

## **International Journal of Global Energy Issues**

ISSN online: 1741-5128 - ISSN print: 0954-7118

<https://www.inderscience.com/ijgei>

---

### **The impact of innovations and intellectualisation on sustainable national development**

Oleksandr Kubatko, Rytis Krušinskas, Leonid Melnyk, Bohdan Kovalov, Pavlo Denysenko

**DOI:** [10.1504/IJGEI.2025.10067976](https://doi.org/10.1504/IJGEI.2025.10067976)

#### **Article History:**

|                   |                  |
|-------------------|------------------|
| Received:         | 16 January 2023  |
| Last revised:     | 31 May 2023      |
| Accepted:         | 17 October 2023  |
| Published online: | 16 December 2024 |

---

## The impact of innovations and intellectualisation on sustainable national development

---

Oleksandr Kubatko\*

Economics, Entrepreneurship and Business

Administration Department,

Sumy State University,

Sumy, Ukraine

Email: okubatko@econ.sumdu.edu.ua

\*Corresponding author

Rytis Krušinskas

School of Economics and Business,

Kaunas University of Technology,

Kaunas, Lithuania

Email: rytis.krusinskas@ktu.lt

Leonid Melnyk and Bohdan Kovalov

Economics, Entrepreneurship and Business

Administration Department,

Sumy State University,

Sumy, Ukraine

Email: melnyksumy@gmail.com

Email: b.kovalov@econ.sumdu.edu.ua

Pavlo Denysenko

NetCracker Technology,

Bilopil's'kyi Shlyakh Str. 26,

Sumy, Ukraine

Email: pavlo.denysenko@gmail.com

**Abstract:** Innovations are an integral part of the modern global economy. The purpose of this research is to investigate impact of innovations and intellectualisation on sustainable national development. Based on the World Bank sets, two models with panel data from selected economies (Bulgaria, the Czech Republic, Hungary, Kazakhstan, Poland, Romania, Moldova, the Slovak Republic, Ukraine and Uzbekistan) in 2006–2018 were built. Using random-effects GLS regression it was proved that factors of intellectualisation and innovations (both exogenous and endogenous) increase the level of economic growth. Empirical results proved that intellectualisation of the economy of endogenous origin is one of the stimulators of improving the environmental situation (when there is an increase in the number of researchers in the country by 100 people, the amount of carbon dioxide per capita decreases by 84–131 kg), while exogenous intellectualisation turned out to be a statistically

insignificant factor. The paper proved several decarbonisation drivers, which include energy efficiency and life expectancy. Following the results, policy recommendations were provided and indicated the importance of national education development and innovation fostering. This can be achieved by revising learning standards according to market requirements, retraining educators and using a competence-based approach.

**Keywords:** innovations; intellectualisation; sustainable development; sustainability; economic growth; carbon dioxide emissions.

**Reference** to this paper should be made as follows: Kubatko, O., Krušinskas, R., Melnyk, L., Kovalov, B. and Denysenko, P. (2025) 'The impact of innovations and intellectualisation on sustainable national development', *Int. J. Global Energy Issues*, Vol. 47, Nos. 1/2, pp.39–56.

**Biographical notes:** Oleksandr Kubatko is Doctor in Economics. He is an Associate Professor of Economics, Entrepreneurship and Business Administration Department at Sumy State University, Ukraine. He has published more than 50 scientific papers, including publications in international peer-reviewed journals. He is a Leader of two and a Contributor to more than ten scientific and research projects, including international ones. His research interests include environmental economics, energy economics and health economics.

Rytis Krušinskas is a Professor in Finance at School of Economics and Business, research group 'Sustainable Economy', Kaunas University of Technology, Lithuania. He has published more than 60 scientific papers. His research interests include technology investment effectiveness and impact valuation at micro- and macro-levels; economic and financial impact valuation for digitalisation processes at organisational, sectoral, country level; financial management processes for startups; decarbonisation impact on financial performance.

Leonid Melnyk is Doctor in Economics and he is a Professor in the Department of Economics at Entrepreneurship and Business Administration, Director of the Institute for Development Economics of Ministry of Education & Science and The National Academy of Science of Ukraine, Sumy State University, Ukraine; Author and Co-author of more than 400 scientific and other publications, and 45 books. His research interests include development economics, the third industrial revolution and industry 4.0, social and economic EU studies, economics and business; ecological economics, economics of systems development, economics of enterprise, information economics and economics of sustainability.

Bohdan Kovalov PhD graduated from Sumy State University. Currently, he is an Associate Professor in the Department of Economics, Entrepreneurship and Business Administration, Sumy State University. His research interests and publications include sustainable development and sustainable lifestyle, resource security, digital transformation and digitalisation and entrepreneurship, startups.

Pavlo Denysenko graduated from Sumy State University. Currently, he is a QA Engineer at NetCracker Technology Corp., Sumy, Ukraine. He is the Author of more than 30 scientific papers. His research interests and publications include sustainable development, knowledge economy and environmental economics.

---

## 1 Introduction

Innovative processes are becoming one of the most important priorities for the development of society. Their aim of any innovation is to reduce the anthropogenic load, energy dependence and maintain ecosystem stability (Rezny et al., 2019). Innovation also contributes to labour force development and attraction of investment to ensure sustainability (Melnik et al., 2022). In modern conditions of constant transformational changes in the development of socio-ecological and economic systems, the main competitive advantage of economy is the ability to create, accumulate, distribute and apply new knowledge (Krusinskas et al., 2021; Harshad, 2022; Maris, 2022). COVID-19 pandemic also forced shifting from traditional socio-economic framework to digitally based (Andrişan and Modreanu, 2022).

The concept of ecologically sustainable development aims at the development of economic systems through self-organisation with sufficient external support, which excludes the possibility of transition to a state of irreversible environmental degradation. For the economic system, the concept of sustainable development aims at a partial transfer of financial resources from rich countries to poorer ones with a wide exchange of ecological knowledge. However, the processes of globalisation that began in the second half of the last century created favourable conditions for the development of transnational corporations. Thus, it was much more profitable for many international firms to transfer ecologically dirty production to less developed countries (which had less stringent requirements for production conditions) than to invest in domestic country into the resource and energy saving technologies. To prevent these processes in the implementation of investment projects, it is necessary to include an environmental impact assessment of the impact of possible environmental damage on human capital (Tarkhov et al., 2012).

Intellectualisation of processes in socio-ecological-economic systems should take place in the direction from economic growth to economic development with account to environmental sustainability. It is also strongly supported the idea that post-pandemic recovery might significantly consider environmental effects and bonuses (Bardy and Rubens, 2022).

The transition to a knowledge economy is a major factor, which determines the success of social, economic and ecological policies in the national economies. The concept of the knowledge economy has different interpretations, some of which are presented in Table 1.

**Table 1** Different approaches to define the concept of ‘knowledge economy’

| No. | Definition                                                                                                                                                                                                    |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | An economy, where the driving force of progress is knowledge concentrated in human capital (Kahin and Foray, 2006)                                                                                            |
| 2   | An economic paradigm, in which the processes of accumulation and use of knowledge are the dominant factor (Cavusgil, 2021)                                                                                    |
| 3   | The stage of development of the post-industrial economy, during which human intelligence and knowledge, information and disruptive technologies turn into a decisive development factor (Alvino et al., 2020) |

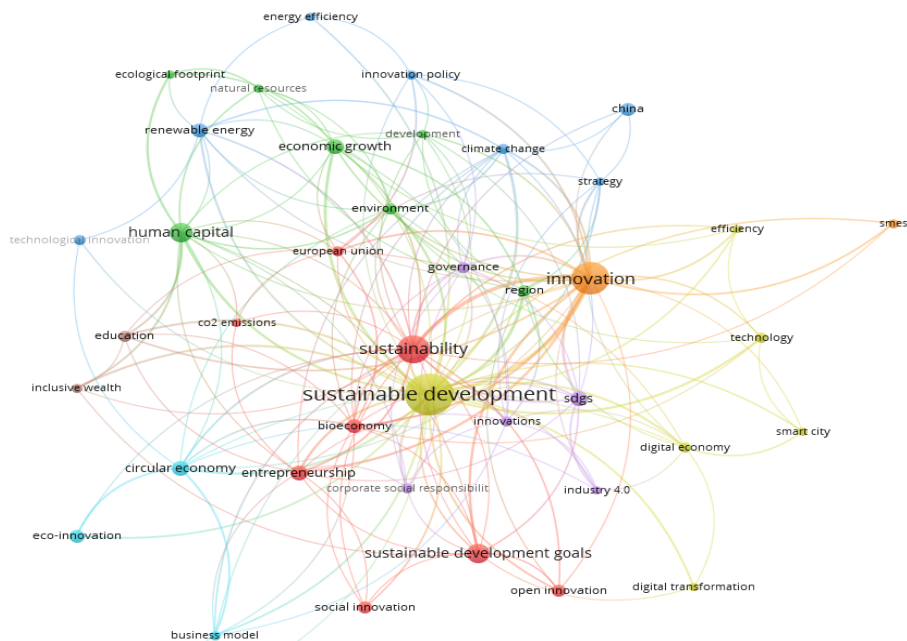
One of the features of the transition to the ‘knowledge society’ is the process of intellectualisation of economic activity. The main features of the intellectualisation of the economy are considered to be: the change of the industrial-type economy to an economy

based on knowledge and information, the transformation of different labour forms, growth of the creative class (Sineviciene et al., 2020), the formation of a new system of behavioural economic patterns in the conditions of global development. Intellectualisation of ecologically balanced socio-economic development is the process of expanding the scale and deepening the role of mental work and its results in the process of intensifying the interaction of natural, industrial and social subsystems aimed at achieving the sustainability of the socio-ecological-economic system as a whole. The knowledge economy maximises the use of the intelligence of each individual and the collective intelligence of the socio-ecological-economic system with the aim of accumulating, spreading and using new knowledge, in particular, at improving the use of the natural resource potential of the system, its preservation and reproduction. It is also considered that knowledge economy should be based on plenty cooperation of business and educational institutions for better labour force competencies and performance (Nahla, 2023; Yu et al., 2023; Artyukhov et al., 2021). Therefore, the paper aims to formalise the connections between the intellectualisation of the economy and indicators of labour productivity and resource productivity of ensuring sustainable development.

## 2 Literature review

Bibliometric analysis was conducted using Scopus Toolkit and VOS viewer software. To find out the proper results in the Scopus database, such keywords were utilised: ‘sustainable development’, ‘intellectualisation’ and ‘innovation’. The time span was 2017–2022 September. The results of the analysis are presented in Figure 1.

**Figure 1** The network map of keywords about sustainable development (see online version for colours)



*Source:* Developed by authors, using Scopus.

The result of the analysis is a network map of keywords from scientific publications, united in certain clusters. It also shows that intellectualisation and innovations affect different pillars of sustainability: economic (keywords: economic growth, digital economy, Industry 4.0), social (keywords: human capital, corporate social responsibility, governance) and environmental (keywords: climate change, bio-economy, eco-innovation).

Separately, it should be noted the approach according to which the intellectual potential consisting of information and innovation is placed in the same row with the personnel potential (for the enterprise), as well as with the entrepreneurial potential. This option is particularly suitable for the analysis of socio-ecological-economic systems, since the key factor is the intelligence factor, which is inextricably linked to the creative activity of a person, which goes beyond its purely role in innovative transformations. In addition, the growing role of information as a special resource of the era of the scientific and technological revolution has to be noted. Information and knowledge become the most valuable life product, a necessary condition and element of production activity. All this is consistent with the concept of V.I. Vernadsky about the 'noosphere' – a determining factor of human interaction with the environment.

At the same time, it is especially important to take into account the impact of the intellectualisation of the region's economy on the achievement of its ecologically balanced development. Taking into account empirical experience that emphasises the effectiveness of attracting local natural resources to the regional production system, we offer such an indicator as the productivity of one ton of conventional fuel. In addition, you can use such indicators as the generation and management of waste, the comparative efficiency method based on the assessment Levelised Cost of Energy (LCOE), efficiency of use of production resources (Matsenko and Ovcharenko, 2013), including the specific weight of water reused for production needs; specific gravity of discharge of polluted return water; transport efficiency (Shkarupa et al., 2017); specific weight of reforestation and land reclamation, etc.

The concept of intellectualisation was introduced into the scientific discourse by (Becker, 1962; Schultz, 1961). Later, in the study Romer (1990) on economic growth, intellectualisation was considered as an important element of systems development. Separate OECD studies emphasise the importance of education and intellectualisation for economic growth (OECD, 2022). The identification, presentation and elaboration of intellectualisation by theorists and practitioners also included the definition of this concept (Silvestre and Țircă, 2019). In general, the concept of intellectualisation is defined as the process of creating knowledge, competencies and skills, which contribute to personal, social and economic well-being. Harry Becker, who was one of the first to use the term 'intellectualisation' (Becker, 1962), believes that education, lifelong learning and healthcare are components of human capital that have consequences for economic productivity, and the European Commission today shares a similar opinion (European Commission, 2022). It should be noted that, in general, approaches to the potential of intellectualisation of the economy should be considered at different economic levels (Melnik, 2021; Sineviciene et al., 2019; Yao et al., 2019; Hrytsenko et al., 2021; Omelyanenko et al., 2022; Prokopenko and Omelyanenko, 2020; Tirtso et al., 2020). In real-economic processes, intellectualisation can have either an ecologically positive or ecologically destructive role (Fagerberg, 2018). This depends on a variety of factors, which will be revealed further in our study. However, most research outline that the impact of innovation on the environment is friendly, especially when the country has

achieved a certain level of socioeconomic development and can implement decarbonisation strategies (Marginson, 2010; Varadarajan, 2017). In developed countries corporate social and environmental responsibility is an integral element of ensuring corporate performance (Lahouirich et al., 2022).

Following the discussion, there are two main hypotheses tested in this study: *Hypothesis 1*: Factors of intellectualisation and innovations increase the level of economic growth, expressed by GDP per capita. *Hypothesis 2*: Factors of intellectualisation and innovations reduce the environmental footprint, expressed by CO<sub>2</sub> emissions per capita.

### 3 Materials and methods

In the scientific literature, there are a significant number of methods that allow to estimating the dynamics of GDP per capita using factor analysis (Carlaw et al., 2006; Brown et al., 2008). However, the set of factors included in the economic-mathematical modelling differs for different models. It all depends on what hypotheses are put forward, as well as on the availability of data and evaluation approaches. Our study hypotheses are related to the fact that for the GDP growth and environmental quality improvement it is important to increase the number of researchers working in the country and stimulate the national intellectual potential. It should be done by developing internal mechanisms for the production of innovative products based on domestic technologies. In this case, the results of innovative activities produced in the country will not be exposed to diffusion barriers due to the homogeneity of institutional, linguistic, political and economic conditions. To conduct empirical research, first of all, it is necessary to analyse in detail the statistical data bases of the research. Among the most important international databases, it is worth highlighting such indicators as: Policy Index for Small and Medium Enterprises, Global Innovation Index, Economic Transparency Index and Business Conduct Index. Let's consider these indicators separately.

The Small and Medium Enterprise Policy Index is a statistical framework for comparative analysis of countries with economies in transition to assess the progress of small and medium enterprise development in comparison with developed economic systems. It is considered that SMEs have significant contribution to economic development (Kasemi and Gadi, 2022). The SME index was first developed in 2006 due to the joint work of such institutions as the OECD, the European Commission, the EBRD and the ETF. Eight years after its creation, the methodology for applying the Index of small and medium-sized enterprises was improved in the direction of wider consideration of the intensity of implementation, provision of recommendations and comparability of studies.

The Global Innovation Index is created on the basis of taking into account the factors that make it possible to evaluate the indicators of innovative activity, and has the following characteristics: an overview of more than 120 countries of the world, including information about the place in the ranking, strengths and weaknesses; more than 80 tables with statistical indicators collected from more than 30 international databases, including about 60 tables with actual data, 20 tables with integral indicators. The Global Transparency Index is calculated by Cornell University together with the INSEAD business school and the World Intellectual Property Organisation. Numerous empirical research proved that better country innovation performance (measured by Global

Innovation Index) ensures better country economic performance (measured by GDP growth) (Ibraghimov, 2022; Hakhverdyan and Shahinyan, 2022; Kozmenko et al., 2010).

The World Index of Corruption Perceptions is based on independent expert surveys conducted by the World Bank, Freedom House, World Economic Forum, etc. The ease of doing business index, created to compare the ease of doing business between countries of the world, compiled by the World Bank on the basis of annual data. The index of competitiveness of the economy is presented at the World Economic Forum

To test the first hypothesis (factors of intellectualisation and innovations increase the level of economic growth, expressed by GDP per capita), three variants of model 1 were used. Each variant represents different combinations of factors, of the same data set, to see the possible problems of over/underestimation of model and provide upper/lower levels of regression coefficient. The model investigates the dependence of GDP per capita from the set of social, economic, resource and structural determinants, with account to the indicators characterising the type of intellectualisation (for exogenous – payments abroad for use of intellectual property; for endogenous – the number of researchers per 1 million people in the country). Similarly, to test the second hypothesis (factors of intellectualisation and innovations reduce the environmental footprint, expressed by CO<sub>2</sub> emissions per capita), three variants of model 2 (differing by combinations of factor characteristics) were utilised. The dependence of CO<sub>2</sub> emissions per capita on a variety of the above-mentioned determinants was investigated.

$$GDP_{pc} = F(Ef, PO, FDI, R, Ch, LE, AGR, IND, GFCF, PGR, EC, EU) \quad (1)$$

$$CO_2_{pc} = F(Ef, PO, FDI, R, Ch, LE, AGR, IND, GFCF, PGR, EC) \quad (2)$$

where:

$GDP_{pc}$  – GDP per capita (constant US dollars);

$Ef$  – Energy efficiency (GDP/kg of oil equivalent per year);

$PO$  – Oil price (US dollars);

$FDI$  – Foreign direct investment (% of GDP);

$R$  – Number of researchers per one million people;

$Ch$  – Payments for the use of intellectual property (US dollars);

$LE$  – Life expectancy at birth (years);

$AGR$  – Agriculture and fisheries (% of GDP);

$IND$  – Industry (% of GDP);

$GFCF$  – gross fixed capital formation (% of GDP);

$PGR$  – Population growth rate (% to a previous year);

$EC$  – Consumption of energy resources per capita (tons of oil equivalent);

$EU$  – Binary variable of EU membership.

In order to estimate the following regressions with the empirical statistical software it is needed to present the dependent and independent variables in analytical form:

$$GDP_{pc} = (\beta_0 + \beta_1 Ef + \beta_2 PO + \beta_3 FDI + \beta_4 R + \beta_5 Ch + \beta_6 LE + \beta_7 AGR + \beta_8 IND + \beta_9 GFCF + \beta_{10} PGR + \beta_{11} EC + \beta_{12} EU)$$

Actually, it is expected that  $\beta_1$  is positive and statistically significant, since energy efficiency positively adds to GDP. As for the  $\beta_2$ , it is expected that oil price increase shrinks the GDP. As for the  $\beta_3$ , it is expected that foreign direct investment increases the GDP. As for the  $\beta_4$ , it is expected that increase in number of researchers per one million people increases the GDP. As for the  $\beta_5$ , it is expected that increase use of intellectual property increases the GDP. As for the  $\beta_6$ , it is expected that increase in Life expectancy at birth increases the GDP. As for the  $\beta_7 - \beta_{12}$  it is expected that increase in share of agriculture and fisheries, share of Industry, gross fixed capital formation, population growth rate, consumption of energy resources per capita increases the GDP.

For the current study, a group of countries historically and economically connected with Ukraine was selected, in particular: Bulgaria, the Czech Republic, Hungary, Kazakhstan, Poland, Romania, Moldova, the Slovak Republic and Uzbekistan. The research period was taken from 2006 to 2018 according to the data available at the World Bank. To test the above-mentioned hypotheses, three models were used using different combinations of factor characteristics while maintaining a single dependent variable.

Empirical evaluation of the theoretical model may have its specific features, regarding the choice of the specification model and different factors included. The form of a regression model itself can be both linear and non-linear. In this case, we use a linear model, which allows us to interpret the obtained results as absolute values.

#### 4 Research results and discussion

Using STATA 16.0 software, we obtained the following results (see Table 2).

**Table 2** The estimated results of the random-effects generalised least squares (GLS) regression for the impact of innovation factors on GDP per capita

|                                                           | (1)                    | (2)                    | (3)                    |
|-----------------------------------------------------------|------------------------|------------------------|------------------------|
| <i>Variables</i><br>(Dependent variable – GDP per capita) | <i>Model 1.1</i>       | <i>Model 1.2</i>       | <i>Model 1.3</i>       |
| Energy efficiency                                         | 0.920***<br>(4.19e-07) | 2.027<br>(0)           | 2.340<br>(0)           |
| Oil price                                                 | 31.27***<br>(0.000494) | 22.91***<br>(2.45e-07) |                        |
| Foreign direct investment                                 | 27.03<br>(0.175)       | 18.22*<br>(0.0643)     | 14.43<br>(0.180)       |
| Number of researchers per one million people              | 2.637***<br>(0)        | 1.392***<br>(0)        | 0.968***<br>(3.17e-07) |

**Table 2** The estimated results of the random-effects generalised least squares (GLS) regression for the impact of innovation factors on GDP per capita (continued)

|                                                           | (1)                      | (2)                     | (3)                        |
|-----------------------------------------------------------|--------------------------|-------------------------|----------------------------|
| <i>Variables</i><br>(Dependent variable – GDP per capita) | <i>Model 1.1</i>         | <i>Model 1.2</i>        | <i>Model 1.3</i>           |
| Payments for the use of intellectual property             | 2.68e-08<br>(0.854)      | –3.48e-07<br>(1.38e-05) | –4.12e-07***<br>(6.47e-07) |
| Life expectancy at birth                                  | 382.4***<br>(0.000878)   | 361.9***<br>(7.88e-08)  | 323.2***<br>(1.02e-07)     |
| Agriculture and fisheries                                 | –21.79<br>(0.644)        | 36.05<br>(0.429)        | 145.9***<br>(1.12e-07)     |
| Industry                                                  | 408.0***<br>(0)          | –11.15<br>(0.757)       | –25.08<br>(0.531)          |
| Fixed capital formation                                   | –17.39<br>(0.757)        | 39.49<br>(0.194)        | 18.32<br>(0.548)           |
| Population growth rate                                    |                          | 812.7***<br>(0.00250)   |                            |
| Consumption of energy resources per capita                |                          | 2.502***                | 3.388***                   |
| EU membership                                             |                          | –370.5<br>(0.569)       |                            |
| Constant                                                  | –39.667***<br>(3.37e-06) | –35.590***<br>(0)       | –33.819***<br>(0)          |
| Observations                                              | 120                      | 120                     | 120                        |
| Number of ID                                              | 10                       | 10                      | 10                         |

With an increase in energy efficiency (GDP/kg of oil equivalent) per one unit in the group of selected countries, an increase in GDP per capita in the range from 0.94 to 2.34 dollars is observed. On average, it can be argued that investing in energy efficiency has a double effect on GDP per capita indicators – as can be seen from models 1.2 and 1.3.

Oil prices are a statistically significant factor in the 99% confidence interval. When oil prices grow by one USD, the GDP per capita increases by 22–31 US dollars. Thus, it can be noted that the mentioned economic systems are still highly dependent on oil, which can be partially explained by the resource curse factor.

It is worth emphasising the double positive effect of improving the achievements of intellectual activity and the state of the environment. First, with an increase in the level of intellectualisation, there is an increase in the well-being of the country and the population in particular, which makes it possible to invest in more energy- and resource-saving technologies, according to (Abbas and Sağsan, 2019; Olssen and Peters, 2005). Secondly, with the increase in the level of intellectualisation, the opportunities of creating national technological solutions open up to combat the deterioration of the environment (Yu-Xia et al., 2021). These results are also supported by correlation analysis, which proved the positive influence of intellectualisation on economic development (see Appendix A).

If we consider the indicators of life expectancy at birth, the results show that in countries where the average life expectancy is higher, GDP per capita also increases. In particular, the results confirm that with an increase in life expectancy at birth by one year, GDP per capita increases by 323.2–382.4 US dollars. Obtained results once more proved our hypotheses of the need to invest in social capital to maintain ecologically sustainable development. There may be another cause-and-effect relationship when the development of the social sphere significantly contributes to an increase in the life expectancy of the population. These conclusions also supported by another scientific research (Ramli et al., 2022).

Agriculture and fishing as a structural variable is a statistically significant factor. Thus, with the growth of agriculture and fisheries as a share of GDP by one percentage point, there is an increase in GDP per capita by 145 US dollars. That means for the group of selected economies, agriculture remains an important structural element of the national economy.

The share of the industrial sector in the structure of GDP turned out to be a statistically significant factor in only one of the three models. Thus, with the growth of the industrial sector as a share of GDP by one percentage point, there is an increase in GDP per capita by 408 US dollars. That is, for the group of post-communist bloc countries, the industrial sector is an important structural element of the national economy. Despite the processes of dematerialisation and orientation on a service economy, the basis of the economic systems of these countries is the industrial sectors and real-production processes (Kartanaitė et al., 2021).

The results of the estimated impact of a variety of determinants on CO<sub>2</sub> emissions are presented in Table 3.

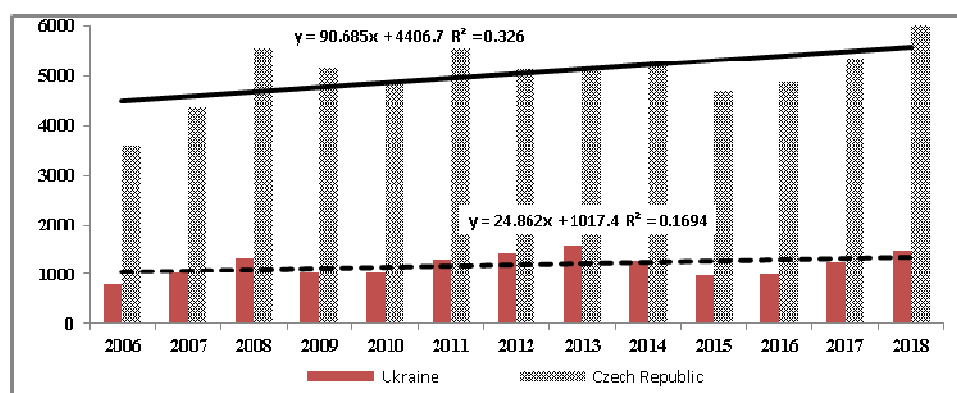
**Table 3** The estimated results of the random-effects generalised least squares (GLS) regression for the impact of innovation factors on CO<sub>2</sub> emissions per capita

|                                                                                 | (1)                      | (2)               | (3)               |
|---------------------------------------------------------------------------------|--------------------------|-------------------|-------------------|
| <i>Variables</i><br>(Dependent variable – CO <sub>2</sub> emissions per capita) | <i>Model 2.1</i>         | <i>Model 2.2</i>  | <i>Model 2.3</i>  |
| Energy efficiency                                                               | –0.00152***              | –0.000668***      | –0.000304***      |
| Oil price                                                                       | 0.0114                   | 0.00483           |                   |
| Foreign direct investment                                                       | 0.00944                  | –0.00262          | –0.00131***       |
| Number of researchers per one million people                                    | 0.000188                 | –0.000843***      | –0.00131***       |
| Payments for the use of intellectual property                                   | 3.51e-10**               | 8.09e-11          | –6.30e-11         |
| Life expectancy at birth                                                        | 0.368***                 | 0.263***          | 0.361***          |
| Agriculture and fisheries                                                       | –0.200***                | –0.187***         | –0.0375           |
| Industry                                                                        | 0.486***                 | 0.0932***         | 0.0939***         |
| Fixed capital formation                                                         | –0.0496                  | –0.00434          | –0.0187           |
| Population growth rate                                                          |                          | 1.388***          |                   |
| Consumption of energy resources per capita                                      |                          | 2.039***          | 3.103***          |
| Constant                                                                        | –0.0415***<br>(3.37e-06) | –0.5124***<br>(0) | –0.3141***<br>(0) |
| Observations                                                                    | 120                      | 120               | 120               |
| Number of ID                                                                    | 10                       | 10                | 10                |

Empirical results prove that intellectualisation of the economy of endogenous origin is one of the stimulators of improving the environmental situation (when there is an increase in the number of researchers in the country by 100 people, the amount of CO<sub>2</sub> per capita decreases by 84–131 kg), while exogenous intellectualisation turned out to be a statistically insignificant factor. Other decarbonisation drivers are energy efficiency, life expectancy, and population growth.

However, real indicators of energy efficiency in Ukraine still remain at an extremely low level in comparison with individual EU countries (see Figure 2). From Figure 1, it can be seen that the added value created from a unit of consumed energy resources in Ukraine is approximately 3 to 4 times less than the corresponding indicator in the Czech Republic that is why mechanisms of state regulation of the development of alternative energy should be improved, and appropriate strategic directions of development.

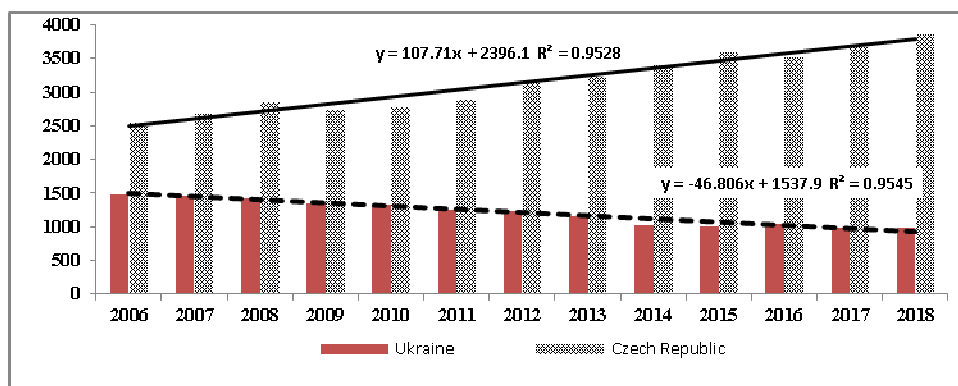
**Figure 2** Output of GDP per ton of oil equivalent of energy resources (see online version for colours)



Foreign direct investment (% of GDP) turned out to be a statistically significant factor in the 90% confidence interval only for the third model and with an increase in the share of direct foreign investment by one percentage point in the GDP structure the CO<sub>2</sub> emissions per capita reduces by one kilogram per capita.

In the context of research on the intellectualisation of ecologically sustainable development, it is important to identify the exact type of intellectualisation by source (exogenous – when the results of intellectual work are imported into the country in the form of the purchase of patents, know-how or ready-made innovative products, or endogenous – when intellectual developments are produced within the country) is to the greatest extent a catalyst of economic growth and at the same time – a reduction of anthropogenic load. Proceeding from the latter, we emphasise that every economic system should concentrate not on attracting other people's intellectual property rights, but on the creation and commercialisation of its own intellectual developments. Creating domestic intellectual product does not burden the home economic system, and does not create additional pressure on other items of expenditure.

It is noted the following interesting fact that in Ukraine during the analysed period, the number of researchers per one million of the existing population is only decreasing, while in the Czech Republic these indicators are only increasing. In addition, it is worth noting the negative trends of these processes, since the number of scientific personnel during the last decade has greatly decreased (see Figure 3).

**Figure 3** The number of researchers per one million inhabitants in Ukraine and the Czech Republic during 2006–2018 (see online version for colours)

It is worth emphasising the double positive effect of improving the achievements of intellectual activity and the state of the environment. First, with an increase in the level of intellectualisation, there is an increase in the well-being of the country and the population in particular, which makes it possible to invest in more energy- and resource-saving technologies. Secondly, with the increase in the level of intellectualisation, the possibility of creating one's own technological solutions to combat the deterioration of the environment opens up.

Most of the Central and Eastern European countries that have recently joined the European Union have aligned their innovation strategies with the Europe 2020 Strategy, which defined the Union's agenda for economic development for the current decade. All of them have invested in EU-backed innovation and seen improvements in their innovation capabilities. However, improvements in GII performance and rankings over the past five years have generally been quite low, underscoring the long-term nature of the investment required and the extent of the institutional and political coordination and implementation challenges that need to be addressed.

In conditions where the natural resource potential of the post-communist economies is mostly used extensively, the reserves of its growth are exhaustive with many negative consequences for the environment (Sineviciene et al., 2020). At the same time, the implementation of innovative economically justified technologies is becoming a promising direction for achieving environmental sustainability – that is, the way to improve resource and energy use. In the context of ecologically balanced development, the factors of intellectualisation, together with the presence of relevant scientific and innovative achievements, can also be defined as drivers of ecologically safe and cost-effective natural resource potential usage.

## 5 Conclusions and policy implications

The first tested hypothesis about the fact that intellectualisation and innovations increase the level of economic growth was proved; thus, factors of intellectualisation and innovations (both exogenous and endogenous) increase the level of economic growth. Other statistically significant drivers of GDP per capita growth for selected transition

economies include oil prices, life expectancy, share of agriculture and fishery in GDP, share of industry in GDP and population growth rate.

The second hypothesis about the fact that intellectualisation and innovations reduce the environmental footprint, expressed by CO<sub>2</sub> emissions per capita was only partially confirmed; thus only endogenous factors (e.g., the number of researches per one million people) stimulate ecological footprint reduction (expressed by CO<sub>2</sub> emissions per capita). Exogenous factors have no statistically significant impact on CO<sub>2</sub> emissions per capita. Other decarbonisation drivers include energy efficiency and life expectancy.

The main trends affecting innovation in Ukraine are related to several facts: emigration of educated people; post-industrialisation; innovation becomes an increasingly important prerequisite for the development of high productivity, competitive and growing economies and is integrated into global value chains; the innovation economy relies on a reliable and coherent national innovation system.

The results indicated the importance of education development. This can be achieved by revising learning standards according to market requirements, retraining educators, and using a competence-based approach. Innovations can be fostered by supporting innovative companies with financial and non-financial incentives, and developing a legislative framework to create a proper institutional environment (less corruption, less bureaucracy, etc.).

The study has some limitations: the results are based on the analysis of a small group of countries within a relatively short-time period. Therefore, further research should concentrate on the extension of the model and the use of other econometric approaches (e.g., lag models).

## Acknowledgements

The publication contains the results of research conducted within the framework of the research project: 'Restructuring of the national economy in the direction of digital transformations for sustainable development' (No. 0122U001232).

## References

- Abbas, J. and Sağsan, M. (2019) 'Impact of knowledge management practices on green innovation and corporate sustainable development: a structural analysis. *Journal of Cleaner Production*, Vol. 229, pp.611–620. Doi: 10.1016/j.jclepro.2019.05.024.
- Alvino, F., Di Vaio, A., Hassan, R. and Palladino, R. (2020) 'Intellectual capital and sustainable development: a systematic literature review', *Journal of Intellectual Capital*, Vol. 22, No. 1, pp.76–94.
- Andrișan, G. and Modreanu, A. (2022) 'An overview of the fourth industrial revolution through the business lens', *Business Ethics and Leadership*, Vol. 6, No. 1, pp.39–46. Doi: 10.21272/bel.6(1).39-46.2022.
- Artyukhov, A., Volk, I., Vasylieva, T. and Lyeonov, S. (2021) 'The role of the university in achieving SDGs 4 and 7: a Ukrainian case', Paper presented at the *E3S Web of Conferences*, Vol. 250. Doi: 10.1051/e3sconf/202125004006.
- Bardy, R. and Rubens, A. (2022) 'Weighing externalities of economic recovery projects: an alternative to green taxonomies that is fairer and more realistic', *Business Ethics and Leadership*, Vol. 6, No. 3, pp.23–34. Doi: 10.21272/bel.6(3).23-34.2022.

- Becker, G.S. (1962) 'Investment in human capital: a theoretical analysis', *Journal of Political Economy*, Vol. 70, No. 5, pp.9–49.
- Brown, P., Lauder, H., Ashton, D., Yingje, W. and Vincent-Lancrin, S. (2008) 'Education, globalisation and the future of the knowledge economy', *European Educational Research Journal*, Vol. 7, No. 2, pp.131–156. Doi: 10.2304/eej.2008.7.2.131.
- Carlaw, K., Oxley, L., Walker, P., Thorns, D. and Nuth, M. (2006) 'Beyond the hype: intellectual property and the knowledge society/knowledge economy', *Journal of Economic Surveys*, Vol. 20, No. 4, pp.633–690. Doi: 10.1111/j.1467-6419.2006.00262.x.
- Cavusgil, S.T. (2021) 'Advancing knowledge on emerging markets: past and future research in perspective', *International Business Review*, Vol. 30, No. 2. Doi: 10.1016/j.ibusrev.2021.101796.
- European Commission (2022) *New Circular Economy Strategy – Environment*. Available online at: <https://ec.europa.eu/environment/circular-economy/>
- Fagerberg, J. (2018) 'Mobilizing innovation for sustainability transitions: a comment on transformative innovation policy', *Research Policy*, Vol. 47, No. 9, pp.1568–1576. Doi: 10.1016/j.respol.2018.08.012.
- Hakhverdyan, D. and Shahinyan, M. (2022) 'Competitiveness, innovation and productivity of the country', *Marketing and Management of Innovations*, Vol. 1, pp.108–123. Doi: 10.21272/mmi.2022.1-08.
- Harshad, D. (2022) 'The constitution of value', *Financial Markets, Institutions and Risks*, Vol. 6, No. 2, pp.75–90. Doi: 10.21272/fmir.6(2).75-90.2022.
- Hrytsenko, P., Voronenko, V., Kovalenko, Y., Kurman T. and Omelianenko, V. (2021) 'Assessment of the development of innovation activities in the regions: case of Ukraine', *Problems and Perspectives in Management*, Vol. 19, No. 4, pp.77–88. Doi: 10.21511/ppm.19(4).2021.07.
- Ibraghimov, E.A. (2022) 'Management of innovation in Azerbaijan', *Relationships with Competitiveness and Sustainable Development Marketing and Management of Innovations*, Vol. 1, pp.247–256. Doi: 10.21272/mmi.2022.1-18.
- Kahin, B. and Foray, D. (2006) *Advancing Knowledge and the Knowledge Economy*, The MIT Press.
- Kartanaitė, I., Kovalov, B., Kubatko, O. and Krušinskas, R. (2021) 'Financial modeling trends for production companies in the context of industry 4.0', *Investment Management and Financial Innovations*, Vol. 18, No. 1, pp.270–284. Doi: 10.21511/imfi.18(1).2021.23.
- Kasemi, S. and Gadi, I. (2022) 'Small and medium enterprises and economic growth in Algeria through investment and innovation', *Financial Markets, Institutions and Risks*, Vol. 6, No. 1, pp.55–67. Doi: 10.21272/fmir.6(1).55-67.2022.
- Kozmenko, S., Vasil'yeva, T. and Leonov, S. (2010) 'The structuring of components of the net domestic product according to the innovation criterion', *Innovative Marketing*, Vol. 6, No. 4, pp.30–41. Doi: 10.21511/im.6(4).2010.01.
- Krusinskas, R., Rubio, J.G., Kovalov, B., Soskina, N.M. and Benetyte, R. (2021) 'Role of R&D expenditure, CEO compensation and financial ratios for country's economic sustainability and innovative growth', *International Journal of Global Energy Issues*, Vol. 43, Nos. 2/3, pp.228–246. Doi: 10.1504/ijgei.2021.10037740.
- Lahouirich, M.W., El Amri, A., Oulfarsi, S., Sahib Eddine, A., El Bayed Sakalli, H., and Boutti, R. (2022) 'From financial performance to sustainable development: a great evolution and an endless debate', *Financial Markets, Institutions and Risks*, Vol. 6, No. 1, pp.68–79. Doi: 10.21272/fmir.6(1).68-79.2022.
- Marginson, S. (2010) 'Higher education in the global knowledge economy', *Procedia-Social and Behavioral Sciences*, Vol. 2, No. 5, pp.6962–6980. Doi: 10.1016/j.sbspro.2010.05.049.
- Maris, M. (2022) 'Management of competitiveness in the EU member states', *The Main Strengths and Weaknesses Marketing and Management of Innovations*, Vol. 2, pp.110–120. Doi: 10.21272/mmi.2022.2-10.

- Matsenko, O. and Ovcharenko, D. (2013) 'The quality of energy resources controlling as a part of effective enterprise management', *Economic Annals-XXI*, Vols. 9/10. No. 1, pp.75–78. Available online at: <http://essuir.sumdu.edu.ua/handle/123456789/74620>
- Melnyk, L. (2021) 'Socio-natural antientropic potential: the role of economy and innovations', *Environment, Development and Sustainability*, Vol. 23, No. 3, pp.3520–3542. Doi: 10.1007/s10668-020-00730-0.
- Melnyk, M., Kuchkin, M. and Blyznyukov, A. (2022) 'Conceptualization and measuring the digital economy', *Business Ethics and Leadership*, Vol. 6, No. 2, pp.127–135. Doi: 10.21272/bel.6(2).127-135.2022.
- Nahla, N. (2023) 'University-company collaboration: what are the obstacles in Algeria?', *Socio-Economic Challenges*, Vol. 7, No. 1, pp.59–64. Doi: 10.21272/sec.7(1).59-64.2023.
- OECD (2022) *OECD and the sustainable development goals: delivering on universal goals and targets*. Available online at: <https://www.oecd.org/dac/sustainable-development-goals.htm>
- Olssen, M. and Peters, M.A. (2005) 'Neoliberalism, higher education and the knowledge economy: from the free market to knowledge capitalism', *Journal of Education Policy*, Vol. 20, No. 3, pp.313–345. Doi: 10.1080/02680930500108718.
- Omelyanenko, V., Pidorychev, I., Voronenko, V., Andrusiak, N., Omelianenko, O., Fyliuk, H., Matkovskiy, P. and Kosmidailo, I. (2022) 'Information & analytical support of innovation processes management efficiency estimations at the regional level', *International Journal of Computer Science and Network Security*, Vol. 22, No. 6, pp.400–407. Doi: 10.22937/IJCSNS.2022.22.6.50.
- Prokopenko, O. and Omelyanenko, V. (2020) 'Intellectualization of the phased assessment and use of the potential for internationalizing the activity of clusters of cultural and creative industries of the Baltic Sea Regions', *TEM Journal*, Vol. 9, No. 3, pp.1068–1075. Doi: 10.18421/TEM93-31.
- Ramli, M., Boutayeba, F. and Nezai, A. (2022) 'Public investment in human capital and economic growth in Algeria: an empirical study using ARDL approach', *Socio-Economic Challenges*, Vol. 6, No. 2, pp.55–66. Doi: 10.21272/sec.6(2).55-66.2022.
- Rezny, L., White, J.B. and Maresova, P. (2019) 'The knowledge economy: key to sustainable development?', *Structural Change and Economic Dynamics*, Vol. 51, pp.291–300. Doi: 10.1016/j.strueco.2019.02.003.
- Romer, P.M. (1990) 'Endogenous technological change', *Journal of Political Economy*, Vol. 98, No. 5, pp.71–102.
- Schultz, T.W. (1961) 'Investment in human capital', *The American Economic Review*, Vol. 51, No. 1, pp.1–17.
- Shkarupa, O.V., Karintseva, O.I. and Zhukova, T.A. (2017) 'Ecological modernization of the transport system in Sumy for green growth of economics', *International Journal of Ecology and Development*, Vol. 32, No. 3, pp.75–85. Available online at: <http://www.ceser.in/ceserp/index.php/ijed/article/view/4982>
- Silvestre, B.S. and Țîrcă, D.M. (2019) 'Innovations for sustainable development: moving toward a sustainable future', *Journal of Cleaner Production*, Vol. 208, pp.325–332. Doi: 10.1016/j.jclepro.2018.09.244.
- Sineviciene, L., Kubatko, O.V., Sotnyk, I.M. and Lakstutiene, A. (2019) 'Economic and environmental performance of post-communist transition economies', *Eurasian Studies in Business and Economics*, Vol. 11, No. 1, pp.125–141.
- Sineviciene, L., Lakstutiene, A., Ali, A.I.Y., Matsenko, O., Denysenko, P. and Kasyanenko, V. (2020) 'Human capital development as a factor in achieving sustainable development and enterprise competitiveness', *International Journal of Global Environmental Issues*, Vol. 19, Nos. 1/3, pp.231–242. Doi: 10.1504/IJGENVI.2020.114878.

- Tarkhov, P., Matsenko, O., Krugliak, A. and Derkach, Z. (2012) 'Provision of integrity and reliability in hygienic examination of investment projects for human capital development', *Hygiene and Sanitation*, Vol. 5, pp.91–94. Available online at: <https://essuir.sumdu.edu.ua/handle/123456789/74619?locale=en>
- Tirto, T., Ossik, Y. and Omelyanenko, V. (2020) 'ICT support for industry 4.0 innovation networks: education and technology transfer issues', *Advances in Design, Simulation and Manufacturing II*, Engineering. Springer, Cham. Doi: 10.1007/978-3-030-22365-6\_36.
- Varadarajan, R. (2017) 'Innovating for sustainability: a framework for sustainable innovations and a model of sustainable innovations orientation', *Journal of the Academy of Marketing Science*, Vol. 45, No. 1, pp.14–36. Doi: 10.1007/s11747-015-0461-6.
- Yao, Y., Ivanovski, K., Inekwe, J. and Smyth, R. (2019) 'Human capital and energy consumption: evidence from OECD countries', *Energy Economics*, Vol. 84. Doi: 10.1016/j.eneco.2019.104534.
- Yu, Y., Xinxin, W., Ruoxi, L. and Tingting, Y. (2023) 'The mediating role of human capital in the relationship between education expenditure and science and technology innovation: evidence from China', *Socio-Economic Challenges*, Vol. 7, No. 1, pp.129–138. Doi: 10.21272/sec.7(1).129-138.2023.
- Yu-Xia, T., Kubatko, O., Karintseva, O. and Piven, V. (2021) 'Decarbonisation drivers and climate change concerns of developed economies', *International Journal of Environment and Pollution*, Vol. 69, pp.1–2. Doi: 10.1504/IJEP.2021.125194.

## Appendix A

Partial correlation between the GDP per capita with intellectualisation, innovations and other explanatory variables

|                                 | <i>gdp<sub>per-s</sub></i> | <i>gdp<sub>en-y</sub></i> | <i>oil<sub>pr-e</sub></i> | <i>foreign-w</i> | <i>research-e</i> | <i>charge-r</i> | <i>lifeex-y</i> | <i>agricul-l</i> | <i>indust-l</i> | <i>grosse-p</i> |
|---------------------------------|----------------------------|---------------------------|---------------------------|------------------|-------------------|-----------------|-----------------|------------------|-----------------|-----------------|
| <i>gdp<sub>percapit-s</sub></i> | 1.0000                     |                           |                           |                  |                   |                 |                 |                  |                 |                 |
| <i>gdp<sub>energy</sub></i>     | 0.7460                     | 1.0000                    |                           |                  |                   |                 |                 |                  |                 |                 |
| <i>oil<sub>price</sub></i>      | 0.1951                     | 0.1449                    | 1.0000                    |                  |                   |                 |                 |                  |                 |                 |
| <i>foreign<sub>dir-w</sub></i>  | -0.057                     | -0.0577                   | -0.0250                   | 1.0000           |                   |                 |                 |                  |                 |                 |
| <i>research<sub>e</sub></i>     | 0.6923                     | 0.3724                    | 0.0001                    | -0.1339          | 1.0000            |                 |                 |                  |                 |                 |
| <i>charges<sub>for-r</sub></i>  | 0.2435                     | 0.0057                    | 0.0832                    | -0.0795          | 0.5344            | 1.0000          |                 |                  |                 |                 |
| <i>life<sub>expect-y</sub></i>  | 0.6773                     | 0.7912                    | -0.0451                   | -0.1056          | 0.464             | -0.0763         | 1.0000          |                  |                 |                 |
| <i>agricul<sub>ur-l</sub></i>   | -0.606                     | -0.4413                   | -0.1365                   | -0.0440          | -0.492            | -0.2485         | -0.356          | 1.0000           |                 |                 |
| <i>industry<sub>m-l</sub></i>   | 0.3373                     | 0.1289                    | 0.0904                    | 0.0068           | -0.050            | -0.0559         | -0.072          | -0.311           | 1.0000          |                 |
| <i>grosscapit-p</i>             | -0.022                     | -0.1234                   | -0.0115                   | 0.1803           | -0.231            | -0.2561         | -0.194          | 0.2043           | 0.4700          | 1.0000          |

