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Can the Monkeys Leave the Export Processing Zones? Exploring the Maquiladora Bias in the Economic Complexity Index in Latin America

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Abstract

This paper shows the existing mismatches between the calculated Economic Complexity Index (ECI) values and other indicators of the level of development and economic sophistication in Latin America's countries. The study provides evidence of the systematic differences in the ranking of countries that points to the existence of some sort of bias, and it attempts to explain the bias for countries that are systematically listed by the ECIin a rank above the one that should correspond them using other development measures. The paper proposes an explanation based on the existence of Export Processing Zones (EPZs) where products that are more complex than the average of the productive structure can be produced and exported, biasing the ECI measurement.

Keywords: Economic complexity; trade composition; international trade; maquiladora industry; Latin America

I. Introduction

The origin of this paper is the surprise derived from the ranking of Latin American countries proposed by the Atlas of Economic Complexity, which does not correspond to what would be expected based on other indicators of development inputs and outputs. This article explores the existing mismatches between the calculated Economic Complexity Index (ECI) values for 2014 (Atlas of Economic Complexity, 2015) and other indicators of the level of development and economic sophistication in Latin America.

According to the Atlas of Economic Complexity, a country's economic complexity depends on the knowledge and wide ranging capabilities ofits society and its firms that become translated into great variety of products and exports. Thus, a country's exports are considered a proxy for its economic complexity, so that the productive structure of a country is complex if it exports a large number of different and sophisticated products. This will be reflected in the ECI for exported products.

The Economic Complexity Index proposed by Hidalgo and Hausmann is based on their Method of Reflections, which can be used to characterize the structure of bipartite networks (2009:10570). They calculate the EC Index using only trade data from exports, disaggregated by country and by product, both elements being part of the network, meaning that two or more countries are related if they export the same product and two or more products are related if they are exported by the same country. These authors first calculate the Revealed Comparative Advantage (RCA), defined as "the share of product *p* in the export basket of country *c* to the share of product *p* in world trade", for every country in every product.

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Then they create a matrix of 0/1 values where countries appear in rows and products in columns, 1 meaning that a country's RCA value in the corresponding product is equal to or greater than 1, and 0standing forother values (Hidalgo and Hausmann, 2009:10571). It is important to note that in the ECI advantages in a country's products are understood as an expression of the know-how and capabilities required to produce them.

Diversity ($k_{c,0}$) is then calculated by adding up the values of every country, which are shown in the rows, the diversification of a country's export basket being a proxy for abundant knowledge and different capabilities. Likewise, Ubiquity ($k_{p,0}$) is obtained as the sum of values of every product. This measure indicates the number of countries that are relevant exporters of a product, a high number meaning that a lot of countries have the capabilities required for its production and export, so that such capabilities are relatively common (Hausmann, Hidalgo *et al.*, 2013:24).

Such values are iteratively refined using the Method of Reflections to calculate "the average value of the previous-level properties of a node's neighbors" (Hidalgo and Hausmann, 2009:10571). So average ubiquity of the products exported by a country is added to their complexity to calculate $k_{c,1,}$ and so forth. For example, for two countries with the same $k_{c,0}$ and, therefore, the same apparent degree of Diversity, the country exporting less ubiquitous products will have a higher Complexity value. Similarly, for two products with low Ubiquity ($k_{p,0}$), the Complexity value will be higher for the one exported by more diversified exporters. Thus, the Method of Reflection allows us to gradually add more information on the Complexity of countries and products. According to Hidalgo and Hausmann (2009:10573-4), iteration 18gives a more accurate and stable indicator of a country's complexity, which is more strongly correlated with GDP per-capita adjusted for Purchasing Power Parity. The ECI values of countries and of products, which are calculated in the same process, are then normalized by subtracting their respective means and dividing them by their respective standard deviations.

Hausmann *et al.* (2011) explain that the EC Index is important "because countries whose economic complexity is greater than what we would expect, given their level of income, tend to grow faster than those that are «too rich» for their current level of economic complexity" (p. 27). For them, economic complexity is a "driver" of prosperity, rather than a symptom or expression of it.

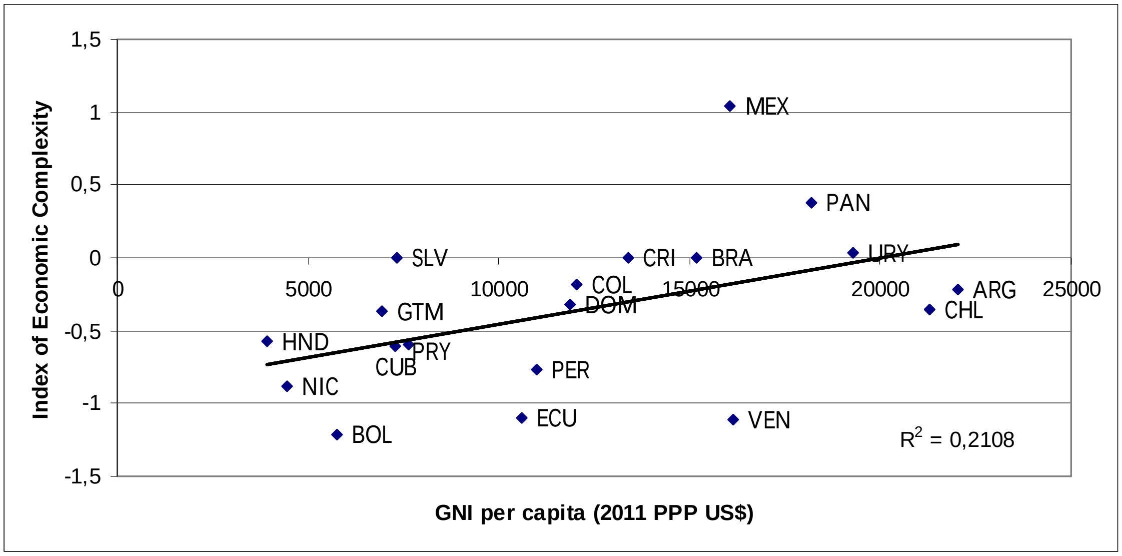
Alongside this introduction to the ECI framework, the study is arranged into a further four sections. In section two we will show the ECI's relationship with other development and complexity measurements, paying special attention to systematic differences in the ranking of Latin American countries that point to the existence of some sort of bias. In section three we will attempt to explain the bias in countries that systematically rank higher than they should in the ECI, which will be carried out using different development measures and forwarding a hypothesis based on the existence of free zones where products that are relatively more complex than the rest of the country's productive structure are produced and exported, consequently biasing the ECI measurement. A proxy will be used to capture this bias. Section four will present the results of an econometrists timed at validating the proxy by exploring whether it can address the measured bias. The final section is devoted to the conclusions of the paper, which mainly deal with the difficulties involved in understanding the exports from free zones as an expression of the capabilities of a country's production system.

2. Economic Complexity Index in Latin America

Hausmann *et al.* (2011) demonstrate the strong correlation between ECI values and income per capita, stating that in "countries with a limited relative presence of natural-resource exports […] economic complexity accounts for 75 percent of the variance of income per capita" (p. 27). However, since there are many countries that are rich in natural resources, this relationship between ECI and GDP per capita must take into account that countries where the extractive sector is prominent can become rich even if they are not complex (i.e. Libya). This "has more to do with geology than know-how" (p. 27), so that the result after measuring the income generated by extractive activities, is that 73 percent of income variation across the 128 countries considered can be explained by the ECI values. Nevertheless, the 2014 ECI values for the 19 Latin American countries included in the Atlas show a much lower capacity to explain variance. The correlation between the 2014 Gross National Income per capita (in 2011 PPP US$)

calculated by the UNDP[4] and the 2014 ECI has a Pearson coefficient of 0.459 (statistically significant at 95 percent confidence interval) while R^2 (the capacity to explain variance) is just 21 percent (Figure 1).

Figure 1.- Index of Economic Complexity and GNI per capita (2014)



Source: Prepared by the authors based on the Atlas of Economic Complexity and theUNDP.

The relationship between ECI values and other proxies that are commonly used to capture a country's know-how, capabilities, innovation capacity or level of development, and are supposed to be related to economic complexity, has been calculated. The Human Development Index and some of its components, such as Life expectancy at birth, mean years of schooling for adults aged 25 and older have been chosen, alongside a proxy for structural change (the share of agriculture in GDP) calculated by the World Bank's World Development Indicators, and four other proxies for technological capabilities offered by the UNESCO in its 2015 report UNESCO Science Report. Towards 2030: patent applications and grants in the 2009-2013periodby applicant's country of origin per million inhabitants, ranking in the Global Innovation Index, and scientific publications per million inhabitants (Table 1)

The ECI values are not significantly correlated with seven of the nine proxies. The only significant correlations are with GNI per capita, at the 95 percent level of confidence, and with the Global Innovation Index, at the 99 percent level of confidence. This mismatch between the ECI values and the basic set of proxies for development and economic complexity is actually surprising, since one would expect the capabilities and know-how captured by the ECI to be reflected in other dimensions of a country's economic and social performance.

Thus, the Spearman rank correlation has been calculated to analyze how the countries are ranked according to the ECI values (Table 2). In this case, correlation improves because two variables are significant at the 99 percent (Patent Application and Global Innovation Index) and another two at the 95 (GNI per capita and Patent Grants).

[4] We have used GNI per capita because there were no 2014 GDP pc data for all Latin American countries.

Table 1. Pearson Correlation Coefficients between Economic Complexity Index (2014) and Development and Economic Complexity Proxies

Variable	Pearson Correlation Coefficient	Significance	R^2
GNI per capita (in 2011 PPP US$) (2014)	0.459*	0.048	0.21
Human Development Index (2014)	0.331	0.167	0.11
Life expectancy at birth (2014)	0.377	0.112	0.14
Average years of schooling of adults aged 25 or older (2014)	0.085	0.729	0.01
Share of agriculture in GDP (2014)	-0.448	0.054	0.20
Patent applications by applicant's country of origin per million inhabitants (2009-2013)	0.455	0.050	0.21
Patents grants by applicant's country of origin per million inhabitants (2009-2013)	0.402	0.088	0.16
Global Innovation Index[a] (rank) (2014)	-0.693**	0.001	0.48
Scientific publications per million inhabitants (2014)	0.342	0.152	0.12

[a] There is no information on Cuba, so correlation was calculated for 18 countries.
* Significant at the 95% level. ** Significant at the 99% level.

Source: Own elaboration based on Atlas of Economic Complexity, PNUD, World Bank and UNESCO (2015) [Patent applications, direct and national phase entries through Patent Cooperation Treaty, total count by applicant's country of origin per million inhabitants (p. 194);Patent grants, direct and national phase entries through Patent Cooperation Treaty, total count by applicant's country of origin per million inhabitants (p. 194);Global Innovation Rank 2014 (p. 745); and Scientific publications per million inhabitants 2014 (p. 777)].

In the next step we have compared the ranking of countries arising from ECI values with that arising from our alternative set of variables for every single variable, also calculating the averages (Table 3). In this case we have excluded the Global Innovation Index because it provides no data for Cuba. It can be stated that the differences in the rankings are not at all random. Some countries almost always rank higher with the ECI than with the other variables in the set. The clearest case is El Salvador, whose ECI ranking is, in average, 11.4 positions better. The standard deviation is very low, just 0.7, so, according to the ECI,El Salvador is always between 10 and 12 positions above what it should be. The same can be said, albeit to a lesser extent, about Honduras, Guatemala and Mexico, which are always an average of 5 positions in the ECI ranking. On the other hand, certain countries always rank worse by the ECI values. The clearest cases are Venezuela, Cuba and Chile, which appear between 8 and 10 places below their position according to other proxies. Perhaps the most striking case is Chile, one of the richest, most successful Latin American countries and always in the topmost positions in income, development and quality of institutions rankings. However, based on the ECI values always, Chileranks approximately eight positions below what would be expected using other proxies.

Table 2. Spearman Correlation Coefficients between Economic Complexity Index (2014) and development and economic complexity proxies

Variable	Spearman Correlation Coefficient	Significance
GNI per capita (in 2011 PPP US$) (2014)	0.518*	0.023
Human Development Index (2014)	0.377	0.111
Life expectancy at birth (2014)	0.343	0.150
Average years of schooling of persons above 25 years of age or older (2014)	0.091	0.712
Share of agriculture in GDP(2014)	-0.400	0.090
Patents applications by applicant's country of origin per million inhabitants (2009-2013)	0.578**	0.010
Patents grants by applicant's country of origin per million inhabitants (2009-2013)	0.535*	0.018
Global Innovation Index[a] (rank) (2014)	-0.732**	0.001
Scientific publications per million inhabitants	0.419	0.074

[a] There is no information on Cuba, so correlation was calculated for 18 countries.
* Significant at the 95% level. ** Significant at the 99% level.
Source: Prepared by the authors basedon the Atlas of Economic Complexity, the UNDP, the World Bank and the UNESCO (2015).

The mismatches between what could be expected and the ECI values, shown in Table 3, point to a problem in the results of the ECI procedure. Since ECI values are supposed be able to predict future growth based on the differences between actual ECI values and those that could be expected from income levels, growth prospects for El Salvador should be much higher than for other countries with the same income level; what is more, against all evidence, Chile, which is successfully becoming a developed country, should have worse growth prospects than other countries with its same income level.

We believe that such mismatches show some kind of bias in the calculation of ECI values. The authors mentioned above reckon that the role of the income generated by extractive activities should be taken into account in the relationship between ECI and GDP per capita, since "geology" can explain high GDP per capita levels that can be captured by ECI values. The following section addresses one of the possible biases that could affect the calculation of EC indices, thus explaining the unanticipated values mentioned above, focusing on those countries whose ECI is higher than expected.

Table 3. Differences between Ranking According to ECI Values and to Other Development and Economic Complexity Proxies

Variable / Country	HDI	Life Expectany	Years of Schooling	GNIc PPP	Patent Applications	Scientifc Publications	Patent Grants	Agriculture as GDP%	Average	Standard Deviation
El Salvador	11	12	12	10	11.5	12	11.5	11	11.4	0.7
Honduras	7	3	7	7	5	7	3.5	5	5.6	1.7
Guatemala	7	7	7	5	4.5	6	4.5	3	5.5	1.5
Mexico	7	5	6.5	5	4.5	5	6	2	5.1	1.5
Colombia	5	6	8	2	2	2	2	3	3.8	2.3
Dominican Republic	4	5	4.5	1	4	9	2	-1	3.6	3.0
Uruguay	0	2	4.5	0	0	-1	2	10	2.2	3.6
Panama	2	2	2	2	2	5	-1	0	1.8	1.8
Costa Rica	1	-2.5	4	3	3	0	3	2	1.7	2.1
Paraguay	1	4	-1.5	0	-3	2	2.5	5	1.3	2.7
Brazil	3	5	5.5	1	-4	-2	0	-1	0.9	3.4
Nicaragua	1	-7	1	2	2.5	-2	2.5	3	0.4	3.4
Bolivia	-3	0	-9	-2	-0.5	-6	-0.5	-3	-3.0	3.1
Argentina	-7	-1	-5.5	-7	-1	-5	-4	1	-3.7	3.0
Peru	-5	-5	-10	-4	-3.5	-3	-2.5	-4	-4.6	2.3
Ecuador	-6	-9	-3.5	-5	-3	-7	-4.5	-5	-5.4	1.9
Chile	-8	-9	-7.5	-8	-9	-9	-8	-9	-8.4	0.6
Cuba	-9	-11.5	-13	1	-8.5	-6	-11	-10	-8.5	4.4
Venezuela	-11	-6	-12	-13	-6.5	-7	-8	-12	-9.4	2.8

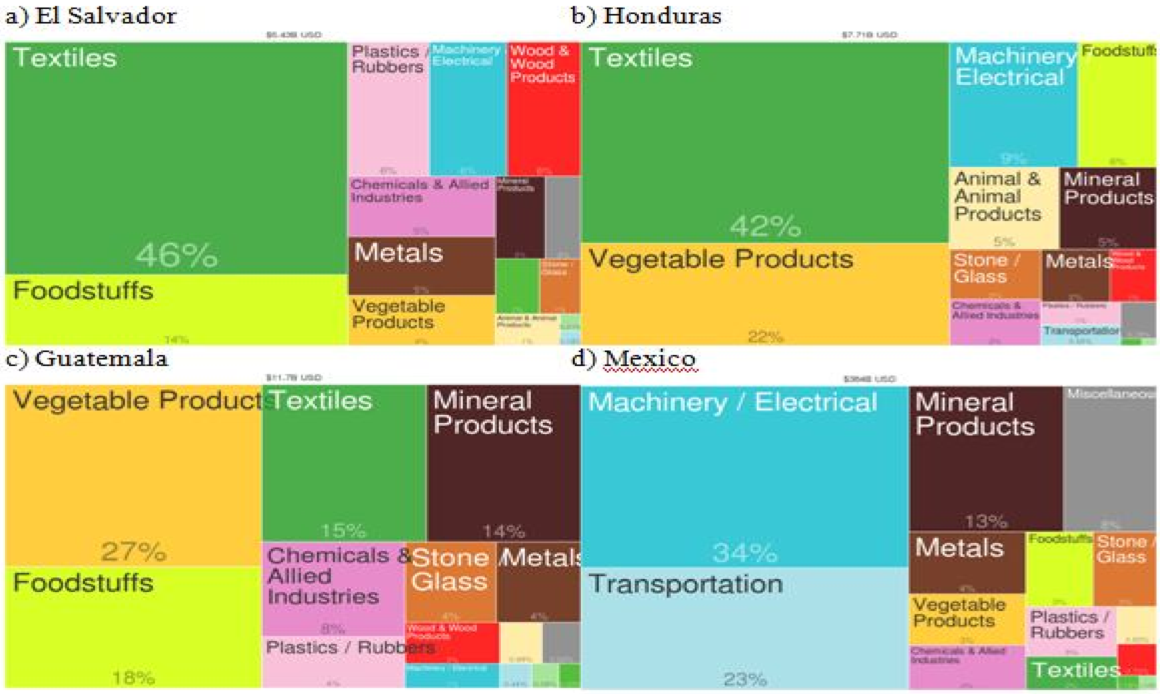
Source: Prepared by the authors based on the Atlas of Economic Complexity, the UNDP, the World Bank and the UNESCO (2015).

3. Exploring the Maquiladora Bias in ECI values

The data in Table 3 show that, besides El Salvador, there are three other outliers where the mean is over twice the standard deviation. These four countries have in common that they are closely linked with the USA, that they have signed free trade agreements and that a significant part of their population has emigrated there and sends remittances back to their home country.

Since the ECI values are calculated on trade data, the focus has been placed on these countries' exports. In 2014, the USA was the main trading partner for all four of them. Data from the Atlas of Economic Complexity show that it accounted for 42, 56, 37 and 71 percent, respectively, of El Salvador, Honduras, Guatemala and Mexican exports. Nevertheless, more important than the USA's relevance as a partner, is the composition of these four countries' exports (Figure 2), which has evolved in recent decades to the point where the role of natural resources and products based on themes no longer as crucial as before. In the three Central American countries the role of textile products, chemicals, plastic and electrical machinery has gained relevance. For instance, in Mexico transport equipment and electrical machinery account for almost 60 percent of total exports.

Figure 2. Composition of exports by group of products, 2014



Source: Taken from the Atlas of Economic Complexity.

The transformation in these four countries has been driven by Foreign Direct Investment (FDI) and often takes the form of a*maquiladora*, a term used to refer to factories that import material and equipment on a duty-free and tariff-free basis for their assembly, processing or manufacturing for exportation, not for the local market. These factories are often located along the border orin Export Processing Zones (EPZs), which include *zonas francas* or free zones, temporary import systems and drawback systems. They form part of global value chains and produce finished goods (i.e. LCD TV sets or computers on the Mexican border), although this does not mean that such production relies on local capabilities. For example, when Mexico exports high-tech products such as LCD TV sets, the value added by local capabilities and labour is only present in the last stages of assembling and packaging for the target consumer. As De la Torre *et al.* (2015: 89) say "the discrepancy between where final goods are produced and exported and where value is created and captured seems to have grown".

Although *maquilas* date back to the60s in the Dominican Republic, building on a strong knowledge base on the phenomenon, Mexico is perhaps the country with the greatest volume of mauledora exports. The literature available provides no evidence of strong demand links between the maquiladora industry, which imports most of its inputs, and the rest of the national industry, nor of important positive productivity spill over. For example, Buitelaar *et al.* (1999) recognize that, although much of them introduce modern management and organization techniques, thus contributing to the development of human resources and production skills, their contribution to innovation and their linkages with the productive sector are weak, since they mainly demand imported inputs. Jenkins *et al.*(1998) highlight that backward linkages between EPZ firms and the rest of the domestic economies in Central America are rather minimal and that "these linkages do not develop automatically and that active government involvement is needed to form them". Mortimore (2003) states that the apparent competitiveness in the Caribbean Basin in the apparel assembly industry in EPZs is illusory, since it is not based on the countries' real technical progress and does not significantly contribute to productive development. In a more recent study on Mexico, Moreno-Brid (2009) explains the lack of export-led growth, despite trade expansion, as a result of the dominant share of manuals in Mexico's industrial exports. Although Mexico exports high-tech industrial goods, most of the technology involved already comes in the imported components of the items, so that Mexico only undertakes the assembly process "with low-skilled labor, little value added and low and stagnant labor productivity" (p. 230).

Hanson (2010) underlines that, while Mexico "has progressed from assembling apparel to assembling electronics and auto-parts, it remains specialized in the labor-intensive processing of inputs for the US economy" (p. 1000), and has thus faced competition with China. When controlling for unobserved heterogeneity with fixed effects, Waldkirch (2010) estimates that, as opposed to maquiladora FDI, non-maquiladora FDIhas a positive impact on Mexico's total factor productivity.

Using Hidalgo and Hausmann's analogy of products being trees and firms being monkeys, the literature suggests that monkeys living in the trees of Export Processing Zones do not usually go to other trees in the country. In other words, free zone factories play a role in the reduction of assembly costs for multinational corporations in global value chains, which is why they can produce and export goods with high economic complexity, such as high tech products. However, this does not imply that the country has the technological means or capabilities to design or produce the main parts of such products. Our hypothesis is that the high ECI values of these four Latin American countries are to some extent related to Relative Comparative Advantages based on their maquiladora exports, which are not a result of their true national capabilities and know-how. In short, we suggest that the ECI values obtained are altered by a "Maquiladora Bias" that limits the capacity to capture the true capabilities and know-how of the countries where maquiladora plants operate. We refer to the same phenomenon proposed by UNCTAD's Trade and Development Report 2002:

Statistics showing a considerable expansion of technology-intensive, supply-dynamic, high value-added exports from developing countries are misleading. Such products indeed appear to be exported by developing countries, but in reality those countries are often involved in the low-skill assembly stages of international production chains organized by transnational corporations (TNCs). Most of the technology and skills are embodied in imported parts and components, and much of the value added accrues to producers in more advanced countries where these parts and components are produced, and to the TNCs which organize such production networks (UNCTAD, 2002, p. V)

We have used proxy for the presence of these *maquila* firms in the exports of the Latin American countries considered in the paper. Since the production of *maquila* factories is mainly exported to rich countries, we have focused on exports to the USA of manufactured goods that are not dependent on primary products. This proxy measures the share of manufactured exports in Harmonized System chapters 28 to 99 to the United States in the total exports of a country and has been calculated using UN Comtrade 2014 data for all the countries considered. This variable has a correlation coefficient of 0.467 with the ECI values. The partial correlations between the ECI values and our development and complexity proxies, controlled by this proxy that tries to capture the Maquiladora Bias have been calculated (Table 4).

Table 4. Partial Correlation Coefficients between Economic Complexity Index (2014) and Development and Economic Complexity Proxies, Controlled by the Share of Manufactured Exports to US to Total Exports (2014)

Variable	Correlation Coefficient	Significance	R2
GNI per capita (in 2011 PPP US$) (2014)	0.551**	0.003	0.55
Human Development Index (2014)	0.582*	0.011	0.48
Life expectancy at birth (2014)	0.492*	0.038	0.41
Average years of schooling of persons above 25 years of age or older (2014)	0.328	0.184	0.30
Share of agriculture in GDP(2014)	-0.546*	0.019	0.45
Patents applications by applicant's country of origin per million inhabitants (2009-2013)	0.640**	0.004	0.54
Patents grants by applicant's country of origin per million inhabitants (2009-2013)	0.637**	0.004	0.54
Global Innovation Indexa (rank) (2014)	-0.783**	0.000	0.69
Scientific publications per million inhabitants (2014)	0.546*	0.019	0.45

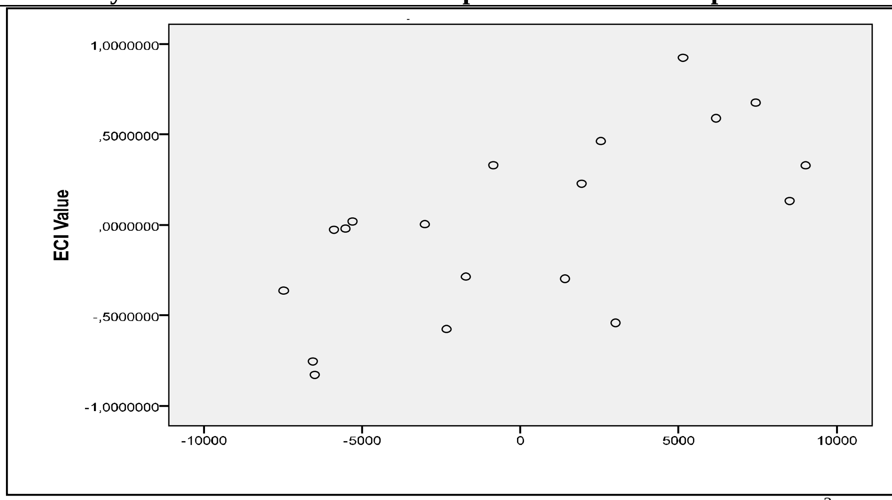
[a] There is no information on Cuba, so correlation was calculated for 18 countries.

* Significant at the 95% level. ** Significant at the 99% level.

Source: Prepared by the authors based on the Atlas of Economic Complexity, the UNDP, the World Bank and the UNESCO (2015). The partial correlation coefficients are higher in all cases, and the significance and capacity of this model that takes into account the export manufactures share to the USA proxy, also improves.

All R^2 results increase dramatically between 0.37 and 0.21, which is proof that our *Maquiladora* Bias proxy captures part of the missing information between the development and complexity variables and the ECI values, as did the variable proposed by Hausmann *et al.* (2011) that captured natural resources based income. The plot for the relationship between ECI values and GNIpc PPP controlled by the share of manufactured exports to US to total exports (Figure 3) proves that our proxy captures a bias in the ECI values and improves adjustment between the two variables.

Figure 3.- XY plot for partial correlation between ECI values and GNIpc PPP controlled by the share of manufactured exports to US to total exports

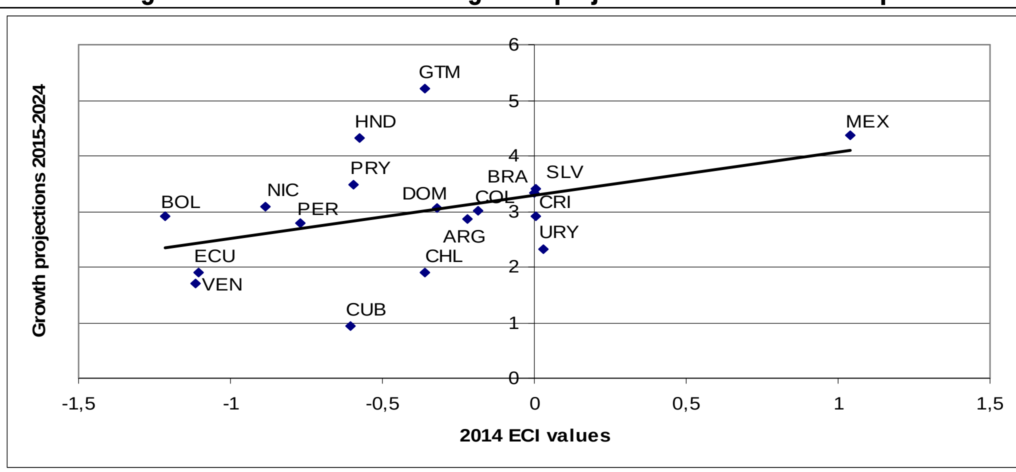


GNI pc PPPR^2= 0.55

Source: Prepared by the authors.

It is important to note that, if this *maquiladora* bias is confirmed, which we believe has been proved, predictions based on those biased ECI values would also be biased (Figure 5). In the 2015-2024 growth projections generated by the Atlas of Economic Complexity, Guatemala, Honduras and Mexico, three of the four countries that are most affected by the *maquiladora* bias, are expected to be the best performers. At the same time, the three countries with the other negative bias are listed among the expected worst performers. Will the facts make this a reality? We think that perhaps they should be corrected taking into account the bias presented in this paper.

Figure 5.- 2014 ECI values and growth projections for the 2015-2024 period



Source: Prepared by the authors based on data from the Atlas of Economic Complexity.

Final Considerations

This article proves the existence of an important, rather than merely random, bias in the ranking of Latin American countries generated by ECI values, since some countries are consistently placed in a higher position than their "natural" one according to their relative level of income, human development, structural change or technological capabilities. El Salvador is a straightforward example, but also Honduras, Guatemala and Mexico are part of this group. At the same time, the paper demonstrates that the ECI values for other countries such as Venezuela, Cuba and Chile, are much lower than would be expected from their relative level of income.

Focusing on the firstly mentioned countries, this paper forwards a hypothesis to explain this bias through the effect of the maquiladora industry on their exports. We have used as a proxy to capture this effectthe share of manufactured exports to US to total exports that has been calculated andbeen used to calculate partial correlations that have, in all cases, improved the correlation coefficient, significance and explanatory capacity. Consequently, we believe that this statistical procedure proves the existence of a *maquiladora* bias in the ECI values calculated by the Atlas of Economic Complexity for Latin American countries.

Finally, if this maquiladora bias is confirmed, we would suggest it be taken into account when generating growth projections, which would no doubt downgrade the growth expectations of Guatemala, Honduras, El Salvador and Mexico in relation to other Latin American countries that are not so involved with EPZ exports.

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