Journal of Research Administration
Society of Research Administrators International

THE SCIENCE IMPACT ON A COUNTRY'S SUSTAINABLE DEVELOPMENT

[1] Zaira T. Satpayeva, [2] Dana M. Kangalakova, [3] Gulnara N. Nyussupova, [4] Assem S. Smagulova

[1, 2] Institute of Economics of Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan, [3, 4] Al-Farabi Kazakh National University

Abstract — The goal of this research was to assess the impact of science on a country's sustainable development, taking into account its scientific potential. Statistical and correlation analysis were the main research methods used. Benchmark data included World Bank data from 2013 and 2018, the Global Knowledge Index (the "Research, Development and Innovation" sub-index), the Legatum Prosperity Index, the Social Progress Index, the Environmental Performance Index and the SDG Index for 2020. The research identified that science has a significant positive impact on a country's sustained development; however, that impact can be unclear subject to the country's scientific potential. In countries with low scientific potential, the link between scientific and sustainable development factors are stronger than in countries with average scientific potential, even though the effect from R&D for the former is less than for the latter. Research findings may serve as the basis for key factors in the development of scenarios and mechanisms to increase a country's performance in achieving sustainable development..

Index Terms — Economic sustainability, environmental sustainability, Impact Assessment Model, knowledge, R&D, social progress, social sustainability, Sustainable Development Goals.

INTRODUCTION

Academic interest in the impact of science on a country's economic [1]-[5], social [6], [7], and socio-economic [8], [9], development have helped create a real theoretical and practical research base. However, research that considers statistical measurements, algorithms and methods for analysing and assessing the impact of science on a country's sustainable development still remain under-developed.

The "Frascati Manual" describes the term "science" as creative and systematic activities performed to increase knowledge, including the knowledge about humankind, culture and society, and also to find ways of applying available knowledge to achieve practical society development goals [10]. The goal of scientific activities is to develop and systemise objective knowledge of reality through the generation of new knowledge. At the same time, the practical goals of developing society are to improve the standard of living and quality of life for its people. The nature of research and its impact on the development of society have undergone significant changes over the years. As such, views on scientific research and how its impact on society is regarded as a whole have changed from complete denial in the middle ages to becoming a part of current state policy [11], [12].

According to Bacon, science, which is closely linked to technology, politics, industry and religion, is capable of improving the general economic situation and standard of living [13]. Nowadays, it is generally recognised that innovation and knowledge are generated from a variety of sources and make a significant contribution to the development of society. New technology is necessitated by the organised social and economic efforts made by countries to achieve breakthroughs aimed at supporting national interests and public welfare [14]. The role and place of science in a country's sustainable development allow us to determine its impact on social development processes. As such, the role of science in a country's development in international terms is characterised by the term "impact", which implies the long-term "direct and indirect impact of research on a specific person or community, or on society as a whole, including the benefits for economic, social, human and natural capital". It is worth pointing out that science has a long-term impact on various aspects of life (health, culture, education, society, environment, politics, technology, management, economics, as well as public and international interests) [15]. For example, science contributes to education and human capital development which serve as the fundamental foundation for achieving sustainable development across various levels, including the macro, intermediate, and micro levels [16], [17].

In the Impact Assessment Model, the impact of science on a country's development is assessed by means of input (financing scientific research and development (R&D), co-investment, researchers, research infrastructure, etc.), activities (R&D, training, commercial, etc.), output (publications, patents, know-how, collaborations, new jobs, etc.), outcome (improved job performance, increased revenue from the export of technology, spin-off companies, knowledge exchange, etc.) and impact (economic growth, innovations, social progress, improved health, improved environment, etc.) parameters [18].

The intensive development of science, technology and innovation will result in an accelerated transition to inclusive and ecologically sustainable economic development [19], [20]. The "social benefits" of R&D lie in their contribution to a nation's social capital, the stimulation of new approaches to social issues, the awareness of public debates and the development of policy. "Cultural benefits" are represented by the augmentation of cultural capital (attitudes to other societies and cultures, the guarantee of a better understanding of one's own history, the preservation and enrichment of culture, etc.). "Ecological benefits" favour a nation's natural capital (reducing waste and pollution, expanding wildlife preservation areas or biodiversity, etc.). "Economic benefits" consist of increases in a nation's economic capital by expanding the skills' base and improving productivity [21].

Thus, science, by influencing the development of the economy and society, ecology and environmental development, is one of the factors of sustainable development.

Objective research into the impact of science on a country's sustainable development will help substantiate the key areas for measures to improve the role of science in achieving Sustainable Development Goals. So, the research goal was to assess the science impact on a country's sustainable development, considering its scientific potential. The research hypothesis was the assumption of a strong link between a country's scientific and sustainable development and that the greater a country's scientific potential is, the stronger link is.

Methods

Research was conducted based on an indexed and comparative approach using secondary data, specifically World Bank data on R&D expenses (% of GDP) for 2013 and 2018 and subsequent indices for 129 countries for 2020: the Global Knowledge Index ("Research, Development and Innovation" (RDI) sub-index), the Legatum Prosperity Index, the Social Progress Index, the Environmental Performance Index and the Sustainable Development Index (SDG). Due to a lack of data on one or several indices, countries such as Hong Kong, the Syrian Arab Republic, Barbados, Belize, Brunei Darussalam, Seychelles, Bhutan, Venezuela and Eswatini were not considered. SPSS and Microsoft Excel statistical packages were used to process statistics.

Statistical and correlation analyses were used as the main research methods. The Spearman correlation ratio was used as the main correlation analysis because the Kolmogorov-Smirnov criterion for verifying the hypothesis that data collected confirmed standard distribution showed that the data (indices) under consideration is not regarded as standard distribution (see Table I).

TABLE I
ONE-SAMPLE KOLMOGOROV-SMIRNOV NORMAL TEST SUMMARY

Indicator		Sub-index RDI of Global Knowledge Index	Legatum Prosperity Index	Social Progress Index	Environmental Performance Index	SDG Index
Most Extreme Differences	Absolute	0.172	0.086	0.088	0.096	0.098
	Positive	0.172	0.086	0.075	0.096	0.068
	Negative	-0.106	-0.064	-0.088	-0.079	-0.098
Test Statistic		0.172	0.086	0.088	0.096	0.098
Asymptotic Sig. (2-sided test)*		<0.001	0.020	0.015	0.005	0.004

Notes:

1) The number of observations is 129;
2) *Lilliefors Corrected

Source: Compiled by the authors based on SPSS

The K. Spearman correlation method is used to measure degrees of correlation between 1 and -1. A positive correlation value proves a positive (direct) link between variables, while a negative value proves a negative (reverse) link, and a zero value – no link. According to the Chaddock scale, if an absolute correlation ratio value is less than 0.3 then the correlation is weak, if the value is between 0.3 and 0.5 – then the correlation is moderate, 0.5 and 0.7 – marked, 0.7 and 0.9 – high, over 0.9 – extremely high and 1 – severe.

The research conceptual framework is the Impact Assessment Model, where the input index is the "Research, Development and Innovation" sub-index of Global Knowledge Index (integrated index of the development of science), while the output indices are the Legatum Prosperity Index (integrated index of economic development), the Social Progress Index (integrated index of social development) and the Environmental Performance Index (integrated index of ecological development), which provide an overview of a country's economic, social and ecological sustainable development, as well as the SDG Index (integrated index of sustainable development), which demonstrates how close a country in achieving its sustainable development goals.

To determine a country's level of economic, social and sustainable development, there are proposed the presenting the information in question in the form of a numerical scale and literal code (see Table II).

TABLE II
NUMERICAL RATING SCALE AND INTERPRETATIONS OF INDEXES

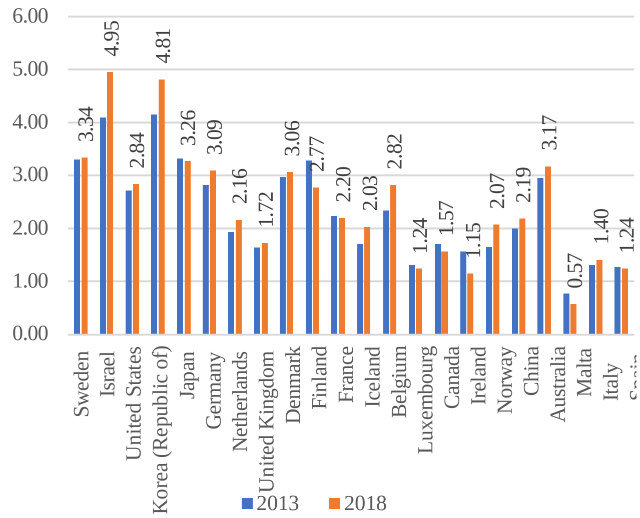
Zone	Class	Rating			Value
A	A++	0.9 – 1	9 - 10	90 - 100	Highest level
	A+	0.8 - 0.9	8 - 9	80 - 90	Very high level
	A	0.7 - 0.8	7 - 8	70 - 80	High level
B	B++	0.6 - 0.7	6 - 7	60 - 70	Above average level
	B+	0.5 - 0.6	5 - 6	50 - 60	Average level
	B	0.4 - 0.5	4 - 5	40 - 50	Below average level
C	C++	0.3 - 0.4	3 - 4	30 - 40	Satisfactory level
	C+	0.2 - 0.3	2 - 3	20 - 30	Low level
	C	0.1 - 0.2	1 - 2	10 - 20	Very low level
D	D	0 - 0.1	0 - 1	0 - 10	Unsatisfactory level

Source: Compiled by the authors on the base [22]

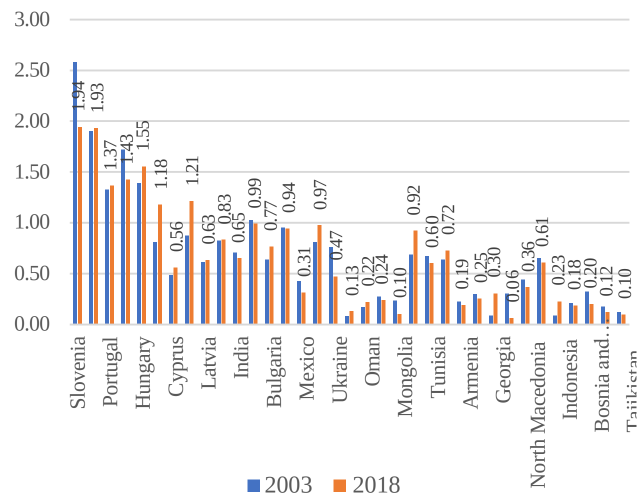
As the Global Knowledge Index helps us assess a country's ability to create, accept and distribute knowledge, the assumption is that it can be used to determine the country's scientific potential. To record specifically scientific knowledge, there are proposed the using one of its sub-indices – "Research, Development and Innovation", according which 26 countries possess average scientific potential, 96 possess low scientific potential and 7 – unsatisfactory scientific potential.

Results and discussion

The period between 2003 and 2018 observes growing R&D costs in the GDP of the majority of countries with low scientific potential, as well as in those with high scientific potential. The scientific and technological leaders are those 10 countries with the greatest scientific potential according to the "Research, Development and Innovation" sub-index of Global Knowledge Index, and maintaining an economy scientific content figure (share of R&D expenses in GDP) of 2.1-4.9% (see Fig. 1).



a) countries with average scientific potential



b) countries with low scientific potential

Fig 1. Scientific content of countries with different scientific potential, % of GDP, 2003-2018
Source: Compiled by the authors based on World Bank data

R&D investment policy aids the sustainable development of countries, specifically their social, economic and ecological sustainable development (see Table III).

TABLE III
CORRELATION BETWEEN SCIENTIFIC INDICATORS AND A COUNTRY'S SUSTAINABLE DEVELOPMENT (SPEARMAN'S RHO)

Index	Sub-index RDI of Global Knowledge	Legatum Prosperity Index	Social Progress Index	Environmental Performance Index	SDG Index

	Index				
Sub-index RDI of Global Knowledge Index	1				
Legatum Prosperity Index	0.863**	1			
Social Progress Index	0.828**	0.957**	1		
Environmental Performance Index	0.817**	0.896**	0.928**	1	
SDG Index	0.778**	0.881**	0.910**	0.891**	1

Notes:

1) The number of observations is 129;
2) ** The correlation is significant at the 0.01 (2-tailed), * The correlation is significant at the 0.05 (2-tailed).

Source: Compiled by the authors based on SPSS

A statistically significant positive (direct) link has been observed between the Global Knowledge Index "Research, Development and Innovation" sub-index and the Legatum Prosperity Index (0.863), the Social Progress Index (0.828), the Environmental Performance Index (0.817) and the SDG Index (0.778), which testifies to the important impact science has on a country's sustainable development.

It should be noted that when considering the influence of science on the sustainable development of a country, depending on the technological potential of countries, there are differences. In this respect, countries with low scientific potential register a statistically significant positive link between the condition of the environment, social progress and a flourishing society, and how it achieves sustainable development goals. This is in direct contrast to countries with average scientific potential where the links in statistical terms are not significant (see Table IV).

TABLE IV
CORRELATION OF A COUNTRY'S SCIENTIFIC AND SUSTAINABLE DEVELOPMENT INDICATORS ACCORDING ITS SCIENTIFIC POTENTIAL (SPEARMAN'S RHO)

No.	Country categorisation according to the RDI sub-index of Global Knowledge Index	Number of countries	Legatum Prosperity Index	Social Progress Index	Environmental Performance Index	SDG Index

1	Countries with average scientific potential, of which:	26	0.266	0.089	0.235	0.034
	- above average	7				
	- average	7				
	- below average	12				
2	Countries with low scientific potential, of which:	96	0.7**	0.654**	0.634**	0.581**
	- satisfactory	7				
	- low	38				
	- very low	51				

Notes:

1) The seven countries (Burundi, Guinea, Lesotho, Angola, Togo, Mauritania, Chad) with unsatisfactory scientific potential were not considered;

2) ** The correlation is significant at the 0.01 (2-tailed), * The correlation is significant at the 0.05 (2-tailed).

Source: Compiled by the authors based on SPSS

The findings might be explained primarily by the possible lack of non-linearity between science and the ecological situation, social progress and the flourishing of society, and, on the whole, by the sustainable development in countries with average scientific potential, secondly, the major impact of qualitative instead of quantitative factors on their scientific development (the qualification levels of scientific staff, the scientific infrastructure, the scientific community and collaboration, the transfer of technology, technological progress and others); thirdly, an increase in the impact of non-technological innovations on a country's development; and fourthly, the impact of the secondary effects of R&D and others.

In summary, science has a significant positive impact on a country's sustainable development, including on specific aspects of sustainable development (economic, social and ecological). In this respect, in countries with low scientific potential, the link between their scientific and sustainable development is stronger than in countries with an average scientific potential.

Conclusion

A literature review and analysis of statistics indicate that the intensive development of science and technology effects a quicker transition to inclusive and sustainable development. The prevalence of the COVID-19 coronavirus infection not only removes scientific development and its impact on a country's sustainable development from the agenda, but also testifies to the increased role of science in the same process, specifically, medical science – to combat the virus, and the role of other scientific areas – to overcome the problems and consequences brought about the pandemic and quarantine.

Algorithms and methods for analysing and assessing the impact of science on a country's sustainable development still remain under-developed, especially for countries with different scientific potential. This research fills this gap at a sufficient scientific and methodological level. The scientific level of research in comparison with other scientific works in this area is determined by the fact that it is one of the first attempts to apply a new approach to the analysis of the science impact on the sustainable development of countries with different scientific potential. The approach used in the article is theoretically grounded, statistically and logically verified.

According to the research 26 countries possess average scientific potential, 96 possess low scientific potential and 7 – unsatisfactory scientific potential. And there are no countries with high level of scientific potential. The research findings allow us to come to the conclusion that science has a significant positive impact on a country's sustainable development, including on specific aspects of sustainable development (economic, social and ecological). Meantime, in countries with low scientific potential, the link between scientific and sustainable development factors are stronger than in countries with average scientific potential, even though the effect from R&D for the former is less than for the latter. For this reason, the majority of countries with low scientific potential and also countries with high scientific potential maintain a policy of increasing R&D expenses.

This research may become the basis for future research in assessing the science impact on a country's sustainable growth, specifically the future study of the impact of science on the sustainable development of a country taking into account that country's scientific potential, the level of its socio-economic development, concrete cases at the macro- and micro levels, and others.

Acknowledgement

This research is funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (BR21882122 "Sustainable development of natural-economic and socio-economic systems of the West Kazakhstan region in the context of green growth: comprehensive analysis, concept, forecast estimates and scenarios").

References

[1] R. A. Solow, "Technical change and the aggregate production function," Review of Economics and Statistics, vol. 39, no. 3, pp. 312-320, 1957.

[2] T. W. Swan, "Economic growth and capital accumulation," The Economic Record, vol. 32, no. 2, pp. 334-361, 1956.

[3] P. Romer, "Endogenous technological change," The Journal of Political Economy, vol. 98, no. 5, pp. 71-102, 1990.

[4] A. Rodríguez-Pose, and B. Bilbao-Osorio, "From R&D to innovation and economic growth in the EU," Growth and Change, vol. 35, no. 4, pp. 434-455, 2004.

[5] F. G. Alzhanova, A. A. Kireyeva, Z. T. Satpayeva, A. A. Tsoy, and A. Nurbatsin, "Analysis of the level of technological development and digital readiness of scientific-research institutes," Journal of Asian Finance, Economics and Business, vol. 7, no. 12, pp. 1133–1147, 2020.

[6] N. J. Van Rensburg, A. Telukdarie, and P. Dhamija, "Technology in Society 4.0 applied in Africa: Advancing the social impact of technology," Technology in Society, vol. 59, 101125, 2019.

[7] A. D. Alene, and O. Coulibaly , "The impact of agricultural research on productivity and poverty in sub-Saharan Africa," Food Policy, vol. 342, pp. 198–209, 2009.

[8] K. Fukuda, "Science, technology and innovation ecosystem transformation toward," International Journal of Production Economics, vol. 220, 107460, 2019.

[9] B. P. Cozzarin, "Performance measures for the socio-economic impact of government spending on R&D," Scientometrics, vol. 68, no. 1, pp. 41–71, 2006.

[10] Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, the Measurement of Scientific, Technological and Innovation Activities. Paris: OECD Publishing, 2015, 398 p.

[11] F. F. Rybakov, "Economics of scientific and technological progress: A retrospective analysis," MSTU Bulletin, vol. 45, no. 13, pp. 37–40, 2010. (In Russian)

[12] A. A. Kireyeva, V. Lakhonin, and Z. Kalymbekova, "Digital transformations to improve the work and distribution of the state scholarships programs," Journal of Distribution Science, vol. 17, no. 3, pp. 41–47, 2019.

[13] J. K. Fuz, "Francis Bacon's "Nova Atlantis" (1629)," in Welfare Economics in English Utopias. Dordrecht: Springer, 1952.

[14] M. Coccia, "Technology in society. Why do nations produce science advances and new technology?," Technol. Soc., vol. 59, pp. 101-124, 2009.

[15] B. Godin, and C. Dore. (2004). Measuring the impact of science: beyond the economic dimension [Online]. Available: http://www.csiic.ca/PDF/Godin_Dore_Impacts.pdf

[16] D. Kangalakova, A. Dzhanegizova, Z. Satpayeva, K. Nurgaliyeva, and A. Kireyeva, "Distribution of knowledge through online learning and its impact on the intellectual potential of PhD students," Journal of Distribution Science, vol. 21, no. 4, pp. 47–56, 2023.

[17] A. Panzabekova, A. Satybaldin, G. Alibekova, and N. Abilkayir, "Human capital for sustainable development: a comparative analysis of regions of the Republic of Kazakhstan," IOP Conference Series: Earth and Environmental Science, vol. 317, 012013, 2019.

[18] "OECD 2019 Reference framework for assessing the scientific and socio-economic impact of research infrastructures," OECD Science, Technology and Industry Policy Papers, vol. 65, pp. 1-50.

[19] P. P. Walsh, E. Murphy, and D. Horan, "Technological Forecasting & Social Change The role of science, technology and innovation in the UN 2030 agenda," Technol. Forecast. Soc. Chang, vol. 154, 119957, 2020.

[20] L. Hetemäki, "The role of science in forest policy-Experiences by EFI," For. Policy Econ, vol. 105, pp. 10-16, 2019.

[21] L. Bornmann, "Measuring the societal impact of research," EMBO Rep, vol. 13, no. 8, pp. 673–676, 2012.

[22] S. N. Pavlova, Comprehensive Assessment of Innovation: Theory, Methodology, Practice. Yakutsk: Sphere, 2011, 480 p. (In Russian)

Zaira T. Satpayeva is a PhD in Economics, Associated Professor, Head of Department of scientific and technological and innovative development of Institute of Economics of Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan. Her research interests are science, technology, innovation, gender, digitalization and regional development. ORCID: 0000-0002-1644-3709.

Dana M. Kangalakova is a PhD in Economics, Associated Professor, Head of Department of social problems and human capital of Institute of Economics of Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan. Her research interests are human capital, intellectual potential, small business, innovation, gender and regional development. ORCID: 0000-0001-8388-8559.

Gulnara D. Nyussupova is a D.Sc. in Geography, Professor, Head of the Department of geography, land management and cadastre of Al-Farabi Kazakh National University. Her research interests are GIS in economic and social geography, demographic processes, human potential and human resources. ORCID: 0000-0001-5294-2671.

Assem S. Smagulova is a PhD student of Al-Farabi Kazakh National University. Her research interests are renewable energy sources, wind energy, Eurasian Economic Union. ORCID: 0000-0002-7451-7470.