International Economic Integration from the Perspective of Economic Complexity and Economic Fitness: A Methodological Proposal

Arturo González[1,2][a], Sanny González[2][b], Gabriel Pereira[1][c], Gerardo Blanco[2][d] and Christian von Lücken[3][e]

[1]*Universidad Americana, Facultad de Ciencias Económicas y Administrativas, Lab-iDi, Asunción, Paraguay*
[2]*Universidad Nacional de Asunción, Facultad Politécnica, Grupo de Investigación en Sistemas Energéticos, San Lorenzo, Paraguay*
[3]*Universidad Nacional de Asunción, Facultad Politécnica, Núcleo de Investigación y Desarrollo Tecnológico, San Lorenzo, Paraguay*

Keywords: International Economic Integration, Economic Complexity, Economic Fitness, Development, Economic Block.

Abstract: International Economic Integration can be described as a process in which a group of countries seeks mutual benefits through mechanisms such as the elimination and/or reduction of trade, social, and political barriers between others. From an economic point of view, the importance of the integration of countries is fundamental for their development simply because most of them are part of some system of international economic integration. In this work, the issue of economic integration will not be discussed in depth but instead will oversee proposing some well-known metrics in the field of economic development that could be very useful as analysis and decision-making tools. in the process of regional economic integration. In this sense, this work proposes using concepts and metrics of Economic Complexity and Economic Fitness to identify combined productive capacities between countries that are part of an economic block, whether real or fictitious. The problem in understanding how economically integrate the countries is to identify the combined productive capacities that would exist if two or more countries that make up an economic block are considered as a single country. Experimental analyzes were carried out for a fictitious case, where a world with 10 countries and 15 products is presented; in addition, 3 economic blocks were defined, which were analyzed applying economic complexity and economic fitness metrics. The results obtained reflect the great importance of economic integration since, by establishing economic blocks, it is possible to capture more productive capacities by improving both the diversity of the economic block and the ubiquity of the products produced in it by addressing the productive capacities of the member countries.

1 INTRODUCTION

As time progresses, it is evident that societies are heading towards a global integration that has been exponentially accelerated thanks to the advancement of technology. From an economic point of view, the importance of the integration of countries is fundamental for their development, and this is simply because, except for a few cases, countries are part of some system of international economic integration (whether regional or international) without discussing the degree of effectiveness or usefulness of these (Pérez Bustamante., 2012).

International Economic Integration can be described as a process (which can be very diverse in its methods) through which a group of countries seeks mutual benefits through mechanisms such as the elimination and/or reduction of trade, social, and political barriers between others. In this way, two or more national markets, previously separate and of different dimensions, come together to form a unified

[a] https://orcid.org/0000-0001-5672-3679
[b] https://orcid.org/0000-0002-8385-2852
[c] https://orcid.org/0000-0001-9966-6715
[d] https://orcid.org/0000-0001-9773-8922
[e] https://orcid.org/0000-0002-2198-1237

González, A., González, S., Pereira, G., Blanco, G. and von Lücken, C.
International Economic Integration from the Perspective of Economic Complexity and Economic Fitness: A Methodological Proposal.
DOI: 10.5220/0012059400003485
In *Proceedings of the 8th International Conference on Complexity, Future Information Systems and Risk (COMPLEXIS 2023)*, pages 109-121
ISBN: 978-989-758-644-6; ISSN: 2184-5034

economic space in such a way as to reduce disadvantages and/or difficulties existing in separate countries (Pérez Bustamante., 2012).

Achieving International Economic Integration is complex since it depends on many factors and variables (Economic, Geopolitical, Social, among others.). Although there are cases of quite successful economic integration blocks (European Union, and others in South America), there are still difficulties to overcome to get countries to embark on this process. In this work, the issue of economic integration will not be discussed in depth but only when immediately relevant, proposing the use of some well-known metrics in the field of economic development as analysis and decision-making tools for regional economic integration processes.

In this sense, this work proposes the use of concepts and metrics of Economic Complexity (Hidalgo & Haussman., 2009) and Economic Fitness (Tacchella et al., 2012) to identify combined productive capacities between countries that are part of an economic bloc, whether real or fictitious, and thus be able to measure the global performance of the economic blocks worldwide as if it were a country.

To achieve the goals mentioned above, it is important to be able to answer the following questions: Is it possible to use complex systems to analyze cases of international economic integration? Are the methods based on complex systems adequate to analyze cases of regional integration? Is it possible to quantify the productive capacities of economic blocks and not only of countries? And finally, is it possible to propose a method of quantifying the productive capacities of the economic blocks?

In this article, you can find a well-detailed methodological proposal to address the problem of International Economic Integration, for which the proposal is systematically detailed, and a fictitious practice case is presented for the experimental application of the models.

The article is presented as follows: Section 2 presents a literature review of the studied areas; Section 3 presents the Methodology proposed and applied in this work; in Section 4, the Results and Discussions are shown and finally, in Section 5, the Conclusions.

2 LITERATURE REVIEW

2.1 Economic Complexity

The economic complexity is related to the ubiquity and diversity of the accumulated knowledge in a determined economy. Then, in a specific country, as more people from different sectors interact, combining their knowledge to produce diverse products, a more complex economy could be expected. Therefore, the economic complexity of a country can be expressed as the share of productive knowledge it accumulates, because of using and combining that knowledge (Hausmann et al., 2011).

Knowledge can only be accumulated, transferred, and preserved if inserted in a people´s network or in organizations that apply that knowledge for productive purposes. If producing a product requires a specific type or combination of knowledge, then the countries that produce that product reveal that they have the capabilities and required knowledge to produce it (Hidalgo & Haussman., 2009; Hausmann et al., 2011).

The economic complexity of a country reflects the amount of productive knowledge of its economy, measured using 2 main indicators, the diversity, and the ubiquity.

Diversity relates to the number of products produced in a specific country, while ubiquity refers to the number of countries that produce a specific product.

$$Diversity = Kc, 0 = \sum_p Mcp \quad (1)$$

$$Ubiquity = Kp, 0 = \sum_c Mcp \quad (2)$$

To generate a more accurate measure of the number of available capabilities of a country or the required capabilities for a product, it is necessary to correct the information that the diversity and ubiquity hold, using each of them to correct the other and vice versa. As proposed by (Hidalgo & Haussman., (2009); Hausmann et al., (2011)), this can be expressed as the following equations:

$$\bar{M}_{cc'} = \sum_p \frac{M_{cp} M_{c'p}}{K_{c,0} K_{p,0}} \quad (3)$$

Therefore, the Economic Complexity Index (ICE) is defined as follows (Hidalgo & Haussman., (2009); Hausmann et al., (2011)):

$$ECI = \frac{\vec{K} - <\vec{K}>}{stdev(\vec{K})} \quad (4)$$

Where, $<\vec{K}>$ is an average, stdev() represents the standard deviation, and $\vec{K}$ is the eigenvector of $\bar{M}_{cc'}$ associated with the second largest eigenvalue.

Analogously, the Product Complexity Index (PCI) is defined.

$$ICP = \frac{\vec{Q} - <\vec{Q}>}{stdev(\vec{Q})} \quad (5)$$

Where, $\vec{Q}$ is the eigenvector of $\bar{M}_{pp'}$ associated to the second largest eigenvalue.

[Experimental Data Box]

All the data and results can be found at: https://bit.ly/complexis23_Data

Table 1: Product Export Matrix - Test Model for Experimental Analysis (X_{cp}).

X_{cp}	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}	p_{11}	p_{12}	p_{13}	p_{14}	p_{15}
c_1	0	42.627	0	0	0	0	0	0	0	0	0	7.095	0	0	0
c_2	28.350	277.775	1.674	371.691	46.857	3.034.718	26.355.142	0	1.515.962	0	14.802	42.371.264	6.284.352	1.372.309.632	1.201.978
c_3	0	5.216	0	9.158	0	156.295	86.464	24.779	5.648.211	16.256.469	304.646	10.071	619.167	0	0
c_4	26.227	40.294	0	4.780	0	12.626.318	4.678	6.920	3.306.102	65.784.052	31.552	444.469.600	362.779	33.522	8.441
c_5	430.025.280	102.318.904	6.954.244	58.085.384	234.929	233.119.760	137.473.696	84.333.632	90.806.104	0	29.043.196	5.741.459.456	369.889.600	185.851.248	9.093.049
c_6	6.400.370	11.242.664	6.264	3.643.282	725.795	4.410.605	307.132	0	4.157.532	0	2.731	7.407.275	10.967	5.067.202	17.794
c_7	6.871.145	6.349.536	0	15.359.048	0	96.720.000	10.334.506	332.191	25.312.052	0	503.529	182.173.968	11.194.842	116.190.032	274.509
c_8	0	0	0	29.464.208	17.703.662	16.929	0	810.382	24.814.384	42.568.613.888	12.799.707	12.226.431	3.497	1.548.972	2.750
c_9	518.443.552	95.476.752	29.089.984	11.991.583	17.625.200	456.977.600	81.602.312	289.626.240	8.044.192.768	27.847.991.296	27.986.572	21.523.519.488	496.113.344	124.086.304	194.398.960
c_{10}	25.424.708	2.667.031	76.896	1.779.958	0	18.301.440	16.807.418	4.748.828	403.493.536	638.850.560	640.625	297.708.000	1.121.468	39.320.432	822.995

Table 2: Experimental Process to obtain the Export Matrix that contains an International Economic Block (X_{cp} to X_{mp}) - Example of Ec. Block. #1.

$$C' = \{c_1, c_2, c_3, c_5\}$$

(a) Conformation of the International Economic Bloc #1

EB_{kp}	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}	p_{11}	p_{12}	p_{13}	p_{14}	p_{15}
c_1	0	42.627	0	0	0	0	0	0	0	0	0	7.095	0	0	0
c_2	28.350	277.775	1.674	371.691	46.857	3.034.718	26.355.142	0	1.515.962	0	14.802	42.371.264	6.284.352	1.372.309.632	1.201.978
c_3	0	5.216	0	9.158	0	156.295	86.464	24.779	5.648.211	16.256.469	304.646	10.071	619.167	0	0
c_5	430.025.280	102.318.904	6.954.244	58.085.384	234.929	233.119.760	137.473.696	84.333.632	90.806.104	0	29.043.196	5.741.459.456	369.889.600	185.851.248	9.093.049

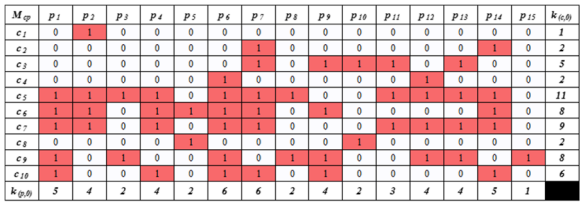
(b) The Export matrix of the Economic Block #1 (EB_{kp}) is built

	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}	p_{11}	p_{12}	p_{13}	p_{14}	p_{15}
$B =$	430.053.630	102.644.522	6.955.918	58.466.233	281.786	236.310.773	163.915.302	84.358.411	97.970.277	16.256.469	29.362.644	5.783.847.886	376.793.119	1.558.160.880	10.295.027

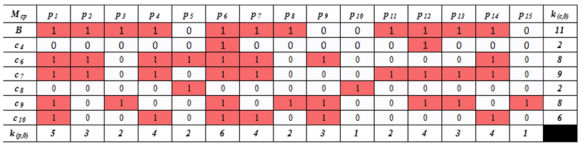
*(c) Calculation of Vector "**B**", using the (**9**, of total export values of the International Economic Block #1*

X_{mp}	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}	p_{11}	p_{12}	p_{13}	p_{14}	p_{15}
B	430.053.630	102.644.522	6.955.918	58.466.233	281.786	236.310.773	163.915.302	84.358.411	97.970.277	16.256.469	29.362.644	5.783.847.886	376.793.119	1.558.160.880	10.295.027
c_4	26.227	40.294	0	4.780	0	12.626.318	4.678	6.920	3.306.102	65.784.052	31.552	444.469.600	362.779	33.522	8.441
c_6	6.400.370	11.242.664	6.264	3.643.282	725.795	4.410.605	307.132	0	4.157.532	0	2.731	7.407.275	10.967	5.067.202	17.794
c_7	6.871.145	6.349.536	0	15.359.048	0	96.720.000	10.334.506	332.191	25.312.052	0	503.529	182.173.968	11.194.842	116.190.032	274.509
c_8	0	0	0	29.464.208	17.703.662	16.929	0	810.382	24.814.384	42.568.613.888	12.799.707	12.226.431	3.497	1.548.972	2.750
c_9	518.443.552	95.476.752	29.089.984	11.991.583	17.625.200	456.977.600	81.602.312	289.626.240	8.044.192.768	27.847.991.296	27.986.572	21.523.519.488	496.113.344	124.086.304	194.398.960
c_{10}	25.424.708	2.667.031	76.896	1.779.958	0	18.301.440	16.807.418	4.748.828	403.493.536	638.850.560	640.625	297.708.000	1.121.468	39.320.432	822.995

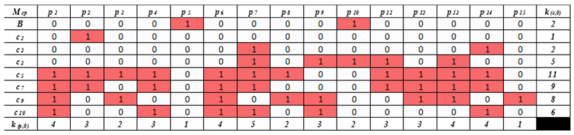
(e) Vector "B" replaces all the countries that make up the International Economic Block #1 and the export matrix that contains it is formed. As a result, the Matrix (X_{mp}) is obtained.



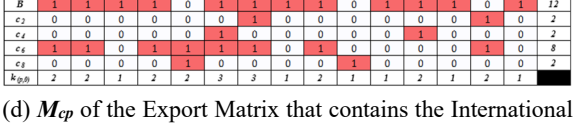
(a) M_{cp} from the Original Export Matrix



(b) M_{cp} of the Export Matrix that contains the International Economic Block #1



(c) M_{cp} of the Export Matrix that contains the International Economic Block #1



(d) M_{cp} of the Export Matrix that contains the International Economic Block #1

Figure 1: M_{cp} Matrices of the *(a)* Original Export Matrix (X_{cp}) and of the *(b, c & d)* Export Matrices of the Economic Blocks (X_{mp}) Proposed for this study calculated with the **Eq. 7**.

It is necessary to consider the Revealed Comparative Advantage to establish the M_{cp} Matrix, which allows the calculations of the Economic Fitness. The definition of Revealed Comparative Advantage (RCA) proposed by Balassa (1965) makes countries and products comparable since it represents the exports of products by country. This index establishes that a country has revealed a comparative advantage in a product if it exports more than the rest of the world, in which case the RCA index adopts a value equal to or greater than one; if it is less than one, it indicates the opposite. It is formally defined as:

$$RCA_{\mathrm{cp}} = \frac{\frac{\mathrm{X_{cp}}}{\mathrm{X_{cT}}}}{\frac{\mathrm{X_{Mp}}}{\mathrm{X_{MT}}}} \tag{6}$$

Where:

$\mathrm{X_{cp}}$ = Exports of the country "c" of the product "p".

$\mathrm{X_{cT}}$ = Total Exports of the country "c".

$\mathrm{X_{Mp}}$ = Total World Exports of the product "p".

$\mathrm{X_{MT}}$ = Total World Exports of the year (All Products).

This measure makes it possible to build a matrix that connects each country with the products it manufactures. The entries in the matrix are 1 if the export of the product in each country with Revealed Comparative Advantage is greater than or equal to 1, and 0 otherwise. We formally define this as the $\boldsymbol{M_{cp}}$ matrix as (Hidalgo & Haussman., (2009); Hausmann et al., (2011)):

$$M_{cp} = \begin{cases} 1, & \text{if } \mathrm{RCA_{cp}} \geq 1 \\ 0, & \text{otherwise} \end{cases} \tag{7}$$

2.2 Economic Fitness

The Economic Fitness theory proposes a new algorithm that shows an iterative and non-linear approach, which makes it possible to efficiently capture the link formed between the export basket of different countries and their industrial competitiveness (Tacchella et al., 2012; Cristelli et al., 2013; Tacchella et al., 2013). This model has its initial basis in the construction of a binary matrix of countries and products (*Mcp*), which represents the export basket of each country, whose elements are 1 if country *"c"* exports product *"p"* with revealed comparative advantage and 0 otherwise (See **Eq. 7**). This method consists of coupled non-linear maps and new information is added in each iteration.

Therefore, the general idea of the algorithm proposed in the Economic Fitness theory lies in defining an iteration process for the Fitness of the countries ($\mathrm{F_c}$) with the complexity of the products ($\mathrm{Q_p}$) and then obtaining the values of the convergence. In the case of $\mathrm{F_c}$, it is appropriate to be proportional to the sum of the exported products weighted by their complexity $\mathrm{Q_p}$.

For the case of $\mathrm{Q_p}$ it becomes less intuitive because, in a first approximation, the complexity of a product is inversely proportional to the number of countries that export it. However, in each iteration, more information is added, considering that if a country has a high level of Fitness, the weight is reduced to limit the complexity of a product. On the other hand, countries with low Fitness contribute more and tend to limit the complexity of the products (Tacchella et al., 2012; Cristelli et al., 2013; Tacchella et al., 2013; Pugliese, Zaccaria & Pietronero., 2016). These ideas are summarized in the iteration of the following equations:

$$\begin{cases} \tilde{\mathrm{F}}_{\mathrm{c}}^{(\mathrm{n})} = \sum_{\mathrm{p}} \mathrm{M_{cp}} \mathrm{Q_p^{(n-1)}} \\ \tilde{\mathrm{Q}}_{\mathrm{p}}^{(\mathrm{n})} = \dfrac{1}{\sum_{\mathrm{c}} \mathrm{M_{cp}} \frac{1}{\mathrm{F_c^{(n-1)}}}} \end{cases} \rightarrow \begin{cases} \mathrm{F_c^{(n)}} = \dfrac{\tilde{\mathrm{F}}_{\mathrm{c}}^{(\mathrm{n})}}{\langle \tilde{\mathrm{F}}_{\mathrm{c}}^{(\mathrm{n})} \rangle_{\mathrm{c}}} \\ \mathrm{Q_p^{(n)}} = \dfrac{\tilde{\mathrm{Q}}_{\mathrm{p}}^{(\mathrm{n})}}{\langle \tilde{\mathrm{Q}}_{\mathrm{p}}^{(\mathrm{n})} \rangle_{\mathrm{p}}} \end{cases} \tag{8}$$

Where:

n = Index of iteration.

c = Total number of countries.

p = Total number of products.

$\mathrm{F_c}$ = Fitness of the country "c".

$\mathrm{Q_p}$ = Product Complexity "p".

$\mathrm{M_{cp}}$ = Product − Country Logical Matrix.

$Obs.$: $\tilde{\mathrm{F}}_{\mathrm{c}}$ and $\tilde{\mathrm{Q}}_{\mathrm{p}}$ corresponding to the normalization

Since this theory proposes that less complex exporters make a dominant contribution to product complexity, non-linearity is a fundamental Mathematical property that is unavoidable given the problem of economic diversification (Cristelli et al., 2013). For the definition of the complexity of the products, the sum in the denominator is strongly dominated by the countries with a lower Fitness measure. Another issue that must be considered when considering the product complexity denominator is that, as the total number of countries that export that specific product increases, this means that the complexity of the products decreases, considering thus the product's ubiquity.

2.3 Economic Complexity and Economic Fitness

The application of the Economic Complexity metrics has had a great impact from the 2010s onwards (Hidalgo & Haussman., 2009; Haussman et al., 2011). It has become a quite popular tool for studying economic development, economic geography and has been applied to numerous case studies (Countries,

cities, etc.) It has also been related to other topics, such as greenhouse gas emissions, economic growth and inequality, in addition to extrapolating their metrics for cases unrelated to the economy or at least not directly (Hidalgo., 2021).

Although there are multiple applications and work carried out under the Economic Complexity approach, there are still many challenges in terms of research topics, overcoming the issue of the difficulty of having reliable data in the world and even more outside of the products (services, patents, and others.), in addition, several points remain pending, such as being able to work at subnational or even international levels (International Economic Blocks). In short, one of the greatest contributions to the development of Economic Complexity lies not in the mathematical model itself, but in the integration of researchers from areas of knowledge that long ago were on separate paths (network scientists, economic geographers, innovation economists, physicists, and others.) achieving a very interesting interaction between academics from different areas (Hidalgo., 2021).

Another metric for the analysis of the Economic Complexity of countries and products is the Economic Fitness proposed by Tacchella et al. (2012). In a study carried out by Cristelli et al. (2013) a comparison was made between both methods. To deepen the methods and metrics of Economic Fitness, the following literature is recommended (Tacchella et al., 2013; Cristelli, Tacchella & Pietronero., 2015; Mariani et al., 2020; Morrison et al., 2017; Vinci & Benci., 2018 and Hidalgo., 2021).

2.4 International Economic Integration

International Economic Integration refers to the process by which countries in a particular region coordinate their economic policies and remove trade barriers to increase trade and investment among each other. In South America, regional economic integration has been a major objective for many years, aiming to boost economic growth and reduce poverty (Carranza, 2017; Basnet & Pradhan, 2017).

One of the key initiatives in South America toward economic integration is the formation of the Southern Common Market (MERCOSUR), established in 1991. MERCOSUR is a customs union that promotes free trade and the movement of goods, services, and people among its member countries. MERCOSUR has helped to reduce trade barriers and increase trade among its members, resulting in increased economic growth and improved standards of living for the citizens of its member countries. (Basnet & Pradhan, 2017; Caceres, 2011).

Despite these positive developments, MERCOSUR has faced many challenges in its pursuit of economic integration. One of the main challenges has been the lack of political will among its members to fully implement the agreements and remove all trade barriers. This has resulted in the slow progress of MERCOSUR and limited its ability to achieve its goals of boosting economic growth and reducing poverty. (Baer et al., 2002).

Another challenge facing MERCOSUR is the lack of coordination among its members on macroeconomic policies, such as fiscal and monetary policies. This lack of coordination can lead to imbalances in trade and investment among its members and undermine the objectives of economic integration. To overcome this challenge, MERCOSUR must establish stronger mechanisms for policy coordination among its members and ensure that their policies are aligned with the objectives of the organization. (Baer et al., 2002).

In conclusion, regional economic integration in South America has made some progress. However, there is still much work to be done to boost economic growth and reduce poverty. MERCOSUR must overcome its challenges and establish stronger mechanisms for policy coordination to achieve its objectives. Further research is needed to assess the impact of MERCOSUR on economic growth and poverty reduction in South America and to identify the most effective ways to promote economic integration in the region.

There are several approaches used to analyze regional economic integrations, including the neo-classical trade theory, the new trade theory, and the political economy approach.

The neo-classical trade theory views regional economic integration as a means of increasing trade and promoting economic growth by removing trade barriers and creating a single market. This approach focuses on the benefits of trade, such as increased efficiency and specialization, and argues that these benefits will lead to increased economic growth and improved living standards for the participating countries citizens. (Pereira et al., 2021; González et al., 2019).

On the other hand, the new trade theory focuses on the importance of economies of scale and the role of multinational corporations in shaping trade patterns. This approach recognizes that multinational corporations can use their bargaining power to influence trade policies and shape the trade structure within a region. The new trade theory also recognizes that technological advances and the growth of the service sector have changed the nature of trade,

making it more difficult for governments to influence trade patterns through traditional trade policies. (Amine,1986).

The political economy approach focuses on the role of political institutions and power relations in shaping regional economic integration. This approach argues that the political dynamics of a region, including the distribution of power among countries and the bargaining power of different actors, significantly impact the success or failure of regional economic integration efforts. The political economy approach recognizes that the distribution of costs and benefits of integration is not equal among the participating countries, and that the ability of countries to participate in regional integration efforts is influenced by their relative power and bargaining position (Zaman et al., 2021; Timini & Viani, 2022).

3 METHODOLOGIES

This paper proposes a well-structured methodology to analyze the incidence of different regional and international economic blocks in world economic complexity. To achieve the goal, not only the well-known methods such as Economic Complexity or Economic Fitness, which have been studied from 2010 onwards, are required.

In this sense, a methodology is presented that extrapolates concepts of economic complexity to analyze regional economic integration, as seen in the work of Pereira, González & Blanco., (2021) or González, Pereira & González., (2022), who did so to identify sustainability capacities in the countries. Therefore, it is feasible to establish a methodological and experimental framework to apply to real data and real economic blocks (even fictitious) such as MERCOSUR (In South America) and the EU (In Europe), among others.

A methodology defined in two parts is presented; in the first where the Methodology is designed based on the tools and metrics of Economic Complexity and Economic Fitness. In the second part, the recommended Experimental Process is presented.

3.1 Economic Complexity and Economic Fitness Approaches for International Economic Integration: A Methodological Proposal

The Methodological Design for the Study of International Economic Integration is presented in three well-detailed steps, for analyzing the scientific community and its possible practical application. The steps are detailed below:

Step 1: The Problem of International Economic Integration

The theory of Economic Complexity establishes that those countries that can produce and export more products than others and that these products are not exported by other countries to a large extent have a great probability of having more complex economies and consequently greater probability of development and well-being for its inhabitants. In simple terms, productive capabilities are highly embedded in societies with complex economies.

Therefore, and from this point of view, the problem in understanding how to integrate the countries economically is to identify the combined productive capabilities which would exist if two or more countries that make up an economic bloc are considered as a single country. This process is feasible to analyze, and a theoretical and experimental work framework can be established, which is presented in this study and begins as follows.

Originally there is a matrix X_{cp} of World Exports for a certain year, where:

- $i = \{1,2,3,..,c\}$ where "c" is the quantity of countries with records of total exports in the world in a certain period (usually it is annual).
- $j = \{1,23,..,p\}$ where "p" is the quantity of registered and standard coded products in the world (The Standard International Trade Classification (SITC) or the Harmonized System (HS) code can be used as a reference for real products).

$$X_{cp} = \begin{array}{c} \\ c_1 \\ c_2 \\ \vdots \\ c_i \end{array} \begin{array}{c} \begin{array}{cccc} p_1 & p_2 & \cdots & p_j \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} \\ x_{21} & x_{22} & \cdots & x_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} \end{bmatrix} \end{array}$$

Each entry in the Matrix corresponds to the total exported (in monetary terms, generally in US Dollars) from a country "i" registered for the product "j". So, for this study, it is proposed to analyze regional economic integration through "Economic Blocks", if possible, it would be good if such blocks exist. In any case, it does not matter that they are fictitious since they could be a case study for academic purposes.

An "Economic Block" is defined as a composition of at least two countries, which can be fictitious or real, where the combination of productive capabilities

is assumed by adding the total exports of each similar product from the member countries.

The process of defining the analysis of the International Economic Integration begins with the definition of the "Economic Blocks", where there is a matrix, whose entries correspond only to the data of the products exported from the countries that make up the block. The following matrix is obtained:

$$EB_{kp} = \begin{array}{c} \\ c'_1 \\ c'_2 \\ \vdots \\ c'_l \end{array} \begin{array}{c} \begin{array}{cccc} p_1 & p_2 & \cdots & p_j \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} \\ x_{21} & x_{22} & \cdots & x_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ x_{l1} & x_{l2} & \cdots & x_{lj} \end{bmatrix} \end{array}$$

where:

- $C' = \{c' \ / \ c' \in X_{cp} \ \vee \ n(C') \geq 2\}$ where C' represents the set of countries that are part of a certain international economic block. E.g. $C' = \{c_1, c_2, c_{11}\}$ international economic block made up of countries c_1, c_2 and c_3.
- $l = \{1, 2, 3, \ldots, k\}$ where $k = n(C')$ and represents the quantity of countries of a cert of a certain international economic block. E. g. If the set $C' = \{c_1, c_2, c_{11}\}$ of the countries that are part of a given international economic block is taken, $k = n(C')$ represents the number of countries that belong to the block. It is a mandatory condition that $k \geq 2$.

Subsequently, a single-row vector is obtained that corresponds to the sum of all the export values of all the countries of the block, for each one of the products, maintaining the quantity of these and thus disappearing the countries that originated them. the block. The block vector is obtained as follows:

$$B = (b_{11} \quad b_{12} \quad \cdots \quad b_{1j})$$

and each of the of the entries of the vector is calculated as follows:

$$b_{1j} = \sum_{m=1}^{k} x_{mj} \qquad (9)$$

This new vector B replaces the countries that belong to the economic bloc and there is a new world export matrix for the given year. There is the particularity that $k < c$ since the Economic Block had to absorb at least two countries to be considered as such.

The new export matrix, including the economic block represented by B, should have the dimension X_{mp} where $m = 1 + (c - k)$. In this way, there is 1 (one) new country and "k" countries of the economic block are excluded from the total of "c" original countries. The matrix is as follows:

$$X_{mp} = \begin{array}{c} \\ B = c_1 \\ c_2 \\ \vdots \\ c_f \end{array} \begin{array}{c} \begin{array}{cccc} p_1 & p_2 & \cdots & p_j \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} \\ x_{21} & x_{22} & \cdots & x_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ x_{f1} & x_{f2} & \cdots & x_{fj} \end{bmatrix} \end{array}$$

Where:

- $f = \{1,2,3,..,m\}$ where "m" is the quantity of countries and the international economic block with records of total exports in the world in a in a specific year.
- $j = \{1,23,..,p\}$ where "p" is the quantity of registered and standard coded products in the world.

The data will be obtained from the export matrix $\boldsymbol{X_{mp}}$ to carry out the analysis of the incidences of the international economic blocks with the selected metrics (Economic Complexity or Economic Fitness).

Step 2: Quantification of Productive Capabilities of International Economic Blocks.

To determine if a country has minimum productive capacities for a certain product, Hidalgo & Haussman., (2009) established the use of the Revealed Comparative Advantage Index (RCA) proposed by Balassa. (1965) as a mechanism; therefore, it is a mandatory step to use the Economic Complexity and Economic Fitness metrics.

Then, we calculate the VCR index for the Original Export Matrix ($\boldsymbol{X_{cp}}$) and for the Export Matrix that includes an International Economic Block (All the $\boldsymbol{X_{mp}}$ of the blocks formed). It is recommended to carry out the analysis with a single economic block at a time, or failing that, if tests are to be carried out with two or more blocks at the same time, that these be mutually exclusive with their member countries, that is, that each block has its own their own countries without repeating them in the other blocks (More details on this subject are presented in Section 3.2).

Once the calculations of the RCA (See **(6)** to $\boldsymbol{X_{cp}}$ and to all the $\boldsymbol{X_{mp}}$ blocks have been completed, the $\mathbf{M_{cp}}$ matrix must be determined for each case. With this it is possible to obtain the different measures of Economic Complexity or Economic Fitness.

Step 3: Complexity approaches to the model: Economic Complexity and Economic Fitness

Given the $\boldsymbol{M_{cp}}$ Matrix, calculated according to the procedure mentioned in the previous step, it is then

possible to use the mathematical models of complexity measures proposed by Hidalgo & Haussman., (2009) for the case of Economic Complexity and those proposed by Tacchella et al., (2012) in the case of the Economic Fitness models. **Figure 2** shows a scheme of the main metrics recommended to apply to the analysis of international economic integration.

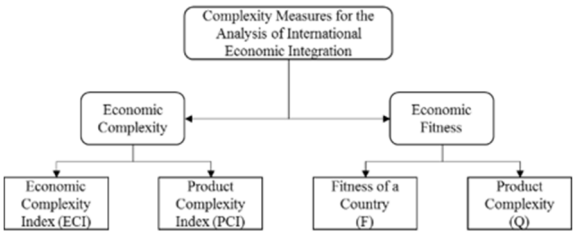


Figure 2: Recommended Measures of Complexity.

If the Economic Complexity approach is used, the recommended metrics are the Economic Complexity Index (**ECI**) and the Product Complexity Index (**PCI**). It would also be feasible to carry out the Product Space calculations, however, with the first two measurements, it would be enough. In the case of the Economic Fitness approach, the metrics are recommended: Country Fitness (**F**) and Product Complexity (**Q**). They would be the counterparts of the previous ones. Both approaches have their particularities, pros and cons, and the debate on them continues to this day.

3.2 Experimental Application Steps

It is important to note that in section 3.1, a methodology has been developed in a general way that allows the study of international economic integration, however making a detailed study with real data entails quite an interesting effort and even makes it quite difficult to apply the two approaches. proposed (Economic Complexity and Economic Fitness). It is possible, that for a real situation, it should be done separately. In this part of the work, some steps to follow are proposed to apply an experimental case study, where all the recommended metrics are used (See **Figure 2**).

The experimental process carried out in this study will be systematically detailed, as well as recommendations for its application with a real case. This will serve to have a first approximation of what it would have at the time of a real application. It is important to highlight that an Experimental Data Box will be presented in a general way that will serve as a guide in this section and in each step. The data, results and graphs will be available in a repository for those who are interested (See Experimental Data Box).

Step 1: Definition of Fictitious Economic Blocks

For this experimental study, a dummy export data matrix was defined, consisting of ten countries ($c = 10$) and fifteen export products ($p = 15$). Thus, there is an $\boldsymbol{X_{cp}}$ matrix with the following dimensions $\boldsymbol{X_{10,15}}$ for further analysis. Matrix entries were arbitrarily defined and randomly drawn from a real export dataset, with 147 countries and more than 1000 products. It is recommended to adopt this procedure that ensures a good random process, however functions that generate a random matrix can be used for analysis.

To have a basic guide of this procedure, and those that come in the following steps, an "**Experimental Data Box**" is presented where you can observe the steps that will be described. In this sense, the Fictitious Matrix for this case study can be seen in **Table 1**.

For a possible application to real cases, the use of export data is recommended either under the SITC coding or under the HS coding. With a disaggregated four-digit export database, it will be possible to have a very good basis for working on the procedure presented in this paper.

Step 2: Definition of the International Economic Blocks and Initial Calculations.

For this case study, three fictitious economic blocks were established that will be analyzed separately in such a way as to compare the results obtained first with the reference, which is the Original Matrix (Without any economic block), and with the results obtained from the other blocks. Given that there are a total of ten fictitious countries, the conformation of the 3 blocks is the following:

- $C' = \{c_1, c_2, c_3, c_5\}$ → Ec. Block #1
- $C' = \{c_4, c_6, c_8\}$ → Ec. Block #2
- $C' = \{c_{10}, c_9, c_7, c_5, c_3, c_1\}$ → Ec. Block #3

This step simply consists of grouping the countries that make up an international economic bloc into sets $\boldsymbol{C'}$. For an application with real data, existing blocks such as the European Union or MERCOSUR can be used, but also for academic purposes fictitious blocks or those that are not really conformed can be created, such as URUPABOL (Uruguay, Paraguay, and Bolivia in South America) or the BRICS bloc (Brazil, Russia, India, China, and South Africa). In this way, many issues could be analyzed that could be

starting points for economic integration policies between countries, among other things.

Then, the following steps should be systematically applied:

- Build an export matrix where there are only the countries that make up a block or in this case, the different blocks. In other words, the Export Matrix $\boldsymbol{EB_{kp}}$ is defined.
- Immediately the vector $\boldsymbol{B}$ must be calculated, which consists of the sum of all the exports of each country for each of the products, using **(9**.
- Subsequently, the new Export Matrix is established where the data of all the countries that are part of the blocks are replaced by the respective data of vector $\boldsymbol{B}$. The Final Exportation Matrix $\boldsymbol{X_{mp}}$ is defined.
- Finally, the corresponding calculations are made to obtain the $\boldsymbol{M_{cp}}$ Matrix of each of the economic blocks studied. The **(6** and the **(7** are used for this purpose.

Once these steps are completed, the mathematical complexity models can be applied to each case. **Table 2** shows in detail the process to be followed with one of the blocks defined for this study as an example. And **Figure 1** shows the four $\boldsymbol{M_{cp}}$ matrices that will be applied to the mathematical models of complexity for this case study.

The problem of International Economic Integration is complex, and with many edges to observe and certainly, this proposal has a high potential to become an analysis tool that can be used by policy makers and decision makers within the framework of the problem.

Step 3: Experimental Rounds under the Economic Complexity and Economic Fitness models

For the case study, calculations will be made for all previously recommended complexity measures (See **Figure 2**). The mathematical-computational model was created based on the Economic Complexity models proposed by Hidalgo & Haussman., (2009) and based on the Economic Fitness models proposed by Tacchella et al., (2012) and runs were made using proprietary models in the software MatLab®. (In case any interested party requires the models, they can request it from the authors without any inconvenience).

The calculations were systematically performed as follows:

Table 3: Complexity Measures Applied to the Study Matrices.

Applied to	**Economic Complexity**		**Economic Fitness**	
	ECI	**PCI**	**F**	**Q**
Original Matrix	x	x	x	x
Ec. Block #1	x	x	x	x
Ec. Block #2	x	x	x	x
Ec. Block #3	x	x	x	x

Step 4: Analysis of Experimental Results

Once the experimental runs were finished to the data presented with the approaches to economic complexity and economic fitness, the following analyzes of the results and discussions were carried out:

- ***Descriptive analysis of the results of the MCP (original matrix and economic blocks):*** Descriptive analysis of two fundamental indicators for the studies of the complexity metrics that are: the diversity of the countries ($\boldsymbol{k_{c,0}}$) and the ubiquity were carried out and the ubiquity of products ($\boldsymbol{k_{p,0}}$). The discussions about these results will mark the guideline on the results of the different complexity measures.
- ***Analysis of the results corresponding to the complexity of the products for each metric (ICP & Q_P):*** For practical purposes, the positions that the products occupy according to their performance with the PCI and the PCI and the QP were used. It is important to keep in mind that the number of products does not vary depending on the configuration of the economic blocks, therefore, it is easier to directly compare the variation of the performances according to the position in the ranking that the products occupy. Depending on this, analysis and discussions were carried out.
- ***Analysis of the results corresponding to the economic complexity of the countries for each metric (ECI & FC):*** It is important directly the variation of the performances according to the position in the ranking that

each country and each block occupies based on the performance of its **ECI** and the **F_C**. The comparisons were made for each economic block and for the original matrix each with themselves but comparing the results obtained in the ECI Vs. F_C in such a way to analyze and discuss those results.

In the case of the application to real data, it is advisable to carry out a good study either using the Economic Complexity measures or the Economic Fitness measures. Although it is not something extremely difficult to do, there are many factors and elements that must be analyzed for each approach. In fact, the analyzes carried out in this work are barely minimal.

Step 5: Conclusions and Recommendations

After the analysis of the results, a conclusion on the methodological proposal is presented, as well as a critical review of the results and the model presented.

4 RESULTS & DISCUSSIONS

After the application of the mathematical models of Economic Complexity and Economic Fitness, to the different M_{cp} matrices (Original Matrix and Economic Blocks), the following coupled results of some discussions are presented. Prior to the analysis of the results of the complexity metrics, in **Figure 3**, you can see a graph where the behavior of the ubiquities of the products is recorded. It is observed that the economic blocks affect the different ubiquities as the block is more comprehensive or large. In the curve of the original matrix (light blue line), ubiquity peaks are observed, that is to say that there were products for which many countries had the capacity to produce them, however, for Economic Block #3 (the block with the largest number of members), ubiquities decrease drastically, which implies that many capabilities are absorbed, both by the block itself, which becomes more diverse, and by products that become less ubiquitous, which could affect the complexities (**ECI & F_c**).

In **Figure 4**, another very important indicator for complexity measures can be seen, which is the diversity of countries. It can be clearly seen in the figure that the crosses are not continuous, since the economic blocks that were formed imply the disappearance of the countries that formed them. In general, blocks that include many countries, or even those that contain countries that are already diverse, have a high diversity index. However, those blocks like Ec. Block #2 (**B#2**), whose member countries are c_4, c_6 and c_8; which are countries with a low level of diversity, clearly affect the bloc. It is important to note that both Diversity and Ubiquity by themselves do not provide all the information on the complexity of a given country. Although the block is not very diverse, perhaps the capabilities that they ended up "absorbing" could generate an increase, or rather, a variation in complexity.

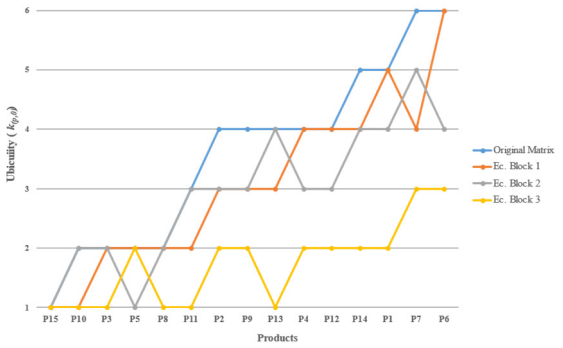


Figure 3: $k_{p,0}$ - Ubiquity of the Products for each matrix M_{cp} (Original Matrix and Economic Blocks).

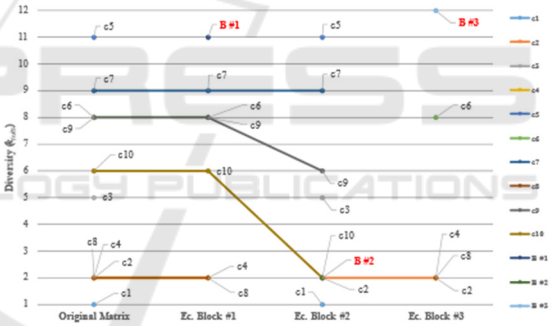


Figure 4: $k_{c,0}$ - Diversity of the countries and economic blocks defined in each matrix M_{cp} (Original Matrix and Economic Blocks).

Analyzing the first measure of complexity, **Figure 5** shows the results of the PCI of the Products for each case study. This measure corresponding to the Economic Complexity approach shows a very important variation for each of the economic blocks and initially to the results corresponding to the original matrix. The most complex product for the Initial Matrix is Product 15 (p_{15}) which undergoes variations in its position and consequently its complexity did. The most evident behavior is that the complexities undergo considerable changes due to the variation of blocks, at least with the PCI metric.

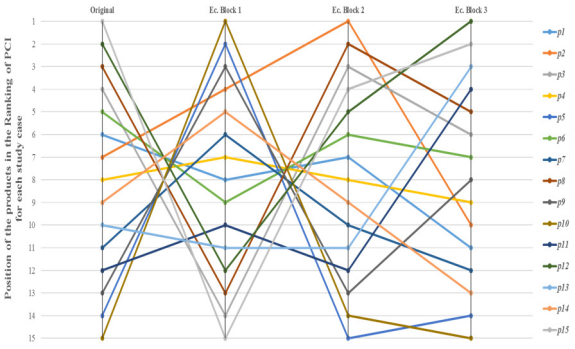


Figure 5: Position in the performance ranking of Product Complexity Index (**PCI**) for all case studies.

On the other hand, in **Figure 6**, the results of the positions of the products based on the $\mathbf{Q_p}$ metric show more robust (They maintain the same position regardless of the economic block analyzed) results for the main products (the most complex ones), especially those characterized by low ubiquity. The behavior is quite different from that recorded in **Figure 5**. The products p_{15}, p_6 and p_8 are quite robust to the variation of the economic blocks. In this way, it can be observed how the results of the complexity of products (**PCI & $\mathbf{Q_p}$**), set the pattern of the effects produced by the economic integration of the countries.

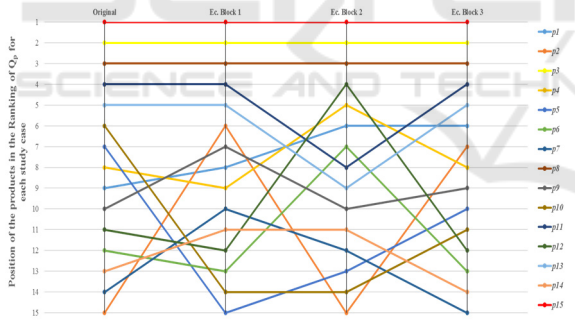


Figure 6: Position in the performance ranking of Product Complexity ($\mathbf{Q_c}$) for all case studies.

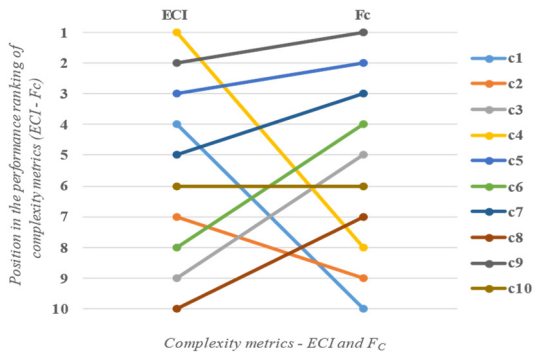


Figure 7: Position in the performance ranking of complexity metrics (**ECI - $\mathbf{F_c}$**) for the case of the Original Matrix.

Observing from the point of view of the countries, in **Figure 7**, you can see the results of the original matrix, where only the countries are and without any blocks. The differences between the ranking of the countries for the **ECI** and $\mathbf{F_c}$ metrics show certain differences, although in some cases, such as c_4, c_2 and c_1, which are very marked, the rest, relatively, behave in a similar way. The logic behind the results can be observed, for example, c_4 and c_9, which are the best performers for the different metrics (**ECI** and $\mathbf{F_c}$), the first is characterized by having low diversity and the other with high diversity, however, for the **ECI** approach, the c_4 products are less ubiquitous, which generates that greater capacities are required, however, for the Fc approach, the c_9 country that has a higher level of diversity, has several products that are less ubiquitous, so it provides more information to generate a highly complex situation in the country.

In the case of Economic Block #1, in **Figure 8**, it is found that for both metrics, the most complex country is c_9, given that in this case, the block studied is in the highest places in both cases, therefore that it can be seen joining the economic bloc favors the member countries and what has been mentioned so far has been fulfilled.

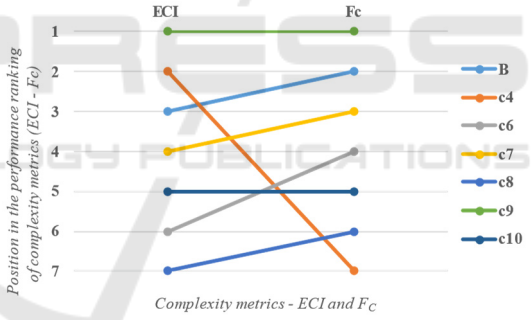


Figure 8: Position in the performance ranking of complexity metrics (**ECI - $\mathbf{F_c}$**) for the case of the International Economic Block #1.

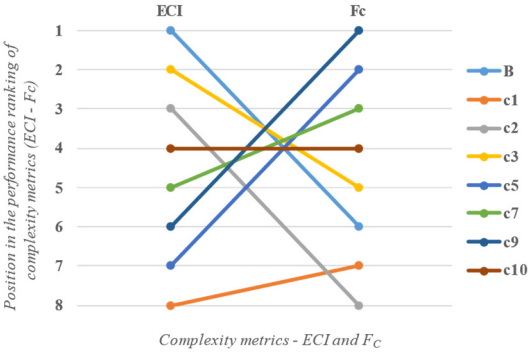


Figure 9: Position in the performance ranking of complexity metrics (**ECI - $\mathbf{F_c}$**) for the case of the International Economic Block #2.

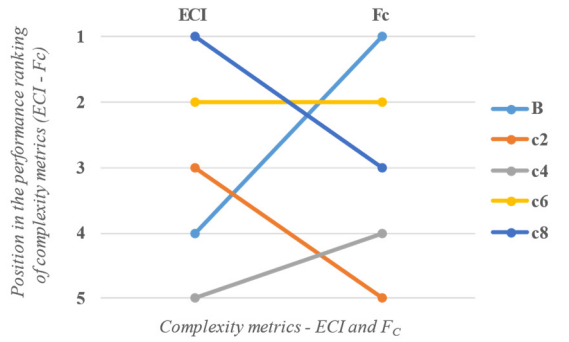


Figure 10: Position in the performance ranking of complexity metrics (**ECI - F_c**) for the case of the International Economic Block #3.

In the case of Economic Block #2, there are two well-marked behaviors. Within the same block is the country c_2, which already in **Figure 7**, occupied the first places with the **ECI**, however, in the same way, this behavior is repeated.

In the latter case, the behavior of the last economic block studied can be observed. Economic block #3 represents the block with the largest number of countries (See **Figure 10**). In the case of the **F_c,** the Block represents the country with the highest fitness, on the other hand, the country c_8, is located in the highest position with the **ECI**, since at the end of the capacity identification process, it ends up with only two products with comparative advantages, in addition, these products end up being less ubiquitous, which is why for the approach (**ECI**), it ends up becoming a more complex economy.

5 CONCLUSIONS

With this work, it was possible to carry out a very important analysis that allowed us to describe the results obtained by applying various complexity metrics to some case studies where economic blocks were formed with various experimental tests with fictitious data. In this way some very important questions could be answered to begin to study international economic integration.

It is possible to apply Economic Complexity metrics (Economic Complexity Index and Product Complexity Index) and also Economic Fitness metrics (Country Fitness and Product Complexity), for which certain hypotheses must be assumed, which certainly they would be quite strong, but mainly it must be assumed that when establishing an economic bloc, the productive capacities of the countries that are part of the economic blocs are directly added, which is very simple in practical terms, however, in the It actually represents a very complex and difficult situation to achieve. But following the methodological proposal, it is possible to quantify the productive capacities of an economic block quite effectively.

The most important points that can be concluded with the results of the experimental tests are that the economic blocks affect both the ubiquity of the products and the diversity of the countries, which implies a direct effect on the complexity metrics (**ECI, PCI, F_c** and **Q_c**). The economic blocks represent an opportunity for countries to improve their possible situations in terms of Complexity, which would increase the probability of achieving development (increasing complexity implies increasing the probability of achieving economic development and improvement in many things).

It is very important to highlight that this methodological procedure is the first step to advance in an area that has practically not taken this type of problem into account, which is economic integration or international productive integration. The complexity of creating integration ties between different nations is high and has been the subject of study for a long time, and this methodology aims to provide a useful tool that can be used by policy makers and decision makers as an input in the process. analysis and design of international policies in the area. The problem of international economic integration will always persist; therefore, new analytical tools and perspectives will always be of great help in the process.

In terms of academic essays, it is recommended to continue with them, experimentally, applying more than one economic block for each run or calculation of complexity metrics (both approaches) in addition to carrying out more in-depth studies to interpret the particularities obtained by both approaches. and their differences (Economic Complexity Vs. Economic Fitness). In the case of the use of real export data, it is recommended to study historical data and approach the studies with separate approaches (Economic Complexity and on the other hand Economic Fitness), in such a way that an analysis of the results can be adequately carried out.

ACKNOWLEDGEMENTS

The authors are very grateful to the Paraguayan National Council of Science and Technology (CONACyT) for financial support through the PRONII Program.

AUTHORS CONTRIBUTIONS

The authors declare the following contributions in this study:

Activities	Methodology	Literature Review	Mathematic Model	Data	Manuscript	Calculations	Results Analysis
A.G.	X	X	X	X	X	X	X
S. G.	X	X	X	X	X	X	X
G. P.		X		X	X		X
G. B.	X				X		X
C. vL.	X				X		X

REFERENCES

Amine, L. S. (1986). Multinational corporations in Eastern Europe: Welcome trade partners or unwelcome change agents?. *Journal of Business Research*, *14*(2), 133-145.

Balassa, B. (1965). Trade liberalisation and "revealed" comparative advantage 1. *The manchester school*, *33*(2), 99-123.

Basnet, H. C., & Pradhan, G. (2017). Regional economic integration in Mercosur: The role of real and financial sectors. *Review of development finance*, *7*(2), 107-119.

Basnet, H. C., & Pradhan, G. (2017). Regional economic integration in Mercosur: The role of real and financial sectors. *Review of development finance*, *7*(2), 107-119.

Baer, W., Cavalcanti, T., & Silva, P. (2002). Economic integration without policy coordination: the case of Mercosur. *Emerging Markets Review*, *3*(3), 269-291.

Cristelli, M., Gabrielli, A., Tacchella, A., Caldarelli, G., & Pietronero, L. (2013). Measuring the intangibles: A metrics for the economic complexity of countries and products. *PloS one*, *8*(8), e70726.

Cristelli, M., Tacchella, A., & Pietronero, L. (2015). The heterogeneous dynamics of economic complexity. *PloS one*, *10*(2), e0117174.

Carranza, G. G. (2017). Íter constitutivo y desafíos del Parlamento del Mercosur. Especial alusión al caso argentino. *Cuestiones constitucionales*, (36), 51-77.

Caceres, L. R. (2011). Economic integration and unemployment in Mercosur. *Journal of Economic Integration*, 45-65.

González, S.; Pereira, G. and González, A. (2022). Sustainability and Goal Fitness Index for the Analysis of Sustainable Development Goals: A Methodological Proposal. In *Proceedings of the 7th International Conference on Complexity, Future Information Systems and Risk - COMPLEXIS,* ISBN 978-989-758-565-4; ISSN 2184-5034, pages 105-115. DOI: 10.5220/0011122400003197

González, A., Ortigoza, E., Llamosas, C., Blanco, G., & Amarilla, R. (2019). Multi-criteria analysis of economic complexity transition in emerging economies: The case of Paraguay. *Socio-Economic Planning Sciences*, *68*, 100617.

Hausmann R, Hidalgo CA, Bustos S, Coscia M, Chung S, Jimenez J., Simoes, A., Yildirim, M., 2011. The Atlas of economic complexity: mapping paths to prosperity. Cambridge, Mass: Center for International Development, Harvard University; Harvard Kennedy School; Macro Connections, Massachusetts Institute of Technology

Hidalgo CA, Hausmann R. The building blocks of economic complexity. Proc Natl Acad Sci USA 2009;106(26):10570–5. http://dx.doi.org/10.1073/pnas.

Hidalgo, C. A. (2021). Economic complexity theory and applications. *Nature Reviews Physics*, *3*(2), 92-113.

Mariani, M. S., Vidmer, A., Medo, M., & Zhang, Y.-C. (2015). *Measuring economic complexity of countries and products: which metric to use? The European Physical Journal B, 88(11).* doi:10.1140/epjb/e2015-60298-7

Morrison, G., Buldyrev, S. V., Imbruno, M., Doria Arrieta, O. A., Rungi, A., Riccaboni, M., & Pammolli, F. (2017). On economic complexity and the fitness of nations. *Scientific Reports*, *7*(1), 15332.

Pugliese, E., Zaccaria, A., & Pietronero, L. (2016). On the convergence of the Fitness-Complexity Algorithm. *The European Physical Journal Special Topics*, *225*(10), 1893-1911.

Pereira, G.; González, A. and Blanco, G. (2021). Complexity Measures for the Analysis of SDG Interlinkages: A Methodological Approach. In *Proceedings of the 6th International Conference on Complexity, Future Information Systems and Risk - COMPLEXIS,* ISBN 978-989-758-505-0; ISSN 2184-5034, pages 13-24. DOI: 10.5220/0010374600130024

Pérez Bustamante, R. (2012). Formas y ventajas de la integración. *Mediterráneo Económico*, *22*, 205-212.

Pereira, G., González, A., & Ríos, R. (2021). Capturing multidimensional energy poverty in South America: a comparative study of Argentina, Brazil, Uruguay, and Paraguay. *Frontiers in Sustainable Cities*, 46.

Tacchella, A., Cristelli, M., Caldarelli, G., Gabrielli, A., & Pietronero, L. (2012). A new metrics for countries' fitness and products' complexity. *Scientific reports*, *2*(1), 1-7.

Tacchella, A., Cristelli, M., Caldarelli, G., Gabrielli, A., & Pietronero, L. (2013). Economic complexity: conceptual grounding of a new metrics for global competitiveness. *Journal of Economic Dynamics and Control*, *37*(8), 1683-1691.

Timini, J., & Viani, F. (2022). A highway across the Atlantic? Trade and welfare effects of the EU-Mercosur agreement. International Economics, 169, 291-308.

Vinci, G. V., & Benzi, R. (2018). Economic complexity: Correlations between gross domestic product and fitness. *Entropy*, *20*(10), 766.

Zaman, M., Pinglu, C., Hussain, S. I., Ullah, A., & Qian, N. (2021). Does regional integration matter for sustainable economic growth? Fostering the role of FDI, trade openness, IT exports, and capital formation in BRI countries. *Heliyon*, *7*(12), e08559.