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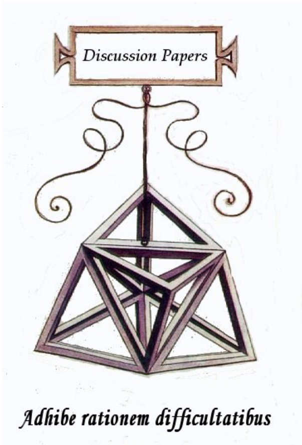

Mateusz Jankiewicz

The role of economy servitisation and governance effectiveness in the interconnections between environmental, social and economic development: a spatial approach

Discussion paper n. 330

2026

Discussion paper n. 330, presented: **April 2026**

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Please cite as:/Si prega di citare come:

Mateusz Jankiewicz (2026), "The role of economy servitisation and governance effectiveness in the interconnections between environmental, social and economic development: a spatial approach", Discussion Papers, Department of Economics and Management – University of Pisa, n. 330 (http://www.ec.unipi.it/ricerca/discussion-papers).

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Mateusz Jankiewicz

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Abstract

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Keywords: geographical proximity, governance quality, economy servitisation, spatial VAR model, sustainable development

JEL CLassification: C51, O14, Q56

The role of economy servitisation and governance effectiveness in the interconnections between environmental, social and economic development: a spatial approach

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Abstract. The paper aims to assess the simultaneous relationships among three dimensions of sustainable development, while accounting for modifications to the economic structure and governance quality. The study was conducted across 149 selected countries from 2012 to 2023. To ensure spatial homogeneity, countries are divided into five clusters based on their geographic location. The linkages between the sustainable development pillars are verified using a spatial vector autoregressive (spVAR) model, in which performance in each sustainability dimension is calculated using Sustainable Development Goals (SDGs) indices. Moreover, the connections between countries are defined in two ways: (1) as the nearest neighbourhood in the geographical space, (2) as the governance quality level similarity. The results show a significant relationship between sustainable development achievement for individual dimensions in almost all established clusters. The economic and environmental situations are rather negatively related, unlike economic and social sustainability and social and environmental sustainability. Additionally, except for African economies, the sustainability achievement is driven by the ongoing servitisation process. Moreover, the significance of the government quality level for sustainable development performance is concluded.

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Introduction

Nowadays, Sustainable Development is a crucial issue for countries' governments. The simultaneous growth of the economic, social, and environmental spheres is difficult to achieve. According to the definition proposed in the "Report of the World Commission on Environment and Development: Our Common Future", Sustainable Development (SD) is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 37). Nevertheless, the direct relationship among economic, social, and environmental conditions was highlighted during the Earth Summit in Rio de Janeiro.

Based on the principle of justice across the environmental, social, and economic pillars of SD, the Triple Bottom Line (TBL) concept was developed (Elkington, 1997). This concept is one of the most commonly used tools for assessing SD achievement level. The literature notes that decisions related to one of the pillars should not harm the remaining issues (Klarin, 2018). On the other hand, the United Nations organisation in the Sustainable Development Reports provide the Sustainable Development Goals Index (SDG Index), which shows the level of achievement of the objectives defined in the 2030 Agenda for Sustainable Development for 17 Sustainable Development Goals (SDGs) specified (Diaz-Sarachaga et al., 2018). The SDGs are not grouped into three sets based on the character of development, as the TBL concept would suggest. In this paper, the proposed division is presented, and based on the SDG Indices for specific goals, the environmental, social, and economic development measures are calculated. Additionally, the relationship between these three pillars of SD is assessed. This linkage is considered in the context of recent economic structural changes associated with servitisation, as well as the political situation in countries and spatial dependence.

The development of the services sector has been driven mainly by the digitalisation of many aspects of the economy. This tendency is most often observed in high-income countries (Opresnik & Taisch, 2015). The support for economic growth from the servitisation process is well known. In the literature, the positive influence of economic transformation towards servitisation on the environmental and social issues is also highlighted (Jankiewicz, 2025; Hojnik, 2018). Sustainability issues are also closely linked to countries' governance effectiveness. Governance institutions, for example, are charged with policy development, implementation, and enforcement (Brizga et al., 2024). All decisions made by rulers have a significant impact on a state's development. The effectiveness, credibility, and legitimacy of governments substantially influence the achievement of SD. Moreover, governments try to imitate rulers from other economies to some extent by introducing specific regulations. In this study, the mentioned imitation effect is presented as a government-situation similarity matrix in the considered spatial models. Spatial dependence is also included due to the mutual relations among countries, which are very important for today's development. The significance of the spatial aspect in the sustainability issues is also strongly underlined (Shaker, 2015; Wang et al., 2022).

This research aims to assess the interactions among environmental, social, and economic development in countries, considering economic structural transformation. Additionally, the impact of the political situation (measured using governance indices) and cooperation between countries (as a spatial factor) is included in the models. The analysis is conducted for 149 selected countries worldwide, divided according to their location (the continents on which they are placed). At the beginning, the composite ecological, social, and economic measures are calculated based on the SDG Index values. Next, spatial Vector Autoregression (spVAR) models are employed to verify the relationships among the three pillars of SD. The economic structure transformation is described by the shares of value added in GDP from the services, industry, and agriculture sectors. The political situation is evaluated using the World Governance Indicators (WGI): control of corruption, government effectiveness, political stability and absence of violence/terrorism, regulatory quality, rule of law and voice accountability. To verify the significance of cooperation between countries and the imitation effect in governance, the spatial factor is included. In this connection, two spatial weights matrices are defined: (1) based on the number of nearest neighbours; (2) based on the similarity of the political situation.

The main question this study addresses is: How do interactions among environmental, social, and economic development differ across countries grouped by geographical location? The following questions are also speculated: (1) Does the servitisation process have an equal impact on sustainability in different continents? (2) Does the political situation support Sustainable Development in all three pillars? (3) How does the governance situation similarity between countries influence their sustainability?

Literature review

Studies of the interconnections among the environmental, social, and economic pillars of SD were presented in the literature. For example, Hernández-Medina (2025) conducted research on the interactions among the four pillars of sustainable development in selected Latin American countries. She used the SDI as the dependent variable in her analysis. She concluded that interactions between environmental and economic factors, as well as between environmental and social dimensions, have a negative impact on the considered countries' sustainability. The interconnections between the three dimensions of SD are also the subject of the study conducted by Jankiewicz (2026). He considered the relationship between European Union countries during 2015-2022. Negative dependence between the ecological and economic dimensions was observed in his study. Moreover, he shows the one-way dependency between the economic and social dimensions, and the non-significant linkage between the social and environmental pillars of SD. In turn, Singh et al. (2021) highlighted the relevance of development across all dimensions to sustainability, analysing the linkage between composite indicators for the three pillars and sustainable development as a whole. Other studies mainly focused on the relationship between two of the dimensions. The negative character of the linkage between the environmental and economic pillars was shown in studies by Jahanger et al. (2022), Murshed et al. (2021), and Orhan et al. (2021).

The studies examining the impact of economic structural transformations on sustainable development most often highlighted the supporting role of the services sector in development. For example, Luo and Liu (2024) underlined the positive linkage between sustainability and servitisation, a result of the ongoing digitalisation process. The same conclusion, about the supporting character of servitisation for SD, was obtained in their studies Jankiewicz (2025), Johl et al. (2024) and Menon et al. (2024). Also, changes in the industry sector are considered substantial for achieving sustainability. Most often, the detrimental effects on ecological development are highlighted (Nasrollahi et al., 2020; Rasheed et al., 2024; Saba et al., 2024). One of the few studies presenting the conclusion about the opposite character of the mentioned relationship is the analysis conducted by Alcorta (2015) and Hemakumara and Dissanayake (2020).

The importance of government effectiveness for sustainability was also pointed out in the literature. Van Zeijl-Rozema et al. (2008) noted that the national government is involved in decision-making regarding both well-being and environmental protection, which are crucial parts of SD. They highlighted the need to create a policy supporting sustainable strategies. In turn, Masnyk et al. (2023) proved that policy coherence has a substantial impact on Sustainable Development achievement in Ukraine. Addin (2025) found that improving governance positively influenced certain SDGs. These conclusions he reached based on his study comparing governance effectiveness across seven world regions and three income groups using the World Governance Indicators. Güney's (2017) research also concludes that supporting SD requires improving governance. Nevertheless, he used genuine investments to describe the level of sustainable development. He also conducted the analysis, dividing countries into developed and developing ones. The relationship between governance quality and SD in Africa was the subject of research conducted by Adebayo et al. (2025). They considered the influence of governance characteristics on the economic, social and environmental pillars separately, concluding that improving governance quality has a positive impact on SD. Moreover, they described individual pillars of SD using GDP per capita, the Human Development Index (HDI), and CO2 emissions levels, respectively. The same positive effect on Sustainable Development from government quality growth is evident in studies by Naseer et al. (2025) and Saeed et al. (2025). In turn, Armstrong and Li (2022) noted that governments should establish sustainable governance structures that balance environmental, economic, and social issues.

The novelty of the presented analysis lies in using government situation similarity as the neighbourhood criterion to construct the spatial weights matrix. So far, the majority of spatial analyses conducted on sustainability achievement have been based on the geographical proximity between territories (Cai et al., 2022; Fong et al., 2020; Luo et al., 2023). In the studies conducted by Jankiewicz and Szulc (2024; 2025), spatial weights matrices were constructed based on socio-economic situation and innovation-level similarity. They created proximity matrices using HDI and Regional Innovation Index (RII) values for analyses of energy and economic sustainability, respectively.

Methods and data

The analysis is conducted based on the data from 149 selected countries in the years 2012-2023. The empirical part of the research starts with the calculation of environmental, social and economic situation levels. For this purpose, the Sustainable Development Goals were divided into three groups, as presented in Table 1.

Table 1. The division of SDGs according to the three dimensions of sustainable development

Environmental	**Social**	**Economic**
SDG**6**; SDG**7**; SDG**12**; SDG**13**; SDG**15**	SDG**1**; SDG**2**; SDG**3**; SDG**4**; SDG**5**; SDG**10**; SDG**11**; SDG**16**	SDG**8**; SDG**9**

*Note: SDG no. 14 is not included in the table due to the lack of data for many countries selected for the analysis; SDG no. 17 is not included due to its importance for all other goals (regardless of the nature)

For all SDGs mentioned above, values of the SDG index were taken directly from the Sustainable Development Report database (https://dashboards.sdgindex.org/explorer/, accessed: 27.02.2026). All indices take on values between 0 and 100, where the maximum value denotes the achievement of the established goal in the 2030 Agenda. The composite measure defined to calculate the level of each SD dimension is the arithmetic average of SDG indices belonging to a concrete group:

$$CI_{ki,t} = \frac{\sum_{z=1}^{n_k} SDI_{ki,t}^{z}}{n_k}, \tag{1}$$

where $CI_{ki,t}$ is the value of the composite indicator for the k^{th} dimension in the i^{th} country in time t, $SDI_{ki,t}^{z}$ is the value of the z^{th} Sustainable Development Index in the i^{th} country in time t for the k^{th} dimension, and n_k denotes the number of SDGs in the k^{th} dimension. The calculation of the composite indicator using the arithmetic average is possible because SDIs are expressed in the same scale. Next, the IPS (Im-Pesaran-Shin) stationarity test for panel data is employed to verify whether the unit root occurs in the panels.

To check whether the spatial analysis is reasonable to conduct, the Moran's I test for the occurrence of spatial autocorrelation was conducted. The test statistic takes the following form (Moran, 1948; Schabenberger & Gotway, 2005):

$$I = \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \cdot \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\,[y_i - \bar{y}][y_j - \bar{y}]}{\frac{1}{n}\sum_{i=1}^{n}[y_i - \bar{y}]^2} = \frac{n}{S_0} \cdot \frac{\boldsymbol{z}^T \boldsymbol{W} \boldsymbol{z}}{\boldsymbol{z}^T \boldsymbol{z}}, \tag{2}$$

where y_i is the observation of the process in the ith region, $\bar{y}$ denotes the average value of the process, and $\boldsymbol{W}$ is the matrix of spatial connections between units. This research focuses on two types of spatial weights matrices. The first is the geographical neighbourhood matrix based on the established number of nearest neighbours. The number of neighbours chosen depends on the Akaike criterion values (AIC) resulting from spatial autoregressive (SAR) models estimated for all three dimensions of SD. The number of neighbours from 3 to 10 is considered and finally the number of neighbours where the AIC is the lowest is chosen.

The second matrix is built using the political similarity between countries, where the governance quality distance is calculated. The construction of the second matrix takes place in several steps:

a) The calculation of governance quality. The measure of governance quality (GQ) is the arithmetic average of values describing characteristics defined in World Governance Indicators (WGI) – control of corruption, government effectiveness, political stability and absence of violence/terrorism, regulatory quality, rule of law and voice accountability. Each of the characteristics takes values from -2.5 to +2.5 and is expressed in the same scale.
b) The determination of the distance between pairs of countries according to the formula:

$$d_{ij} = |GQ_i - GQ_j|, \tag{3}$$

where GQ_i and GQ_j denote the governance quality measures for the i^{th} and j^{th} country, respectively.

c) The determination of borderline level g of the similarity between countries. In this study, the third decile of all distances constitutes the borderline level.
d) The inversion of non-zero elements of the distance matrix (marked as $\boldsymbol{D}$) is made according to the formula:

$$d_{ij}^* = \begin{cases} \frac{1}{d_{ij}}, & i \neq j \wedge d_{ij} < g \\ 0, & i = j \vee d_{ij} > g \end{cases} \tag{4}$$

e) The row standardization to one.

When the spatial weights matrices are given, in the next step, the spatial Vector Autoregressive (spVAR) model is estimated and verified in order to assess the significance of the relationship between SD dimensions. The general form of the model is as follows:

$$
\begin{gathered}
\ln(CI)_{i,t}^{k} = \beta_0^k + \alpha_1^k \ln(CI)_{i,t-1}^{1} + \alpha_2^k \ln(CI)_{i,t-1}^{2} + \alpha_3^k \ln(CI)_{i,t-1}^{3} + \\
+\beta_1^k \ln(SVA)_{i,t} + \beta_2^k \ln(IVA)_{i,t} + \beta_3^k \ln(AVA)_{i,t} + \gamma_1^k \boldsymbol{W}^* \ln(SVA)_{i,t} + \\
+\gamma_2^k \boldsymbol{W}^* \ln(IVA)_{i,t} + \gamma_3^k \boldsymbol{W}^* \ln(AVA)_{i,t} + \gamma_4^k \boldsymbol{W}^* \ln(CI)_{i,t}^{1} + \gamma_5^k \boldsymbol{W}^* \ln(CI)_{i,t}^{2} + \\
+\boldsymbol{W}^* \gamma_6^k \ln(CI)_{i,t}^{3} + \beta_4^k GQ_{i,t} + \varepsilon_{i,t}^{k},
\end{gathered} \tag{5}
$$

where $\ln(CI)_{i,t}^{k}$ denotes the natural logarithm of sustainability measure in the particular dimension in the k[th] equation ($k \in \{1,2,3\}$) in time t, $\ln(CI)_{i,t-1}^{1}$, $\ln(CI)_{i,t-1}^{2}$ and $\ln(CI)_{i,t-1}^{3}$ are lagged natural logarithms of environmental, social and economic situation measures, respectively. Whereas, $\ln(SVA)_{i,t}$, $\ln(IVA)_{i,t}$ and $\ln(AVA)_{i,t}$ are the shares of value added in GDP per capita coming from services, industry and agriculture, $GQ_{i,t}$ denotes the governance quality level, $\boldsymbol{W}^* \ln(CI)_{i,t}^{1}$, $\boldsymbol{W}^* \ln(CI)_{i,t}^{2}$, $\boldsymbol{W}^* \ln(CI)_{i,t}^{3}$, $\boldsymbol{W}^* \ln(SVA)_{i,t}$, $\boldsymbol{W}^* \ln(IVA)_{i,t}$ and $\boldsymbol{W}^* \ln(AVA)_{i,t}$ indicate the spatial lags of individual variables, wherein $\boldsymbol{W}^*$ is the block matrix of spatio-temporal connections in the form of (Szulc & Jankiewicz, 2018):

$$
\boldsymbol{W}^* = \begin{bmatrix} \boldsymbol{W}_1 & \cdots & \boldsymbol{0} \\ \vdots & \ddots & \vdots \\ \boldsymbol{0} & \cdots & \boldsymbol{W}_T \end{bmatrix}. \tag{6}
$$

The $\boldsymbol{W}_t$ $(t = 1,2,\ldots,T)$ is the spatial weights matrix created based on the number of neighbours in time t, which is fixed in the whole period of the research.

Similarly, the model is defined for the distance matrix built using the governance quality similarity:

$$
\begin{gathered}
\ln(CI)_{i,t}^{k} = \beta_0^k + \alpha_1^k \ln(CI)_{i,t-1}^{1} + \alpha_2^k \ln(CI)_{i,t-1}^{2} + \alpha_3^k \ln(CI)_{i,t-1}^{3} + \\
+\beta_1^k \ln(SVA)_{i,t} + \beta_2^k \ln(IVA)_{i,t} + \beta_3^k \ln(AVA)_{i,t} + \gamma_1^k \boldsymbol{D}^* \ln(SVA)_{i,t} + \\
+\gamma_2^k \boldsymbol{D}^* \ln(IVA)_{i,t} + \gamma_3^k \boldsymbol{D}^* \ln(AVA)_{i,t} + \gamma_4^k \boldsymbol{D}^* \ln(CI)_{i,t}^{1} + \gamma_5^k \boldsymbol{D}^* \ln(CI)_{i,t}^{2} + \\
+\boldsymbol{D}^* \gamma_6^k \ln(CI)_{i,t}^{3} + \beta_4^k GQ_{i,t} + \varepsilon_{i,t}^{k},
\end{gathered} \tag{7}
$$

whereby $\boldsymbol{D}^*$ is the block matrix of spatio-temporal connections defined as:

$$
\boldsymbol{D}^* = \begin{bmatrix} \boldsymbol{D}_1 & \cdots & \boldsymbol{0} \\ \vdots & \ddots & \vdots \\ \boldsymbol{0} & \cdots & \boldsymbol{D}_T \end{bmatrix}. \tag{8}
$$

In this case, the individual matrices ($\boldsymbol{D}_1, \boldsymbol{D}_2, \ldots, \boldsymbol{D}_T$) are not the same in time, because the values of weights depend on the distance between the governance quality of countries, which is changing over time. The governance quality level is used for the period 2011-2022 to take into account the possible results of laws introduced the year before.

The analysis is conducted for a few subgroups of countries, and for the assessment of need, the division and checking its acceptability, the spatial heterogeneity evaluation is done. For this purpose, the factor detector based on the Q-statistics is used (Song et al., 2020):

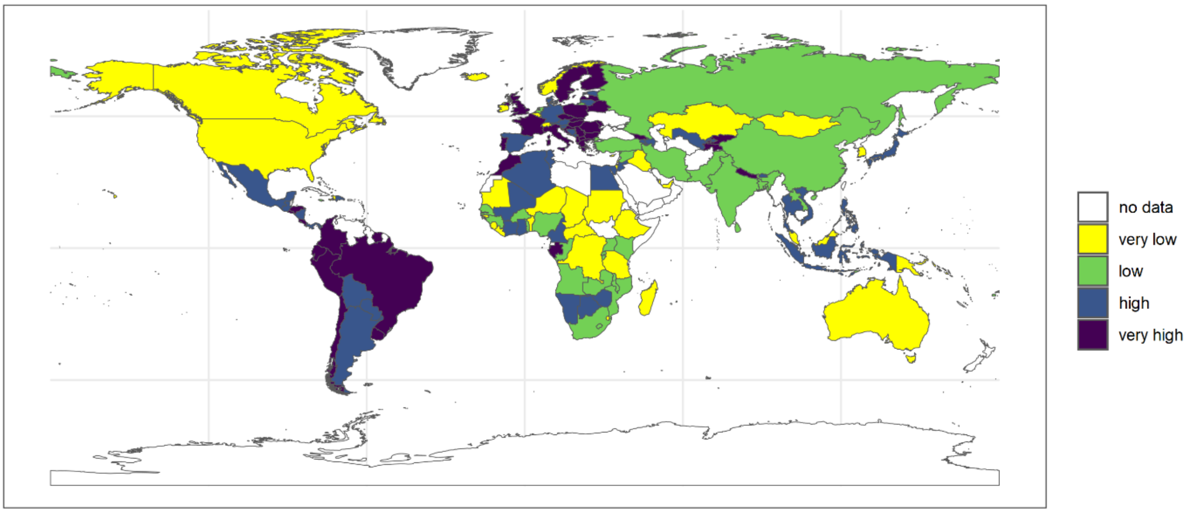
$$
Q = 1 - \frac{\sum_{j=1}^{M} N_{v,j} \sigma_{v,j}^2}{N_v \sigma_v^2}, \tag{9}
$$

where N_v and σ_v^2 indicate the number and population variance of observations within the whole study area, and $N_{v,j}$ and $\sigma_{v,j}^2$ denote the number and population variance of observations within the j^{th} sub-region of variable v $(j = 1, \ldots, M)$. The higher value of Q indicates a higher importance of the explanatory variable – the variance within sub-regions is relatively small, but the variance between sub-regions is large.

Empirical results

The study starts with the assessment of the level of environmental, social and economic sustainability achievement in selected world countries. Figure 1 presents the spatial distribution of the ecological situation in 2023. The results only in the last year of analysis are shown because the spatial distribution is very similar during the research period. The values of sustainability measures are divided into four groups using the positional characteristics of descriptive statistics. Countries with values below the median reduced by quarter deviation are classified in the group named "very low". Units with values between the median reduced by quarter deviation and the median form a group "low". Next cluster (named "high") contains countries that are characterised by values higher than the median and lower than the median plus the quarter deviation. The remaining territorial units create the group with the best situation of the considered phenomenon.

Figure 1. The spatial distribution of the environmental sustainability achievement level in 2023



The highest level of ecological sustainability achievement in 2023 was in South American countries and most European states. These are two areas with the greatest similarity in the case of the environmental situation. Countries with the lowest levels of the calculated measure are scattered throughout the considered area. In this cluster are countries such as Australia, Canada, the United States of America, Kazakhstan, Norway, Ethiopia, Chad, and Niger. Therefore, both relatively rich and relatively poor countries characterise weak environmental conditions. Moreover, they are located in different continents – Africa, Asia and North America, for example. What is more, the mentioned areas show much greater differentiation of ecological sustainability achievement compared to Europe or South America.

In turn, Figure 2 presents the spatial distribution of the social sustainability achievement measure in 2023. Here, a more homogenous distribution is noted than in the case of environmental sustainability. The highest level of social sustainability achievement in 2023 was observed in the western, central and northern parts of Europe, Australia, Canada and Japan. The value of the considered measure above the median was also noted, for example, in the remaining part of Europe, northern Asia, Argentina, Mexico and the United States of America. Almost all countries in Africa (apart from Algeria) are characterised by a social situation level below the median, and most of them belong to the cluster with "very low" values for the considered phenomenon. The most diversified areas in terms of social sustainability achievement are Asia and North America. Generally, countries in the north tend to have better social conditions. The central part of the world is dominated by economies with the weakest social sustainability achievement level.

Figure 2. The spatial distribution of the social sustainability achievement level in 2023

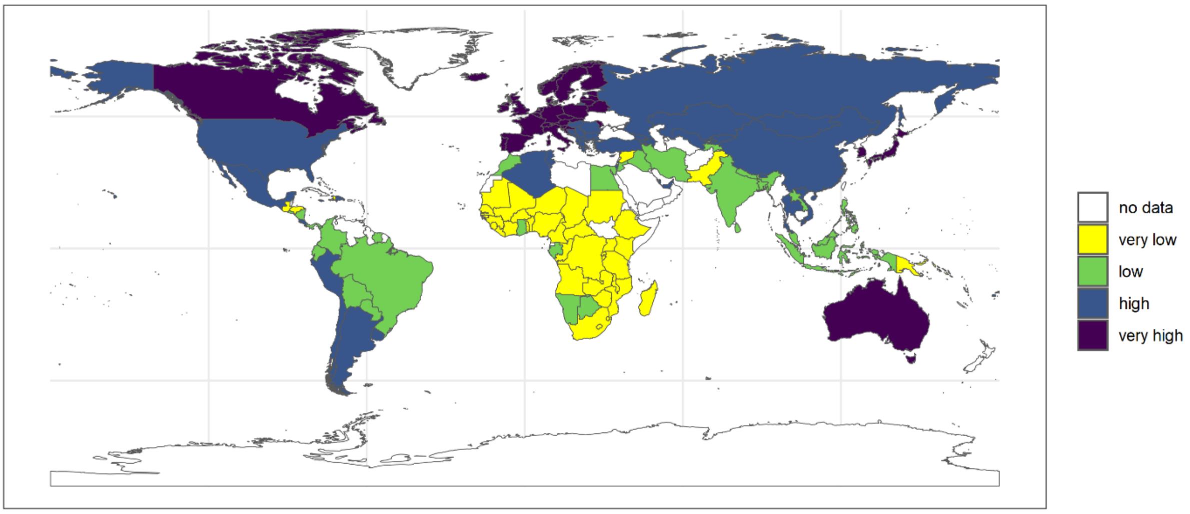


Figure 3 shows the spatial distribution of the economic development level in 2023. Similar to the differentiation shown in Figure 2, most European countries were characterised by the highest levels of economic sustainability achievement. To this group, Australia, Canada, the United States of America, China, Japan and Chile were also classified. Most African countries were in the bottom half of the economic development rankings, and the central part of this area is dominated by economies classified even in the cluster with the lowest levels of the analysed measure. The most heterogeneous parts of the world in terms of economic sustainability achievement in 2023 were Asia and North America, where states were classified into all four indicated groups of considered measure values. Taking economic conditions into account, the northern part of the world was, on average, better developed than the southern part.

Figure 3. The spatial distribution of economic sustainability achievement level in 2023

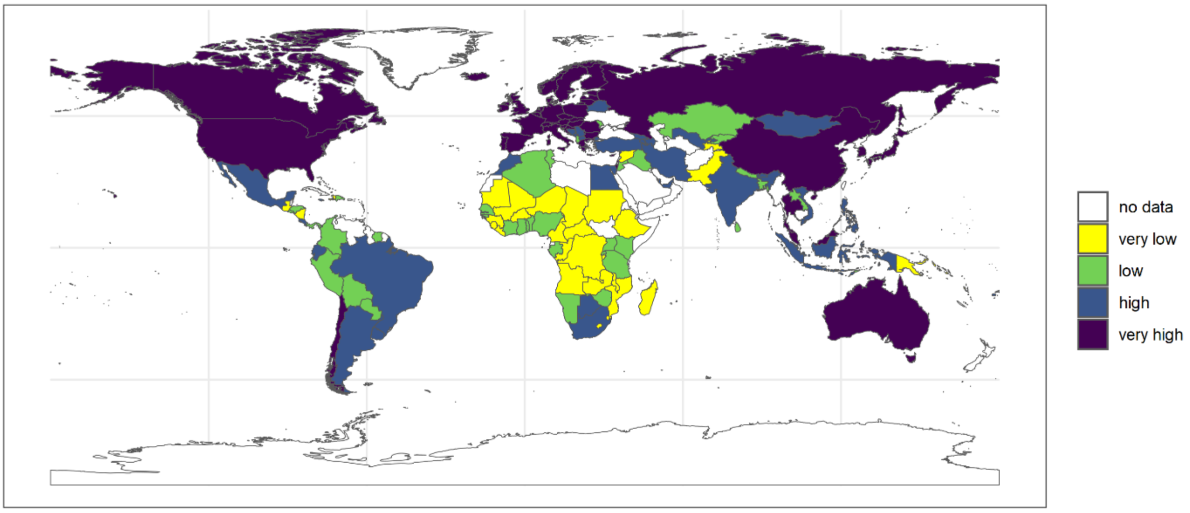
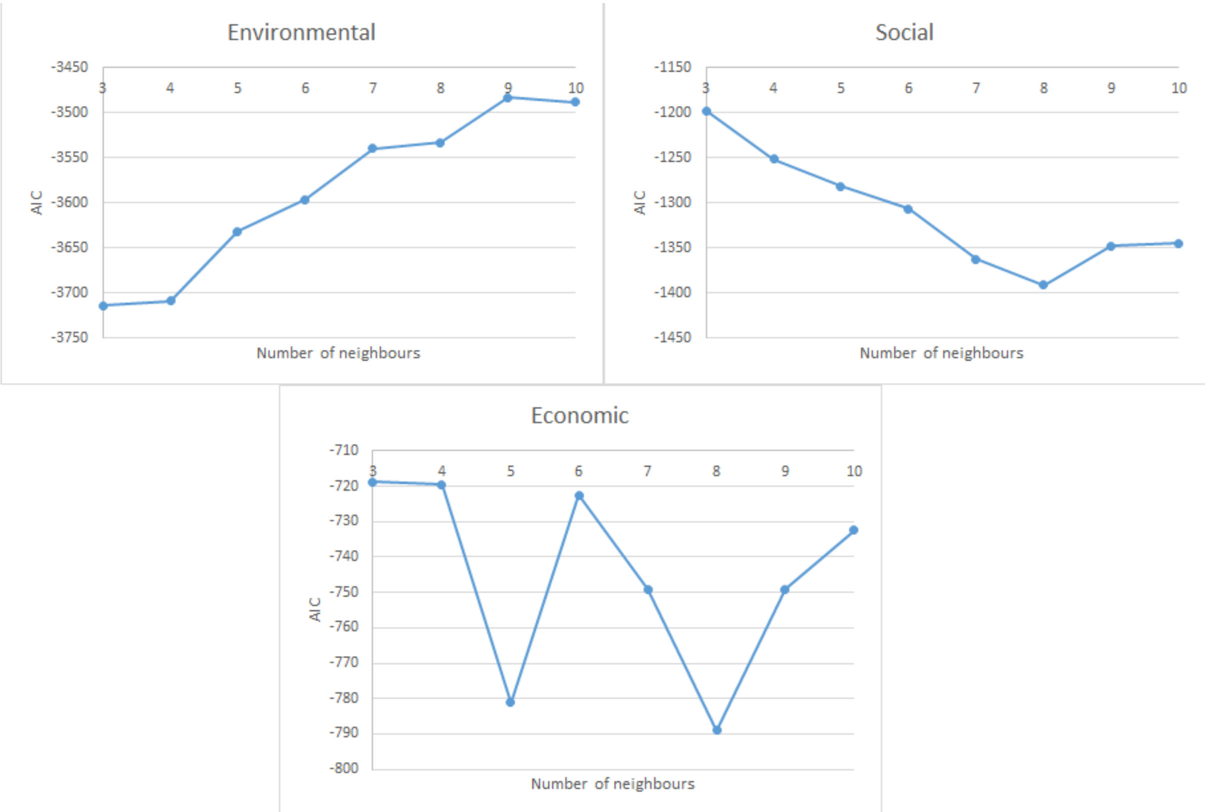


Figure 4. Values of the Akaike criterion resulting from SAR models



Before the spatial autocorrelation occurrence is verified, it is necessary to choose an adequate number of neighbours for the weights matrix ***W*** based on the nearest neighbours criterion. For this purpose, the spatial autoregressive (SAR) models were estimated and verified for every SD dimension. In SAR models, the ***W*** matrix built for a number of neighbours from 3 to 8 was used. Figure 4 presents the values of the Akaike criterion (AIC) resulting from all estimated models. The model is better while the AIC value is lower. The choice of the number of neighbours is not unambiguous, seeing the graphs within Figure 4. The minimum values of AIC for social and economic sustainability achievement correspond with the eight neighbours. On the other hand, analysing the environmental sustainability, the AIC increases with an increase in the number of neighbours, which is a non-desirable situation. Finally, a matrix based on the 8 nearest neighbours (8NN) was chosen, where AIC is minimal for two of the three SD dimensions, accepting the inconvenience resulting from a higher value of AIC for ecological situation analysis.

In Table 1, the results of Moran's I test for the spatial autocorrelation occurrence are presented. The Moran's I statistic is calculated for every SD dimension in two versions. The first version relates to the dependence between countries based on the geographical neighbourhood (8NN – matrix $\boldsymbol{W}^*$), the second uses the governance quality similarity between countries to establish neighbourhood (matrix $\boldsymbol{D}^*$). In all six cases, the I-statistic is significant, and we can conclude about the relevant dependence of neighbouring countries in the matter of sustainability achievement. The weakest linkage is observed for environmental sustainability achievement, and this is the expected result, observing the spatial distribution of values of the calculated measure. Moreover, the geographical proximity has a greater importance than the neighbourhood established based on governance quality for ecological and social situations across the world. The I statistics have a higher value for $\boldsymbol{W}^*$ than the $\boldsymbol{D}^*$ matrix. The opposite situation for economic sustainability is noted. The similarity of governance effectiveness has stronger significance than geographical proximity for economic sustainability achievement. Generally, based on the positive values of Moran's I, we can see that the countries established as neighbours are characterized by similar levels of the sustainability achievement in all SD dimensions, but this similarity varies in strength.

Table 1. The results of the Moran test for the spatial autocorrelation occurrence

Moran test	**Environmental**	**Social**	**Economic**
$\boldsymbol{W}^*$ matrix	$I = 0.2529$ (0.0000) ***	$I = 0.7152$ (0.0000) ***	$I = 0.5656$ (0.0000) ***
$\boldsymbol{D}^*$ matrix	$I = 0.0367$ (0.0051) ***	$I = 0.5525$ (0.0000) ***	$I = 0.6903$ (0.0000) ***

Table 2 presents the results of the unit root occurrence test proposed by Im, Pesaran and Shin. The test is conducted for all dependent variables that will be used in the spVAR model estimated later. The dependent variables are defined as natural logarithms of sustainability achievement measures determined at the beginning of the research. As we can observe, all values of test probability (p-values) allow us to reject the null hypothesis that the unit root in panels occurs. Hence, all considered variables are stationary and do not require additional transformations.

Table 2. The results of the Im-Pesaran-Shin (IPS) test for the unit root in panels

IPS test	**Environmental**	**Social**	**Economic**
Statistics	$T = -2.4912$***	$T = -2.4181$***	$T = -2.3413$**
p-value	0.0005	0.0025	0.0352

Before the final models are presented, the assessment of the spatial heterogeneity between and within chosen clusters should be shown. Table 3 presents values of Q-statistics, which make the comparison of dispersion variances between observations in the whole considered area and strata of variables. Analysing the relative spatial heterogeneity between continents around the World, the significance of Q statistics in the case of social and economic sustainability suggests the high importance of grouping variables for the assessment of sustainability achievement. The lack of the spatial heterogeneity for environmental sustainability can results from the low level of variation (see Table A1 in Appendix). Therefore, the division of countries into five regimes according to their location should improve the situation with the occurrence of spatial heterogeneity. To check whether the economies are divided into relatively homogenous areas considering all SD dimensions, the spatial heterogeneity within regimes is assessed. In three of five clusters, the Q statistics are non-significant for each SD dimension. For North and Latin America, only economic sustainability achievement shows relative heterogeneity in space, which can be caused by two outliers: the United States of America and Canada, which perform relatively high economic development in comparison with the others. Only in Europe, the results of the Q-statistic significance are convergent with the results noticed for the whole considered area. There, the relative heterogeneity is observed in the social and economic dimensions of SD. In this case, the relatively higher development of the western part of the continent may be a potential cause of observed heterogeneity. Despite the noted spatial heterogeneity within regimes in three of fifteen cases, the division of countries according to the continent on which they are located is acceptable.

Table 3. The results of spatial heterogeneity identification: Q-statistics

Spatial heterogeneity: World Grouping variable – Continent with 5 values: **Africa, North and Latin America, South America, Asia with Australia, Europe**		
Environmental sustainability	Social sustainability	Economic sustainability
$Q = 0.1661$	$Q = 0.6554$ (***)	$Q = 0.4763$ (***)
Spatial heterogeneity within regimes Grouping variable – Location with 4 values: **North-East, North-West, South-East, South-West**		
Africa		
$Q = 0.1188$	$Q = 0.1202$	$Q = 0.0430$
North and Latin America		
$Q = 0.2562$	$Q = 0.3200$	$Q = 0.5603$ (***)
South America		
$Q = 0.3969$	$Q = 0.3995$	$Q = 0.1976$
Asia and Australia		
$Q = 0.0126$	$Q = 0.0339$	$Q = 0.0727$
Europe		
$Q = 0.2355$	$Q = 0.5224$ (***)	$Q = 0.5464$ (***)

Table 4. The results of estimation and verification of spatial VAR models in regimes for the matrix defined by the nearest neighbourhood ($\boldsymbol{W}^{*}$)

Cont.	**Africa**			**North and Latin America**			**South America**			**Asia, Australia and Oceania**			**Europe**		
Param.	**Estimate**			**Estimate**			**Estimate**			**Estimate**			**Estimate**		
	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO
α_1^k ENV(-1)	0.3054 ***	0.1538 ***	-0.0288	0.1238 ***	0.1087 ***	0.0668 **	0.1514 ***	0.1130 ***	0.0368	0.3474 ***	0.2146 ***	-0.0258	0.1941 ***	0.0859 ***	-0.0794 ***
α_2^k SOC(-1)	0.0964 ***	0.1821 ***	0.1692 ***	0.0943 ***	0.1035 ***	0.2020 ***	0.1141 ***	0.0939 ***	0.0651 ***	0.1748 ***	0.1214 ***	0.1223 ***	0.1608 ***	0.1302 ***	0.0284 **
α_3^k ECO(-1)	-0.0897 **	0.0361	0.4324 ***	-0.0427	0.2165	0.1962	-0.0545	-0.0070	0.2523 **	-0.0850 ***	0.0768 **	0.4785 ***	-0.0245 **	0.0704 **	0.5260 ***
β_1^k SER	-0.0180	-0.0344 **	0.0154	0.1058 ***	0.1070 ***	0.0817 ***	0.0982	0.1476 ***	-0.0370	0.0767 ***	0.1249 ***	0.0148	0.1279 ***	0.1808 ***	0.0113
β_2^k IND	0.0354 ***	-0.0325 ***	0.0268 ***	0.1236 *	0.0156	-0.1539	0.1910 ***	0.0714	0.1674 **	0.0036	-0.0277	-0.0086	0.1212 ***	-0.0711 ***	0.0497 **
β_3^k AGR	-0.0168 ***	-0.0346 ***	-0.0219 ***	0.1164	-0.2435	-0.2454 ***	-0.0951	-0.0380	0.0463	0.0361 **	-0.0682 ***	-0.0454 ***	0.0273 ***	0.0416 ***	-0.0350 ***
γ_1^k $\mathbf{W}^{*}$SER	0.0882 ***	0.0209	-0.0322	0.0918	0.0684 ***	-0.0136	0.1031	0.1286 ***	-0.0381	-0.0535	0.0277	-0.0437	0.1910 ***	0.1007 ***	0.0104
γ_2^k $\mathbf{W}^{*}$IND	0.0523	-0.0308	-0.1167 ***	0.1637 **	0.1350 **	0.1408	0.1812 ***	0.0973	0.1699	0.0256	0.1370 ***	-0.0599 **	0.0059	0.1582 ***	-0.0797 **
γ_3^k $\mathbf{W}^{*}$AGR	0.0822 ***	-0.0165 ***	0.0682 ***	0.1273	-0.0891	0.1375	-0.1026	-0.0342	0.1113	-0.0115	0.0505	0.0243	-0.0101	0.0035	0.0338 ***
γ_4^k $\mathbf{W}^{*}$ENV	0.3118 ***	0.1732 ***	-0.0346 **	0.1063 ***	0.1127 ***	0.1049 ***	0.1220 ***	0.0911 ***	0.0676 ***	0.2642 ***	0.1714 ***	0.0063	0.1881 ***	0.0943 ***	0.1026 ***
γ_5^k $\mathbf{W}^{*}$SOC	0.2283 ***	0.1268 ***	0.1044 ***	0.1009 ***	0.1641 ***	0.1282 ***	0.1485 ***	0.1576 ***	0.0235	0.1877 ***	0.1244 ***	0.0470 ***	0.1387 ***	0.1571 ***	0.0027
γ_6^k $\mathbf{W}^{*}$ECO	-0.0263	0.2856 ***	0.4027 ***	0.0113	0.1000 ***	0.2583 ***	0.0445	0.0129	0.2419 ***	0.0541 ***	0.0473 ***	0.4467 ***	-0.0302	0.0829 ***	0.4163 ***
β_4^k GOV	0.0022	0.1765 ***	0.0409 ***	0.1529	0.0638	-0.0213	0.1379 ***	0.2423 **	0.0413	-0.0248	0.0270	0.0340	-0.0512 ***	0.0612 ***	0.0151 **
β_0^k CONST	0.0818 ***	0.0389 ***	-0.0356 ***	0.0281 ***	0.0230 ***	0.0185 ***	0.0362 ***	0.0388 ***	-0.0011	0.0648 ***	0.0521 ***	-0.0328 ***	0.0394 ***	0.0389 ***	-0.0295 ***

Table 4 shows the results of estimation and verification of spatial VAR models in regimes employing the proximity matrix defined by the nearest neighbourhood criterion ($\boldsymbol{W}^{*}$). Analysing the dependence between sustainability achievement in individual dimensions, we can observe that there is a positive feedback loop in the case of social and environmental pillars for every cluster. It results from the significance of parameters α_2^k in the first equation (Eq. 1) and α_1^k in the second equation (Eq. 2). The statistical significance of parameter α_2^k in the third equation for Africa, North and Latin America, and also South America informs about one-way linkage between social situation and economic performance, where the development in social aspect improves the economic sustainability. In the two remaining groups this positive linkage has a two-way character, resulting from the additional significance of the α_3^k parameter in Eq. 2. The most diverse relationship according to the considered area is the relationship between sustainability achievement in environmental and economic pillars. Only across Europe does it have a two-way negative character. The same adverse relation, but one-way, occurs in Africa and Asia with Australia, where the improvement in the economic situation harms environmental sustainability. In the case of South America, this linkage is irrelevant.

The positive sign of the significant parameter β_1^k in every equation estimated for North and Latin America shows the supportive influence of services sector expansion on the sustainability achievement. A similar impact of servitization we can observe for Asia with Australia, and Europe; however, in two of three equations, excluding economic sustainability achievement, where the parameter is irrelevant. In the case of South America and Africa, the linkage between servitisation and sustainability is significant only for the social pillar; nevertheless, it has the opposite impact: destructive for Africa and supportive for South America.

Considering the influence of economic structure modification on sustainability it is worth noting that industrialization supports the sustainability achievement in Africa better than the expansion in the agricultural sector. In the case of Europe, the positive and statistically significant parameter β_1^k in the 1st and 3rd equations indicated that the development of industry supports environmental and economic sustainability. Moreover, in the considered area, an increase in the share of value added in GDP coming from agriculture positively influences the environmental and social dimensions of SD. A more destructive character of agricultural expansion can be observed in Asia and Australia. Changes in the economic structure as a whole have less of an impact across the Americas.

There are also statistically significant spatial dependencies between neighbouring countries based on the eight nearest neighbours criterion. The positive sign of parameters γ_4^k, γ_5^k and γ_6^k in the 1st, 2nd and 3rd equations, respectively, informs about the similarity of sustainability achievement level in closely located considered units. This situation occurs in every studied cluster, where the strongest impact is observed according to the economic situation. Moreover, we can conclude that an increase in governance quality level supports the achievement of social environmental sustainability in Africa, South America and Europe. The positive effect of the development of governance is also noted in the case of economic development across Africa and Europe. Moreover, the significance of the impact of governance effectiveness on the environmental situation is visible in South America and Europe, but with the opposite character – positive and negative, respectively. The lack of significance of parameter β_4^k in the case of North and Latin America can result from the high correlation of the governance quality (variable GOV) with the share of value added in GDP coming from services and spatial lags of social and economic sustainability, that are already recognized as relevant (see Table A2 in Appendix).

Table 5 presents the results of estimation and verification of the spatial VAR (spVAR) models for the linkage between sustainability achievement in three pillars using the governance quality level similarity as the criterion to fix the neighbourhood ($\boldsymbol{D}^*$). Similar to the case of previously estimated spVAR models, the feedback loop of positive character between social and environmental sustainability achievement levels is observed in every considered group of countries. The simultaneous supportive impacts between social and economic situations can be concluded from statistically significant parameters α_3^k in Eq. 2 and α_2^k in Eq. 3, indicated for countries located in Africa, Europe, and Asia with Australia. Also, in three of five clusters there is a positive feedback loop between ecological and economic sustainability achievement. This situation results from the significance of parameters α_3^k and α_1^k in the 1st and the 3rd equations, respectively, estimated for Europe, Asia and South America. Therefore, we can observe that the imitation of actions taken in countries with similar governance quality significantly improves the relationship between the environmental and economic situation across the considered areas. Also positive, but only one-way linkage is noticed for North and Latin America. Africa is the one continent where, despite considering the connections based on the governance effectiveness, the linkage between economic and ecological development remains negative.

The supportive character of the servitisation process for the sustainability achievement in North and Latin America, and also Europe, is concluded based on the significance of parameter β_1^k in every equation. In the remaining clusters, the positive linkage is noticed in two of three sustainability dimensions: social and economic for African states, and environmental and social for countries situated in South America, and jointly Asia and Australia.

A little change we can observe in the case of the influence of agricultural sector expansion. In Africa, this impact turned out to be positive on the economic performance compared with the previously estimated model. This means that some international cooperations based on similar governance quality can make the agricultural expansion friendly for economic growth. Moreover, the same type of cooperation can generally make the changes in the agricultural sector important for the achievement of environmental and economic sustainability in South America.

Table 5. The results of estimation and verification of spatial VAR models in regimes for the matrix defined by governance similarity ($\boldsymbol{D}^{*}$)

Cont.	Africa			North and Latin America			South America			Asia, Australia and Oceania			Europe		
Param.	Estimate			Estimate			Estimate			Estimate			Estimate		
	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO	Eq. 1 - ENV	Eq. 2 - SOC	Eq. 3 - ECO
α_1^k ENV(-1)	0.4054 ***	0.1322 ***	-0.0001	0.1085 **	0.1190 ***	0.1168 **	0.0989 ***	0.1373 ***	0.0834 ***	0.3537 ***	0.0736 ***	0.1499 ***	0.2629 ***	0.2388 ***	0.1748 ***
α_2^k SOC(-1)	0.2169 ***	0.2528 ***	0.3274 ***	0.1013 ***	0.1099 ***	0.1266 ***	0.1003 ***	0.1307 ***	0.0585 ***	0.1831 ***	0.1187 ***	0.1205 ***	0.0906 ***	0.2071 ***	0.1754 ***
α_3^k ECO(-1)	-0.1320 ***	0.1489 ***	0.4627 ***	0.0988	0.0744	0.1936	0.0782 ***	0.0501	0.2161 ***	0.0988 ***	0.0847 ***	0.4230 ***	0.0875 ***	0.0985 ***	0.6475 ***
β_1^k SER	-0.0389	0.0728 ***	0.0644 ***	0.1125 ***	0.1086 ***	0.0698 **	0.0868 ***	0.1451 ***	0.0091	0.0526 ***	0.1359 ***	-0.0288	0.3046 ***	0.0477 ***	0.0962 ***
β_2^k IND	-0.0092	-0.0150 ***	0.0433 ***	0.0715	0.1006 ***	0.1138	0.0987 ***	0.0682	0.1204 **	0.1787 ***	0.0294	-0.0597 ***	0.1137 ***	0.1135 ***	0.0244
β_3^k AGR	-0.0228 ***	-0.0377 ***	0.0281 ***	0.0924	-0.0033	-0.2957 **	0.0631 **	-0.0358	0.1542 ***	0.0776 ***	-0.0558 ***	-0.0762 ***	0.0519 ***	0.0000	-0.0302 ***
γ_1^k $\mathbf{D}^*$SER	0.2014 ***	-0.0811 **	-0.0163	0.1293 ***	0.0416	0.0460	0.0596 ***	0.1729 ***	0.0674 ***	0.1417 ***	0.0850 ***	-0.0002	0.2177 ***	0.1362 ***	-0.1762 ***
γ_2^k $\mathbf{D}^*$IND	0.1452 ***	-0.0458	-0.0352	0.0068	0.1651 ***	0.0577	0.1253 ***	0.0515	0.1790 ***	-0.0614 ***	0.0993 ***	-0.1538 ***	0.1018 ***	0.0444 ***	0.0024
γ_3^k $\mathbf{D}^*$AGR	0.0656 ***	0.0489 ***	-0.0112	0.0973	0.0572	0.1390 ***	0.1544 ***	-0.1075	-0.0930 ***	-0.0200	0.0204	0.0020	-0.0463 ***	0.0548 ***	0.0071
γ_4^k $\mathbf{D}^*$ENV	0.1163 ***	0.1734 **	-0.1729 ***	0.1173 ***	0.0923 ***	0.0444 **	0.1125 ***	0.1103 ***	0.0616 ***	0.1316 ***	0.2092 ***	0.0543 ***	0.1187 ***	-0.0489	-0.1256 ***
γ_5^k $\mathbf{D}^*$SOC	0.0195	-0.0178	-0.0426	0.0945 ***	0.0842 ***	0.0616 ***	0.0830 ***	0.0777 ***	0.0606 **	0.0285 ***	0.1924 ***	0.1726 ***	-0.1339 ***	0.1136 ***	-0.0596 ***
γ_6^k $\mathbf{D}^*$ECO	0.1078 **	0.2685 ***	0.4194 ***	0.0791	0.0933 ***	0.1673 ***	0.0813 ***	0.0456	0.2294 ***	-0.0837 ***	0.0432	0.3870 ***	-0.0199	0.0301 **	0.2447 ***
β_4^k GOV	-0.0302 **	0.1073 ***	-0.0658 ***	0.0728	0.0747	0.0780 **	0.0855 ***	0.1741 ***	-0.0964 ***	-0.0498 ***	-0.0119	-0.1203 ***	-0.0786 ***	0.0822 ***	0.0009
β_0^k CONST	0.0887 ***	0.0218 **	-0.0334 ***	0.0267 ***	0.0279 ***	0.0236	0.0251 ***	0.0329 ***	0.0142 ***	0.0739 ***	0.0345 ***	0.0010	0.0359 ***	0.0483 ***	0.0054 ***

Analysing the significance of the spatially lagged dependent variable, we can see only one change in comparison with models estimated using the $\boldsymbol{W}^{*}$ matrix. For African countries, we cannot conclude about similarity in the social sustainability level between units with a similar quality of governance. In the remaining four groups, the positive values of statistically significant parameters γ_4^k, γ_5^k and γ_6^k in the 1st, 2nd and 3rd equations, respectively, indicate the supportive character of changes in all SD dimensions in countries with similar governance level for their sustainability achievement in the given country. Considering the influence of the governance effectiveness on the sustainability in each cluster, we can notice its positive impact for social development in Africa, Europe and South America. The significance of governance quality is also noted in the case of economic performance, but for four groups of countries and with opposite character – positive for North and Latin America, and negative for Africa, South America, and jointly Asia and Australia. Also, the different sign of the relevant parameter β_4^k is received for environmental sustainability achievement. In Africa, Europe, and Asia connected with Australia, governance actions can harm the ecological performance, contrary to the situation in South America. These results show that connecting the sustainability achievement in a given country with the sustainability level in countries of similar governance quality can cause a deterioration of SD goals achievement. The problem may be in introducing similar laws to those in other countries, to which the current political situation is not adapted.

Additionally, the diagnostic tests for the models estimated using $\boldsymbol{W}^{*}$ and $\boldsymbol{D}^{*}$ matrix are calculated. The test results are presented in the Appendix, Tables A4 and A5. Tables contain tests for autocorrelation, cross-sectional dependence, and heteroscedasticity of residuals. What is more, the Hansen-J test results are shown. Comparing the results of diagnostic tests, we note that they perform better in models estimated using a neighbourhood defined by governance quality similarity. Apart from cross-sectional independence, the lack of autocorrelation and of residuals' heteroscedasticity is observed across more equations.

Discussion

This study provides some information on the linkage between sustainability achievement across the three dimensions of SD. One of the most often noted relations is the positive feedback loop between social and economic spheres, which is also underlined by Hernández-Medina (2025). She also pointed out the opposite character of linkage in the case of environmental and economic pillars. The research shown above presents that the ecological and environmental development can follow the same growth path. Nevertheless, it is difficult to meet personal needs while protecting the natural environment, as Brundtland's Commission (WCED, 1987) writes. The issue is that economic growth remains the primary goal of every economy. Actually, the problem of economic growth is the most visible across developing countries, especially in Africa (Ojah et al., 2022). The faster economic development is expected to improve their inclusiveness. One of the tools identified for achieving this objective is digitalisation (Ibrahim et al., 2024), which expands the servitisation process. As the study shows, given the simultaneous pursuit of sustainability across the three dimensions of SD, the economic transformation towards servitisation does not favour African countries. Changes in the mentioned character have a greater impact in relatively more developed countries (Friesenbichler & Kuegler, 2022). Moreover, African countries cannot overcome poverty and achieve decent living conditions due to the deepening inequalities.

As the ecological Kuznets curve (EKC) suggests, improvements in the environmental dimension can be observed when a certain level of economic growth is reached. Therefore, some researchers have argued that the SDGs should be determined by their significance (Eisenmenger et al., 2020). For example, in developing countries, at the beginning of development, a social situation driven by economic growth should be a priority, even if it harms the natural environment. The research presented in this paper confirms that, in relatively highly developed countries, ecological conditions do not have to degrade as a result of economic development.

An important factor in achieving sustainability is also the country's institutional context. Governance effectiveness and trustworthiness significantly influence citizens' well-being. Governments more often take action to introduce sustainability-friendly laws, especially in the environmental dimension (Addin, 2025). Governments also benefit from other countries' experiences and try to enact similar laws if those laws have proven effective. Hence, this study employs the governance quality similarity as one of the connection criteria between economies. On the other hand, the introduced law can negatively influence when it is not tailored to the individual's economic and social situation. New legislation can deepen inequalities (Fadiran et al., 2025) and, as a result, worsen human well-being, thereby impacting SD. The bringing of law is also conditioned by cultural factors, for example (Omweri, 2024). Therefore, governments should cooperate to achieve sustainability worldwide, but they must assess the legitimacy of new rules in light of the individual characteristics of economies. Moreover, cooperation between geographically nearest neighbours is equally important for achieving sustainability.

This research and the presented discussion show that goals according to the SD for countries differ depending on their economic development level, geographical location, and governance quality. Some economies, such as those in Africa, have to focus on economic growth, whereas more developed economies (like those in Europe) can pay greater attention to environmental performance. Moreover, the methods for achieving sustainability differ according to countries' development levels.

Conclusions

The general aim of this study was to assess relationships among sustainability achievement levels across three dimensions of sustainable development. Considering these linkages across five separate clusters of countries (divided by location), we can conclude that there are few differences in the significance and direction of the relationships. The positive two-way relationship between social and environmental performance is unchanging regardless of the group of countries considered. Moreover, the often underlined linkage is the mutual support between economic sustainability and the social situation. The improvement in economic performance creates greater opportunities, for example in the labour market, and, as a result, supports the reduction of poverty. On the other hand, improving conditions for the development of human capital expands the possibilities for its commitment, thereby accelerating economic growth. In the case of African countries, we can see the negative impact of economic development on achieving ecological sustainability. It stems from the desire to equalise economic growth with that of relatively more developed countries, and this development is done at the expense of the natural environment. Such linkage is observed in most developing economies.

On the other hand, the relationship between economic and ecological performance can change through imitation of actions in countries with a similar level of governance quality. Nevertheless, changes in law that the government decides on should be introduced thoughtfully, because any new statute that is not suited to the current political climate can undermine sustainability goals, as shown in this analysis. Cooperation between countries with similar governance quality levels is stronger in achieving economic sustainability. This results from the highest value of Moran's I statistic for economic performance, using a proximity matrix based on governance quality level similarity.

The next conclusion, based on the conducted research, is that economic transformations have different impacts on achieving sustainability across all dimensions. The servitisation process is the most adverse for African countries, where the main objective is fast economic development. A certain degree of economic growth is needed for simultaneous expansion in the services sector and an increase in the sustainability achievement level. African countries, as developing and least developed, should improve their SD performance using mechanisms other than servitisation. The supportive character of expansion in the services sector is evident across the remaining four clusters of economies, which are assigned to relatively more developed states.

It is worth noting that spatial dependencies in sustainability achievement levels are also significant. It shows that cooperation between economies, not only those located near each other in space but also those similar in political performance, is very important for improving the world's sustainability.

This research also has a few limitations. First, the large number of countries could not consider all SDGs in assessing sustainability across all SD dimensions. Moreover, creating a composite indicator from already-calculated SDG indices for individual goals does not allow for a detailed interpretation of the sustainability achievement level within the given dimension. What is more, the desire to consider more countries reduced the analysis's time range, potentially weakening the study's temporal aspect.

The research should be supplemented by an analysis of the impact of economic structure modifications on sustainable development as a whole, which will constitute further considerations in this topic. Moreover, another division of countries will aim to increase the spatial homogeneity of the examined clusters. What is more, there is also the opportunity to use another type of spatial connection matrix.

Appendix

Table A1. The descriptive statistics of variables used in the study

	Mean	Median	Min	Max	Standard deviation	Coefficient of variation
$\ln ENV$	4.2655	4.2795	3.7176	4.4336	0.0983	2.3044%
$\ln SOC$	4.1690	4.2357	3.0722	4.5363	0.2768	6.6396%
$\ln ECO$	4.0145	3.9890	3.3251	4.5124	0.2698	6.7204%
$\ln SER$	3.9828	3.9984	1.8638	4.4286	0.2090	5.2470%
$\ln IND$	3.1803	3.2069	1.0203	4.2969	0.3772	11.8620%
$\ln AGR$	1.9065	2.0512	-2.9307	3.7917	1.1500	60.3180%
$\boldsymbol{W}^*ENV$	4.2697	4.2630	4.1287	4.3813	0.0550	1.2873%
$\boldsymbol{W}^*SOC$	4.1596	4.2045	3.6517	4.5091	0.2334	5.6099%
$\boldsymbol{W}^*ECO$	4.0068	3.9872	3.5649	4.4721	0.2070	5.1656%
$\boldsymbol{W}^*SER$	3.9759	3.9791	3.4216	4.2412	0.1292	3.2492%
$\boldsymbol{W}^*IND$	3.1915	3.1774	2.7203	3.7737	0.17327	5.4290%
$\boldsymbol{W}^*AGR$	1.9460	1.9237	-0.1714	3.4266	0.8229	42.2850%
$\boldsymbol{D}^*ENV$	4.2655	4.2713	3.7555	4.3961	0.0499	1.1690%
$\boldsymbol{D}^*SOC$	4.1671	4.1831	3.2387	4.5269	0.2222	5.3325%
$\boldsymbol{D}^*ECO$	4.0133	3.9629	3.4010	4.4986	0.2309	5.7525%
$\boldsymbol{D}^*SER$	3.9829	3.9813	3.2879	4.3428	0.1499	3.7631%
$\boldsymbol{D}^*IND$	3.1894	3.1943	2.4103	4.2090	0.1644	5.1549%
$\boldsymbol{D}^*AGR$	1.8952	2.2001	-2.1090	3.5296	0.9603	50.6700%
GOV	2.9474	2.7812	0.9812	4.8674	0.8579	29.1070%

Table A2. The correlation matrix between exogenous variables – the $\boldsymbol{W}^*$ matrix

	$\ln SER$	$\ln IND$	$\ln AGR$	$\boldsymbol{W}^*SER$	$\boldsymbol{W}^*IND$	$\boldsymbol{W}^*AGR$	$\boldsymbol{W}^*ENV$	$\boldsymbol{W}^*SOC$	$\boldsymbol{W}^*ECO$	GOV
$\ln SER$	1,0000	-0,4249	-0,5974	0,5422	-0,1588	-0,4788	0,2438	0,4666	0,4185	0,6504
$\ln IND$	-0,4249	1,0000	-0,0815	-0,1234	0,4123	-0,0444	-0,0001	0,0243	0,0092	-0,1539
$\ln AGR$	-0,5974	-0,0815	1,0000	-0,5543	-0,0750	0,7048	-0,2220	-0,6006	-0,6008	-0,7821
$\boldsymbol{W}^*SER$	0,5422	-0,1234	-0,5543	1,0000	-0,3067	-0,8031	0,4190	0,7405	0,7144	0,5973
$\boldsymbol{W}^*IND$	-0,1588	0,4123	-0,0750	-0,3067	1,0000	-0,0177	-0,0105	0,0344	-0,0370	-0,1136
$\boldsymbol{W}^*AGR$	-0,4788	-0,0444	0,7048	-0,8031	-0,0177	1,0000	-0,3499	-0,8312	-0,8564	-0,6372
$\boldsymbol{W}^*ENV$	0,2438	-0,0001	-0,2220	0,4190	-0,0105	-0,3499	1,0000	0,4855	0,3864	0,2306
$\boldsymbol{W}^*SOC$	0,4666	0,0243	-0,6006	0,7405	0,0344	-0,8312	0,4855	1,0000	0,9081	0,5932
$\boldsymbol{W}^*ECO$	0,4185	0,0092	-0,6008	0,7144	-0,0370	-0,8564	0,3864	0,9081	1,0000	0,6383
GOV	0,6504	-0,1539	-0,7821	0,5973	-0,1136	-0,6372	0,2306	0,5932	0,6383	1,0000

Table A3. The correlation matrix between exogenous variables – the $\boldsymbol{D}^*$ matrix

	$\ln SER$	$\ln IND$	$\ln AGR$	$\boldsymbol{D}^*SER$	$\boldsymbol{D}^*IND$	$\boldsymbol{D}^*AGR$	$\boldsymbol{D}^*ENV$	$\boldsymbol{D}^*SOC$	$\boldsymbol{D}^*ECO$	GOV
$\ln SER$	1,0000	-0,4249	-0,5974	0,6000	-0,2665	-0,5883	0,0646	0,6066	0,6015	0,6504
$\ln IND$	-0,4249	1,0000	-0,0815	-0,1603	0,0138	0,1595	-0,0376	-0,1607	-0,1631	-0,1539
$\ln AGR$	-0,5974	-0,0815	1,0000	-0,6655	0,3101	0,7467	0,0465	-0,6980	-0,7400	-0,7821

$\boldsymbol{D}^{*}SER$	0,6000	-0,1603	-0,6655	1,0000	-0,5528	-0,8146	0,1717	0,8439	0,8275	0,8735
$\boldsymbol{D}^{*}IND$	-0,2665	0,0138	0,3101	-0,5528	1,0000	0,2287	-0,1402	-0,2889	-0,3101	-0,3653
$\boldsymbol{D}^{*}AGR$	-0,5883	0,1595	0,7467	-0,8146	0,2287	1,0000	0,1408	-0,8675	-0,9048	-0,9270
$\boldsymbol{D}^{*}ENV$	0,0646	-0,0376	0,0465	0,1717	-0,1402	0,1408	1,0000	0,1607	0,0566	-0,0051
$\boldsymbol{D}^{*}SOC$	0,6066	-0,1607	-0,6980	0,8439	-0,2889	-0,8675	0,1607	1,0000	0,9175	0,9267
$\boldsymbol{D}^{*}ECO$	0,6015	-0,1631	-0,7400	0,8275	-0,3101	-0,9048	0,0566	0,9175	1,0000	0,9327
GOV	0,6504	-0,1539	-0,7821	0,8735	-0,3653	-0,9270	-0,0051	0,9267	0,9327	1,0000

Table A4. The results of diagnostic tests for the spVAR models estimated using $\boldsymbol{W}^{*}$ matrix

Africa			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 71.2440 (0.0000)	F = 118.7400 (0.0000)	F = 31.6060 (0.0000)
Pesaran CD test	z = -0.2866 (0.7744)	z = -0.6610 (0.5086)	z = 1.7190 (0.0856)
Breuch-Pagan test	BP = 102.9400 (0.0000)	BP = 202.8800 (0.0000)	BP = 121.6800 (0.0000)
Hansen-J-Test: ***J* = 67.8967 (p-value ~ 1)**			
North America			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 34.7330 (0.0000)	F = 5.1701 (0.0248)	F = 18.4060 (0.0000)
Pesaran CD test	z = 11.1020 (0.0000)	z = 4.0177 (0.0001)	z = -0.0730 (0.9418)
Breuch-Pagan test	BP = 32.3950 (0.0012)	BP = 41.6830 (0.0000)	BP = 29.1370 (0.0038)
Hansen-J-Test: ***J* = 0.5943 (p-value ~ 1)**			
South America			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 90.7010 (0.0000)	F = 24.0490 (0.0000)	F = 51.533 (0.0000)
Pesaran CD test	z = 6.6785 (0.0000)	z = -1.3372 (0.1812)	z = 12.273 (0.0000)
Breuch-Pagan test	BP = 7.7093 (0.5637)	BP = 21.5740 (0.0103)	BP = 13.8990 (0.1260)
Hansen-J-Test: ***J* = 9.5608e-14 (p-value ~ 1)**			
Asia and Australia			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 12.5270 (0.0005)	F = 60.8880 (0.0000)	F = 8.5340 (0.0037)
Pesaran CD test	z = -0.2689 (0.7882)	z = -1.2923 (0.1963)	z = -0.4566 (0.6480)
Breuch-Pagan test	BP = 121.4400 (0.0000)	BP = 136.7500 (0.0000)	BP = 68.0650 (0.0010)
Hansen-J-Test: ***J* = 6.7657 (p-value ~ 1)**			
Europe			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 15.8520 (0.0001)	F = 32.1960 (0.0000)	F = 31.2510 (0.0000)
Pesaran CD test	z = 0.9485 (0.3429)	z = 1.4569 (0.1452)	z = 1.2733 (0.2029)
Breuch-Pagan test	BP = 147.3600 (0.0000)	BP = 86.0960 (0.0000)	BP = 78.6910 (0.0004)
Hansen-J-Test: ***J* = 55.3080 (p-value ~ 1)**			

Table A5. The results of diagnostic tests for the spVAR models estimated using $\boldsymbol{D}^{*}$ matrix

Africa			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 6.6565 (0.0102)	F = 28.0960 (0.0000)	F = 13.9580 (0.0002)
Pesaran CD test	z = -1.6392 (0.1012)	z = -1.0632 (0.2877)	z = 2.7198 (0.0065)
Breuch-Pagan test	BP = 75.7590 (0.0037)	BP = 175.6900 (0.0000)	BP = 92.8450 (0.0001)
Hansen-J-Test: ***J* = 42.9642 (p-value ~ 1)**			
North America			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 47.6340 (0.0000)	F = 1.4852 (0.2255)	F = 19.2940 (0.0001)
Pesaran CD test	z = -1.4293 (0.1529)	z = 3.6538 (0.0003)	z = -0.1185 (0.9057)
Breuch-Pagan test	BP = 38.1120 (0.0001)	BP = 17.1030 (0.1458)	BP = 30.8710 (0.0021)
Hansen-J-Test: ***J* = 1.8396 (p-value ~ 1)**			
South America			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 1.5135 (0.2219)	F = 7.7889 (0.0064)	F = 6.9160 (0.0101)
Pesaran CD test	z = -0.1469 (0.8832)	z = -1.9210 (0.0547)	z = 1.2197 (0.2226)
Breuch-Pagan test	BP = 9.2589 (0.4137)	BP = 20.0710 (0.0175)	BP = 24.3790 (0.0037)
Hansen-J-Test: ***J* = -8.6511e-15 (p-value ~ 1)**			
Asia and Australia			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 16.0340 (0.0001)	F = 19.8350 (0.0000)	F = 4.9276 (0.0271)
Pesaran CD test	z = -1.0802 (0.2801)	z = -1.0560 (0.2910)	z = -0.2932 (0.7694)
Breuch-Pagan test	BP = 4.9276 (0.0271)	BP = 73.2040 (0.0002)	BP = 38.2160 (0.3691)
Hansen-J-Test: ***J* = 59.3356 (p-value ~ 1)**			
Europe			
Test	**Eq. 1. - ENV**	**Eq. 2. – SOC**	**Eq. 3. - ECO**
Wooldridge test	F = 3.0270 (0.0827)	F = 8.1907 (0.0044)	F = 6.4513 (0.0115)
Pesaran CD test	z = -0.8916 (0.3726)	z = -1.6463 (0.8720)	z = 0.1612 (0.8720)
Breuch-Pagan test	BP = 63.4210 (0.0139)	BP = 77.2860 (0.0005)	BP = 79.7000 (0.0003)
Hansen-J-Test: ***J* = 27.8523 (p-value ~ 1)**			

Acknowledgement

I would like to extend my sincere thanks to Professor Angela Parenti from the Department of Economics and Management of the University of Pisa for guidance, practical and insightful suggestions during the preparation of this paper. Thanks to the advice from Professor, this research was created during the visit at the University of Pisa.

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