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The Collapse of Venezuela vs. The Sustainable Development of Selected South American Countries

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Abstract: The purpose of the study is to examine the longitudinal trajectories of five selected South American countries in the period between 1990 and 2018, applying the Quintuple Helix Innovation Model (QHIM). The aim is to analyse the trends of each country through the relationship of its helices using indicators extracted from an international database in order to establish their articulation and synergies to go in search of sustainable development. Within this dynamic, Venezuela represents the axis country of the study and Argentina, Chile, Colombia, and Peru make up the group that allows the comparison. The research focuses attention on two periods of Venezuelan politics since they allow measuring the variations of the countries under study. The base year is 1996 and is called the pre-Hugo Chávez Frias (HCF) period; the cutoff year for the comparison is 2014 and is called the post-HCF period. The study is longitudinal and descriptive. For the analysis, the five knowledge subsystems (helices) of the QHIM were redefined in order to have precise concepts; a database was designed based on World Bank indicators that were later thematically related to each of the helices. The interrelationships between the helices of each country were also specified in order to determine which were the weakest and which had the most positive or negative influence. In order to calculate the percentage variation of the countries, the Data Envelopment Analysis (DEA) method was applied. In this sense, the most relevant finding is related to the decisions made in the last twenty years from the political helix in Venezuela because it deactivated and disarticulated the others, causing that country to collapse.

Keywords: Venezuela; peripheral countries; Quintuple Helix Innovation Model; sustainable development; comparative study; collapse

1. Introduction

The search for sustainable development by each country in today's competitive world involves the intensive use of knowledge that, synergistically among its actors, enhances innovation initiatives that result in decision-making aimed at the progressive improvement of the living conditions of its population [1]. Based on this argument, this study examines the performance of five South American countries selected under two criteria, similar population size and investment in Research and Development of less than 0.5% of their GDP, in order to determine whether, in the period between 1990 and 2018, each of them evolved positively [2]. In this general framework, Venezuela is used as the axis of the research and two key political moments of that country are identified to evaluate its performance, as well as those of Argentina, Chile, Peru, and Colombia. Therefore, the key question

guiding the research is: can a country's sustainable development be determined by the influence of the political decisions taken at specific historical moments?

Venezuela's transition from a democratic to a socialist government marked a before and after regarding its development [3]. For this reason, a comparative study was carried out in the same region to observe longitudinally each of the five selected countries and determine whether the political actor played a relevant and dominant role, positive or negative, over the other actors in each one of them. The Quintuple Helix Innovation Model (QHIM) was selected for the evaluation, which defines actors as helices and, in turn, the latter act as interacting knowledge subsystems. Two measurements were applied; the first one considered the use of families of indicators for each of the five helices between 1990 and 2018 in the five countries. In the second, a statistical test known as the Data Envelopment Analysis (DEA) method was used to validate trends at two-time intervals. In that sense, the argument that supports this measure is based on determining the situation of the five countries in 1996, just two years before President Hugo Chávez Frias came to power. The second evaluation was carried out in 2014, just one year after the abrupt departure from power due to his death [4].

An analytical perspective of the focus of this study is to examine how tolerance and trust promote innovation in enabling environments for helices to generate initiatives that allow the development of capabilities [5]. However, these effects are nuanced in a context of increasing social diversity, and this serves to weaken the links between the helices and make it difficult for people to share information and knowledge and thus generate "social control" [6,7].

Under Chávez's governmental mandates between 1999 and 2013, significant changes were made in the regulatory frameworks, in government institutions, in the education system, and in the productive sector, affecting the environment and society itself. The most striking thing about this case was that, in spite of being the period of highest economic revenues in the history of Venezuela due to the exponential increase in the price of the oil basket, that country regressed significantly [8].

For its part, the South American region experienced dictatorial processes and critical situations of violence and hyperinflation, among other events, in the second half of the last century that forced significant percentages of these populations to emigrate, mainly to neighbouring countries [8]. Argentina and Chile went through military regimes and Peru and Colombia experienced economic problems, guerrilla warfare and drug trafficking. Since 1990, at different rates, but each one with a democratic system of governance, they have been able to progressively improve the general conditions of their population and correct development problems, without ignoring the fact that the region is peripheral [8]. However, precisely one of the failures detected in these types of countries is the low capacity of articulation among its helices and this factor hinders the development of innovative initiatives.

Consequently, the premise is that the sustainability of countries is based on the generation of spirals of articulated knowledge, with the active participation of the helices that are properly applied to facilitate progress [9]. In that line, one differentiating factor of development is to know the capabilities of each country and, in that regard, the educational helix, which includes R&D, which plays a fundamental role.

When the political helix does not work properly, the set of dynamic interactions associated with public policies hinders the interactions of the other helices [10]. Countries that progress in a sustained manner do so because their helices are adequately articulated with medium- and long-term plans [11]. That is to say, the measures adopted by a society are oriented towards the search of the welfare of the people.

This study identified that the Quintuple Helix Innovation Model has not yet been applied to peripheral regions to investigate the relationship between causes and effects related to the sustainable development of such countries. No studies were found in which families of indicators were applied to each of the helices; in order to achieve a conceptual approximation between the helices and the indicators, the former were redefined.

2. Literature Review

Theoretical-Conceptual Approaches

This section identifies the most cited models in the specialized literature that explain the relationships between the actors of a society and presents them in Table 1. What underlies as a backdrop in each approach are the policies required to promote sustainable development in a country and the interactions between the actors that convey that progress.

Sustainable development (SD) emerged as a concept in 1987 in the publication of the Brundtland Report and sought to warn of the negative consequences being generated in the environment by economic development and globalization [12]. It referred to the ability to meet the needs of the present generation through the consumption of natural resources without compromising their availability for future generations [13]. There is a difference between sustainable development and sustainability, because the latter is an objective of the former. Nowadays, it is assumed that SD is an improvement in the environment and in the quality of life of people without endangering the sustenance for the survival of future generations and the planet. The three pillars of the SD are economic, social, and environmental sustainability [14].

Table 1. Evolution of the approaches used as guides to achieve sustainable development.

Author(s)	Typologies	Evolution
Bush (1945) [15]	Linear model	Considered as the first explanatory approach to the relations between government, industry, and universities. This interpretation was considered as a linear process since it described the generation of knowledge as the progression of what scientists did in their laboratory, then it passed onto the engineers in order to look for applications, and finally, the product reached the market
Botana and Sábato (1968) [16]	Sábato's Triangle	This approach allowed for understanding the importance of the interactions between the three actors (government–university industry). The basic relations between the vertices of the triangle were also defined. This model had among its objectives to present a development proposal. The authors considered the political actor as the mobilizer and generator of circuits.
Freeman (1987) [17]	National Innovation Systems (NIS)	The NIS definition recognizes the importance of knowledge in all its forms. It is the engine of change and plays a crucial role in the economic and social progress. Therefore, it is complex and systemic. This approach has been widely used in Latin America and has been evolving.
Callon (1994) [18]	Research Compass Card model	This Eurocentric view of social actors explains the characteristics and interactions of developed countries. Quality education is a key factor to understand the dynamics of the other actors. This model presents five analytical dimensions that are articulated to generate initiatives.
Gibbons (1994) [19]	Mode 1 and Mode 2	The new production of knowledge is linked to new practices and different relationships. Passing from mode 1 to mode 2 implies going from the disciplinary to the interdisciplinary; from the laboratory to the context of applications; from institutional knowledge to networked knowledge and where the scientist is one more actor.
Leydesdorff and Etzkowitz (1998) [20]	Triple Helix	This model is a tool that applies to developed countries because it assumes that some activities are automatically related to economic growth. While this is true, the model focuses on universities but recognizes the dynamic interactions with the other actors. It even proposes the creation of new intermediary organizations that are relevant for promoting knowledge generation processes.
Chesbrough (2003) [21]	Open innovation	This approach was considered as a new paradigm for innovative organizations. It assumes that companies generate new dynamics of identification and use of knowledge in and out of the organizations. It promotes a logic based on continuous change and allows interacting with new agents.

Table 1. *Cont.*

Author(s)	Typologies	Evolution
Carayannis (2006) [22]	Mode 3	This new mode, called hybrid, focuses on closing the gaps between innovation and civil society. It assumes that emerging technologies do not always coincide with society's demands and needs, which limits their potential impact. It proposes as a central element to adopt new strategies to seek the development of a competitive and knowledge-based society.
Carayannis (2010) [23]	Quadruple Helix Innovation Model	The evolution to the fourth helix comes from the relationship between models such as Mode 2 and the triple helix. It incorporates a new 'actor' defined as the environmental one. It is interpreted that renewable and non-renewable natural resources must be part of a new culture that aims to take care of the planet and the decisions of each actor must have an impact in favour of this aspect.
Carayannis et al. (2012) [24]	Quintuple Helix Innovation Model	Under the same approach of the helices, a fifth is incorporated which was defined as a new subsystem of knowledge called social capital. This actor (society) must be the interlocutor and auditor of the decision-making processes. In this model, social media plays a key modelling and moderating role. It suggests that universities are the mobilizers of the main initiatives that lead to innovative proposals aimed at solving problems.

Vannevar Busch's model could be considered as a valid starting point to explain the sustainable development of countries, beginning with the idea that science played a preponderant role [25]. Undoubtedly, the creation of the agencies that finance S&T activities has gravitated, to a greater or lesser degree, in the sustainable development of the countries [10]. However, to progress, a set of transversal decisions is required that allows long-term measures to be applied, handling different scenarios, among which are the social, economic, political, educational, health-related, technological, and cultural ones.

Regarding the theoretical approaches most used in Latin America, Sábato's Triangle is identified in the first place. This proposal was published in 1968, and it could be asserted that the general proposals are still valid. Moreover, this model served as the basis for neo-approximations as the triple helix of development directly and, indirectly, for others. The initial approach was based on designing a model of scientific-technological policy that would leverage the structure that allows supporting the productive apparatus of each country with knowledge. The authors argued that there should be synergy among the three actors (agents) and expressed that the State was the one that designed and executed public policy. They spoke of the capacity to generate knowledge from what they called scientific-technological infrastructure (provider of technology) and from the demand that the productive sector requires [16].

Another of the approaches used in the region to explain the dynamics of the countries in favour of development is the one referred to as the National Innovation Systems (NIS). The co-evolution of the definition of this model has been constant and has been modified in the last three decades. It was originally defined as a network of public and private institutions "whose activities and interactions initiate, import, modify and diffuse new technologies" [17]. A multiplicity of specialists addressed this issue developing a significant number of contributions [1,26–31]. New approaches appeared related to how social innovation systems operate [32]. Other proposals have even raised what they called national business systems [33]. In addition, in fact, the scalability level of the approach has been changing along with its conceptual typology that now includes definitions such as the following: national innovation systems, regional innovation systems, local innovation systems, technological innovation systems, sector innovation systems, social innovation systems and, even, the discussion about the global innovation system has been started [11,34].

A different approximation to the approaches about the functioning of a contemporary society is the one proposed by the team led by Gibbons known as the new production of knowledge and exemplified in what they called Mode 1 and Mode 2 [19]. The adoption of new ways of managing the dynamics related to R&D and the innovative role that is required to impact on social improvements

affect the cultural setting. This means that a new common sense must be applied. In this context, the new mode of knowledge production is replacing or reforming established institutions, disciplines, practices, and policies. In summary, Mode 1 is related to the linear model of thinking about R&D, and Mode 2 is linked to an interactive model. This indicates that Gibbons's team shows the transit from the schemes based on the problems defined in the academic field, which are transferred to be solved in the context of the applications. This model reflects another evolution by going from the disciplinary to the multidisciplinary. Moreover, it goes from rigid organizational forms to a heterogeneous effort where various organizations intervene, from schemes where science does not have a direct responsibility in the social, to a new reflective scheme where values and social interests are considered. Finally, this approach shows the evolution where the results are not only academic but also the society is the valid interlocutor of said results [19,35].

This approach proposed by Gibbons's team has evolved and new proposals have emerged that even speak of a Mode 3. These theories suggest that the advance of different aspects (socio-technical change) affects the knowledge–innovation relationship. They indicate that there is a co-evolution of emerging modes of interaction based on pluralism or the participation of social actors to generate value to society [24,36].

One of the most cited models in the world is the Triple Helix of Development proposed by Leydesdorff and Etzkowitz (1998) [20]. This approach uses the same actors as Sábato's Triangle, but the centre of gravity shifts from government to universities, research centres, and institutes. This model describes and analyses the relationships between universities, industry, and government as a dynamic process that seeks solutions. For the authors, the heuristic theme that revolves around the analysis of innovation processes is of particular interest. In reality, it is a normative scheme that influences the design of innovation policies. Its constant evolution is related to the promotion of new processes both for the market and for the resolution or reduction of social problems [37–39]. This model has already been applied to countries in the Latin American and Caribbean regions, specifically in the Dominican Republic, incorporating the issue of open innovation from a global perspective [40].

The focus on open innovation was developed by Chesbrough [21] and has been considered as a new paradigm given the impact on its applications. Its evolution has been marked by its use in subjects such as open science and its most recent application as a method for the design of public policies [41].

Beyond the co-evolution of the approach, both by the seminal authors and by other specialists, an advancement of the model was proposed in which a helix was included and it was named the Quadruple Helix Innovation System. This new helix adds the factor linked to public aspects based on the media, culture, and civil society as an important interlocutor of what is propelled in the other three helices [24]. This means that society has a weight of relevance in the decisions if their general educational level is adequate to be a true interlocutor [42].

A new theoretical–conceptual breakthrough emerged in this line known as the Quintuple Helix Innovation Model, also proposed by Carayannis et al. (2012) [24]. This approach includes a new helix to those already mentioned and it is called natural capital (environment and its protection). The abuse of renewable and non-renewable natural resources is no longer conceived without the global society participating in the substantive decisions on the impact this generates.

This model of the Quintuple Helix of Innovation was based on an exhaustive review of the knowledge production models of Gibbons: Mode 1, Mode 2, and Mode 3, and the Triple and Quadruple Helix to propose a more evolved and integrating model [36]. This implies that, if this model were applied to a country and its performance were evaluated based on the operation of the helices, the one that manages to articulate the dynamic capabilities of the five helices based on the circulation of knowledge would be conceived as a success. Therefore, it would guarantee, in theory, sustainable development.

As it is logical, with theoretical–conceptual efforts of this magnitude, a prolific discussion of each of them was generated and the initial postulates evolved towards new explanatory approaches, without implying the existence of global agreements in any of them.

Once the theoretical–conceptual models were examined, the one called Quintuple Helix of Innovation was selected for the present study. It is considered the most advanced and will be applied to Venezuela, Colombia, Peru, Chile, and Argentina. Figure 1 shows the model and its components divided into 5 helices.

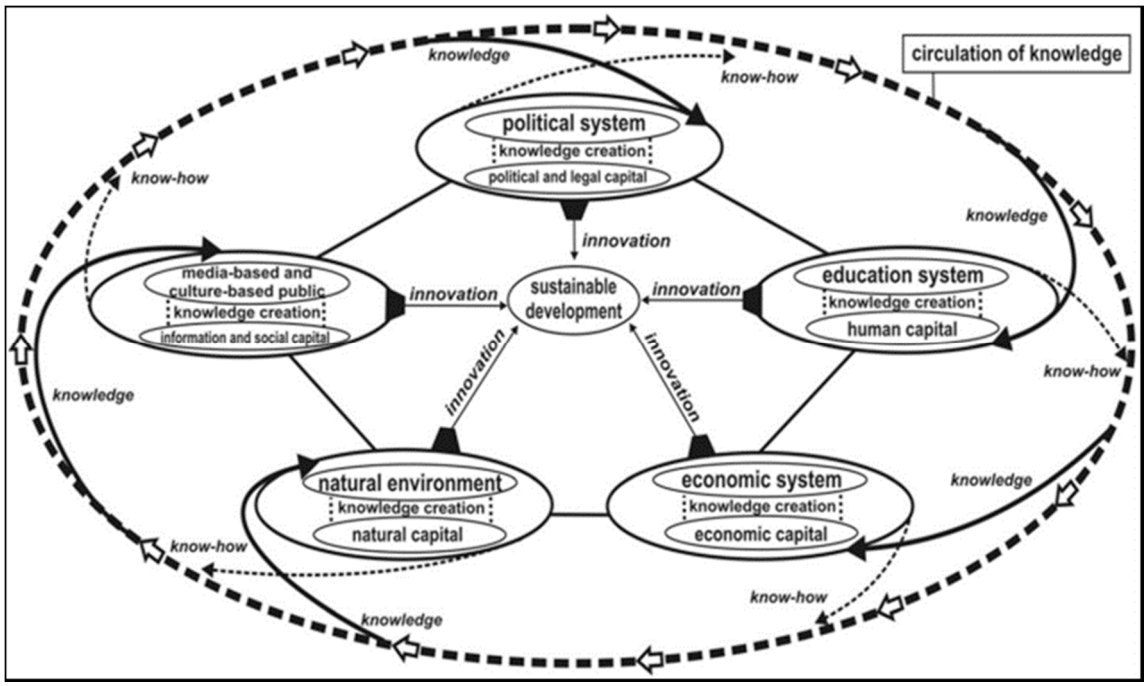

Figure 1. Quintuple Helix of Innovation Model (QHIM). Source: Carayannis et al. 2012 [24].

This model will be the theoretical basis and conceptual adjustments will be made to each of the helices to relate them to the families of indicators that were deliberately selected. Each helix will be seen as a knowledge subsystem (know-how) that feeds back to the general knowledge system as interactive spirals that generate constant circulation of knowledge. The objective is to identify innovation processes aimed at improving decision-making in each country.

3. Methodology

In this study, different steps were taken in order to organize the information used in each section. The first step was directed to support the theoretical–conceptual framework that served as a reference to determine the global trends driven by knowledge based on the four industrial revolutions.

A second step focused on the exhaustive review of the specialized literature to identify and select an explanatory model that would allow for analysing the performance of the countries examined.

The third step was oriented to search for indicators in multilateral institutions' databases that allowed evaluating each helix separately, using structured statistics in the group of figures.

The methodological strategy used a time window between 1990 and 2018, in which annual statistical series were structured for each graph. Subsequently, infographics were built for each helix, in order to give coherence to each subsystem. Finally, the analysis of the cross-knowledge information of each helix was carried out to examine the systems in each country.

For each of the five helices, statistical international data from the World Bank and The Network for Science and Technology Indicators - Ibero-American and Inter-American (RICYT) were used. It is important to note that the original definitions of each indicator were used. This allows for the data to be comparable for all the countries in the same period.

Specifically, it is interesting to apply families of indicators to each helix seeking comparability of the selected countries in the period studied. The objective is to determine what the set of measures taken

in each of them has been, in order to assess whether it is oriented towards the search for sustainable development (see Table 2).

Table 2. Definition of the helix indicators selected and relationship between the helices and indicators used in Figures 2–6.

Helix	Definition	Indicator Selected	Relation Between Helix and Indicators
Political System Helix	The helix related to the Political System is managed by governments. It is understood as a subsystem of knowledge with transversal impact on all the helices	2.(a) Voice and Accountability 2.(b) Political Stability and Absence of violence 2.(c) Government Effectiveness 2.(d) Regulatory Quality 2.(e) Rule of law 2.(f) Control of Corruption	(a) It seeks to measure performance based on the series of government decisions that are taken on issues such as the control of corruption at all levels. (b) It is understood as the collection of the perceptions on the quality of public services and on the quality of the public function. Another measurement has to do with political stability and the absence of violence, including terrorism. (d) It is understood as the capture of the perceptions about the capability of the government to formulate and apply sound policies and regulations. (e) It is understood as the set of perceptions about whether the agents trust the rules of society and abide by them. (f) It is understood as the perceptions of the extent to which citizens of a country can participate in the selection of their government, as well as freedom of expression, freedom of association, and free media.
Education System Helix	The helix defined as the Education System is linked to science and technology activities. It is conceptualized as a subsystem of knowledge based on training and research that also has a transversal impact on all the helices.	3.(a) Doctoral Graduates 3.(b) Number of Scientists 3.(c) Patent Granted 3.(d) Ratio (%) Patents granted/Patent applications 3.(e) Publications in WoS 3.(f) Publications in WoS (per 1,000,000 inhabitants)	To measure it, the following indicators are used: indicators linked to doctoral-level training and size of the scientific community, and output indicators related to the scientific articles published in the Web of Science (WoS) and the granted patents.
Economic System Helix	The helix called the Economic System is another subsystem of knowledge and refers to the improvement of the market, to new jobs and to the growth of the economy.	4.(a) GDP (thousands of millions of US$) 4.(b) Inflation, consumer prices (annual %) 4.(c) Total Reserves (Thousands of millions of US$) 4.(d) Gross savings (% of GDP) 4.(e) FDI, net inflows (% of GDP) 4.(f) Starting a business	(a) This is defined as the price of the buyer and is the sum of the gross added value of all producers residing in the economy plus any tax on the product, minus any subsidy not included in the value of the products. (b) This indicator is measured through the consumer price index. (c) It is defined as the country's Total Reserves. (d) It is calculated as the gross national income minus the total expenditures, plus the net transfers. It is understood as the acquisition of a long-term management interest through direct investment of foreign capitals in net investment inflow. (d) The last indicator refers to the activities that allow starting a business in a given country.
Natural Environment Helix	The helix defined as environmental refers to the natural capital of each country and the protection that is made of it through global and local measures.	5.(a) CO_2 Emissions 5.(b) Renewable energy consumption 5.(c) Electric power transmission and distribution losses (% of output) 5.(d) Methane emissions	(a) It is understood as the carbon dioxide emissions that are derived from the burning of fossil fuels and the manufacture of cement. It is understood as the consumption of renewable energy and its share in the total final energy consumption. It measures transmission and distribution losses including theft. It is interpreted as the methane emissions that are derived from human activities such as agriculture and industrial production of methane.
Media-based and culture-based public Helix	The public helix is based on media and culture. In this study, it is defined as the capacity of interlocution of society as a whole to deal with the other helices, especially with the measures taken by governments.	6.(a) Intentional homicides (per 100,000 people 6.(b) Prevalence of undernourishment (% of population) 6.(c) Global Peace Index 6.(d) Unemployment, total (% of total labour force) 6.(e) Life expectancy at birth (years) 6.(f) Air transport, registered carrier departures worldwide	(a) It refers to intentional homicides and is understood as estimates of unlawful killings inflicted on purpose as a result of domestic disputes, interpersonal violence, violent conflicts over land resources, intergovernmental violence over lawns or control, and predatory violence and killings by armed groups. (b) It refers to the population that is below the minimum level of food energy consumption. It is used to report annual changes in the state of global peace at the subnational, national, regional, and global levels. (c) The GPI is highly correlated with other measures of quality of life. (d) It is defined as the proportion of the labour force that does not have a job but is available to look for a job. (e) It indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life. (f) It includes the departures of registered carriers around the world. They are take-offs and national take-offs abroad of the airlines registered in a country.

This theoretical–conceptual discussion seeks to focus the analysis in a space that has not been worked on in the specialized literature of sustainable development in peripheral countries. For this

reason, the definitions of each helix in the model applied were adapted and selected families of indicators that demonstrate these aspects were used.

3.1. Data Envelopment Analysis Model

In order to assess the trajectories of each of the five countries, two periods were selected between 1990 and 2018. The criterion used was as follows: 1996 was selected as the base year to determine where each country was in the period prior to the arrival of Hugo Chávez Frias (HCF) to the presidency of Venezuela. The year 2014 was selected because HCF left the presidency in 2013 and it is intended to determine if there was any percentage variation between the countries. The Data Envelopment Analysis (DEA) method was used to determine this condition. This model allows us to estimate the efficiency level of each country, in regard to other countries, in each year selected. With this we will able to evaluate if the efficiency of the country has changed or has remained constant over time.

DEA is a non-parametric technique for estimating the efficiency of the economic units under study, called Decision-Making Units (DMUs), based on the inputs used and the outputs generated. DEA was built based on the concept of efficiency proposed by Farrell [43] and later popularized by Charnes et al. [44] and Banker et al. [45]. An advantage of DEA models lies in the few assumptions that they propose in estimating the production frontier that converts inputs into outputs.

The production frontier is generated through linear programming, which considers each of the DMUs under study for its construction. The efficiency index of each DMU is measured by the distance of that unit and the estimated production frontier for all DMUs under study. Thus, a DMU is said to be efficient if its index is equal to 1 and it will be inefficient if the indicator is less than the unit. In this paper, the DMUs represent each of the countries, which can be seen as the production functions that generate different outputs through the combination of a set of inputs. DEA models take two forms: (i) input-oriented and (ii) output-oriented. In the first approach, the linear programming model is configured so as to determine how much the input use of a firm could contract if used efficiently in order to achieve the same output level. In contrast, in output-oriented DEA, the linear programmer is configured to determine a firm's potential output given its inputs if it operated efficiently along the best-practice frontier.

Let us define the set of DMUs as $J = \{1, 2, \ldots, n\}$, where each DMU is composed of m inputs and s outputs. We denote the input and output vectors for each *DMUj* by $\mathbf{x}_j = \left(x_{1j}, x_{2j}, \ldots, x_{mj}\right)'$ and $\mathbf{y}_j = \left(y_{1j}, y_{2j}, \ldots, y_{sj}\right)'$, respectively. The matrices of inputs and outputs *X*, *Y* are defined as:

$$\boldsymbol{X} = (x_1, \boldsymbol{x}_2, \cdots, x_n) \in \mathrm{R}^{mxn} \tag{1}$$

$$\boldsymbol{Y} = \left(\boldsymbol{y}_1, \boldsymbol{y}_2, \cdots, \boldsymbol{y}_n\right) \in \mathrm{R}^{sxn} \tag{2}$$

The production possibility set is defined using the nonnegative combination of DMUs in the set J as:

$$P = \left\{(x, y) | x \geq \sum_{j=1}^{n} \lambda_j x_j, 0 \leq y \leq \sum_{j=1}^{n} \lambda_j y_j, \lambda \geq 0\right\} \tag{3}$$

According to Banker et al. [45], the output-oriented DEA model can be represented as follows.

We use the output-oriented model since we do not have input variables.

$$\begin{aligned} &\underset{\theta_1,\ldots,\theta_S,\lambda_1,\ldots,\lambda_n}{Max} \quad \theta \\ &s.a \\ &\sum_{j=1}^{n} y_{rj}\lambda_j \geq \theta y_{ro}, r = 1,2,\ldots,s \\ &\sum_{j=1}^{n} x_{ij}\lambda_j \leq \theta x_{io}, i = 1,2,\ldots,m \\ &\sum_{j=1}^{n} \lambda_j = 1 \\ &\lambda_j \geq 0, j = 1,2,\ldots,n \end{aligned} \tag{4}$$

where θ is the efficiency score, y_{ro} and x_{ro} are the values for the r^{th} output and the i^{th} input for the DMU of interest (DMU_o), respectively; y_{rj} is the value of the r^{th} output for the j^{th} DMU, x_{ij} is the value of the i^{th} input for the j^{th} DMU.

3.2. DEA Model only with Outputs

In this paper, we only have indicators about different aspects of each country, which are considered as our output variables. However, inputs variables are missing. To deal with this problem, we apply an extension of the DEA model, proposed by Lovell and Pastor [46], which does not take into account inputs (or outputs if it is the case). The output-oriented DEA model in line with Lovell and Pastor [46] can be defined as follows:

$$\begin{aligned} &\underset{\theta_1,\ldots,\theta_S,\lambda_1,\ldots,\lambda_n}{Max} \quad \theta \\ &s.a \\ &\sum_{j=1}^{n} y_{rj}\lambda_j \geq \theta y_{ro}, r = 1,2,\ldots,S \\ &\sum_{j=1}^{n} \lambda_j = 1 \\ &\lambda_j \geq 0, j = 1,2,\ldots,n \end{aligned} \tag{5}$$

Considering an efficient DMU, we propose here that each output to be increased can be treated as a separate objective function, thus, the following model considers as objective functions the independent optimization of the increment of each output in order to subsequently obtain an aggregate relative efficiency for the country (DMU) of interest [47]:

$$\begin{aligned} &Max\theta_1 \\ &Max\theta_2 \\ &\ldots \\ &Max\theta_s \\ &s.a \\ &\sum_{j=1}^{n} y_{rj}\lambda_j \geq \theta y_{ro}, r = 1,2,\ldots,S \\ &\sum_{j=1}^{n} \lambda_j = 1 \\ &\lambda_j \geq 0, j = 1,2,\ldots,n \end{aligned} \tag{6}$$

The problem with the above model is that it is difficult obtain an optimal solution due to the fact that all objectives have to be optimized simultaneously. So, we apply a global criterion that

mathematically combines multiple objective functions. The following model sums up the set of all objective functions:

$$\begin{aligned} &\underset{\theta_1,\ldots,\theta_S,\lambda_1,\ldots,\lambda_n}{Max} \sum_{s=1}^{S} \theta_s \\ &s.a \\ &\sum_{j=1}^{n} y_{rj}\lambda_j \geq \theta y_{ro}, r = 1,2,\ldots,S \\ &\sum_{j=1}^{n} \lambda_j = 1 \\ &\lambda_j \geq 0, j = 1,2,\ldots,n \end{aligned} \tag{7}$$

This system will produce a vector of $(\theta_{o1},\ldots,\theta_{oS},\lambda_{o1},\ldots,\lambda_{0n})$ for DMU_o. After solving the same system for every $DMU_i, i = 1,\ldots,n$, we can use the results to build an efficiency index for each country:

$$\theta_n = \frac{1}{S}\sum_{s=1}^{S}\frac{1}{\theta_{ns}}$$

4. Results

The Quintuple Helix Innovation Model (QHIM) is the basis of the analysis to compare the five selected countries. Next, each helix is examined independently as a sub-system of knowledge, using families of specific indicators to subsequently cross-fertilize the knowledge of all the helices to analyse each system (country).

The helix presented in Figure 2 represents the Political Sub-system and this is managed by each government. Six graphs (Figure 2a–f) are shown, in which Venezuela presents negative trends unlike the other countries assessed.

The Control of corruption is measured in Figure 2a. The data show that Chile is the only one of the 5 countries with positive data and it remains in a range of 1 to 1.5 throughout the study period. Subsequently, Peru, Colombia, and Argentina are found, but they appear with negative numbers in a range between −0.5 and 0, indicating that the perception of the society is negative. Finally, Venezuela presents a sustained negative downward line, moving further away from the intermediate countries on a key issue such as corruption.

In Figure 2b, Government effectiveness is measured. In this area, Chile once again appears with positive and sustained indicators at a significant distance from the rest of the countries. Argentina, Colombia, and Peru present similar negative indicators but all three countries show ascending curves, two of them surpassing the 0 barrier at the end of the period. In the opposite vector is Venezuela, with a negative downward curve that implies a progressive deterioration of the conditions of that country.

Figure 2c measures Political stability and the absence of violence. In this indicator, Chile is again observed with positive data. Argentina starts with negative data and manages to pass the barrier of 0 to stay above this in the last 6 years. Peru begins with negative data, but it is the country with the highest growth approaching 0. Colombia is the country with the worst performance, but its growth curve is constant, and it surpasses Venezuela, which is again the only country with negative data and without improvement in the period evaluated.

In Figure 2d, the Regulatory quality is measured. In this area, Chile maintains a sustained timeline with positive indicators at a significant distance from the rest, establishing that this country has a group of policies that propels its helices, generating results for its society. Secondly, Colombia, Argentina, and Peru appear again with very similar negative indicators and the 3 countries show slight upward trends. Finally, Venezuela presents an alarming sustained decline that indicates continued mismanagement.

In Figure 2e, the Rule of law is measured. Once again, Chile maintains a high performance always above 0, at a considerable distance from countries such as Argentina, Colombia, and Peru that

are placed with negative indexes since the turn of the XXI century. However, in the last three years, they have improved by approaching the line of 0. The only country with a sustained negative trend is Venezuela.

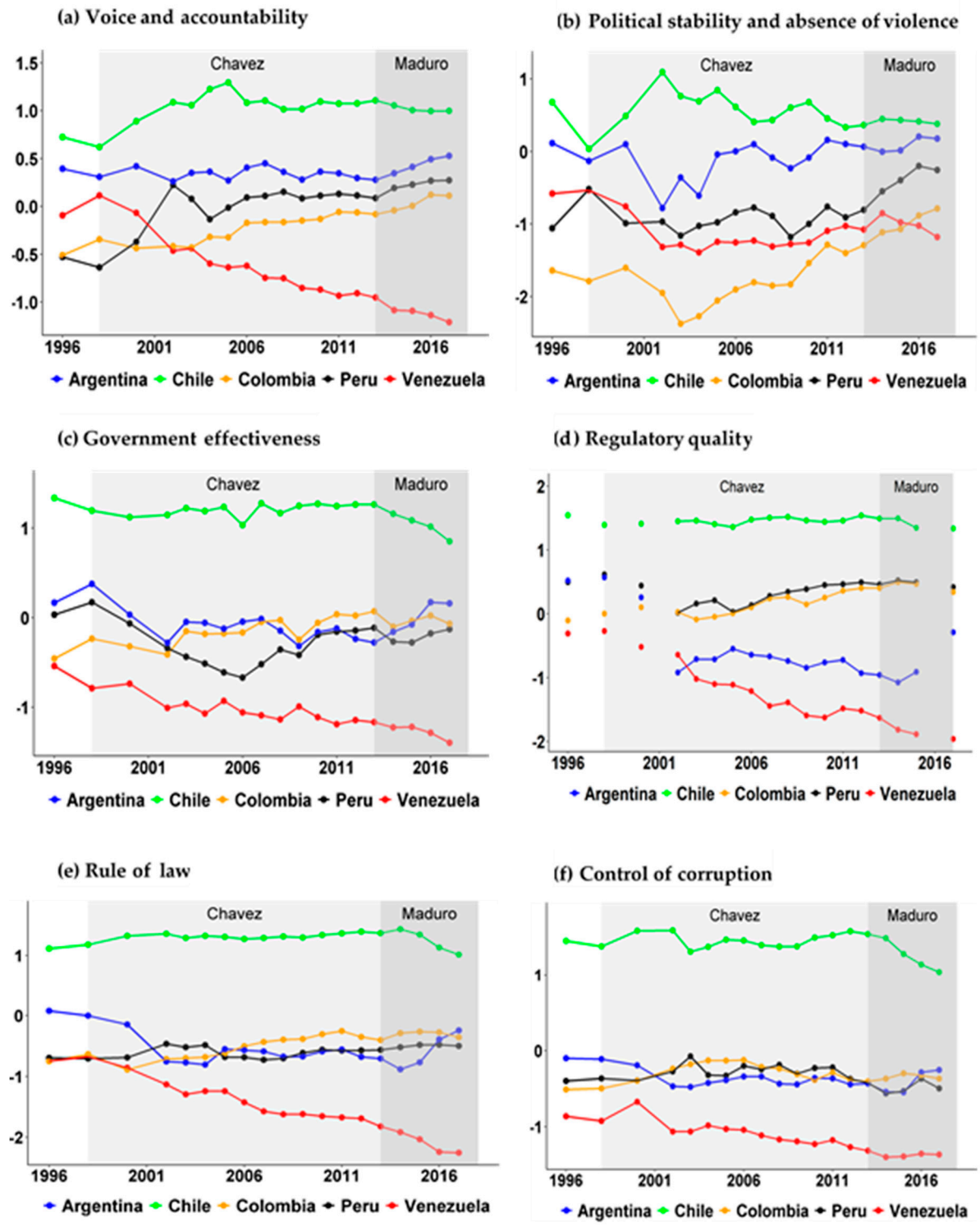

Figure 2. Political System helix: indicator approach. Source: World Bank, 2018 [48].

In Figure 2f, the Voice and accountability of a country are measured. In this indicator, Chile maintains a sustained line with positive indicators. Argentina, Peru, and Colombia appear at an important distance with upward trends and all three are above 0. Venezuela again appears with

negative data in a sustained downward curve, a fact that indicates that this helix does not work and impacts the other four helices paralyzing them.

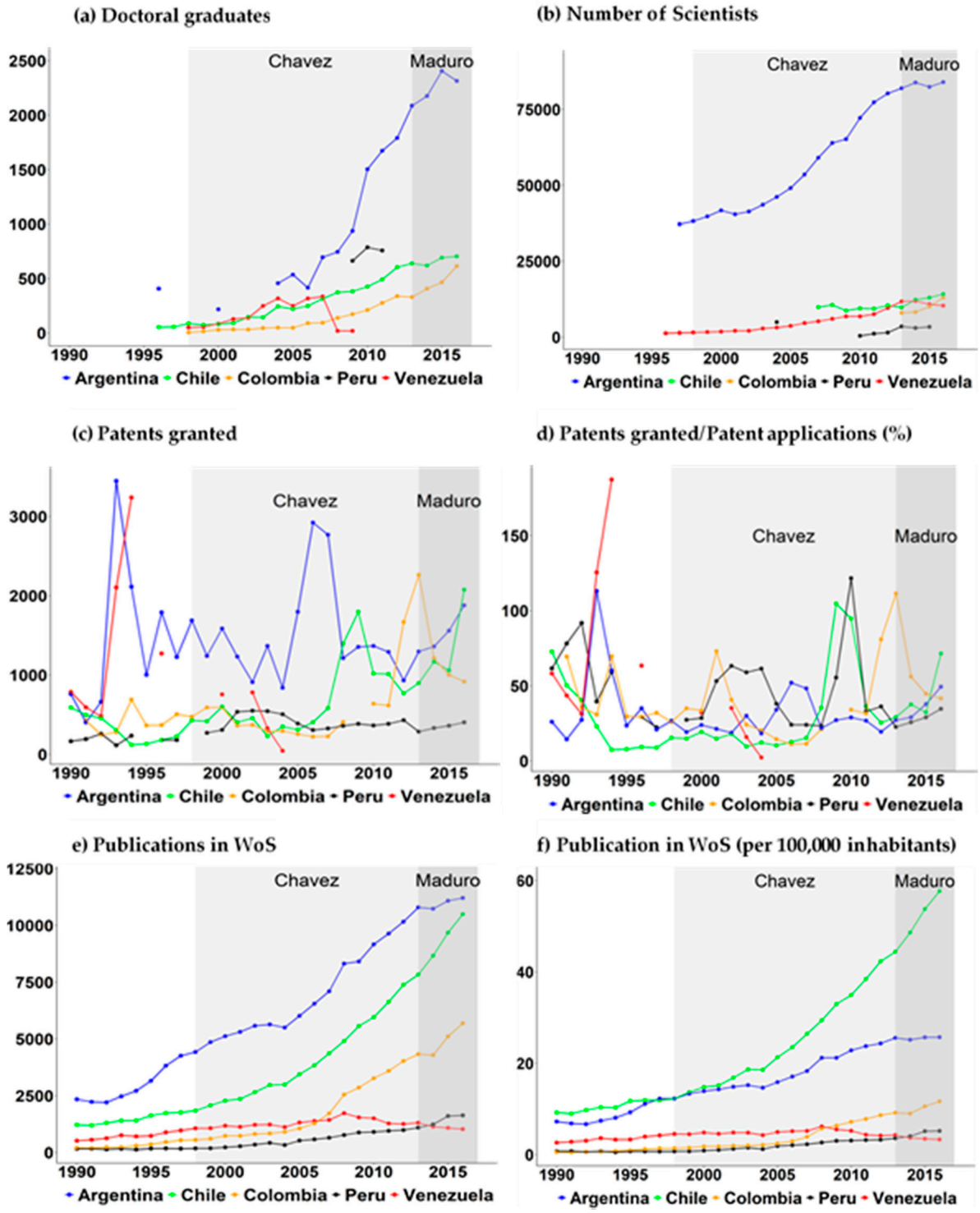

Figure 3. Education System Helix: Research and development indicator approach. Source: World Bank and RICYT, 2018 [48,49].

When examining the performance of each of the indicators of this helix and the influence they have on the other helices, it is clear that the set of decisions that each government takes accelerates or slows down the processes of each country. In the case of Venezuela, the results indicate that there is a

general progressive deterioration that points to the collapse of the entire system. This situation has greater repercussions when reviewing the annual report of Organization of the Petroleum Exporting Countries (OPEC) in 2016, because this entity certified that Venezuela's proven oil reserves were at a level of 300.880 million barrels, exceeding those of Saudi Arabia and officially classifying Venezuela as the country with the largest oil reserves in the world, a figure that represents 24.8% of the planet's reserves. In fact, Venezuela in recent years, and particularly since 2004, has experienced the largest income boom recorded in the country's economic history.

The helix related to Figure 3 represents the educational system linked to science and technology activities.

When examining Figure 3a, the total number of graduates per year in doctoral programs can be seen. This allows projecting the growth of the scientist communities. In this graph, Argentina presents a pronounced growth curve in which the effort that this country is making to grow is inferred. In second place, Peru appears in a time window of only 3 years. Chile appears with a moderate but sustained growth curve, being the country with the smallest population of the five. Venezuela is the country with the highest drop and, since 2010, there are no more available data. The drop in the number of graduates is significant, a fact that should generate an alarm for the future of that country in the field of R&D. Although Colombia appears in fifth place until Venezuela collapses, that country shows an upward trend.

By examining Figure 3b related to the number of scientists, the trends of each country can be determined. Argentina again shows coherence in the effort and its growth curve is significant. Colombia appears in second place although it is surpassed by Venezuela and Chile in recent years. The data from Venezuela are once again alarming because they present the most important fall in the last 2 years of the period evaluated. Chile, being the smallest country, ends up placing itself in second place in the last year. It talks about the coherence of a set of policies that affect its growth. Peru presents data in the last 7 years with an increasing trend that is closing the gap with respect to the group of intermediate countries.

In the indicator of products referring to the total number of patents granted (Figure 3c), it is observed that Argentina and Chile are the countries with the most patents granted. Colombia and Peru compete for third and fourth place in several years, and Venezuela is again the country with the largest drop, even disappearing in the last 11 years. The relevant thing about it is that in the pre-Chavez period, Venezuela was the leader in patents in three years and never below the second place.

In Figure 3d, the indicator referring to the ratio of patents granted to patent applications is presented. Venezuela again appears with the highest numbers in the pre-Chavez period. What is striking about the case of this country is that there is a sustained decline that culminates with the disappearance of patents in 2004 by a political measure of Chavez that established that knowledge was for free use, where anyone could take advantage of the intellectual production of another person. The four countries being compared with Venezuela remain in a fluctuating range in the ratio because it is not possible to accurately predict the number of patents that will be applied for or granted in each year. The remarkable thing is that in the last 4 years, Peru, Chile, and Argentina grew steadily, and Colombia, which was the country with the best ratio, showed a fall in the same period.

Figure 3e presents the Web of Science (WoS)-based scientific output indicator that shows the total number of items allocated to each country per year. In this graph, Argentina presents the highest number of publications throughout the period evaluated and, in addition, its growth curve is sustained, with only some slight fluctuations. Nevertheless, Chile is the country with the highest growth curve in the evaluated period and it is so pronounced that, in the last year, it is significantly closer to Argentina. If this trend continues in a short time, it would become the number one of the five countries evaluated in this study. The third country with significant growth is Colombia. Basically, starting in 2007, the ascending curve became more pronounced, achieving relevant quotas that show that there are positive promotion policies in this area. Peru positioned itself fourth at the end of the evaluated period. This country presents a slight but sustained growth curve that begins in 2004. The country that shows

the greatest setback is Venezuela. At the beginning of the nineties, it doubled and tripled in scientific production to Colombia and Peru, respectively. In the last 8 years, there has been a sustained fall that denotes the lack of a body of policies that leverage scientific production.

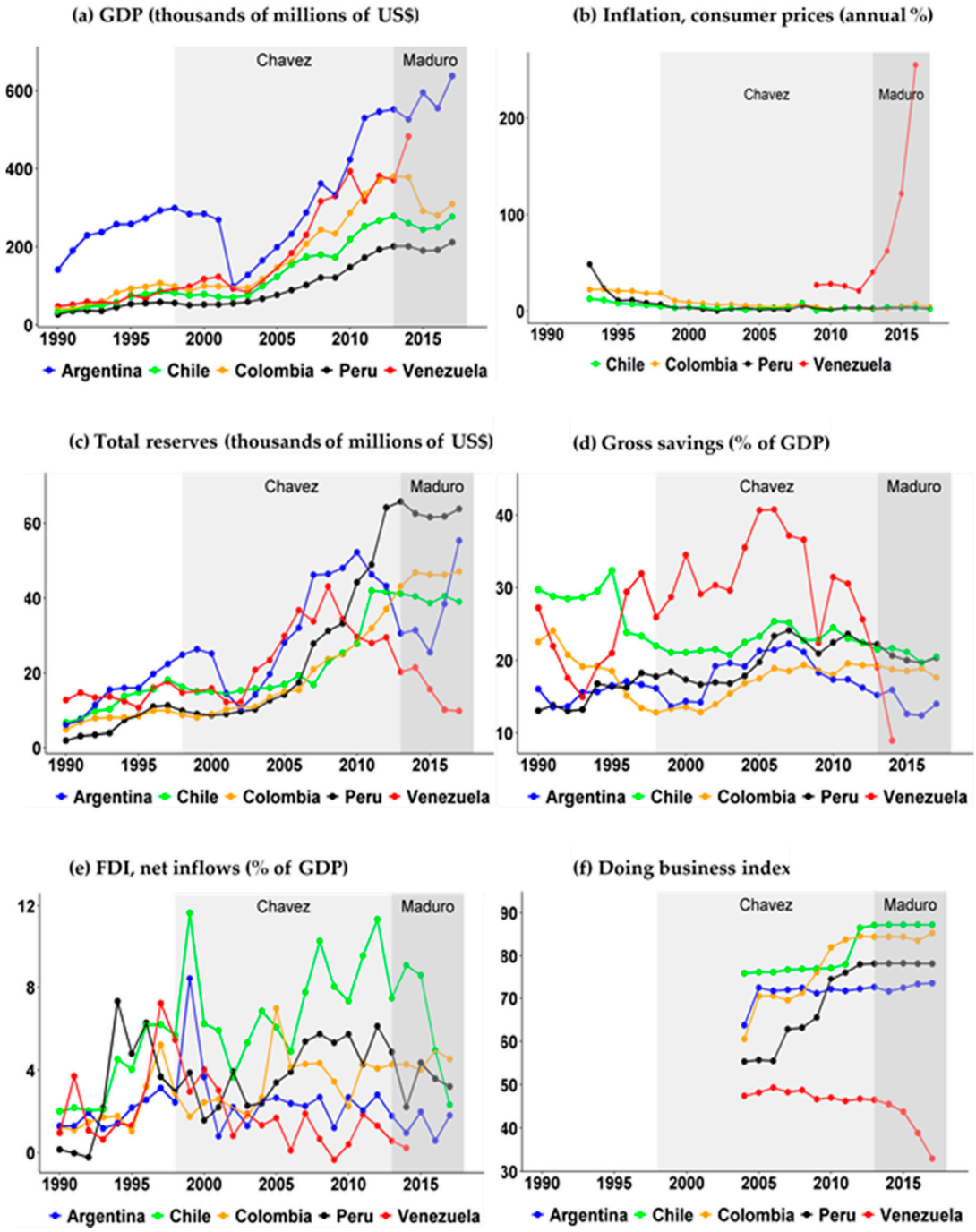

Figure 4. Economic System helix: indicator approach. Source: World Bank, 2018 [48].

The output indicators in Figure 3f show the correlation of the number of scientific publications in the WoS per 100,000 inhabitants. In this relationship, Chile appears in first place in a sustained manner at a significant distance from the rest. This is due to a better coefficient between population, scientists, and products. Argentina is in second place because its growth curve is smaller than Chile's. In the case of Colombia, it can be seen that there is a sustained effort in this area in that country, given that it was the nation with the lowest number of publications at the beginning of the nineties, but, since then, it has

presented a sustained growth that has allowed it to position itself in third place in scientific production. The case of Peru is similar to that of Colombia in terms of the effort to improve, but its growth curve is less pronounced and therefore ranks fourth in this area. The country with the largest drop is Venezuela. It went from third place in the pre-Chavez period to last place as of 2012. In reality, the decline is seen from 2009 and this is attributed to the substantial decrease in resources granted to universities and research centres, as well as to the sustained emigration of scientists residing in that country.

The helix referring to Figure 4 represents the economic sub-system. Six indicators (Figure 4a–f) are shown, in which Venezuela presents the worst values when examining the helix. All the trends in that country are negative except in the case of GDP during a period of time. However, after 2014, the tendency changes radically for the worst according to data from the International Monetary Fund (IMF) [50].

When examining Figure 4a, GDP in thousands of millions of US$, it is seen that Venezuela is in most years in second place and, even in two of them, it equals Argentina in first place. This means that the country has an important GDP but, nevertheless, the economic helix does not work and deactivates the others. This is striking because, for the year 2018, according to data produced by the IMF, Venezuela's GDP fell to −18.0%, and by the end of that year the economy of that country was in the presence of the worst crisis in magnitude and duration of its contemporary economic history and the worst recession process in 5 consecutive years in Latin America in the last 38 years. That represents a loss of 46.9% of total GDP in just 5 years (2014–2018). In the case of Argentina, it can be seen that this country experienced a precipitous fall between 2000 and 2003, but subsequently managed to grow progressively almost constantly. The other three economies show upward trends since 2003.

In the second graph (Figure 4b), inflation is measured. Venezuela presents two moments with inflation peaks above 3 digits, the last period being the highest in its history. The other 3 countries show a moderate behaviour with inflation of 1 digit in the last years, and Argentina does not present data.

In the third graph (Figure 4c), Total Reserves are measured. Two opposite phenomena are observed. Peru went from last to first place and Venezuela was the country with the highest reserves in 4 of the years under study to be in the last place. The alarming fact is that it is a pronounced descending line, becoming critical due to the constant loss of economic support. The policies adopted by Latin American countries and the independence of their central banks have allowed price stability to become the norm, not the exception, to the point that several countries with hyperinflation (Peru and Argentina) have managed to reduce it to one digit in a short time. The high and persistent inflation in Venezuela can be attributed, among other factors, to the ill-advised management of the economic policy in recent years, particularly the exchange, fiscal and monetary policy, the institutional weakness of the Central Bank of Venezuela (BCV) and the fall in production in multiple items. Most striking is that the other 4 countries have upward trends; however, Argentina had a fall with a rebound. The growth of Peru is noteworthy because, in the last 7 years, it has gone to first place in this region, marking a considerable difference from the rest.

In the fourth graph (Figure 4d), the Gross savings (% of GDP) are measured. It is observed that the Venezuelan productive apparatus does not work. That country was in first place between 1995 and 2012, presenting an abrupt fall that now places it in last place. The review of the gross saving of that country shows that, in 2017, it reached its lowest level since 1970, which confirms that the Venezuelan productive apparatus was disarticulated and does not have the necessary levels to grow and generate distributed wealth. On the other hand, the other 4 countries in this group of data show a homogeneous behaviour with slight fluctuations within the percentage range of 10 and 25, which indicates some stability.

In the fifth graph (Figure 4e), Foreign direct investment (% of GDP) is measured. In examining the case of Venezuela, it can be seen that the country was placed twice in first place. That means that it was the most attractive country of those evaluated. However, since 2004, it fell to last place, presenting a trend close to zero in recent years with the lowest Foreign Direct Investment in the Continent. In that sense, another expression of the incoherent macroeconomic management related to the negative business environment generated by the development model implemented by the last two

governments is represented by low levels of foreign direct investment. When reviewing the behaviour of the other countries, Chile stands out again with the largest investment in the last 13 years.

The sixth graph (Figure 4f) measures the capacity of each country to start businesses. The data show that Venezuela once again presents a vertiginous fall due to a set of inadequate measures promoted from the helix of the political sub-system. That indicates that the helix works in reverse and the consequence is that there are no conditions to invest. This indicator shows that the other 4 countries present similar indicators in a high range. However, Colombia shows a significant drop in the last year examined.

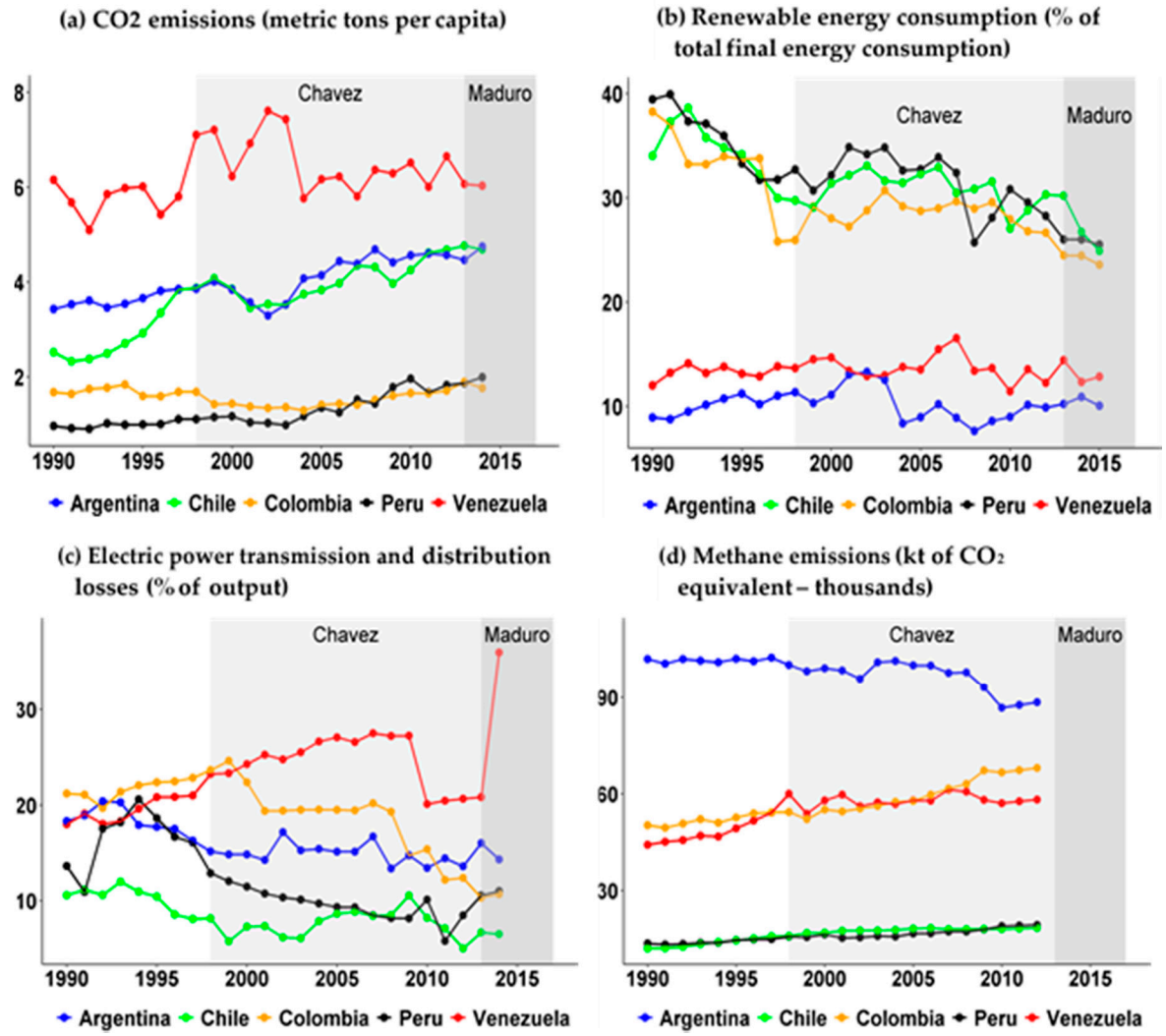

Figure 5. Natural environment helix: indicator approach. Source: World Bank, 2018 [48].

The environmental helix has a high degree of importance because it is related to the consumption of renewable resources at rates higher than their replacement and of non-renewable due to their exhaustion, together with the growing pollution that exists in the world. The awareness of these aspects comes from the type and level of education received by each society and the ability to take measures aimed at minimizing the negative impact on the part of the actors of the other helices.

In Figure 5a, CO_2 emissions are presented (measured per metric ton per inhabitant). The data show that Venezuela is the greatest polluter of the countries examined. The aggravating factor is that the data do not indicate any decrease and that implies inability to properly manage this helix. Both Argentina and Chile are in a lower band, but they do not show a tendency to improve either. Finally, Peru and Colombia appear in a significantly lower band, in which the latter, despite having the

largest population of the group evaluated, is the one that presents the best performance in the last year evaluated.

Figure 5b presents the share of Renewable energy consumption (% of total final energy consumption) in each of the five countries examined. The data show that Peru, Chile, and Colombia show similar behaviour in terms of both decreasing trends and the ranges in which they operate. It is inferred that the policies applied in these countries are similar and that the actions taken are consistent with the data. On the other hand, Venezuela and Argentina show similar behaviours despite the fact that the profiles of both countries in energy matters are different. Venezuela has sustained data within a low range and ranks fourth. Argentina ranks fifth in this type of consumption and in only three of those years is it on a par with Venezuela.

Figure 5c shows that, in the pre-Chavez period, the five countries remained in a range between 10 and 22%. By 1990, Venezuela was in third place and in two years even equalled Peru in fourth place as the countries with the lowest losses. The trajectories show how the other 4 countries began a process of improvement from the year 2000 and their tendencies are towards progressive decrease, with some slight fluctuations. The opposite case is Venezuela. This country, which has the largest reserves of gas and oil in the world, far from decreasing, increased the loss of power in energy and only recorded an improvement between 2010 and 2011. However, the values show that the loss of energy power began again in the final years of Chavez's period and a significant increase is appreciated in 2015 with Maduro as president. The negative gap that Venezuela presents in this indicator with respect to the other 4 countries examined in 2015 is significant in and marks the direction of each one.

Figure 5d shows three different behaviours of the countries examined with regard to methane emissions. On the one hand, Argentina remains with little fluctuation in a higher range, which indicates that it could not improve in this category. At a significant distance and in a medium range are Colombia and Venezuela with similar behaviour during the evaluated period and present a slight growth trend. In a low range, Peru and Chile appear with almost equal timelines and a slight increase. Therefore, in this indicator, there are three different behaviours, which indicate the application of different ways of managing this issue.

The helix related to Figure 6 represents the public subsystem based on media and culture and, in this study, it is interpreted as the society.

In Figure 6a, Intentional homicides are presented. The data show that Chile is the country with the lowest homicide rate. Argentina and Peru follow closely, a fact that demonstrates the stability of these countries in this issue of such importance. For its part, Colombia appears as the country with the highest homicide rate in the 1990s of the last century, but, since 2003, there is a pronounced downward curve that brings it closer to the other 3 countries. Venezuela is in the opposite vector. The data show a sustained increase with small fluctuations that express erroneous policies on security matters that are distorted by the excess of militarization with all that this entails.

In Figure 6b, the Prevalence of malnutrition (% of the population) is presented. In this category, Chile and Argentina have the lowest percentage of malnutrition in the population. Colombia and Peru show indicators with a downward trend, which indicates the existence of a fully operational helix. The only country that shows an upward trend is Venezuela and this factor indicates the existence of a humanitarian crisis [51].

In Figure 6c, the Global Peace Index (GPI) is presented. This indicator shows that Chile appears as the best positioned and remains stable throughout the period evaluated. Argentina is the second country of those analysed with the best index in terms of Peace levels. On the other hand, Peru appears third but presents a significant increase between 2012 and 2014 to go down and settle near Argentina. Finally, Venezuela and Colombia appear with a similar behaviour and with the highest levels. In the last reference year, the indicator is levelled, and this indicates that there is a failure in these countries in this area.

In Figure 6d, total Unemployment is shown. The indicator refers to the relationship between unemployment and the proportion of the labour force that does not have a job but is available to look

for a job. The behaviour of the 5 countries in the evaluated period is similar with higher peaks in the first half for Argentina, Colombia, and Venezuela. One aspect of relevance in these data is that in the case of Venezuela, the government changed the definition of the indicator and since 2009, it includes as employees those who work in the informal economy and, therefore, 'improves' its performance.

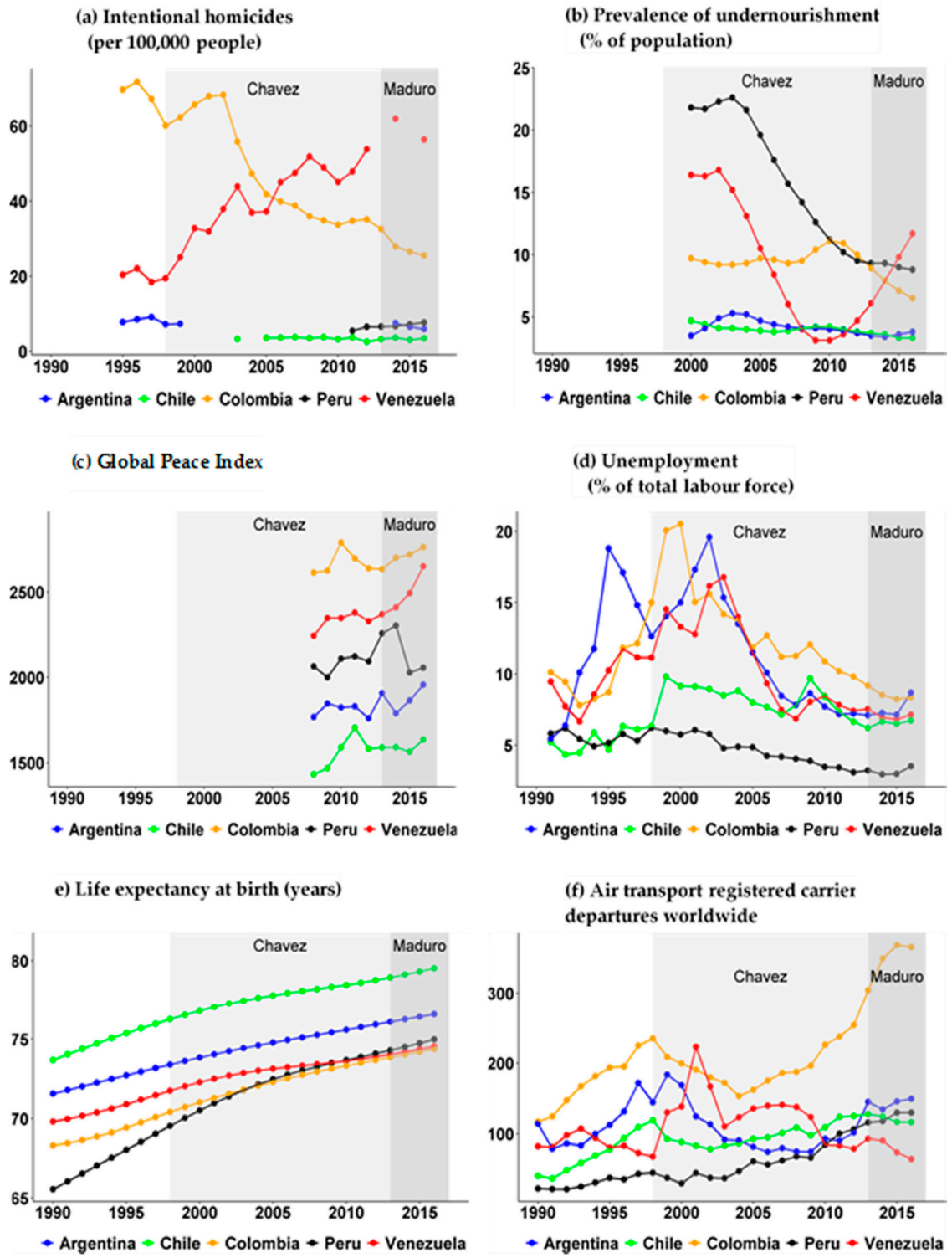

Figure 6. Media-based and culture-based public Helix: indicator approach is based on the general performance of society. Source: World Bank, 2018 [48].

In Figure 6e, Life Expectancy at Birth (years) is presented. This indicator allows observing how countries move forward in this area linked to quality of health if the rest of the helices work properly. The data indicate that Chile has the longest life expectancy by far. Argentina continues to hold second place throughout the period evaluated, but Venezuela, which was the third country with a significant difference from Colombia and Peru, begins to decelerate its growth from 2004 onwards, to finish last, equalling Colombia in recent years. Peru, for its part, moved from last to third place, a fact that demonstrates an overall improvement in the conditions in that country.

In Figure 6f, Air transport (departures of registered transporters around the world) is shown. In this area, Colombia is the country best-positioned and only in 2001, it was surpassed by Venezuela. It also has a pronounced growth curve. The remaining countries appear with similar behaviours and in recent years have upward trends. The only country with a negative balance is Venezuela. In the last 9 years, the number of take-offs has decreased, and this fact demonstrates the existence of an important structural problem.

Finally, by correlating the model of the quintuple helix of innovation with the families of selected international indicators, it can be seen that four of the countries examined are in search of the path of sustainable development. If each of them continues to design and apply innovative initiatives that seek more flexible legal frameworks, the knowledge that solves problems, reduction of CO-emissions, green technologies, and a new balance with nature, and reducing levels of corruption, they will continue to improve their performance. In this line, it is verified that Chile is the country with the best records and Venezuela is the one that shows the worst ones. What is most alarming is that the latter presents a negative general trend, indicating that in the last 20 years, its helices have never worked. Therefore, the collapse is in progress and a marking indicator of that situation is the emigration of millions of Venezuelans in recent years [52]. Behind this process of mass departure of highly skilled personnel, there were multiple factors, including political repression and systematic attacks by Venezuela's Bolivarian socialist government on national and international firms (Economic System Helix) and on the education (Education - R&D System Helix) [4,8,53].

The indicators selected as outputs are in Table 3. The results of the DEA model are shown in Table 4. We considered two years to assess performance of each country: 1996 and 2014. We took into account 18 of the 28 indicators, since they are the ones with the complete statistical series throughout the evaluated period and because these years represent the starting and ending of Chavez's tenure.

Table 3. Selected indicators of each helix for the application of the DEA.

Political System Helix	Education System Helix	Economic System Helix	Environment System Helix	Social System Helix
• Voice and accountability • Political stability and absence of violence • Government effectiveness • Regulatory quality • Rule of law • Control of corruption	• Publications in WoS • Publication in WoS (per 100,000 inhabitants)	• GDP (thousands of millions of US$) • Total reserves (thousands of millions of US$) • Gross saving (% of GDP) • DFI, net inflows (% of GDP)	• CO_2 emissions (metric tons per capita) • Renewable energy consumption) (% of total final energy consumption) • Electric power transmission and distribution losses (% of output)	• Unemployment rate (%) • Life expectancy at birth (years) • Air transport (number of people)

Table 4. Result of the application of the DEA model to the 5 countries studied.

Country	1996 Index	2014 Index	Var. %
Peru	0.17	0.25	45.7%
Chile	0.64	0.45	−29.9%
Argentina	0.28	0.37	31.5%
Colombia	0.31	0.41	29.9%
Venezuela	0.18	0.04	−74.6%

5. Discussion

When there are no adequate balances between the knowledge subsystems (helices) to leverage a country's sustainable development, several combinations can occur that end up being negative. We are talking about strong and weak helices, their interactions, and the influence of one on the others in a given period of time. If a helix imposes itself in a negative way by exercising power and dominating decisions, then the system loses the capacity of intermediation in decision-making and could fail in the pursuit of the common good of that society.

Incorporating indicators into the Quintuple Helix of Innovation Model allows observing the dynamics and the trends of each country examined. The data obtained based on descriptive statistics allows understanding of the relative value of each helix at a given time or period and, in addition, a rough estimate can be made of the behaviour of the set of helices in order to establish their position (strong or weak).

It is assumed that South America is defined as a developing region and this aspect is relevant when contextualizing this analysis.

In this study, Venezuela is the country that presents trajectories with negative trends in each of the helices over the period studied. The other four countries exhibit moderate growth behaviours but at different rates, which allows inferring a better articulation of their helices in terms of solving or improving their problems and directing their efforts towards sustainable development.

In the case of Venezuela, both the context evaluated and the trend of the indicators suggest that the political helix exerts a negative influence on the rest and this is due to inadequate public policy decisions. This effect was intensified with the implementation of the so-called Socialism of the 21st Century and occurred despite the fact that, under the regime of Hugo Chávez Frias, that country received more oil revenues than the sum obtained by all previous governments combined. A distinctive characteristic in this case has been the dominance of that helix and the displacement of the others towards weak positions. Even in the last 4 years, one can observe how the general negative slope has been accentuated. This indicates a collapse of the model and, therefore, of that country.

With the DEA Method, it was possible to establish that Venezuela was the country that had the greatest negative variation when examining the two periods evaluated with a −74.6%. On the other hand, Chile appears with a negative variation of −29.9%, and this value indicates that this country should examine the operation of its helices from the perspective of the indicators applied, but it is still the country with the best value in the 2014 Index. Finally, Peru achieved the greatest overall progress of the countries examined with a positive value of 45.7%, followed by Argentina with 31.5% and Colombia very close with 29.6%. From these data, it can be deduced, therefore, that in Venezuela the decisions taken throughout the period have not been adequate to promote the sustainable development of that country. The change of regime towards the so-called socialism of the 21st century had a negative impact on economic, educational, environmental, and social aspects.

It is known that the South American region is conceptually considered peripheral and, within this group of countries, there are also marked differences in terms of development. While some countries play to jump to the category of emerging countries such as Peru, Venezuela is clearly regressing in all aspects and therefore, the architecture of its political model makes it an unsustainable country in terms of development.

When examining the Quintuple Helix Model applied to the five selected countries, it was observed that Venezuela is the only one that is constantly regressing in the five knowledge subsystems with a final 2014 Index value far removed from the other four. This means that none of its helices work properly and, therefore, the circulation of knowledge of the macrosystem is not adequate. The helix that represents political capital was identified as one that does not allow the others to interact dynamically to correct problems.

6. Conclusions

The South American region presents marked differences among its countries in terms of social, economic and political progress, to such an extent that while some of them play to jump into the category of emerging, others are on their way to collapse, as the indicators in this study show.

The holistic vision of the Quintuple Helix Innovation Model allows extrapolating that the current collapse of Venezuela obeys the set of measures applied by the last two governments, specifically between 1998 and 2018 (political helix). This was due to the exacerbated incidence of these regimes to slow down the other helices. This process dismantled the circulation of knowledge that should have been oriented to the sustained development of that country.

The evidence shows that Venezuela presents the greatest setback of the five countries evaluated and when examining the longitudinal trajectories of the indicators of the five helices of that country, the final values are negative. This indicates that the five knowledge subsystems work inadequately.

It is concluded that, when in a country, there is a marked influence of political decisions, with direct restrictive incidence towards the development of the other helices, the impact ends up being negative on its development and Venezuela is an example of this. The regression observed in all aspects evaluated shows that the architecture of its neo-socialist political model turned it into an unsustainable country that ended up collapsing.

For their part, the other four countries have evolved favourably but at different growth rates. Chile presents a drop in its 2014 Index of −29% but it is still the country with the highest value of the five evaluated. That result is an alert for that country and the recommendation is to review the interactions of its helices, so that they seek to revitalize innovative initiatives that allow them to return to the path of development. Peru, Argentina and Colombia have progressed and their values are positive, a fact that shows that there have been dynamic articulations between their knowledge sub-systems that have leveraged their growth.

The DEA method validated the result of the trends of each country and allows concluding that the dynamism of the development initiatives passes through the generation of dynamic interactions of all the helices, without influences that unbalance the forces towards any of them.

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