Paper prepared for International Conference on Globalisation, Growth and Development in Asia at the University of Nottingham Malaysia Kuala Lumpur, 14th -15th January 2009

On Volume Based Measures of Revealed Comparative Advantage: An Empirical Test for ASEAN

A.K.M. Azhar
Universiti Putra Malaysia

R.J.R Elliott
University of Birmingham

T.M.H. Violet
Universiti Putra Malaysia

VERY PRELIMINARY – PLEASE DO NOT QUOTE OR REFERENCE

Abstract

Within the empirical international trade literature there is a long tradition of analyzing patterns of specialization across countries employing an index of revealed comparative advantage (RCA) that was first proposed by Balassa (1965). Azhar and Elliott (2008) reviewed geometrically the properties of the RCA indices that followed the original Balassa index. In this paper we employ these proportional volume based RCA measures to the data to investigate the patterns of comparative advantage in the ASEAN region. Preliminary results demonstrate only small differences between alternative measures of RCA.

JEL classification: F14, F19
Keywords: international trade, revealed comparative advantage, international specialisation.

Email: akmazhar@putra.upm.edu.my.. Funding from MOSTI Malaysia Escience research grant # 5450283 is gratefully acknowledged.

I Introduction

The pervasive forces of globalisation and the gradual multilateral removal of trade barriers have led to a renewed interest in the nature of a country's patterns of trade and specialisation. Coupled with the recent empirical tests of the theory of comparative advantage (see e.g. Bernhofen and Brown 2004; 2005) the ability to accurately measure intra- and inter-country and regional comparative advantage and specialisation has returned to prominence for both academics and policymakers. Moreover, recent work by Hausmann *et al*. (2007) makes it clear that what a country exports can have dramatic ramifications for future employment and growth prospects.

International trade economists have long considered comparative advantage as one of the main theoretical explanations of international trade flows even after the emergence of economies of scale as an explanation of trade in the 1980s as part of the *new trade theory* literature (Matsuyama 1995; Davies, 1997). The theory of comparative advantage is common to both Ricardian comparative cost theory and Heckscher-Ohlin factor-proportions theory. However, the theory has proven difficult to extend beyond these simple models. Against this background Deardorff (1980) provides a version of the comparative-advantage proposition in a fully specified multi-country, multi-good general equilibrium formulation of comparative advantage.[1] Thus, to identify which good or industry a country has a comparative advantage or disadvantage one merely needs to observe the sign on the difference between autarkic and free trade relative prices (country-specific opportunity costs).

[1] Deardorff (1980) provides three different illustrations of the difficulty of extending the law of comparative advantage: Jones (1961); Travis (1964; 1972); and Drabicki and Takayama (1979). Recently this model has been labelled as the Ricardo-Haberler-Deardorff (RHD) theorem of comparative advantage (Bernhofen 2005a; 2005b).

A problem arises however when we come to the measurement of comparative advantage due to the unobservable nature of autarkic prices.[2] The standard approach in the empirical literature is to employ measures of revealed comparative advantage following Balassa (1965).[3] In these measures, sectoral national shares are compared with international shares so that comparative advantage and hence patterns of specialisation can be inferred from the examination of various combinations of trade (exports and imports) and/or production (or consumption) levels.

The implication of the "choice" of how to define comparative advantage means that there are a number of alternative RCA indices and a number of associated extensions and transformations. To obtain a measure of comparative advantage that is firmly grounded in the theory it is important to have a clear understanding of the empirical properties of those RCA indices that have already gained acceptance within the mainstream empirical trade literature.

In terms of empirical applications of RCA indices the literature has recently been given additional impetus from the new economic geography literature that attempts to examine patterns of specialisation across countries and how economic integration or the forces of

[2] Bernhofen and Brown (2004; 2005) use Japan's nineteenth-century opening-up to international trade to test the predictions of the RHD theorem as Japan moved swiftly from autarky (1851-1853) to open international trade with a set of goods that can be considered fairly homogenous: thus providing an excellent natural experiment. The predictions of the RHD theorem were validated by the data.

[3] Attempts to ground measures of RCA in the theory of comparative advantage include Hillman (1980) and Bowen (1983).

globalisation are reflected in changes in patterns of specialisation. See e.g. Brulhart (2001), Amiti (1999) and Laursen (2000).[4]

In this paper, we first review the volume-based indices of RCA that followed Balassa (1965), and identify those measures which are proportional[5]. We then take these proportional volume based RCA measures to the data to investigate the patterns of comparative advantage within the ASEAN region for the manufacturing sector. The remainder of this paper is organised as follows: Section II provides a review of the recent geometric analysis of RCA measures by Azhar and Elliott (2008) that analyses the proportional properties of the Balassa index and some of its recent extensions in the volume–based RCA measurement literature. Section III employs the proportional measures to investigate the patterns and ranking of comparative advantage in the ASEAN countries. Section IV summarises and concludes.

II. Volume Based Measures of RCA

It has become customary practice in the empirical trade literature to analyse specialization patterns of countries using a measure of RCA pioneered by Balassa (1965). This index is widely known as the BRCA index and is the most widely measure for analysing the pattern of

[4] Previous applications of the RCA index include Aquino (1981), Crafts and Thomas (1986); van Hulst *et al.* (1991); and Lim (1997).

[5] In measuring comparative advantage using variations of the original BRCA, one desirable property for any index is that of proportionality. This means the rate of change of any RCA measure with respect to either of its parameters must be equal and opposite. We illustrate this functional proportionality test for each of the measures that we will analyse in this paper.

comparative advantage within and across countries. However, there are a number of potential weaknesses with the BRCA index. Despite this, BRCA has remained popular and numerous studies continue to use it as an indicator of a country's comparative advantage. Later studies attempt to improve the original BRCA index by proposing alternative or complimentary measures[6]. Following Azhar and Elliott (2008) we now review the alternative volume-based RCA measures[7]

The Balassa's methodology for measuring RCA can be represented as;

$$B = \frac{\frac{X_j^H}{X^H}}{\frac{X_j^W}{X^W}}$$

where;

X_j^H - *i*th country's exports from industry or sector *j*

X^H - *i*th world exports from industry or sector *j*

X_j^W - total exports of country *i*

X^W - total world exports

[6] The second desirable property of an empirical measure is symmetry. Suppose that if by design the minimum and maximum values of an index are respectively zero and 2. Then symmetry is taken to imply if in the home country one sector had an RCA value of 1.5 then ROW should have an equal but opposite value of 0.5. In this way, it does not matter from which side we calculate the index the meaning will be the same. See Azhar and Elliott (2003, 2006) for further discussions on concept of 'symmetry in intra industry trade and adjustment measures. This concept applies equally well to measures of RCA and international specialisation and/or competitiveness. We illustrate this property of the GRCA index in this paper The third desirable property is scaling. This is easiest to observe.

[7] There is also an attempt to analyse RCA from the quality perspective or the quality based approach to measuring RCA. See Azhar *et al*. (2009).

To ease the exposition of this paper we employ the following definitions;

Let;

$$\frac{X_j^H}{X^H} = r$$

and

$$\frac{X_j^W}{X^W} = R \qquad (1a)$$

So we can write;

$$B = \frac{r}{R} \text{ or } r = B(R) \qquad (1b)$$

and for B to be defined as the "Home" country that is not a sole exporter i.e. we have the restriction $X_j^W \neq 0$ (i.e. $R > 0$) and when $r > (<)R$, we have $B > (<)1$.

The B index is representative of a simple share performance measure of exports of a country's commodity (or sector or industry) r, relative to that of the same commodity's exports in the rest of the world (or region) R .

An index value greater than one is interpreted as a country having a comparative advantage in that commodity whilst a B index of less than one in interpreted as a country having a comparative disadvantage in the production of that commodity.

Consider the functional form of the BRCA;

$$F(r,R) = \frac{r}{R} \Rightarrow r = B(R) \qquad (2)$$

$\frac{\partial F}{\partial r} = \frac{1}{R}$ $\frac{\partial F}{\partial R} = -\frac{r}{R^2}$ $\Rightarrow r = B(R)$ is not proportional. Figure 1 presents the geometry of the BRCA index.[8] Note that BRCA with $0 < B < \infty$ .are disproportionate rays from the origin in the RCA box (see Azhar and Elliott, 2008) are similar to Grubel-Lloyd rays in the trade box (see Azhar et al, 1998). Other properties of the Balassa index are well known and are problematic when making cross country comparisons or when using BRCA indices in econometric studies.

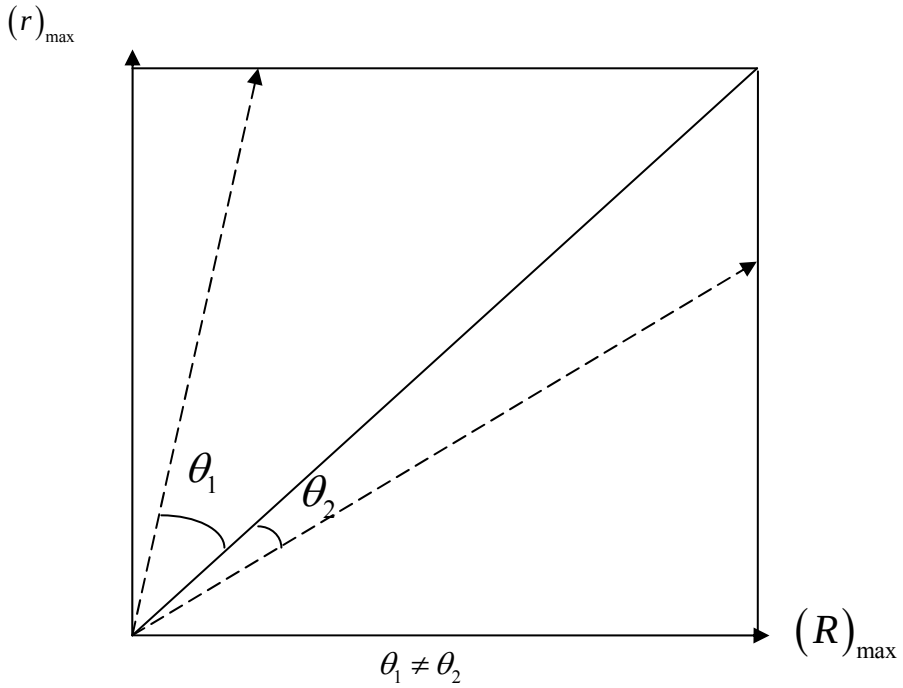


Figure 1: The Geometry of the BRCA index

[8] Lederman *et al.* (2008) propose an index similar to the index proposed by Vollrath (1991). Under the test for proportionality the function is proportional. However it is not presented here, for details see Azhar and Elliott (2008).

Next we consider the SRCA index developed by Laursen (1998) which is given by $SRCA = \frac{RCA-1}{RCA+1}$.[9]

i.e. using our simplifying terminology;

$$SRCA = \frac{\frac{r}{R}-1}{\frac{r}{R}+1} = \frac{\frac{r-R}{R}}{\frac{r+R}{R}} = \frac{r-R}{r+R} \qquad (3)$$

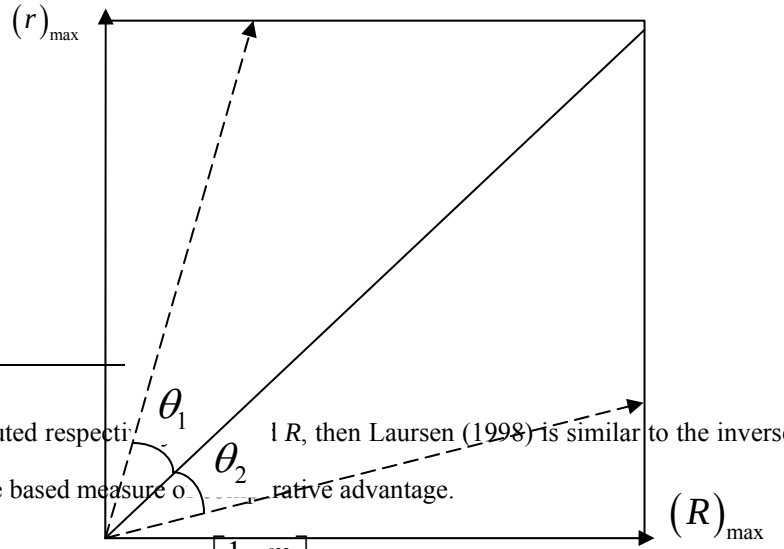
Now let; $\frac{r-R}{r+R} = m$

then; $r - R = m(r + R)$

Simplifying, the Laursen (1998) *SRCA* index can be represented by;[10]

$$r = \underbrace{\frac{1+m}{1-m}}_{slope}(R) \qquad (3a)$$

Note that (3a) is of the form of (2) where *m* equals the slope $\frac{1+m}{1-m}$ and *C* equals zero. In an *r* versus *R* Cartesian construct, (3a) are equi-rays from the origin. See the geometric representation in Figure 2.



[9] If *X* and *M* are substituted respecti[illegible] *R*, then Laursen (1998) is similar to the inverse of Balance *et al* (1987) $\frac{X-M}{X+M}$ trade based measure o[illegible] rative advantage.

[10] Similarly if $\frac{RCA+1}{RCA-1}$ then we have $r = \left[\frac{1-m}{1+m}\right]R$. Given m $\geq 0 \Rightarrow$ we have [illegible] e.

$$\theta_1 = \theta_2$$

Figure 2: Laursen (1998) SRCA index

The test of proportionality for SRCA gives us;

$$F(r,R) = \frac{r-R}{r+R} \Rightarrow r = \left(\frac{1+B}{1-B}\right)(R)$$

$\frac{\partial F}{\partial r} = \frac{2R}{(r+R)^2}$ $\frac{\partial F}{\partial R} = -\frac{2R}{(r+R)^2}$ $\Rightarrow r = \frac{1+B}{1-B}(R)$ is proportional. The geometry of SRCA is presented in Figure 2. Note that the SRCA are proportionate rays from the origin in the RCAB.

The third index we consider is proposed by Proudman and Redding (2000) and can be presented as;

$$WRCA_j^i = \frac{BRCA_j^i}{\left(\frac{1}{N}\sum_{i=1}^{N} BRCA_j^i\right)}$$

Using (1a) we have;

$$WRCA_j^i = \frac{\frac{r}{R}}{\left(\frac{1}{N}\sum_{i-1}^{N} \frac{r}{R}\right)}$$

Since ;

$\frac{1}{N}\sum_{i=1}^{N}\frac{r}{R}=\overline{C}$ a constant,

Dropping subscripts we have;

$WRCA_j^i=\frac{r}{R}\frac{1}{\overline{C}}$ i.e. $r=WRCA\left(\overline{C}\right)\left(R\right)$ or $F(r,R)=\frac{\frac{r}{R}}{\overline{C}}$

When we employ a test of proportionality on WRCA;

$$F(r,R)=\frac{\frac{r}{R}}{\overline{C}} \quad \Rightarrow r=B\overline{C}R \tag{4}$$

$\frac{\partial F}{\partial r}=\frac{1}{\overline{C}}\left(\frac{1}{R}\right)$; $\frac{\partial F}{\partial R}=-\frac{r}{\overline{C}R^2}$ $\Rightarrow r=B\overline{C}R$ is not proportional. For the geometry of WRCA see Figure 3. WRCA are disproportionate rays in the RCAB.

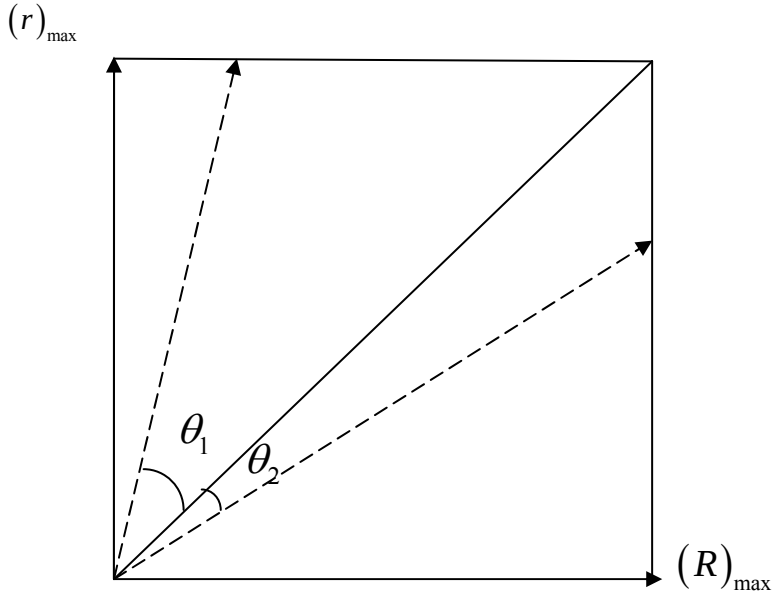


Figure 3: Proudman and Redding (2000) WRCA index

The fourth index we consider in this section of the paper was developed by Hoen and Oosterhaven (2006) who adopted a difference approach by taking the difference between the sectoral or industrial export shares of the home country and the world.

Hoen and Oosterhaven (2006), is given by;[11]

$$ARCA = \frac{X_j^H}{X^H} - \frac{X_j^W}{X^W}$$

From (1a), we have;

$$ARCA = r - R \qquad (5)$$

or

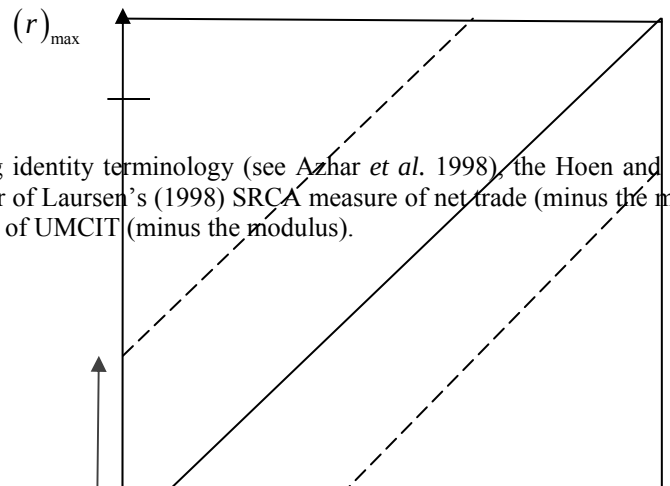
$$r = R + \underbrace{ARCA}_{\text{int}ercept} \qquad (5a)$$

However, since $m = 1$, in an r versus R Cartesian construct (5a) are the equi-rays running parallel to the perpendicular bisector with $r = R$ and intercept $c = ARCA$. Note that as in (5a) suppose $r > (<) R$, then the comparative advantage (disadvantage) is with the home country.

A test of proportionality for ARCA gives;

$$F(r, R) = r - R \Rightarrow r = R + B$$

$\frac{\partial F}{\partial r} = 1 \qquad \frac{\partial F}{\partial R} = -1 \qquad \Rightarrow r = B + R$ is proportional. See Figure 4 for the geometry of the ARCA index. Note that ARCA are proportionate rays running parallel to the line of zero comparative advantage in the RCAB (similar to NT rays in the Trade Box)



[11] In trade accounting identity terminology (see Azhar *et al.* 1998), the Hoen and Oosterhaven (2006) ARCA index is the numerator of Laursen's (1998) SRCA measure of net trade (minus the modulus), i.e. the Menon and Dixon(1997) measure of UMCIT (minus the modulus).

Figure 4: Hoen and Oosterhaven (2006) ARCA index

The fifth index we consider is Yu *et al*. (2008) who develop the NRCA index which uses the ARCA index but defines the condition of comparative advantage neutral;

$$r - R = 0 \Leftrightarrow \frac{r}{R} = 1 \Rightarrow \frac{X_H^j}{X_H} = \frac{X_R^j}{X_R} \tag{6}$$

and following (6), the comparative neutral condition for both Home and the rest of the world (ROW) is thus;

$$\hat{X}_H^j = X_H \left(\frac{X_R^j}{X_R} \right)$$

But under actual conditions they posited a so called comparative "actual" condition for the home country which is measured as;

$$\Delta X_H^j \equiv X_H^j - \hat{X}_H^j = X_H^j - X_H \left(\frac{X_R^j}{X_R} \right) \tag{7}$$

i.e. they assumed CA "actual" > CA "neutral". Normalising by X_R (world exports) they proposed the NRCA index on basis that "the degree of deviation of a country's actual exports

from its comparative advantage neutral level in terms of its relative scale with respect to the world export market.

Yu *et al*. (2008) claim that their index "provides a proper indication of the underlying comparative advantage". The NRCA index is given by;

$$NRCA = \frac{\Delta X_H^j}{X_R} = \frac{X_H^j}{X_R} - \frac{X_H}{X_R}\left(\frac{X_R^j}{X_R}\right) \tag{7a}$$

Consider (7a);

$$\Delta X_H^j = X_H^j - X_H\left(\frac{X_R^j}{X_R}\right)$$

i.e. from (1);

$$X_H^j - \Delta X_H^j = X_H\left(\frac{X_R^j}{X_R}\right) = X_H\left(R\right) \tag{8}$$

Dividing (8) by X_H we have;

$$\frac{X_H^j}{X_H} - \frac{\Delta X_H^j}{X_H} = R$$

again from (1);

$$r = \frac{\Delta X_H^j}{X_H} = R$$

from (5);

$$r - R = ARCA = \frac{\Delta X_H^j}{X_H}$$

i.e.

$$\Delta X_H^j = X_H\left(ARCA\right)$$

from (3) we have;

$$\frac{\Delta X_H^j}{X_R} = NRCA = \frac{X_H}{X_R}(ARCA) \tag{9}$$

i.e. NRCA equals ARCA multiplied by the ratio of home country to world exports (k).

Consider the test for proportionality on the NRCA index;

$$F(r,R) = \frac{X_H}{X_R}(r-R) \Rightarrow r = R + \frac{X_R}{X_H}(B)$$

$\frac{\partial F}{\partial r} = \frac{X_H}{X_R}$ $\frac{\partial F}{\partial R} = -\frac{X_H}{X_R}$ $\Rightarrow r = R + \frac{X_R}{X_H}(B)$ is proportional. See Figure 5 for the geometry of the NRCA index. NRCA are proportionate rays similar to ARCA rays in the RCAB but due to the factor *k*, the range is smaller

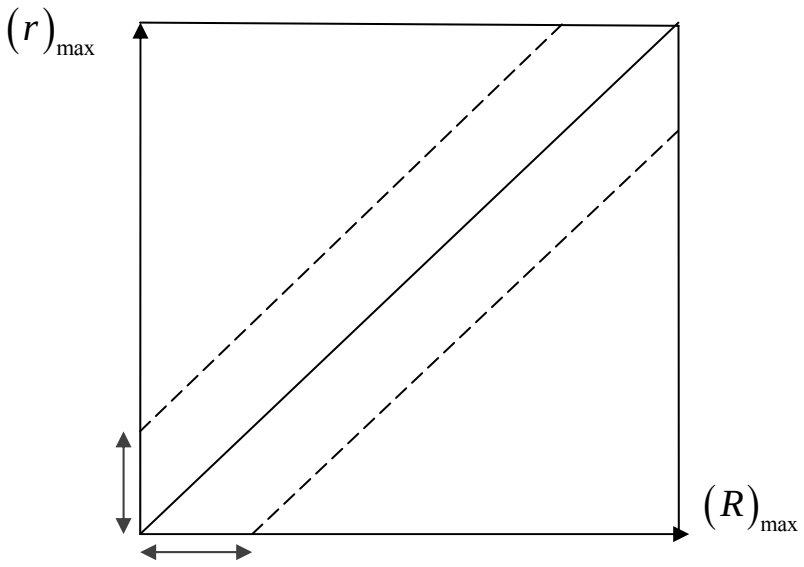


Figure 5: Yu *et al.* (2008) NRCA inde

Finally, we consider the contribution proposed by Azhar and Elliott (2008) which adopts a Grubel-Lloyd (1975) style of measure incorporating both the share the net and share features of the home and world or reference countries' exports.

Following the properties of Azhar and Elliott (2006), they proposed the Geometric RCA where;

$$GRCA = 1 - \frac{r-R}{r+R} \qquad \text{i.e.} \qquad GRCA = 1 - SRCA \tag{10}$$

Performing a test of proportionality on GRCA we get;

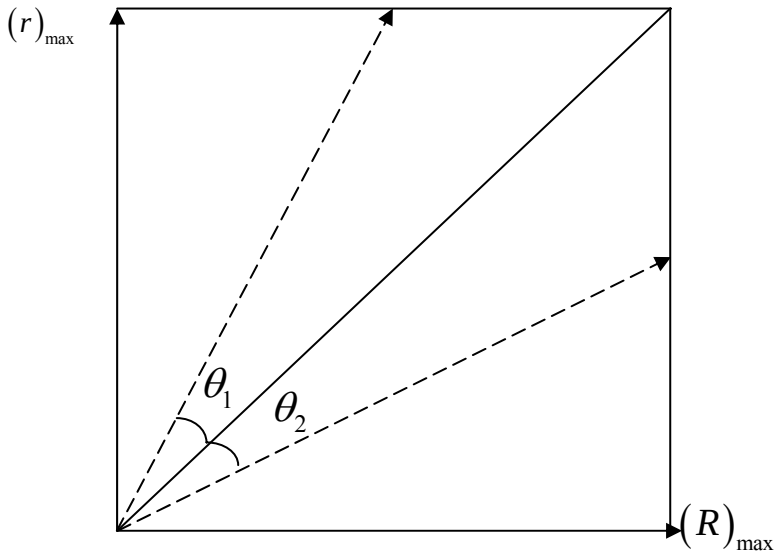
$$F(r,R) = 1 - \frac{r-R}{r+R} \Rightarrow r = \left(\frac{B}{2-B}\right)R$$

$$\frac{\partial F}{\partial r} = \frac{2R}{(r+R)^2} \Rightarrow \text{as } r \to 0 \text{, we have} \left(\frac{\partial F}{\partial r}\right)_R = \frac{2}{(R)}$$

$$\left(\frac{\partial F}{\partial R}\right)_r = -\frac{2r}{(r+R)^2} \Rightarrow \text{as } R \to 0 \text{, we have} \left(\frac{\partial F}{\partial R}\right)_r = -\frac{2}{(r)}$$

The partial derivatives presented above verify that the rate of change of *RCA*, $\left(\frac{\partial F}{\partial R}\right)_r$ is similar but opposite to $\left(\frac{\partial F}{\partial r}\right)_R$. Hence $F(r,R) = 1 - \frac{r-R}{r+R}$ or $r = \left(\frac{B}{2-B}\right)R$ is proportional.

The geometry of the GRCA index is shown in Figure 6. GRCA are proportional rays in the RCAB similar to the PQV rays in the Product Quality Space (see Azhar and Elliott, 2006). Note also here that this GRCA measure is also symmetric, see footnote 6).



$$\theta_1 = \theta_2$$

Figure 6: Azhar and Elliott (2008) GRCA index

Weighting Considerations

It is also possible to present weighted version of the GRCA index. When it is expressed in this form we can formulate weights (w). We have from (10);

$$GRCA = 1 - \frac{r - R}{(r + R)}, \quad \text{with } 0 < GRCA < 2$$

Define;

$$w = \frac{r + R}{\sum(r + R)} = \frac{(r + R)^T}{\sum(r + R)^T} \tag{10a}$$

The superscript T refers to the sum of r and R. The weighted RCA takes the form:

$$GRCA_W = GRCA \frac{(r + R)^T}{\sum(r + R)^T} \tag{10b}$$

Such an approach allows us to observe the importance or significance of any one industry within the economy.

III. Empirical Application for the ASEAN region

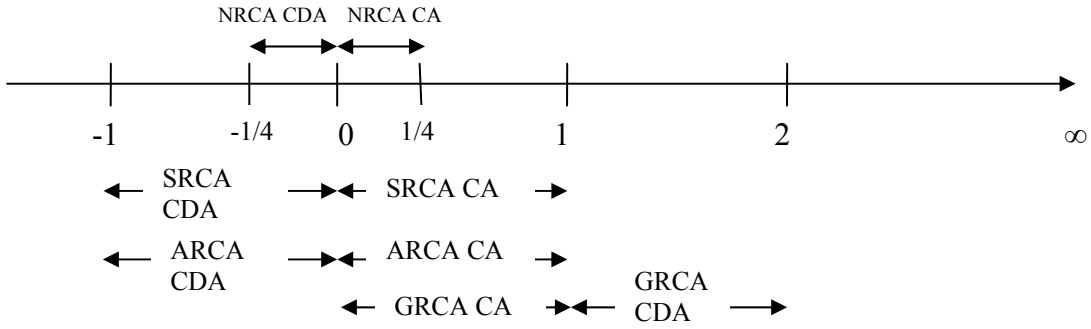
The four proportional and scaled RCA measures from the section II are summarised in Table 1. We include the range of index and how each index is represented in equation form.

Table 1: The SRCA, ARCA, NRCA and GRCA proportional and scaled indices of RCA

RCA measures	Equations	Range
Laursen (1998) SRCA index	$(r-R)/(r+R)$	-1<SRCA<1
Hoen and Oosterhaven (2006) ARCA index	$r-R$	-1<ARCA<1
Yu *et al.* (2008) NRCA index	$\left(\frac{\sum Xi}{\sum Xj}\right)(r-R)$	$-\frac{1}{4} < NRCA < \frac{1}{4}$
Azhar and Elliott (2008) GRCA index	$1-\frac{r-R}{r+R}$	0<GRCA<2

The properties of the four proportional and scaled indices can be further illustrated by means of a simple diagram. See figure 8.

Figure 8: Range of CA and CDA for SRCA, ARCA, NRCA and GRCA



The range of comparative advantage (CA) and comparative disadvantage (CDA) for all the four approaches is presented in Figure 8. The SRCA index of comparative advantage (disadvantage) ranges between zero and 1 (-1 and zero). For the ARCA index comparative advantage (disadvantage) ranges between zero and unity (negative unity and zero) The SRCA and ARCA indices share an identical range of comparative advantage and comparative disadvantage. For the GRCA index, comparative advantage (disadvantage) is between zero and unity (unity and two). Finally, for the NRCA index, comparative advantage (disadvantage) is between negative 1/4 and zero (zero and 1/4). We now compare the four

measures using data from the ASEAN region for 2002 to 2006 for trade export data obtained from UN comtrade database.

There have been hundreds of applied RCA studies published in recent years. These include Das (1998) who conducted a study of changing comparative advantage and Asian exports and De Benedictis (2005) who examined Italian comparative advantage, Ferto and Hubbard (2003) analysing the competitiveness of the Hungarian agricultural products, and recently Mahani and Loke (2008) in a study of the competitiveness of the Malaysian manufactured goods. Many of these applied studies employ the traditional Balassa (1965) BRCA index as their main methodological tool for measuring international competitiveness or specialization. In this section, we attempt to take the four proportionate measures in section 2 to the data. In particular, we want to check and demonstrate whether there are any significant differences in the findings of comparative advantage for manufacturing sectors in ASEAN.

Azhar and Elliott (2008) provided a numerical comparison for the use of the GRCA index methodology compared to the other recent extensions to the RCA measurement literature but did not apply their framework to real data. The contribution of this short note is to compare the performances of the four symmetric measures previously summarised. In particular we wish to analyse how the SRCA, ARCA, GRCA, and NRCA indices compare when they are taken to the data. We test the use of these four measures using UN comtrade data for four ASEAN countries, Indonesia, Malaysia, Thailand, and Singapore for the manufacturing sectors (SITC 511-899). Table 2 summarises the sectoral share for each country for two years.

Table 2: Sectoral Exports in Total Exports for ASEAN countries (2002 and 2005)

SITC	Product	Indonesia		Malaysia		Thailand		Singapore	
		2002	2005	2002	2005	2002	2005	2002	2005
5	Chemicals	0.09	0.11	0.06	0.07	0.08	0.10	0.11	0.14
6	Manufactured goods	0.34	0.34	0.09	0.10	0.16	0.16	0.05	0.06
7	Machinery and transport equipment	0.31	0.32	0.75	0.72	0.57	0.58	0.75	0.72
8	Miscellaneous manufactured articles	0.26	0.24	0.11	0.11	0.19	0.16	0.10	0.08

All trade data are from the COMTRADE database and authors own calculation

Table 2 exhibits the respective sectoral share of manufacturing exports for each country for 2002 and 2005. As expected the sectoral export performance shares although low are highest for Singapore in the chemicals sector (SITC 5) for both 2002 and 2005 compared to its ASEAN neighbours. Chemicals in the share of total exports are lowest in Malaysia (reflecting the relatively small domestic chemicals sector in the country). However Malaysia tops the group in SITC 7 (Machinery and transport equipment) with 0.75 for 2002 and 0.72 for 2005. This performance in SITC 7 is shared by Singapore (perhaps reflecting the extensive levels of re-exports from the country's SITC 7 imports from Malaysia).

In Table 3 we present the RCA values calculated yearly from 2002 to 2006 for each of the four measures for each of our four countries.

Table 3: ON VOLUME BASED MEASURES OF RCA: AN EMPIRICAL TEST FOR ASEAN

	Xi	∑Xi	Xj	∑Xj	r	R	SRCA $\frac{r-R}{r+R}$	Rank	ARCA $r-R$	Rank	$\sum Xi / \sum Xj = k$	NRCA $k*(r-R)$	Rank	GRCA $1-\frac{r-R}{r+R}$	Rank
2002(value in million US dollars)															
SITC (Rev3) 5: Chemicals															
Indonesia	2969.2	57158.8	671934.0	6341959.0	0.05	0.11	-0.34	3	-0.05	3	0.009012799	-0.00048673	3	1.34	3
Malaysia	4386.7	94058.3	671934.0	6341959.0	0.05	0.11	-0.39	4	-0.06	4	0.014831111	-0.00087967	4	1.39	4
Singapore	11645.7	125177.1	671934.0	6341959.0	0.09	0.11	-0.06	1	-0.01	1	0.019737923	-0.00025495	1	1.06	1
Thailand	4166.2	68107.9	671934.0	6341959.0	0.06	0.11	-0.27	2	-0.04	2	0.010739253	-0.00048090	2	1.27	2
SITC (Rev3) 6: Manufactured goods															
Indonesia	10926.0	57158.8	1701339.0	6341959.0	0.19	0.27	-0.17	1	-0.08	1	0.009012799	-0.00069503	1	1.17	1
Malaysia	6538.4	94058.3	1701339.0	6341959.0	0.07	0.27	-0.59	3	-0.20	3	0.014831111	-0.00294772	3	1.59	3
Singapore	4898.4	125177.1	1701339.0	6341959.0	0.04	0.27	-0.75	4	-0.23	4	0.019737923	-0.00452266	4	1.75	4
Thailand	8151.9	68107.9	1701339.0	6341959.0	0.12	0.27	-0.38	2	-0.15	2	0.010739253	-0.00159560	2	1.38	2
SITC (Rev3) 7: Machinery and transport equipment															
Indonesia	9788.7	57158.8	2595819.0	6341959.0	0.17	0.41	-0.41	4	-0.24	4	0.009012799	-0.00214553	4	1.41	4
Malaysia	56655.1	94058.3	2595819.0	6341959.0	0.60	0.41	0.19	2	0.19	2	0.014831111	0.00286287	2	0.81	2
Singapore	79472.6	125177.1	2595819.0	6341959.0	0.63	0.41	0.22	1	0.23	1	0.019737923	0.00445233	1	0.78	1
Thailand	28910.7	68107.9	2595819.0	6341959.0	0.42	0.41	0.02	3	0.02	3	0.010739253	0.00016297	3	0.98	3
SITC (Rev3) 8: Miscellaneous manufactured articles															
Indonesia	8193.0	57158.8	1701339.0	6341959.0	0.14	0.27	-0.30	1	-0.12	1	0.009012799	-0.00112597	1	1.30	1
Malaysia	8013.8	94058.3	1701339.0	6341959.0	0.09	0.27	-0.52	3	-0.18	3	0.014831111	-0.00271508	3	1.52	3
Singapore	10651.6	125177.1	1701339.0	6341959.0	0.09	0.27	-0.52	4	-0.18	4	0.019737923	-0.00361549	4	1.52	4
Thailand	9873.6	68107.9	1701339.0	6341959.0	0.14	0.27	-0.30	2	-0.12	2	0.010739253	-0.00132412	2	1.30	2

2003															
SITC (Rev3) 5: Chemicals															
Indonesia	3386.6	61058.2	806888.0	7427922.0	0.06	0.11	-0.32	3	-0.05	3	0.008220092	-0.00043701	2	1.32	3
Malaysia	5407.9	104707.2	806888.0	7427922.0	0.05	0.11	-0.36	4	-0.06	4	0.014096432	-0.00080323	4	1.36	4
Singapore	18455.1	159963.3	806888.0	7427922.0	0.12	0.11	0.03	1	0.01	1	0.021535404	0.00014519	1	0.97	1
Thailand	5257.3	80323.3	806888.0	7427922.0	0.07	0.11	-0.25	2	-0.04	2	0.010813697	-0.00046691	3	1.25	2
SITC (Rev3) 6: Manufactured goods															
Indonesia	11175.4	61058.2	1961069.0	7427922.0	0.18	0.26	-0.18	1	-0.08	1	0.008220092	-0.00066570	1	1.18	1
Malaysia	7363.6	104707.2	1961069.0	7427922.0	0.07	0.26	-0.58	3	-0.19	3	0.014096432	-0.00273030	3	1.58	3
Singapore	6636.6	159963.3	1961069.0	7427922.0	0.04	0.26	-0.73	4	-0.22	4	0.021535404	-0.00479216	4	1.73	4
Thailand	9391.5	80323.3	1961069.0	7427922.0	0.12	0.26	-0.39	2	-0.15	2	0.010813697	-0.00159061	2	1.39	2
SITC (Rev3) 7: Machinery and transport equipment															
Indonesia	9772.6	61058.2	2977819.0	7427922.0	0.16	0.40	-0.43	4	-0.24	4	0.008220092	-0.00197974	4	1.43	4
Malaysia	59494.6	104707.2	2977819.0	7427922.0	0.57	0.40	0.17	2	0.17	2	0.014096432	0.00235840	2	0.83	2
Singapore	97859.6	159963.3	2977819.0	7427922.0	0.61	0.40	0.21	1	0.21	1	0.021535404	0.00454112	1	0.79	1
Thailand	35191.0	80323.3	2977819.0	7427922.0	0.44	0.40	0.04	3	0.04	3	0.010813697	0.00040250	3	0.96	3
SITC (Rev3) 8: Miscellaneous manufactured articles															
Indonesia	8484.7	61058.2	1961069.0	7427922.0	0.14	0.26	-0.31	1	-0.13	1	0.008220092	-0.00102794	1	1.31	1
Malaysia	8851.9	104707.2	1961069.0	7427922.0	0.08	0.26	-0.51	3	-0.18	3	0.014096432	-0.00252994	3	1.51	3
Singapore	13410.0	159963.3	1961069.0	7427922.0	0.08	0.26	-0.52	4	-0.18	4	0.021535404	-0.00388028	4	1.52	4
Thailand	10621.0	80323.3	1961069.0	7427922.0	0.13	0.26	-0.33	2	-0.13	2	0.010813697	-0.00142508	2	1.33	2

2004															
SITC (Rev3) 5: Chemicals															
Indonesia	4015.9	64483.5	984506.0	9039523.0	0.06	0.11	-0.27	3	-0.05	3	0.007133507	-0.00033266	2	1.27	3
Malaysia	7096.0	126500.2	984506.0	9039523.0	0.06	0.11	-0.32	4	-0.05	4	0.013994123	-0.00073912	4	1.32	4
Singapore	23022.9	198632.6	984506.0	9039523.0	0.12	0.11	0.03	1	0.01	1	0.021973792	0.00015372	1	0.97	1
Thailand	6909.1	96247.9	984506.0	9039523.0	0.07	0.11	-0.21	2	-0.04	2	0.010647453	-0.00039531	3	1.21	2
SITC (Rev3) 6: Manufactured goods															
Indonesia	12866.5	64483.5	2378826.0	9039523.0	0.20	0.26	-0.14	1	-0.06	1	0.007133507	-0.00045388	1	1.14	1
Malaysia	9789.9	126500.2	2378826.0	9039523.0	0.08	0.26	-0.55	3	-0.19	3	0.013994123	-0.00259966	3	1.55	3
Singapore	8234.4	198632.6	2378826.0	9039523.0	0.04	0.26	-0.73	4	-0.22	4	0.021973792	-0.00487165	4	1.73	4
Thailand	11815.1	96247.9	2378826.0	9039523.0	0.12	0.26	-0.36	2	-0.14	2	0.010647453	-0.00149492	2	1.36	2
SITC (Rev3) 7: Machinery and transport equipment															
Indonesia	11522.7	64483.5	3586907.0	9039523.0	0.18	0.40	-0.38	4	-0.22	4	0.007133507	-0.00155589	4	1.38	4
Malaysia	69047.0	126500.2	3586907.0	9039523.0	0.55	0.40	0.16	2	0.15	2	0.013994123	0.00208544	2	0.84	2
Singapore	120305.4	198632.6	3586907.0	9039523.0	0.61	0.40	0.21	1	0.21	1	0.021973792	0.00458956	1	0.79	1
Thailand	42776.5	96247.9	3586907.0	9039523.0	0.44	0.40	0.06	3	0.05	3	0.010647453	0.00050723	3	0.94	3
SITC (Rev3) 8: Miscellaneous manufactured articles															
Indonesia	9196.0	64483.5	2378826.0	9039523.0	0.14	0.26	-0.30	1	-0.12	1	0.007133507	-0.00085993	1	1.30	1
Malaysia	10712.8	126500.2	2378826.0	9039523.0	0.08	0.26	-0.51	3	-0.18	3	0.013994123	-0.00249756	3	1.51	3
Singapore	15519.1	198632.6	2378826.0	9039523.0	0.08	0.26	-0.54	4	-0.19	4	0.021973792	-0.00406578	4	1.54	4
Thailand	12038.6	96247.9	2378826.0	9039523.0	0.13	0.26	-0.36	2	-0.14	2	0.010647453	-0.00147019	2	1.36	2

2005															
SITC (Rev3) 5: Chemicals															
Indonesia	4493.0	85659.9	1091752.0	10276731.0	0.05	0.11	-0.34	4	-0.05	3	0.008335326	-0.00044830	3	1.34	4
Malaysia	7625.4	140962.9	1091752.0	10276731.0	0.05	0.11	-0.33	3	-0.05	4	0.013716706	-0.00071519	4	1.33	3
Singapore	26135.1	229652.3	1091752.0	10276731.0	0.11	0.11	0.03	1	0.01	1	0.022346824	0.00016911	1	0.97	1
Thailand	8912.6	110110.0	1091752.0	10276731.0	0.08	0.11	-0.14	2	-0.03	2	0.010714497	-0.00027100	2	1.14	2
SITC (Rev3) 6: Manufactured goods															
Indonesia	14401.5	85659.9	2614786.0	10276731.0	0.17	0.25	-0.20	1	-0.09	1	0.008335326	-0.00071945	2	1.20	1
Malaysia	10358.1	140962.9	2614786.0	10276731.0	0.07	0.25	-0.55	3	-0.18	3	0.013716706	-0.00248213	3	1.55	3
Singapore	10456.6	229652.3	2614786.0	10276731.0	0.05	0.25	-0.70	4	-0.21	4	0.022346824	-0.00466837	4	1.70	4
Thailand	13637.4	110110.0	2614786.0	10276731.0	0.12	0.25	-0.35	2	-0.13	2	0.010714497	-0.00130015	1	1.35	2
SITC (Rev3) 7: Machinery and transport equipment															
Indonesia	13602.3	85659.9	3932851.0	10276731.0	0.16	0.38	-0.41	4	-0.22	4	0.008335326	-0.00186628	4	1.41	4
Malaysia	76544.4	140962.9	3932851.0	10276731.0	0.54	0.38	0.17	2	0.16	2	0.013716706	0.00219901	2	0.83	2
Singapore	134880.1	229652.3	3932851.0	10276731.0	0.59	0.38	0.21	1	0.20	1	0.022346824	0.00457279	1	0.79	1
Thailand	49192.2	110110.0	3932851.0	10276731.0	0.45	0.38	0.08	3	0.06	3	0.010714497	0.00068637	3	0.92	3
SITC (Rev3) 8: Miscellaneous manufactured articles															
Indonesia	10272.4	85659.9	2614786.0	10276731.0	0.12	0.25	-0.36	2	-0.13	1	0.008335326	-0.00112124	1	1.36	2
Malaysia	11740.0	140962.9	2614786.0	10276731.0	0.08	0.25	-0.51	3	-0.17	3	0.013716706	-0.00234766	3	1.51	3
Singapore	15582.8	229652.3	2614786.0	10276731.0	0.07	0.25	-0.58	4	-0.19	4	0.022346824	-0.00416955	4	1.58	4
Thailand	13351.1	110110.0	2614786.0	10276731.0	0.12	0.25	-0.35	1	-0.13	2	0.010714497	-0.00142701	2	1.35	1

2006															
SITC (Rev3) 5: Chemicals															
Indonesia	8724.5	100798.6	1224797.0	11887549.0	0.09	0.10	-0.09	2	-0.02	2	0.008479343	-0.00013972	2	1.09	2
Malaysia	8756.5	160669.2	1224797.0	11887549.0	0.05	0.10	-0.31	4	-0.05	4	0.013515755	-0.00065594	4	1.31	4
Singapore	30837.6	271800.9	1224797.0	11887549.0	0.11	0.10	0.05	1	0.01	1	0.022864335	0.00023835	1	0.95	1
Thailand	10440.3	130580.0	1224797.0	11887549.0	0.08	0.10	-0.13	3	-0.02	3	0.010984602	-0.00025351	3	1.13	3
SITC (Rev3) 6: Manufactured goods															
Indonesia	7702.1	100798.6	2964191.0	11887549.0	0.08	0.25	-0.53	3	-0.17	2	0.008479343	-0.00146643	2	1.53	3
Malaysia	13121.7	160669.2	2964191.0	11887549.0	0.08	0.25	-0.51	2	-0.17	3	0.013515755	-0.00226637	3	1.51	2
Singapore	11577.5	271800.9	2964191.0	11887549.0	0.04	0.25	-0.71	4	-0.21	4	0.022864335	-0.00472736	4	1.71	4
Thailand	16424.4	130580.0	2964191.0	11887549.0	0.13	0.25	-0.33	1	-0.12	1	0.010984602	-0.00135739	1	1.33	1
SITC (Rev3) 7: Machinery and transport equipment															
Indonesia	15411.3	100798.6	4441023.0	11887549.0	0.15	0.37	-0.42	4	-0.22	4	0.008479343	-0.00187134	4	1.42	4
Malaysia	84443.3	160669.2	4441023.0	11887549.0	0.53	0.37	0.17	2	0.15	2	0.013515755	0.00205421	2	0.83	2
Singapore	156779.5	271800.9	4441023.0	11887549.0	0.58	0.37	0.21	1	0.20	1	0.022864335	0.00464675	1	0.79	1
Thailand	58371.1	130580.0	4441023.0	11887549.0	0.45	0.37	0.09	3	0.07	3	0.010984602	0.00080658	3	0.91	3
SITC (Rev3) 8: Miscellaneous manufactured articles															
Indonesia	1557.0	100798.6	2964191.0	11887549.0	0.02	0.25	-0.88	4	-0.23	4	0.008479343	-0.00198337	2	1.88	4
Malaysia	13454.7	160669.2	2964191.0	11887549.0	0.08	0.25	-0.50	2	-0.17	2	0.013515755	-0.00223836	3	1.50	2
Singapore	17742.0	271800.9	2964191.0	11887549.0	0.07	0.25	-0.59	3	-0.18	3	0.022864335	-0.00420879	4	1.59	3
Thailand	14318.6	130580.0	2964191.0	11887549.0	0.11	0.25	-0.39	1	-0.14	1	0.010984602	-0.00153453	1	1.39	1

An immediate observation for 2002 is that all four methods show full agreement in all sectors. For both 2003 and 2004, only the NRCA index exhibits dissimilarity in positional rankings in the chemicals sector while these measures were in agreement in all other sectors. In 2005, all four measures were in agreement except in the chemicals and miscellaneous manufactured articles sectors where both the ARCA and NRCA were in agreement but differ with the SRCA and GRCA both of which were in turn in agreement in the positional rankings. Also in 2005 only the NRCA differ with the other three measures in positional rankings in SITC 6 manufactured goods. We have a repeat of 2005 again in 2006 where ARCA and NRCA combine to agree and differ with SRCA and GRCA both of which were again in agreement in the manufactured goods sector. The only further differences in the results tend to be only for SITC 8 (Miscellaneous manufactures) where the rankings of NRCA differ a little in comparison with other indices.

In context of the chemicals sector, all four measures show Singapore has a comparative advantage in the chemicals sector. For example, for all the four measures employed, although Singapore has comparative disadvantage with respect to rest of the world (ROW), it has advantage in chemicals with respect to its ASEAN peers for each year from 2002 to 2006. Further results show that for 2005, as expected Singapore again has the lead in the Chemicals (SITC 5) and Transport equipment sectors (SITC 7), and Indonesia in the Manufactured goods (SITC 6) from 2002 to 2005 and only in 2005 where it was ranked second in positional ranking by the NRCA. Malaysia was found to be ahead in the positional rankings in the transport and machinery equipment (SITC 7) while Thailand in the Miscellaneous manufactures (SITC 8) sector. Likewise, when we extract the differences in sectoral rankings for these ASEAN countries from 2002 to 2006 we see a common pattern of consensus among the four measures. What we are primarily interested in this paper is how

these four measures compare, and employing these data, we see that the types of sectors from ASEAN countries i.e. their rankings in RCA and international competitiveness do differ but only slightly.

In future work we will investigate whether ranking patterns have changed over time and how or if they will change with closer ASEAN integration, the emergence of China or the (inevitable) impending global recession.

IV SUMMARY AND CONCLUSIONS

In this paper we have briefly outlined the methodologies behind existing measures of RCA and examined how the nature of RCA values differs across ASEAN countries between 2002 and 2006. One of the paper's objectives was to examine the nature of Singapore's comparative advantage in manufacturing in particular the position of its chemical industry compared to its ASEAN neighbours. In line with this objective, the widely used Balassa (1965) index of revealed comparative advantage (BRCA) was discussed and its properties discussed. We also considered the extensions to the BRCA index and conducted proportionality tests on these extensions and illustrated the geometry of these measures.

We then took the four proportionate indices to data obtained from the comtrade database for industries and sectors at the SITC (Rev 3) 3-digit level that is used to proxy an industry. Our empirical exercise has demonstrated that the results in classifying sectoral competitiveness of these countries by these four different approaches do not differ except for a few minor cases. In particular the results show that all four approaches do not differ much in measuring RCA

and international specialisation for this limited number of countries and years. The results of all four measures showed that Singapore tends to have a comparative advantage in the chemicals sector relative to its Asean neighbours. Malaysia was found to be international competitive compared to its ASEAN neighbours in machinery and transport equipment in these years while Indonesia was in the manufactured goods sector and finally Thailand was documented to have international competitiveness in the miscellaneous manufactures sector.

Future work will consider lower levels of aggregation and also to conduct further analysis on their functional forms and behaviour on these classes of functions (see Azhar and Elliott, 2008). Further tests of reliability and significance involving richer data sets to include conducting further empirical analysis of the relationship of ASEAN RCA values with theoretically relevant explanatory variables would also be interesting.

REFERENCES

Amiti, M. (1999), Specialization Patterns in Europe, *Review of World Economics,* Vol. 135(4), pp. 573-593.

Aquino, A. (1981), Changes over Time in the Pattern of Comparative Advantage in Manufactured Goods: An Empirical Analysis for the Period 1972-1974, *European Economic Review*, Vol. 15, pp. 41-62.

Azhar, A.K.M. and Robert J.R. Elliott C.R. Milner (1998), Static and Dynamic Measurement of Intra industry Trade and Adjustment: A Geometric Reappraisal, *Review of World Economics,* Vol 134 (3), pp 404-422.

Azhar, A.K.M. and Robert J.R. Elliott (2003), On the Measurement of Trade induced Adjustment. *Review of World Economics,* Vol 139 (3), pp 419-439.

Azhar, A.K.M. and Robert J.R. Elliott (2006), On the Measurement of Product Quality in Intra industry Trade, *Review of World Economics,* Vol 142(3), 476-495.

Azhar, A.K.M. and Elliott, R.J.R. (2008), Measure for Measure: A Geometric Interpretation of RCA Indices, *mimeo*.

Azhar, A.K.M., Elliott, R.J.R. and Violet, T.M.H. (2009), On Quality-Based Measures of Revealed Comparative Advantage, *mimeo*.

Balassa, B. (1965), Traded Liberalization and Revealed Comparative Advantage. *The Manchester School of Economic and Social Studies*, Vol. 33, pp. 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*, Vol 69, pp157-161.

Bernhofen, D. (2005a), Gottfried Haberler's 1930 Reformulation of Comparative Advantage in Retrospect, *Review of International Economics* 13(5), pp 997-1000.

Bernhofen, D. (2005b), The Empirics of Comparative Advantage: Overcoming the Tyranny of Nonrefutability. *Review of International Economics,* Vol. 13 (5) pp 1017-1023.

Bernhofen, D. and John C Brown (2004) A Direct Test of the Theory of Comparative Advantage: The Case of Japan, *Journal of Political Economy*, Vol. 112 (1),pp 48-67.

Bernhofen, D. and John C. Brown (2005) An Empirical Assessment of the Comparative Advantage Gains from Trade: Evidence from Japan, *American Economic Review*, Vol 95(1), 208-225.

Bowen, H.P. (1983), On the Theoretical Interpretation of Indices of Trade Intensity and Revealed Comparative Advantage, *Review of World Economics*, Vol. 119(3), pp. 464-72.

Brulhart, M. (2001), Growing Alike or Growing Apart? Industrial Specialization of the EU Countries., *In EMU and Its Impact on Europe and Developing Countries*, ed. C. Wyplosz,

Crafts, N. and Thomas, M. (1986), Comparative Advantage in UK Manufacturing Trade 1910-1935, *Economic Journal*, Vol. 96, pp.629-645.

Das, D. (1998). Changing Comparative Advantage and the Changing Composition of Asian Exports, *The World Economy,* Vol. 21, No.1, pp. 121-140.

Davies, D.R. (1997), Critical Evidence on Comparative Advantage? North-North Trade in a Multilateral World, *Journal of Political Economy*, Vol. 105, 5, pp. 1051-1060.

De Benedictis, L. (2005), Three Decades of Italian Comparative Advantages, *The World Economy*, Vol. 28, No. 11, pp. 1679-1709.

Deardorff, A.V. (1980), The General Validity of the Law of Comparative Advantage, *Journal of Political Economy*, Vol. 88, pp. 464-957.

Drabicki, J.Z. and Takayama, A. (1979), An Antinomy in the Theory of Comparative Advantage, *Journal of International Economics*, Vol. 9, pp. 211-23.

Ferto, I and Hubbard, L. (2003), Revealed Comparative Advantage and Competitiveness in Hungarian Agri Food Sectors. *The World Economy*, Vol 26(2), pp 247-249.

Hausmann, R., Hwang, J. and Rodrik, D. (2007), What You Export Matters. *Journal of Economic Growth*, Vol. 12 (1), pp. 1-25.

Hillman, A.L. (1980), Observations on the Relation between "Revealed Comparative Advantage" and Comparative Advantage as indicated by Pre-Trade Relative Prices, *Review of World Economics*, Vol. 116, pp. 315-321.

Hoen, A.R. and Oosterhaven, J. (2006). On the Measurement of Comparative Advantage. *Annals of Regional Science*, Vol. 40, pp. 677-691.

Jones, R.W. (1961), Comparative Advantage and the Theory of Tariffs: A Multi-Country, Multi-Commodity Model, *Review of Economic Studies*, Vol. 28, pp. 161-175.

Laursen, K. (2000), *Specialization, Trade and Growth*, Routledge.

Laursen, K.(1998), Revealed Comparative Advantage and the Alternatives as Measures of International Specialisation, Department of Industrial Economics and Strategy, Copenhagen Business School.

Lederman, D., M. Olarreaga, and E. Rubiano (2008), Trade Specialization in Latin America: The Impact of China and India, *Review of World Economics*, Vol 144 (2), pp 248-271.

Lim, K.T. (1997), Analysis of North Korea's Foreign Trade by Revealed Comparative Advantage, *Journal of Economic Development*, Vol. 22, pp. 97-117.

Mahani Zainal Abidin and Wai Heng Loke (2008), Revealed Comparative Advantage of Malaysian Exports: The Case for Changing Export Composition, *Asian Economic Papers*, Vol 7(3), pp 130-147.

Matsuyama, K. (1995), Complementarities and Cumulative Processes in Models of Monopolistic Competition, *Journal of Economic Literature*, Vol. 33, pp. 701-29.

Menon, J. and Dixon, P (1997), Intra versus Inter industry Trade: Relevance for Adjustment Costs, *Review of World Economics*, Vol 133, pp 164-169.

Proudman, J. and Redding, S, (2000), Evolving Patterns of International Trade, *Review of International Economics*, Vol 8 No. 3, pp. 373-396.

Travis, W.P. (1964), *The Theory of Trade Protection*, Cambridge, Mass.: Harvard University Press.

Travis, W.P. (1972), Production, Trade, and Protection When There are Many Commodities and Two Factors, *American Economic Review*, Vol. 62, pp. 87-106.

van Hulst, N.R., Mulder, R. and Soete, L.L.G. (1991), Exports and Technology in Manufacturing Industry, *Review of World Economics*, Vol. 127, pp. 246-264.

Vollrath, T.L. (1991) A Theoretical Evaluation of Alternative Trade Intensity Measures of Revealed Comparative Advantage. *Review of World Economics*, Vol. 127(2), pp. 265-280.

Yu, R., Cai, J. And Leung, P. (2008), The Normalized Revealed Comparative Advantage Index, *Annals of Regional Science*, DOI 10.1007/s00168-008-0213-3.