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Article

Interplays of Institutional, Economic, Social and Environmental Systems in Sustainable Development in Latin America

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ABSTRACT

This research seeks to identify the direct effects and interactions of the economic, social, environmental and institutional dimensions or systems on sustainable development for 16 Latin American countries between 2007 and 2019. The sustainable development index (SDI) proposed by Hickel (2020) is used as the dependent variable, as are the pillars of Legatum's prosperity index, grouped into the indicated dimensions (explanatory variables). A dynamic panel data model is estimated using the generalised method of moments. The results indicate that business conditions, economic quality, health and education have positive and significant direct effects on the SDI. It is corroborated that the interactions between institutional and economic, as well as institutional and social, and economic and social dimensions have a positive effect on the SDI, although only the first interaction is statistically significant. As for the other interactions, the results show negative signs and only the interactions between the environmental dimension and the economic dimension and social dimension, respectively, are statistically significant. For Latin America, improvements in the SDI are associated with the economic and social dimensions (weak sustainability). This is reinforced by the strengthening of the institutional framework but with higher levels of CO_2 emissions and material footprint, whose indirect effects along with the rest of the dimensions condition the possibility of achieving better results in terms of sustainability.

KEYWORDS: sustainable development; institutionalism; economic dimension; social dimension; environmental dimension; dynamic panel data; generalised method of moments

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INTRODUCTION

Sustainable Development

The evolution of economic theory, from classical to neoclassical, has determined the change of conception in terms of economic progress. Since the beginning of the 20th century, the emphasis of economic growth has focused, as [1] states, on maximising profit, consumption and progress,

without highlighting the implications in terms of nature conservation. This traditional vision has generated great inequalities in terms of social gaps, strong territorial imbalances and a profound deterioration of the environment and natural resources.

Initiatives and studies surrounding the problem have given rise to a series of events that allowed the debate on the subject to begin through the so-called Brundtland Report [2], in which the concept of sustainable development is specified and agreed upon under the proposal of a change or transformation implicit in the concept of development itself. This requires an understanding of the importance of the role played by environmental conversation and social wellbeing in achieving better conditions and quality of life. This implies incorporating into the analysis of growth not only manufacturing capital stock or human capital but also nature as another factor of production that is not substitutable so that the change in the levels of capital over time must be non-negative in order to be considered sustainable [3].

This initial concept was based on an intergenerational idea and the need to ensure environmental conversation as a way of sustaining life on our planet. The emphasis was therefore on recognising the importance of nature. The definition of sustainability has been transformed, given that, at least initially, it considered three systems: environmental, economic and social [4–10]. The conceptualisation of the role, importance and interrelationship between them is still under debate today. This is based on the idea of recognising the three systems without further linkage and then relating them in terms of the need to create an equitable (economy and society), liveable (society and environment) and viable (environment and economy) society, based on the importance of ecosystem services, be they provisioning, regulating or recreational. This interrelationship of systems permits sustainability without identifying a leading role for any of the three systems so that each system is viewed as one corner of a triangle, in which the linkage of all is required to achieve sustainable development [5,6].

Daly [4] uses the 3E model (environment, equity and economy) to establish a hierarchy of systems, proposing that they form a pyramid whose base comprises the environmental dimension, the centre comprises the economic dimension and the apex comprises equity or quality of life, thus prioritising the objectives of preserving nature over the rest of the systems.

Dimensions of Sustainable Development

In these models and in subsequent developments, a fourth dimension or system is recognised, thus the interactions of these dimensions are mediated by the formal and informal institutional environment, as well as socio-cultural capital [4–6,9,11], acknowledged by authors like [9] as the dimension necessary to harmoniously develop the rest of the dimensions.

In this way, the dimensions of sustainable development that take place in an area are often in conflict with or feel tension towards the environmental dimension, which seeks to preserve the environment and natural resources whilst considering the planetary limits. On the other hand, the economic dimension proposes a model based on cooperation and collaboration, to which the socio-cultural dimension is added, which contributes to the search for equity and respect for diverse cultures, ethnic groups, ancestral knowledge, modes of consumption and social organisation based on social capital. Finally, the political-institutional dimension refers to the normative and regulatory framework, which promotes democratic governance and citizen participation, supported by decentralisation processes.

Specifically, the economic dimension focuses on the organisation of economic activity from production to consumption, overcoming the concept of profit maximisation based on economic rationality and subordinating it to premises such as environmental conservation and social welfare based on growth, efficiency and stability [10].

In this way, the economic dimension seeks to modify classic patterns of production and consumption, conditioned by environmental conservation and the rational exploitation of natural resources. In this search for new patterns or forms of production and consumption, some initiatives include business associativity strategies, collective ventures linked to the solidarity economy, the economy of the common good and the circular economy, which aim to convert linear processes and models into circular ones. In terms of consumption, it is advisable to encourage responsible consumption, thus promoting collaborative consumption [12–14].

The environmental dimension, for its part, aims to preserve and recover natural resources and is related to: the political-institutional dimension in terms of the regulatory framework; the socio-cultural dimension through changes in consumption patterns and through the use of natural resources; and the economic dimension through the transformation of forms of production, a more equitable distribution of resources and a change in the growth paradigm in favour of consumers.

It is therefore related to the ecosystem services of regulation and provisioning provided by nature, without which it is not possible to conceive of life as it exists today since they are necessary to satisfy the present and future needs of the population.

Meanwhile, the social dimension is related to the sustainable human development approach, which is centred on the individual, the satisfaction of his or her needs and the achievement of equity, generally linked to culture but also to education and health, housing and security as basic conditions for an acceptable standard of living.

In addition, this dimension is linked to elements of the social fabric or social capital and demographic variables such as ethnicity, gender and education. These elements allow it to be related to the economic dimension, i.e., with the possibilities of sectoral integration (associativity)

and competitiveness through the competencies of human talent and their capacity to shape development [14].

While the importance of elements such as health, education, equal rights and opportunities, ancestral knowledge and traditional modes of consumption and production is undeniable, the literature also recognises the role of social capital in these processes at individual, community and organisational levels.

Networks, relationships, trust, norms and values are vital in order to achieve sustainable territorial development, as they make it possible to take advantage of environmental opportunities for collective benefit, not only purely economically but also through organisations such as those of the social and solidarity economy [15–18].

As aforementioned, authors such as [4–6] and, more recently, [11], [19] and [20] add to these three dimensions a fourth one: the political-institutional dimension, associated with the institutional framework (trust and transparency) and with governance. The latter also includes political participation and community management as the mechanism that enables grassroots decision-making in addition to the strengthening of decentralisation processes through the autonomy of local governments.

Glass and Newig [20] detail at least four key elements for institutional sustainability, linked to participation in: policy design and implementation; policy coherence, associated with the rules and principles governing institutions, their structure and public policy implementation; the adaptive and reflective capacity of institutions to adjust and evaluate public policies; and finally, democratic institutions including the quality of the electoral process and freedom and access to information and civil rights.

Moreover, [20] manage to identify that the quality of democratic institutions and participation has a positive impact. In terms of coherence and adaptation, the negative results illustrate the complexity of the interaction of institutional factors and the need to assess them in the long term, as their impacts require profound system-wide transformations to achieve positive effects on sustainability.

Platje [19] identifies four elements of institutional capital that impact sustainable development linked to the public domain, institutional strength, good governance and institutional equilibrium and whose effects must be analysed in the economic, social and environmental systems or dimensions but also in the interaction between the economic and social, economic and environmental, and social and environmental systems, in some cases opposing each other. For example, concerning the public domain, property rights can be seen as a form of inclusion and economic stability but also have negative impacts on the environment, while institutional strength would have positive effects in terms of access to health, education and the market.

With respect to governance, its strengthening results in clear rules of the game, limits to corruption, incentives for environmentally friendly

practices and a positive impact on sustainability [21], although authors such as [22] identify indicators such as the size of the government and e-government that could have a negative influence.

Relevance and Interactions of the Dimensions of Sustainable Development

Although there seems to be a consensus on the recognition of these systems as part of sustainable development, their role, importance and interaction differ significantly between authors and disciplines, giving rise to alternatives or approaches. On one hand is weak sustainability, framed in a utilitarian or anthropic vision, and on the other is strong sustainability, based on the recognition of the ecosystem, ecology and environmental and natural resource conservation.

In the case of weak sustainability, the emphasis is placed on the accumulation of manufactured capital, without considering the limits of natural capital; therefore, the accumulation compensates for and overcomes the loss of natural capital. As [23] argues, from a weak or anthropocentric perspective, "natural and manufactured capital can perfectly substitute each other. The substitutability of the diverse types of capital implies that what is essential is to preserve an aggregate level of natural capital plus manufactured capital, and not to preserve natural capital" (p. 13). Weak sustainability is addressed by neoclassical theory through the Hartwick-Solow model, in the sense that consumption should be maintained and welfare achieved through the equitable distribution of income [24].

Strong sustainability or the so-called ecological economy focuses on nature as the capital that provides the necessary resources for the development of the economic and social dimensions. In fact, it considers that natural capital and manufacturing capital are not substitutes, as in weak sustainability, but are complementary and it is not possible to think of increasing the latter without recognising the former and the limits in its factor endowments.

The "super-strong" current, on the other hand, argues that nature also gives rise to a series of additional values that make it a natural heritage, "understood as an inheritance received from our ancestors that must be maintained, bequeathed to future generations and is not necessarily tradable in the market" ([25], p. 47), recognising other additional and different valuations to the economic and ecological ones.

While the weak current is limited to establishing taxes, correcting prices or valuing negative externalities, the strong and super-strong currents conceive other business models framed within the economy of the common good or called "good living" or "sumak kawsai" in some South American countries [10]. Relevant proposals include the collaborative economy or the social or solidarity economy [25] and the circular economy, as proposed in some Latin American legislation, such as that of Ecuador. In the latter, important changes have been achieved based on a

strong vision of sustainable development, in some cases considering nature as additional capital with the status of heritage, improving the population's wellbeing or "sumak kawsai" and even incorporating a third sector of popular or solidarity economy.

There is an unresolved debate surrounding approaches in terms of the relevance of a particular dimension within sustainable development or, alternatively, the way in which systems are related in complementarity or trade-off in the search for a balance [26]. Beckerman [27] recognises that while environmental problems exist and limit the satisfaction of future generations' needs, the morally acceptable objective is to contribute to the welfare of the population through redistributive processes Achieving this should already be considered "sustainability", under the premise that it is necessary to establish an institutional framework that regulates the imperfections of the market in relation to nature conservation.

In this regard, [28] argue that "there is still much additional work needed to elaborate (1) the complex interconnections between the goals; (2) the means-ends continuum toward an overarching goal; and (3) a 'narrative of change' to describe the societal shifts and policy reforms necessary to achieve the SDGs" (p. 350). Specifically, the complexity of the interrelationships between all the elements or dimensions of sustainable development requires a holistic view that makes the system as a whole work, overcoming the tensions that can arise between goals, so that not all goals can be achieved permanently in all dimensions; sustainability must take precedence over each dimension in isolation [29].

Holden et al. [30] rethink this proposal for balance based on moral imperatives that demand the achievement of three key elements: satisfying human needs, guaranteeing social equity and respecting natural limits, which has not been achieved because economic growth seems to take the predominant role, showing strong contradictions with the environment and the results achieved [31].

Thus, according to [30] and similar to [15], economic growth cannot be considered a sustainable development objective but rather a means: "True, economic growth may contribute to a more sustainable development by improving social welfare, satisfying human needs, and lifting people out of poverty, but economic growth may also reduce social equity by contributing to income and wealth inequality" ([30], p. 216). From an environmental point of view, "economic growth may bring about the technological solutions needed to mitigate greenhouse gases and adapt to climate change, but economic growth may also contribute to less sustainable development" ([30], p. 216).

There are authors such as [15] who propose two ends, following the original proposal of [2] and as established by [31]. These are preserving the environment and achieving societal wellbeing as a means of economic growth, technological advances and innovations, as well as the policies and regulations necessary for the achievement of these two objectives.

Meanwhile, [32] recognise the great challenges in the conceptualisation

of sustainable development to reach a consensus in terms of the interactions of the dimensions. They also acknowledge the need to rethink the role of the social dimension, forgotten in most approaches [33], both in terms of importance and measurement, and whose achievements in terms of improving the living conditions of the population have not turned out as expected, as these achievements have been at the cost of greater emissions and material footprint [31]. In this regard, Latin America could consider energy efficiency, which reduces CO_2 emissions more than urbanisation [34], or the development of information and communication technologies or artificial intelligence (AI) by designing public policies that encourage innovations in these areas. Recent studies stand out, such as the one by [35], who propose reducing carbon emissions through the use of AI, whose effects are differentiated by considering trade openness, income levels and AI development in the 69 countries analysed. This is similar to information and communication technologies, where the relationship is not linear [36]. Looking at developed countries, there appears to be a robust and significantly positive correlation of AI with green innovation, highlighting the crucial role of AI in fostering environmental innovation [37].

Meanwhile, [38] study the relationship between the digital economy and CO_2 emissions, identifying a non-linear relationship influenced by economic and regulatory factors, whose effectiveness in reducing emissions depends on adequate natural resources and anti-corruption regulation, leading to heterogeneous results in different regions and countries.

The debate, then, seems to have focused on the interaction between the environmental and economic dimensions, identifying tensions that translate into the well-known negative impacts of production systems on the environment [8,32].

In this context, the existence of the four systems or dimensions in sustainable development and the tensions that are generated between them are recognised. The tensions could even reduce achievements in terms of sustainability and the interaction or mediation of the institutional framework, as well as of the environmental-economic, environmental-social and economic-social systems. Here, this is analysed for Latin America.

To this end, we use the sustainable development index (SDI) proposed by [39] as a measure of sustainability, which considers not only social (education and health) and economic results but also penalises them in environmental terms through CO_2 emissions and material footprint and the indicators of the prosperity index developed by the [40], which includes indicators of the four dimensions of sustainable development as explanatory variables.

In this way, the aim is to establish the role played by the institutional and cultural environment (social capital) in the achievement of the SDGs in Latin America, understanding that the region is in a process of

transition and strengthening of institutionalism, civic and political participation, personal and economic freedoms, decentralisation processes and community management, leveraged by the enactment of a regulatory framework contextualised by social welfare and nature conservation.

Furthermore, given the existing debate between the tensions evidenced in the different dimensions, the aim is to identify the influence, magnitude and meaning of these interrelationships in the sustainability results, considering the link between the economic-social, economic-environmental and social-environmental systems.

RESEARCH METHOD

The study considered 16 Latin American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, Peru, Uruguay and Venezuela), for which an attempt was made to identify the indicators of the four dimensions explained, which influence the behaviour of the sustainable development index as a dependent variable for the period 2007 to 2019. Only these countries were considered since the variables analysed are only available for them in the period under consideration.

The indicators used for the purpose of the research are, on one hand, the SDI proposed by [39] based on the conception of strong sustainability and, on the other hand, the pillars of the Legatum Prosperity Index [40] for the explanatory variables related to the dimensions.

The SDI is based on the variables considered for human development, such as education, life expectancy at birth and income level, measured as gross domestic product per capita, estimating a geometric mean (development index). As well as these aspects, the SDI also incorporates CO_2 emissions and material footprint, creating an ecological impact index of the level of economic growth. Thus, the SDI is the ratio of the human development index (HDI) to the ecological impact index.

The development index is calculated as the geometric mean of the product of the life expectancy index, the education index and the income index. In the former, it is the quotient of life expectancy minus 20 years and the subtraction between 85 and 20 years, which represent the lower and upper limits of the world statistics.

In the second aspect, the average years of schooling index considers the years of schooling completed divided by 15 (which is the maximum years of education needed for a profession) and the expected years of schooling index (expected years of schooling divided by 18, which implies having completed a Master's degree). The third aspect is the income index, which differs from the HDI, which considers an income threshold of $75,000 per capita per year. Since this value is incompatible with the need to not exceed the planetary boundaries, a value of $20,000 is used instead.

So, it is estimated as the difference of logarithms of the gross domestic product per capita at constant values minus the minimum value and

divided by the difference between the maximum and minimum values. For the ecological impact index, CO_2 emissions and material footprint (extraction of materials from ecosystems) are considered with respect to per-capita planetary boundaries.

A country would be expected to have a high development index but not at the expense of a high ecological impact index, which would imply that planetary boundaries are not respected. Thus, countries with a high development index and a low ecological impact index will be in the top positions for the SDI, while those with a high development index but a high ecological impact index will be in the bottom positions.

As indicated, the dimensions were measured using the pillars of the Legatum Institute's prosperity index. This tool was first developed in 2007 and it contributes to the identification of opportunities for improvement in twelve basic pillars that allow the 167 countries that form part of the study to move towards a path of greater wellbeing and progress. In this index, three domains are incorporated: social inclusion, an open economy and empowered people [41].

In each domain, there are a series of pillars. In the inclusive society domain, these are safety and security, personal freedom, governance and social capital. In the open economy domain, these are business conditions, infrastructure, access to markets and the quality of the economy, while the empowerment domain includes living conditions, health, education and the environment. In turn, each of the pillars is made up of a series of indicators that are detailed in Table 1.

Table 1. Domains, pillars and elements of the Prosperity Index.

Domain	Pillar	Elements
Inclusive society	Safety and security	Civil war and strife. Terrorism. Terror and political violence. Violent crime. Property crime.
	Personal freedom	Agency. Freedom of association. Freedom of communication and access to information. Absence of legal discrimination. Social tolerance.
	Governance	Executive constraints. Political accountability. Rule of law. Government integrity. Government effectiveness. Regulatory quality.
	Social capital	Personal and family relationships. Social networks. Interpersonal trust. Institutional trust. Civic and social participation.
Open economy	Investment in the local area	Property rights. Investor protection. Contract enforcement. Ecosystem financing. Restrictions on foreign investment.
	Business conditions	Competitiveness. Domestic market. Business start-up environment. Burden of regulation. Price distortions. Labour market flexibility.
	Infrastructure and market access	Market distortions. Barriers to imports (tariffs). Scale of trade openness. Customs administration. Transport. Water. Energy. Communications.
	Economic quality	Property rights. Investor protection. Contract enforcement. Ecosystem financing. Restrictions on foreign investment.

Table 1. *Cont.*

Domain	Pillar	Elements
Empowering people	Living conditions	Risk protection. Connectivity. Housing. Basic services. Nutrition. Material resources.
	Health	Longevity. Physical health. Mental health. Care system. Preventive health. Behavioural risk factors.
	Education	Adult skills. Tertiary education. Secondary education. Primary education. Initial education.
	Environment	Preservation efforts. Oceans. Freshwater. Exposure to air pollution. Forests, lands, and soils. Emissions.

Note: Adapted from the Legatum Institute [40].

The index reports each country's position in global terms. For each of its components, a score is generated and expressed between 0 and 100, which indicates the value in each indicator, element, pillar or domain. Scores closer to 100 mean that the country presents a better performance.

The pillars of safety and security, personal freedom, governance and social capital were considered as the institutional dimension; the economic dimension included investment in the local area, business conditions, infrastructure and market access and economic quality. In the social dimension, the following were examined: living conditions, health and education. Finally, the environmental dimension included the environmental pillar (preservation efforts, oceans, freshwater, exposure to air pollution, forests, lands, soils and emissions).

When the data used contain observations from multiple units (in this case countries) over time, panel data estimates should be considered. Panel data estimations could be static, which implies that the past of the dependent variable is not considered as explanatory. This static estimation attempts to understand the heterogeneity of the data. If it comes from individuals (countries), fixed effects are considered more appropriate; if, on the contrary, it is a product of chance, random effects will be the best estimation.

While the proposal can be performed through a static analysis, in which fixed effects or random effects estimates are developed according to the origin of the unobserved heterogeneity, this would fail to capture the dynamic behaviour of the time series, in which the SDI depends to some extent on its historical performance (endogenous explanatory variable).

Additionally, as the purpose of the research is to identify the effect not only of the dimensions on sustainable development but also the interactions between them that may lead to opposite effects, it is not possible to estimate dynamic panel data through standard methodologies. This dynamic analysis requires the incorporation of lags of this endogenous variable, with which the fixed or random effects models generate biases that do not allow consistent estimates and a differentiated

treatment of the estimates is required. The inclusion of these lags generates the existence of a correlation between them and the regression error term, so instrumental variables that meet two conditions must be incorporated: non-correlation with the residuals (exogeneity condition) and correlation between the instruments and the endogenous explanatory variables (relevance condition).

Arellano and Bond [42] propose estimation through the generalised method of moments (GMM), in which it is possible to include the interaction between systems or dimensions. This GMM is used to estimate dynamic panel data models, where the lagged dependent variable is one of the explanatory variables. The method considers the differences between the exogenous explanatory variables and the lags of the endogenous variable as instruments.

Such estimations can be carried out in one or two stages. For a one-stage approach, initial moments and weights are used based on the within-sample variances of the instrumental variable differences, which means that a simplified weighting matrix is used that does not adjust for potential heteroscedasticity or autocorrelation in the residuals. The second step is to use an initial estimate to calculate an optimal weighting matrix that reflects heteroscedasticity and autocorrelation in the residuals. This matrix is used to obtain estimates that are asymptotically more efficient.

Given that a dependent variable is affected by its past, by not incorporating its lags as an explanatory variable, the error of the estimation picks up this effect and is also related to its past (autocorrelation). This is why to justify the estimation through GMM, it must be corroborated that there is first-order autocorrelation in the equations in first differences to guarantee the presence of dynamic effects, while in the second-order one, the null hypothesis of no autocorrelation must be accepted as a condition for the validity of the estimation.

In addition, it is necessary to analyse the instruments incorporated by means of the Sargan-Hansen test, for which the null hypothesis of over-identification of the equations must be accepted as an element of validity for the instruments used. If this hypothesis is rejected, a two-stage GMM or robust error GMM would be estimated due to the possible existence of heteroscedasticity, in which the Hasen test would be used for the validity of the instruments.

In the context of the GMM dynamic panel data method, the appropriate selection of instruments is crucial in order to obtain valid and efficient estimates. Instruments must meet two main conditions: relevance and exogeneity. Relevance of the instruments means that the instruments must be correlated with the endogenous variables (explanatory variables) in the model. In technical terms, the instruments must explain a significant part of the variability of the endogenous variables.

Exogeneity of the instruments means that the instruments must be uncorrelated with the error term of the model. This ensures that the instruments do not capture the part of the error term that is influencing

the dependent variable, which could bias the estimates. Exogeneity is assessed by over-identification tests, such as the Hansen test (also known as the Sargan-Hansen test). This test examines whether the additional restrictions imposed by the overidentified instruments are valid. A non-significant Hansen test result (i.e., a high *p*-value) suggests that the instruments are exogenous.

In the estimation of dynamic panel data models using the GMM, lags of explanatory variables are commonly used as instruments. Lags are used because they are often correlated with the current and future values of the same variables, providing relevant information for the estimation of the model. Moreover, under certain conditions, lags of explanatory variables can be considered exogenous with respect to the present error term, fulfilling the condition of being uncorrelated with the differenced error term.

Within this modelling, we aimed to estimate the SDI by considering this lagged variable and variables associated with the systems or dimensions, as indicated in General equation (1).

$$\begin{aligned} SDI_{it} = \alpha + \gamma_p SDI_{it-p} &+ \beta_1 ENVD_{it} + \beta_2 ID_{it} + \beta_3 SD_{it} + \beta_4 ED_{it} \\ &+ \beta_5 (ENVD_{it} * ID_{it}) + \beta_6 (ENVD_{it} * SD_{it}) \\ &+ \beta_7 (ENVD * ED_{it}) + \beta_8 (ED_{it} * ID_{it}) + \beta_9 (SD_{it} * ID_{it}) \\ &+ \beta_{10} (SD_{it} * ED_{it}) + \varepsilon_{it} \end{aligned} \quad (1)$$

The SDI is the sustainable development index, considering its lags as endogenous lagged variables, ENVD: the environmental dimension, ID: the institutional, SD: the social and ED: the economic. The interactions between the dimensions and the institutional framework and between the dimensions are considered.

β would be expected to be positive because each of the improvements in the dimensions should contribute to sustainable development, as should the mediation of the institutional framework and the interaction between the dimensions. Three models are estimated; all of them consider the SDI lags, the institutional framework and the environmental dimension. The second model also incorporates the economic dimension with its interactions and the third includes the social dimension with its interactions.

Although panel data estimation using GMM is a robust methodology, there are limitations and biases to be considered related to model specification, selection and number of instruments, sample size that may generate inconsistent estimators, presence of heteroscedasticity and autocorrelation in the errors, affecting the validity of the inferences. For this purpose, over-identification tests, such as the Hansen test, were used to verify the validity of the instruments and the model specification, the implementation of methods robust to heteroscedasticity and autocorrelation, such as the use of robust standard errors and the largest possible sample size given the available data.

RESULTS

Interactions of the Dimensions of Sustainable Development in Latin America

As indicated, the SDI is composed of two indicators: the human development index and the ecological impact index. For the countries analysed in Latin America, Costa Rica was ranked number one in 2019 and the top country in the world. The country with the lowest position was Uruguay (94th out of the entire available global sample), whose behaviour was characterised by a constant deterioration of the index since 1990 because of a greater increase in CO_2 emissions and material footprint compared to the growth in the HDI.

Most of the Latin American countries studied experienced a sustainable growth in the SDI related to a higher growth in the HDI than in the ecological impact index. Mexico was the only country that managed to decrease its CO_2 emissions and material footprint. Countries such as Argentina, Chile, Uruguay and Venezuela recorded declines in the SDI in the study period, resulting from the acceleration of the ecological impact, although in the case of Venezuela, the behaviour was reinforced by a fall in the HDI.

A preliminary examination of the interrelationships between the dimensions of sustainable development could be made by linking the social objective of sustainable development through the HDI with measurements of CO_2 emissions and material footprint as variables of the environmental objective. Figure 1 shows that countries with higher HDI levels are also associated with greater ecological impact. Considering the thresholds indicated by [40]—6.52 and 1.74 tons per capita of CO_2 and material footprint respectively and a minimum value of 0.80 for the HDI—it is observed that although Chile Argentina, Uruguay and Costa Rica obtained satisfactory social results, all four of them exceeding the optimal level of CO_2 emissions. Only countries like Honduras, Guatemala and Nicaragua did not achieve the social objectives but were below the threshold for CO_2 emissions.

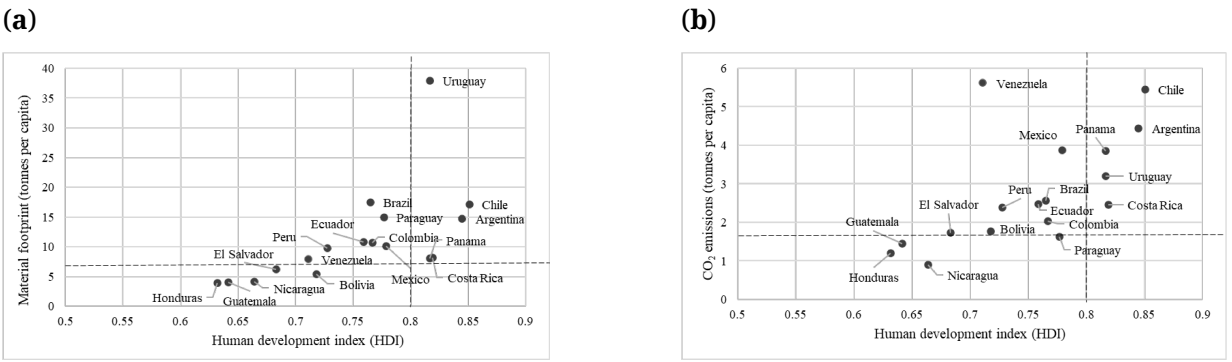

Figure 1. Interactions in the environmental and social dimensions (2020). **(a)** Interactions in the material footprint and social dimensions. **(b)** Interactions in the CO_2 emissions and social dimensions. Note: prepared by the authors based on data from [39].

Similarly, considering the ecological impact of the material footprint, the results do not differ significantly in that those countries that exceeded the optimal HDI value were also those with the highest material footprints (Uruguay, Chile, Argentina, Panama and Costa Rica), while those with the poorest social results were those that report the lowest ecological impact (Honduras, Guatemala, El Salvador, Nicaragua and Bolivia). Uruguay stands out with a material footprint that exceeds the desirable threshold by more than sixfold.

If we consider the economic objectives measured through the gross domestic product per capita (in constant values) and its relation to the ecological impact (CO_2 emissions) with the social objectives (HDI), we can see in Figure 2 that an increase in gross domestic product per capita is generated at the cost of higher CO_2 emissions but produces better results in the social objectives.

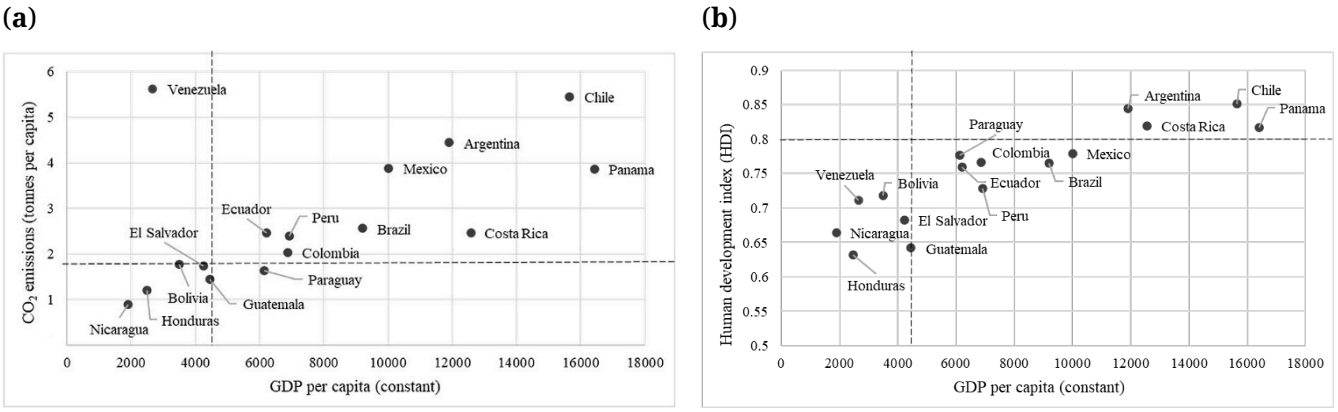

Figure 2. Economic-environmental and economic-social interactions (2020). (**a**) Interactions in the CO_2 emissions and GDP per capita. (**b**) Interactions in HDI and GDP per capita. Note: prepared by the authors based on data from [39].

Based on the classification proposed by the World Bank for 2023 of countries with low, medium-low, medium-high and high incomes, the Latin American countries analysed are at least in the medium-low level, and these are the ones with the lowest CO_2 emissions, except in the case of Paraguay. Although it is on the threshold, Panama's income level is medium-high and Venezuela's emissions are more than double the optimum limit, but they are both medium-low-income countries. High-income countries such as Chile and Panama have a higher environmental impact.

With respect to the relationship between economic and social objectives, the highest HDI levels (above the optimal threshold of 0.80) were reported in those countries with high income (Chile and Panama) or close to the upper limit of upper-middle incomes (Argentina and Costa Rica).

When looking at institutionality through the governance index generated as part of the Legatum prosperity index pillars (which considers indicators such as executive constraints, political accountability, rule of law, government integrity, government effectiveness and regulatory

quality), one would expect them to reduce ecological impact but at the same time lead to better levels of per capita income and social performance.

Figure 3 is based on the classification of countries according to their governance index, with those that rank below 25th in the world ranking (Uruguay), those that rank between 50th and 25th (Chile and Costa Rica) and those that rank above 50th place, which covers the rest of the countries analysed, with Venezuela, Nicaragua and Honduras registering the least favourable performances.

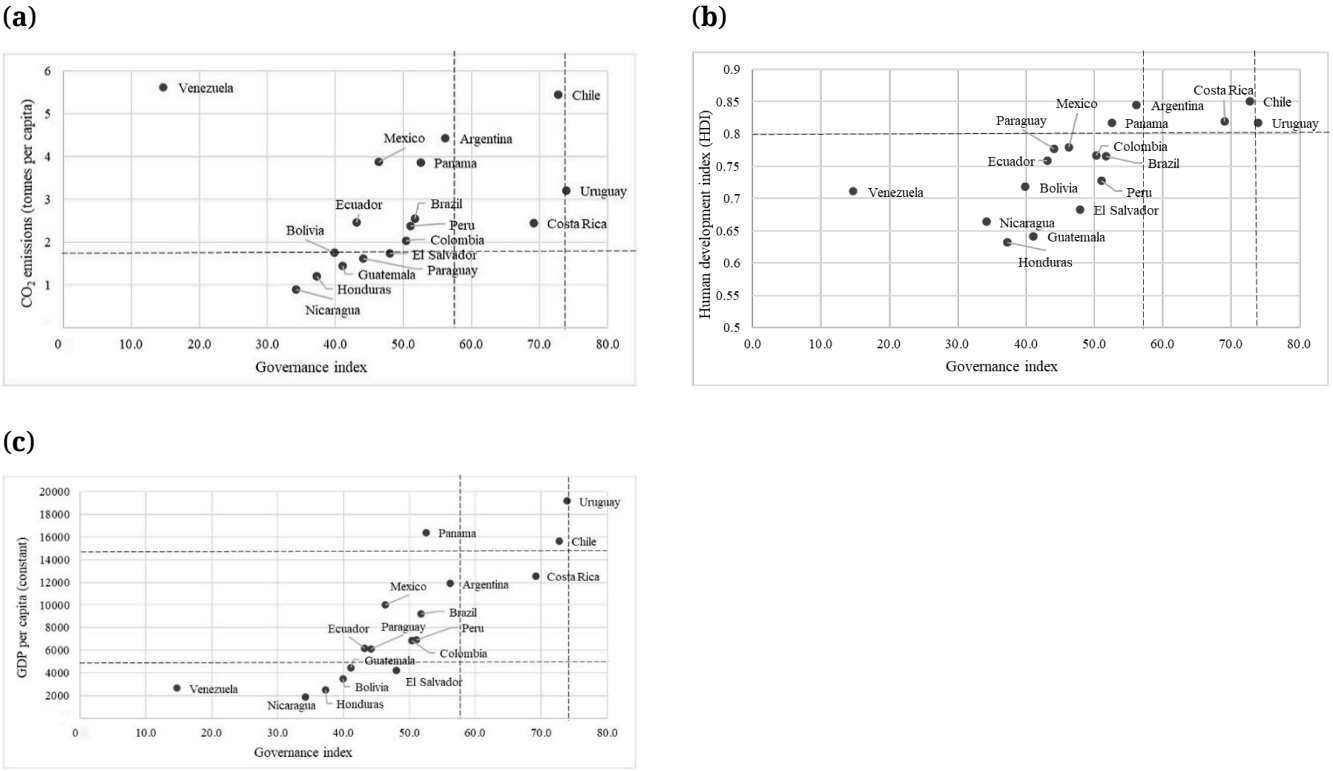

Figure 3. Economic, social and environmental interactions with the institutional framework (2020). (**a**) Interactions in the CO_2 emissions and Governance index. (**b**) Interactions in HDI and Governance index. (**c**) Interactions in the GDP per capita and Governance index. Note: prepared by the authors based on data from [39] and [41].

When comparing these governance results with economic and social performance, it is observed that the strengthening of governance leads to better income and human development levels but not with respect to ecological impact, whose relationship does not seem to indicate what is theoretically proposed since strengthened governance does not reduce environmental impact.

Specifically, Chile, with encouraging results in governance (29th place), reported together with Venezuela (the worst institutional performance at 167th out of 167 countries analysed) the highest levels of CO_2 emissions. It is also true that Costa Rica, ranked 34th in the governance index, slightly exceeded the suggested CO_2 emissions threshold and Colombia, ranked 71st, achieved results close to this environmental impact limit.

Panel Estimation of Dynamic Data Using GMM

To model the analysed interactions as well as the direct effect of each of the dimensions on sustainable development, measured through the SDI, three dynamic panel data models are estimated by considering the generalised method of moments. All three models consider the lagged SDI, given that the variable depends on its past (dynamic model) as well as the environmental dimension. The first model additionally incorporated the institutional or environmental dimension (social capital, safety and security, personal freedom and governance), as well as the interaction of this dimension with the environmental dimension. The second model also considers the economic dimension (investment, business conditions, infrastructure and economic quality), the interaction between this dimension and the institutional and environmental dimensions. The third model additionally considers the social dimension and its interactions with the institutional, economic and environmental dimensions.

In all the estimations, a robust GMM was required because in the three cases presented in Table 2, problems of heteroscedasticity were evidenced that did not allow the null hypothesis of over-identification of the Hasen-Sargan test to be accepted.

Table 2. Panel estimation of dynamic data for SDI by robust GMM.

Variables		Model 1	Model 2	Model 3
SDI first lag		1.0034***	1.0214***	1.0223***
		(0.0420)	(0.0246)	(0.0468)
Environmental Dimension		0.0449	0.0915**	0.3816***
		(0.0322)	(0.0395)	(0.1424)
InstitutionalDimension	Social capital	0.0846***	0.0414*	0.0552
		(0.0312)	(0.0248)	(0.0414)
	Safety and security	0.0425***	0.0197*	0.0154
		(0.0157)	(0.0116)	(0.0224)
	Personal freedom	0.0229	0.0180	0.0440
		(0.0365)	(0.0293)	(0.0296)
	Governance	0.0555**	−0.0037	−0.0087
		(0.0251)	(0.0258)	(0.0457)
Economic Dimension	Investment	-	0.0053	−0.0749
			(0.0305)	(0.0500)
	Business conditions	-	0.1172***	0.1658**
			(0.0398)	(0.0778)
	Infrastructure	-	−0.0213	0.0381
			(0.0260)	(0.0297)
	Economic Quality	-	0.0771***	0.0780***
			(0.0260)	(0.0261)

Table 2. *Cont.*

Variables		Model 1	Model 2	Model 3
Social Dimension	Living conditions	-	-	0.0731
				(0.0631)
	Health	-	-	0.1227*
				(0.0673)
	Education	-	-	0.1758*
				(0.0993)
Institutional and environmental interaction		-4.25×10^{-9}***	-4.07×10^{-9}***	-6.83×10^{-9}
		(1.58×10^{-9})	(1.43×10^{-9})	(4.26×10^{-9})
Institutional and economic interaction		-	1.36×10^{-14}***	1.44×10^{-14}*
			(4.81×10^{-15})	(8.04×10^{-14})
Institutional and social interaction		-	-	4.87×10^{-13}
				(4.98×10^{-13})
Environmental and economic interaction		-	-7.44×10^{-9}***	-9.33×10^{-9}*
			(2.40×10^{-9})	(5.32×10^{-9})
Environmental and social interaction		-	-	-6.45×10^{-7}**
				(2.94×10^{-7})
Economic and social interaction		-	-	1.13×10^{-13}
				(5.44×10^{-13})
Constant		−11.2570***	−15.6390***	−47.9720***
		(4.2140)	(2.9527)	(17.4022)
Wald test (chi2)		1.19×10^{6}***	261431.04***	2.50×10^{6}***
Arellano-Bond test for AR (1) in initial differences		−2.39**	−2.39**	−2.51**
Arellano-Bond test for AR (2) in initial differences		−1.10	−1.19	−1.18
Hansen test of overidentifying restrictions		14.71	3.81	0.20

Note: values in brackets with standard errors. Significant up to 1% (***), between 1% and 5% (**) and between 5% and 10% (*).

The estimations of the three models—in which the dimensions and their interactions are gradually added—allowed us in all cases to accept the hypothesis of the Hansen test of overidentification (validity of the instruments). This test was used because the presence of heteroscedasticity and its correction through a robust estimation meant that it was not possible to use the Sargan test. In addition, the Arellano-Bond hypothesis of no second-order autocorrelation was accepted in all models.

The first model's results indicate that the values achieved in the SDI depend significantly and positively on its first lag, as well as on social capital, safety and security and governance. With respect to the interaction between the institutional dimension and the environmental dimension, the result was negative, which corroborates what was analysed in the previous section. Thus, improvements in the institutional variables raise performance in terms of sustainability, although the interaction between these variables and the environmental dimension

reduces it. This is because although the regulatory framework has achieved improvements in social and economic aspects that contribute to sustainability, it has been at the detriment of environmental conditions.

In the second model, the first SDI lag as well as social capital, safety and security and the interaction of the environment with the institutional dimension remain significant and with the signs reported in the first model. In addition, the environmental dimension, business conditions and economic quality also contribute significantly to better sustainability outcomes but not the interaction between the environment and the economic dimension, which shows an inverse relationship with the SDI. In Latin American countries, as indicated above, economic development has been isolated from the environmental dimension, hence improved economic performance has been achieved because of higher carbon emissions, which is reflected in these results. Regarding the positive interaction between the institutional and economic dimensions, the rules and regulations established have been designed to obtain better economic and social performance that positively impacts the SDI, so that, although it has environmental effects, it seems that socio-economic improvements mitigate these effects.

With respect to the third model that considers the social dimension and its interactions with the institutional, economic and environmental dimensions, the results are maintained in terms of a direct and significant relationship with the first SDI lag, the environmental dimension, business conditions and economic quality in addition to health and education, included in this model (Table 3).

Table 3. Summary of the estimated direct effects of the dimensions on the SDI of the global model (Model 3).

Variables		Direction of the relationship	Significance
Environmental Dimension		+	Significant
Institutional Dimension	Social capital	+	Not significant
	Safety and security	+	Not significant
	Personal freedom	+	Not significant
	Governance	–	Not significant
Economic Dimension	Investment	–	Not significant
	Business conditions	+	Significant
	Infrastructure	+	Not significant
	Economic Quality	+	Significant
Social Dimension	Living conditions	+	Not significant
	Health	+	Significant
	Education	+	Significant

Note: The signs indicate the relationships of the explanatory variables with the SDI. A '+' sign indicates that as the explanatory variable increases the SDI improves, while a '–' sign implies a deterioration of the SDI as the explanatory variable increases.

In the institutional dimension, although no variable was statistically significant, the relationship is direct: improvements in institutional aspects increase sustainability, except in the case of governance, which showed an inverse relationship. As for the economic dimension, only investment showed a negative relationship with SDI; improvements in business conditions, infrastructure and economic quality have direct positive effects on sustainability, although only economic quality and business conditions are significant. Finally, all the variables of the social dimension have a positive impact on sustainability, but only education and health are statistically significant.

In terms of indirect effects, the results corroborate that the interactions between the institutional and economic dimensions, as well as institutional, economic and social, have a positive effect on the SDI, although only the first interaction is statistically significant (Table 4).

Table 4. Summary of the estimated indirect effects on the SDI of the global model (Model 3).

Variables	Direction of the relationship	Significance
Institutional and environmental interaction	–	Not significant
Institutional and economic interaction	+	Significant
Institutional and social interaction	+	Not significant
Environmental and economic interaction	–	Significant
Environmental and social interaction	–	Significant
Economic and social interaction	+	Not Significant

Note: The signs indicate the relationships of the explanatory variables with the SDI. A '+' sign indicates that as the explanatory variable increases the SDI improves; while a '–' sign implies a deterioration of the SDI as the explanatory variable increases.

The relationship between these interactions and the SDI indicates that improvements in the institutional framework strengthen economic and social performance, which in turn has a positive impact on the SDI, specifically in terms of the HDI (the numerator of the SDI), which compensates for and overcomes the ecological deterioration recorded in the countries analysed. Thus, although the institutional dimension does not show statistical significance in any of its variables (direct effect), its impact on economic and social conditions reinforces individual results, specifically in terms of health, education, business conditions and economic quality. Additionally, despite not being significant, the interaction between the economic and social dimensions also reinforces and contributes to improving the SDI results (at least in terms of the numerator).

In the case of the other interactions, the results show negative signs. Only the interactions between the environmental dimension and the economic and social dimensions are statistically significant. Thus, better

economic performance in terms of business conditions and economic quality implies an environmental deterioration that has a negative impact on sustainability. Although it improves human development, the effect on the ecological impact reduces the SDI. In any case, the result of this interaction is lower than the direct effects of the variables of the economic dimension that were significant, so the aggregate effect implies an improvement in the SDI.

The environmental and social interaction similarly shows an inverse relationship, in the sense that an improvement in terms of ecological impact reduces human development and thus the SDI, given that better social performance demands better levels of income and productivity, which would imply an environmental sacrifice for these countries. Despite this negative impact, the aggregate results show that the effects of health, education and environment on the SDI are larger than the negative effect of the interaction.

DISCUSSION

The evolution of the concept of sustainable development has revealed the difficulties in reaching a consensus in terms of its ends and means, as well as in harmonising the systems or dimensions that comprise it. In the first case, although Brundtland's proposal [2] initially emphasised nature conservation and the satisfaction of generational needs, it has been difficult to consider economic growth as a means rather than an end, as there are still major imbalances, differences and inequalities. This is especially true in Latin American countries, which have not overcome poverty or achieved human development objectives. Various authors [26,27,30] warn of the need to rethink sustainability objectives in the light of moral imperatives, placing the satisfaction of society's basic needs above any other purpose, understanding that there are environmental limitations.

In the second case, harmonising social, environmental and economic performance within a framework of formal and informal institutions, in addition to cultural elements (social capital), has been a challenge that has not yet been overcome and, as the results indicate, is difficult to balance [8,28,29,31–33]. The strengthening of institutions is recognised as a key element to incentivise the reduction of the environmental impact of economic growth and improvements in social development [11,19,20] through property rights, the regulatory framework, a decrease in corruption and increase in transparency, citizen participation in management and decision-making and the strengthening of decentralisation processes. Nonetheless, efforts in this area, at least in Latin America, have not been related to improvements in environmental conservation.

Unlike authors such as [20] who identify a certain positive impact whilst recognising that institutional changes are long-term and their effects even require cultural modifications, the results of this study fail to

identify significant direct effects of the variables considered in the institutional dimension or their interaction with the environmental or social dimension. However, the economic dimension did have a significant interaction. Regarding the environmental and social dimensions, the Latin American countries that managed to strengthen their institutional framework achieved better results in terms of HDI and per capita income but at the cost of higher CO_2 emissions and material footprint.

As reported in the literature [8,28,29,31–33], the interactions between the dimensions show strong tensions that demand the prioritisation of the SDGs, even more so in countries with notable inequalities. For Latin America, social development has been the focus of public policies, driven by economic growth, but it is also necessary to recognise the progress made in terms of institutionalisation and ecological impact in recent years.

While the strengthening of institutions has been directed towards improving the wellbeing of the population, eradicating poverty and reducing existing gaps, it has also contributed to economic growth. Yet the challenge remains to consider nature as a non-substitutable and scarce factor of production by encouraging new business models, clean technologies and circular processes, which require infrastructure, green financing, investment and resources that are limited in these economies.

For Latin America, improvements in the SDI are associated with the economic and social dimensions (weak sustainability). This is reinforced by the strengthening of the institutional framework but with higher levels of CO_2 emissions and material footprint, whose indirect effects with the rest of the dimensions condition the possibility of achieving better results in terms of sustainability and of achieving strong sustainability. This is despite the existence in some countries of a regulatory framework that recognises nature as a heritage.

CONCLUSIONS

Given that the dependent variable used is an index that considers social and economic objectives as the numerator and environmental impact as the denominator, the results corroborate that improvements in the environmental dimension indicators make it possible to achieve higher levels of sustainability by reducing the ecological impact. The institutional framework does not contribute significantly to the SDI, whereas business conditions, economic quality, health and education do.

The interactions of the environmental dimension with the institutional, economic and social dimensions were negative, so the improvement in the SDI is achieved through human development (social and economic) but not through the reduction of the ecological impact, although in all cases these indirect effects are smaller than the direct ones.

Institutionality reinforces the direct positive effect of business conditions and economic quality on the SDI. This effect on the numerator (the HDI) is also reinforced by the direct and significant effect of improvements in terms of education and health and of the interaction of

the social dimension with the institutional dimension, although it is not significant.

Integrating the dimensions of sustainable development in Latin America is a complex process that must overcome major challenges associated with persistent gaps and inequalities in the region, which complicate the equitable distribution of the benefits of sustainable development. In addition, many communities, especially in rural areas, lack access to essential services, such as education, healthcare and clean water, limiting their ability to participate in sustainable initiatives.

The economies of many Latin American countries rely heavily on the extraction and export of natural resources, such as oil, minerals and agricultural products, which can be incompatible with environmental sustainability. This model prioritises short-term economic growth over environmental preservation, which generates conflicts between economic and environmental objectives. Furthermore, the integration of social, economic and environmental policies often lacks coordination between different levels of government and sectors, which is further hampered by corruption and a lack of transparency as well as the weak institutional framework needed to implement effective sustainable policies.

From an environmental point of view, Latin America must also address its vulnerability to natural disasters that can divert resources and attention from sustainable development initiatives, which is even more worrying in a context where the implementation of climate change adaptation and mitigation measures can be costly and compete with other economic and social priorities.

This is compounded by cultural challenges associated with ethnic diversity, social conflicts related to unequal distribution of resources and social exclusion, lack of investment, dependence on external aid, low environmental awareness, and a shortage of capacity building and training programmes in sustainable practices for communities and industry sectors.

In view of the results found, the challenge in Latin America is therefore associated with the implementation of an integrated approach that orients public policies towards the preservation of the environment while strengthening social and economic objectives. Strategies should therefore consider incentives for new forms of business, the use of information and communication technologies, the orientation towards a circular and digital economy, encompassing the promotion of renewable energies, sustainable management of natural resources, sustainable agriculture, sustainable urban development, waste management, climate change mitigation and adaptation, the strengthening of environmental governance and environmental education and awareness. These policies will not only contribute to environmental protection but will also promote economic development and social welfare in the region through their direct effects as well as interactions.

Based on the specific characteristics of each country, strategies should

be oriented towards: creating policies that explicitly integrate social, economic and environmental objectives, ensuring the participation of all stakeholders; strengthening institutions, promoting education and using sustainable technologies and innovative practices; and supporting regional and international partnerships to share knowledge, resources and best practices in sustainable development.

DATA AVAILABILITY

The dataset analyzed in the study can be found at [39–41].

CONFLICTS OF INTEREST

The author declares that there is no conflict of interest.

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