NAFTA@10

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Editors

Foreword

The research assembled in this volume has been undertaken by academic and government researchers writing in a personal capacity. Foreign Affairs and International Trade Canada managed and assembled this volume with the objective of contributing to, and encouraging, debate on an issue of major importance to the Department, to the Government of Canada, and to Canadians. The views expressed in this volume, however, are those of authors and do not reflect the views of the departments represented in this volume or of the Government of Canada.

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Specialization in NAFTA Partner Countries: What Factors Explain the Observed Patterns?

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Introduction

There are three principal theories of why countries trade: the Ricardian model, the Heckscher-Ohlin model and increasing returns to scale.[1] In the Ricardian model, comparative advantage comes from technological superiority; countries concentrate output in those sectors in which they have a technological advantage. Heckscher-Ohlin (HO) theory, on the other hand, suggests that all countries have access to the same technologies, and comparative advantage comes from the relative abundance of factors. Hence, countries relatively rich in capital or other resources will have output mixes shifting in favour of those sectors that use these abundant resources intensively. The increasing returns to scale model suggests that trade could take place even if the economies have identical tastes, technology and factor endowments, since economies of scale would generate comparative advantage and strengthen the tendency to specialize.

There is a considerable amount of research which empirically tests the importance of these theoretically established reasons in explaining trade flows. To cite a few of them, Leamer (1984), Harrigan (1995) and Bernstein and Weinstein (2002) estimate the relevance of the HO model using trade and production data. Bowen et al. (1987), Trefler (1993, 1995), Davis et al. (1997) and Harrigan (1997) use models where technological differences across countries are introduced, thereby incorporating both Ricardian and HO aspects. Davis and Weinstein (1999, 2003) assess the relative importance of comparative advantage and increasing returns in accounting for production structure and trade. Recently, Antweiler and Trefler (2002) developed a methodology for estimating returns to scale using a data set consisting of a large number of countries.

Researchers have realized that for a model to be realistic, it should be able to integrate all key determinants of trade and specialization into a single coherent framework. However, both in theory and empirical work, this realization has not met with much success. As far as the study of specialization is concerned, Leamer (1997) is the only paper that combines two variables, the Ricardian and the HO, in determining specialization in OECD countries. Due to data limitation,

[1] The other potential reason, the supply by oligopolists in each others' markets, as developed by Brander (1981), is not considered a significant factor for trade. All these theories are based on the supply side of the economy. The demand side, differences in tastes, can also lead to trade, but has only rarely been analyzed as a source of comparative advantage (an exception is Markusen, 1986 and Hunter and Markusen, 1988).

however, he has to make some compromises. First, his model does not directly incorporate an HO variable. For this purpose, Leamer op. cit. uses a common country factor as a proxy for all industries, instead of a more direct measure such as factor endowment and intensity. Second, he does not allow for effects other than the Ricardian and the HO to play any role in specialization. Third, his model is a cross-country examination with one year of data and hence cannot capture the dynamics of change over time.

In order to fill this gap, this paper incorporates all theoretical determinants of trade to evaluate specialization that has taken place in North America (Canada, the United States and Mexico) from 1980 to 2000. It decomposes the relative importance of Ricardian, HO, increasing returns and trade policy in determining the specialization patterns in 23 manufacturing industries. By doing so, it indirectly evaluates the conjecture made by Leamer (1993) more than a decade ago that economies of scale may play an important role in the regional division of manufacturing between Canada and the United States, whereas the factor proportion effect would capture most of the effect for Mexico.

The North American market consists of the world's most productive and capital intensive country (the United States), a relatively poor labour intensive country (Mexico), and Canada in between these two extremes. The huge differences in productivity, factor proportion and market size among these three countries make North America a good laboratory to study the relative importance and mutual interaction of these factors in setting up specialization. Furthermore, at the time of signing of Canada-United States Free Trade Agreement (FTA) in 1988 and the North American Free Trade Agreement (NAFTA) among Canada, United States and Mexico in 1993, it was considered that these agreements would lead to more specialization in production. NAFTA was also supposed to be a facilitator in technology transfer from an advanced to a less advanced partner country. This paper sheds light on whether these expectations have been realized.

The results show that the level of specialization in NAFTA countries has increased for some industries and decreased for others, but there is no discernable trend for many industries. On balance, the overall specialization is slightly up. Obviously, some industries are more concentrated than others. The most concentrated industries are the building of ships and boats, leather products and aircraft and spacecraft, whereas the least concentrated industries are rubber and plastics, electrical machinery and chemicals. On average, high-tech industries are more concentrated than others. Further, all the high-tech industries are over-represented in the United States and most of them are under-represented both in Canada and Mexico. The prediction is that at least in one high-tech industry, office accounting and computing machinery, the United States might capture an even larger share over time.

Somewhat counter-intuitively, for the last two decades Canada has remained the least specialized country in North America. The regionalization index shows that in terms of employment structure, Canada and the United States have become more similar (diversified) over time, whereas both of them have become more dissimilar (specialized) to Mexico. Interestingly, the United States has a larger than expected size of all five high-tech sectors, whereas Canada barely maintains its share in only one high-tech industry.

Out of 23 industries, the Ricardian variable (revealed labour productivity advantage) has a significant role in explaining specialization in 21 industries, the HO variable (capital-labour ratio) in 17 industries and the increasing returns to scale variable (R&D intensity) in eight industries. Food and beverages, textiles, chemicals and miscellaneous manufacturing are the only Ricardian sectors. The value added of the first three industries is predicted to become concentrated in the more productive country, whereas miscellaneous manufacturing is predicted to locate in the less productive country. For the other eleven industries, the Ricardian variable determines specialization along with the HO variable. They include industries like machinery and equipment, metal, wood, pharmaceuticals, petroleum, apparel and rubber and plastics. Except apparel, the Ricardian effects reveal that all of them tend to locate in the country with higher labour productivity, whereas the HO effect states that all of them tend to locate in the low capital intensive country.

The locations of the production of leather and motor vehicles are driven by both Ricardian and increasing returns variables. Leather tends to be concentrated in a highly productive and less R&D intensive country, whereas motor vehicles tend to be concentrated in the highly productive and high R&D intensive country. Electrical machinery, the only industry where the Ricardian variable has no effect, is a HO and increasing returns to scale sector, indicating that having higher productivity and a higher capital-labour ratio is the reason for concentration in this industry. For all the remaining five industries, which contribute more than a quarter of value added in total manufacturing in NAFTA countries, the production location is determined by all three factors. These five industries include three of the five high-tech sectors, namely aircraft and spacecraft, radio, television and communication equipment, office accounting and computing machinery. The other two industries in this category are pulp, paper, printing and publishing and tobacco products. The prediction is that these five industries tend to be over-represented in a country with high productivity, low capital intensity (except office accounting and computing machinery) and high R&D intensity.

Even though the specialization patterns in NAFTA countries are driven by all three factors, the role of the Ricardian variable is more important not only in terms of number of industries in which this variable is significant, but also in terms of the value added that these industries contribute. The predominant role of Ricardian effects suggests that technological differences are substantial among NAFTA countries. It also suggests that if there is a convergence of productivity levels, it is rather slow. Otherwise, there should not be such a significant impact of the productivity variable in determining production locations in the two decades of data.

Results show that the role of NAFTA is not very important in determining specialization. NAFTA affected specialization in only three industries, raising it in one industry (refined petroleum) and reducing it in two industries (motor vehicles and radio, television and communication equipment).

Since the Ricardian and HO effects generate somewhat opposite effects in countries with very different factor endowments and technology, the findings of interplay of these two effects in many industries suggest that the adjustment in

North America was moderate, as was the pace of specialization. There probably was some technology transfer and wage increase in the less developed countries as the Ricardian model would indicate; there probably was a bit of wage pressure on unskilled workers in more developed countries and some advantage of specialization in all countries as the HO model would predict. The role of increasing returns to scale in shaping the North American manufacturing sector is important mostly in the high-tech sectors. Among eight industries where the increasing returns to scale variable is significant along with other variable(s), five are high-tech and medium-high tech industries.

NAFTA Trade and Specialization

Both export orientation and import penetration of the manufacturing sector in all three NAFTA countries have increased over time (Table 1). In 2000, together these countries exported more than one-fifth of their manufacturing gross production and imported more than one-quarter of their consumption, an increase of about ten percentage from a decade ago. Among them, Canada is the most open economy, with about 53 percent of its manufacturing production (consumption) exported (imported) in 2000.

Table 1. Manufacturing Trade Orientation of NAFTA Countries (Percent)

	Export Orientation			**Import Penetration**		
	1990	1995	2000	1990	1995	2000
NAFTA	13.2	17.4	21.5	16.4	21.1	26.5
Canada	36.2	50.2	52.7	37.4	49.5	52.6
U.S.	11.1	13.6	16.8	14.5	18.0	22.6
Mexico	10.2	39.6	43.3	15.6	39.0	46.4

Source: OECD, Structural Analysis (STAN) and Bilateral Trade (BTD) databases.
Note: Export orientation is defined as the share of exports in gross production and import penetration is defined as the share of imports in consumption, which in turn is calculated as gross production *less* exports *plus* imports. The trade data in the OECD database are in U.S. dollars, and gross production data for Canada and Mexico were converted to U.S. dollars using average annual market exchange rates for national currencies.

The detailed account of intra-NAFTA trade is provided in Table 2. Looking across the first row, it is clear that in 1990 the share of NAFTA countries in Canada's total manufacturing exports was about 80 percent (79.2 percent for the United States and 0.5 percent for Mexico), which increased to 88 percent in 2000. Similarly, NAFTA countries' share of U.S. exports increased from about 30 percent in 1990 to about 38 percent in 2000. The fastest intra-region export growth occurred for Mexico from 76 percent in 1990 to 92 percent in 2000. As a result of this intra-regional export growth, 55 percent of NAFTA countries' manufacturing exports were destined to their own markets in 2000. On the import side, the intra-regional integration is less pronounced. For NAFTA as a whole, the share of NAFTA partners in its total manufacturing imports increased from 33 percent in 1990 to about 41 percent in 2000.

Table 2. Share of Intra-NAFTA Trade in Manufacturing (in Percent)

	1990				2000			
	Canada	**U.S.**	**Mexico**	**NAFTA**	**Canada**	**U.S.**	**Mexico**	**NAFTA**
Exports								
Canada	-	79.2	0.5	79.7	-	87.6	0.5	88.0
U.S.	22.2	-	7.5	29.7	23.3	-	14.4	37.7
Mexico	1.2	75.1	-	76.4	2.1	90.2	-	92.3
NAFTA	16.4	20.5	5.7	42.6	15.7	29.9	9.6	55.2
Imports								
Canada	-	66.9	1.3	68.2	-	66.9	3.5	70.4
U.S.	18.1	-	5.1	23.1	17.7	-	11.1	28.7
Mexico	1.1	66.8	-	67.9	1.8	79.3	-	81.1
NAFTA	14.0	15.3	4.1	33.4	13.1	19.5	8.6	41.2

Source: OECD, Bilateral Trade Database (BTD).
Note: For the export part of the table, the country as column heading indicates the source, and the country as row heading shows the destination. However for the import part, the country as column heading indicates the destination, whereas the country as row heading indicates the sources.

The increase in the shares of intra-NAFTA exports in three countries' exports by more than 12 percentage points and of imports by 8 percentage points in a period of one decade is a reflection of a deeper product market integration that is taking place among these three countries. Of course, the degree of integration varies a great deal by industry. For example, in 2000 the share of intra-NAFTA imports in total NAFTA imports ranged from 72 percent in pulp, paper, printing and publishing to only 16 percent in pharmaceuticals. Now the question is, how has this increased integration affected the specialization pattern? This subject is discussed in the rest of this section. As in Leamer (1997), specialization is measured using revealed comparative advantage (RCA), after correcting for country size and for industry size using the following formula:

$$RCA_{ij} = \frac{\left[v_{ij} / \left(v_i - v_{ij}\right)\right]}{\left[v_j / \left(v - v_j\right)\right]}, \quad (1)$$

where v_{ij} = value added in industry *i* for country *j*, $v_i = \sum_j v_{ij}$ = total NAFTA countries' value added in industry *i*, $v_j = \sum_i v_{ij}$ = total value added in country *j* and $v = \sum_i \sum_j v_{ij}$ = total NAFTA value added.[2]

As in Leamer, we use the rest-of-NAFTA and rest-of-industry value added instead of total NAFTA and total manufacturing value added to correct for country-size

[2] We have used value added data rather than trade data to compute RCA. We could have used gross production data rather than value added. Again, if the proportion of intermediate inputs used in gross output is not very different among countries (which we assume to be the case), the relative RCA among countries will be the same whether we use gross production or value added data.

effects, which spreads the magnitude of RCA.[3] The results on the extent of specialization using value added data by country and industry for two time periods (1980-1981 and 1999-2000), are given in Table 3, where industries are ordered based on international system of industrial classification (ISIC) codes. The detailed list of ISIC codes and industry names is given in Appendix 1. We have used data for 23 manufacturing industries, most of them at the 2-digit level, with three industries at the 3-digit level, and one industry at the 4-digit level.[4]

The revealed comparative advantage of the first industry for Canada in 1980-1981 is 1.31, meaning that Canada had 31% more value added in the food and beverages industry than would have predicted based on the size of this industry in NAFTA and the size of Canada. Based on RCA in 1999-2000, the only sectors that are larger than expected in Canada are wood products with RCA of 2.26 (2.26 times or 126% larger than what is expected), railroad and transport equipment (89% larger than expected), basic metals, motor vehicles and trailers, and pulp, paper, printing and publishing. During this period, the biggest negative RCA for Canada is in office and computing machinery, with RCA of 0.23 (a size of only 23% of what is predicted based on country and industry size). The other two very small sectors in Canada are pharmaceuticals, with RCA of 0.33, followed by refined petroleum, with RCA of 0.52.

For the United States, some of the larger than expected sectors are the building of ships and boats, aircraft and spacecraft, tobacco, radio TV and communication equipment, pharmaceuticals, machinery and equipment, refined petroleum, electrical machinery and apparatus, fabricated metal and office and computing machinery. The aircraft and spacecraft industry is twice as large as expected, and miscellaneous manufacturing is 2.17 times larger than expected.[5] The relatively smaller sectors in the United States, to name a few, are leather (RCA of 0.34), food and beverages (RCA of 0.5) and motor vehicles and trailers (RCA of 0.56).

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[3] The control of industry and country effects in the formula does not alter the value of RCA from more than one to less than one or vice versa from the RCA if it were calculated using the regular formula without any correction. What the correction does is that it raises (lowers) the value of RCA in those industries which would have RCA greater (smaller) than one if calculated using the regular formula. In other words, the correction increases the range of RCA.

[4] The industry-wide data on value added in national currencies were converted to U.S. dollars by using GDP purchasing power parity exchange rates given by the OECD. This implicitly assumes that relative prices are the same in different industries; to the extent that they are not, output comparison will be distorted. The use of PPP for GDP will overestimates the value of the industries whose relative prices are falling and underestimate the value of those whose relative prices are rising.

[5] Miscellaneous manufacturing is predominantly medical, precision and optical instruments. In addition, it also includes furniture and fixtures, recycling and other manufacturing which are not included elsewhere. Hence, the result for the United States is driven by its unusually high share of value added in medical, precision and optical instruments.

Table 3. Specialization by Country and Industry

Industry	Canada 1980-1981	Canada 1999-2000	U.S. 1980-1981	U.S. 1999-2000	Mexico 1980-1981	Mexico 1999-2000
Food and beverages	1.31	0.99	0.52	0.50	2.28	2.81
Tobacco products	0.64	0.72	1.79	1.97	0.52	0.36
Textiles	0.68	0.65	0.57	0.66	2.71	2.34
Wearing apparel	1.32	1.49	0.75	0.65	1.27	1.45
Leather products	1.04	0.73	0.39	0.34	3.69	4.91
Wood products	1.60	2.26	0.63	0.65	1.44	0.78
Pulp, paper, print & publishing	1.70	1.42	0.94	1.19	0.50	0.35
Refined petroleum	0.47	0.52	1.28	1.44	1.11	0.92
Chemicals excl pharma	1.02	0.79	1.02	1.21	0.95	0.89
Pharmaceuticals	0.63	0.33	1.10	1.73	1.20	0.88
Rubber and plastics	1.05	1.18	1.01	1.08	0.94	0.71
Other non-metallic mineral	1.02	0.76	0.55	0.62	2.42	2.40
Basic metals	1.11	1.69	1.02	0.64	0.87	1.28
Fabricated metal	0.96	0.97	1.40	1.38	0.52	0.53
Machinery and equipment	0.76	0.87	1.77	1.64	0.42	0.41
Office account. & computing mach.	0.22	0.23	6.03	1.31	0.15	1.39
Electrical m. and apparatus	0.78	0.70	1.27	1.13	0.82	1.09
Radio, TV & commu. equipment	0.95	0.67	1.23	1.85	0.72	0.47
Motor vehicles and trailers	0.97	1.56	0.75	0.56	1.62	1.74
Building of ships & boats	1.67	0.71	1.21	2.88	0.16	0.06
Aircraft and spacecraft	0.77	1.02	2.55	2.00	0.11	0.09
Railroad and transport equip.	2.07	1.89	0.42	0.88	2.33	0.53
Miscellaneous manufacturing	0.53	0.59	2.34	2.17	0.37	0.38

Note: In the manufacturing sector, there are altogether 23 industries at ISIC 2-digit level. Among them, we took 16 industries as they are; combined two 2-digit industries (ISIC 21: pulp, paper and paper product and ISIC 22: printing and publishing) into one. We also combined other three 2-digit industries (ISIC 33: medical, precision and optical instruments; ISIC 36: manufacturing not elsewhere mentioned and ISIC 37: recycling) into another and called it miscellaneous manufacturing. Furthermore, we split one 2-digit industry (ISIC 24: chemicals) into two (24: chemicals excluding pharmaceuticals, and ISIC 2423: pharmaceuticals) and another 2-digit industry (ISIC 35: other transport equipment) into three 3-digit industries (ISIC 351: building and repairing of ships and boats; ISIC 353: aircraft and spacecraft; ISIC 352 *plus* ISIC 359: railroad equipment and transport equipment). This leaves us with the total of 23 industries as the sample for the study. The number in parentheses behind the industry name in the table represents the ISIC code.

For Mexico, the larger than expected sectors are leather products (almost 400% larger than expected), food and beverages, non-metallic minerals, textiles, motor vehicles and trailers, apparel, office accounting and computing machinery, basic metals and electrical machinery. On the other hand, Mexico has only 9 percent of its expected size of value added in the aircraft and spacecraft industry.[6] Mexico has an even lower share of expected size for the building of ships and boats.

Table 4. Country Distribution of Concentrated Industries by Technology Definition

Technology Classification	Number of industries	Share in value added in 1999-2000	Number of larger than expected industries in 1999-2000		
			Canada	U.S.	Mexico
High-tech manufactures	5	24.7	1	5	1
Medium-high-tech manufactures	5	26.4	2	3	2
Medium-low-tech manufactures	6	20.2	2	4	2
Low-tech manufactures	7	28.7	3	2	4
Total	**23**	**100**	**8**	**14**	**9**

Note: In the column entitled "number of industries", the number reported is based on our scheme of aggregation rather than on the ISIC industry count that falls into a certain classification. For example, based on ISIC codes there are six industries in medium-high-tech manufacturers. However, since we have aggregated ISIC 352 and 359 into one industry in this study, we count the industry number as five not six. Also note that in Table 3, the ISIC 33 is aggregated with ISIC 36, and 37 and we count the aggregate of 33, 36 and 37 as high-tech, as ISIC 33 is a predominant sector in terms of value added.
In terms of ISIC codes, the four categories of technology classification consists of following industries:
High-tech manufactures: 2423, 30, 32, 33 and 353
Medium-high-tech manufactures: 24 excluding 2423, 29, 31, 34, 352 and 359
Medium-low-tech manufactures: 23, 25, 26, 27, 28 and 351
Low-tech manufactures: 15-22, 36 and 37

Based on the data in Table 3, we present the country distribution of specialization by the OECD's technology classification in Table 4. The first column provides the four technology classifications, and the second column lists the respective ISIC codes for industries which fall under each category, the names of which can be read both from Table 3 and Appendix 1.

The five high-tech manufacturing industries which contribute more than a quarter of manufacturing value added in NAFTA are concentrated in the United

[6] In Canada, out of 23 industries, the RCA remained larger than one in six industries in both periods. RCA changed from being greater than one to less than one in five industries and vice versa in two industries. For the remaining 10 industries, Canada's RCA was lower than one in both periods. For the United States, there were 13 industries whose RCA was greater than one in both periods. There was only one industry each which changed from being greater than one to less than one and vice versa, while the remaining eight industries had RCA less than one. In the case of Mexico, the RCA was greater than one in six industries in both periods. For four industries, the RCA changed from greater than one to less than one, whereas for three industries the case was reversed. The remaining 10 industries had RCA less than one.

States. Canada's shares in all these sectors are far smaller than expected (ranging from 23 percent to 79 percent), except in aircraft and spacecraft, in which Canada just maintains its share. Mexico has larger than expected value added in office accounting and computing machinery (39 percent larger than expected), which comes at Canada's cost.

Industry and Country Specialization

Based on the results given in Table 3, we compute cumulative industry specialization indices across NAFTA countries which are reported in Table 5. These indices are value added weighted averages of the absolute values of the RCA. The industry specialization index is computed using the following formula:

$$s_i = \sum_j \log_2 \left| RCA_{ij} \right| w_j, \qquad \text{where } w_j = \sum_i v_{ij} \Big/ \sum_i \sum_j v_{ij}$$

The weight is country *j*'s share of total value added in NAFTA.[7]

What is clear from Table 5 is that some industries have highly specialized production patterns, while others are more uniformly distributed. The most highly concentrated industry in 1999-2000 is the building of ships and boats, followed by leather products and aircraft and spacecraft. On the other hand, the least concentrated industries are rubber and plastics, electrical machinery and chemicals. The index for the most concentrated industry (building of ships and boats) is almost three times higher than that of the least concentrated, rubber and plastics. The industries with low specialization indices are the ones that are distributed more or less symmetrically relative to the size of the country.

[7]To compute the specialization index in Tables 5 and 6, we converted the specialization index in Table 3 into base 2 logarithmic function (log 2 forms), then computed the weighted index and converted it back to level form to report in this table. Since we have to weight RCA in three countries to arrive at the industry cumulative index for NAFTA, the results differ depending on whether RCA value is used in level form or in log 2 form. And for the weighted average of this nature, log 2 form is a better form to adopt because it allows equal chance for each country to influence the index whether the country has larger than or smaller than expected size of industry. That is not the case if RCA is used in level form. For example, suppose that in a particular industry two countries have RCA = 2 and RCA = 0.5 in level forms. If we convert it into log 2 forms, they will have RCA = 1 and RCA = –1 respectively. Now in the weighting scheme, if we use the level form, the country with RCA = 2 will dominate the results, whereas if we use absolute value of log 2 form, both countries will have equal chance of affecting the cumulative specialization index. Leamer (1997) justifies the use of log 2 forms. The similar rationale applies for computing the country cumulative index.

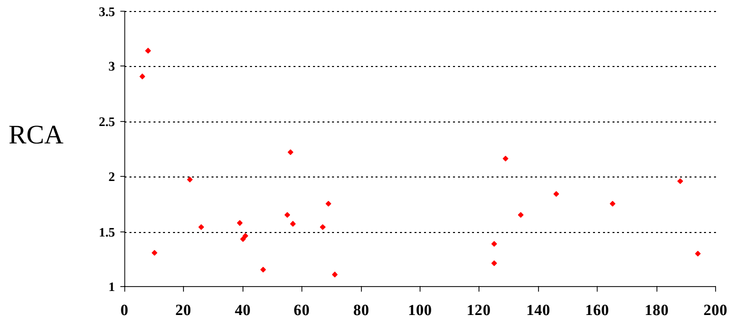
Table 5. NAFTA Specialization by Industry

	Value added using PPP exchange rates			Specialization index with value added weights		
	Total (billions)	Share (%)	Per worker ($'000)			
	1999-2000	1999-2000	1999-2000	1980-1981	1988-1989	1999-2000
Rubber and plastics	71	3.9	53	1.01	1.06	1.11
Electrical machinery and apparatus	47	2.6	54	1.27	1.34	1.15
Chemicals excl. pharmaceutical	125	6.7	133	1.02	1.15	1.21
Pulp, paper, printing, publishing	194	10.7	67	1.14	1.17	1.30
Railroad and transport equip.	10	0.6	61	2.38	1.98	1.31
Fabricated metal	125	6.9	64	1.40	1.34	1.39
Refined petroleum	40	2.4	210	1.31	1.26	1.43
Office and computing machinery	41	2.1	135	5.90	3.83	1.46
Wearing apparel	26	1.4	27	1.32	1.28	1.54
Basic metals	67	3.6	78	1.05	1.70	1.54
Wood products	57	3.0	47	1.57	1.25	1.57
Textiles	39	2.1	36	1.78	1.54	1.58
Machinery and equipment	134	7.5	58	1.77	1.93	1.65
Other non-metallic mineral	55	3.0	69	1.78	2.11	1.65
Pharmaceuticals	69	3.9	189	1.13	1.13	1.75
Motor vehicles and trailers	165	9.0	99	1.33	1.52	1.75
Radio, TV & commu. equipment	146	8.4	101	1.23	1.92	1.84
Food and beverages	188	10.0	71	1.89	1.92	1.96
Tobacco products	22	1.3	449	1.78	1.60	1.97
Misc. manufacturing	129	7.3	58	2.33	2.45	2.16
Aircraft and spacecraft	56	3.0	92	2.64	4.58	2.22
Leather products	6	0.3	32	2.48	2.81	2.91
Building of ships & boats	8	0.4	41	1.38	2.02	3.14
Total manufacturing	**1,820**	**100.0**	**72.2**			

Source: OECD, STAN Database

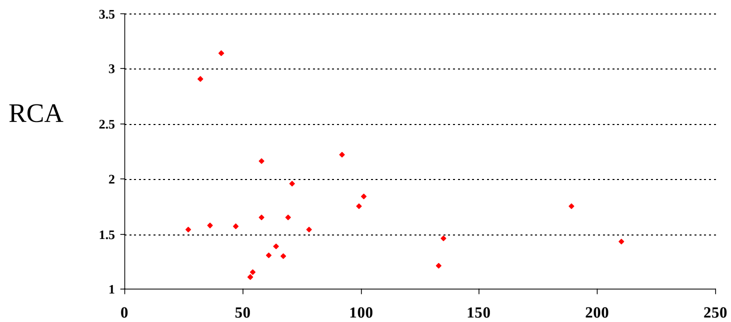
Note: The data are in U.S. dollars using purchasing power parity (PPP) exchange rates. The list of industries is sorted by the specialization index of 1999-2000 (the last column) from least to most specialized.

Figure 1. Specialization and Total NAFTA Value Added, 1999-2000



NAFTA value added per worker (in thousands of U.S. $)

Figure 2. Specialization and NAFTA Productivity, 1999-2000



Total NAFTA value added (in billions of U.S. $)

It is also obvious that the relative ranking of specialization across industries is changing over time. For example, in 1980-1981 the most specialized industry was office and computing machinery, whereas in 1988-1989 it was aircraft and spacecraft, and yet in 1999-2000 it was the building of ships and boats. Also in some cases, we see that the RCA of an industry fluctuates without a clear trend. There are 13 industries whose RCA in 1988-1989 rose (fell) from the level in 1980-1981 and fell (rose) in 1999-2000. The reversal of specialization patterns implies that there is a continuous restructuring going on across industries in NAFTA countries. Therefore, the results might be misleading if one relies only on few years of data. This is one of the reasons why data for 21 years (1980-2000) in the econometric study in Section 4 has been used.

We can employ data in Table 5 to study the relationship of specialization with total value added and labour productivity. The association of the specialization index and total NAFTA value added by industry is shown in Figure 1. The plot shows that there is no association between these two variables, which is a comforting result, especially because a negative relationship would suggest that the specialization index is very much influenced by the level of data aggregation.

Even though looking at the endpoints on the left hand side, suggests that there is a negative relationship, that is not the case for most of the industries. For example, the third smallest industry, railroad and transport equipment, is the fifth least specialized industry, whereas the second largest, food and beverages, is the sixth largest specialized industry.

The relationship between specialization and labour productivity shown in Figure 2 is slightly negative. This could be suggestive of the fact that the labour productivity differences among NAFTA countries might be larger for those industries whose overall labour productivity levels are low compared to those whose labour productivity levels are high. Put differently, technological catch up or convergence is probably faster in sectors with higher labour productivity levels, so that productivity differences are not very effective in affecting RCA in these industries, thereby keeping their specialization index low.

Next, we compute the country specialization index using the following formula:

$$s_j = \sum_i \log_2 \left| RCA_{ij} \right| w_i , \qquad \text{where } w_i = \sum_j v_{ij} \Big/ \sum_i \sum_j v_{ij}$$

The weight is industry *i*'s share in NAFTA. The results for the country specialization index are given in Table 6, where we have also provided total value added and the share of value added for all three countries based on two different data sources. The first set of results presented under the column heading “at the two-digit level” use the same data source that we have used so far in this paper, the OECD’s STAN database. According to this data, Canada and Mexico have comparable manufacturing sizes, and they have gained shares over time.

The results for the specialization index show that Mexico is the most specialized country, with an index of 2.06 in 1999-2000; Canada is the least specialized one, with the United States in the middle. Since the specialization index could be sensitive to the level of data aggregation, the country specialization index using ISIC 3-digit data with 59 manufacturing industries is also calculated. The results are reported under the column heading “at the 3-digit level” in Table 6. Since the historical data are not available at this level, the index was computed only for the years 1997 and 1999. As the data on 2-digit and 3-digit levels use different sources, these two estimates are not perfectly comparable. However, comparing the results allows us to make a point that even at 3-digit level, Mexico is the most specialized country, followed by the United States and then Canada.

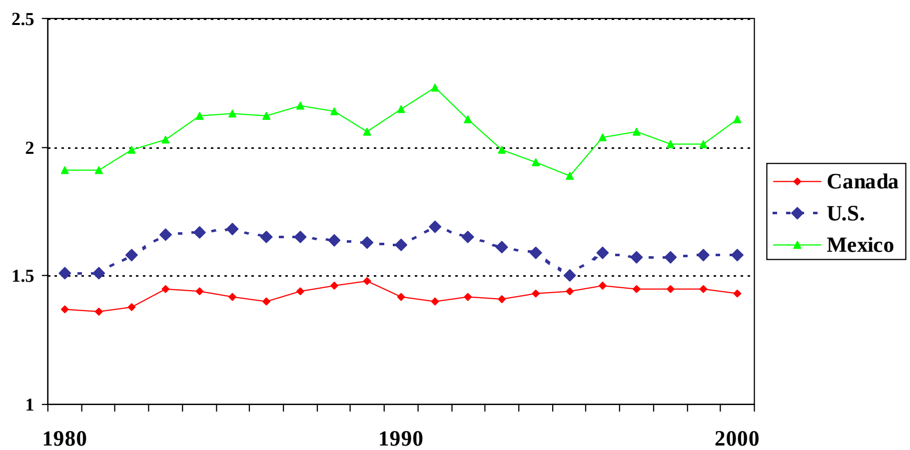
It is clear from Table 6 that all three countries became more specialized in 1999-2000, compared to the situation in 1980-1981. However, all of them had reached a higher level of specialization previously, in 1988-1989. To understand the dynamics of specialization over time, Figure 3 plots specialization indices (based on 2-digit data) in the three countries for 21 years. The country specialization rose in the 1980s and started falling in the 1990s but did not fall all the way to the level from where it had started in the early 1980s. Put differently, the three NAFTA countries grew dissimilar in the decade of the 1980s, raising their specialization level, but reversed this trend in the 1990s by becoming more similar (diversified) in their production structure.

Table 6. Specialization by Country

		At the two-digit level			At the three-digit level	
		1980-1981	1988-1989	1999-2000	1997	1999
Value added in billions of U.S.$	Canada	45,735	82,779	157,799	150,887	183,531
	U.S.	619,849	998,788	1,500,802	1,825,688	1,962,644
	Mexico	49,670	88,410	161,584	83,503	89,792
Share of value added (%)	Canada	6.40	7.08	8.67	7.32	8.21
	U.S.	86.67	85.37	82.46	88.62	87.78
	Mexico	6.93	7.56	8.88	4.05	4.02
Specialization index	Canada	1.36	1.47	1.44	1.58	1.67
	U.S.	1.51	1.63	1.58	1.67	1.70
	Mexico	1.91	2.10	2.06	3.62	3.78

Note: The data at the two-digit level are from the STAN database and those for the three-digit level are from Structural Statistics for Industry Services (SSIS) database of the OECD. These data are based on two different sources. SSIS uses data collected through annual industrial or business surveys supplementing them with censuses and with administrative sources. STAN attempts to provide data consistent with annual National Accounts using a wide range of data sources such as annual business surveys and/or censuses, as well as labour force surveys, business registers, income surveys, I/O tables. As a result, there is a difference in coverage between these two data sets. Some of these differences are as follows. Business surveys typically cover establishments and/or enterprises above a certain size limit (with more than a certain number of employees). Establishments with no employees are generally not covered. On the other hand, in National Accounts, attempts are made to get a more complete picture of industrial activity consistent with other accounts through the use of data coming from a variety of alternative sources mentioned above. However, adjustments and estimations carried out in countries may differ. Nevertheless, National Accounts (hence, STAN database) are traditionally considered more internationally comparable.

Figure 3. Country Specialization Indices



It is rather surprising that Canada has remained less specialized than the United States throughout the last two decades. This result is contrary to the generally held perception that bigger countries are less specialized. When looked at in the context of NAFTA, it makes sense why Canada is the least specialized country. In terms of productivity, the capital-labour ratio, skill intensity and R&D intensity Canada remains mainly in the middle, with United States as the leader in all indicators and Mexico is at the bottom. Hence it is not generally the case that industries will concentrate largely in Canada, unless natural resources are a factor in location, as in wood products where Canada has twice the size of its economic share (Table 3).

The above discussion helps to explain the specialization evident in manufacturing industries in three NAFTA partner countries. However, it does not explain how the bilateral production structure of these countries is changing. To assess this bilateral specialization index for these three countries, we use Krugman’s index of regional specialization (RS). For a pair of countries *j* and *j'* it is defined as follows:

(2) $$RS_{jj'} = \sum_{i=1}^{n} \left| \frac{e_{ij}}{e_j} - \frac{e_{ij'}}{e_{j'}} \right| ,$$

where e_{ij} is the employment in industry $i = 1, \ldots, n$ for country *j*, e_j is total employment in country *j* and similarly for country *j'*. The index ranges from zero to two. If the index between countries *j* and *j'* is equal to zero, then the two countries are completely diversified; if the index is equal to two, then the countries are completely specialized. Using data at both 2-digit and 3-digit levels, we present the Krugman’s index in Table 7.

Table 7. Krugman's Index of Regional Specialization

	ISIC 2-digit				**ISIC 3-digit**		
	1980	**1990**	**1994**	**2000**	**1997**	**1998**	**1999**
Canada-U.S.	0.31	0.28	0.29	0.27	0.33	0.32	0.36
Canada-Mexico	0.44	0.46	0.48	0.60	0.71	0.70	0.71
U.S.-Mexico	0.53	0.55	0.53	0.63	0.76	0.75	0.75

Source: OECD, STAN Database for the 2-digit level and SSIS Database for the 3-digit level.
Note: For the 2-digit level, the employment data for Mexico is headcounts of total employees, so it excludes the self-employed and unemployed family workers. For Canada, the data are number of jobs engaged in domestic production rather than headcounts. Therefore, Canadian employment data have both employed, self-employed and unpaid contributions but people with more than one job (full- or part-time) are counted more than once. For the United States, the employment data are total head counts of all persons who are engaged in domestic production. At the 3-digit level, there are altogether 59 industries. The employment data are in number of employees for Canada and the United States and total employment for Mexico.

Comparing the degree of specialization between Canada and the United States at the 2-digit level, we see that the two countries are becoming slightly more similar, as the specialization index fell from 0.31 in 1980 to 0.27 in 2000. However, Canada and Mexico and the United States and Mexico are becoming more dissimilar as the indices between this pair of countries rose over time.[8] Both levels of data show that among these three countries, the most similar ones are Canada and the United States, followed by Canada and Mexico, and by United States and Mexico.

Explanation of Specialization

So far, we have analyzed the specialization pattern that is taking place across industries and countries in the North American market. The next question is what is shaping this specialization pattern? What are its determinants? As discussed in Section 1, there are basically three trade theories, Ricardian, Heckscher-Ohlin, and increasing returns to scale that explain specialization across countries. In this section, we conduct an econometric test integrating all these three factors to determine their relative role in explaining specialization patterns in North America in the last two decades.

The variable suggested by the Ricardian model is relative technological differences across sectors in different countries. Since the data on technological differences are not available, differences in labour productivity are used to compute the Ricardian variable — revealed productivity advantage (RPA) — which is defined as follows.

(3) $$RPA_{ij} = \frac{y_{ij} / (y_i - y_{ij})}{y_j / (y - y_j)},$$

where $y_{ij} = v_{ij} / e_{ij}$ value added per employee in industry *i* for country *j*, $y_i = \sum_j y_{ij} / \sum_j e_{ij}$ is NAFTA's value added in industry *i;* $y_j = \sum_i y_{ij} / \sum_i e_{ij}$ is value added per employee in the manufacturing sector as a whole in country *j;* y is per employee value added for NAFTA (aggregate of all industries and countries).[9] As in RCA, we take out the industry and country size effects while computing RPA. Using this index, a country is said to have a Ricardian technological advantage in a sector if its productivity in that sector is high after adjusting for the sector and the country's general level of productivity. In a world of incomplete specialization, loosely speaking, this theory predicts that when a country becomes relatively more productive compared to other countries in a particular sector, the more productive country will increase its production share in that sector.

According to the Heckscher-Ohlin model, comparative advantage comes from the abundance of factor endowments. The theory states that, *ceteris paribus*, if a country is capital abundant (has a higher capital-labour ratio compared with another country), it will produce more of those goods which are more capital intensive in production. So a capital abundant country will have a higher

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[8] The 3-digit level data show a somewhat different trend. But since there is no time lag in these data, we find 2-digit data more reliable to study changes over time.

[9] In this computation, I combine the value added and employment data that were used separately in the previous sections.

proportion of those goods which use capital more intensively and a labour abundant country will have more labour intensive goods. Among other things, a variable suggested by this theory is the capital-labour ratio, which we use in this paper (data-description is provided in Appendix 4).[10] Leamer (1997) estimates a similar model but using a country's overall value added per worker adjusted for the composition of output for the HO variable. He considers it an uncomfortable way of representing the HO model and suggests the capital-labour ratio as a better representation.

In addition, R&D intensities (share of business R&D expenses in gross output) are employed as another explanatory variable. The hope is that once the technological differences and factor abundance effects are controlled, whatever is left over to explain in the pattern of international specialization can be attributed to returns to scale. According to this theory, since average cost falls with the level of production, a country with a larger domestic market can produce at lower costs. And when opened for trade, the country with the larger domestic market will have a comparative advantage in foreign markets. Even in a free trade regime, as long as there are transport costs, there will still be a tendency for production to concentrate in a country where domestic markets are large. In NAFTA's context, it is probably the United States for which size might be a more helpful factor in raising industry concentration than for other countries.

There is not a single convincing way to represent the presence of increasing returns in an empirical test. There are studies using a measure of intra-industry trade as a proxy for it. However, Davis (1995) shows that intra-industry is also consistent with Ricardian and Heckscher-Ohlin explanations. In a series of papers, Davis and Weinstein (1999, 2003) run regressions for the share of a country's production on the share of its demand and interpret that if there were increasing returns to scale, there should be more than a one-for-one response in production as a result of a change in demand.[11] The method suggested by Davis and Weinstein (op cit.) could be a reasonable way of introducing returns to scale,

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[10] Alternatively, we could have used the total manufacturing capital-labour ratio instead of industry-wide, but we opted for the latter hoping that this might capture the effects of both factor abundance and factor intensity differences.

[11] The more than proportionate change in production as a result of a change in demand occurs in a model of increasing returns to scale with transport costs. The argument goes as follows. In a world with increasing returns, typically each good is produced in only one location. When there are transport costs, a country with unusually strong demand for a good makes an excellent site for production. In order to save transport cost and enjoy the benefit of declining average cost with production, firm will be established in the market with relatively higher demand and export to the market where demand is relatively low. Thus if there are increasing returns to scale and transport costs, a strong demand can lead that country to export the good. However, in the traditional comparative advantage model, a strong demand leads to the imports of that good. To explain how it happens, let us take an extreme case of two countries with similar size, endowment and technology, but with different demand condition, one country consuming more of a good than the other country. The similarity of size, endowment and technology will dictate the country to produce the same goods in the same proportion in two countries. Hence, the country which have higher demand for one good should import that good from the country which have lower demand for it.

but it is not helpful for the present purpose. The reason is that with the data available, it is possible to have the estimate either for each industry (by pooling data over years) or for each year (by pooling data over industries). It is not possible to have both industry and year dimensions in the estimation, which are essential for this study.
In a recent paper, Antweiler and Trefler (2002) approach the problem using the factor content of trade. This is a novel approach; however, it requires input-output tables comprising all industries and years, which is not possible due to data limitations. Because of these difficulties with other approaches, R&D intensity is used as a proxy for increasing returns. Moreover, since the data on R&D expenses are not available for Mexico by industry, their total economy-wide R&D to GDP ratio is used to compute R&D expenses for each industry, such that industry R&D expenses are a constant fraction of its GDP (see Appendix 4 for data description).

We saw that specialization varies across countries and over time, so the model of cross-country variation in specialization should allow for country effects and time trends. We assume that there are industry specific time trends which are common across countries. In this case, pooling observations across countries is an efficient estimator. Using *i* to denote country, *j* to denote industry and *t* to denote time, and assuming that specialization patterns are log-linear, we have

$$\ln(RCA_{ijt}) = \beta_{0j} + \beta_{1ij} + \beta_{2j}\, t + \beta_{3j} \ln(RPA_{ijt}) + \beta_{4j} \ln(k_{ijt}/l_{ijt}) + \beta_{5j} \ln(r_{ijt}/q_{ijt}) + \beta_{6j} NAFTA + u_{ijt} \quad (4)$$

where β_{0j} is the intercept, β_{1ij} is fixed country effect, β_{2j} is coefficient for time trend, *k* is capital stock, *l* is labour employment, *r* is business expenditure on R&D and *q* is gross output. With data on RCA, RPA, capital-labour ratio, and R&D intensity, this equation is estimated over a panel of countries and years for industry *j*. For reference, the data on these explanatory variables for year 2000 are presented in Appendix 2. NAFTA is a dummy variable, which take the value of zero from years 1980 to 1993 and value of one from 1994 to 2000.

The estimates of equation (4) are reported in Appendix 3. The industries are sorted into five subgroups depending on the statistical significance of t-values of the Ricardian (RPA), Heckscher-Ohlin (*k/l*), and increasing returns to scale (R&D intensity) variables. First, there are four Ricardian industries with t-values significant only for the Ricardian variable. Then there are 11 industries with t-values significant for both the Ricardian and HO variables. The third subgroup consists of two industries with statistically significant impacts of the Ricardian and the increasing returns variables, which is followed by one HO and increasing return industry, the fourth subgroup. Finally, for the fifth subgroup of the remaining five industries, all three variables have significant effects on specialization. Within each subgroup, commodities are ordered by the adjusted R^2.[12]

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[12] The high R^2 value in time series data indicates that there could be a unit root in the data series. Indeed, data series in many industries had unit roots suggesting that the data were nonstationary. They were stationary at the first difference, but since we wanted to check the regression results at the level form rather than at the first difference, we checked whether these series were cointegrated. We found that they were cointegrated and hence there was

The sectors which are only Ricardian are food and beverages, miscellaneous manufacturing, textiles and chemicals. For food and beverages, the coefficient for RPA is 0.58, meaning the value added of this sector rises by 0.58 percent with 1-percent increase in revealed labour productivity. Hence, if one moves from a less productive to a more productive country, the value added of this sector rises by 0.58 percent of the revealed labour productivity differences in the two countries. Similarly, for the other two industries (textiles and chemicals) the comparative advantage rises by moving from the less productive to more productive country. The elasticity of 1.23 for chemicals predicts that the value added of this industry rises by 23 percent more than the difference in labour productivity, as we move from a country with low labour productivity to the one with high productivity. For miscellaneous manufacturing, the comparative advantage runs in the opposite direction; it tends to be located in less productive countries.[13] This is a bit counterintuitive considering the fact that it consists mainly of medical and precision instruments.

Both the Ricardian and the HO factors have significant impact on specialization in eleven industries. The list includes: (1) machinery and equipment (2) non-metallic minerals (3) ship buildings (4) rubber and plastics (5) apparel (6) refined petroleum (7) fabricated metal (8) wood (9) railroad and transport equipment (10) pharmaceutical and (11) basic metals. The coefficients for the Ricardian variables are positive for 10 industries except apparel. Hence these 10 industries are expected to be concentrated in the more productive country; that is, the Ricardian comparative advantage rises from the low productive to the high productive country, except for apparel whose size falls as productivity rises. On the other hand, the negative coefficients on the capital-labour ratio for all 11 industries predict that these products are under-represented in countries with higher capital-labour ratios (HO effect).

This is an interesting result; the increase in labour productivity and capital intensity play opposite roles in determining the sizes of these industries in a country. Other things being the same, when we move from a more productive country (for example the United States) to a low productive country (for example

no spurious correlation. All industries passed the cointegrating regression Durbin Watson test, as computed DW statistics were higher than the critical value at the 5% level, thereby validating our estimation approach.

[13] If we look at RCA for 2000 in Table 3, Mexico is over-represented in food and beverages and textiles, whereas the U.S. is under-represented in both. However, in chemicals, it is the U.S. which has the larger than expected sector. Looking at Appendix 2, in absolute terms the U.S. is the most productive country in food and beverages, and chemicals and Canada in textiles. And according to the coefficients reported in Annex 3, all three sectors are predicted to concentrate in the more productive country. Then why are food and beverages not concentrated in the U.S. and textile in Canada rather than in Mexico? There are two possible reasons for this seemingly contradictory result. First, the results are driven not only by year 2000 but all 21 years of data. Second and more important, what matters is not the absolute sectoral productivity differences across countries, rather it is relative productivity differences across sectors compared with other countries. For example, even though Mexico is not the most productive country in food and beverages and textiles, it could be relatively more productive in these sectors compared with other sectors. Appendix 2 somewhat confirms this line of argument.

Mexico) the sizes of these sectors will fall, yielding higher (lower) than expected sizes for the United States (Mexico). On the contrary, as we move from a high capital intensive country such as the United States to a low capital intensive country such as Mexico, the prediction is that the sizes of all these sectors rises from its initial position causing under-representation in the United States and over-representation in Mexico. In the end, the equilibrium level of specialization would be determined out of these two conflicting forces — the Ricardian and the HO — one counterbalancing the other. On average, the most productive country, the United States, is also the most capital intensive, while the least productive country, Mexico, is also the least capital intensive. Since productivity and capital intensity have opposite effects cancelling each other, the restructuring of the industries is somewhat locked in without much effect in any country. That could be the reason why the specialization has not changed rapidly in North America.

Combined Ricardian and increasing returns variables have influenced two industries: leather and motor vehicles. The Ricardian effects state that for both sectors, the value added rises in more productive countries. However, R&D intensities show that leather tends to be located in a country with a low level of R&D intensity, whereas motor vehicles tend to be located in a high R&D intensive country. The location of production of electrical machinery and apparatus is driven by both HO and increasing returns. The value added of this sector increases by 13 percent if capital intensity rises by 100 percent and by 4 percent if R&D intensity rises by 100 percent.

All the three variables are significant in determining the production location of the remaining five industries, namely: (1) pulp, paper, printing and publishing (2) aircraft and spacecraft (3) radio, television and communication equipment (4) office and computing machinery, and (5) tobacco products. Based on the sign of prediction, these industries are expected to concentrate in the more productive, less capital intensive country (except for office and computing machinery) and high R&D intensive countries.

Note that among the five high-tech manufacturers listed in Table 4, the specialization in three industries (aircraft and spacecraft; radio, television and communication equipment; and office and computing machinery) is determined by all three factors. For the other two, the production location of medical, precision and optical instruments is determined by the Ricardian variable, and that of pharmaceuticals is determined by both Ricardian and HO variables.

In sum, out of 23 industries in the manufacturing sector, there is only one industry, electrical machinery, where the Ricardian variable is not statistically significant in determining production location. Among the 22 industries where revealed comparative advantage has significant effects, productivity superiority of a country leads to higher value added in all these industries except in miscellaneous manufacturing and apparel. The Heckscher-Ohlin model is statistically significant in a total of 17 industries. Out of these, having a higher capital-labour ratio leads to larger value added in only two industries, electrical machinery and apparatus and office and computing machinery. In all the other 15 industries, the predicted sizes fall with the increase in capital intensity. The third factor — R&D intensity — is statistically significant for eight industries, with positive effects in seven and negative in leather products. Out of these seven industries, five are high-tech and medium-high-tech sectors.

The results also show that there are no industries whose production location is determined either only by the HO effect or only by the increasing returns to scale effect. Office accounting and computing machinery is the only industry for which all three variables are positively statistically significant. Since the United States is the most productive, most capital intensive and most R&D intensive in this industry (Appendix 2), the prediction is that this industry will concentrate more in the United States; Canada and Mexico might further loose their shares with respect to this industry.

The NAFTA dummy is significant only for three industries, positively for refined petroleum and negatively for motor vehicles and trailers and radio, television and communication equipment. The NAFTA coefficient of 0.15 in refined petroleum means that NAFTA led to a one time 16 percent $\left(= e^{0.15} - 1\right)*100$ increase in specialization in this industry, whereas NAFTA decreased specialization in motor vehicles by 8 percent and in radio, television and communication equipment by 12 percent. Therefore, once we control all other gravitas of specialization, NAFTA did not have much additional impact. Trefler (1999) has reached a similar conclusion regarding the impact of the 1988 Free Trade Agreement on Canadian specialization. His study was not specially designed to estimate specialization, but he does it for Canada at the aggregate level (without any industry dimension) by computing the Herfindahl index.

Next, we look at the economic significance of these three factors in determining the specialization by computing the *beta* coefficient for each. Even though the elasticities (the coefficients in the log-linear model) are not susceptible to the units of measurements of the dependent and independent variables, we cannot rank the importance of the explanatory variables simply by comparing them. The reason is that the magnitude of change in the dependent variable due to change in an independent variable depends both on the coefficient and the *range* of data. A beta coefficient takes both these factors into account and tells the number of standard deviation changes in the dependent variable induced by a one standard deviation change in an independent variable. These statistics are useful in answering questions regarding which independent variables are important in determining movement in the dependent variable. The beta coefficient for an independent variable is obtained by multiplying its coefficient by the ratio of its standard deviation to the standard deviation of the dependent variable.

The beta coefficients are presented in Table 8, and the industries are reported in the same order as in Appendix 3. Comparing the absolute magnitude of beta coefficients of three variables, it is evident that the Ricardian model is the most important explanatory variables for eight industries, the HO for 11 industries and R&D intensity for the remaining four industries. Furthermore, the Ricardian model is the second most important explanatory variable for 12 industries, the HO for eight industries, and R&D intensity for the remaining three industries.

The last two columns of Table 8 rank the relative importance of three variables in determining specialization in each industry. Next, using the magnitude of beta coefficients of a variable across industries from this table, we can sort an industry list according to the importance of this variable in determining specialization in each industry. For example, the 10 industries which have the largest Ricardian impacts are: (1) refined petroleum (2) tobacco (3) chemicals (4) radio, TV and communication equipment (5) basic metals (6) rubber and plastics (7) pharmaceuticals (8) motor vehicles (9) other non-metallic metal, and (10) wood products. For all these industries, the beta coefficient for the Ricardian variable is larger than 0.5, with the highest at 1.16 for the refined petroleum industry. It means that if the standard deviation of labour productivity in refined petroleum increases by one standard deviation, the predicted value added of this industry rises by 1.16 standard deviation. This list shows that these are the industries whose production location is most responsive for a given change in the Ricardian variable. However, it does not necessarily mean that the Ricardian variable is the most important factor in determining specialization in these industries, compared to other variables.

Similarly, the 10 industries with largest HO effects are: (1) refined petroleum, (2) wood products (3) radio, TV and communication equipment (4) railroad and transport equipment (5) tobacco (6) apparel (7) pharmaceutical (8) chemicals (9) basic metals, and (10) fabricated metals. Note that seven of these industries also made the list of 10 industries which have the largest Ricardian effects. Similarly, the top five industries with highest increasing returns to scale are: (1) motor vehicle (2) aircraft and spacecraft (3) office accounting and computing machinery (4) radio, TV and communication equipment, and (5) chemicals.

With this discussion, the analysis of empirical results is complete. Based on the above results on specialization, we can now make some inference about the adjustment process that has taken place in North America. The nature of industrial restructuring and adjustment differs according to each country's economic structure and the forces that are at play. If the forces were only Ricardian in nature, the signing of NAFTA would not have had much benefit to a more productive country and would have had moderate adjustment costs for low skilled workers in such a country. In this case, the less productive country would be expected to have benefited from superior technology in partner countries helping wage convergence from below, but would not have been expected to benefit from its endowment differences. On the other hand, if the adjustment were only HO, there would have been a great gain from exchange, but also potentially great pressures on wages of the unskilled workers in the capital abundant country, the United States in this case. The poor country (Mexico) would have benefited from being able to expand output in low skilled intensive sectors, but with less benefit from potential technology transfer. Finally, if internal market size were the only determinant of production location, the United States would have attracted most of the production.

Table 8. Beta Coefficients and Determinants of Specialization

	Ricardian model (RPA)	HO model (*k/l* ratio)	IRS model (R&D intensity)	Important determinants of specialization	
				First	Second
Food and beverages	0.12	0.09	0.05	R	HO
Misc. manufacturing	-0.05	0.00	0.19	IRS	R
Textiles	0.32	0.11	0.04	R	HO
Chemicals excl. pharma	1.13	-0.50	0.71	R	IRS
Machinery and equipment	0.23	-0.28	-0.03	HO	R
Other non-metallic mineral	0.53	-0.20	0.05	R	HO
Building of ships & boats	0.34	-0.35	0.02	HO	R
Rubber and plastics	0.81	-0.44	0.23	R	HO
Wearing apparel	-0.25	-0.76	0.10	HO	R
Refined petroleum	1.16	-2.28	-0.12	HO	R
Fabricated metal	0.47	-0.45	0.24	R	HO
Wood products	0.52	-2.20	-0.10	HO	R
Railroad and transport equip.	0.36	-0.99	0.22	HO	R
Pharmaceuticals	0.71	-0.72	0.13	HO	R
Basic metals	0.85	-0.48	-0.21	R	HO
Leather products	0.13	0.14	-0.10	HO	R
Motor vehicles and trailers	0.55	0.01	1.26	IRS	R
Electrical machinery and apparatus	0.16	0.45	0.28	HO	IRS
Pulp, paper, printing and publishing	0.13	-0.34	0.33	HO	IR
Aircraft and spacecraft	0.21	-0.26	1.08	IRS	HO
Radio, TV & commu. equipment	0.92	-1.04	0.77	HO	R
Office and computing machinery	0.39	0.21	1.01	IRS	R
Tobacco products	1.15	-0.88	0.47	R	HO

R: Ricardian model
HO: Heckscher-Ohlin model
IRS Increasing returns to scale model

In other words, as Leamer (1997) has explained for advanced countries, the Ricardian framework is less robust with respect to explaining the economic gains but more so with respect to the adjustment problems. For less productive countries, this framework is more promising on the potential benefit of technology transfer, but less so on endowment benefit to them. On the other hand, the HO effect predicts larger economic gains and somewhat severe adjustment problems in developed countries. For a less developed country, it predicts benefits from the endowment effect without any possibility of technology transfer.

The interplay of these three factors in determining specialization, especially of Ricardian and Heckscher-Ohlin effects, indicates that the adjustment process of NAFTA was moderate; the end result fell somewhere between the two extremes suggested by the Ricardian and HO models. There were some benefits to reap from specialization for all countries as shown by the HO model; there were benefits from technology transfer; after all these factors are taken into account, there are only a few industries where size mattered.

Conclusions

We have measured the pattern of international specialization in 23 manufacturing industries that has taken place in the last two decades in the North American Free Trade Agreement (NAFTA) partner countries, Canada, the United States and Mexico. Results show that the degree of specialization varies across industries and countries. Some industries have become more concentrated, while others have become more uniformly distributed. But the patterns of specialization have no clear trend in many industries, indicating continuous dynamic forces at play.

Among the 23 manufacturing industries, except for electrical machinery, the Ricardian variable (represented by revealed productivity advantage) explains production location for all other 22 industries, the Heckscher-Ohlin (HO) (represented by capital-labour ratio) for 17 industries and increasing returns (represented by the ratio of R&D to gross production) for eight industries. For four industries, the specialization patterns are predicted only by the Ricardian variable, whereas for 19 other industries they are predicted either by two or all three variables. Among them, the specialization of 11 industries is the combined effects of the Ricardian and HO variables. Furthermore, Ricardian and increasing returns to scale variables predict the production location of two other industries. The production location of electrical machinery is determined jointly by HO and increasing returns to scale variables. For the remaining five industries, all three factors are significant in shaping specialization patterns. There is no industry whose production location is explained either only by HO or only by increasing returns to scale.

Except for apparel and miscellaneous manufacturing, the Ricardian effects are positive for all 20 industries indicating that these industries tend to concentrate in more productive countries. On the other hand, the HO effects are negative for 15 industries and positive only for two, electrical machinery and office accounting and computing machinery. It means that except for these two industries, the other 15 industries tend to be under-represented in more capital-intensive countries. Out of these 15, 10 are the industries whose specialization was determined also by the Ricardian variables, indicating that these sectors tend to concentrate in more productive countries. Among the eight industries where R&D intensity has played a role along with other variables in influencing production location, except in the case of leather products, the prediction is that having higher R&D intensity leads to higher value added in a country. Out of eight industries where R&D intensity is significant, five are high-tech and medium-high-tech sectors.

The Ricardian model is either the first or the second main determinant of specialization in 20 industries; the similar number for HO is 19 and for R&D intensity seven. Hence all three variables are effective in determining specialization patterns in NAFTA countries, which confirms Leamer's (1993) conjecture that both factor proportion and increasing returns to scale variables should be operative in the NAFTA countries. The NAFTA impacted the specialization patterns of only three industries, one positively and two negatively.

The impact of industrial restructuring differs among countries depending on productivity and capital intensity levels and the nature of forces that are driving the change. Ricardian and HO models generally predict opposite effects. Hence, the interplay of all three factors, especially of Ricardian and HO, in determining specialization indicates that the adjustment process of NAFTA was moderate, one factor lessening the effect of other. The impact fell somewhere between the two extremes suggested by the Ricardian and HO models. As a result, there were some benefits to reap from specialization for all countries as shown by the HO model; there were potential benefits to achieve from technology transfer as shown by technology differences as a very important factor for specialization in many industries. As the Ricardian effect counterbalanced this effect, there were not severe consequences on low paid workers in developed countries the HO model would suggest.

Even though all three variables affected specialization, in terms of industry counts and the level of value added the industries contribute, the Ricardian variable seems to be the most important. The predominant role of productivity differences in explaining specialization indicates that there are huge technological differences among NAFTA countries. And, even if there were convergence to productivity levels, it is probably slow. Had it not been so, productivity differences should not have had the enormous impact in determining the production location in so many industries for such a long period of time.

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Appendix 1

International System of Industrial Classification (ISIC), Revision 3

ISIC Codes	*Industry*	*ISIC Codes*	*Industry*
15	Food products and beverages	28	Fabricated metal
16	Tobacco products	29	Machinery and equipment
17	Textiles	30	Office, accounting and computing machinery
18	Wearing apparel, dressing and dying of fur	31	Electrical machinery and apparatus
19	Leather, leather products and footwear	32	Radio, TV & communication equipment
20	Wood and products of wood and cork	33	Medical, precision and optical instruments
21	Pulp, paper and paper products	34	Motor vehicles, trailers and semi-trailers
22	Printing and publishing	35	Other transport equipment
23	Coke, refined petroleum products and nuclear fuel	351	Building and repairing of ships & boats
24 excl. 2423	Chemicals excluding pharmaceuticals	353	Aircraft and spacecraft
2423	Pharmaceuticals	352 + 359	Railroad equipment and transport equipment
25	Rubber and plastics products	36	Manufacturing, not elsewhere counted
26	Other non-metallic mineral products	37	Recycling
27	Basic metals	15-37	Total manufacturing

Appendix 2

The Values of Ricardian, Heckscher-Ohlin and Increasing Returns to Scale Variables in 2000

	Revealed productivity advantage (RPA)			Capital labour ratio (in thousands of US $ at PPP exchange rates)			Share of R&D in gross production (%)		
	Canada	**U.S.**	**Mexico**	**Canada**	**U.S.**	**Mexico**	**Canada**	**U.S.**	**Mexico**
Food and beverages	61	74	60	63	105	18	0.115	0.318	0.132
Tobacco products	323	605	76	130	289	38	0.005	0.009	0.002
Textiles	53	42	24	62	60	9	0.054	0.024	0.024
Wearing apparel	39	38	10	12	26	1	0.065	0.028	0.010
Leather products	32	48	20	28	39	4	0.006	0.002	0.006
Wood products	73	46	24	73	37	1	0.056	0.037	0.013
Pulp, paper, print and publishing	64	72	35	94	79	25	0.170	0.637	0.020
Refined petroleum	140	306	73	876	778	8	0.056	0.243	0.011
Chemicals excl. pharmaceutical	115	142	83	234	235	66	0.313	1.719	0.032
Pharmaceuticals	100	212	117	121	234	80	0.947	2.669	0.018
Rubber and plastics	62	58	24	49	70	16	0.102	0.349	0.015
Other non-metallic mineral	75	69	67	98	103	28	0.016	0.183	0.034
Basic metals	101	71	128	264	194	130	0.235	0.129	0.024
Fabricated metal	63	70	28	31	61	9	0.163	0.400	0.020
Machinery and equipment	71	62	30	31	67	15	0.392	1.395	0.017
Office and computing machinery	69	150	90	59	120	34	0.622	2.128	0.015
Electrical m. and apparatus	57	69	19	28	36	9	0.313	0.789	0.015
Radio, TV & commu. equipment	96	128	21	47	141	1	5.594	5.319	0.021
Motor vehicles and trailers	112	117	53	109	102	26	0.492	3.832	0.080
Building of ships & boats	44	45	5	54	65	5	0.100	0.100	0.000
Aircraft and spacecraft	109	94	44	44	81	0	1.257	2.128	0.001
Railroad and transport equip.	78	62	56	43	71	16	0.028	0.265	0.002
Misc. manufacturing	45	65	29	17	55	5	0.407	4.118	0.016
Total	**73**	**80**	**41**	**96**	**142**	**17**	**1.319**	**3.039**	**0.112**

Appendix 3

Estimates of the Specialization Equation, dependent variable log of specialization, 1980-2000

Independent variables	Constant	RPA	*k/l* ratio	R&D intensity	NAFTA	Adj. R^2	Best Model		
Food and beverages	1.24 (3.12)**	0.58 (5.23)**	0.05 1.40	0.06 1.19	-0.02 -0.94	0.99	R		
Misc. manufacturing	-0.30 -0.40	-0.11 (-2.57)*	0.00 -0.13	0.07 0.87	0.04 1.11	0.99	R		
Textiles	1.20 1.65	0.78 (3.90)*	0.06 0.85	0.07 0.89	0.02 0.30	0.97	R		
Chemicals excluding pharmaceuticals	0.45 0.87	1.23 (10.0)*	-0.05 -1.19	0.06 0.99	0.00 0.14	0.69	R		
Machinery and equipment	-0.86 (-3.59)**	0.89 (13.7)**	-0.12 (-12.1)**	-0.01 -0.44	0.00 0.01	0.99	R	HO	
Other non-metallic mineral	1.30 (2.85)**	1.01 (5.79)**	-0.20 (-2.23)*	0.04 0.71	-0.01 -0.11	0.98	R	HO	
Building of ships & boats	-1.47 (-3.13)**	0.54 (5.76)**	-0.31 (-4.47)**	0.01 0.30	0.15 1.55	0.97	R	HO	
Rubber and plastics	0.24 1.03	0.89 (19.4)**	-0.06 (-3.73)**	0.03 1.07	0.00 0.37	0.96	R	HO	
Wearing apparel	0.28 0.65	-0.28 (-6.54)**	-0.15 (-2.82)**	0.03 0.84	0.04 1.55	0.94	R	HO	
Refined petroleum	0.72 1.93	0.91 (16.9)**	-0.42 (-7.28)**	-0.03 -0.81	0.15 (2.40)*	0.94	R	HO	
Fabricated metal	0.36 0.92	0.90 10.04	-0.12 -5.96**	0.07 1.71	-0.04 -1.30	0.98	R	HO	
Wood products	-0.67 (-3.23)**	0.93 (9.30)**	-0.41 (-4.81)**	-0.05 -1.88	0.08 1.40	0.90	R	HO	
Railroad and transport equip.	0.94 1.72	0.35 (2.64)*	-0.35 (-8.98)**	0.08 1.50	0.07 0.89	0.89	R	HO	
Pharmaceuticals	1.36 1.46	0.97 (8.24)**	-0.39 (-3.17)**	0.02 0.24	-0.04 -0.78	0.88	R	HO	
Basic metals	-0.08 -0.10	0.58 (5.11)**	-0.22 (-2.59)*	-0.07 -0.86	-0.02 -0.37	0.88	R	HO	
Leather products	-0.64 -0.69	0.82 (6.89)**	0.10 1.35	-0.23 (-2.56)*	-0.02 -0.40	0.99	R		IRS
Motor vehicles and trailers	3.11 (5.45)**	1.27 (17.1)**	0.00 0.05	0.30 (4.52)**	-0.08 (-2.07)*	0.96	R		IRS
Electrical m. and apparatus	0.11 0.67	0.11 0.75	0.13 (2.13)*	0.04 (2.08)*	0.00 -0.04	0.89		HO	IRS

Pulp, paper, printing and publishing	0.67 1.88	0.87 (10.1)**	-0.18 (-4.55)**	0.13 (3.15)**	0.03 1.24	0.99	R	HO	IRS
Aircraft and spacecraft	2.72 (2.86)**	0.67 (6.10)**	-0.10 (-3.71)**	0.48 (5.78)**	0.10 1.12	0.99	R	HO	IRS
Radio, TV & commu. equipment	1.70 (4.02)**	0.96 (12.7)**	-0.40 (-8.37)**	0.19 (4.43)**	-0.11 (-2.80)**	0.98	R	HO	IRS
Office accounting and computing machinery	4.12 (3.27)**	0.94 (6.84)**	0.18 (3.11)**	0.47 (4.01)**	0.03 0.37	0.97	R	HO	IRS
Tobacco products	4.56 (4.50)**	0.64 (9.49)**	-0.30 (-3.39)**	0.38 (4.34)**	0.01 0.14	0.94	R	HO	IRS

There are 21 years (1980-2000) of data for each industry in each country. The three countries are pooled together; as a result the total number of observations is 63 for each regression. The dependent variable is the measure of specialization as defined by equation (1). The independent variables are revealed productivity advantage (RPA) as defined by equation (3), the capital-labour ratio (*k/l* ratio) in thousands of U.S. dollars at purchasing power parity exchange rates, and the ratio of R&D to gross production (R&D intensity). The dependent and these three independent variables are in log forms. The model was estimated using country dummies and a time trend, but theirs results are not included to conserve space. NAFTA is used as a dummy variable.

R: Ricardian model
HO: Heckscher-Ohlin model
IRS Increasing returns model

The t-values are given in parentheses
** indicates significant at 1 percent level
* indicates significant at 5 percent level

Appendix 4: Data Description

Capital stock

The capital stock data for Canada are taken from Statistics Canada's series on "fixed non-residential capital, geometric infinite year end net stock at current price" at North American industrial classification system (NAICS) and converted to the international system of industrial classification (ISIC) codes using NAICS to ISIC concordance given in OECD's database. The data are converted from Canadian dollars into U.S. dollars using purchasing power parity exchange rates.

For the United States, the capital stock data are from Table 3.1ES "Current-Cost Net Stock of Private Fixed Assets by Industry, year end estimates" of the Bureau of Economic Analysis (BEA)'s home page. These data were in U.S. SIC87, and we transferred them into ISIC Revision 3 using concordance given in OECD's structural analysis (STAN) database. For some industries that we are interested in, the BEA did not have separate data; sometimes two industries were aggregated into one. In that case, we used data on gross fixed capital formation (GFCF) in STAN database (which have all industries that we are using in this study) as a guideline to separate the combined capital stock data of BEA into two industries. For example, the capital stock data corresponding to industries ISIC-17 and ISIC-18 were combined in the BEA data set. However, these industries have separate data on GFCF in the STAN database. Using these STAN data, we computed the total GFCF of these two industries and their shares in this total. And according to these shares, we distributed the combined capital stock data of BEA into ISIC-17 and ISIC-18 industries. A similar approach was adopted for ISIC industries 29 and 30, industries 31 and 32.

For Canada we use data on *non-residential* series and for the U.S. we use data on private capital. Even though *private* capital includes both residential and non-residential capital in the private sectors, in terms of manufacturing, the private capital stock is equal to non-residential capital stock, as there is no residential capital in manufacturing industries. Therefore, the two series that we have used for Canada and the U.S. are comparable for manufacturing industries. Furthermore, in manufacturing sectors, all capital stock data are private, as the government sector has no capital stock in manufacturing.

The capital stock data for Mexico is computed using data on GFCF from World Bank's "Trade and Production Database" from 1976 to 1991 and beyond 1991 we use data on investment from the OECD's structural statistics for industry and services (SSIS) database. The data on SSIS were in Mexican Pesos and were converted into U.S. dollars using purchasing power parity exchange rates. To generate capital stock data from GFCF and investment, we use the following method. For example, the net capital stock in base year 1976 (subscript of zero) is calculated using the following mechanism:

$$k_0 = I_0/(\delta + g) ,$$

where g is the average growth rate of investment over the entire period, δ is the depreciation rate, k_0 is the capital stock at base year 1976 and I_0 is the investment in base year 1976. For the subsequent years, the data are computed using the following formula:

$k_t = I_t + (1-\delta)k_{t-1}$, where t runs from year 1977 to 2000.

R&D Data

For both Canada and the U.S., the R&D data are obtained from OECD's analytical business enterprise research and development (ANBERD) database from 1987 to 2000. However, for years 1980 to 1986 we use data from U.S. National Science Foundation (USNSF) for the U.S. and Statistics Canada for Canada. Since the USNSF data were in U.S. SIC87 codes and Canadian data were in Canadian SIC81, they were converted into ISIC revision 3.

However there were some industries which did not have data and were aggregated with other industries. For example, for the U.S., for ISIC 15 and 16 industries, the data were aggregated for some years and were given separate for other years. We decompose the data that were in aggregate using the proportion of data from the year they were given separately. A similar approach was adopted for ISIC industries 17, 18 and 19 and for ISIC industries 20 whose data were given along with industries ISIC 21 and 22. The data on ISIC 351 was appropriated as the difference of R&D value on aggregate manufacturing and the R&D sum of all other industries. A similar approach was adopted for Canada.

For Mexico, there were no industry R&D data. I took the share of economy-wide R&D to GDP ratio from the OECD's main science and technology indicator (MSTI) and computed the total R&D by industry simply by multiplying this ratio by industry GDP.

For the study, all R&D data were converted to the same unit of measurement using purchasing power parity exchange rates.