | 0.484617 |
| ΔPOP_15_64_LN | | | | 3.646704 |
| Cross-section fixed effects | Yes | Yes | Yes | Yes |
| R-squared | 0.787213 | 0.829872 | 0.807529 | 0.810558 |

*, **, and *** denote the significance of the coefficients at 1%, 5% and 10% error

Table 3 represents the fixed effects calculated due to constructed models.

Thus, the obtained results show that an increase in investment both in human capital and in physical capital leads to accelerated economic growth of countries and the convergence of poorer countries to a richer ones.

To study the social factors influence on the dynamics of national income we use the VAR approach that concentrates on the research of its volatility causes and reaction on impulses. For this purpose, we construct the panel vector autoregression model.

**Table 3.** Fixed effects calculated due to constructed models

| Country | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Armenia | 0.024058 | 0.019678 | 0.027125 | 0.012702 |
| Bulgaria | -0.024964 | -0.031207 | -0.030838 | -0.011481 |
| Belarus | 0.023514 | 0.015108 | 0.017077 | 0.015675 |
| Chili | -0.014704 | -0.061004 | -0.000728 | -0.009334 |
| Estonia | 0.034561 | 0.036644 | 0.018565 | 0.027056 |
| Indonesia | -0.046747 | - | -0.038308 | -0.030230 |
| Poland | -0.008750 | -0.009697 | -0.007464 | -0.008341 |
| Paragway | -0.001606 | -0.001958 | 0.019765 | -0.001346 |
| Russian Federation | 0.055708 | 0.052050 | 0.046846 | 0.043888 |
| Serbia | -0.062459 | -0.062453 | -0.042929 | -0.051374 |
| Ukraine | -0.000588 | -0.007072 | -0.010587 | -0.005839 |

Thus, as indicators that characterize the cross-country income differences in the models the gross domestic product per capita (in current US dollars) and gross national income (in current US dollars) are used.

The social aspects of society development in the models are described by following indicators: food production index, tuberculosis incidents (per 100 thousand population), life expectancy at birth for men and women (in years), infants mortality rate (per 1,000 newborns), AIDS rate (percent of the population aged 15-49), unemployment rate, population growth rate, fertility rate (births per woman), share of labour force in the population aged 15 and over, mortality rate (per 1 thousand people), health care expenditures per capita (current US $), percent of population aged 15-64, R&D expenditures (in percent to GDP), fraction of high-tech products exports in total exports of products, Internet users (per 100 people), fraction of population with access

to improved sanitary conditions, carbon dioxide emissions (metric tons per capita), the fraction of the population entering the high education institutions (percent of population), public expenditure on education (as a percentage to GDP), the number of mobile communication users (per 100 people).

The testing of these variables for the presence of a unit root indicated that almost all variables are first order integrated, except for the growth rate of population that is second order integrated (Table 4). Therefore, in the model the first differences of variables will be used.

At the next stage of the research, we analyze the relationship between the variables based on the cause and effect relationship analysis by Granger causality test and constructing the correlation matrix.

According to the constructed correlation matrix, the indicators having a close relationship with the variables that measure the income of countries - GDP and GNI per capita - are the following: the amount of carbon dioxide emissions, health care expenditures, Internet users and the life expectancy at birth for women and men.

**Table 4.** The results of unit root testing of VAR model variables

| Variable | Name of variable in the model | Order of integration |
|---|---|---|
| Carbon dioxide emissions | CO2_EMIS_LN | I(1) |
| Death rate | DEATH_RATE_LN | I(1) |
| Public expenditures on education | EDU_SPEN_GDP_LN | I(1) |
| The share of the population entering the high education institutions | ENROL_SCHOOL_LN | I(1) |
| Fertility_rate | FERTILITY_RATE_LN | I(1) |
| Food production index | FPI_LN | I(0) |
| GDP per capita | GDP_CAP_LN | I(1) |
| GNI per capita | GNI_PER_CAPITA_LN | I(1) |
| Health care expenditures per capita | HEALTH_EXP_CAP_LN | I(1) |
| Fraction of high-tech products exports in total exports of products | HIGH_TECH_EXPORT_ LN | I(1) |
| Tuberculosis incidents | INC_TUB_LN | I(1) |
| Internet users | INTERNET_USERS_LN | I(1) |
| Life expectancy at birth for women | LEB_FEM_LN | I(1) |
| Life expectancy at birth for men | LEB_MALE_LN | I(1) |
| Fraction of labour force in the population aged 15 and over | LF_PART_RATE_LN | I(1) |
| Number of mobile communication users | MOB_SUBS_LN | I(1) |
| Infants mortality rate | MORT_RATE_INF_LN | I(1) |
| Fraction of population aged 15-64 | POP_15_64_LN | I(1) |
| Population growth rate | POP_GR_LN | I(2) |
| AIDS rate | PREV_HIV_LN | I(1) |
| R&D to GDP ratio | RD_GDP_LN | I(1) |
| Fraction of population with access to improved sanitary conditions | SANIT_FAC_LN | I(1) |

| | | |
|---|---|---|
| Unemployment rate | UN_RATE_LN | I(1) |

At the same time Granger's causality test indicated that the number of Internet users and cellular networks, the fraction of the population aged 15-64 and the health care expenditures (with lags 1-5), birth rate (with lags 3 and 4) and R&D expenditures (lags 2 and 5) contributed to the explanation of the countries income.

The Johansen test indicated no cointegration relations between variables.

All these indicators were included in the model as endogenous variables. In addition, the rate of foreign direct investments growth is added to the model as indicator measuring the attractiveness of the country for the foreign investors.

Thus, the vector model of autoregression in the reduced form was estimated with an intercept and one lag that was determined based on the application of the Schwarz information criterion. The obtained vector autoregression model satisfies the condition of stability as evidenced by the non-exaggeration by the inverse roots of the characteristic autoregression polynomial the unit value (in absolute values).

Based on the constructed model, impulse response functions were generated for differenced gross national income per capita (fig. 1).

Analyzing the impulse response functions, we conclude that the positive shocks in all variables (except R&D expenditures, the number of Internet users and the fraction of population aged 15-64) lead to an increase in the gross national income per capita and its further stabilization. At the same time, the change of these three indicators provokes a slight deterioration of GNI per capita during the first two years, its further growth and stabilization after the 6th period.

The volatility of national income per capita is explained by its own fluctuations by almost 65% since the 8th year. The variation in the number of cellular communication users and the growth rate of foreign direct investment account for about 18% and 9% of the fluctuations of GNI per capita growth.

At the same time, the variation in spending on health and R&D explains about 3% of the variation in gross national income per capita.

In order to verify the robustness of the obtained results, we constructed a similar model for a gross domestic product per capita that presented similar results. The GDP per capita behavior is similar to the GNI per capita response to the simulated impulses, except for the response to a positive shock in health care spending.

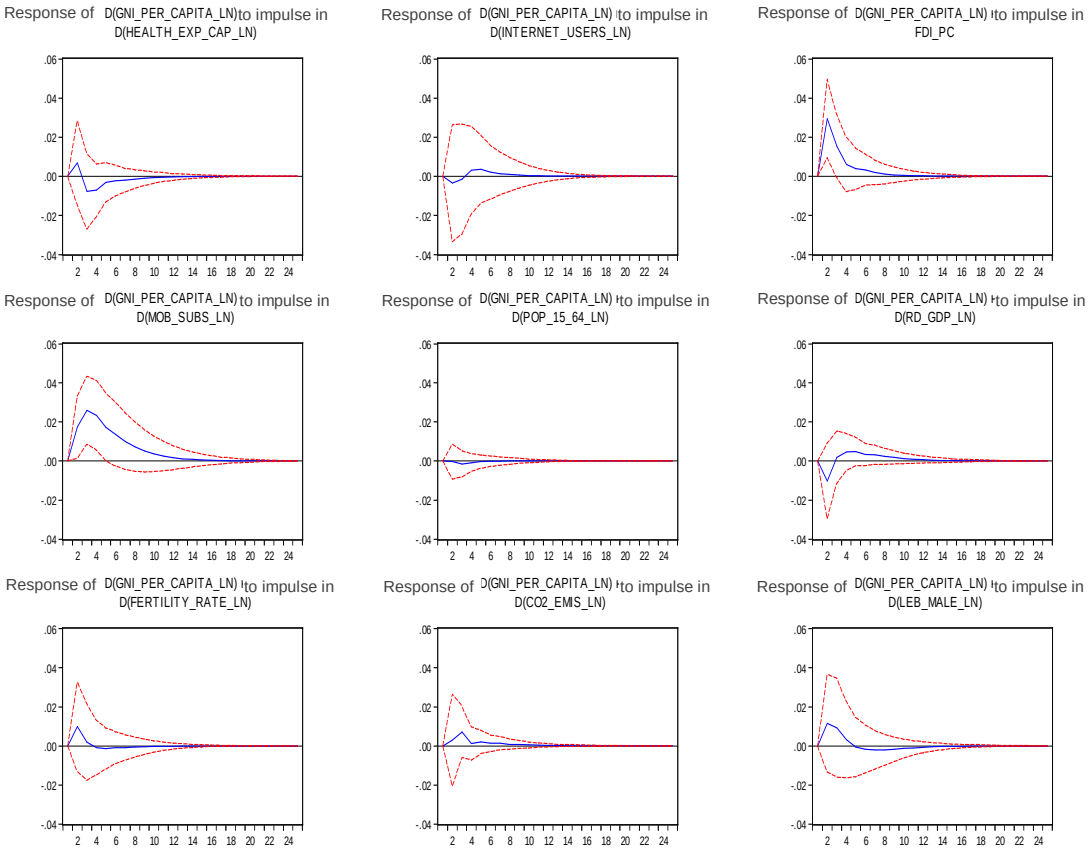


**Fig. 1.** Impulse responses functions for differenced gross national income per capita

A positive shock in this variable leads to an initial deterioration of GDP per capita and its subsequent stabilization after the 6th period.

## 5 Conclusions

Summing up the results and interpreting them, we note that the inalienable factors of production included in the aggregate production function are investments in human capital and social infrastructure.

The largest impact on the countries' gross national income per capita has the proportion of the population enrolling the higher education and the share of labor force in the total population over 15 years that prove the role of human capital accumulation as a driving force of economic growth.

Moreover, positive shocks in all social aspects indicators (except R&D expenditures, the number of Internet users and the fraction of population aged 15-64) lead to an increase in the gross national income per capita.

In this context, we note that it is possible to accumulate human capital for an arbitrarily long time, since its marginal productivity is a constant value. The pace of growth of a country investing in human capital will increase even on a balanced growth path.

In turn, insufficient investment in infrastructure also could explain the insignificant convergence between countries primarily due to lack of its mobility and the impossibility of purchasing in international markets.

As a further research it could be the one based on data for low-income and high-income countries including such indicators as labor force with basic, intermediate and advanced education.

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