Value-Added Trade and Empirical Distributions of RCA Indices

Kaveri Deb & Bodhisattva Sengupta

Journal of Quantitative Economics

ISSN 0971-1554
Volume 16
Number 1

J. Quant. Econ. (2018) 16:235-264
DOI 10.1007/s40953-017-0071-x

Springer

J. Quant. Econ. (2018) 16:235–264
https://doi.org/10.1007/s40953-017-0071-x

ORIGINAL ARTICLE

Value-Added Trade and Empirical Distributions of RCA Indices

Kaveri Deb[1] · **Bodhisattva Sengupta**[2]

Published online: 13 February 2017

Abstract Revealed Comparative Advantage (RCA) indices aid in identification of the sectors in which countries reveal comparative advantage or disadvantage. Apart from serving such a dichotomous measure, the RCA indices are frequently employed as cardinal or ordinal measures over time. Application of the indices for comparative analyses calls attention towards the distributions of RCA indices, which must reasonably be stable over time, sectors and countries. Stability of index distributions facilitates the usage of indices as cardinal or ordinal measures over time. The present paper therefore analyses the empirical distributions of RCA indices to determine their suitability. However, such an analysis would be incomplete if the implications for RCA indices due to growing significance of global supply chains are not recognized. Hence apart from analyzing the distributions of gross trade based RCA indices, the distributions of domestic value-added in export based indices are also examined, and the differences are noted. Similar extensive analyses on the distributions of RCA indices are lacking in the literature. In this sense, the present paper makes an important contribution to the existing literature on RCA indices.

Keywords Revealed Comparative Advantage Index · Exports · Imports · Value-added trade · Distribution · Cardinal · Ordinal

JEL Classification F14 · C12

✉ Kaveri Deb
kaveri@iiitg.ac.in

Bodhisattva Sengupta
bsengupta@iitg.ernet.in

[1] Department of Humanities and Social Sciences, Indian Institute of Information Technology Guwahati, Guwahati, Assam 781001, India

[2] Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati, Guwahati, Assam 781039, India

1 Introduction

Various indices of Revealed Comparative Advantage (RCA) are used to predict the pattern of inter-industry goods trade among countries. It is expected that such indices reflect the relative advantage/disadvantage that a country has in exporting a product. Further, based on the values of any particular index, it is possible to generate cross country rankings with respect to a particular sector, or cross sector rankings with respect to a particular country. Such applications hint towards the usage of these indices as ordinal measures. In addition, the indices facilitate quantification of the extent of comparative advantage of a country in a sector compared to some other country, or the extent of comparative advantage of a sector in a country compared to any other sector. This application indicates that RCA indices can be used as cardinal measures.[1] Changing temporal distribution of RCA indices are also helpful in determining the trend of comparative advantage over time. However for the application of the indices as cardinal or ordinal measures or for temporal comparisons, the stability in country index distributions over sectors (in a given year) or stability in sectoral index distributions over countries (in a given year) or stability in sectoral/country index distributions over time (for a given country/sector) is required.

The RCA index initially proposed by Balassa (1965) has undergone many transformations in order to address various deficiencies of the original index. The primary objective in this paper is to analyze the empirical distributions of the Balassa index and its subsequently suggested modifications, for their stability over time or sectors or countries, so as to facilitate their reliable usage for the above mentioned purposes. Since global production networks are assuming growing importance in the area of world trade, the analysis in this paper emphasizes both gross export (henceforth *GX*) based indices, as well as their domestic value-added in export (henceforth *VAX*) transformations. To our knowledge, this is the first attempt to compare and contrast the properties of RCA indices based on both *GX* and *VAX*.

2 Review of the Literature

Application of Balassa's original RCA index in various studies to infer (a) the presence of strong or the weak sectors of a country in comparison to other countries or (b) to identify the comparative advantage or disadvantage of a country in a commodity compared to other commodities, are many (Batra et al. 2005; Smyth 2005; Wignaraja 2011; Karaalp 2011; Hassan 2013). Further, the index also found its application in determining the changes in pattern of comparative advantage of countries over time (Hiley 1999; Kijboonchoo and Kalayanakupt 2003). Apart from independent researchers, usage of the particular index is also encouraged by policymakers. For instance, the International Trade Unit of World Bank, in order to develop a toolkit for "competitiveness diagnostics", extensively used Balassa's RCA index (Sáez et al. 2014). As already noted, such applications presuppose the fact that the country/sectoral index distributions of RCA index values are stable over sectors/countries in any given year,

[1] See Ballance et al. (1987).

or over time for any given sector/country. We need to understand the implications for unstable index distribution with unstable mean.

If the computed average is not stable and not equal to zero (which would not be the case with a symmetrical distribution), then if one country gains comparative advantage in a product in a year, it would not be possible to say for certain that it has gained comparative advantage compared to other countries.[2] Hence, comparing countries for a particular product in year becomes quite unfeasible. Similar observations could be made while comparing sectors for a country in any given year. Thus usage of the index as a cardinal measure is questionable.

An unstable mean implies an unstable distribution. If the distribution of index values across countries (commodities) for a particular commodity (country) differs from the distribution of index values across the same group of countries (commodities) for another commodity (country) in a given year, then the same numerical value of the index may have different implications for different commodities (countries). Thus ranking of sectors (countries) with respect to a country (commodity) can be problematic. As a result, the index may not be suitable as an ordinal measure (Yeats 1985).

On similar grounds, if the distribution of sectoral index values for a country differs from year to year, then problem may arise in interpreting the index values over time. As observed by Leromain and Orefice (2014) the concept of comparative advantage is ex-ante in nature as it is based on pre-trade relative prices. Using pre-trade prices, inferences are drawn about post-trade scenario. In this regard, RCA indices are good proxies for comparative advantage if the indices are sticky over time. Stability of index distribution over time through stability of the mean also ensures reliable applicability of the index for time series analysis (Yu et al. 2009).

Application of RCA indices ignoring the aforesaid words of caution, will lead to erroneous conclusions at best, and potentially damaging policy prescriptions at worst. Recognizing the fact, empirical distribution of RCA indices have been analyzed in the existing literature. For instance, Hoen and Oosterhaven (2006) using the data for Netherlands and Poland for the year 1997, documented empirical evidences of fluctuating mean value (above 1) for Balassa's index. Benedictis and Tamberi (2001, 2004) as well as Hinloopen and Marrewijk (2001) have analyzed the stability of Balassa index distribution over time. Benedictis and Tamberi (*ibid*) noticed the distribution to be stable over 1986–1996 for France but unstable for Italy, Germany and Japan. Hinloopen and Marrewijk (*ibid*) by grouping the individual observations on 12 members of European Union found the distributions to be considerably stable both over months and the years from 1992 to 1996.

Considerations about the distributional deficiencies of the Balassa index have generated extensive research in this area, and eventually a number of alternative RCA indices have been suggested with the aim of overcoming one or more shortcomings of the original index. Table 1 provides a brief summary on the distribution of the Balassa index and its various subsequently suggested modifications.

From Table 1 we can infer the skewness in distribution of the original Balassa index. The subsequently suggested indices intended to address the problems of

[2] As it does not necessarily follow that some other country has lost comparative advantage in that same product.

Table 1 RCA Index specifications

Index	Proposed by	Formula	Comparative Advantage Neutral point	Limit	Characteristics of distribution
Balassa	Balassa (1965)	$\frac{X_a^i / X_t^i}{X_a^w / X_t^w}$	1 (approx)	$[0, +\infty)$	Asymmetric, non-normal
Revealed Symmetric Comparative Advantage (RSCA)	Dalum et al. (1998) and Laursen (1998)	$\frac{\frac{X_a^i / X_t^i}{X_a^w / X_t^w} - 1}{\frac{X_a^i / X_t^i}{X_a^w / X_t^w} + 1}$	0 (approx)	$[-1, +1)$	Symmetric-induces normality
Additive Revealed Comparative Advantage (ARCA)	Hoen and Oosterhaven (2006)	$\frac{X_a^i}{X_t^i} - \frac{X_a^w}{X_t^w}$	0 (approx)	$(-1, +1)$	Symmetric, stable arithmetic mean across sectors only
Normalised Revealed Comparative Advantage (NRCA)	Yu et al. (2009)	$\frac{X_a^i}{X_t^w} - \frac{X_t^i}{X_t^w}\frac{X_a^w}{X_t^w}$	0	$[-\frac{1}{4}, +\frac{1}{4}]$	Symmetric, stable arithmetic mean across sectors and across countries
Log-of-Balassa	Vollrath (1991)	$ln\frac{X_a^i / X_t^i}{X_a^w / X_t^w}$	0 (approx)	$[-\infty, +\infty)$	Symmetric-induces normality

In all the index specifications, i denotes any particular country and a denotes any particular sector. t is the sum of all sectors and w is the world total. However, while calculating the index values in this paper, t and w will include the sum of all sectors and sum of all countries respectively, on which data would be available. Therefore X_a^i is the exports of product a by country i, X_t^i is the exports all products by country i, X_a^w is the exports of product a by all countries and X_t^w is the exports of all products by all countries.

Due to the inclusion of all countries and all commodities in the reference group, the comparative advantage neutral points for the indices of Balassa, RSCA, ARCA and Log-of-Balassa have approximate values. In case of comparison with respect to the rest of the world or rest of commodities, the comparative advantage neutral points will be exactly equal to 1 or 0. The calculations of the limits are available on request

asymmetry, non-normality and unstable mean, which are associated with the Balassa index. The indices reveal comparative advantage/disadvantage if the calculated index values exceed/fall short of unity (for Balassa index) or zero (for all other indices). Only NRCA index, because of stability in calculated mean (equal to comparative advantage neutral point) across sectors (for a country in a year) or across countries (for a sector in a year), is theoretically suitable for application as a cardinal/ordinal measure with respect to a country/sector in a year. Among other indices, ARCA index is theoretically more appropriate for usage as a cardinal measure with respect to a country only and as an ordinal measure with respect to a sector only in a year, because of stability in calculated mean only across sectors (for a country in a year). The remaining three indices of Balassa, RSCA and Log-of-Balassa seem to suffer inherently from the problem of unstable distributions over sectors/countries, as the calculated mean values across sectors (for a country) or across countries (for a sector), may fluctuate from the theoretically defined comparative advantage neutral point. Given these features, stability in index distributions over time may be expected for NRCA index (both for sectoral and country index distributions) and for ARCA index (only for sectoral index distribution).

The first aim of present analysis is to examine the stability properties (over time, sectors and countries) of all the five RCA indices presented in Table 1. To the best of our knowledge, such a comprehensive study on the empirical distributions of RCA indices is lacking in the existing literature. The previously cited studies of Benedictis and Tamberi (*ibid*) as well as Hinloopen and Marrewijk (*ibid*) are based on Balassa's RCA index only. Moreover, these studies address the incompleteness in a partial fashion because they do not look into the stability of index distributions over three parameters (time, sector and countries), in the manner as presented in the current paper.

As pointed out before, it is vital to recognize the growing incidences of production fragmentation. Global value-added supply chains imply increasingly inter-linkaged production processes across countries. As a result, inputs need to cross borders multiple times. This leads to considerable double counting, due to which, the amount of domestic value-added in exports may be exaggerated in the gross trade data (Johnson 2014). For example, a country might appear to be a dominant exporter in a particular sector based on *GX* values, but in reality may be contributing very little to that sector in value-added terms. Thus the difference between trade based on *GX* and *VAX* must be realized at the time of analyzing the comparative advantage of countries (Koopman et al. 2014). With these considerations in mind, we recalculate RCA indices by introducing *VAX*. Next, the differences between the behaviors of their empirical distributions with that of *GX* based indices are examined. This constitutes a significant research contribution of the paper, as the existing literature tends to overlook the behavior of the RCA index distributions after they have been adjusted for *VAX*.

In sum, this paper intends to evaluate the empirical distribution of all five indices presented in Table 1, with the objective of determining the stability in their country/sectoral distributions over sectors/countries and time, using both gross trade, as well as trade in value-added. An index with most stable distribution over sectors, countries and time, can reliably be used as a cardinal or ordinal measure or for temporal comparisons, and we need to determine how important global production networks are in influencing the stability in index distributions.

To analyze the data, we use the following methodology. First, empirical distributions of various RCA indices are determined through a study of their summary statistics. Similar analysis has been carried out by Hinloopen and Marrewijk (2001). In their paper, they report the summary statistics only for the *GX* based index of Balassa. In this paper we however consider both *GX* and *VAX* based values for Balassa index and its subsequent modifications.

Second, Wilcoxon (1945) signed rank test is used to analyze the temporal distributions of various RCA indices with respect to separate countries and sectors, with due recognition to differences between *GX* and *VAX* based indices. Although Benedictis and Tamberi (2004) in their paper make use of the signed rank test, they restrict themselves to the examination of *GX* based Balassa index for separate countries only.

Third, Wilcoxon (1945) rank sum test is used to analyze the stability of the sectoral or country index distributions over countries or sectors for a particular year. Similar attempts at analyzing the empirical distributions of RCA indices over sectors or countries have not been made in the existing literature.

It is to be noted that these tests do not presuppose the shape of the distribution. This characteristic will particularly be helpful given that not many of the RCA indices are normally distributed. Hence, statistical inferences will not be biased.

Using the methodology outlined above, our analyses yield the following results:

(a) The *GX* based ARCA index consistently features stable distributions over time. When the indices are adjusted for *VAX*, NRCA index exhibits stable distributions over time consistently.
(b) Both *GX* and *VAX* based NRCA indices have the most stable distributions over sectors.
(c) Both *GX* and *VAX* based ARCA and NRCA indices report the most stable distributions over countries

Given the growing significance of global value chains, the main conclusion of the paper is drawn on the basis of the performance of *VAX* based indices. On observing consistent performance of NRCA index under all considered circumstances, it is recommended in the paper that the NRCA index be reliably used by the policy makers for comparative analysis, after adjusting it for *VAX*. Henceforth, ad hoc usage of any other index may be erroneous.

The paper is divided into three more sections. The data and methods of analysis are described in "Methodology and Data" section. Results are discussed in "Results" section, while the last section concludes.

3 Methodology and Data

In order to adjust the *GX* values for *VAX*, the current paper adopts the conceptual framework developed by Hummels et al. (2001). The following expression for *VAX* is used:

$$VAX = \hat{A}_V (I - A^D)^{-1} X \tag{1}$$

Assuming N sectors, A_V is a $(1 \times N)$ row vector of domestic value-added coefficients, such that each a_j^V represents sector j's ratio of value-added to gross output. $\hat{A}_V$ is

the $(N \times N)$ diagonal matrix constructed from the row vector A_V. I is the $(N \times N)$ identity matrix. A^D is a $(N \times N)$ domestic input-output coefficient matrix, such that each a_{ij}^D depicts the amount of domestically produced input from sector i used to produce one unit of sector j's output. X is the $(N \times 1)$ vector of GX. $(I - A^D)^{-1}X$ is a $(N \times 1)$ vector representing the total domestic output requirement from each sector i to produce N sectoral exports. Each element in the resulting column vector VAX, provides a measure of the domestic contribution of a sector in a country's exports of all N sectors.[3]

It is to be noted that Hummels et al.'s (*ibid*) conceptual framework relies on two restrictive assumptions. First, it assumes away the presence of export processing zones by considering similar technologies for manufacture of goods meant for domestic final consumption, and goods meant for exports. Second, intermediate goods exports by multiple countries are ignored after assuming that a country's imports have 100% foreign content. These assumptions have been studied in the literature by Koopman et al. (2012), Daudin et al. (2011) as well as Johnson and Noguera (2012), and their implications for domestic or foreign content in trade have been examined. But as recognized in Deb and Hauk (2015), destination of a country's exports and ultimate usage of those exports in the destination country as an intermediate or final good is of little relevance, if the objective is to determine the changes in behavior of RCA indices with the incorporation of VAX. This paper therefore retains the adopted methodology of Hummels et al. (*ibid*) while calculating the sectoral VAX of a country.

The data on domestic value-added, gross output and input-output coefficient matrices for 36 countries on 16 merchandise sectors are obtained from the World Input–Output Tables (WIOT) 2008 and 2011 of the World Input–Output Database (WIOD). These two particular years are selected in order to evaluate the performance of indices during the onset of the financial crisis and years following the onset. Although more recent data after 2008 might have been preferable, the WIOT are available only till the year 2011. The list of 36 countries and the descriptions on each of the 16 sectors are provided in Appendix A and B respectively. In this paper, the calculated index values reveal the comparative advantages/disadvantages of each of the 36 countries in each of the 16 sectors, while exporting to United States. While calculating the index values for a sector (a) with respect to a country (i), the reference group of sectors (t) and countries (w) comprise of all the 16 sectors and all the 36 countries respectively. First the GX based indices are computed for each year, and then they are adjusted for VAX using the expression (1). Since the database does not provide any separate data on bilateral export figures, the final use of sectoral imports by United States from each country from the International Supply and Use Table (ISUT) 2008 and 2011 of WIOD, are assumed to mirror final gross exports by each country to USA.

After adjusting the RCA indices for sectoral VAX, their empirical distributions are compared with that of the RCA indices based on GX. The empirical distributions corresponding to both versions of each RCA index are first analyzed by examining their respective summary statistics. The measures on means, medians, skewness and kurtosis are separately studied for each RCA index for each selected year. Fluctuations in means

[3] The details on the derivation of expression (1) can be provided on request.

and medians over time help in understanding the stability of empirical distributions of RCA indices. Measures on skewness and kurtosis help in depicting the extent of symmetry or asymmetry in the distributions. For each year the sample includes all countries and all sectors with available data.

An analysis of the summary statistics of RCA indices provides a preliminary guide to the stability of their empirical distributions over time. Empirical tests on the shifts of the distributions will be able to establish a more on hand "proof" on the statistical significance of those shifts, and will therefore serve as a robustness check on the performance of indices. For that purpose, a two tailed Wilcoxon's signed rank test on the data is performed. The Wilcoxon's signed rank test checks for any difference in distributions between two samples, provided that these two samples are not independent, but matched or paired or they constitute repeated measurements on a single sample. Thus, the signed rank test tests for the null hypothesis of equal distributions through equal means, against the alternative hypothesis of unequal distributions through unequal means. In order to provide an intensive analysis on time stability, sectoral distributions of only 6 countries, and country distributions of only 7 sectors are considered.[4] The 6 countries are Canada, China, Germany, India, Japan and Mexico. These 6 countries are the primary exporters of merchandise to USA, and they together constitute about 13% of the total merchandise exports to USA. The descriptions on 7 sectors (sector 3, 8, 9, 13, 14, 15 and 16) are provided in Appendix B. These 7 sectors constitute about 79% of the total merchandise exports to USA from various countries. Further, these 7 sectors comprise more than 75% of the merchandise exports from each of the selected 6 countries to USA.[5] We assume that these 6 countries and 7 sectors will be sufficient representations of the entire sample.

The stability analysis is not only restricted to time but can also be extended to countries and sectors, to determine the usefulness of RCA indices as cardinal or ordinal measures with respect to countries or sectors. Since comparisons over sectors or over countries involve unmatched or non-paired data, Wilcoxon's signed rank test is not suitable. In this respect, Wilcoxon's rank sum test is applicable in determining the statistical significance of shift in sectoral/country index distributions over countries/sectors in a given year.

The rank sum test examines the hypothesis that two independent samples are drawn from two populations which share similar distributions. Under the assumption of identically shaped distributions, testing for differences in distributions imply testing for differences in means or medians.[6] For testing the stability in sectoral/country index distributions over countries/sectors, the same 6 countries/7 sectors selected for signed rank test, are considered.[7]

[4] For calculating the index values for each country or sector in a year, the reference group comprises of 36 countries and 16 sectors.

[5] Calculations are based on the data on merchandise exports from 36 countries to USA for the year 2011, obtained from WIOD.

[6] Lucid representations of the signed rank and rank sum test can be found in Conover (1999).

[7] Since rank sum test examines two sets of sample observations at a time, considerations of all 36 countries or 16 sectors will imply analyzing ${}^{36}C_2$ or ${}^{16}C_2$ cases for country or sectoral stability. We instead assume that the considered set of countries or sectors will be able to represent the entire sample efficiently.

4 Results

The results for our analyses are presented in this section. But before proceeding with the discussion of the results, it is worthwhile to note the changes in the sectoral rankings of indices for some countries, as presented in "Differences in Sectoral Ranks between GX and VAX based Indices". This will help the reader to form an idea about how adjustment of *GX* based indices for *VAX* might produce discernable changes in the export basket of a country. The results for stability analyses are thereafter presented in "Discussions on the Summary Statistics, Discussions on Wilcoxon's Signed Rank Test Results, Discussions on Wilcoxon's Rank Sum Test Results" sections.

4.1 Differences in Sectoral Ranks Between *GX* and *VAX* Based Indices

For examining the changes in sectoral ranks due to adjustment of *GX* based indices for *VAX*, the index values for 6 countries (Canada, China, Germany, India, Japan and Mexico) considered for Wilcoxon's signed rank and rank sum test are selected. The sectoral ranks corresponding to only Balassa index and NRCA index are presented in Tables 2, 3, 4, 5, 6 and 7 for the year 2011. The RSCA index and Log-of-Balassa index (to preserve space, from now on while discussing results in this and subsequent subsections, we will refrain from using the word 'index' along with the name of the index) being monotonic transformations of the Balassa, report similar sectoral rankings (although different index values) for any country. Similarly NRCA is a monotonic transformation of the ARCA with respect to a country (but not with respect to a sector), and therefore, the two indices report similar sectoral rankings (but different index values) for any country. For these reasons, the ranks for RSCA, ARCA and Log-of-Balassa are not separately reported in the tables below, but can be provided on request.[8]

A study of the tables will reveal that the ranks for many sectors have not changed after adjustment of the index values for *VAX*, e.g., NRCA ranks for sectors 3, 9, 15 (for Canada), and 3, 14, 15 (for China); Balassa ranks for sectors 12, 14, 16 (for China), and 9, 14, 15 (for Germany) etc. Changes may however be noted for some sectors also. Canada reported comparative advantage in sectors 1, 2 and 8 on the basis of *GX* based Balassa but comparative disadvantage on the basis of *VAX* based Balassa. Similar movements can be observed for the same sectors with respect to NRCA. Reverse inferences can be made from the calculated index values for sectors 6, 10 and 13. *GX* based Balassa and NRCA report comparative disadvantage in those sectors. But their *VAX* based counterparts report comparative advantage. Changes in the sectoral rankings can be noted for other countries too. Given this scenario, we can expect changes in country rankings with respect to a sector.

[8] These facts will also be evident from the results of the rank sum test reported in Tables 14, 15, 16 and 17. Different values for Log-of-Balassa may be reported in some cases due to zero exports of a sector by a country.

Table 2 Sectoral ranks with *GX* and *VAX* based RCA Indices: Canada

Ranks	Balassa Index		NRCA Index	
	Sector (*GX* RCA)	Sector (*VAX* RCA)	Sector (*GX* RCA)	Sector (*VAX* RCA)
1	2	15	15	15
	(8.37320)	(2.69300)	(0.03319)	(0.02276)
2	15	3	3	3
	(2.71835)	(1.62173)	(0.00413)	(0.00383)
3	8	13	8	13
	(2.00347)	(1.25630)	(0.00375)	(0.00238)
4	3	7	1	7
	(1.52913)	(1.14427)	(0.00007)	(0.00030)
5	7	10	7	10
	(1.05366)	(1.10866)	(0.00006)	(0.00028)
6	1	6	2	6
	(1.04888)	(1.04209)	(<0.00001)	(0.00004)
7	13	12	6	12
	(0.97558)	(0.97749)	(−0.00007)	(−0.00015)
8	10	16	10	11
	(0.86468)	(0.88309)	(−0.00016)	(−0.00016)
9	12	8	12	8
	(0.81944)	(0.83807)	(−0.00019)	(−0.00028)
10	9	11	11	16
	(0.56230)	(0.82160)	(−0.00025)	(−0.00081)
11	16	2	13	5
	(0.50740)	(0.68349)	(−0.00027)	(−0.00151)
12	14	9	5	2
	(0.32947)	(0.58483)	(−0.00209)	(−0.00196)
13	6	1	9	9
	(0.17113)	(0.53513)	(−0.00420)	(−0.00377)
14	4	14	16	1
	(0.15768)	(0.44421)	(−0.00568)	(−0.00397)
15	5	4	4	4
	(0.12230)	(0.22913)	(−0.01015)	(−0.00784)
16	11	5	14	14
	(0.03873)	(0.16720)	(−0.01816)	(−0.00911)

The values in parentheses are the calculated index values

Due to such noticeable discrepancies in rankings between the *GX* and *VAX* based indices, it is essential to study the distributions of such indices separately, and note the differences involved. We can now proceed with the comparative analysis on the stability of *GX* and *VAX* based index distributions.

Table 3 Sectoral ranks with *GX* and *VAX* based RCA Indices: China

Ranks	Balassa Index		NRCA Index	
	Sector (*GX* RCA)	Sector (*VAX* RCA)	Sector (*GX* RCA)	Sector (*VAX* RCA)
1	6	5	14	14
	(2.82694)	(2.05269)	(0.05618)	(0.02077)
2	5	6	5	12
	(2.59634)	(1.94583)	(0.00792)	(0.00971)
3	10	11	4	1
	(2.49382)	(1.72516)	(0.00515)	(0.00626)
4	11	10	10	5
	(2.37446)	(1.56375)	(0.00372)	(0.00500)
5	12	12	12	10
	(2.01818)	(1.55240)	(0.00224)	(0.00377)
6	14	14	11	4
	(1.99405)	(1.48414)	(0.00073)	(0.00346)
7	4	1	6	16
	(1.20476)	(1.27989)	(0.00032)	(0.00300)
8	16	16	2	6
	(0.96732)	(1.16448)	(<−0.00001)	(0.00213)
9	13	4	16	11
	(0.94543)	(1.12983)	(−0.00079)	(0.00174)
10	3	2	13	7
	(0.44100)	(0.82927)	(−0.00126)	(−0.00118)
11	7	13	7	8
	(0.29481)	(0.79251)	(−0.00173)	(−0.00215)
12	9	7	1	2
	(0.21203)	(0.78237)	(−0.00238)	(−0.00277)
13	1	9	8	13
	(0.18787)	(0.71144)	(−0.00761)	(−0.00505)
14	15	3	3	3
	(0.06701)	(0.63073)	(−0.00911)	(−0.00596)
15	2	8	9	9
	(0.03978)	(0.53087)	(−0.01577)	(−0.00686)
16	8	15	15	15
	(0.02286)	(0.09389)	(−0.03761)	(−0.03187)

The values in parentheses are the calculated index values

4.2 Discussions on the Summary Statistics

The summary statistics for each index are presented for the years 2008 and 2011. The differences in means, medians, skewness and kurtosis for each index are noted between the years.

Table 4 Sectoral ranks with *GX* and *VAX* based RCA Indices: Germany

Ranks	Balassa Index		NRCA Index	
	Sector (*GX* RCA)	Sector (*VAX* RCA)	Sector (*GX* RCA)	Sector (*VAX* RCA)
1	7	13	15	13
	(2.36535)	(2.44678)	(0.01181)	(0.00775)
2	15	15	13	15
	(2.02886)	(1.95737)	(0.00618)	(0.00741)
3	9	9	9	9
	(1.96223)	(1.69982)	(0.00548)	(0.00366)
4	13	7	7	14
	(1.94126)	(1.46433)	(0.00095)	(0.00327)
5	14	14	2	7
	(0.78236)	(1.34572)	(<−0.00001)	(0.00055)
6	12	12	6	12
	(0.78156)	(1.01634)	(−0.00005)	(0.00006)
7	11	10	11	11
	(0.60012)	(0.62200)	(−0.00006)	(−0.00020)
8	10	11	12	6
	(0.38609)	(0.61607)	(−0.00014)	(−0.00036)
9	3	6	10	10
	(0.26284)	(0.27627)	(−0.00044)	(−0.00056)
10	5	16	1	5
	(0.16795)	(0.22967)	(−0.00078)	(−0.00085)
11	16	3	5	8
	(0.15200)	(0.21686)	(−0.00118)	(−0.00094)
12	8	5	8	3
	(0.08832)	(0.18356)	(−0.00202)	(−0.00278)
13	1	8	3	16
	(0.06001)	(0.06945)	(−0.00342)	(−0.00309)
14	6	1	14	2
	(0.04399)	(0.05799)	(−0.00350)	(−0.00355)
15	4	4	16	1
	(0.01901)	(0.01906)	(−0.00582)	(−0.00464)
16	2	2	4	4
	(0.01214)	(0.00830)	(−0.00703)	(−0.00575)

The values in parentheses are the calculated index values

The summary statistics for each of the *GX* based indices are presented in Tables 8. Corresponding statistics for *VAX* based indices are presented in Tables 9. The following discussions on the distributions of each index are based on casual observations of summary statistics.

Table 5 Sectoral ranks with *GX* and *VAX* based RCA Indices: India

Ranks	Balassa Index		NRCA Index	
	Sector (*GX* RCA)	Sector (*VAX* RCA)	Sector (*GX* RCA)	Sector (*VAX* RCA)
1	16	16	16	16
	(7.06788)	(5.93656)	(0.03485)	(0.01022)
2	1	1	1	1
	(1.53542)	(1.73863)	(0.00037)	(0.00187)
3	4	9	2	9
	(0.73147)	(1.28466)	(<−0.00001)	(0.00077)
4	9	4	6	4
	(0.70990)	(1.14583)	(−0.00002)	(0.00044)
5	6	6	11	6
	(0.61410)	(1.10761)	(−0.00012)	(0.00003)
6	12	12	12	11
	(0.44481)	(0.72995)	(−0.00029)	(−0.00014)
7	2	8	10	8
	(0.29056)	(0.49974)	(−0.00052)	(−0.00026)
8	3	11	7	5
	(0.20321)	(0.47802)	(−0.00054)	(−0.00033)
9	13	10	5	10
	(0.18720)	(0.44976)	(−0.00100)	(−0.00042)
10	14	13	9	7
	(0.18246)	(0.40381)	(−0.00138)	(−0.00042)
11	8	5	8	12
	(0.16511)	(0.38075)	(−0.00155)	(−0.00054)
12	5	14	4	2
	(0.15951)	(0.36499)	(−0.00161)	(−0.00123)
13	10	2	3	3
	(0.11895)	(0.33360)	(−0.00310)	(−0.00145)
14	7	7	13	13
	(0.07650)	(0.31088)	(−0.00447)	(−0.00165)
15	11	3	15	14
	(0.06888)	(0.20796)	(−0.00961)	(−0.00309)
16	15	15	14	15
	(0.00108)	(0.05053)	(−0.01102)	(−0.00379)

The values in parentheses are the calculated index values

The means and the medians corresponding to the Balassa, RSCA and Log-of-Balassa reported in Tables 8 and 9 show evidences of some minor fluctuations over time. Similar fluctuations are however not observed for the ARCA and the NRCA in both the tables. Thus the empirical distributions of latter two indices can be expected

Table 6 Sectoral ranks with *GX* and *VAX* based RCA Indices: Japan

Ranks	Balassa Index		NRCA Index	
	Sector (*GX* RCA)	Sector (*VAX* RCA)	Sector (*GX* RCA)	Sector (*VAX* RCA)
1	15	15	15	15
	(3.14303)	(3.19662)	(0.02163)	(0.02036)
2	13	12	13	13
	(1.79114)	(1.67604)	(0.00457)	(0.00361)
3	12	13	2	12
	(0.90943)	(1.56296)	(<−0.00001)	(0.00313)
4	14	10	6	14
	(0.72142)	(1.36076)	(−0.00003)	(0.00104)
5	10	11	12	10
	(0.48757)	(1.18731)	(−0.00005)	(0.00064)
6	9	14	11	11
	(0.40532)	(1.09189)	(−0.00009)	(0.00012)
7	11	7	10	8
	(0.36329)	(0.73477)	(−0.00032)	(−0.00034)
8	6	8	7	7
	(0.24752)	(0.71659)	(−0.00052)	(−0.00038)
9	1	9	1	6
	(0.19484)	(0.58034)	(−0.00059)	(−0.00045)
10	16	6	5	5
	(0.19001)	(0.24697)	(−0.00123)	(−0.00123)
11	7	3	8	9
	(0.14740)	(0.16814)	(−0.00177)	(−0.00263)
12	3	16	9	3
	(0.12733)	(0.13999)	(−0.00298)	(−0.00354)
13	8	1	3	16
	(0.09436)	(0.08610)	(−0.00356)	(−0.00413)
14	2	4	14	2
	(0.02127)	(0.04768)	(−0.00394)	(−0.00414)
15	4	2	16	1
	(0.01007)	(0.03208)	(−0.00488)	(−0.00538)
16	5	5	4	4
	(0.00795)	(0.01934)	(−0.00623)	(−0.00668)

The values in parentheses are the calculated index values

to be more stable over time than any other index. Further, the reported means for the ARCA and NRCA are much closer to zero—the comparative advantage neutral point. This aids in easier interpretation for the average sector or country.

Table 7 Sectoral ranks with *GX* and *VAX* based RCA Indices: Mexico

Ranks	Balassa Index		NRCA Index	
	Sector (*GX* RCA)	Sector (*VAX* RCA)	Sector (*GX* RCA)	Sector (*VAX* RCA)
1	15	15	15	15
	(2.15752)	(2.60847)	(0.01999)	(0.01735)
2	14	3	14	3
	(1.29311)	(1.32864)	(0.00710)	(0.00163)
3	10	2	10	2
	(1.04922)	(1.07680)	(0.00005)	(0.00038)
4	1	11	2	11
	(0.93436)	(1.01079)	(<−0.00001)	(0.00001)
5	3	16	6	10
	(0.92731)	(0.96534)	(−0.00006)	(−0.00016)
6	12	10	1	7
	(0.74510)	(0.92185)	(−0.00008)	(−0.00019)
7	16	7	11	16
	(0.60233)	(0.88453)	(−0.00016)	(−0.00019)
8	13	14	12	6
	(0.59030)	(0.86245)	(−0.00024)	(−0.00032)
9	7	12	3	5
	(0.43674)	(0.84580)	(−0.00051)	(−0.00059)
10	4	13	7	8
	(0.41514)	(0.67913)	(−0.00059)	(−0.00076)
11	8	5	5	12
	(0.37905)	(0.59679)	(−0.00150)	(−0.00083)
12	11	4	8	14
	(0.30969)	(0.59273)	(−0.00207)	(−0.00181)
13	5	6	13	13
	(0.29542)	(0.54238)	(−0.00404)	(−0.00240)
14	6	1	16	1
	(0.22032)	(0.53254)	(−0.00410)	(−0.00320)
15	9	8	4	4
	(0.12671)	(0.45610)	(−0.00630)	(−0.00333)
16	2	9	9	9
	(<0.00001)	(0.23382)	(−0.00749)	(−0.00559)

The values in parentheses are the calculated index values

As apparent from the values on skewness and kurtosis, the distribution of the RSCA is closer to a normal distribution than any other index. In fact, the adjustment of the *GX* based RSCA for *VAX* makes its normality even more prominent. The distribution of remaining four indices can in no way be described as normal. We do however note

Table 8 *GX* based Balassa/RSCA/ARCA/NRCA/Log-of-Balassa Index: entire sample analysis

Summary statistics/year	Balassa		RSCA		ARCA		NRCA		Log-of-Balassa	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Mean	1.158	1.153	−0.277	−0.301	<0.001	<0.001	<0.001	<0.001	−1.017	−1.067
Median	0.496	0.436	−0.337	−0.392	−0.002	−0.002	<−0.001	<−0.001	−0.653	−0.777
Standard deviation	1.887	2.156	0.538	0.534	0.093	0.098	0.004	0.005	2.016	1.966
Skewness	4.108	5.224	0.265	0.360	1.980	2.607	2.410	3.947	−1.244	−1.101
Kurtosis	26.855	40.704	1.837	1.919	12.794	16.661	55.641	62.827	5.271	5.140
No. of observations	576	576	576	576	576	576	576	576	563	565

Table 9 *VAX* based Balassa/RSCA/ARCA/NRCA/Log-of-Balassa Index: entire sample analysis

Summary statistics/year	Balassa		RSCA		ARCA		NRCA		Log-of-Balassa	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Mean	1.047	1.070	−0.203	−0.214	<0.001	<0.001	<0.001	<0.001	−0.669	−0.718
Median	0.674	0.658	−0.194	−0.206	−0.007	−0.008	−0.00001	−0.00001	−0.394	−0.418
Standard deviation	1.507	1.740	0.453	0.464	0.076	0.081	0.003	0.003	1.508	1.599
Skewness	8.828	10.356	−0.023	0.043	2.360	2.717	0.831	0.696	−1.619	−1.834
Kurtosis	134.260	170.622	2.049	2.019	13.531	16.287	47.767	42.442	7.866	10.033
No. of observations	576	576	576	576	576	576	576	576	576	576

an improvement in symmetry of the NRCA distribution through changes in the levels of skewness.

Thus, on the basis of analysis in this subsection we conclude that ARCA and NRCA have more time stable distributions than any other index. Unlike RSCA, they are however not normal. But normality is not a necessary criterion for stable distribution. Adjustment of indices for *VAX* does not alter our conclusion.

4.3 Discussions on Wilcoxon's Signed Rank Test Results

Preliminary analysis on the empirical distribution of RCA indices presented in the "Discussions on the Summary Statistics" section, incorporates all countries and all sectors in the yearly samples. As discussed, the analysis in this subsection corresponds to a few countries and sectors.

The shifts of the sectoral distributions for each country over time are analyzed using the Wilcoxon's signed rank test. The summary of results for the signed rank test on *GX* based RCA indices and *VAX* based RCA indices are presented in Tables 10 and 11 respectively. In both the tables for each country in each year, the number of sectors is 16. Tables 10 and 11 report the standard normal approximations of the test statistic and the corresponding p values for each country and index. They also report the numbers of accepted cases for null hypothesis for all countries together for each index. Based on the number of countries studied, the reported numbers of cases in each table where the null hypothesis gets accepted for each index, are out of total 6 cases.

A glance at the above tables reveals slight improvement in results upon adjusting the indices for *VAX*. In Table 10, only ARCA can be considered to feature the most stable empirical distribution, as it reports the largest number of accepted cases for null hypothesis. In Table 11 the performance of ARCA is matched by that of Balassa and NRCA.

We also test the stability of the *GX* and *VAX* based country index distributions over years for 7 separate sectors using the signed rank test. For each sector in each year the number of countries is 36. Tables 12 and 13 report the standardized normal approximations of the test statistic and the corresponding p values for each sector and index. They also report the numbers of accepted cases for null hypothesis for all sectors together for each index. Based on the number of sectors, the reported numbers of cases for acceptance of null hypothesis at the end of each table are out of a total 7 cases for each index.

A comparison of Tables 12 and 13 reveals that adjustment of indices for *VAX*, again improves the stability in the empirical distributions of some indices without harming the rest. Overall, *VAX* adjustments make Balassa, RSCA and NRCA more time stable than the rest.

Although not apparent from "Discussions on the Summary Statistics" section, the analysis in this subsection indicates that *VAX* adjustment may improve the stability in distribution of indices over time in general. Integrating our observations with respect to countries and sectors in Tables 11 and 13, *VAX* based Balassa and NRCA can be considered to generate most stable empirical distributions over time. The ARCA, although as good as the NRCA as per the analysis in "Discussions on the Summary

Table 10 Signed rank test on *GX* based Indices: country wise

Country	Year combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
Canada	2008–2011	0.776	1.965*	0.465	0.207	2.068*
		(0.438)	(0.049)	(0.642)	(0.836)	(0.039)
China	2008–2011	−1.758	−1.862	−0.621	<0.001	−1.448
		(0.079)	(0.063)	(0.535)	(1.000)	(0.148)
Germany	2008–2011	1.293	1.344	0.207	−0.052	1.448
		(0.196)	(0.179)	(0.836)	(0.959)	(0.148)
India	2008–2011	2.068*	2.172*	1.241	2.689**	2.172*
		(0.039)	(0.030)	(0.215)	(0.007)	(0.030)
Japan	2008–2011	0.517	0.155	0.517	−2.534*	−0.414
		(0.605)	(0.877)	(0.605)	(0.011)	(0.679)
Mexico	2008–2011	0.543	0.750	0.310	1.086	0.795
		(0.587)	(0.453)	(0.756)	(0.278)	(0.427)
Total no. of accepted cases for null hypothesis		5	4	6	4	4

* Significant at 5% level. ** Significant at 1% level. For each country in each year there are observations on 16 sectors

Table 11 Signed rank test on *VAX* based Indices: country wise

Country	Year combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
Canada	2008–2011	−0.517	<0.001	0.259	0.465	0.155
		(0.605)	(1.000)	(0.796)	(0.642)	(0.877)
China	2008–2011	−0.259	−0.052	0.259	0.362	0.207
		(0.796)	(0.959)	(0.796)	(0.717)	(0.836)
Germany	2008–2011	1.758	2.120*	<0.001	−0.517	2.379*
		(0.079)	(0.034)	(1.000)	(0.605)	(0.017)
India	2008–2011	−0.776	−0.672	−0.621	1.758	−0.827
		(0.438)	(0.501)	(0.535)	(0.079)	(0.408)
Japan	2008–2011	−0.517	−1.189	0.052	−1.396	−1.551
		(0.605)	(0.234)	(0.959)	(0.163)	(0.121)
Mexico	2008–2011	0.672	0.931	0.672	1.293	0.879
		(0.501)	(0.352)	(0.501)	(0.196)	(0.379)
Total number of accepted cases		6	5	6	6	5

** Significant at 1%; * Significant at 5%. For each country, 16 sectoral observations are available in each year

Statistics" section and as per the results presented in Table 11, falls short of it in Table 13. However, the distribution of the *GX* based ARCA can be considered to be most stable over time on the basis of the results presented in Tables 10 and 12. If these country and sector specific results of "Discussions on Wilcoxon's Signed Rank Test Results" are integrated with the findings in "Discussions on the Summary Statistics" section (which studies the stability in index distributions over time with all countries and all sectors in a yearly sample, on the basis of casual observations of summary statistics), NRCA can be selected to be most time stable, after it has been adjusted for *VAX*. On the basis of *GX* however, ARCA may be selected to most time stable.

4.4 Discussions on Wilcoxon's Rank Sum Test Results

To evaluate the stability of country/sectoral index distributions over sectors/over countries, the Wilcoxon's rank sum test is used. Tables 14 and 16 report the standardized normal approximations for the test statistic, the corresponding p values, and the number of accepted cases for null hypotheses for sectors and for countries respectively, for each *GX* based index. Tables 15 and 17 report the same parameters with respect to each *VAX* based index. Wilcoxon's rank sum test is performed by considering two sectors or two countries at a time. In Tables 14 and 15, results corresponding to only 7 sectors (as considered in Tables 12 and 13) are reported. The sectors being considered in a group of two for the test, the number of reported cases for acceptance of null hypothesis, are out of a total of 21 cases in Tables 14 and 15 for each index. In both the tables for each sector, the numbers of countries are 36. The year of analysis is 2011, which is the most recent out of 2 considered years.

Table 12 Signed rank test on *GX* based Indices: sector wise

Sector codes	Year combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
3	2008–2011	0.126	0.063	0.644	−0.251	0.126
		(0.900)	(0.950)	(0.520)	(0.802)	(0.900)
8	2008–2011	−0.165	0.306	−1.383	−0.141	0.180
		(0.869)	(0.759)	(0.167)	(0.888)	(0.857)
9	2008–2011	−1.210	−1.634	−0.660	0.299	−1.241
		(0.226)	(0.102)	(0.509)	(0.765)	(0.215)
13	2008–2011	−0.550	−0.157	−0.534	0.361	−0.157
		(0.582)	(0.875)	(0.593)	(0.718)	(0.875)
14	2008–2011	−0.094	−0.016	0.110	−0.157	−0.079
		(0.925)	(0.988)	(0.912)	(0.875)	(0.937)
15	2008–2011	0.911	1.005	−1.115	0.456	1.949
		(0.362)	(0.315)	(0.265)	(0.649)	(0.051)
16	2008–2011	2.718**	2.781**	2.859**	2.042*	2.828**
		(0.007)	(0.005)	(0.004)	(0.041)	(0.005)
Total no. of accepted cases for null hypothesis		6	6	6	6	6

* Significant at 5% level. ** Significant at 1% level. For each sector in each year there are observations on 36 countries

Table 13 Signed rank test on *VAX* based Indices: sector wise

Sector codes	Year combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
3	2008–2011	0.047	−0.031	0.707	0.377	−0.079
		(0.962)	(0.975)	(0.480)	(0.706)	(0.937)
8	2008–2011	−1.005	−0.581	−2.262*	−1.885	−0.377
		(0.315)	(0.561)	(0.024)	(0.059)	(0.706)
9	2008–2011	−1.084	−0.911	−0.550	−0.141	−0.801
		(0.278)	(0.362)	(0.582)	(0.888)	(0.423)
13	2008–2011	−0.738	−0.314	−0.723	0.330	−0.330
		(0.460)	(0.753)	(0.470)	(0.742)	(0.742)
14	2008–2011	0.330	0.456	0.346	0.676	0.393
		(0.742)	(0.649)	(0.730)	(0.499)	(0.695)
15	2008–2011	1.445	1.445	1.791	0.770	2.090*
		(0.148)	(0.148)	(0.073)	(0.441)	(0.037)
16	2008–2011	0.597	1.225	0.330	−0.141	1.194
		(0.551)	(0.220)	(0.742)	(0.888)	(0.233)
Total no. of accepted cases for null hypothesis		7	7	6	7	6

* Significant at 5% level. For each sector in each year there are observations on 36 country observations are available

In Tables 16 and 17, results corresponding to 6 countries (considered in Tables 10, 11) are reported. The countries being considered in a group of two for the test, the numbers of reported cases for acceptance of null hypothesis are out of a total of 15 cases for each index in both the tables. In both the tables for each country, the numbers of sectors are 16. The results in Tables 16 and 17 are reported for the year 2011 only.

As evident from Tables 14 and 15, NRCA has the most stable empirical distribution over sectors. Since, Wilcoxon's rank sum test studies shifts in distributions through shifts in means or medians (assuming the distributions are of identical shapes), the results corresponding to NRCA in Tables 14 and 15 are consistent with the observation that the arithmetic mean of the index values across countries is stable between sectors, with the value being fixed at zero. Hence, stability of the mean serves dual purpose—as a cardinal measure with respect to a sector and as an ordinal measure with respect to a country. It is not only possible to reliably determine the extent of comparative advantage of one country over another in a sector, it is also possible to rank different sectors for a country reliably. The other indices report larger cases for rejection of the null hypothesis for equality of distributions. As reported in Table 1, only NRCA, can generate theoretically stable mean across countries with respect to a sector. Hence, larger cases of rejection of null hypothesis for other indices in Tables 14 and 15 must not be surprising. One may also notice from Tables 14 and 15 that, *VAX* adjustment improves the stability in distributions of ARCA and NRCA only. Other indices witness a marginal decline in the number of cases for stable distributions. This finding is in contradiction to those reported in Tables 10, 11, 12 and 13.

As per the results reported in Table 16, all but the Log-of-Balassa are found to be considerably stable over countries. Since, the arithmetic means of the ARCA values and NRCA values across sectors for a particular country is theoretically zero and stable over countries in any given year, the results corresponding to ARCA and NRCA is as per expectations. Although theoretical structure of the Balassa and RSCA does not support the stability of sectoral mean over countries for any year, the results presented in Table 16 suggests that the fluctuations around mean may not be significant. Thus all the four indices are reliable as cardinal measures with respect to a country and as ordinal measures with respect to a sector in any year. The analysis of *VAX* based indices in Table 17 however upholds the superiority of ARCA and NRCA over all the other indices. Thus *VAX* adjustments make the indices more at par with their respective theoretical structures. It is also worth noting from Tables 16 and 17, that *VAX* adjustment only improves the stability in distribution of Log-of-Balassa. The number of cases for stable distribution either remains the same or falls for other indices.[9]

[9] The results for the stability of country/sectoral index distributions over sectors/over countries for the year 2011 are further reaffirmed by the non-parametric Kolmogorov Smirnov (KS) test. KS is devised for unpaired samples and hence is not applicable for analyzing the shifts in empirical distributions over time. The test determines whether two samples are drawn from two populations with identical distribution functions, by comparing two cumulative distribution functions. KS test detects shifts in distributions due to changes in means, standard deviations, presence of outliers, differences in skewness or kurtosis or number modes etc. In the context of this paper, however, KS does not produce results significantly different from the rank sum test. The results can be obtained from the authors on request. Since the usage of the index as a cardinal or ordinal measure in any given year is based on the stability of index distribution through stability

Table 14 Rank sum test on *GX* based Indices: over sectors

Sector combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
3–8	1.092	1.092	−1.183	0.631	0.909
	(0.275)	(0.275)	(0.237)	(0.528)	(0.364)
3–9	−0.135	−0.135	0.383	<0.001	−0.135
	(0.893)	(0.893)	(0.702)	(1.000)	(0.893)
3–13	−1.295	−1.295	−1.126	−0.653	−1.295
	(0.195)	(0.195)	(0.260)	(0.514)	(0.195)
3–14	0.529	0.529	3.086**	2.005*	0.529
	(0.597)	(0.597)	(0.002)	(0.045)	(0.597)
3–15	2.748**	2.748**	3.458**	1.858	2.748**
	(0.006)	(0.006)	(0.001)	(0.063)	(0.006)
3–16	0.541	0.541	1.532	1.824	0.541
	(0.589)	(0.589)	(0.126)	(0.068)	(0.589)
8–9	−0.924	−0.924	1.183	−0.518	−0.736
	(0.356)	(0.356)	(0.237)	(0.604)	(0.462)
8–13	−1.802	−1.802	−0.822	−1.250	−1.633
	(0.072)	(0.072)	(0.411)	(0.211)	(0.102)
8–14	−0.710	−0.710	3.097**	1.678	−0.518
	(0.478)	(0.478)	(0.002)	(0.093)	(0.605)
8–15	1.599	1.599	3.694**	1.554	1.840
	(0.110)	(0.110)	(0.0002)	(0.120)	(0.066)
8–16	−0.743	−0.743	2.174*	1.250	−0.552
	(0.457)	(0.457)	(0.030)	(0.211)	(0.581)
9–13	−0.969	−0.969	−0.901	−0.574	−0.969
	(0.333)	(0.333)	(0.368)	(0.566)	(0.333)
9–14	0.552	0.552	2.973**	1.892	0.552
	(0.581)	(0.581)	(0.003)	(0.059)	(0.581)
9–15	2.669**	2.669**	3.604**	1.532	2.669**
	(0.008)	(0.008)	(0.0003)	(0.126)	(0.008)
9–16	0.698	0.698	1.363	1.611	0.698
	(0.485)	(0.485)	(0.173)	(0.107)	(0.485)
13–14	2.714**	2.714**	3.356**	2.557*	2.714**
	(0.007)	(0.007)	(0.001)	(0.011)	(0.001)
13–15	3.739**	3.739**	3.705**	2.286*	3.739**
	(0.0002)	(0.0002)	(0.0002)	(0.022)	(0.0002)
13-16	2.489*	2.489*	2.579*	2.320*	2.489*
	(0.013)	(0.013)	(0.010)	(0.020)	(0.013)
14-15	2.365*	2.365*	0.867	−0.349	2.365*
	(0.018)	(0.018)	(0.386)	(0.727)	(0.018)

Table 14 continued

Sector combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
14-16	−0.158	−0.158	−2.129*	−0.518	−0.158
	(0.875)	(0.875)	(0.033)	(0.604)	(0.875)
15-16	−2.433*	−2.433*	−3.063**	−0.259	−2.433*
	(0.015)	(0.015)	(0.002)	(0.796)	(0.015)
No of accepted cases for null hypothesis	14	14	9	17	14

** Significant at 1%; * Significant at 5%. For each sector in the year 2011 there are observations on 36 countries

Table 15 Rank sum test on *VAX* based Indices: over sectors

Sector combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
3–8	0.856	0.856	−0.563	1.678	0.856
	(0.392)	(0.392)	(0.573)	(0.093)	(0.392)
3–9	−0.394	−0.394	0.237	0.191	−0.394
	(0.693)	(0.693)	(0.813)	(0.848)	(0.693)
3–13	−1.701	−1.701	−1.453	−0.788	−1.701
	(0.089)	(0.089)	(0.146)	(0.431)	(0.089)
3–14	0.113	0.113	1.137	1.216	0.113
	(0.910)	(0.910)	(0.255)	(0.224)	(0.910)
3–15	3.063**	3.063**	3.874**	2.343*	3.063**
	(0.002)	(0.002)	(0.0001)	(0.019)	(0.002)
3–16	−0.507	−0.507	−0.315	1.059	−0.507
	(0.612)	(0.612)	(0.753)	(0.290)	(0.612)
8–9	−1.047	−1.047	0.777	−1.149	−1.047
	(0.295)	(0.295)	(0.437)	(0.251)	(0.295)
8–13	−2.365*	−2.365*	−1.791	−2.376*	−2.365*
	(0.018)	(0.018)	(0.073)	(0.018)	(0.018)
8–14	−1.453	−1.453	1.284	0.011	−1.453
	(0.146)	(0.146)	(0.199)	(0.991)	(0.146)
8–15	2.038*	2.038*	3.762**	1.701	2.038*
	(0.042)	(0.042)	(0.0002)	(0.089)	(0.042)
8–16	−1.667	−1.667	0.146	−0.552	−1.667
	(0.096)	(0.096)	(0.146)	(0.581)	(0.096)
9–13	−1.216	−1.216	−1.216	−0.788	−1.216
	(0.224)	(0.224)	(0.224)	(0.431)	(0.224)
9–14	0.169	0.169	0.980	1.070	0.169
	(0.866)	(0.866)	(0.327)	(0.285)	(0.866)
9–15	3.221**	3.221**	3.784**	1.948	3.221**
	(0.001)	(0.001)	(0.0002)	(0.051)	(0.001)

Table 15 continued

Sector combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
9–16	−0.304	−0.304	−0.608	0.811	−0.304
	(0.761)	(0.761)	(0.543)	(0.417)	(0.761)
13–14	2.174*	2.174*	2.219*	1.881	2.174*
	(0.030)	(0.030)	(0.027)	(0.060)	(0.030)
13–15	4.145**	4.145**	4.246**	2.759**	4.145**
	(<0.001)	(<0.001)	(<0.001)	(0.006)	(<0.001)
13–16	1.104	1.104	1.194	1.588	1.104
	(0.270)	(0.270)	(0.233)	(0.112)	(0.270)
14–15	3.255**	3.255**	2.568*	1.092	3.255**
	(0.001)	(0.001)	(0.010)	(0.275)	(0.001)
14–16	−0.912	−0.912	−1.340	−0.507	−0.912
	(0.362)	(0.362)	(0.180)	(0.612)	(0.362)
15–16	−3.458**	−3.458**	−3.942**	−1.611	−3.458**
	(0.001)	(0.001)	(0.0001)	(0.107)	(0.001)
No. of accepted cases for null hypothesis	13	13	14	18	13

** Significant at 1%; * Significant at 5%. For each sector in the year 2011, observations on 36 countries are available

Based on the results of the data analyses presented in the current and previous subsections, it is not difficult to note that *VAX* adjustments may produce a tendency towards improvement in the empirical distributions of NRCA, both in terms of symmetry and stability. The same observation cannot however be unequivocally made about other indices on the basis of present data analyses.

5 Conclusion

The primary objective of this paper is to analyze and compare the empirical distributions of RCA indices based on *GX* data and sectoral *VAX* data. The exercise assumes significance on the recent emergence of global supply chains in real world and prevalence of *GX* based studies in the current literature. We find that *VAX* adjustments tend to produce more stable and symmetrical distributions in some but not all indices. Our contention is RCA indices should be based on *VAX* due to the growing contribution of global supply networks in international trade. In this respect, results corresponding to the empirical distributions of such RCA indices are more important for policy analysis.

Footnote 9 continued
of sectoral mean (for a country) or country mean (for a sector), rank sum test, which is based on shifts of median and/or mean is more appropriate in this paper.

Table 16 Rank sum test on *GX* based Indices: over countries

Country combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
Canada–China	−0.188	−0.188	−0.226	−0.151	−0.188
	(0.851)	(0.851)	(0.821)	(0.880)	(0.851)
Canada–Germany	1.357	1.357	0.339	−0.038	1.357
	(0.175)	(0.175)	(0.735)	(0.970)	(0.175)
Canada–India	1.847	1.847	1.357	0.942	1.847
	(0.065)	(0.065)	(0.175)	(0.346)	(0.065)
Canada–Japan	1.960	1.960	1.055	0.641	1.960
	(0.050)	(0.050)	(0.291)	(0.522)	(0.050)
Canada–Mexico	0.867	0.867	0.565	0.377	0.593
	(0.386)	(0.386)	(0.572)	(0.706)	(0.553)
China–Germany	1.470	1.470	0.565	−0.113	1.470
	(0.142)	(0.142)	(0.572)	(0.910)	(0.142)
China–India	1.658	1.658	1.508	0.641	1.658
	(0.097)	(0.097)	(0.132)	(0.522)	(0.097)
China–Japan	1.771	1.771	1.244	0.415	1.771
	(0.077)	(0.077)	(0.214)	(0.679)	(0.077)
China–Mexico	0.905	0.905	0.791	0.226	0.632
	(0.366)	(0.366)	(0.429)	(0.821)	(0.527)
Germany–India	0.264	0.264	0.867	0.716	0.264
	(0.792)	(0.792)	(0.386)	(0.474)	(0.792)
Germany–Japan	0.528	0.528	0.565	0.528	0.528
	(0.598)	(0.598)	(0.572)	(0.598)	(0.598)
Germany–Mexico	−0.678	−0.678	−0.038	0.415	−1.028
	(0.498)	(0.498)	(0.970)	(0.679)	(0.304)
India–Japan	0.038	0.038	−0.151	−0.151	0.038
	(0.970)	(0.970)	(0.880)	(0.880)	(0.970)
India–Mexico	−1.583	−1.583	−0.980	−0.490	−1.976
	(0.113)	(0.113)	(0.327)	(0.624)	(0.048)
Japan–Mexico	−1.583	−1.583	−0.754	−0.075	−1.976
	(0.113)	(0.113)	(0.451)	(0.940)	(0.048)
No. of accepted cases for null hypothesis	15	15	15	15	13

For each country in the year 2011, observations on 16 sectors are available

On the basis of our findings,[10] *VAX* based NRCA index should be chosen to reliably serve as a cardinal or as an ordinal measure of comparative advantage, or for over time comparisons. However, one major drawback of the NRCA index is potential

[10] Summarized in "Review of the Literature" section.

Table 17 Rank sum test on *VAX* based Indices: over countries

Country combinations	Balassa	RSCA	ARCA	NRCA	Log-of-Balassa
Canada–China	−1.168	−1.168	−0.942	−0.754	−1.168
	(0.243)	(0.243)	(0.346)	(0.451)	(0.243)
Canada–Germany	1.093	1.093	0.226	−0.151	1.093
	(0.274)	(0.274)	(0.821)	(0.880)	(0.274)
Canada–India	1.244	1.244	0.641	−0.226	1.244
	(0.214)	(0.214)	(0.522)	(0.821)	(0.214)
Canada–Japan	0.980	0.980	0.302	0.188	0.980
	(0.327)	(0.327)	(0.763)	(0.851)	(0.327)
Canada–Mexico	0.302	0.302	0.490	0.226	0.302
	(0.763)	(0.763)	(0.624)	(0.821)	(0.763)
China–Germany	1.847	1.847	0.716	0.415	1.847
	(0.065)	(0.065)	(0.474)	(0.679)	(0.065)
China–India	2.261*	2.261*	1.244	0.603	2.261*
	(0.024)	(0.024)	(0.214)	(0.547)	(0.024)
China–Japan	1.809	1.809	0.980	0.829	1.809
	(0.070)	(0.070)	(0.327)	(0.407)	(0.070)
China–Mexico	1.508	1.508	1.281	0.791	1.508
	(0.1327)	(0.132)	(0.200)	(0.429)	(0.132)
Germany–India	−0.603	−0.603	0.377	−0.188	−0.603
	(0.547)	(0.547)	(0.706)	(0.851)	(0.547)
Germany–Japan	−0.038	−0.038	0.188	0.339	−0.038
	(0.970)	(0.970)	(0.851)	(0.735)	(0.970)
Germany–Mexico	−1.018	−1.018	−0.188	0.075	−1.018
	(0.309)	(0.309)	(0.851)	(0.940)	(0.309)
India–Japan	0.415	0.415	−0.151	0.490	0.415
	(0.679)	(0.679)	(0.880)	(0.624)	(0.679)
India–Mexico	−1.432	−1.432	−0.603	0.565	−1.432
	(0.152)	(0.152)	(0.547)	(0.572)	(0.152)
Japan–Mexico	−0.754	−0.754	−0.226	−0.188	−0.754
	(0.451)	(0.451)	(0.821)	(0.851)	(0.451)
No. of accepted cases for null hypothesis	14	14	15	15	14

* Significant at 5%. For each country in the year 2011, observations on 16 sectors are available

non-normal distribution, which renders it unsuitable for parametric tests assuming normally distributed errors.

Appendix A

36 countries included in the sample for each year (also constituting reference group for calculation of RCA indices)—Australia, Austria, Belgium, Bulgaria, Brazil, Canada, China, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hungary, Indonesia, India, Ireland, Italy, Japan, Korea, Lithuania, Mexico, Malta, Netherlands, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Turkey, Taiwan and Rest of the World (excluding Cyprus, Latvia, Luxembourg, Sweden and USA which had to be deleted at various stages of calculation).

Appendix B

Description of 16 merchandise sectors

Sector code	Sector description
1	Agriculture, hunting, forestry and fishing
2	Mining and quarrying
3	Food, Beverages and tobacco
4	Textiles and textile products
5	Leather, leather and footwear
6	Wood and products of wood and cork (excluding furniture)
7	Pulp, paper, printing and publishing
8	Coke, refined petroleum and nuclear fuel
9	Chemicals and chemical products
10	Rubber and plastics
11	Other non-metallic minerals manufactures (e.g., glass and glass products, ceramic ware, cement, lime and plaster, articles of asbestos, asphalt etc.)
12	Manufacture of basic metals and fabricated metals excluding machinery and equipment
13	Machinery (not elsewhere classified)
14	Electrical and optical equipments
15	Transport equipments
16	Manufacturing (not elsewhere classified); recycling. Manufactures under this category includes furniture, jewellery, musical instruments, sports goods, toys etc.

References

Balassa, B. 1965. Trade Liberalisation and 'Revealed' Comparative Advantage. *Manchester School of Economics and Social Studies* 33: 99–123.

Ballance, R.H., H. Forstner, and T. Murray. 1987. Consistency Tests of Alternative Measures of Comparative Advantage. *The Review of Economics and Statistics* 69 (1): 157–161.

Batra, A., and Z. Khan. 2005. Revealed Comparative Advantage: An Analysis for India and China. Indian Council for Research on International Economic Relations (ICRIER), New Delhi. Working Paper No. 168.

Benedictis, L.D., and M. Tamberi. 2001. A Note on Balassa Index of Revealed Comparative Advantage. Dipartmento di Economia, Universita' Politecnica delle Marche. Working Paper No. 158.

Benedictis, L.D., and M. Tamberi. 2004. Overall Specialization Empirics: Techniques and Applications. *Open Economies Review* 15: 323–346.

Conover, W.J. 1999. *Practical Nonparametric Statistics*. New Delhi: Wiley.

Dalum, B., K. Laursen, and G. Villumsen. 1998. Structural Change in OECD Export Specialisation Patterns: Despecialisation and 'Stickiness'. *International Review of Applied Economics* 12: 423–443.

Daudin, G., C. Rifflart, and D. Schweisguth. 2011. Who Produces for Whom in the World Economy? *Canadian Journal of Economics* 44 (4): 1403–1437.

Deb, K., and W.R. Hauk. 2015. RCA Indices, Multination Production and the Ricardian Trade Model. *International Economics and Economic Policy*. doi:10.1007/s10368-015-0317-z.

Dimaranan, B., E. Ianchovichina, and W.J. Martin. 2007. China, India, and the Future of the World Economy: Fierce Competition or Shared Growth? Policy Research Working Paper No. 4304, World Bank, Washington, DC.

Hassan, M. 2013. An Analysis of Competitiveness of Pakistan's Agricultural Export Commodities. *Journal of Business and Management* 11: 29–34.

Hiley, M. 1999. The dynamics of changing comparative advantage in the Asia-Pacific region. *Journal of the Asia Pacific Economy* 4: 446–467.

Hinloopen, J., and C. Marrewijk. 2001. On Empirical Distribution of the Balassa Index. *Weltwirtschaftliches Archiv* 137 (1): 1–35.

Hoen, A.R., and J. Oosterhaven. 2006. On the Measurement of Comparative Advantage. *The Annals of Regional Science* 40: 677–691.

Hummels, D., J. Ishii, and K. Yi. 2001. The nature and growth of vertical specialization in world trade. *Journal of International Economics* 54: 75–96.

Johnson, R. 2014. Five Facts about Value-Added Exports and Implications for Macroeconomics and Trade Research. *Journal of Economic Perspectives* 28 (2): 119–142.

Johnson, R., and G. Noguera. 2012. Accounting for Intermediates: Production Sharing and Trade in Value-added. *Journal of International Economics* 86: 224–236.

Karaalp, H.S. 2011. Competitiveness of Turkey in Eurasia: A Comparison with CIS Countries. *China-USA Business Review* 10: 727–744.

Kijboonchoo, T., and K. Kalayanakupt. 2003. Comparative Advantage and Competitive Strength of Thai Canned Tuna Export in the World Market: 1982–1998. *ABAC Journal* 23: 19–33.

Koopman, R., Z. Wang, and S. Wei. 2012. Estimating Domestic Content in Exports when Processing Trade is Pervasive. *Journal of Development Economics* 99: 178–189.

Koopman, R., Z. Wang, and S. Wei. 2014. Tracing Value-Added and Double Counting in Gross Exports. *American Economic Review* 104 (2): 459–494.

Laursen, K. 1998. Revealed Comparative Advantage and the Alternatives as Measures of International Specialisation. Danish Research Unit for Industrial Dynamics. Working Paper No. 98-30.

Leromain, E., and G. Orefice. 2014. New Revealed Comparative Advantage Index: Dataset and Empirical Distribution. *International Economics* 139 (2014): 48–70.

Sáez, S., D. Taglioni, E. Marel, C. Hollweg, and V. Zavacka. 2014. *Valuing Services in Trade: A Toolkit for Competitiveness Diagnostics*. Washington, DC: The World Bank.

Smyth, D.A. 2005. Ireland's Revealed Comparative Advantage. *Quarterly Bulletin Central Bank of Ireland Dublin* 1: 101–114.

Vollrath, T.L. 1991. A Theoretical Evaluation of Alternative Trade Intensity Measures of Revealed Comparative Advantage. *Weltwirtschaftliches Archiv* 127: 265–280.

Wignaraja, G. 2011. Economic Reforms, Regionalism and Exports: Comparing China and India. East-West Centre Policy Studies 60.

Wilcoxon, F. 1945. Individual Comparisons by Ranking Methods. *Biometric Bulletin* 1: 80–83.

Yu, R., J. Cai, and P. Leung. 2009. The Normalized Revealed Comparative Advantage Index. *The Annals of Regional Science* 43: 267–282.

Yeats, A.J. 1985. On the Appropriate Interpretation of the Revealed Comparative Advantage Index: Implications of a Methodology based on Industry Sector Analysis. *Weltwirtschaftliches Archiv* 121: 61–73.