DANISH RESEARCH UNIT FOR INDUSTRIAL DYNAMICS

DRUID Working Paper No. 98-30

Revealed Comparative Advantage and the Alternatives as Measures of International Specialisation

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December 1998

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3rd. December 1998

Abstract

The paper is an analysis of Balassa's 'revealed comparative advantage' (*RCA*). The papers shows that when using the *RCA*, it should always be adjusted in such a way, so that it becomes symmetric. The conclusion is based on a theoretical discussion of the properties of the measure, but also on convincing empirical evidence, based on the Jarque-Bera test of normality of the error terms from regressions, using both the *RCA* and the 'Revealed Symmetric Comparative Advantage' (the *RSCA).*

The *RSCA* is also compared to other measures of international trade specialisation. These measures included the Michaely index and the chi square measure. The conclusion emerging from the analysis is that the *RSCA* is - on balance - the best measure of comparative advantage.

Keywords

revealed comparative advantage, international specialisation.

JEL Classification

C43 F14.

ISBN(87-7873-069-4)

Contents

1. INTRODUCTION

More than 30 years ago Bela Balassa published a paper (Balassa, 1965), using for the first time, the measure of 'revealed comparative advantage' (*RCA*). Since then the measure has been applied in numerous reports (e.g. UNIDO, 1986; World Bank, 1994) and academic publications (e.g. Aquino, 1981; Crafts and Thomas, 1986; van Hulst *et al.*, 1991; Lim, 1997), as a measure of international trade specialisation. This paper is an analysis of the properties of the *RCA* index, mainly from an empirical point of view. The paper is organised as follows. Firstly, Section 2, contains a description of the *RCA* index, and the values of the index when compared for countries across sectors on the one hand, and across countries for each sector on the other hand. In Section 3, it is argued that when using the *RCA*, it should always (at least in econometric analysis) be adjusted in such a way, that it becomes symmetric. Section 4, compares the adjusted *RCA* (labelled the 'revealed symmetric comparative advantage' or '*RSCA*' in short) to other measures of international trade specialisation, used in the literature. These other measures include the Michaely index and the chi square measure. Finally, Section 5 sums up.

2. TRADE SPECIALISATION OF COUNTRIES

Revealed Comparative Advantage (Balassa, 1965) can be defined as:

$$RCA_{ij} = \frac{X_{ij} / \sum_i X_{ij}}{\sum_j X_{ij} / \sum_i \sum_j X_{ij}} . \qquad (1)$$

The numerator represents the percentage share of a given sector in national exports - X_{ij} are exports of sector *i* from country *j*. The denominator represents the percentage share of a given sector in OECD exports. The *RCA* index, thus, contains a comparison of national export structure (the numerator) with the OECD export structure (the denominator). When *RCA* equals 1 for a given sector in a given country, the percentage share of that sector is identical with the OECD average. Where *RCA* is above 1 the country is said to be specialised in that sector and vice versa where *RCA* is below 1. However, since the *RCA* turns out to produce an output which cannot be compared on both sides of 1[1], the index is made symmetric, obtained as *(RCA-1)/(RCA+1)*; this measure ranges from -1 to +1. The measure is labelled 'Revealed Symmetric Comparative Advantage' (*RSCA*).

The Appendix Table contains specialisation figures among 19 OECD countries for 1990, based on calculations on the OECD STAN database (1995 edition). From the Appendix Table, it can be seen that among *OECD catching-up countries* Spain is specialised in (among other things) petroleum refineries; stone, clay and glass; shipbuilding; and motor vehicles. Areas of under-specialisation include office machinery and computers; communication equipment and semiconductors; and instruments. Among *small high-income countries* it can for instance be seen that Denmark is specialised in food, drink & tobacco; wood, cork and furniture; and in pharmaceuticals. Areas of relative weakness include motor vehicles; and office machinery. Among the *large high-income countries*, Germany has a relative strength in machinery (electrical and non-electrical), as well as in motor vehicles. Areas of relative weakness include petroleum refineries, and sectors producing information and communication technology goods, more generally. The US is, on the other hand, specialised in office machinery and computers, as well as in aerospace, while areas of relative weaknesses include textiles, footwear and leather; stone, clay and glass; and shipbuilding.

The Appendix Table can also be helpful in illustrating the criticism of the *RCA* measure for not reflecting comparative advantage for each country, across sectors (Yeats, 1985). If one looks at Australia's specialisation in 'textiles, footwear and leather' it can be seen that among the exports of Australia, this product group ranks fourth, while Australia only ranks sixth within this product group. Yeats (1985) made a correlation between the ranks across sectors and the ranks across 47 countries based on 1976-1978 trade data (aggregated over those three years). He found significant correlation coefficients between the two in 60 per cent of the cases only (5 per cent level), and based his forceful criticism on this finding. In order to test the results of Yeats we made a similar analysis to that of Yeats, based on observations for every year 1970-1993, 22 sectors and the 19 OECD countries in the Appendix Table (ranked within each year). While it is true that large differences in country sizes can cause problems, when applying the *RCA* across

1 A fuller discussion of this topic is present in Section 3.

countries, it seems likely that Yeats' results overestimate the problem (at least when more developed countries are compared to each other, as in our case), as we found less than two per cent insignificant rank correlations (1 per cent level) for each of the 19 countries and 24 years (456 correlations). None of the rank correlations were insignificant at the 5 per cent level. When pooling all the data (10032 observations), we found a (highly significant) rank correlation coefficient of 0.80.

3. THE SYMMETRIC *RCA*

In the previous section the *RCA* index was made symmetric, although not much explanation was given for following this procedure. However, this section will argue that the index should always be made symmetric (when used in econometric analysis)[2], because the 'pure' *RCA* is basically not comparable on both sides of unity, as the index ranges from zero to one, if a country is said not to be specialised in a given sector, while the value of the index ranges from one to infinity, if a country is said to be specialised. Vollrath (1991) suggests to take the logarithm to the *RCA*, as a solution to this problem. However, in the case that a country exports zero in a sector, the index is not defined.

This section will illustrate the issue by discussing it in the context of the question of whether countries tend to decrease or increase the level of specialisation. The methodology will only briefly be presented in this paper, while the reader can consult Dalum, Laursen and Villumsen (1998) in particular (or Cantwell, 1989), for further detail. Stability (and specialisation trends) is tested by means of the following regression equation (country by country):

$$RSCA_{ij}^{t_2} = \alpha_i + \beta_i RSCA_{ij}^{t_1} + \epsilon_{ij} \qquad (2)$$

The superscripts t_1 and t_2 refer to the initial year and the final year, respectively. The dependent variable, *RSCA* at time t_2 for sector *i*, is tested against the independent variable which is the value

2 Another and very similar measure to the *RSCA* has been applied by Hariolf Grupp in various publications (see e.g. Grupp, 1994). The so-called *RPA* can be defined as:
$RPA_{ij} = (RTA^2-1)/(RTA^2+1) * 100$,
where *RPA* is short for 'Revealed Patent Advantage', and *RTA* is short for 'Revealed Technological Advantage', calculated in an analogous way to the *RCA* (see Equation 1), but based on US patent data.

Table 1: An example of the effect of RCA vs. RSCA

	RCA_{t-1}	RCA_t	$RSCA_{t-1}$	$RSCA_t$	Specialisation/de-spec.
Automobiles	8	4	7/9	3/5	D
Aeroplanes	1/4	1/8	-3/5	-7/9	S
Computers	1	2	0	1/3	S
Chemicals	1/2	1	1/3	0	D
Result for all sectors	De-specialisation		Neutral		

of the *RSCA* in the previous year t_1. α and β are standard linear regression parameters and ϵ is a residual term. Basically, the size of β* measures how stable the specialisation pattern of a country has been, between the two periods. If β* is low, one can talk about a high degree of turbulence, while the pattern can be said to be unchanged, if β* is not significantly different from one. β*/R* (R* is the correlation coefficient from the regression) measures whether the level of specialisation has gone up or down between the two periods (an increase or a fall in dispersion of specialisation). If β*/R* > 1, specialisation increases, while specialisation decreases, if β*/R* < 1.

However, if the non-adjusted *RCA* is used in estimating Equation 2, one can obtain biassed estimates (an example of an application of the non-adjusted RCA includes Crafts and Thomas, 1986). One way of expressing the problem is that the Balassa measure has the disadvantage of an inherent risk of lack of normality because it takes values between zero and infinity with a (weighted) average of 1.0. A skewed distribution violates the assumption of normality of the error term in regression analysis, thus not producing reliable *t*-statistics. Another way of putting the problem is that the use of the non-adjusted *RCA* in regression analysis gives much more weight to values above one, when compared to observations below one. The problem can be illustrated by an example. If for instance, a country increases its *RCA* value from 1/2 to 1, between two periods (as in Table 1), specialisation in this sector has increased by factor two. Similarly, if the *RCA* value goes up from 1 to 2, specialisation has increased by factor two. However, the absolute differences are 1/2 and 1, respectively.

Table 1 displays the problem in the context of an increased or decreased level of

Table 2: Differences between increased or decreased specialisation, using RCA and RSCA respectively, 1971-1991. (n=19 sectors).

	RSCA			RCA		
	β*	β*/R*	Jarque-Bera test (*p*-value)	β*	β*/R*	Jarque-Bera test (*p*-value)
Australia	0.83 *	0.97	0.1361	0.99 *	1.20	0.0001
Austria	0.87 *	0.95	0.3355	0.80 * #	0.88	0.4875
Belgium	0.99 *	1.06	0.5212	0.86 * #	0.92	0.6226
Canada	0.80 *	0.98	0.8990	0.80 * #	0.86	0.3142
Denmark	0.89 *	0.94	0.2970	1.04 *	1.16	0.0001
Finland	0.74 * #	0.91	0.2588	0.84 * #	0.89	0.0001
France	0.63 * #	0.94	0.6430	0.64 * #	0.97	0.8434
Germany (West)	0.43 * #	0.67	0.0524	0.58 * #	0.77	0.0689
Greece	0.94 *	1.04	0.5236	0.83 *	1.05	0.0001
Italy	0.72 * #	0.93	0.6375	0.69 * #	0.96	0.9402
Japan	0.94 *	1.01	0.4987	0.77 * #	0.86	0.3432
The Netherlands	0.68 * #	0.81	0.6720	0.84 * #	0.88	0.6980
New Zealand	1.08 *	1.20	0.7572	0.86 * #	0.90	0.0001
Norway	0.83 *	0.94	0.0163	1.44 * #	1.58	0.0076
Portugal	0.60 * #	0.87	0.9373	0.68 *	1.05	0.1725
Spain	0.51 * #	0.76	0.9591	0.55 * #	0.83	0.4504
Sweden	0.65 * #	0.85	0.4358	0.78 * #	0.90	0.0800
United Kingdom	1.02 *	1.35	0.5817	1.05 *	1.28	0.5842
United States	0.81 * #	0.87	0.7089	0.72 * #	0.74	0.9748
Mean	0.79	0.95		0.83	0.98	

* denotes significantly different from zero at the 10% level.
# denotes significantly different from unity at the 10% level.

specialisation, between two periods (*t-1* and *t*). In the example specialisation has gone up or down by exactly the same percentages, on both sides of unity. However, since the changes in the *RCA*s above one are numerically much larger than the values below one, the conclusion, when using the Balassa figures is that the country has de-specialised, when in fact it remained neutral.

Table 2 reproduces the results of the estimations based on Equation 2, both using the original Balassa figures, and by using the *RSCA*. The results show that (at least in this case) the fall in specialisation between 1971-1991 is less outspoken, when using the unadjusted *RCA*. The Table also contains the results of the Jarque-Bera test for normality of the error terms. The hypothesis of normality of the error terms can be rejected for 2 out of 19 regressions (10 per cent level), when using the adjusted *RCA*, while the hypothesis can be rejected for 8 out 19 regressions, when the standard Balassa figures are applied.

4. THE *RCA* AND THE ALTERNATIVES

Although widely used, the *RCA* is not the only measure, which has been applied for measuring international trade specialisation. Other measures include the Michaely index and the chi square measure.[3] This section will define the two alternative measures, and then compare each individual measure to the *RSCA*.

The Michaely index can be defined as:

$$MI_{ij} = X_{ij} / \sum_i X_{ij} - M_{ij} / \sum_i M_{ij}, \qquad (3)$$

where X_{ij} are exports of sector *i* from country *j*, and M_{ij} are imports for sector *i* to country *j*. The first part of the formula (before the minus sign) represents the percentage share of a given sector in national exports, while the latter part represents the percentage share of a given sector in national imports. The measure ranges between [-1;1], with a neutral value of zero. If the value of the index is positive, a country is specialised in a sector, while given a negative value, a country is said to be under-specialised in a sector. The indicator was developed by Michael Michaely (1962/67), as an 'index of dissimilarity' for a country. In the original contribution, Michaely sums over the sectors for each country, so that the larger the value of the index, the less similar is the commodity composition of the country's exports and imports. The index takes the value of zero in the case of perfect 'similarity'. Nevertheless, since the original contribution of Michaely, a number of researchers, working on international trade (e.g. Kol and Mennes, 1985; Webster and Gilroy, 1995), has applied the index, as a measure of trade specialisation at the level of the sector.

Another *very* similar measure has been introduced by CEPII (1983), termed the Contribution to the Trade Balance (*CTB*). The *CTB* can be defined as:

3 Other measures include for example Bowen's (1983) *net trade index*. However, this particular index has been criticised for a number of reasons, including the underlying assumption of identical and homothetic preferences across countries (see Ballance *et al.*, 1985).

$$CTB_{ij} = \frac{X_{ij} - M_{ij}}{(\sum_i X_{ij} + \sum_i M_{ij})/2} * 100 - \frac{\sum_i X_{ij} - \sum_i M_{ij}}{(\sum_i X_{ij} + \sum_i M_{ij})/2} * \frac{X_{ij} + M_{ij}}{\sum_i X_{ij} + \sum_i M_{ij}} * 100, \qquad (4)$$

where the letters denote the same, as in Equation 3. The measure ranges between [-400;400]. Values greater than zero (less than zero) of the *CTB* index identify those sectors which give a contribution higher (lower) than their percentage share in the country's total trade. The measure has e.g. been applied by Amendola *et al.* (1992), Amable (1997) and Guerrieri (1997). In this paper we shall compare only the Michaely index to the *RSCA* index, since the *CTB* measure correlates strongly with the Michaely index by definition, leaving the pros and cons of the Michaely index and the *CTB* index alike. The two measures differ only, if very large trade unbalances are present for a given country. Hence, in the real world the two measures are close to being identical.[4]

In comparison with the *RSCA*, the Michaely index is a measure of relative net export in a given sector. However, when comparing the *RSCA* to the Michaely index, the type and size of intra industry-trade becomes of importance. One advantage of the index is the elimination of re-export as a source of distortion, when calculating comparative advantage. However, when intra-industry trade is due to the fact that firms in other sectors purchase equipment not only domestically, but also by means of imports, the Michaely index will underestimate the comparative advantage of a country in a given sector. An example of this is given in Table 3, in the case of the Danish specialisation in shipbuilding. It can be seen that the value of the *RSCA* points to being (rather strongly) specialised in this sector, whereas the Michaely index points to being slightly under-specialised in this sector. The explanation is that Denmark has a strong shipping sector, not only buying ships from domestic shipyards. So in this case, this paper will argue that the *RSCA* is the better measure of comparative advantage. In general it seems reasonable to argue that the benefit of avoiding problems, due to re-exports are smaller than the (to some extent arbitrary)[5] demand of other sectors in the economy. Another argument for using

4 In a correlation between the two measures across 24 years and 22 sectors (528 observations), for 19 countries, all countries displayed correlation coefficients of about 0.99.

5 Following Linder (1961) and Krugman (1980), it can be argued that e.g. the relative strength of the Danish shipyards is, at least partially, due to the strength of the shipping industry (and maybe vice-
(continued...)

the *RSCA* rather than the Michaely index, is that the *RSCA* can be applied in an analogous way on patent data (see e.g. Soete, 1981), as well as on e.g. investment data. The Michaely index can be used on trade data only.

The χ^2 measures the sum of the squared difference between the export distribution of a given country and the total OECD divided by the OECD export distribution. The definition of the χ^2 measure can be set up as follows:

$$\chi^2 = [(X_{ij}/\sum_i X_{ij}) - (\sum_j X_{ij}/\sum_i\sum_j X_{ij})]^2/(\sum_j X_{ij}/\sum_i\sum_j X_{ij}), \quad (5)$$

where the letters denote the same as in the definition of the *RCA*, in Equation 1. The χ^2 measures the squared difference between the export distribution of a given country and the total OECD divided by the OECD export distribution. The size of χ^2 is an indication of how strongly each country is specialised. The more a country differs from OECD, the greater the value. In the original formulation, Archibugi and Pianta (1992) always sums over the sectors (*i*), in order to arrive at one single number for each country in such a way, that if a country has an export structure exactly similar to the OECD, the value of the indicator will be zero. However, since we want to compare directly to the *RSCA*, we have left out the summation. This procedure does of course not change the properties of the measure. However, a very important difference between the chi square measure and the *RSCA* is that the chi square is only devised to measure the level of specialisation, as it both takes high values, when a country is seen to be (much) less specialised than the average of the countries, and when the country is (much) more specialised in a commodity group as compared to the average of the countries. The measure ranges between [0;∞[, although the index only takes the value of zero, if there is only one country in the world, producing everything. When compared to the *RSCA*, the index has a disadvantage of producing very large values, when one commodity class makes up a large percentage of total exports. An example of this phenomena can be found in Table 3, where the chi square value for Denmark's export of food, drink & tobacco is 5.5, while the second largest value is only 0.95 (indicating

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5(...continued)
versa). However, it would be awkward to argue that Denmark has no comparative advantage in building ships and boats.

Table 3: An example of differences between indices of specialisation: Denmark 1990.

	RSCA	Michaely index	χ^2
Food, drink and tobacco	0.581	0.166	5.527
Textiles, footwear and leather	-0.049	-0.026	0.005
Wood, cork and furniture	0.484	0.023	0.703
Paper and printing	-0.219	-0.032	0.054
Industrial chemicals	-0.271	-0.061	0.204
Pharmaceuticals	0.508	0.022	0.530
Petroleum refineries (oil)	-0.104	-0.015	0.008
Rubber and plastics	0.149	0.000	0.024
Stone, clay and glass	0.011	0.002	0.000
Ferrous metals	-0.363	-0.032	0.106
Non-ferrous metals	-0.577	-0.012	0.127
Fabricated metal products	0.218	0.012	0.109
Non-electrical machinery	0.048	0.030	0.012
Office mach. and computers	-0.458	-0.031	0.165
Electrical machinery	-0.104	-0.008	0.017
Communic. eq. and semiconductors	-0.201	-0.001	0.069
Shipbuilding	0.502	-0.001	0.353
Other transport	-0.633	-0.004	0.030
Motor vehicles	-0.683	-0.034	0.951
Aerospace	-0.414	-0.008	0.130
Instruments	0.023	0.008	0.001
Other manufacturing	-0.514	-0.005	0.082

Danish under-specialisation in motor vehicles). Food, drink & tobacco made up 27 per cent of Danish exports in 1990. Compare this figure to e.g. Danish specialisation in non-electrical machinery (made up just about 13 per cent of total Danish exports in 1990), where the chi square value is 0.012. A difference of no less than factor 461, while the difference between specialisation in the two sectors, using the *RSCA*, is (only) factor 12. One implication of the χ^2 measure bias is that the index is very sensitive to *changes* in the size of large commodity classes, over time.

Table 4 contains correlations between the *RSCA* index and the two other measures discussed in this paper, for each individual country in the STAN database, across 22 sectors and 24 years.

Table 4: Correlations between the RSCA index, and other indices of international trade specialisation; yearly observations 1970-1993, across 22 sectors (n=528).

	Michaely index	χ^2
Australia	0.76	0.68
Austria	0.62	0.76
Belgium	0.35	0.65
Canada	0.75	0.78
Denmark	0.57	0.52
Finland	0.68	0.60
France	0.47	0.76
Germany (West)	0.55	0.77
Greece	0.73	0.58
Italy	0.64	0.59
Japan	0.72	0.75
The Netherlands	0.77	0.77
New Zealand	0.68	0.58
Norway	0.73	0.66
Portugal	0.71	0.54
Spain	0.66	0.68
Sweden	0.71	0.66
United Kingdom	0.37	0.73
United States	0.62	0.73
Average	0.64	0.67

Note: All correlation coefficients different from zero at the 1 per cent level.

For what concerns the χ^2 measure, it has been adjusted in Table 4, so that the index can be directly compared to the other measures[6], as the numerator has been multiplied by -1, if the 'non-squared' numerator was smaller than zero. As already pointed out it should be stressed that the chi square measure has only been used in the literature for measuring the level of specialisation (and hence change in the level), while the other measures also capture the direction of specialisation. However, as shown in Section 3, also the *RSCA* can be used for measuring change in the level of specialisation. A question which arises is then: Do the *RSCA* regressions and the χ^2 measure generally point in the same direction, when it comes to an increased or a decreased

6 The problem is that - as mentioned earlier - that the χ^2 measure *both* takes high values if a country is (much) more specialised in a sector, *and* if a country is (much) less specialised in a sector.

level of specialisation? In order to investigate this question, we pooled seven years[7], and examined whether specialisation went up or down from year to year, using both types of indices (114 observations in total, given six periods and 19 countries). As mentioned earlier, the condition for increased specialisation in the case of the *RSCA* is that $\beta^*/R^* > 1$ ($\beta^*/R^* < 1$ for de-specialisation), while the equivalent condition for the χ^2 measure is $\chi^2_{t2}/\chi^2_{t1} > 1$ ($\chi^2_{t2}/\chi^2_{t1} < 1$ for de-specialisation). The result of a correlation analysis displays a highly significant σ, although the σ equals 0.32 only. So the answer to the question posed above is that the two measures do in general point in the same direction, when it comes to an increased or decreased level of specialisation, but the two measures do certainly not always point in the same direction.

More generally, when looking at measures reflecting the direction of specialisation however, it can be seen from Table 4 that although this paper has stressed differences between the different measures of international specialisation, the measures do in fact correlate for all 19 countries. In this context, it should be stressed that the correlations between the *RSCA* on the one hand, and the chi square measure on the other, was to some extent expected, as the definitions of these two measures applies different combinations of basically the same components.

5. CONCLUSION

This paper has (in Section 3) shown that when using the *RCA*, it should always (at least in econometric analysis) be adjusted in such a way, so that it becomes symmetric. The conclusion was based on a theoretical discussion of the properties of the measure, but also on convincing empirical evidence, based on the Jarque-Bera test of normality of the error terms from regressions, using both the *RCA* and the *RSCA*.

Section 4 compared the *RSCA* to other measures of international trade specialisation, used in the literature. These measures included the Michaely index (and the *CTB* measure) and the chi square measure. The conclusion emerging from the analysis is that the *RSCA* is the best measure of comparative advantage, although all measures have their pros and cons. Nevertheless, the measures correlate rather strongly.

7 The years: 1972; 1975; 1978; 1981; 1984; 1987; and 1990.

REFERENCES

Amable, B. (1997) 'The effect of foreign trade specialisation on growth: Does specialisation in electronics foster growth?', paper presented at the *Conference on Trade, Economic Integration and Social Coherence*, Vienna, Austria, January.

Amendola, M., P. Guerrieri and P. Padoan (1992). 'International Patterns of Technological Accumulation and Trade', *Journal of International and Comparative Economics*, Vol. 1, pp. 173-197.

Aquino, A. (1981). 'Change 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.

Archibugi, D. and M. Pianta (1992). *The Technological Specialisation of Advanced Countries. A Report to the EEC on International Science and Technology Activities*, Dortrecht, Kluwer Academic Publishers.

Balassa, B. (1965). 'Trade Liberalization and 'Revealed' Comparative Advantage', *The Manchester School of Economic and Social Studies*, Vol. 32, pp. 99-123.

Ballance, R., H. Forstner and T. Murray (1985). 'On Measuring Revealed Comparative Advantage: A Note on Bowen's Indicies', *Weltwirtschaftliches Arhiv*, Vol. 121, pp. 346-350.

Bowen, H.P. (1983). 'On the Theoretical Interpretation of Trade Intensity and Revealed Comparative Advantage', *Weltwirtschaftliches Archiv*, Vol. 119, pp. 464-472.

Cantwell, J. (1989). *Technological Innovation and Multinational Corporations*, Oxford, Blackwell.

CEPII (1983). *Economie Mondiale: la montée des tension*, Paris.

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

Dalum, B., K. Laursen and G. Villumsen (1998). 'Structural Change in OECD Export Specialisation Patterns: De-specialisation and 'Stickiness'', *International Review of Applied Economics*, Vol. 12, pp. 447-467.

Grupp, H. (1994). 'The measurement of technical performance of innovations by technometrics and its impact on established technology indicators', *Research Policy*, Vol. 23, pp. 175-193.

Guerrieri, P. (1997) 'The changing world trade environment, technological capability and the competitiveness of the European Industry', paper presented at the *Conference on Trade, Economic Integration and Social Coherence*, Vienna, Austria, January.

Kol, J. and L.B.M. Mennes (1985). 'Intra-industry specialization: Some observations on concepts and measurement', *International Journal of Economics*, Vol. 21, pp. 173-181.

Krugman, P. (1980). 'Scale Economies, Product Differentiation, and the Pattern of Trade', *American Economic Review*, Vol. 70, pp. 950-959.

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

Linder, S.B. (1961). *An Essay on Trade and Transformation*, Stockholm, Almquist and Wiksell.

Michaely, M. (1962/67). *Concentration in International Trade, Contributions to Economic Analysis*, Amsterdam, North-Holland Publishing Company.

Soete, L.L.G. (1981). 'A general Test of the Technological Gap Trade Theory', *Weltwirtschaftliches Archiv*, Vol. 117, pp. 638-666.

UNIDO (1986), 'International comparative advantage in manufacturing: Changing profiles of resources and trade', Unido publication sales no. E86 II B9, Vienna, United Nations Industrial Development Organization.

van Hulst, N., R. Mulder and L.L.G. Soete (1991). 'Exports and Technology in Manufacturing Industry', *Weltwirtschaftliches Archiv*, Vol. 127, pp. 246-264.

Vollrath, T.L. (1991). 'A Theoretical Evaluation of Alternative Trade Intensity Measures of Revealed Comparative Advantage', *Weltwirtschaftliches Archiv*, Vol. 127, pp. 265-280.

Webster, A. and M. Gilroy (1995). 'Labour Skills and the UK's Comparative Advantage with its European Union Partners', *Applied Economics*, Vol. 27, pp. 327-342.

World Bank (1994), 'China: Foreign Trade Reform', Country Study Series, Washington D.C., World Bank.

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*, Vol. 121, pp. 61-73.

Appendix Table: Export specialisation figures (*RSCAs*), for 1990 for 19 OECD countries and the 22 STAN sectors

	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Italy	Japan	Netherl.	New Ze.	Norway	Portugal	Spain	Sweden	UK	US
Food, drink and tobacco	0.65	-0.43	0.10	-0.14	0.58	-0.52	0.23	-0.23	0.52	-0.15	-0.86	0.44	0.77	0.13	-0.04	0.12	-0.57	-0.04	0.01
Textiles, footw. and leather	0.17	0.21	0.13	-0.73	-0.05	-0.29	0.04	-0.06	0.70	0.51	-0.48	-0.03	0.25	-0.62	0.73	0.14	-0.50	-0.06	-0.30
Wood, cork and furniture	-0.76	0.46	-0.03	0.56	0.48	0.58	-0.21	-0.15	-0.52	0.26	-0.86	-0.27	0.16	0.13	0.54	-0.09	0.46	-0.55	-0.13
Paper and printing	-0.48	0.28	-0.18	0.54	-0.22	0.77	-0.14	-0.14	-0.59	-0.34	-0.66	-0.07	0.29	0.34	0.20	-0.12	0.57	-0.15	-0.05
Industrial chemicals	-0.40	-0.14	0.15	-0.22	-0.27	-0.27	0.10	0.08	-0.41	-0.26	-0.19	0.26	-0.54	0.01	-0.36	-0.13	-0.33	0.08	0.05
Pharmaceuticals	-0.10	0.12	0.09	-0.72	0.51	-0.43	0.20	0.04	-0.13	-0.16	-0.61	-0.02	-0.48	-0.48	-0.40	0.01	0.29	0.29	-0.02
Petroleum refineries (oil)	0.43	-0.67	0.21	0.16	-0.10	-0.22	-0.19	-0.39	0.54	-0.06	-0.66	0.55	0.06	0.62	0.22	0.41	0.08	0.08	-0.06
Rubber and plastics	-0.51	0.15	0.05	-0.11	0.15	-0.32	0.14	0.05	-0.33	0.13	-0.11	0.05	-0.31	-0.30	-0.30	0.21	-0.12	-0.01	-0.17
Stone, clay and glass	-0.42	0.28	0.20	-0.38	0.01	-0.24	0.10	-0.02	0.48	0.40	-0.20	-0.15	-0.64	-0.18	0.42	0.34	-0.30	-0.12	-0.31
Ferrous metals	0.08	0.28	0.38	-0.29	-0.36	0.15	0.12	0.02	0.24	-0.03	0.08	-0.14	-0.25	0.20	-0.57	0.18	0.23	-0.07	-0.55
Non-ferrous metals	0.77	0.04	0.19	0.46	-0.58	0.15	-0.06	-0.09	0.46	-0.34	-0.47	-0.08	0.45	0.75	-0.72	-0.10	-0.08	0.03	-0.12
Fabricated metal products	-0.27	0.24	-0.01	-0.19	0.22	0.02	0.04	0.12	-0.39	0.24	-0.21	-0.02	-0.38	-0.08	-0.20	0.05	0.11	-0.07	-0.19
Non-electrical machinery	-0.52	0.11	-0.35	-0.42	0.05	0.04	-0.15	0.15	-0.75	0.17	0.05	-0.27	-0.69	-0.28	-0.56	-0.23	0.13	0.01	0.01
Office mach. and computers	-0.52	-0.49	-0.59	-0.28	-0.46	-0.51	-0.20	-0.28	-0.96	-0.22	0.28	0.02	-0.97	-0.38	-0.75	-0.35	-0.23	0.22	0.28
Electrical machinery	-0.51	0.11	-0.31	-0.46	-0.10	-0.14	0.01	0.11	-0.41	0.02	0.17	-0.21	-0.40	-0.37	0.04	-0.05	-0.06	-0.05	-0.02
Communic. eq.and semicon.	-0.63	0.01	-0.43	-0.16	-0.20	-0.10	-0.22	-0.22	-0.84	-0.42	0.43	-0.19	-0.87	-0.49	-0.28	-0.57	-0.04	-0.02	0.14
Shipbuilding	0.01	-0.67	-0.84	-0.73	0.50	0.60	-0.21	-0.21	-0.60	-0.42	0.44	-0.25	-0.73	0.84	-0.18	0.31	0.06	-0.48	-0.27
Other transport	-0.67	0.13	-0.39	0.24	-0.63	0.11	-0.09	-0.22	-0.94	0.21	0.46	-0.29	-0.95	-0.58	-0.33	-0.36	-0.31	-0.40	-0.26
Motor vehicles	-0.55	-0.21	0.07	0.34	-0.68	-0.60	-0.02	0.12	-0.93	-0.27	0.24	-0.53	-0.93	-0.75	-0.35	0.22	-0.01	-0.23	-0.18
Aerospace	-0.60	-0.91	-0.68	-0.05	-0.41	-0.92	0.11	-0.23	-0.84	-0.30	-0.89	-0.29	-0.93	-0.47	-0.80	-0.28	-0.42	0.34	0.48
Instruments	-0.38	-0.19	-0.55	-0.54	0.02	-0.39	-0.11	0.03	-0.81	-0.30	0.26	0.01	-0.76	-0.34	-0.66	-0.58	-0.10	0.09	0.16
Other manufacturing	-0.13	0.03	0.61	-0.65	-0.51	-0.53	-0.16	-0.25	-0.66	0.28	-0.07	-0.44	-0.55	-0.65	-0.30	-0.28	-0.54	0.32	-0.19

Danish **R**esearch **U**nit for **I**ndustrial **D**ynamics

The Research Programme

The DRUID-research programme is organised in 3 different research themes:

- The firm as a learning organisation

- Competence building and inter-firm dynamics

- The learning economy and the competitiveness of systems of innovation

In each of the three areas there is one strategic theoretical and one central empirical and policy oriented orientation.

Theme A: The firm as a learning organisation

The theoretical perspective confronts and combines the ressource-based view (Penrose, 1959) with recent approaches where the focus is on learning and the dynamic capabilities of the firm (Dosi, Teece and Winter, 1992). The aim of this theoretical work is to develop an analytical understanding of the firm as a learning organisation.

The empirical and policy issues relate to the nexus technology, productivity, organisational change and human ressources. More insight in the dynamic interplay between these factors at the level of the firm is crucial to understand international differences in performance at the macro level in terms of economic growth and employment.

Theme B: Competence building and inter-firm dynamics

The theoretical perspective relates to the dynamics of the inter-firm division of labour and the formation of network relationships between firms. An attempt will be made to develop evolutionary models with Schumpeterian innovations as the motor driving a Marshallian evolution of the division of labour.

The empirical and policy issues relate the formation of knowledge-intensive regional and sectoral networks of firms to competitiveness and structural change. Data on the structure of production will be combined with indicators of knowledge and learning. IO-matrixes which include flows of knowledge and new technologies will be developed and supplemented by data from case-studies and questionnaires.

Theme C: The learning economy and the competitiveness of systems of innovation.

The third theme aims at a stronger conceptual and theoretical base for new concepts such as 'systems of innovation' and 'the learning economy' and to link these concepts to the ecological dimension. The focus is on the interaction between institutional and technical change in a specified geographical space. An attempt will be made to synthesise theories of economic development emphasising the role of science based-sectors with those emphasising learning-by-producing and the growing knowledge-intensity of all economic activities.

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The Ph.D.-programme

There are at present more than 10 Ph.D.-students working in close connection to the DRUID research programme. DRUID organises regularly specific Ph.D-activities such as workshops, seminars and courses, often in a co-operation with other Danish or international institutes. Also important is the role of DRUID as an environment which stimulates the Ph.D.-students to become creative and effective. This involves several elements:

- access to the international network in the form of visiting fellows and visits at the sister institutions
- participation in research projects
- access to supervision of theses
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