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Revealed comparative advantages and regional specialization: Evidence from Colombia in the Pacific Alliance

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ABSTRACT

This paper is a methodological contribution to the calculation and use of Revealed Comparative Advantage (RCA) indexes. We first explain why the RCA index of Contribution to the Trade Balance (CTB) is theoretically relevant. However, as other RCA indexes might also be reliable measures of comparative advantages, we present standardized tools to compare RCA indexes computed for a given set of countries, products and periods. We illustrate with Colombia in the Pacific Alliance. In that case, the CTB index should be preferred to eight other representative RCA indexes. Therefore, the CTB index might be useful for empirical analysis, besides its theoretical relevance. Last, we suggest highlighting products that constitute strengths (weaknesses) for a country in international trade according to its ability to maintain through time the highest (lowest) CTB index compared with other countries. Again, we illustrate with Colombia in the Pacific Alliance and discuss implications for Colombian economic policy.

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Revealed comparative advantage; regional specialization; Colombia; Pacific Alliance

1. Introduction

The concept of comparative advantage refers to the ability of a country to produce some good/service not only with higher productivity, as initially proposed by Ricardo, but also higher product differentiation than other countries in a given trade area (Lafay, 1987). Since the pioneer work of Balassa (1965), the standard method for the measurement of comparative advantages is the calculation of a Revealed Comparative Advantage (RCA) index on the basis of *trade flows*. The underlying assumption is that trade flows can "reveal" comparative advantages. Let i, j be two countries and k a product or set of them (close substitutes). A higher RCA index for i than for j with respect to k indicates that i has a higher comparative advantage than *j* for that product, or a lower comparative disadvantage.

In practice, however, there is no definite consensus on the appropriate way to calculate an RCA index (French, 2017). Moreover, once an RCA index has been calculated, the way to use that information to better understand the regional specialization of a country, that is, which products constitute strengths and which other products constitute weaknesses for the international trade of that country in a given area, remains unclear. In this respect, this

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paper provides answers to the following two questions: "Which RCA index should be applied to a given set of countries, products and time periods?" and "How can knowledge about the regional specialization of countries be obtained from an RCA index?". Concerning the first question, Section 2 presents a specific RCA index among the many RCA indexes available in the literature, that is, the RCA index in terms of *Contribution to the Trade Balance* (CTB) (De Saint Vaulry, 2008). The CTB index is not applied as much as the standard RCA index initially suggested by Balassa (1965). We argue that more attention should be given to the CTB index because it possesses valuable features that, from a theoretical standpoint, make its measures of comparative advantages relevant.

Nonetheless, other RCA indexes might also have valuable features. In this regard, Section 3 introduces eight representative RCA indexes along with the CTB index, and then elaborates on a set of tools whose aim is to compare RCA indexes from the vantage point of the quality of their application to a given set of countries, products and time periods. Such quality is assessed on the basis of three empirical properties: "time stationarity", "shape" and "ordinal ranking bias". This section compiles some tools already suggested in the literature as well as new tools in order to make the comparison more precise. In addition, the standardized method of comparison we suggest can be applied in the analysis of international trade, whether academic and/or policy-oriented. We give an example of the application of the aforementioned method for the case of Colombia in the Pacific Alliance. For this case, we find that the CTB index best complies with the three aforesaid empirical properties. Thus, in addition to its theoretical relevance, the CTB index may prove useful for empirical analysis.

Last, Section 4 suggests other tools to better understand the regional specialization of countries on the basis of the CTB index, assuming that this index is selected for that kind of analysis. Again, these tools are meant to be applied in various contexts and the case of Colombia in the Pacific Alliance is used as an illustration. This section is structured on two key concepts: "comparative-advantage sustainability" and "comparative-disadvantage recurrence". Ultimately, this paper is a methodological contribution to the calculation and use of RCA indexes.

2. Measuring comparative advantages: the contribution to the trade balance index

Revealed comparative advantage is a key concept in international economics: if comparative advantages determine trade flows, then we can use trade flows to compute an index that reveals comparative advantages. Accordingly, exchange rates, formal/informal trade barriers or internal/external shocks might introduce distortions in trade flows. These distortions might, in turn, bias the measure of comparative advantages. In addition, an RCA index based on trade flows does not provide information about the main channels – factor endowments, institutions, infrastructures, and so on – responsible for comparative advantages (Leromain & Orefice, 2014; Siggel, 2006). In summary, an RCA index based on trade flows approximates the extent to which comparative advantages exist and, by construction, does not give information about their *ex ante* origin (see for example: Amoroso, Chiquiar, & Ramos-Francia, 2011; Marconi, 2012; Nyahoho, 2010). Considering these limitations, many solutions exist for the calculation of an RCA index from the vantage point of trade flows. Here, the choice is made to emphasize the CTB index proposed by the CEPII¹ (French Research Center in International Economics). Let *J* be a set of countries that form a trade area (for instance, the world or a regional trade area such as the Pacific Alliance); *K* a set of goods/services (for example, the 255 three-digit items from the Standard International Trade Classification (SITC)); and *T* a set of time periods (for instance, each year from 1995 to 2017). In addition, let X_{ikt} be the exports of $k \in K$ from *i* to the other countries among *J* in time period *t*; M_{ikt} the imports of *k* by *i* from the other countries among *J* in *t*; $w_{kt} = \sum_{j \in J} (X_{jkt} + M_{jkt}) / \sum_{j \in J} \sum_{l \in K} (X_{jlt} + M_{jlt})$, that is, the weight of *k* in the total trade within *J* in *t*; and Y_{it} the GDP of *i* in *t*. We write as CTB_{ikt,r} the CTB index of country *i* with respect to good/service *k* in the time period *t*, with $r \in T$ as a "reference" time period (whose role will be explained later). CTB_{ikt,r} is calculated as follows:

$$CTB_{ikt,r} = \frac{1}{Y_{it}} \left[\frac{w_{kr}}{w_{kt}} (X_{ikt} - M_{ikt}) - w_{kt} \sum_{l \in K} \frac{w_{lr}}{w_{lt}} (X_{ilt} - M_{ilt}) \right]$$
(1)

The CTB index is the GDP-normalized difference between:

- (1) $\frac{w_{kr}}{w_{kt}}(X_{ikt} M_{ikt})$, which corresponds to the trade balance registered by *i* with respect to *k* in *t*, adjusted by w_{kr}/w_{kt} ; and:
- (2) (2) $w_{kt} \sum_{l \in K} \frac{w_{lt}}{w_{lt}} (X_{ilt} M_{ilt})$, which is the total adjusted trade balance registered by *i* in *t*, proportional to w_{kt} .

The adjustment by w_{kr}/w_{kt} of every $X_{ilt} - M_{ilt}$, including $X_{ikt} - M_{ikt}$, and therefore of every trade flow related to *i* in *t* aims to better reveal comparative advantages. As suggested previously, some exports/imports might increase or decrease, but part of this variation may be the result of short-run fluctuations rather than structural changes linked to comparative advantages. Consequently, trade flows should be adjusted. The CTB index assumes the following:

Assumption 2.1. If $w_{kt} \neq w_{kr}$, trade flows in t within J are distorted by short-run fluctuations.

According to Assumption 2.1, trade flows in the time period r are not biased by short-run fluctuations (or such bias is minimized). Consequently, every trade flow related to i in t should be multiplied by w_{kr}/w_{kt} to reflect w_{kr} instead of w_{kt} (see the example below). $w_{kt} \sum_{l \in K} \frac{w_{lr}}{w_{lt}} (X_{ilt} - M_{ilt})$ is then erected as the comparative-advantage neutral level of the trade balance related to (i; k; t). This theoretical level stems from the following assumption:

Assumption 2.2. For a given country *i*, the absence of comparative advantages or disadvantages corresponds to the distribution of the (adjusted) trade balance of *i* in

¹www.cepii.fr/CEPII/en/welcome.asp.

proportion to the weight of each product k in the total (adjusted) trade of the area under consideration (see Lafay, 1987).

The theoretical level is therefore compared to the actual (adjusted) level, namely, $\frac{w_{kr}}{w_{kt}}(X_{ikt} - M_{ikt})$. If the latter is greater than the former, then trade flows are supposed to reveal a comparative advantage for *i* with respect to *k* in *t*; the converse is true if the latter is lower than the former. The CTB index is calculated as the difference between the actual trade balance and the theoretical trade balance. A difference equal to zero indicates neither comparative advantage nor comparative disadvantage for (*i*; *k*; *t*); a strictly positive difference indicates a comparative advantage, and a strictly negative difference reflects a comparative disadvantage. This method of revealing comparative advantages possesses valuable features that are important not only from a theoretical standpoint, but also for empirical research.

First, because the CTB index is based on trade balance (i.e., net exports) comparative advantages can be measured more precisely. In the canonical Ricardian example, comparative advantages are determined by relative productivity. However, a country might have a comparative advantage with respect to its trade partners if it differentiates its products through quality, branding or post-sale customer service (Jaimovich & Merella, 2015). On the one hand, if for a given product k a country i has higher productivity with respect to some trade partners, k can be traded at a lower price and eventually exported. On the other hand, however, foreign countries can trade differentiated versions of the same product. These close substitutes might have a higher price, yet i will import them due to demand for variety. Eventually, a country exports differentiated versions of a given product and simultaneously imports others. Such intra-industry trade implies that an RCA index should reveal comparative advantages through both exports and imports (Lafay, 1987). In this regard, the logic of the CTB index is to focus on the trade balance that results from exports and imports. To reveal comparative advantage, the trade balance must be sufficiently high to indicate that the country's combination of productivity and product differentiation offsets the productivity and product differentiation of other countries within the trade area under consideration. Accordingly, Assumption 2.2 determines the threshold of the trade balance that reveals comparative advantages.

Second, the extent of comparative advantages depends on w_{kt} , which is the weight of k in total trade (in t). If the weight is higher, then the theoretical trade balance of i for k is higher, and thus i must register a higher trade balance with respect to k to have a comparative advantage for that product. Indeed, if w_{kt} is higher, some countries have a higher ability to trade with others, which should stem from an improvement in their productivity or product differentiation. This makes it harder for i to have a comparative advantage for k, resulting in an increase in the theoretical trade balance. Consequently, Assumption 2.2 is consistent with the fact that comparative advantages are relative across countries for a given product.

Third, the extent of comparative advantages depends on $\sum_{l \in K} \frac{w_{lr}}{w_{li}} (X_{ilt} - M_{ilt})$, which is the total (adjusted) trade balance of *i* (in *t*). If this total trade balance is higher, then the same logic as before applies: the theoretical trade balance of *i* for *k* is higher, and thus *i* must register a higher trade balance with respect to *k* to have a comparative advantage for that product. By construction, no country has a comparative advantage for all products. If i increases its total trade balance, then i should have improved its productivity or differentiation for some products. Consequently, comparative advantage is gained for some products but lost for others. k might be among those products for which comparative advantage is lost. Therefore, to maintain its comparative advantage for k, i must also improve productivity or product differentiation, which in turn translates into an increase in the theoretical trade balance in k. Eventually, Assumption 2.2 is consistent with the fact that comparative advantages are relative across products for a given country.

Fourth, the consistency between the CTB index and the across-country/product relative nature of comparative advantages is supported by the following property: $\sum_{j \in J} \sum_{l \in K} CTB_{jlt,r} \rightarrow 0 \ \forall t, r$. This property of the CTB index indicates that if *i* has a comparative advantage for *k*, then *i* has a comparative disadvantage for other products, and other countries have a comparative disadvantage for *k*. Independent of the period *t* and the adjustment of trade flows through the period *r* (see Assumption 2.1), no country has a comparative advantage for the same product.

Finally, the difference between the trade balance and the theoretical trade balance is normalized by the GDP of i in t. This normalization aims to link the existence of comparative advantages to the economic size of i in t. Thus, if two countries show the same positive difference, the CTB index is *higher* for the country with the lowest GDP. Indeed, in this case, a lower GDP indicates a higher international specialization, and therefore a *higher* comparative advantage; consequently, the CTB index is higher. According to the same logic, if two countries show the same negative difference, the CTB index is lower for the country with the lowest GDP.

Example 2.3. Suppose that in the trade area comprising England and Portugal, two products are traded: cloth and wine. Trade is as follows in 1821:

		Exports (£)		Imports (£)			
		England	Portugal	England	Portugal	Trade by product (f)	
1821	Cloth Wine	42 6	6 18	6 18	42 6	96 48	

What comparative advantages do these trade flows reveal? First, we adjust the flows at issue using 1815 as the reference year and assuming the following:

		Exports (£)		Imports (£)			
		England	Portugal	England	Portugal	Trade by product (\pounds)	
1815	Cloth Wine	28 8	2 2	2 2	28 8	60 20	

Writing 0 for year 1815, 1 for year 1821, *C* for cloth and *W* for wine, we thus have $w_{C0} = 60/(60 + 20) = 3/4$, $w_{W0} = 20/(60 + 20) = 1/4$, $w_{C1} = 96/(96 + 48) = 2/3$, and $w_{W1} = 48/(96 + 48) = 1/3$. Thus, $w_{C0}/w_{C1} = \frac{3/4}{2/3} = 9/8$, and $w_{W0}/w_{W1} = \frac{1/4}{1/3} = 1/3$.

		Adjusted	Adjusted exports (£)		mports (£)	
		England	Portugal	England	Portugal	Adj. trade by product (f)
1821	Cloth Wine	47.25 4.5	6.75 13.5	6.75 13.5	47.25 4.5	108 36

3/4. Using these last two coefficients to adjust exports and imports in 1821, we obtain the following:

Thus, cloth and wine, respectively, amount to three quarters -108/(108 + 36) – and one quarter -36/(180 + 36) – of total trade in 1821, as in 1815. Thereafter, writing E for England and P for Portugal, and assuming $Y_{E1} = 1000 \pounds$ and $Y_{P1} = 500 \pounds$:

$$\begin{array}{l} \text{CTB}_{EC1,0} = \frac{1}{1000} \times \left[47.25 - 6.75 - \frac{3}{4} (47.25 - 6.75 + 4.5 - 13.5) \right] = 0.016875 \\ \text{CTB}_{EW1,0} = \frac{1}{1000} \times \left[4.5 - 13.5 - \frac{1}{4} (47.25 - 6.75 + 4.5 - 13.5) \right] = -0.016875 \\ \text{CTB}_{PC1,0} = \frac{1}{500} \times \left[6.75 - 47.25 - \frac{3}{4} (6.75 - 47.25 + 13.5 - 4.5) \right] = -0.03375 \\ \text{CTB}_{PW1,0} = \frac{1}{500} \times \left[13.5 - 4.5 - \frac{1}{4} (6.75 - 47.25 + 13.5 - 4.5) \right] = 0.03375 \end{array}$$

Based on the sign of each CTB index, England has a comparative advantage for cloth and a comparative disadvantage for wine in 1821 in the bilateral trade area with Portugal; the converse is true for Portugal in the same area. In addition, the level of comparative advantage of England for cloth is lower than the level of comparative advantage of Portugal for wine, whereas the level of comparative disadvantage of England for wine is lower than the level of comparative disadvantage of cloth.

Remark 2.4. If $\exists k, t : w_{kt} = 0$, the coefficient $\frac{w_{kr}}{w_{kt}}$ cannot be calculated because the denominator would be equal to zero. Nonetheless, in this case, $X_{ikt} = M_{ikt} = 0 \quad \forall i$. Thus, the actual trade balance related to any *i* is already equal to zero before multiplication by some adjustment coefficient, while the total trade balance of *i* would also be multiplied by zero (w_{kt}) before adjustment. Consequently, both the actual trade balance and the theoretical trade balance are equal to zero, as is the normalization of their difference by Y_{it} . Ultimately, $\exists k, t : w_{kt} = 0 \Rightarrow CTB_{ikt,r} = 0 \quad \forall i$. In summary, if no country trades *k* with another in *t*, then no country has a comparative advantage or comparative disadvantage for the corresponding (k; t).

Remark 2.5. Older versions of the CTB index do not include the adjustment procedure for trade flows or are normalized by w_{kt} instead of Y_{it} . See Lafay (1987, 1992) and Marconi (2012). In addition, as suggested by De Saint Vaulry (2008), the CTB index presented above can be multiplied by 1000 to express it as a per millage of GDP (see also Stellian & Danna Buitrago, 2017).

3. A standardized method of RCA index selection

The CTB index is not the sole option for calculating an RCA index based on trade flows, and thus applying the CTB index to a given set of countries, products and time periods must be justified. We, therefore, introduce eight other RCA indexes (3.1) and then elaborate on a set of tools for comparing RCA indexes on the basis of selected desirable properties of an RCA index (3.2). Colombia in the Pacific Alliance is used as an illustration.

3.1. Competitors of the CTB index

We introduce successively i) the index of Balassa (1965), which is the standard in the literature (Beyene, 2014; Bushra & Saba, 2014; OelgemöLler, 2013); ii) the "weighted" version of the standard index from Proudman and Redding (1998), as well as the "symmetric" version from Laursen (2015); iii) the "additive" index from Hoen and Oosterhaven (2006); iv) the indexes from Balassa (1986) and Michaely (1962); v) the "normalized" index from Yu, Cai, and Leung (2009); and vi) the "regression-based" index from Leromain and Orefice (2014). Each index and its interpretation are briefly described.

3.1.1. The standard RCA index

According to Balassa (1965), *i* is supposed to have neither comparative advantage nor comparative disadvantage with respect to *k* in *t* if the part of *k* in the total exports of *i* in *t* equals the same part at the level of the #J countries of the trade area under consideration, namely, if $X_{ikt} / \sum_{l \in K} X_{ilt} = \sum_{j \in J} X_{jkt} / \sum_{l \in K} X_{jlt}$. If the first ratio is greater than the second, *i* has a comparative advantage for *k* in *t*; the converse is true if the first ratio is lower than the second. From this point of view, let B65_{ikt} be the RCA index from Balassa (1965) for a given (*i*; *k*; *t*). B65_{ikt} is given by the following formula:

$$B65_{ikt} = \frac{X_{ikt} / \sum_{l \in K} X_{ilt}}{\sum_{j \in J} X_{jkt} / \sum_{j \in J} \sum_{l \in K} X_{jlt}}$$
(2)

As a result, $B65_{ikt} = 1$ is the comparative-advantage neutral value. $B65_{ikt} > 1$ is supposed to reveal a comparative advantage, and $B65_{ikt} \in [0; 1[$ is supposed to reveal a comparative disadvantage. Note that if $\exists k, t : \sum_{j \in J} X_{jkt} = 0$, $B65_{ikt}$ should be set to its neutral value (1) for every country. Indeed, if no country trades k with another in t, no country is supposed to have the comparative advantage or disadvantage for k in t (whereas the B65 index would be impossible to calculate because its denominator would be equal to zero).

3.1.2. The "weighted" and "symmetric" versions of the standard RCA index

Proudman and Redding (1998) and then Laursen (2015) suggest other indexes derived from the B65 index with the aim of providing more symmetry in the distribution of the overall set of indexes for a given (i; t), namely, $\{RCA_{ikt}; k \in K\}$ (considerations about the symmetry issue will be introduced later). The RCA index from Proudman and Redding (1998), written as WB65_{*ikt*} for (i; k; t), consists of weighting B65_{*ikt*} by the across-item average of the B65 index for (i; t):

$$WB65_{ikt} = \frac{B65_{ikt}}{\frac{1}{\#K} \sum_{l \in K} B65_{ilt}}$$
(3)

With this transformation, $1/\frac{1}{\#K}\sum_{l\in K} B65_{ilt}$ is the new comparative-advantage neutral value, instead of 1. Again, values of the WB65 index greater than the comparative-advantage neutral value are supposed to reveal comparative advantages, whereas lower values (but greater than 0) are supposed to reveal comparative disadvantages.

The RCA index from Laursen (2015), written as SB65, is an approximation of the log-transformation of the B65 index:

$$SB65_{ikt} = \frac{B65_{ikt} - 1}{B65_{ikt} + 1}$$
(4)

With this transformation, 0 is the new comparative-advantage neutral value (instead of 1); once again, greater values of the SB65 index (less than or equal to 1) are supposed to reveal comparative advantages, whereas lower values (greater than or equal to -1) are supposed to reveal comparative disadvantages.

3.1.3. The additive RCA index from Hoen and Oosterhaven (2006)

From the same perspective as Balassa (1965), Hoen and Oosterhaven (2006) suggest an "additive" RCA index, which we write as A_{ikt} for a given (i; k; t):

$$A_{ikt} = \frac{X_{ikt}}{\sum_{l \in K} X_{ilt}} - \frac{\sum_{j \in J} X_{jkt}}{\sum_{j \in J} \sum_{l \in K} X_{jlt}}$$
(5)

Instead of dividing $X_{ikt} / \sum_{l \in K} X_{ilt}$ by $\sum_{j \in J} X_{jkt} / \sum_{j \in J} \sum_{l \in K} X_{jlt}$, the additive index calculates the difference between the former ratio and the latter ratio. In this case, $A_{ikt} = 0$ is supposed to be the comparative-advantage neutral value (instead of 1 as for the B65 index), $A_{ikt} > 0$ is supposed to reveal a comparative advantage (instead of B65_{*ikt*} > 1), and $A_{ikt} < 0$ is supposed to reveal a comparative disadvantage (instead of B65_{*ikt*} $\in [0; 1[)$.

3.1.4. The RCA indexes from Michaely (1962) and Balassa (1986)

These two indexes take into account imports in addition to exports, in contrast to the aforementioned indexes. Like Balassa (1965), the starting point of Michaely (1962) is the part of k in the total exports of i in t, namely, $X_{ikt} / \sum_{l \in K} X_{ilt}$. Unlike Balassa (1965), Michaely (1962) suggests revealing comparative advantage by comparing $X_{ikt} / \sum_{l \in K} X_{ilt}$ on the one hand and $M_{ikt} / \sum_{l \in K} M_{ilt}$ instead of $\sum_{j \in J} X_{jkt} / \sum_{j \in J} \sum_{l \in K} X_{jlt}$ on the other hand. Put differently, for a given (i; k; t), neither comparative advantage nor comparative advantage is assumed to exist if the part of k in the total exports of i in t equals the part of k in the total imports of i in t; that is, $X_{ikt} / \sum_{l \in K} X_{ilt} = M_{ikt} / \sum_{l \in K} M_{ilt}$. If the first ratio is greater than the second ratio, then i is supposed to have a comparative advantage for k in t, and vice-versa if the first ratio is less than the second ratio. From this point of view, the index from Michaely (1962), written as MC_{ikt} for a given (i; k; t), is calculated as follows:

$$MC_{ikt} = \frac{X_{ikt}}{\sum_{l \in K} X_{ilt}} - \frac{M_{ikt}}{\sum_{l \in K} M_{ilt}}$$
(6)

The comparative-advantage neutral value of the MC index is zero. A strictly positive index is supposed to reveal a comparative advantage, and a strictly negative index is supposed to reveal a comparative disadvantage.

Balassa (1986) assumes that there is neither comparative advantage nor comparative disadvantage for a given (i; k; t) if the corresponding trade balance is in equilibrium; that is, $X_{ikt} - M_{ikt} = 0$. Thus, comparative advantage is implied by a trade surplus $(X_{ikt} - M_{ikt} > 0)$ and comparative disadvantage by a trade deficit $(X_{ikt} - M_{ikt} < 0)$. The B86 index is calculated as follows:

$$B86_{ikt} = \frac{X_{ikt} - M_{ikt}}{X_{ikt} + M_{ikt}}$$
(7)

The trade balance $X_{ikt} - M_{ikt}$ is normalized by the total trade registered by *i* in *t* with respect to *k*; that is, $X_{ikt} + M_{ikt}$. The B86 index has the same comparative-advantage neutral value as the MC index and therefore the same interpretation about the existence of comparative advantages.

Remark 3.1. If $X_{ikt} + M_{ikt} = 0$, we set $B86_{ikt} = 0 \forall i$. If *i* does not trade *k* in *t*, then *i* is not supposed to have a comparative advantage or comparative disadvantage for that item in that period (the index would be impossible to calculate because its denominator would be equal to zero). In this case, the index is set at its neutral value.

3.1.5. The "normalized" RCA index from Yu et al. (2009)

The RCA index suggested by Yu et al. (2009), written as NY, shares some similarities with the CTB index. It is based on the difference between actual exports and comparative-advantage neutral exports, which are calculated as the total exports of i multiplied by the weight of k in the total exports of the trade area. Thus, the treatment of exports by the NY index is analogous to the treatment of trade balance by the CTB index. In addition, the NY does not adjust trade flows. Finally, the CTB index includes a normalization by GDP (of i in t), whereas the NY index includes a normalization by total exports (in t). As a result, the NY index is as follows:

$$NY_{ikt} = \frac{1}{\sum_{j \in J} \sum_{l \in K} X_{jlt}} \left(X_{ikt} - \frac{\sum_{j \in J} X_{jkt}}{\sum_{j \in J} \sum_{l \in K} X_{jlt}} \sum_{l \in K} X_{ilt} \right)$$
(8)

3.1.6. The "regression-based" RCA index from Leromain and Orefice (2014)

The RCA index suggested by Leromain and Orefice (2014) starts from the OLS estimation of the following equation:

$$\ln(x_{ijkt}) = \delta_{ijt} + \delta_{ikt} + \delta_{jkt} + \epsilon_{ijkt}$$
(9)

 x_{ijkt} denotes the trade flow of k from i to another country j in t. For each period, the log of x_{ijkt} is decomposed additively into an exporter-importer fixed effect (δ_{ijt}), an exporter-product fixed effect (δ_{ikt}) and an importer-product fixed effect (δ_{jkt}); ϵ_{ijkt} is the residual term.² Using the model of Costinot, Donaldson, and Komunjer (2012), the exporter-product fixed effect verifies:

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$$\delta_{ikt} = \theta \ln(z_{ikt}) \tag{10}$$

 z_{ikt} approximates the Ricardian fundamental productivity level of *i* with respect to *k* in *t*. The coefficient θ , which parameterizes the influence of z_{ikt} over trade flows, captures productivity dispersion across varieties of the same *k*. θ is derived from a Frchet distribution and is assumed to be invariant across countries, products and time. Therefore, once δ_{ikt} is estimated, z_{ikt} is calculated as follows:

$$z_{ikt} = \exp\left(\frac{\delta_{ikt}}{\theta}\right) \tag{11}$$

The regression-based index then consists of calculating $z_{ikt}/\frac{1}{\#K}\sum_{l\in K} z_{ilt}$, which is *i*'s productivity of *k* normalized by *i*'s average productivity across products (in *t*), and $\frac{1}{\#J}\sum_{j\in J} z_{jkt}/\frac{1}{\#J\times\#K}\sum_{j\in J}\sum_{l\in K} z_{jlt}$, which is the same ratio at the level of the #J countries of the trade area under consideration. *i* has a comparative advantage for *k* in *t* if the first ratio is higher than the second; the converse is true if the first ratio is lower than the second. The regression-based index, written as Z, is calculated as follows:

$$Z_{ikt} = \frac{z_{ikt} / \frac{1}{\#K} \sum_{l \in K} z_{ilt}}{\frac{1}{\#J} \sum_{j \in J} z_{jkt} / \frac{1}{\#J \times \#K} \sum_{j \in J} \sum_{l \in K} z_{jlt}}$$
(12)

Like the B65 index, $Z_{ikt} = 1$ is the comparative-advantage neutral value. $Z_{ikt} > 1$ is supposed to reveal a comparative advantage, and $Z_{ikt} \in [0; 1[$ is supposed to reveal a comparative disadvantage.

3.2. The CTB index and its competitors: analysis of their empirical properties

The CTB index has valuable features, independently of the specification of J, K and T for empirical research. As explained in Section 2, the CTB index includes an adjustment process for trade flows that aims to better reveal comparative advantages. In addition, the CTB index is consistent with the across-country/product relative nature of comparative advantages. Furthermore, the CTB index captures the comparative advantages related not only to inter-industry trade but also to intra-industry trade through trade balance. Last, the measure of comparative advantage is linked to the economic size of each country through GDP normalization. No other RCA index combines these features simultaneously. For instance, no other index includes an adjustment process for trade flows nor normalization by GDP. Some are based on exports only (B65, WB65, SB65, A and NY) and therefore are not able to reveal comparative advantages linked to intra-industry trade through imports in addition to exports.

Consequently, the CTB index should be seen as a suitable measure of comparative advantages, although the regression-based index should not be dismissed. Indeed, this index has the merit of being grounded on a theoretical model in the form of a standard Ricardian model (constant returns to scale, perfect competition and labor as the unique factor of production, among others) generalized by allowing for heterogeneity in productivity across varieties of the same product (Costinot et al., 2012).

²French (2017) suggests decomposing x_{ijkt} multiplicatively: $x_{ijkt} = \phi_{ijt}\phi_{ikt}\phi_{jkt} + \epsilon_{ijkt}$. Therefore, $\ln(\phi_{ijt})$, $\ln(\phi_{ikt})$ and $\ln(\phi_{ijkt})$ have the same interpretations as δ_{ijt} , δ_{ikt} , and δ_{jkt} , respectively.

Notwithstanding, this model implies that the regression-based index reveals comparative advantages given by relative productivity only. Put differently, the regression-based index has a clear theoretical interpretation but simultaneously narrows the nature of comparative advantages it is able to capture. On the contrary, an RCA index should encompass product differentiation as an inherent part of comparative advantages. Precisely, the measure suggested by the CTB index, which is based on Assumption 2.2, is compatible with this more flexible concept of comparative advantages, as explained in Section 2.

To summarize, both the CTB index and regression-based index have appreciable strengths. To acquire a clearer picture of the adequate RCA index and possibly justify the use of the CTB index, we must go beyond the previous discussion about the theoretical relevance of an RCA index. To this purpose, let us note that the RCA indexes specifically computed for a given $J \times K \times T$ should show the three following features. The first feature is *time stationarity*. Theory suggests that specialization patterns are sticky. Therefore, the RCA indexes calculated for a given (i; k) – namely, $\{RCA_{ikt}; t \in T\}$ – should not vary greatly over time. Comparative advantages are not fully stationary over time. Rather, there could be some short-run deviations from a long-run value, in the manner of a mean-reverting stochastic process, as suggested by Hanson, Lind, and Muendler (2015). Regardless, higher variation in an RCA index is more likely to be the result of short-run fluctuations in trade flows than the sole reflection of changes in comparative advantages (Laursen, 2015; Leromain & Orefice, 2014). In this respect, an RCA index should be preferred to another if its time stationarity is higher. The second feature is related to shape. The distributions of the RCA indexes calculated for a given (i; t) – namely, {RCA_{ikt}; $k \in K$ } – should be as symmetric as possible and avoid fat tails. The aim is to facilitate across-item and acrosscountry comparisons (Leromain & Orefice, 2014). Last, the third feature is the minimization of the ordinal ranking bias. Assume that i is ranked as the x^{th} country according to the level of its RCA index for some k (in t). Ordinal ranking bias occurs if the RCA indexes shown by *i* for the other items tend to be higher even though they imply that *i*'s rank is less than *x* or tend to be lower even though they imply that *i*'s rank is higher than x (Leromain & Orefice, 2014; Yeats, 1985). An RCA index should avoid ordinal ranking bias as much as possible.

Let us elaborate on a set of tools to measure the extent to which an RCA index is most able to comply with these features and illustrate the application of these tools in the case of Colombia in the Pacific Alliance. First, we briefly explain why this case warrants attention.

3.2.1. Colombia and regional specialization in the Pacific Alliance

Colombia is increasing its participation in regional cooperation, as exemplified by agreements signed with the United States (2006), Canada (2009) and the European Union (2012). In addition, in Latin America, Colombia is now part of the *Pacific Alliance* together with Chile, Mexico and Peru. According to the Lima Declaration of 28 April 2011, one aim of the Pacific Alliance is "to move progressively towards the free movement of goods, services, resources and people".³ To this purpose, Colombia, Chile,

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Member	Chile	Colombia	Mexico	Peru
Total number of items	7797	7542	11,532	7480
Immediate elimination (2015)	7612	7217	10,980	7314
	97.63%	95.69%	95.21%	97.78%
Others	185	325	552	166
	2.37%	4.31%	4.79%	2.22%

Table 1. Tariff elimination schedule for goods, Pacific Alliance.

Source: Documents entitled "Listas de desgravación", website of the Pacific Alliance (alianzapacifico.net/documentos); Authors' calculation.

Mexico, and Peru signed an agreement on 6 June 2012 (Antofagosta), explicitly stating that these four countries must move toward free trade between each other (art. 3.2.a).

To accomplish this change, the protocol of Cartagena De Indias (10 February 2014) includes various commitments. With respect to goods, each member of the Pacific Alliance will eliminate the tariffs applied to the three other members and will not be allowed to increase some existing tariffs or create new ones (art. 3.4). Each member has negotiated schedules for the elimination of tariffs on thousands of items. As shown in Table 1, as of 2015, tariffs have been removed on at least 95.21% of items (Mexico) and up to 97.78% (Peru). The remaining tariffs will be removed more or less progressively over one to seventeen years. In addition, non-tariff barriers are no longer allowed between members, except export subventions to agriculture - although members should seek their elimination (art. 3.16) - and under the motives put forth by the eleventh article of the General Agreement on Tariffs and Trade⁴ (art. 3.6). Finally, imports will not be treated less favorably than domestic production (art. 3.3). With respect to services, the four members will no longer apply restrictions on the number of providers or their location, legal form, number of employees, value of assets and number/value of operations (art. 9.5 and 9.6); some sectors, such as finance, e-commerce or communication, are subject to specific rules (art. 9.2). Similarly, members should seek the elimination of subventions with trade-distorting effects (art. 9.11). Finally, imports will not be treated less favorably than domestic production (art. 9.3).

In this context, which products are most or least able to stimulate the total trade balance of Colombia within the Pacific Alliance? Answering this question will provide analytical insights on how Colombia can use trade in goods in the Pacific Alliance as a tool for promoting growth. Indeed, the movement of the four members of the Pacific Alliance toward free trade might help Colombia increase its exports of a given good k to the three other members. By contrast, imports of k by Colombia from within the Pacific Alliance might not increase or might increase to a lesser extent than the aforementioned increase in exports. In this case, the resulting trade balance of k will increase, indicating that Colombian production of k increases through trade within the Pacific Alliance (everything else being equal), thus contributing to growth at the macro level. The converse is true if exports do not increase as much as imports.

³More information is available at the website of the Pacific Alliance: alianzapacifico.net/en/que-es-la-alianza/#la-alianzadel-pacifico-y-sus-objetivos.

⁴For example, trade restrictions are temporarily allowed to prevent or relieve critical shortages of foodstuffs, or to apply standards or regulations for the classification, grading or marketing of goods in international trade. More details can be found at wto.org/english/res_e/booksp_e/analytic_index_e/gatt1994_e.htm.

Ultimately, investigating Colombian goods that may or may not benefit from the Pacific Alliance – in other words, exploring the regional specialization that Colombia might adopt with respect to Chile, Mexico and Peru – should help optimize the overall effects of this regional trade area on Colombian production. Thus, this kind of investigation could help Colombian policy makers determine the public support required by the business sector to gain fullest advantage from the Pacific Alliance. To identify those products that constitute strengths or weaknesses for the international trade of Colombia within the Pacific Alliance, the calculation of a Revealed Comparative Advantage (RCA) index can be introduced. Consequently, selecting the most adequate RCA index is a preliminary step before inquiring how to infer products that are strengths or weaknesses according to an RCA index.

In addition, the economic literature on the Pacific Alliance remains scarce. In 2016, the journal *Estudios Gerenciales* published an issue dedicated to the Pacific Alliance that included contributions on foreign direct investment (Concha & Gómez, 2016), financial markets (Arbeláez Garca & Rosso, 2016), economic convergence (Mora Mora, 2016) and trade structure (Lámbarry Vilchis, 2016) *inter alia*. Hernández Bernal and Muñoz Ángulo (2015) and Caporale, Costamagna, and Rossini (2016) also examine the trade in the Pacific Alliance. However, none of these contributions explores RCA indexes for Colombia within the Pacific Alliance, with the exception of Montoya-Uribe, Gonzalez-Parias, and Duarte-Herrera (2016). However, Montoya-Uribe et al. (2016) use the SB65 index without a preliminary analysis to fully justify why this index is most adequate.

To implement our case, we must define J, K and T. As we study the regional specialization of Colombia within the Pacific Alliance, $J = \{CL; CO; MX; PE\}$. As for trade flows, we use the data provided by UNCTADStat⁵ according to the 255 three-digit items of the SITC classification⁶ and for each one of the 23 years from 1995 to 2017. Therefore, K will correspond to that classification (trade flows will not include services, as the corresponding data are not yet available), and T will comprise these years. More specifically for the CTB index, data about GDP are taken from World Bank Open Data⁷, and we choose the first available year (1995) as the reference year (r); accordingly, the reference year could be changed in further investigation. Concerning the Z index, we use the estimation of θ in Costinot et al. (2012): $\theta = 6.534$; see the discussion about the estimation of θ in Leromain and Orefice (2014). In addition, as pointed out by French (2017), if $x_{ijkt} = 0$ then $\ln(x_{ijkt})$ cannot be calculated; thus x_{ijkt} is considered a missing value when estimating Equation (9). To avoid such sampleselection bias, we approximate $\ln(x_{iikt})$ by $\ln(x_{iikt} + 1)$; that is, a single US dollar is added to each trade flow. Eventually, we calculate the RCA index nine times (B65, WB65, SB65, A, MC, B86, NY, Z and CTB) for each of the $\#J \times \#K \times \#T = 4 \times$ $255 \times 23 = 23460$ elements of $I \times K \times T$ as designed previously. All calculations are available on request. Table 2 provides summary statistics for each index.

⁵unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx.

 $^{^{6}}$ See unstats.un.org/unsd/cr/registry/regcst.asp?Cl = 14&Top = 2&Lg = 1 for full details about each item.

⁷data.worldbank.org/indicator/NY.GDP.MKTP.CD.

	Mean	Std. Dev.	Q1	Median	Q3	Min	Max
B65	1.042	1.308	7.046e-2	0.590	1.498	0	9.983
WB65	1	1.210	6.835e-2	0.577	1.491	0	8.033
SB65	-0.283	0.554	-0.868	-0.258	0.200	-1	0.818
А	1.402e-19	1.159e-2	-1.143e-3	-6.721e-5	2.649e-4	-0.120	0.314
MC	6.188e-19	1.751e-2	-1.196e-3	-1.150e-6	6.823e-4	-0.348	0.412
B86	-9.613e-2	0.720	-0.838	-8.061e-2	0.596	-1	1
NY	1.470e-20	2.835e-3	-2.647e-4	-1.157e-5	5.570e-5	-3.861e-2	6.422e-2
Z	2.321	1.715	1.223	1.856	2.881	9.522e-2	22.938
СТВ	-1.920e-21	2.991e-4	-1.010e-5	0	7.852e-6	-7.201e-3	1.090e-2

Table 2. Summary statistics of each RCA index, members of the Pacific Alliance, 1995–2017.

Source: Authors' calculation.

3.2.2. Time stationarity

For each type of RCA index, we perform the Harris-Tzavalis unit-root test on the panel data comprising the RCA indexes for each $(i; k) \in J \times K$ calculated yearly from 1995 to 2017; hence 4 countries × 255 products = 1020 panels. The cross-sectional dimension of the panel is large (1020), and the time-series dimension is relatively small (23 time periods). The Harris-Tzavalis unit-root test is designed for this kind of panel data. The standard version of the test is based on the OLS estimation of ρ in the following equation:

$$RCA_{ikt} = \rho \cdot RCA_{ikt-1} + \gamma_{ik} + \epsilon_{ikt}$$
(13)

Equation (13) assumes that all units share the same first-order autoregressive parameter, ρ , while γ_{ik} is a unit-specific intercept (fixed effect); ϵ_{ikt} is the residual term for each (i; k; t). The null hypothesis of the test is $\rho = 1$, that is, RCA_{ikt} contains a unit root and therefore is not stationary. The alternative hypothesis is $|\rho| < 1$, that is, RCA_{ikt} exhibits short-term deviations and finite variance around a time-constant mean. As a consequence, an RCA index should be rejected if it leads to acceptance of the null hypothesis. Table 3 contains the results. We can see that every RCA index, including the CTB index, leads to rejection of the null hypothesis, with p-values very close to zero. Therefore, we should continue our analysis of time stationarity with all nine RCA indexs.

Once given an RCA index, its across-time standard deviation for each country and each item is calculated, namely, $\sigma(\{\text{RCA}_{ikt}; t \in T\}) \forall i, k$. The smaller this variable, the

	ρ	z-stat.	p-value
B65	0.5277	-85.4059	0.0000
SB65	0.4820	-96.6408	0.0000
WB65	0.4922	-94.1407	0.0000
A	0.7160	-39.0976	0.0000
MC	0.7229	-37.3976	0.0000
B86	0.4755	-98.2498	0.0000
NY	0.7152	-39.2916	0.0000
Z	0.2737	-1.50e+2	0.0000
СТВ	0.7130	-39.8481	0.0000

Table 3. Estimation of ρ in Equation (13).

Source: Authors' calculation. Note: The z-statistic and the p-value correspond to the null *panels* contain unit roots ($\rho = 1$) against the alternative *panels are stationary* ($|\rho| < 1$). Number of panels: 1020.

	$ar{\pmb{\sigma}}(RCA_{CO})$	$\bar{\sigma}(RCA)$
B65	0.6267	0.6394
WB65	0.5734	0.5626
SB65	0.2731	0.2855
A	3.0864e-3	2.975e-3
MC	4.098e-3	4.526e-3
B86	0.3517	0.3706
NY	6.049e-4	7.029e-4
Z	2.1698	1.1394
СТВ	4.328e-5	5.199e-5

Table 4. Across-time standard deviation of each RCA index (across-item average).

Source: Authors' calculation.

higher the time stationarity (Hoen & Oosterhaven, 2006; Leromain & Orefice, 2014). Then, the average of $\sigma(\{\text{RCA}_{ikt}; t \in T\})$ can be calculated for every *i*, to account for the average time stationarity across items for each country. This variable is written as $\bar{\sigma}(\text{RCA}_i)$. Eventually, the average of $\bar{\sigma}(\text{RCA}_i)$ can be calculated, which accounts for the average time stationarity across items and (then) across countries. This variable is written as $\bar{\sigma}(\text{RCA})$. Table 4 contains the respective values of $\bar{\sigma}(\text{RCA}_{CO})$ and $\bar{\sigma}(\text{RCA})$ for each RCA index. $\bar{\sigma}(\text{RCA}_{CO})$ is shown because Colombia is the country under study whereas $\bar{\sigma}(\text{RCA})$ aims to measure the average time stationarity for every member of the Pacific Alliance (Colombia included). The CTB index minimizes both variables and therefore shows the greatest average time stationarity compared with the other indexes both for Colombia and for each member of the Pacific Alliance.

However, the time stationarity of RCA indexes should not be explored based on the criterion of standard deviations alone. Indeed, different normalizations are used to build the RCA indexes (GDP for the CTB index, total trade for the NY index, product-specific trade for the B86 index, and so on), and these differences influence standard deviations. Accordingly, we explore time stationarity from the vantage point of other criteria.

First, we follow the path suggested by Laursen (2015), which consists of the OLS estimation of the coefficients α_{0i} and α_{1i} in the following equation:

$$RCA_{ikt_1} = \alpha_{0i} + \alpha_{1i} \cdot RCA_{ikt_0} + \epsilon_{ik}$$
(14)

 t_1 refers to the final available year (i.e., 2017) and t_0 to the first available year (i.e., 1995). The RCA index of *i* in t_1 throughout *K* is set as the dependent variable, and the RCA index in t_0 is set as the independent variable (thus with 255 observations, each corresponding to some *k*); ϵ_{ik} is the residual term for each *k*. In this framework, full-time stationarity for *i* is given by $\alpha_{0i} = 0$ and $\alpha_{1i} = 1$ because with these values the RCA index of *i* in t_1 deviates from the RCA index in t_0 only by the residual term. When α_{0i} is closer to 0 and α_{1i} is closer to 1, the variation of the RCA index between t_0 and t_1 is smaller. As a result, the RCA index provides a better fit with time stationarity in the case of *i*. We estimate the coefficients for the country under study, Colombia, for each RCA index. The results are given in Table 5.

We can see that the B65, WB65, SB65 and Z indexes do not lead α_{0i} to be close to zero. Even the 95% confidence intervals do not include zero. On the contrary, $\alpha_{0i} = 0$ is accepted for the other RCA indexes: A, MC, B86, NY and CTB. Among these last five indexes, the CTB

		Value	t-stat.	Conf. Interval (95%)
B65	a_{0i}	0.57,511 ***	7.80	[0.42,991,0.72,032]
	a_{1i}	0.50,277 ***	8.57	[0.38,718,0.61,836]
WB65	a_{0i}	0.59,682 ***	7.80	[0.44,613,0.74,750]
	a_{1i}	0.40,318 ***	8.57	[0.31,049,0.49,588]
SB65	a_{0i}	-0.07051 *	-2.02	[-0.13,914,-0.00188]
	a_{1i}	0.48,774 ***	9.54	[0.38,701,0.58,847]
Α	a_{0i}	0.00000	0.00	[-0.00123,0.00123]
	a_{1i}	0.15,365 ***	4.16	[0.08095,0.22,635]
MC	a_{0i}	-0.00000	-0.00	[-0.00168,0.00168]
	a_{1i}	0.15,067 ***	4.21	[0.08021,0.22,113]
B86	a_{0i}	-0.03492	-0.93	[-0.10,883,0.03899]
	a_{1i}	0.41,923 ***	7.95	[0.31,538,0.52,308]
NY	a_{0i}	0.00000	0.00	[-0.00029,0.00029]
	a_{1i}	0.13,781 ***	4.16	[0.07261,0.20,302]
Z	a_{0i}	0.60,057 ***	8.09	[0.45,432,0.74,683]
	a_{1i}	0.20,057 ***	8.45	[0.15,384,0.24,731]
CTB	a_{0i}	0.00000	0.00	[-0.00001, 0.00001]
	a _{1i}	1.10,211 ***	30.45	[1.03084,1.17,338]

Table	5.	Estimated	coefficients	in	Equation	(14).
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Source: Authors' calculation. *i* = CO, *N* = 255. * *p* < 0.05, ** *p* < 0.01,*** *p* < 0.001.

index shows the value of α_{1i} closest to 1, namely, 1.10,211. From this point of view, the CTB index is the index that best fits the idea of specialization stickiness in the case of Colombia.⁸

Second, we extend this Laursen-like test by estimating the coefficients α_0 and α_1 for a set of countries (the Pacific Alliance in our case) instead of a single country:

$$RCA_{kt_1} = \alpha_0 + \alpha_1 \cdot RCA_{ikt_0} + \theta_i + \epsilon_{ik}$$
(15)

where θ_i is the dummy variable that accounts for the fixed effect implied by *i*. In addition to $\alpha_0 = 0$ and $\alpha_1 = 1$, full-time stationarity requires $\theta_i = 0 \quad \forall i$ outside the excluded dummy variable, which is already equal to zero by construction, such that the RCA index of *i* in t_1 deviates from the RCA index in t_0 only by the residual term. The results are given in Tables 6 and 7, with the exclusion of the dummy variable associated with Colombia, namely, $\theta_{CO} = 0$.

We can see that the CTB index shows the value of α_1 closest to 1 (1.09377) in addition to accepting $\alpha_0 = 0$ and $\theta_i = 0 \forall i$. The other RCA indexes are associated with $\alpha_1 = 0.40241$ (B86) at best and $\alpha_1 = 0.25324$ (MC) at worst and do not always lead to the acceptance of $\alpha_0 =$ or $\theta_i = 0 \forall i$. Thus, in addition to Colombia alone, the CTB index best fits the notion of specialization stickiness for the whole Pacific Alliance.

3.2.3. Shape

Following the path suggested by Leromain and Orefice (2014), the three following variables are calculated for each RCA index, country and year:

• The across-item difference between mean and median, written as $mm(\{\text{RCA}_{ikt}; k \in K\}) \quad \forall i, t$. The closer this variable is to zero, the smaller the asymmetry around the across-item mean.

⁸Surprisingly, only the CTB index leads to $a_{1i} > 1$. This estimation is compatible with the mean-reversion process implied by $\rho < 1$ in Equation (13). $a_{1CO} = 1.10211$ indicates that the CTB indexes of Colombia tend to be higher in 2017 than in 1995, and $\rho < 1$ indicates that this difference should be conceptualized as the result of short-run deviations from a time-constant mean.

		Value	(, (.),	Conf Intorval (OE0/)
		value	l-stat.	Conf. Interval (95%)
B65	a_0	0.66,207 ***	8.94	[0.51,674,0.80,739]
	<i>a</i> ₁	0.39,025 ***	14.46	[0.33,731,0.44,320]
	θ_{CL}	0.06626	0.65	[-0.13,247,0.26,500]
	θ_{MX}	-0.23,566 *	-2.34	[-0.43,318,-0.03813]
	θ_{PE}	0.20,305 *	2.01	[0.00526,0.40,084]
WB65	a_0	0.64,358 ***	9.54	[0.51,116,0.77,601]
	<i>a</i> ₁	0.35,642 ***	14.63	[0.30,860,0.40,423]
	θ_{CL}	0.00000	0.00	[-0.17,465,0.17,465]
	θ_{MX}	0.00000	0.00	[-0.17,465,0.17,465]
	θ_{PE}	0.00000	0.00	[-0.17,465,0.17,465]
SB65	a_0	-0.10,775 ***	-3.41	[-0.16,978,-0.04572]
	<i>a</i> ₁	0.39,617 ***	14.78	[0.34,355,0.44,878]
	θ_{CL}	-0.00910	-0.21	[-0.09230,0.07410]
	θ_{MX}	0.08412 *	-1.99	[-0.16,707,-0.00118]
	θ_{PE}	0.05680	1.35	[-0.02555,0.13,915]
Α	a_0	-0.00000	-0.00	[-0.00112,0.00112]
	<i>a</i> ₁	0.31,994 ***	15.46	[0.27,934,0.36,054]
	θ_{CL}	-0.00000	-0.00	[-0.00159,0.00159]
	$ heta_{MX}$	0.00000	0.00	[-0.00159,0.00159]
	$ heta_{PE}$	-0.00000	-0.00	[-0.00159,0.00159]

Table 6. Estimated coefficients in Equation (15) (1).

Source: Authors' calculation. N = 1020. By construction, $\theta_{CO} = 0$. * p < 0.05, ** p < 0.01, *** p < 0.001.

Table 7. Estimated coefficients in Equation (15) (2).

		Value	<i>t</i> -stat.	Conf. Interval (95%)
МС	<i>a</i> ₀	-0.00000	-0.00	[-0.00152,0.00152]
	<i>a</i> ₁	0.25,324 ***	13.29	[0.21,583,0.29,064]
	θ_{CL}	0.00000	0.00	[-0.00216,0.00216]
	θ_{MX}	0.00000	0.00	[-0.00216,0.00216]
	$ heta_{PE}$	0.00000	0.00	[-0.00216,0.00216]
B86	a_0	-0.03856	-1.03	[-0.11,237,0.03524]
	<i>a</i> ₁	0.40,241 ***	14.21	[0.34,683,0.45,799]
	θ_{CL}	0.00336	0.06	[-0.10,034,0.10,707]
	θ_{MX}	0.02910	0.52	[-0.08011,0.13,832]
	$ heta_{PE}$	-0.11,210 *	-2.11	[-0.21,657,-0.00763]
NY	a_0	-0.00000	-0.00	[-0.00029,0.00029]
	<i>a</i> ₁	0.30,620 ***	14.19	[0.26,385,0.34,854]
	θ_{CL}	0.00000	0.00	[-0.00041,0.00041]
	$ heta_{MX}$	0.00000	0.00	[-0.00041,0.00041]
	$ heta_{PE}$	0.00000	0.00	[-0.00041,0.00041]
Z	<i>a</i> ₀	0.41,033 ***	5.62	[0.26,705,0.55,360]
	<i>a</i> ₁	0.26,720 ***	12.48	[0.22,519,0.30,920]
	$ heta_{CL}$	0.74,965 ***	10.59	[0.61,070,0.88,861]
	$ heta_{MX}$	0.51,474 ***	7.56	[0.38,113,0.64,834]
	$ heta_{PE}$	2.05702 ***	36.40	[1.94,612,2.16,792]
CTB	a_0	-0.00000	-0.00	[-0.00001, 0.00001]
	<i>a</i> ₁	1.09377 ***	55.62	[1.05518,1.13,235]
	$ heta_{CL}$	-0.00000	-0.00	[-0.00002, 0.00002]
	$ heta_{MX}$	0.00000	0.00	[-0.00002, 0.00002]
	θ_{PE}	0.00000	0.00	[-0.00002, 0.00002]

Source: Authors' calculation. N = 1020. By construction, $\theta_{CO} = 0.* p < 0.05, ** p < 0.01, *** p < 0.001.$

• The across-item skewness, written as $\beta_1(\{\text{RCA}_{ikt}; k \in K\}) \quad \forall i, t$. The closer this variable is to zero, the smaller the asymmetry around the across-item mean.

	$\overline{\textit{mm}}(RCA_{CO})$	$\overline{\textit{mm}}(RCA)$	$\bar{\pmb{\beta}}_1(RCA_{CO})$	$ar{m{eta}}_1({\sf RCA})$	$ar{m{eta}}_2(RCA_{CO})$	$\bar{\pmb{\beta}}_2(RCA)$
B65	0.5274	0.4477	1.5936	1.3198	5.0354	4.2188
WB65	0.5177	0.4237	1.5936	1.3198	5.0354	4.2188
SB65	2.327e-2	-3.312e-3	0.1942	7.0965e-2	1.5693	1.6776
A	9.661e-5	8.858e-5	3.6983	3.1310	69.4592	55.8337
MC	1.7560e-5	5.689e-5	3.6755	1.4858	64.9478	64.2277
B86	6.266e-2	3.512e-2	0.4411	0.1919	1.9533	2.0217
NY	1.936e-5	1.864e-5	3.6983	3.1310	69.4592	55.8337
Z	-6.426e-3	-4.604e-2	1.1180	1.1362	6.1317	4.6413
СТВ	-1.033e-7	1.062e-7	6.1209	1.4702	109.1942	79.6537

Table 8. Across-item mean minus median, skewness and kurtosis of each RCA index (across-time average).

Source: Authors' calculation.

• The across-item kurtosis, written as $\beta_2(\{\text{RCA}_{ikt}; k \in K\}) \quad \forall i, t$. The higher this variable is, the higher the concentration around the across-item mean, and the thinner the tails.

Therefore, the averages of $mm(\{\text{RCA}_{ikt}; k \in K\})$, $\beta_1(\{\text{RCA}_{ikt}; k \in K\})$ and $\beta_2(\{\text{RCA}_{ikt}; k \in K\})$ can be calculated for every *i*. These new variables are written as $\overline{mm}(\text{RCA}_i)$, $\overline{\beta}_1(\text{RCA}_i)$ and $\overline{\beta}_2(\text{RCA}_i)$, respectively, and account for shape on average across time for each country. Eventually, the averages of $\overline{mm}(\text{RCA}_i)$, $\overline{\beta}_1(\text{RCA}_i)$, and $\overline{\beta}_2(\text{RCA}_i)$ can be calculated. These last variables are written as $\overline{mm}(\text{RCA}_i)$, $\overline{\beta}_1(\text{RCA}_i)$, and $\overline{\beta}_2(\text{RCA}_i)$ and account for shape on average across time and (RCA), $\overline{\beta}_1(\text{RCA}_i)$, and $\overline{\beta}_2(\text{RCA}_i)$ and account for shape on average across time and (then) across countries.

As shown in Table 8, the CTB index minimizes $\overline{mm}(\text{RCA}_{\text{CO}})$ and $\overline{mm}(\text{RCA})$ and therefore shows the greatest symmetry on average from the point of view of the mean minus median. However, the CTB index does not minimize $\bar{\beta}_1(\text{RCA}_{\text{CO}})$ and $\bar{\beta}_1(\text{RCA})$ and therefore does not show the greatest symmetry on average from the vantage point of skewness. Nevertheless, the CTB index is able to maximize kurtosis and therefore is once again best able to avoid fat tails for both Colombia and each member of the Pacific Alliance on average.

3.2.4. Ordinal ranking bias

The Pacific Alliance comprises four countries. Thus, for each RCA index and each (i; t) we first distribute the elements of *K* into four groups, each of which is related to a rank between 1 and 4:

- Every k for which i is ranked as the fourth country according to its RCA index in t, namely, K₄(i; t) = {k : RCA_{ikt} < RCA_{ikt} ∀j ∈ J\{i}}.
- Every k for which i is ranked as the third country, namely, $K_3(i;t) = \{k : \text{RCA}_{ikt} < \text{RCA}_{jkt} \ \forall j \in J \setminus \{i;h\} \ \exists h\}.$
- Every k for which i is ranked as the first country, namely, $K_1(i;t) = \{k : \text{RCA}_{ikt} > \text{RCA}_{jkt} \forall j \in J \setminus \{i\}\}.$
- Every k for which i is ranked as the second country, namely, $K_2(i; t) = \{k : \text{RCA}_{ikt} > \text{RCA}_{jkt} \forall j \in J \setminus \{i; h\} \exists h\}.$

Then, we compute $\overline{\text{RCA}}_{itx} = \frac{1}{\#K_x(i;t)} \sum_{k \in K_x(i;t)} \text{RCA}_{ikt} \quad \forall i, t, x$. This variable is the average RCA index that leads *i* to be ranked as the *x*th country in *t*. The extent of the ordinal ranking bias is therefore accounted for as follows⁹

- x = 4: We count how many k outside K_4 are associated with an RCA index less than $\overline{\text{RCA}}_{it4}$; namely, $ORB_{it4} = \#\{k : \text{RCA}_{ik4} < \overline{\text{RCA}}_{it4}; k \in K \setminus K_4\}$.
- x = 3: We count how many k from K_4 are associated with an RCA index higher than $\overline{\text{RCA}}_{it3}$ and how many k from K_1 and K_2 are associated with an RCA index less than $\overline{\text{RCA}}_{it3}$; namely, $ORB_{it3} = \#\{k : \text{RCA}_{ikt} > \overline{\text{RCA}}_{it3}; k \in K_4\} + \#\{k : \text{RCA}_{ikt} \overline{\text{RCA}}_{it3}; k \in K_1 \cup K_2\}$.
- x = 2: We count how many k from K_3 and K_4 are associated with an RCA index higher than $\overline{\text{RCA}}_{it2}$ and how many k from K_1 are associated with an RCA index less than $\overline{\text{RCA}}_{it2}$; namely, $ORB_{it2} = \#\{k : RCA_{ikt} > \overline{\text{RCA}}_{it3}; k \in K_3 \cup K_4\} + \#\{k : RCA_{ikt} < \overline{\text{RCA}}_{it2}; k \in K_1\}.$
- x = 1: We count how many k outside K_1 are associated with an RCA index higher than $\overline{\text{RCA}}_{it1}$; namely, $ORB_{it1} = \#\{k : \text{RCA}_{ikt} > \overline{\text{RCA}}_{it1}; k \in K \setminus K_1\}$.

Remark 3.2. More generally, for *n* countries, $ORB_{itx} = \#\{k : RCA_{ikt} > \overline{RCA}_{itx}; k \in \bigcup_{y=1}^{x-1} K_y(i;t)\} + \#\{k : RCA_{ikt} < \overline{RCA}_{itx}; k \in \bigcup_{y=x+1}^n K_y(i;t)\}$ with $K_y(i;t) = \{k : RCA_{ikt} > RCA_{jkt}; j \in J \setminus J_y \subseteq J \setminus \{i\}; \#J_y = \#J - y; k \in K\} \forall i, t.$

Next, we calculate the across-time average ordinal ranking bias for each country and each rank, written as \overline{ORB}_{ix} , and then the across-rank average of \overline{ORB}_{ix} for a given *i*, written as $\overline{ORB}_i \forall i$. The higher this variable is, the higher the ordinal ranking bias on average for a given country. Similarly, it is possible to calculate the across-country average of \overline{ORB}_i , which therefore accounts for the average ordinal ranking bias for each member of the trade area under consideration. This last variable is written as \overline{ORB} .

Table 9 presents the values of \overline{ORB}_{CO} and \overline{ORB} for each of the studied RCA indexes.

	<u>ORB</u> _{CO}	ORB
B65	12.9674	18.1087
WB65	11.3913	17.7337
SB65	13.7826	19.3859
A	25.4239	29.9674
MC	12.9674	17.7092
B86	9.5652	12.6141
NY	24.3370	25.4810
Z	4.6413	4.9918
СТВ	13.8696	18.9321

Table 9. Ordinal ranking bias of each RCA index (across-time average).

Source: Authors' calculation.

⁹Leromain and Orefice (2014)suggest measuring the ordinal ranking bias by means of Spearman rank correlation, in their case, for the world as the trade area. In our opinion, this type of tool cannot be successfully applied to a four-country trade area such as the Pacific Alliance. Consequently, we suggest another methodology. In addition, we measure the ordinal ranking bias for every possible rank a country might have in the Pacific Alliance, whereas Leromain and Orefice (2014) measure the ordinal ranking bias for the first rank only.:

For instance, on average, 12.9674 of 255 items – approximately 5.09% – are associated with a B65 index that does not reflect Colombia's rank in the Pacific Alliance, and on average, 18.1087 items – approximately 7.10% – are associated with a B65 index that does not reflect every member's rank on average. As we can see, the CTB index does not minimize the ordinal ranking bias, which is minimized by the Z index for both Colombia and each member of the Pacific Alliance on average. The Z index is followed by the B86, B65, WB65, SB65, MC and CTB indexes, with ordinal ranking biases roughly similar for both Colombia and each member of the Pacific Alliance on average.

3.2.5. Summary

Table 10 summarizes the previous analysis for the universe $J \times K \times T$ under consideration. For instance, the B65 index is ranked eighth in terms of the lowest value of $\bar{\sigma}(RAC_{CO})$ and second in terms of the value of α_{1CO} closest to 1. The CTB index is obviously not the best index to avoid ordinal ranking bias but leads to the best results concerning every criterion of time stationarity and 2 of 3 criteria of shape for both Colombia and the members of the Pacific Alliance on average. Ultimately, the CTB index appears – on balance – to be the most accurate for our case because of its empirical properties, in addition to its valuable features for revealing comparative advantages, as explained before.

The previous protocol, which aimed to verify that a chosen RCA index has better statistical features than others, can be applied to other specifications of $J \times K \times T$. Although extensive in length, this protocol is a necessary step before using an RCA index for the purpose of applied economics to ensure that it is the most suitable index.

		B65	WB65	SB65	Α	MC	B86	NY	Z	CTB
Time stationarity										
Unit-root test				Rejecti	on of t	he null h	nypothesi	is		
Std. Dev.	$\min \bar{\sigma}(RCA_{CO})$	8	7	5	3	4	6	2	9	1
	$min\overline{\sigma}(RCA)$	8	7	5	3	4	6	2	9	1
Equation (14)	$\min \alpha_{0CO} $	7	8	6	1	1	5	1	9	1
	$\min a_{1CO} - 1 $	2	5	3	7	8	4	9	6	1
Equation (15)	$\min \alpha_0 $	9	8	6	1	1	5	1	7	1
	$\min \alpha_1 - 1 $	4	5	3	6	9	2	7	8	1
	$\min \theta_{CL} $	8	1	7	1	1	6	5	9	1
	$\min \theta_{MX} $	8	1	7	1	1	6	5	9	1
	$\min \theta_{PE} $	8	1	7	1	1	6	5	9	1
Shape										
Mean — Median	$\min \overline{mm}(RCA_{CO}) $	9	8	5	4	2	6	3	7	1
	min mm(RCA)	9	8	5	4	3	6	2	7	1
Skewness	$\min \bar{\beta}_1(RCA_{CO}) $	5	4	1	8	6	2	7	3	9
	$\min[\bar{\beta}_1(RCA)]$	4	5	1	8	7	2	9	3	6
Kurtosis	$\max \overline{\beta}_2(RCA_{CO})$	6	7	9	2	4	8	3	5	1
	$\max \overline{\beta}_2(RCA)$	7	6	9	3	2	8	4	5	1
Ordinal Ranking	Bias									
	$min\overline{ORB}(RCA_{CO})$	4	3	6	9	5	2	8	1	7
	minORB(RCA)	5	4	7	9	3	2	8	1	6

Table 10. Ranking of the RCA indexes according to their empirical properties.

Source: Authors' calculation. Note: Concerning a_{0CO} , a_0 and each θ -like coefficient (fixed effects), the A, MC, NY and CTB indexes all lead to estimates very close to zero, and consequently these four indexes share the first rank.

In particular, Table 10 might be a helpful benchmark to discuss various competing RCA indexes. We also hope that the CTB index is the best available measure beyond Colombia in the Pacific Alliance.

4. The CTB index and regional specialization

Assume that the CTB index is selected to understand regional specialization, as it should be for Colombia in the Pacific Alliance according to the previous section. If $CTB_{ikt,r} > 0$ then i has a comparative advantage for k in t. This condition is necessary but not sufficient for considering k a strength of i in t with respect to the other countries of the trade area under consideration. Indeed, other countries might also have a comparative advantage for k in t. Moreover, the positive CTB index of other countries might be higher for the same product (and the same period).¹⁰ If so, k should not be identified as a strength of i. Similarly, if a country has a comparative disadvantage – $CTB_{ikt,r} < 0$ – the corresponding product should not be considered a weakness if other countries have a higher comparative disadvantage, that is, $CTB_{ikt,r} < CTB_{ikt,r} < 0 \exists j$. Consequently, to highlight strengths and weaknesses, not only the sign of the CTB index but also the relative rankings of all countries according to their respective CTB indexes should be considered. If *i* has a positive CTB index for *k* in *t* and this positive index is the highest compared with the other countries, then k should be regarded as a strength for *i* in *t*. Conversely, if *i* has a negative CTB index for *k* in *t* and this negative index is the lowest compared with the other countries, then k should be regarded as a weakness for i in t.

Furthermore, if i has the highest positive CTB index for k over various successive periods, this *time sustainability* of i's comparative advantage for k reinforces the status of k as a strength of i in international trade with the other countries. Similarly, if i has the lowest negative CTB index for k over various periods, this *time recurrence* of i's comparative disadvantage for k reinforces the status of k as a weakness of i. Consequently, to highlight strengths and weaknesses, in addition to the sign of the CTB index and the relative rankings of all countries according to their respective CTB indexes, the time dynamics of the relative rankings should be considered. Therefore, to analyze the CTB indexes at our disposal, we introduce the following definitions.

Definition 4.1. Let $(U; u) \in T^2$ with $U \ge u$. For a given k, i shows comparative-advantage sustainability of the u^{th} degree in time period U if $\text{RCA}_{ikt} = \max{\text{RCA}_{jkt}; j \in J} > 0$ $\forall t \in {U; U - 1; \dots; U - u + 1}.$

In the time period U, i shows comparative-advantage sustainability of the u^{th} degree – or, more briefly, " u^{th} -degree sustainability" – in the case of k if the RCA index shown by i for k is both strictly positive and the highest compared with the other countries for each period from U - u + 1 to U. A higher u means that k is a more significant strength.

¹⁰CTB_{*ikt,t*} > 0 does not specify the countries against which *i* has a comparative advantage once the trade area under consideration comprises more than two countries. CTB_{*ikt,r*} > 0 only indicates that CTB_{*ikt,r*} < 0 for at least one other country *j*; that is, at least one other country has a comparative disadvantage for *k* in *t*, without indicating which country in particular.

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Figure 1. CTB index of each member of the Pacific Alliance, SITC item 778, 1995–2017.

Example 4.2. Figure 1 accounts for the CTB index of each member of the Pacific Alliance in the case of the SITC item 778 "Electrical machinery and apparatus, n.e.s.",¹¹ from 1995 to 2017. We can see that Colombia shows the highest CTB index for each year from 1999 to 2017, i.e., 19 years. Thus, in 2017, Colombia shows an 19th-degree sustainability of its comparative advantage for the item at issue.

Definition 4.3. For a given *k*, *i* shows comparative-disadvantage recurrence of the *u*th degree in time period *U* if $\text{RCA}_{ikt} = \min{\{\text{RCA}_{ikt}; j \in J\}} < 0 \ \forall t \in \{U; U-1; \cdots; U-u+1\}.$

In the time period *U*, *i* shows comparative-disadvantage recurrence of the u^{th} degree – or more briefly " u^{th} -degree recurrence" – in the case of *k* if the RCA index shown by *i* for *k* is both strictly negative and the lowest compared with the other countries, for each period from U - u + 1 to *U*. A higher *u* means that *k* is a more significant weakness.

Example 4.4. Figure 2 accounts for the CTB index of each member of the Pacific Alliance in the case of the SITC item 047 "Other cereal meals and flour", from 1995 to 2017. We can see that Colombia shows the lowest CTB index for each year from 2002 to 2017, i.e., 16 years. Thus, in 2017, Colombia shows a 16th-degree recurrence of its comparative disadvantage for the item at issue.

A u^{th} -degree sustainability in U implies a v^{th} -degree sustainability in U $\forall v \in \{1; 2; \dots; u-1\}$. In Example 4.2, if the Colombian CTB index is highest from 1999 to 2017, then it is highest from 2000 to 2017. Thus, the 19th-degree sustainability in 2017 implies a 18th-degree of sustainability in the same year. Similarly, a *u*th-degree $u - v^{\text{th}}$ sustainability in Uimplies a degree sustainability in U - v $\forall v \in \{1; 2; \dots; U-1\}$. In Example 4.2, if the Colombian CTB index is highest from 1999 to 2017 then it is highest from 1999 to 2016. Thus, the 19th-degree sustainability in 2017 implies a 18th-degree sustainability in 2016. The same applies to recurrence. Given these properties, we check for the latest period among the last five periods

¹¹"n.e.s." means "not elsewhere specified" in the SITC.



Figure 2. CTB index of each member of the Pacific Alliance, SITC item 047, 1995–2017.

 $(U \in \{2017; 2016; \dots; 2013\})$ in which each k showed the highest comparativeadvantage sustainability or comparative-disadvantage recurrence (u), if any, in the case of Colombia within the Pacific Alliance.¹² The main results are as follows.

Table 11 presents comparative-advantage sustainability. In each point, the first element is the number u of years from U backwards in which Colombia shows the highest positive CTB index. The second element is the SITC item associated with that number. For example, (1;597) indicates that SITC item 597 shows sustainable comparative advantages of the 1st degree in 2013.

Colombia tends to export primary commodities, particularly petroleum oils, coal, coffee, crude vegetable materials (including plants and their parts, cut flowers and foliage) and non-monetary gold. In 2001, these five products alone amounted to almost 50% of Colombian exports. This proportion increased up to 75% in 2011, 2012 and 2013, and remained above two-thirds in 2017.¹³ Nonetheless, Table 11 suggests that Colombia should be able to stimulate its exports within the Pacific Alliance through products that are not primary commodities, such as plastics, clothing, machinery and chemical products, on the basis of comparative-advantage sustainabilities that are among the highest in 2017. Concerning plastics, SITC items 572 "Polymers of styrene, in primary forms" and 575 "Other plastics, in primary forms" benefit from 23rd- and 15th-degree comparative-advantage sustainabilities, respectively. With respect to clothing, SITC items 612 "Manufactures of leather, n.e.s.; saddlery and harness", 845 "Articles of apparel, of textile fabrics, n.e.s", 844 "Women's clothing, of textile, knitted or crocheted" and 848 "Articles of apparel, clothing access., excl. textile" benefit from 23rd-, 16th-, 15th- and 14th-degree comparative-advantage sustainabilities, respectively. Regarding machinery, SITC items 778 "Electrical machinery and apparatus, n.e.s." and 771 "Electric power machinery, and parts thereof" benefit from 19th- and 9th-degree

¹²Montoya-Uribe et al. (2016) calculate the across-year average of the SB65 index from 2010 to 2014. They calculate the across-year average three times, once for each trade partner of Colombia in the Pacific Alliance. Then, they highlight the items whose average SB65 index is greater than one-third because this value is supposed to be the minimum for revealing noticeable comparative advantages. Here, we suggest another, more in-depth, methodology based on how the relative ranking of every country evolves through time according to the RCA index.

¹³Calculation according to data provided by UNCTADStat.

I able II. Cumpare	auve-auvaillage sustairlability, colorindia in the facilic Annance, 2013-20		
2013		2017	
(1.507)	Dranscal addit for minar ails lubricat dairing	(20.1)	Curar ranfartionany
(160,1)		(200/1)	
(1;691)	Structures & parts, n.e.s., of iron, steel, aluminium	(1;263)	Cotton
(1;711)	Vapour generating boilers, auxiliary plant; parts	(1;511)	Hydrocarbons, n.e.s., & halogenated, nitr. derivative
(1;726)	Printing & bookbinding machinery, & parts thereof	(1;633)	Cork manufactures
(2;281)	Iron ore & concentrates	(1;656)	Tulles, trimmings, lace, ribbons & other small wares
2014		(1;664)	Glass
(1;011)	Meat of bovine animals, fresh, chilled or frozen	(1;735)	Parts, n.e.s., & accessories for machines of 731, 733
(1;023)	Butter & other fats & oils derived from milk	(1;744)	Mechanical h&ling equipment, & parts, n.e.s.
(1;043)	Barley, unmilled	(1;896)	Works of art, collectors' pieces & antiques
(1;045)	Cereals, unmilled (excl. wheat, rice, barley, maize)	(1;971)	Gold, non-monetary (excl. gold ores & concentrates)
(1;072)	Cocoa	(2;231)	Natural rubber & similar gums, in primary forms
(1;121)	Alcoholic beverages	(2;611)	Leather
(1;122)	Tobacco, manufactured	(2;678)	Wire of iron or steel
(1;211)	Hides & skins (except furskins), raw	(2;731)	Machine-tools working by removing material
(1;245)	Fuel wood (excl. wood waste) & wood charcoal	(2;749)	Non-electric parts & accessor. of machinery, n.e.s.
(1;246)	Wood in chips or particles & wood waste	(2;841)	Men's clothing of textile fabrics, not knitted
(1;265)	Vegetable textile fibres, not spun; waste of them	(2;897)	Jewellery & articles of precious materia., n.e.s.
(1;269)	Worn clothing & other worn textile articles	(3;288)	Non-ferrous base metal waste & scrap, n.e.s.
(1;277)	Natural abrasives, n.e.s. (incl. industri. diamonds)	(3;573)	Polymers of vinyl chloride or halogenated olefins
(1;282)	Ferrous waste, scrape; remelting ingots, iron, steel	(3;581)	Tubes, pipes & hoses of plastics
(1;322)	Briquettes, lignites & peat	(3;659)	Floor coverings, etc.
(1;343)	Natural gas, whether or not liquefied	(3;695)	Tools for use in the h& or in machine
(1;525)	Radio-actives & associated materials	(3;772)	Apparatus for electrical circuits; board, panels
(1;613)	Furskins, tanned or dressed, excl. those of 8483	(3;842)	Women's clothing, of textile fabrics
(1;677)	Rails & railway track construction mat., iron, steel	(4;273)	Stone, sand & gravel
(1;699)	Manufactures of base metal, n.e.s.	(4;598)	Miscellaneous chemical products, n.e.s.
(1;712)	Steam turbines & other vapour turbin., parts, n.e.s.	(4;727)	Food-processing machines (excl. domestic)
(1;724)	Textile & leather machinery, & parts thereof, n.e.s.	(4;812)	Sanitary, plumbing, heating fixtures, fittings, n.e.s.
(1;761)	Television receivers, whether or not combined	(4;821)	Furniture & parts
(1;776)	Cathode valves & tubes	(4;899)	Miscellaneous manufactured articles, n.e.s.
(1;783)	Road motor vehicles, n.e.s.	(5;542)	Medicaments (incl. veterinary medicaments)
(1;791)	Railway vehicles & associated equipment	(7;667)	Pearls, precious & semi-precious stones
(1;884)	Optical goods, n.e.s.	(7;813)	Lighting fixtures & fittings, n.e.s.
(2;223)	Oil seeds & oleaginous fruits (incl. flour, n.e.s.)	(8;333)	Petroleum oils, oils from bitumin. materials, crude
2015		(8;554)	Soaps, cleansing & polishing preparations
(1;721)	Agricultural machinery (excl. tractors) & parts	(9;553)	Perfumery, cosmetics or toilet prepar. (excl. soaps)
(1;733)	Machtools for working metal, excl. removing mate.	(9;771)	Electric power machinery, & parts thereof
			(Continued)

Table 11. Comparative-advantage sustainability, Colombia in the Pacific Alliance, 2013-2017.

Table 11. (Continued).

(2;071)	Coffee & coffee substitutes	(9;872)	Instruments & appliances, n.e.s., for medical, etc.	
(2;422)	Fixed vegetable fats & oils, crude, refined, fract.	(12;335)	Residual petroleum products, n.e.s., related mater.	
(3;222)	Oil seeds & oleaginous fruits (excl. flour)	(12;666)	Pottery	
2016		(13;642)	Paper & paperboard, cut to shape or size, articles	
(1;044)	Maize (not including sweet corn), unmilled	(14;848)	Articles of apparel, clothing access, excl. textile	
(1;774)	Electro-diagnostic appa. for medical sciences, etc.	(15;575)	Other plastics, in primary forms	
(1;786)	Trailers & semi-trailers	(15;844)	Women's clothing, of textile, knitted or crocheted	
(2;001)	Live animals other than animals of division 03	(16;845)	Articles of apparel, of textile fabrics, n.e.s.	
(5;091)	Margarine & shortening	(19;778)	Electrical machinery & apparatus, n.e.s.	
(6;873)	Meters & counters, n.e.s.	(23;061)	Sugar, molasses & honey	
(11;325)	Coke & semi-cokes of coal, lign., peat; retort carbon	(23;572)	Polymers of styrene, in primary forms	
(22;321)	Coal, whether or not pulverized, not agglomerated	(23;591)	Insecticides & similar products, for retail sale	
		(23;612)	Manufactures of leather, n.e.s.; saddlery & harness	

Source: Authors' calculation. Note: In each point, the first element is the number u of years from U backward in which Colombia showed the highest RCA-CTB index compared with the other members of the Pacific Alliance, with U = 2013, 2014, 2015, 2016, 2017. The second element is the SITC item associated with u.

comparative-advantage sustainabilities, respectively. Last, concerning chemicals and related products, SITC item 591 "Insecticides and similar products, for retail sale" benefit from 23rd-degree comparative-advantage sustainability, and SITC items 553 "Perfumery, cosmetics or toilet paper. (excl. soaps)" and 554 "Soaps, cleansing and polishing preparations" both benefit from 9th-degree comparative-advantage sustainability. More generally, among all SITC items with comparative-advantage sustainability from 2013 to 2017, 61 are manufactured goods (SITC items whose first digit ranges from 5 to 8), whereas 35 are primary commodities (SITC items whose first digit ranges from 0 to 4, plus item 971 "Gold, non-monetary (excl. gold ores & concentrates)").

Therefore, the Pacific Alliance might provide an opportunity to reduce the dependence of Colombian exports on primary commodities. Accordingly, among the aforementioned primary commodities, petroleum oils and coal also benefit from high comparative-advantage sustainabilities in 2016 and 2017, as suggested by SITC items 321, 325, 333 and 335 (see Table 11). In addition, note that another primary commodity benefits from 23rd-degree comparative-advantage sustainability in 2017, namely, SITC item 061 "Sugar, molasses and honey". Ultimately, the choice to take advantage of the Pacific Alliance to reduce the dependence of Colombian exports on primary commodities will depend on public policy. Indeed, public policy should support these products that are not primary commodities and simultaneously are noticeable strengths for Colombia with respect to the other members of the Pacific Alliance in terms of their comparative-advantage sustainability. This support might consist of better access to infrastructure, promotion of educational skills that are a better fit with the firms producing these strengths, a lower fiscal rate, and so on. In Colombia, this type of support is provided by a public plan called Programa de Transformación Productiva (PTP, translated as "Productive Transformation Program"), which was initiated in 2008 and offers technical assistance to help firms take advantage of regional trade agreements involving Colombia. This technical assistance aims not only to increase productivity and promote innovation, but also to improve the ability of firms to comply with the technical regulations and standards of export destination countries, and to enhance marketing and distribution. In addition, the plan is devoted to specific products, including some of those that have the highest potential to diversify Colombian exports due to their highest comparative-advantage sustainabilities, like plastics, clothing and chemical products.¹⁴ Therefore, further investigation should inquire into the effectiveness of the PTP in contributing to such export diversification.

Similar to the presentation of comparative-advantage sustainability in Tables 11–12 presents comparative-disadvantage recurrence. Three SITC items suffer from the maximum degree of comparative-disadvantage recurrence in 2017: 232 "Synthetic rubber", 654 "Other textile fabrics, woven" and 686 "Zinc". For three other items in the same year, the degree is between 14 and 19: 574 "Polyethers, epoxide resins; polycarbonat., polyesters", 047 "Other cereal meals and flour" and 267 "Other man-made fibres suitable for spinning". We can also observe one 22nd-degree recurrence in 2016, namely, 716 "Rotating electric plant and parts thereof, n.e.s.". These items can be considered *the main weaknesses of Colombia in the Pacific Alliance*. More generally, comparative-disadvantage recurrences apply to a wide spectrum of product categories,

¹⁴More information available at www.ptp.com.co (in Spanish).

2013		(1;784)	Parts & accessories of vehicles of 722, 781, 782, 783
(6;893)	Articles, n.e.s., of plastics	(1;874)	Measuring, analysing & controlling apparatus, n.e.s.
(9;752)	Automatic data processing machines, n.e.s.	(2;266)	Synthetic fibres suitable for spinning
2014		(2;523)	Metallic salts & peroxysalts, of inorganic acids
(1;531)	Synth. organic colouring matter & colouring lakes	(2;685)	Lead
(2;671)	Pig iron & spiegeleisen, sponge iron, powder & granu	(2;764)	Telecommunication equipment, n.e.s.; & parts, n.e.s.
(6;782)	Motor vehic. for transport of goods, special purpo.	(3;017)	Meat, edible meat offal, prepared, preserved, n.e.s.
2015		(3;022)	Milk, cream & milk products (excl. butter, cheese)
(1;268)	Wool & other animal hair (incl. wool tops)	(3;056)	Vegetables, roots, tubers, prepared, preserved, n.e.s.
(1;672)	Ingots, primary forms, of iron or steel; semi-finis.	(3;421)	Fixed vegetable fats & oils, crude, refined, fractio.
(1;674)	Flat-rolled prod, iron, non-alloy steel, coated, clad	(3;551)	Essential oils, perfume & flavour materials
(1;742)	Pumps for liquids	(3;571)	Polymers of ethylene, in primary forms
(1;792)	Aircraft & associated equipment; spacecraft, etc.	(3;621)	Materials of rubber (pastes, plates, sheets, etc.)
(1;793)	Ships, boats & floating structures	(3;675)	Flat-rolled products of alloy steel
2016		(3;692)	Metal containers for storage or transport
(1;579)	Waste, parings & scrap, of plastics	(3;743)	Pumps (excl. liquid), gas compressors & fans; centr.
(2;583)	Monofilaments, of plastics, cross-section > 1mm	(3;748)	Transmis. shafts
(2;665)	Glassware	(4;684)	Aluminium
(3;513)	Carboxylic acids, anhydrides, halides, per.; derivati.	(4;718)	Other power generating machinery & parts, n.e.s.
(3;514)	Nitrogen-function compounds	(5;037)	Fish, aqua. invertebrates, prepared, preserved, n.e.s.
(3;895)	Office & stationery supplies, n.e.s.	(5;278)	Other crude minerals
(4;625)	Rubber tyres, tyre treads or flaps & inner tubes	(5;515)	Organo-inorganic, heterocycl. compounds, nucl. acids
(5;892)	Printed matter	(5;652)	Cotton fabrics, woven
(7;781)	Motor vehicles for the transport of persons	(6;532)	Dyeing & tanning extracts, synth. tanning materials
(22;716)	Rotating electric plant & parts thereof, n.e.s.	(6;673)	Flat-rolled prod., iron, non-alloy steel, not coated
2017		(6;682)	Copper
(1;035)	Fish, dried, salted or in brine; smoked fish	(6;759)	Parts, accessories for machines of groups 751, 752
(1;042)	Rice	(7;334)	Petroleum oils or bituminous minerals > 70% oil
(1;046)	Meal & flour of wheat & flour of meslin	(8;048)	Cereal preparations, flour of fruits or vegetables
(1;054)	Vegetables	(8;057)	Fruits & nuts (excl. oil nuts), fresh or dried
(1;059)	Fruit & vegetable juices, unfermented, no spirit	(8;679)	Tubes, pipes & hollow profiles, fittings, iron, steel
(1;112)	Alcoholic beverages	(9;512)	Alcohols, phenols, halogenat., sulfonat., nitrat. der.
(1;285)	Aluminium ores & concentrates (incl. alumina)	(9;676)	Iron & steel bars, rods, angles, shapes & sections
(1;291)	Crude animal materials, n.e.s.	(9;882)	Cinematographic & photographic supplies
(1;344)	Petroleum gases, other gaseous hydrocarbons, n.e.s.	(10;751)	Office machines
(1;524)	Other inorganic chemicals	(11;651)	Textile yarn
(1;683)	Nickel	(14;574)	Polyethers, epoxide resins; polycarbonat., polyesters
(1;689)	Miscellaneous no-ferrous base metals for metallur.	(16;047)	Other cereal meals & flour
(1;693)	Wire products (excl. electrical) & fencing grills	(19;267)	Other man-made fibres suitable for spinning
(1;714)	Engines & motors, non-electric; parts, n.e.s.	(23;232)	Synthetic rubber
(1;725)	Paper mill, pulp mill machinery; paper articles man.	(23;654)	Other textile fabrics, woven
		(23;686)	Zinc

Table 12. Comparative-disadvantage recurrence, Colombia in the Pacific Alliance, 2013–2017.

Source: Authors' calculation. Note: In each point, the first element is the number *u* of years from *U* backward in which Colombia showed the lowest RCA-CTB index compared with the other members of the Pacific Alliance, with *U* = 2013, 2014, 2015, 2016, 2017. The second element is the SITC item associated with *u*.

ranging from food to miscellaneous manufactured articles and including inedible crude materials and oils, among others.

In response to these weaknesses, Colombia might apply some trade protections. However, as already shown in Table 1, most tariffs were eliminated in 2015, and the rest will be eliminated at later dates, in accordance with the objective of making the Pacific Alliance a free-trade area. More generally, as the members of the Pacific Alliance committed themselves to not implementing subsidies/taxes for both exports and imports (with a few exceptions), there is very little room for an optimal trade policy according to the pattern of comparative advantages (see Costinot, Donaldson, Vogel, & Werning, 2015). Rather, public policy should help increase productivity or promote innovation, as the aforementioned PTP does. Alternatively, public policy should help the firms related to the products considered (noticeable) weaknesses move toward the production of other goods, including those goods for which Colombia benefits from the highest comparative-advantage sustainabilities.

5. Conclusion

This paper elaborates on how to select a Revealed Comparative Advantage (RCA) index and then infer insights on regional specialization. We first explain why an RCA index, specifically the Contribution to the Trade Balance (CTB), is a valuable index from a theoretical standpoint and then suggest a standardized set of tools for analyzing the empirical properties of an RCA index, including the following new tools:

- The application of the Harris-Tzavalis panel-data unit-root test as a preliminary step for measuring the time stationarity of an RCA index.
- A Laursen-like regression (Laursen, 2015) with country fixed-effects to measure the time stationarity induced by an RCA index for a trade area as a whole.
- A new measure of the ordinal ranking bias based on calculation of the average RCA index that leads a country to be ranked as the x^{th} country, followed by counting the number of items that lead the country to have a higher rank despite a lower RCA index than the average RCA index or to have a lower rank despite a higher RCA index.

These new tools, together with standard deviations, Laursen-like regression (Laursen, 2015), mean minus median, skewness and kurtosis aim to better highlight the empirical properties of an RCA index. Consequently, the objective is to show that the CTB index is – on balance – the most suitable RCA index for Colombia in the Pacific Alliance compared with eight other representative indexes, in addition to being a valuable method of revealing comparative advantages. Moreover, we hope the CTB index is also the best available RCA index for other studies.

By employing the concepts of comparative-advantage sustainability and comparative-disadvantage recurrence, we suggest tools to highlight the strengths and weaknesses of countries in a given trade area according to the number of years for which a country shows the highest/lowest CTB index. Ultimately, a general picture of the goods that could benefit most and least from regional agreements can be obtained. We calculate comparative-advantage sustainabilities and comparative-disadvantage recurrences for Colombia in the Pacific Alliance for 2013–2017, and obtain results that might inspire future studies of the design of Colombian public policy. In addition, as suggested previously, because RCA indexes are usually based on trade flows, they do not provide information on the *ex ante* origin of comparative advantages. Consequently, another future line of research is to inquire into the variables that could explain the previously calculated CTB index. These variables are related to factor endowments, human capital and institutions (Costinot, 2009) including labor market regulations (2012; Cuñat & Melitz, 2010) and contract enforcement institutions (Costinot, 2009; Ferguson & Formai, 2013). Industry-specific volatility, like shocks in production techniques (Cun⁻at & Melitz, 2012) should be mentioned as well, in addition to real exchange rates, which influence the costs of imported inputs. Inquiring into such determinants of comparative advantages could, in turn, help optimize the overall effects of the Pacific Alliance on production and its sectoral distribution in Colombia.

Ultimately, this article focuses on Colombia in the Pacific Alliance, but similar research can be performed for other countries and other trade areas. As the methodological tools suggested here are standardized, they can be applied in many different ways. In particular, these tools could be applied to the other members of the Pacific Alliance. Highlighting the strengths and weaknesses of each member would provide a broader picture of the specialization patterns within the Pacific Alliance and, in turn, inspire future studies of each member's public policy (not only Colombia) and mechanisms by which the members of the Pacific Alliance could *cooperate* to enhance welfare through trade between them. The Pacific Alliance enforces various technical committees (market access, sanitary and phytosanitary measures, and rules of origin, among others) but none seeks the aforementioned kind of cooperation. This opportunity to enhance cooperation would serve the very purpose of the Pacific Alliance.

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