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Empirical assessment of long-term aspects of sustainable regional development

Abstract. Sustainable development becomes one of the biggest challenges of the modern world. Despite the global issue, there is an increasing relevance of the intensification of the regional research and collaboration. The paper summarises the international experience of the sustainable development assessment and modelling. It aims to identify factors that contribute to the regional sustainability and to empirically investigate the causal links and long-run cointegration relationships between them using quarterly time series data from 2001 to 2016 for Sumy region of Ukraine. The methodology for the study is based on the vector autoregressive (VAR) and the Johansen VEC approach procedure. The results of the estimation of the aggregate Index of sustainable development (ISD) show a great impact and variability of its economic component, which influences social and environmental indicators as well. The findings of econometric modelling have revealed long-term relationships and positively significant effects of capital related to the labour ratio and education on the regional economic growth. The lack of macroeconomic stability and unrealised potential of technological progress are deemed to make a negative impact on sustainable development. Further considerations based on the intersectoral econometric analysis are provided to support the appropriate policy making suggestions.
Keywords: Sustainable Development; Regional Economics; Cobb-Douglas Function; Causality; Cointegration; VAR; VEC; DSGE; VECM
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Емпіричне оцінювання довгострокових аспектів сталого розвитку регіону
Анотація. У статті досліджено соціально-економічні, фінансові та екологічні чинники сталого регіонального розвитку (СРР). Проаналізовано динаміку агрегованого та компонентних індексів СРР на прикладі Сумської області України в 1995-2016 рр.. На підставі квартальних рядів 2001-2016 рр. емпірично оцінено каузальні та коінтеграційні довгострокові зв'язки складових економічного зростання та міжсекторальні зв'язки, які на них впливають. Підтверджено позитивний ефект нагромадженого капіталу стосовно трудових ресурсів, освіти як чинника людського капіталу та невикористаний потенціал технологічного фактору у забезпеченні сталого розвитку регіону.
Ключові слова: сталий розвиток; регіональна економіка; функція Кобба-Дугласа; каузальність; коінтеграція.

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Эмпирическая оценка долгосрочных аспектов устойчивого развития региона
Аннотация. В статье изучены социально-экономические, финансовые и экологические факторы устойчивого регионального развития (УРР). Проанализирована динамика агрегированного и компонентных индексов УРР с использованием эмпирических данных Сумской области Украины за 1995-2016 гг. На основании квартальных рядов 2001-2016 гг. эмпирически оценены каузальные и коинтеграционные долгосрочные связи составляющих экономического роста и межсекторальные связи, которые на них влияют. Подтверждён позитивный эффект аккумулированного капитала по отношению к трудовым ресурсам, образования как фактора человеческого капитала, а также неиспользованного потенциала технологического фактора в обеспечении устойчивого развития региона.
Ключевые слова: устойчивое развитие; региональная экономика; функция Кобба-Дугласа; каузальность; коинтеграция.

1. Introduction

Sustainable development is the biggest challenge for different regions, countries and the whole contemporary world. Introduced in 1987, as a concept of «development that meets the needs and aspirations of the present without compromising the ability of future generations to meet their own needs» [1], it embraces the issues of enhancing the capabilities of local and international communities to overcome adverse social, economic and environmental risks and trends. Realising the global aspect of this problem, especially in the field of environmental protection, enhancing competitiveness and sustainability of the regions has primarily become the top priority for local and national governments in the USA, Canada and the European Union. Ukraine is at the beginning of this process and faces many challenges concerning decentralisation, financing of tax incentives and bonus programs, organisation of the competitiveness clusters which have proved to be the movers of sustainable spatial development in the world. Regional administrations as full participants in the spatial planning process in Ukraine need to have an appropriate methodology for forecasting and policy conclusions in order to be able to stimulate competitiveness, economic growth, social stability and environmental protection of the region. Therefore, a review of the existing modelling approaches, suitable for Ukrainian conditions, as well as an assessment of their effectiveness on empirical data, becomes relevant.

2. Brief Literature Review

Regional research and econometric modelling have been developing intensively since 1970, mostly in the USA and Europe. The first scholar works of 1970s-1980s mostly imitated national models which were based on the economic theories of supply (neoclassical models of economic growth), demand (neo-Keynesian models of economic

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growth) and general equilibrium theory [2]. The econometric regional research of 1990s was highly influenced by the studies of new economic schools - «New Growth Theory» and «New Economic Geography» [2]. We should note the achievements of the «New Growth Theory» scholars, such as Romer (1990), Barro (1990), Lucas (1993), who assessed the «technology gap» models and associated sustainable regional development with public and government investments in knowledge, human capital, innovations and infrastructure [3, 54-56]. Representatives of the New Economic Geography concept (Krugman, 1991) introduced spatial factors into econometric analysis and studied possible effects of economic integration and spillovers [4]. At present spatial planning and research focuses on establishing «core - periphery» relationships for the long-term balanced development of land resources, cities, rural regions, transport and environment infrastructure organisation, promotion of technologies and innovations [5, 36].

First publications on sustainable development assessment go back to 1970s introducing a measure of economic welfare that accounts for environmental damage [6]. The ideas of the estimation of sustainable economic performance and its improvement by redirecting actions from government to smaller entities (local communities) and integration of universities into this process were introduced later by Daly and Cobb (1989) [7]. For this paper, we used the «early warning indicator» approach that summarises a set of sustainability indicators in a comprehensive aggregate index [8].

From the methodological perspective, along with the structural models, new modelling techniques, including vector autoregression (VAR) [9], vector error correction (VEC) [10-11], dynamic stochastic general equilibrium (DSGE) [12] models have been actively explored since 1980s-1990s to support policy conclusions by adequate prediction, causal inference and scenario analysis. With accumulation of big databases and computer capacity increase, a tendency towards the prevalence of more flexible Bayesian econometric techniques and their combination with traditional frequentist econometrics can be observed in foreign publications.

Domestic economists apply mainly qualitative techniques to analyse and compare economic, social and environmental conditions of different regions and make their stability diagnostics [5]. The study of certain aspects of sustainable spatial development and its modelling was conducted by such domestic scientists as B. Danylyshyn, S. Hrinevska, Y. Kharazishvili, V. Shevchuk, A. Sukhorukov and others. We should note that structural and simulation modelling techniques are mainly applied by the scientists of the National Institute for Strategic Studies [13] and the Institute for Economics and Forecasting [14]. VAR and DSGE approaches have been used by the National Bank of Ukraine to estimate the effects of the monetary policy on the economy and to evaluate the performance of the monetary transmission channels [15]. Local government administrations in Ukraine frequently use such management tools as SWOT (Strength, Weakness, Opportunity and Threat) and STEEP (Social, Technological, Economic, Environmental, Political factors) analysis in decision making and regional policy conclusions [16]. At the same time, there are very few publications in Ukraine that study the aspects of sustainable regional development, as well as the influence of domestic and external shocks on its performance, based on the up-to-date predictive and inference statistical techniques.

3. The purpose of this paper is to study factors that stimulate and decelerate regional sustainable development in Ukraine by estimating the long-term cointegrating relationships (VEC modelling). The empirical assessment was conducted by using statistical data of Sumy region of Ukraine.

4. Results

According to the typology of regions conducted within the EU project «Sustainable Regional Development in Ukraine», Sumy region, together with Vinnitsa, Kirovograd, Kherson and Chernihiv regions, were classified as the fifth type areas that had the lowest level of development [16]. The common features of these regions include negative demographic situation, low urbanisation and population density, high unemployment rate, low share of gross regional product (GRP) in GDP and GRP per capita, low disposable income per capita, high rate of trade volume per capita, low rate of capital and foreign investments per capita, low share of regional export in Ukrainian export and poor external accessibility.

Using methodology of the IN-STREAM research project [8], we estimated the aggregate index of sustainable development (ISD) for Sumy region of Ukraine based on a set of economic, social and environmental indicators with the corresponding weights - 28.33%, 33.33% and 38.33%, respectively. Economic indicators include a group of economic structure variables; terms of trade (the ratio of export to import) and the ratio of research and development expenditures to GRP. Economic structure indicators consit of gross regional product (GRP) per capita, households' revenue per capita (introduced by the author), the ratio of investments to GRP, the relative balance of foreign trade (net exports devided by the sum of exports and imports), as well as stocks which are capital stock per capita and capital stock growth rate. Social indicators include population growth rate; proportion of people older than 60 to the employed population (introduced by the author); the share of food consumption expenditures; social wealth group indicators that represent insurance, education and health expenditures to GDP (this group was assessed using national data) and the crime ratio per 100.000 population. The environmental group includes indicators of emission of greenhouse gasses per capita and per GRP, energy intensity (tons of energy used per million USD GRP), energy imported (we assume no import of mineral oil products based on the oil and gas mining volumes of the region and 10% self-suffucuency in electricity [17]), the proportion of renewable energy [17], the use of water, land and forest resources and waste utilisation (introduced by the author) [16; 18]. All indicators were assessed with the help of normalization grid presented by a vector of possible outcomes (0; 0.25; 0.5; 0.75; 1) depending on the difference of the observed indicator with the benchmark (the average value in the European Union in 2005). The estimated values of the aggregate ISD and its components for Sumy region in 1995-2016 are presented in Figure 1.

Within the investigated period (see Figure 1) the environmental ISD had the highest average values. Its relatively better performance can be explained by the good natural endowments availability and low greenhouse gases emission per

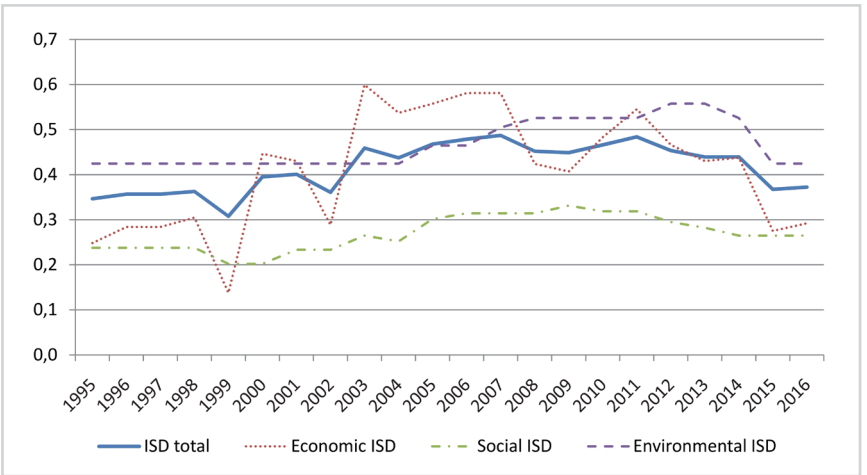

Fig. 1: **Dynamics of the Index of Sustainable Development (ISD) of Ukraine in 1995-2016**
Source: Own processing based on official statistics [18-19]

decreasing population, which questions future sustainability. The social ISD had the lowest values due to the high food relevance and low insurance and medicine expenses, and increasing share of the retired population. High variance of the economic ISD corresponds with the tendencies of the national economy (the drops in 1999, 2009 and 2015). The reduction of the index in 2002 was caused by the deterioration of the terms of trade component.

We conducted exploratory and inference analysis in EViews 9.0 using monthly and quarterly statistical data on social, labour, economic and financial indicators of Sumy region of Ukraine for the period 2001-2016 [18-19]. Environmental statistics was not considered due to its poor availability. Monthly series were transformed into quarterly series by using appropriate frequency conversion method: the average for the stock variables and the sum of the flows. The real values of the indicators were obtained by adjusting for inflation to the base period (2000) with regard to consumer price index; the USD values were calculated by using the average official UAH/USD exchange rate.

As the extended endogenous growth theory suggests, macroeconomic and regional sustainability depends on the accumulation of physical capital and increase in the total output productivity relying on the improvement in human capital (quality education, good health, middle class growth), technological shifts with innovations that lead from resource scarcity to abundance and macroeconomic stability [2; 3]. Taking into account the lack of the latter condition, we tried to find long-run insights in the regional development focusing on the contributions of the capital and human resources and their possible associations with other indicators.

We used a cointegrated VAR approach (VECM) that explores the stationary linear combinations of time series [20, 368]. Its specification is given in (1):

$$\Delta Z_t = \Pi Z_{t-i} + \Gamma_1 \Delta Z_{t-1} + ... \Gamma_{k-1} \Delta Z_{t-k-1} + \varphi X_t + \omega D_t + \varepsilon_t , \qquad (1)$$

where $\Delta Z_t = Z_t - Z_{t-1}$ is a vector of the first differences of endogenous variables $Z_t = [Y_t, X_t, W_t, ...]$;

X_t is a vector of exogenous variables;

$\Gamma_i = (I - A_1 - A_2 - ... - A_k)$ $(i = 1, 2, ..., k - 1)$ is a matrix of the short-term parameters;

$\Pi = -(I - A_1 - A_2 - ... - A_k)$ is a matrix of the long-term parameters.

$\Pi = \alpha\beta^T$,

where α is a matrix of the error correction coefficients (in VECM summary are shown as $ECM(-1)$), displaying the speed of endogenous variables adjustment to equilibrium;

β is long-run matrix of coefficients.

D_t is vector of deterministic components (intercept, trend and dummy variables);

ε_t is a vector of error terms.

The further research, based on the Johansen approach [21], includes the following [20, 371-378]:

1. Exploratory statistical analysis and transformations of the variables.
2. Causality analysis by using Engle-Granger technique.
3. Verification of the properties of time series and the order of integration via using ACF/PACF correlogram analysis, the Augmented Dickey-Fuller Unit Root test (ADF) and the Phillips-Perron (PP) test.
4. Defining the optimal lag structure of the VAR model.
5. Model type selection in terms of inclusion of the deterministic components (intercepts and trends in cointegration equation and VAR).
6. Testing the number of cointegrating vectors (the rank of Π).
7. Estimating the VECM. Checking for weak exogeneity and linear restrictions in the cointegrating vectors. Testing model adequacy and stability.

The basic model was estimated by using the log-linear transformation of the Cobb-Douglas production function [13, 104]:

$$Y_t = \beta_1 K_t^{\beta_2} L_t^{\beta_3} e^{\rho t} \upsilon_t , \qquad (2)$$

where Y_t represents real output;

K_t is real capital input;

L_t is real labour input;

$e^{\rho t}$ is the exponential time trend that denotes technical progress with ρ is the rate of technical progress, t is the time trend; υ_t is the error term.

We used the USD value of households' revenues per capita (*rev_pop*) as a measure of economic growth instead of the commonly accepted GRP for Y_t because of the missing quarterly GRP data. The USD value of the physical capital stock per capita (*cap_pop*) for K_t was calculated based on the depreciated cost of the regional fixed assets adjusted for the quarterly capital investments and the period difference in the foreign investments. The following human capital factors were estimated for L_t: the coefficient of employed population to total population (*emp_pop*), the percentage of population 60 years and older (*pop_ret*), the ratio of employees to retired population (*emp_ret*), the enrolment tertiary rate (*enr_ter*), the ratio of tertiary graduates to population (*gr_pop*), public expenditure on education (% GDP) (*ed_exp*), life expectancy at birth (*lexp*).

By the outlined procedure, we estimated the causal relationship and correlation between the Cobb-Douglas function variables (see Table 1). For the revenue per capita (*Rev_pop*) as a measure of economic welfare, a causal relationship was revealed only with the physical capital (*Cap_pop*) which influenced the forecast of *Rev_pop* significantly within lags 2-4. Neither of the human capital variables but the number of tertiary graduates per population (*gr_pop*) contributed to the forecast of *Rev_pop*. Instead, the value of the households' revenue and capital stock (*Cap_pop*) significantly influenced the forecast of human capital indicators. To find more insights, we added other economic indicators to the analysis: the USD volume of industrial production sold (*Prod*); the USD volume of retail trade (*Trade*); the volume of export and import; the cumulative index of agricultural production (1990 year=100) (*Ind_agr*); the USD value of household's deposits per capita (*Dep_pop*), the USD value of total banking credits (*Cred*), as well as research and development expenditures as % of Prod (*rd_pr*). We also examined the influence of the regional interest rates and official and real effective exchange rates (*Reer*) on the sustainable regional development. Mutual causality between some variables x↔y (see Table 1) points out on the third variable *z*, which affects both variables *x* and y [20, 322].

Correlation coefficients were assessed mainly to eliminate possible multicollinearity problems. As most of the introduced

Tab. 1: **Granger causality and correlation analysis**

	Rev_pop	*Cap_pop*	*Emp_pop*	*Prod*	*Trade*	*Ind_agr*	*Dep_Pop*	*Cred*	*Reer*	*Other*
Rev_pop		←		↔	↔		↔		←	*gr_pop*
Caus:lags		2-4		2	2-4		2-4		2-4	← 2-4
Correl.coef	1	0.63	0.75	0.95	0.98	0.88	0.97	0.83	-0.18	0.63
Cap_pop				↔	↔	←	↔	↔	↔	*D_w*
Caus:lags				2-4	2-4	2-3	2-4	2-4	2-4	← 2-3
Correl.coef	0.63	1	0.78	0.64	0.53	-0.44	0.51	0.66	0.59	
Emp_pop	←	←		←	←	←	←	↔	←	*rd_pr*
Caus:lags	2-4	2-4		2-4	2-4	2-3	2-4	2-4	2-4	← 2-3
Correl.coef	0.75	0.78	1	0.73	0.71	0.03	0.66	0.66	0.02	0.51

Source: Own processing based on official regional and national statistics [18-19]

auxiliary time series (production, trade, deposits, credits, export and foreign investments) had similar trends - they were highly correlated with each other.

The graphical analysis showed two significant structural breaks in the observed data - last quarter of 2008 - first quarter of 2009, and the beginning of 2014. The shifts from growing trends to substantial falls can be explained by huge hryvnia depreciation caused by macroeconomic and political instability. It is noteworthy that the currency depreciation of 1998 and 2008 had a positive long-term effect on the majority of social, economic and even environmental variables. The drop in the currency rate of 2014-2015, multiplied by macroeconomic and political destabilisation, caused an unrecovered negative effect on economic growth which could not get long-run estimation. To handle this problem, we introduced the dummy variables (*D_reer, D_w*) and the structural shift variable (*D_shift*) that displayed the change in the slope parameters. The binomial dummy variable (*D_reer*) takes value 1 in the periods of abnormal *Reer* depreciation, otherwise 0. The dummy war variable (*D_w*) depicts the period of 2014-2016 war actions in the East of Ukraine (see Table 1). Most of the observed indicators except *Ind_agr* had explicit causality with dummy variables *D_reer* and *D_w*.

Seasonal adjustment of the flows' type series was another procedure undertaken to improve the quality of the models. The results of the ADF and PP tests indicate that the series became stationary after the first differencing. As all the variables were integrated of order one, *I*(1), we could proceed with cointegration analysis.

According to the Johansen-Juselius methodology two data sets *I*(1): $y_{1,t}$ and $y_{2,t}$ are said to be cointegrated if there exists a linear relationship of the form $z_t = \beta_1 y_{1,t} + \beta_2 y_{2,t}$, such that z_t is a stationary *I*(0) variable that displays their common trend [21; 20, 358]. The results of cointegration relationship testing and modelling are presented in Table 2. The appropriate lag length for cointegration test and for the VAR systems of each VECM was chosen with the help of respective Akaike information criterion (AIC) and Schwarz Bayesian criterion (SBC). The adequate deterministic restrictions (intercepts and trends in the short and long-term parts of the model) were tested via using the trace and the maximal eigen value statistics moving from the most restrictive to the least restrictive model specification. The initial VEC model based on the Cobb-Douglas function (2) suggested that there was a long-run equilibrium relationship between per capita revenue and capital variables (see Table 2) assuming the existence of a trend, intercept and exogenous dummy variable reflecting periods of abnormal changes in *Reer*.

We should note that VECM (3), which estimated long-run equilibrium relation between revenue and capital not accounting for the labour factor, had a different from VECM 1 deterministic specification (intercept in CE) and VAR order (lag = 1) (see Table 2). It performed better in terms of *F*-statistics of the VAR systems (*t*-statistics for CE and ECM coefficients of both VECMs were significant):

$$\begin{array}{l}\text{Cointegrat ion Equaion: } \ln(Rev\_pop) = 1.62\ln(Cap\_pop) - 4.23 \quad AIC = -8.17. \\ \text{ECM(-1):} \qquad\qquad -0.035\,[-5.049] \qquad\quad -0.017\,[-3.089] \\ F\text{-statistics of VAR systems:} \quad (38.917) \qquad\quad (58.648)\end{array} \tag{3}$$

This is not surprising, as the direction of causation went from physical capital to revenue and then from it to human capital indicators. Besides, the correlation between capital variables might induce the multicollinearity problem that affected the outgoing modelling results (see Table 1). The second VECM with uncorrelated explanatory variables had improved AIC, *F*, and residual statistics (see Table 2). Impulse functions proved that one standard deviation increase in physical capital and education expenses caused growth in the per capita revenue.

Examination of possible long-run relationships of the per capita revenue with the economic and financial time series listed above showed stable cointegration relations and improvement of the regional welfare in response to the positive shocks in the following variables: foreign investments, sales volume of industrial production, volume of loans and savings, retail trade volume and proportion of import in trade, export of goods and services, as well as *Reer*. At the same time, the households' revenue responded negatively to the increase of the wage receivables and the index of agricultural production. We should note instable cointegration relationships with financial development variables due to the permanent crisis in the banking industry since 2008. Statistical tests have justified that the foreign investments made the most significant contribution to economic recovery in 2009-2013 causing an increase in exports, production and per capita revenue. Empirical assessment has proved that this growth was highly influenced by orders from the Russian Federation. Although a shift towards raising the share of agricultural goods in regional exports had occurred after the partial loss of the Russian markets in engineering and chemical production in 2014, although growing farming industry did not have a significant impact on household revenues. This corresponds with the economic theory that does not consider agricultural domination as a way to prosperity unless it stimulates innovations, sustainable use of natural resources, improvement of energy efficiency and health care. Unfortunately, this has not happened yet. Expenses

Tab. 2: **VECMs' summary results based on the Cobb-Douglas function**

N	VECM features	Endogenous Variables (in logarithms)			VAR order / Model AIC	Impulse response
1.		***ΔRev_pop***	***ΔCap_pop***	***ΔEmp_pop***		
	Cointegration equation (CE)	$Rev\_pop = 1.003\ Cap\_pop - 5.50\ Emp\_pop + 0.034\ trend + 34.526$ ($t-stat$: [−6.538], [5.342], [−16.592])				
	ECM(-1)	-0.158 [-2.174]	-0.024 [-1.787]	-0.048 [-5.011]	Lag=4	↑ *Cap_pop* → ↑ *Rev_pop*
	Exogenous variables	*D_reer* [-2.941]	*D_reer* [-10.349]	*D_reer* [-3.041]		
	R^2	0.908	0.795	0.78		↑ *Rev_pop* → ↑ *Emp_pop*
	S.E. equation	0.053	0.037	0.007		
	F-statistic	30.38	11.89	10.90	AIC=-13.537	
2.		***ΔRev_pop***	***ΔCap_pop***	***ΔEd_exp***		
	Cointegration equation	$Rev\_pop = 0.97\ Cap\_pop + 1.94\ Ed\_\exp - 3.64$ ($t-stat$: [−2.024], [−2.247])				
	ECM(-1)	-0.0593 [-4.968]	-0.030 [-3.160]	0 Weak exog	Lag=1	↑ *Cap_pop* → ↑*Rev_pop*
	Deterministic components	*D_reer* [-6.741]	*D_reer* [-11.502]	*D_reer* [-2.578]		
	R^2	0.671	0.755	0.659		↑ *Ed_exp* → ↑ *Rev_pop* lags 4-8
	S.E. equation	0.044	0.035	0.011		
	F-statistic	29.008	44.011	27.541	AIC=-14.154	

Source: Own processing based on official regional and national statistics [18-19]

on research and development had an exponential decline rate after 2008 which was higher than the corresponding recession rates for other economic indicators. Statistical tests have proved that expenditures on innovation influenced regional exports and agriculture but didn't cause economic growth. We see potential for educational institutions in cooperation and partnership with business and local governments to become a driver of innovation activity and sustainable development of the region.

5. Conclusions

We have examined the economic, financial, social and ecological factors of regional development focusing on their impact on economic growth and sustainability, and defined cointegration relationships between them to reveal long-run equilibrium associations. For this purpose, we calculated the aggregate index of sustainable regional development (ISD) and assessed the contribution of economic, social and ecological components. Then we used the Johansen VAR/VEC approach making exploratory and inferential analysis, examining the stationarity of the series, deterministic properties, causality and correlation, and cointegration relations. The findings prove that there is a long-run association between the economic welfare and physical and human capital factors introduced by the Cobb-Douglas production function. The estimated models suggest that foreign investments make the largest contribution to the per capita capital stock accumulation, while most human capital factors do not have an impact on the economic welfare and are dependent on it, but for the expenditures on education that do stimulate economic growth. Assuming a big negative effect of macroeconomic instability on the sustainable regional development, local communities' initiatives towards attracting investments in innovative research projects that involve educational institutions are considered to be a priority in regional policy. Opportunities for interregional associations and business clustering, as well as incentives promoting sustainable development, require further consideration and research.

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