Approaches of Measuring Revealed Comparative Advantage (RCA): Literature Review

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Abstract

This working paper is the first of the series that explore the adaptions and applications of Balassa revealed comparative advantage (RCA) approach in analyzing international specialization and global supply chains. This paper provides a comprehensive review of the existing RCA literature and summarizes major variations of Balassa RCA approach, such as one-way trade based, two-way trade based, with or without normalization, with or without trade scalar such as economy size or income. This paper discusses the pros and cons of each RCA method, and identifies the key elements for consideration when applying and adapting the RCA approach in analysis of international specialization or competitiveness.

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Introduction

The Congress or the U.S. Trade Representative's Office often asks the U.S. International Trade Commission to conduct studies of the impact of certain trade policy on U.S. competitiveness in the global market. They are also interested in developing a better understanding of U.S. industries' abilities to compete with their foreign rivalries in export performance or global value chains, and U.S. firms' specific comparative advantage or disadvantage. However, direct measurement of trade competitiveness based on the classical theory is challenging. With the prevalence of international production network, countries are increasingly specialized in specific tasks or production stages, while heavily relying on imported intermediate inputs. This phenomenon obscures traditional economic and trade statistics, which further complicates the competitiveness analysis. In light of such challenges, Balassa's revealed comparative advantage (RCA) approach has been rediscovered as a feasible alternative to measure trade competitiveness and/or specialization in the context of global supply chains. This paper is the first of the series that explore Balassa's RCA-based approaches. It provides a comprehensive literature review, discussing the pros and cons of each variation of the RCA approach, and identifying the key elements for deliberation when adopting the RCA methods for international trade analysis.

The classical theory of comparative advantage, introduced by David Ricardo in 1817, explains why two countries engage in international trade, given the relative differences in technology, labor productivity, or production costs in industries within the country and between the countries. The Ricardian theory reveals that a country tends to export goods for which it has a comparative advantage, or goods from the industries in which it is relatively more productive. Heckscher and Ohlin extended comparative advantage to the relative differences in factor price and endowment. Their model predicts that a country tends to export goods that use more intensively the factors which the country is relatively more abundantly endowed. In the modern trade world, characterized by global supply chains where the same commodities cross national borders multiple times, and where many countries trade the same commodities with many different trading partners simultaneously, quantifying comparative advantage based on the neoclassical theory becomes empirically difficult. One problem is that the theoretical concept of comparative advantage is based on pre-trade relative prices in a world where markets function perfectly without distortion, while empirical researchers must work with data generated by trade-flows in post-trade equilibria (Vollrath 1991).

Balassa RCA Measures

Liesner (1958) is among the first to use post-trade data to quantify comparative advantage in his assessment of the effects of Britain's entry into the European Common Market. He devised a composite export performance index based on relative export growth and export levels during the period 1953–56 for each of 60 manufactured goods for Britain and its European competitors (Belgium, France, Italy, Luxembourg, Netherlands, Sweden, and West Germany). He used the index as the approximated bilateral comparative advantage, and ranked these 60 manufacturing sectors in Britain based on their relative competitiveness. He concluded that the Britain would gain from participation in the common market by specializing in these sectors (e.g., aircrafts) that it was relatively good at and giving up the sectors (e.g., zinc) that it was relatively inefficient.

In his 1965 paper on the effects of trade liberalization from the Kennedy Round of General Agreement on Tariffs and Trade (GATT), Balassa revised Liesner's approach and proposed using trade flows as an indicator of comparative advantage, arguing trade patterns could reflect the relative costs as well as differences in non-price factors between countries. He noted that a country's export performance in a particular commodity could be evaluated by comparing the relative share of this country in the world exports of this commodity and the changes in this relative share over time. To estimate the relative share, he divided a country's share in total exports of a given commodity by its share in the combined exports of manufactured goods from countries under consideration. He expressed the results in the index number form and called them "the export performance index." His exercises indicated that the United States had the strongest export performance in wrought nickel (the index value at 2,671.2) and the weakest export performance in yarn of wool (the index value at 0.7). He found that this method gave clearcut results in homogeneous products or nondurable consumer goods (e.g., blankets), but less so in aggregated product groups containing a wide variety of heterogenous commodities (e.g., chemicals).

Balassa stated that the export performance indices reveal a country's relative advantage and disadvantage in international trade of certain goods or services—thus his approach has been called the *revealed comparative advantage* (RCA). The export performance index, widely known as Balassa RCA index, is obtained by using the ratio of a country *c*'s share of the industrial countries under consideration in exports of a given commodity *k* to its share in exports of all manufactured goods [1]. The value of RCA index ranges from 0 to ∞, with 1 as the neutral point. If the RCA index is bigger than 1, it reveals country *c* has a comparative advantage in exporting commodity *k*; and if the RCA is smaller than 1, it reveals country *c* has a comparative disadvantage in exporting commodity *k*.

$$RCA1_k^c = \frac{\frac{X_k^c}{\sum_c X_k^c}}{\frac{\sum_k X_k^c}{\sum_c \sum_k X_k^c}} \qquad [1]$$

Liesner (1958) and Balassa (1965) measures are limited with commodity and country coverage, focusing on manufactured goods and selected developed countries. Vollrath (1991)[1] expanded these measures to include all countries and all traded commodities to reflect global comparative advantage as in equation [2], where subscript *k* refers to any specific commodity (whether manufactured or not), and superscripts *c* and *w* refer to the subject country and the world, respectively. Furthermore, Vollrath (1991) applied the actual-to-expected trade framework from Kunimoto (1977) to the RCA index [3]. The expected level of each country's exports for a particular commodity is the product of each country's overall exports and each specified commodity's share in global exports. Thus, deviation above the expected level indicates comparative advantage, while deviation below the expected level indicates comparative disadvantage.

$$RCA2_k^c = \frac{\frac{X_k^c}{\sum_k X_k^c}}{\frac{X_k^w}{\sum_k X_k^w}} = \frac{\frac{X_k^c}{X^c}}{\frac{X_k^w}{X^w}} \qquad [2]$$

$$RCA3_k^c = \frac{X_k^c}{E(X_k^c)} \quad where \quad E(X_k^c) = X^c \times \left(\frac{X_k^w}{X^w}\right) \qquad [3]$$

These three RCA equations consist of the basic RCA models. In general, there are three types of RCA-based applications and interpretations in comparative advantage analysis. The most common one is that with the cardinal value, the index quantifies and reveals a comparative advantage or disadvantage in a particular sector/commodity of a country. Secondly, it indicates the degree of comparative advantage or disadvantage in a particular sector/commodity of a country, as compared to those of other countries. Thirdly, the rankings of countries with respect to a sector/commodity, or the rankings of sectors/commodities in a specific country can be generated based on the index value (Benedictis and Tamberi 2001).

Although it is easy to understand and use, the RCA index is criticized for not actually reflecting the original theoretical concept of comparative advantage that is based on productivity and factor price difference, and for mixing up comparative advantages with other determinants of trade flows such as trade policy effects (Leromain and Orefice, 2013). Laursen (2015) cautioned about the misleading

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[1] Vollrath (1991) evaluates various RCA approaches without providing empirical applications.

application and interpretation of the RCA measure, arguing that it is a measure of international specialization instead of international competitiveness, and it is a measure of relative instead of absolute strength. Benedictis and Tamberi (2001) pointed out that revealed comparative advantage is subject to how the RCA indices are measured—that the choice of sectoral aggregation (e.g., manufacturing goods, goods, or goods and services) and region benchmark (e.g., the EU, OECD countries, the world, or any aggregation of countries) could influence the resulting RCA values, and comparisons may be possible only if they share the same sectoral aggregation and region benchmark.

The RCA index is also criticized for time instability, poor ordinal ranking property, the asymmetry of distribution, the uncertainty of the mean, as well as the unaddressed bias introduced by trade policy, other government intervention, and data distortions (Yeats 1985; Vollrath 1991; Leomain and Orefice 2013; Laursen 2015). The RCA index has a fixed lower bound at 0 and an unlimited upper bound, with 1 being the comparative-advantage neutral point. The asymmetric property of the RCA index affects the comparability across either country or commodity (Yu, Cai, and Leung 2009). In most cases, the mean is above the median, and the distribution is skewed to the right, so changes in the sectors with high RCA values could be over-weighted in terms of the effect on the overall comparative advantage dynamic (Benedictis and Tamberi 2001). The asymmetry of RCA value distributions across industries in a country could lead to conflicting conclusions based on cardinal versus ordinal interpretations, because "the potential for bias is greatest when comparisons are made between industries which have the widest differences in their underlying (country) RCA distributions" (Yeats 1985). In addition, the RCA index is criticized for ignoring economy size and tending to have "small-country bias" (a small economy that exports less tends to have high BRCA values), failing to count for imports flows, and lacking additivity property (Stellian and Danna-Buitrago 2022).

The Normalization of RCA Measures

To address some of the issues identified above, various approaches have been developed to normalize the original RCA measure. Vollrath (1991) proposed using the natural logarithm form of RCA in his *relative export advantage index* $[Ln(RXA_k^c)]$. However, if a country has zero exports of a commodity, the index would be undefined with this approach (Larsen 1998; Yu, Cai, Leung 2008).

Dalum, Laursen and Villumsen (1998) constructed the *Reveal Symmetric Comparative Advantage* $(RSCA_k^c)$[4] for 60 manufacturing sectors of 20 OECD countries in an analysis of export specialization pattern stability during a period of nearly three decades from 1965 to 1992.[2] RSCA is often referred to as the alternative of the logarithmic conversion of the RCA, as it approximates the log transformation of the RCA, while avoiding the problem of zero exports. RSCA scores have a symmetric distribution ranging from -1 to 1, with 0 as the neutral point. If $-1 \leq RSCA^{c}{}_{k} < 0$, sector *k* in country *c* has a comparative disadvantage; if $0 < RSCA^{c}{}_{k} \leq 1$, sector *k* in country *c* has a comparative advantage. The recent Commission study—*the Raspberries for Processing: Conditions of Competition between U.S. and Foreign suppliers, with a Focus on Washington State* (2021)—used the RSCA approach. Benedictis and Tamberi (2001) tested RSCA and found it is possible to have normally distributed residuals only at a low disaggregation level, and it is hard to apply the cardinal interpretation as it tends to induce high distortion for extreme values.

$$RSCA_k^c = \frac{RCA_k^c - 1}{RCA_k^c + 1} = \frac{X_k^c \times X^w - X_k^w \times X^c}{X_k^c \times X^w + X_k^w \times X^c} \quad [4]$$

Proudman and Redding (2000) introduced a modified version of BRCA [5] to evaluate the dynamics of international specialization patterns in 22 manufacturing sectors of G-5 economies (France, Germany, Japan, United Kingdom, and the United States) for the period 1970–93. By analyzing the evolution of the entire distribution of RCA values in a country, Proudman and Redding evaluated the mobility in international specialization pattern as well as the degree of international trade specialization over time. They used the ratio of a country c's share of exports in sector *k* to the benchmark—its average export share in all or N sectors—to normalize the RCA measure, though only to some degree. The mean value, which is also the neutral value, is constant and equals to 1. The distribution of RCA values, however, remains asymmetric. By using the five-year average of RCA values, Proudman and Redding were able to narrow the range of most RCA values to [0,3]. If the RCA value is above 1, it indicates that economy *c* is specialized in sector *k*. Gnidchenko and Salnikov (2015) claimed that the Proudman and Redding approach does not present any advantage over the classic BRCA index, and it is highly sensitive to the number of goods exported, or export diversification.

$$RCA4_k^c = \frac{\dfrac{X_k^c}{\sum_c X_k^c}}{\dfrac{1}{N}\sum_k\left(\dfrac{X_k^c}{\sum_c X_k^c}\right)} = \frac{\dfrac{X_k^c}{X_k^W}}{\dfrac{1}{N}\sum_k\left(\dfrac{X_k^c}{X_k^W}\right)} \quad [5]$$

[2] Opposing to the Heckscher and Ohlin theory, Dalum, Laursen and Villumsen (1998) found that international trade specialization by industry in the OECD countries decreased slightly, while the reduction of trade barriers along with European integration had been ongoing throughout this period.

Hoen and Oosterhaven (2006) viewed the root cause of the problem with the standard RCA lies in its multiplicative property. They proposed instead the *additive RCA measure* ($ARCA_k^c$) [6] by taking the difference between the export shares of the subject country *c* and the reference group of countries *r*. They argued that it is necessary to exclude the subject country *c* from the reference group *r*, as otherwise the ARCA index would become biased. With the exclusion of country *c* from the reference group *r*, the distribution of the ARCA for a particular sector is symmetric ranging from -1 to 1 with a mean of 0. If $0 < ARCA_k^c \leq 1$, country *c* has a revealed comparative advantage in exporting commodity *k*. If $-1 \leq ARCA_k^c < 0$, country *c* has a revealed comparative disadvantage in exporting commodity *k.* Hoen and Oosterhaven noted that while the ARCA is also dependent of the size or the number of sectors as the standard RCA, the distribution of the ARCA as a whole is more stable; and that ARCA emphasizes the comparative advantage of the larger sectors with bigger economic impacts, whereas the standard RCA emphasizes the comparative advantage of smaller sectors. Yu, Cai and Leung (2009) pointed out that while the ARCA makes the comparison of a country's comparative advantage in different commodities feasible, it is not well established for comparison across countries, especially for large countries with a dominant situation in exporting certain commodities.

$$ARCA_k^c = \frac{X_k^c}{X^c} - \frac{X_k^r}{X^r} \qquad [6]$$

Yu, Cai and Leung (2009) noted that the comparative-advantage-neutral point is where a country's real exports of commodity X_k^c equals to its expected exports of commodity $E(X_k^c)$, and their difference can be stated as $\Delta X_k^c = X_k^c - E(X_k^c) = X_k^c - X^c \times \left(\frac{X_k^w}{X^w}\right)$. They proposed normalizing ΔX_k^c by the world exports to derive the normalized RCA *index* ($NRCA_k^c$)[7].

$$NRCA_k^c = \frac{\Delta X_k^c}{X^w} = \frac{X_k^c - E(X_k^c)}{X^w} = \frac{X_k^c - X^c \times \left(\frac{X_k^w}{X^w}\right)}{X^w} = \frac{X_k^c}{X^w} - \frac{X^c \times X_k^w}{X^w \times X^w} \qquad [7]$$

Where

$$\textstyle\sum_c NRCA_k^c = 0 \qquad and \qquad \sum_k NRCA_k^c = 0$$

If $NRCA_k^c > 0$, country *c* has comparative advantage in exporting commodity *k*. If $NRCA_k^c < 0$, country *c* has comparative disadvantage in exporting commodity *k*. The greater (or the lower) the $NRCA_k^c$, the stronger the comparative advantage (or disadvantage). The sum of a commodity's NRCA scores over all countries is equal to 0; and the sum of a country's NRCA scores over all commodities is also equal to 0. Yu, Cai and Leung (2009) stated that with this additive property, the measurement of comparative advantage with NRCA is independent of the classification of the commodities and countries, and thus are not affected by the level of aggregation, providing a useful utility for empirical studies. The distribution of NRCA scores is symmetrical ranging from -0.25 to 0.25, with 0 being the neutral point. Yu, Cai and Leung (2009) noted that the NRCA measure is distinctive from other normalized measures such as RSCA or ARCA, as it would not be affected by zero exports. When the real export equals to 0, $NRCA_k^c = -\frac{X^c \times X_k^w}{X^w \times X^w}$. The extent of comparative disadvantage would be determined by the size of the country's total exports as well as the size of the global exports of that commodity. With a numerical example of Hawaii's selected agricultural products in the U.S. mainland market, they illustrated the patterns of comparative advantage that are revealed by the NRCA index and the standard RCA index could differ considerably. Similar to Hoen and Oosterhaven's finding, Yu, Cai and Leung pointed out that the standard RCA measures tend to have large scores for products that Hawaii has a small market share, while the NRCA measures eliminate such bias and reflect the underlying comparative advantage more precisely and coherently.

Although the normalization approaches of RCA index discussed above address issues such as the asymmetric value distribution and the lack of additive property, they do not solve other problems, especially those associated with double counting in global trade (Moreno-Brieva 2022).

RCA Measures Based on Two-way trade or Net Trade

Traditional RCA index is based on one-way trade, revealing that a country either exports goods which it has comparative advantage, or imports goods which it has comparative disadvantage. However, as mentioned previously, in the modern trade world, a country often simultaneously exports and imports large quantities of same commodities or same categories of commodities. Sometimes, a country's exports of certain goods may primarily contain those previously imported. This double-counting issue is problematic for the classic RCA measure based on nominal trade statistics. To address this problem, various RCA measures based on two-way trade or net trade have been proposed, with some incorporating economy size or income as the scalar to trade volume.

In their assessment of the impact of trade promotion policies on export performance in developing countries, Donges and Riedel (1977) accounted for both exports (X) and imports (M) flows in their respective RCA measure as follows [8]:[3] the positive RCA value indicates comparative advantage, while the negative RCA value indicates comparative disadvantage. However, the RCA measure derived from this equation suffers the same asymmtrical distribution as the standard RCA measure.

$$RCA5_k^c = [\frac{\frac{X_k^c - M_k^c}{X_k^c + M_k^c}}{\left(\frac{X^i - M^i}{X^i + M^i}\right)} - 1] \times (\frac{X_k^c + M_k^c}{X_k^w + M_k^w}) \times [sign\left(X^i - M^i\right)] \quad [8]$$

UNIDO (1982), instead, used a simpler version of the *relative net export index* RNX_k^c[9] with value ranging from -1 to 1. Although it is easy to calculate and absent of structural distortions, RNX suffers some shortcomings. For instance, it generates the value of 1 to indicate very high specialization when imports are 0 even exports are tiny (Gnidchenko and Salnikov 2015).

$$RNX_k^c = \frac{X_{ij} - M_{ij}}{X_{ij} + M_{ij}} \quad [9]$$

Bowen (1983)[4] stated that comparative advantage is properly a net trade concept which is the difference between domestic production and domestic consumption. He proposed an alternative approach using *the net trade intensity index* TI_k^c and *the production intensity index* QI_k^c. Based on the relationship between a country's production Q_k^c, consumption C_k^c, and trade in a commodity *k*, net trade is $T_k^c = Q_k^c - C_k^c$. Bowen noted that in a hypothetical "comparative advantage neutral" world, the expected level of domestic production $E(Q_k^c)$ equals to the expected level of domestic consumption $E(C_k^c)$ for each country and product, and there is no trade between countries. Each country would produce and consume at a level corresponding to its relative economic size in the world $\frac{Y^c}{Y^w}$, measured by gross national product (GNP, Y). RCA indices can be expressed as deviations from this norm [10].

$$TI_k^c = QI_k^c - 1 \quad [10]$$

where

[3] Vollrath (1991) describes the Donges and Riedel type of RCA as: $RCA_k^c = \left[\frac{\frac{X_k^c - M_k^c}{X_k^c + M_k^c}}{\left(\frac{X_k^w - M_k^w}{X_k^w + M_k^w} - 1\right)}\right] \times [sign\ (X_k^w - M_k^w)]$, while Gnidchenko and Salnikov (2015)'s iteration as $RCA_k^c = \left[\frac{\frac{X_k^c - M_k^c}{X_k^c + M_k^c}}{\left(\frac{X^i - M^i}{X^i + M^i}\right)} - 1\right] \times (sign(X^i - M^i)]$, both are slightly different from the original equation in Donges and Riedel (1977).

[4] Bowen (1983) did not apply the alternative approach to empirical analysis.

$$QI_k^c = \frac{Q_k^c}{E(Q_k^c)}$$

$$T_k^c = Q_k^c - E(Q_k^c)$$

$$TI_k^c = \frac{T_k^c}{E(Q_k^c)}$$

$$E(Q_k^c) = E(C_k^c) = Q_k^w \times \left(\frac{Y^c}{Y^w}\right)$$

$$E(T_k^c) = E(Q_k^c) - E(C_k^c) = 0$$

Bowen (1983)'s trade-cum-production approach introduces macroeconomic variables—production and consumption—into RCA measure, and uses a country's economy size or GNP as a weight to scale the economic and trade variables. However, Ballance et al. (1987) criticized Bowen's approach for inappropriately assuming identical and homothetic preferences in consumer demand. Vollrath (1991) pointed out in Bowen's hypothetical world, that countries have no incentive to trade and that the expected trade thus is zero are problematic, as $RCA = \frac{X_k^c}{E(X_k^c)}$ would not be defined. Ballance et al. (1987) conducted consistency tests on various RCA measures and found that trade-cum-production/consumption indices, such as those in Bowen (1983), are highly inconsistent. They also found out that ordinal or dichotomous measures based on trade data only, such as $\frac{X_k^c - M_k^c}{X_k^c + M_k^c}$, or $\frac{X_k^c - M_k^c}{E(X_k^c)}$, reveal a much higher degree of consistency.

In addition to the *relative export advantage index* $[REA_k^c = Ln(RXA_k^c)]$ mentioned early, Vollrath (1991) proposes two two-way trade based RCA measures: *the relative trade advantage index* (RTA_k^c) [11] and *the revealed competitive index* (RC_k^c) [12]. RXA_k^c presents the relative export advantage, while RMA_k^c presents the relative import advantage. If $RXA_k^c > RMA_k^c$, then $RTA_k^c > 0$, and there is a relative trade advantage, even if $RXA_k^c < 1$. If $RXA_k^c < RMA_k^c$, then $RTA_k^c < 0$, and there is a relative trade disadvantage, even if $RXA_k^c > 1$.

$$RTA_k^c = RXA_k^c - RMA_k^c \quad [11]$$

$$RC_k^c = Ln(RXA_k^c) - Ln(RMA_k^c) \quad [12]$$

where

$$RXA_k^c = \frac{\frac{X_k^c}{X_n^c}}{\frac{X_k^r}{X_n^r}} \quad and \quad RMA_k^c = \frac{\frac{M_k^c}{M_n^c}}{\frac{M_k^r}{M_n^r}}$$

Vollrath (1991) further expanded RXA and RMA, and expressed them as functions below:

$$RXA_k^c = \frac{\left\{\frac{\left[\frac{X_k^c/X_k^w}{X^c/X^w}\right]}{\left[\frac{X_n^c/X_n^w}{X^c/X^w}\right]}\right\}}{\left\{\frac{\left[\frac{X_k^r/X_k^w}{X^r/X^w}\right]}{\left[\frac{X_n^r/X_n^w}{X^r/X^w}\right]}\right\}} = \frac{\left\{\frac{\left[\frac{X_k^c}{E(X_k^c)}\right]}{\left[\frac{X_n^c}{E(X_n^c)}\right]}\right\}}{\left\{\frac{\left[\frac{X_k^r}{E(X_k^r)}\right]}{\left[\frac{X_n^r}{E(X_n^r)}\right]}\right\}} \quad and\ RMA_k^c = \frac{\left\{\frac{\left[\frac{M_k^c/X_k^w}{M^c/M^w}\right]}{\left[\frac{M_n^c/M_n^w}{M^c/M^w}\right]}\right\}}{\left\{\frac{\left[\frac{M_k^r/M_k^w}{M^r/M^w}\right]}{\left[\frac{M_n^r/M_n^w}{M^r/M^w}\right]}\right\}} = \frac{\left\{\frac{\left[\frac{M_k^c}{E(M_k^c)}\right]}{\left[\frac{M_n^c}{E(M_n^c)}\right]}\right\}}{\left\{\frac{\left[\frac{M_k^r}{E(M_k^r)}\right]}{\left[\frac{M_n^r}{E(M_n^r)}\right]}\right\}}$$

Superscript *r* refers to the rest of the world (the world minus country *c*), and subscript *n* refers to all other traded commodities (all trade commodities minus commodity *k*). Vollrath (1991) claimed that by making clear distinctions between a specific commodity *k* and all other commodities *n*, and between a specific country *c* and the rest of the world *r*, these indices eliminate the double counting of subject country and subject commodity in the world trade, and thus be closer to measure true comparative advantage. Although Vollrath (1991) approaches largely address the double counting problems in today's international trade, they face a few numeric exceptions. For instance, when the rest of the world *r* do not export or import commodity *k*, X_k^r or M_k^r equals to 0, it is not possible to calculate RXA_k^c or RMA_k^c. The other exception is when country *c* does not export or import of commodity *k*, or X_k^c or M_k^c equals to 0, the log of RXA_k^c or RMA_k^c cannot be calculated (Danna-Buitrago and Stellian 2021).

Lafay (1992) observed that the use of trade balance $(X_k^c - M_k^c)$ introduces methodological problems, such as distortions related to (1) the evolution of specialization in lesser trade flow (or direction of the trade balance), (2) macroeconomic context, and (3) the relative weights of the products. In relation to distortion (1), a decline in the export/import ratio of a product due to an increase in imports could very well be counterbalanced by a shift in the ratio of exports to domestic demand of the same product. He stated that trade balance $(X_k^c - M_k^c)$ indicates the existence of intra flows to reach the domestic source-use balance, where $Q_k^c + M_k^c = C_k^c + X_k^c$ or $Q_k^c - C_k^c = X_k^c - M_k^c$. He argued that it is essential to take into account of the internal economic variables—comparative advantage for a given product will strengthen or weaken depending on whether the corresponding production in a country increases faster or slower than its domestic consumption. However, since detailed, product-level information on domestic production or demand is often not available, Lafay (1992) suggested accounting for such internal economic variables by relating trade balance to GDP (Y^c) through *the relative balance indicator* y_k^c, where

$$y_k^c = 1000 \times \frac{X_k^c - M_k^c}{Y^c}$$

To eliminate the macroeconomic distortions, Lafay (1992) suggested attributing to the subject product a portion of the overall trade surplus or deficit based on its share in total trade (${z_k}^c$), and comparing its relative balance ${y_k}^c$ with the weighted relative balance ${z_k}^c$ in RCA measurement [13]. A positive difference indicates a comparative advantage for product *k* in country *c*, even with a potentially negative relative balance (${y_k}^c$). The values of the weighted indicator (${z_k}^c$) permits a ranking of products according to their respective comparative advantage/disadvantage while accounting for its importance for the country's total trade.

$$RCA6_k^c = y_k^c - z_k^c = \frac{1000}{Y^c} \times \frac{2(M^c X_k^c - X^c M_k^c)}{(X^c + M^c)} \qquad [13]$$

where

$$z_k^c = y^c \times g_k^c \qquad y^c = 1000 \times \frac{(X^c - M^c)}{Y^c} \qquad g_k^c = \frac{(X_k^c + M_k^c)}{(X^c + M^c)}$$

Lafay empirically tested this method with data from 1967–1986 for 32 zones making up the world. He conducted the analysis at both a detailed level (72 product categories) and a more aggregate level. Using the value of the indicator for each product and the rankings obtained from the indicators, he was able to identify the strongest and weakest segments of each economy, the spread between the extremes, and the changes over the study period. Applying structural analysis on these changes, he illustrated the consolidation of Japan's dynamic comparative advantages throughout this period.

Gnidchenko and Salnikov (2015) developed another net trade approach that accounts for economic openness with GDP as a scale variable. They proposed a *net comparative advantage index* (${NCAI_k}^c$) [14] that distributes expected trade of a commodity among countries in proportion of its share of GDP. The addition of the GDP scale variable also accounts for one weakness of the original Balassa index: a poor ordinal ranking property which limits the comparison of RCA index values to a set of similar countries, as is also highlighted by Yeats (1985). Gnidchenko and Salnikov (2015) pointed out that earlier approaches to using economy scale variables in RCA formulas—such as that by Bowen

(1983) which incorporated its GNP scalar in production—face data limitations for detailed commodity groups and assume that countries have identical homothetic preferences.

Their NCAI measure satisfies both Kunimoto (1977) and Vollrath (1991), in which it is expressed as the ratio of the expected-to-actual trade and accounts for both exports and imports via net trade. The value of $NCAI_k^c$ ranges from $-\infty\ to\ \infty$, while the value of a symmetric version of the index, $SNCAI_k^c$, ranges from $0\ to\ 1$.

$$NCAI_k^c = \underbrace{\frac{X_k^c - M_k^c}{X_k^c + M_k^c}}_{RNX_k^c} \times \underbrace{\frac{X_k^c + M_k^c}{Y^c} \Big/ \frac{X_k^w + M_k^w}{Y^w}}_{\mathrm{RTO}_k^c} \tag{14}$$

Where

$$RTO_k^c = \underbrace{\frac{\left(\frac{X_k^c + M_k^c}{X^i + M^i}\right)}{\left(\frac{X_k^w + M_k^w}{X^w + M^w}\right)}}_{RT_k^c} \times \underbrace{\frac{\left(\frac{X^c + M^c}{Y^c}\right)}{\left(\frac{X^w + M^w}{Y^w}\right)}}_{RO^c}$$

so

$$NCAI_k^c = RNX_k^c \times RO^c \times RT_k^c$$

where

RNX_k^c: the relative net export index

RO^c: the relative openness to trade of the country c

RT_k^c: the trade intensity of good k

A symmetric version of the index [15] is represented by:

$$SNCAI_k^c = RNX_k^c \times RO_k^c \times \frac{RT_k^c}{RT_k^c + 1} \tag{15}$$

Gnidchenko and Salnikov (2015) utilized the 2012 UN Comtrade data at the HS 6-digit level to empirically compare their proposed NCAI index against Vollrath's RCA[5] indices for selected countries. They highlighted the utility of their proposed index and its components with the example of frozen

[5] The specific Vollrath RCA equation referenced here is the relative trade advantage index: $RTA_k^c = RXA_k^c - RMA_k^c$.

herrings, which is intensively traded by Russia. Vollrath's index produces a comparative disadvantage for Russian exports of frozen herrings, while their proposed NCA index reports a strong comparative advantage, as the low relative net export index value (${RNX_k}^c$) is offset by the high value of trade intensity (${RT_k}^c$).

Danna-Buitrago and Stellian (2022) built on the previous work by Vollrath (1991), Dalum, Laursen and Villumsen (1998), and others. They adopted the general approaches of RTA, REA, and RC in Vollrath (1991) though with some modifications. Instead of excluding country *c* from the reference country group and commodity *k* from total commodities as Vollrath (1991) advocated, they returned to the original RCA approach and include those in the benchmark groups. Instead of using logarithms as in Vollrath (1991), they used the normalization approach ($\frac{RCA-1}{RCA+1}$) developed by Dalum, Laursen and Villumsen (1998).

$$RTA'^c_k = RXA'^c_k - RMA'^c_k$$

$$REA'^c_k = \frac{RXA'^c_k - 1}{RXA'^c_k + 1}$$

$$RC'^c_k = \left(\frac{RXA'^c_k - 1}{RXA'^c_k + 1} - \frac{RMA'^c_k - 1}{RMA'^c_k + 1}\right)$$

Danna-Buitrago and Stellian (2022) also added two additional changes to the RC'^c_k [16]: 1) weighted by GDP per capita in year *t* [$f(y^c_t)$] as a proxy for factor endowments; and 2) adjusting trade flows in year *t* ($v^r_{k,t}$) to eliminating short-term fluctuations so that the share of *k* in total trade of the world *w* (or the reference country group) is the same for all periods considered and equals to the share associated with the reference period *r*. The resulting value of $RC'^{y,r}_{c,k,t}$ ranges from $-2 \ to \ 2$. Using data from 19 countries in the Euro area for the years 1995 to 2018, Danna-Buitrago and Stellian performed an empirical evaluation of their proposed index against previous versions of RCA measures, in terms of time stability, symmetric distribution, and ordinal ranking bias. They stated that their new class of RCA indices can be applied to study the empirical patterns of international specialization with relative values over consecutive years.

$$RC'^{y,r}_{c,k,t} = \left(\frac{RXA'^r_{c,k,t} - 1}{RXA'^r_{c,k,t} + 1} - \frac{RMA'^r_{c,k,t} - 1}{RMA'^r_{c,k,t} + 1}\right) \times f(y^c_t) \qquad [16]$$

Where

$$f(y_t^c) = \exp\left(1 - \frac{y_t^c}{\frac{1}{\#c} y_t^w}\right)$$

$$RXA'^r_{c,k,t} = RXA'^c_k \times v^r_{k,t} = \frac{\frac{X_k^c}{X^c}}{\frac{X_k^w}{X^w}} \times v^r_{k,t}$$

$$RMA'^r_{c,k,t} = RMA'^c_k \times v^r_{k,t} = \frac{\frac{M_k^c}{M^c}}{\frac{M_k^w}{M^w}} \times v^r_{k,t}$$

$$v^r_{k,t} = \frac{\frac{X^w_{k,r} + M^w_{k,r}}{X^w_r + M^w_r}}{\frac{X^w_{k,t} + M^w_{k,t}}{X^w_t + M^w_t}}$$

Although these two-way trade or net-trade based approaches largely address the double counting problems in today's international trade, there are issues in trade data compatibility. As import data are typically recorded at cost, insurance, and freight (C.I.F.) value, while export data are usually recorded at free on board (FOB) value, there is incompatibility between export and import data, though using one country's export or import data to derive the partner country's corresponding import or export data may circumvent the issue.

Alternatives to RCA Measures

Although researchers have put forth efforts to address various issues associated with the RCA index over the years, none of these approaches deal with its fundamental shortcoming—that it is a measure based on trade-flows in post-trade equilibria. Therefore, it does not actually reflect the classic theoretical concept of comparative advantage that is based either on differences in productivity or factor endowment. In addition, RCA measures reflect the bias from other trade flow determinants, such as government trade policies, trade cost, etc. Costinot et al. (2012) returned to Ricardian comparative advantage based on technological or productivity differences in their estimation of the effects of productivity differences on trade patterns across countries and industries. Instead of using trade flows as a proxy to comparative advantage, they developed relative productivity level at the country-industry level by using relative producer prices, and explicitly accounted for intra-industry heterogeneity in labor productivity as the main structural parameter governing the relationship between productivity and exports in a Ricardian model. Leromain and Orefice (2014) presented a database of RCA measures based on the Costinot et al. (2012) methodology, which extended the coverage to the period 1995–2010, and up to an HS4 digit product classification for manufacturing. They claimed this approach improves the time stability and ordinal ranking property which are identified as the shortcomings of the traditional RCA index distribution.

Summary

Since Balassa coined the term of "revealed comparative advantage" with his classic RCA index in 1965, the RCA approach has become quite popular, as it is intuitive, easy to use yet with limited data requirement. However, the index suffers multiple shortcomings, such as asymmetric value distribution, a lack of additive property, incomparable ordinal and cardinal rankings across countries or industries, and double counting of trade flows, etc. Therefore, many revisions have been explored. See table 1 for the summary of selected RCA variations.

With careful consideration, the RCA method can still be quite useful, providing valuable information on a country's specialization in global supply chains or comparative advantage at a more granular product/sectoral level. However, one must evaluate the following aspects of the RCA approach before applying it to an analysis:

1. ***The benchmark product/sector group***: Should the benchmark product/sector group include all goods and services, all goods, just manufacturing goods, or a subset of the product group? Should commodities such as crude petroleum be excluded from the benchmark group due to its high value in global trade and its volatile price fluctuation? Should the subject product/sector be excluded from the benchmark group to avoid double counting?
2. ***The level of aggregation of product/sector***: What is the right level of aggregation of product/sector for the exercise, at 6-, 4-, or 2-digit HS level, or 4-digit/3-digit ISIC level? How do the different levels of aggregation affect the results?
3. ***The benchmark country group***: Should you choose the world as the reference country group, or countries with a similar development level, or countries within a region? Should the subject country be excluded from the benchmark country group?
4. ***The fluctuation of year-to-year trade data***: How should the short-term fluctuation in trade value be dealt with—by taking an average of multiple years of trade value, or converting nominal trade value to real price using a base year?

5. ***One-way vs. two-way trade***: Should the RCA measure that is based on either export or import flows, or one of the variations that are based on two-way trade or net trad be adopted? What factors should be considered when deciding on this?
6. ***Normalization approaches***: Which normalization methods should be applied? What are the pros and cons in each method, and which numerical exceptions should be taken in account in each of the approaches?
7. ***Scaling trade value***: Does economy size, income level, or other factors affect the comparative advantage or international specialization? Which factor should be accounted for and how?
8. ***The use and interpretation of ordinal and cardinal results:*** Should the RCA approach be used to derive the ordinal or cardinal results? How should these results be used and interpreted?
9. ***Productivity-based alternatives***: At last, should any sensitivity analysis be done on the RCA-based results, and how?

In the follow-up paper, we would like to explore these questions and compare the empirical results based on different approaches.

Table 1 Selected variations of Balassa revealed comparative advantage (RCA) approach

RCA= revealed comparative advantage; RSCA=revealed symmetric comparative advantage; ARCA= additive RCA; NRCA=normalized RCA; RNX= relative net export; RTA= relative trade advantage; RXA= relative export advantage; RMA= relative import advantage; RC=revealed competitive; NCAI=net comparative advantage index; SNCAI=symmetric net comparative advantage index.

X=exports; M=imports; c=country c; k=commodity or industry k; w=the world; r=reference country group; y=gross domestic product.

Approach	Equations	Value range	Specifications
Balassa (1965)	$RCA1_k^c = \frac{\frac{X_k^c}{\sum_k X_k^c}}{\frac{\sum_c X_k^c}{\sum_c \sum_k X_k^c}}$	$[0, \infty)$; the neutral value equals to 1 (or 100 if using percentage); asymmetric distribution.	72 manufacturing sectors using 3-digit and 4-digit SIT classifications; two three-year periods for calculating RCA values; 11 countries.
Vollrath (1991)	$RCA2_k^c = \frac{\frac{X_k^c}{\sum_k X_k^c}}{\frac{X_k^w}{\sum_k X_k^w}} = \frac{\frac{X_k^c}{X^c}}{\frac{X_k^w}{X^w}}$ $RCA3_k^c = \frac{X_k^c}{E(X_k^c)}$ *where* $E(X_k^c) = X^c \times \left(\frac{X_k^w}{X^w}\right)$	$[0, \infty)$; the neutral value equals to 1 (or 100 if using percentage); asymmetric distribution.	n.a.
Proudman and Redding (2000)	$RCA4_k^c = \frac{\frac{X_k^c}{\sum_c X_k^c}}{\frac{1}{N}\sum_k\left(\frac{X_k^c}{\sum_c X_k^c}\right)} = \frac{\frac{X_k^c}{X_k^w}}{\frac{1}{N}\sum_k\left(\frac{X_k^c}{X_k^w}\right)}$	Constant mean and also the neutral value equals to 1; asymmetric distribution.	Using the five-year average
Dalum et al. (1998)	$RSCA_k^c = \frac{RCA_k^c - 1}{RCA_k^c + 1} = \frac{X_k^c \times X^w - X_k^w \times X^c}{X_k^c \times X^w + X_k^w \times X^c}$	$[-1,1]$; a constant mean and also the neutral value equals to 0; symmetric distribution.	60 sectors using 2-4 digit SIT classifications; 20 countries; three periods with difference durations.
Hoen & Oosterhaven (2006)	$ARCA_k^c = \frac{X_k^c}{X^c} - \frac{X_k^r}{X^r}$	$[-1,1]$; a constant mean and also the neutral value equals to 0; symmetric distribution.	n.a.
Yu, Cai and Leung (2009)	$NRCA_k^c = \frac{\Delta X_k^c}{X^w} = \frac{X_k^c - X^c \times \left(\frac{X_k^w}{X^w}\right)}{X^w} = \frac{X_k^c}{X^w} - \frac{X^c \times X_k^w}{X^w \times X^w}$	$[-0.25,0.25]$; a constant mean and also the neutral value equals to 0; symmetric distribution.	10 agricultural products; three subjects (Hawaii, U.S. mainland, and foreign imports); two single years.
Donges and Riedel (1977)	$RCA5_k^c = \left[\frac{\frac{X_k^c - M_k^c}{X_k^c + M_k^c}}{\left(\frac{X^i - M^i}{X^i + M^i}\right)} - 1\right] \times \left(\frac{X_k^c + M_k^c}{X_k^w + M_k^w}\right) \times [sign(X^i - M^i)]$	$(-\infty, \infty)$; the neutral value equals to 0; asymmetric distribution	n.a.

UNIDO (1982)	$RNX_k^c = \frac{X_{ij} - M_{ij}}{X_{ij} + M_{ij}}$	$[-1,1]$; a constant mean and also the neutral value equals to 0; symmetric distribution.	n.a.
Vollrath (1991)	$RTA_k^c = RXA_k^c - RMA_k^c$ $RC_k^c = Ln(RXA_k^c) - Ln(RMA_k^c)$	$(-\infty, \infty)$; the neutral value equals to 0; asymmetric distribution	n.a.
Lafay (1992)	$RCA6_k^c = y_k^c - z_k^c = \frac{1000}{Y^c} \times \frac{2(M^c X_k^c - X^c M_k^c)}{(X^c + M^c)}$	$(-\infty, \infty)$; the neutral value equals to 0; asymmetric distribution	72 product categories; 32 zones; and 160 countries.
Gnidchenko and Salnikov (2015)	$NCAI_k^c = \frac{X_k^c - M_k^c}{X_k^c + M_k^c} \times \frac{X_k^c + M_k^c}{Y^c} \Big/ \frac{X_k^w + M_k^w}{Y^w}$ $SNCAI_k^c = RNX_k^c \times RO_k^c \times \frac{RT_k^c}{RT_k^c + 1}$	The value of $NCAI_k^c$ $(-\infty, \infty)$; the neutral value equals to 0; asymmetric distribution; the value of $SNCAI_k^c$ $(0,1]$; the neutral value equals to 0; symmetric distribution	Selected commodities; selected OECD countries; single year (full country and commodity index values not provided)
Danna-Buitrago and Stellian (2022)	$RC'^{yr}_{c,k,t} = \left(\frac{RXA'^{r}_{c,k,t} - 1}{RXA'^{r}_{c,k,t} + 1} - \frac{RMA'^{r}_{c,k,t} - 1}{RMA'^{r}_{c,k,t} + 1}\right) \times f(y_t^c)$	$[-2,2]$; a constant mean and also the neutral value equals to 0; symmetric distribution.	255 sectors using 3-digit SIT classifications; 19 countries; annual estimates for the years 1995-2018; 1999 as the reference year

Source: compiled by authors.

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