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ABSTRACT *We propose a new way to locate the comparative advantages of two economies linked by international trade. We construct a competitive benchmark based only on the fundamentals of the two economies: endowments, preferences and technologies. The direction of trade is endogenously determined by a linear program with an input–output core. The factor contents of that trade are compared with factor endowments to test the Heckscher–Ohlin model in the presence of different technologies and preferences. We can also evaluate the gains of free bilateral trade. The model is applied to a customs union between Europe and Canada. The Heckscher–Ohlin factor abundance specialization hypothesis is supported by the data.*

KEYWORDS: *Comparative advantage, gains to free trade*

1. Introduction

One of the basic issues in trade theory is the determination of the sources of comparative advantage and hence of trade between countries. The early theories stressed one aspect at a time (such as differences in technology in the Ricardian model and differences in endowments in the Heckscher–Ohlin model). They neutralized the other possible sources of relative domestic price differences in order to prove their argument in the simple way. That is what theory should do.

A number of studies have tried to test the various theories (see the survey by Leamer & Levinsohn, 1995). The tests often reject the Heckscher–Ohlin–Vanek (HOV) model. Two problems are encountered in those studies. Either they do not use independent data on trade, endowments and technologies, in which case the test is largely invalidated, or they are counterfactual by assuming common technologies and/or preferences, in which case it comes as no surprise that the

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HOV model is rejected. Bowen *et al.* (1987) and Trefler (1993, 1995) find empirical support but for a modified HOV model where technology and/or preferences are allowed to depart from those prevailing in the United States. Davis *et al.* (1997) show, on Japanese regional data, that geographical differences in direct factor requirements may be sufficient to restore the HOV predictions on the factor content of trade.

We go a step further by allowing country specific endowments, preferences and technologies, the fundamentals of the economy according to neoclassical theory. We need no reference country for technology, as in Bowen *et al.* (1987), Trefler (1993, 1995) and Davis *et al.* (1997). Numerous distortions, such as monopoly power, externalities, tariffs and other impediments, drive a wedge between the hypothetical and observed patterns of trade. Rather than trying to get a handle on these departures from perfect competition, we give up all the information contained in the trade statistics and return to the fundamentals. On the basis of those, we construct a competitive benchmark by solving a linear program and use it to locate the comparative advantages and the gains from free trade. All patterns of specialization are admitted and, therefore, we do not make the international trade theoretic assumption of a common cone of diversification. To test the Heckscher–Ohlin model, we do not confront the observed factor contents of net trade and those predicted by the theory, but we check whether endowments alone determine the factor movements of free trade; that is, the endogenous trade within the model, controlling for taste and technology.

For illustration, we take two economies, Europe and Canada in 1980, keeping trade with the rest of the world fixed. The choice of the two economies is entirely opportunistic, suggested by data availability. The model is a general equilibrium version of ten Raa & Chakraborty (1991). Since it is based on the fundamentals, with all prices endogenous, the incorporation of the rest of the world as a third economy (or family of economies) would now be a straightforward extension.

From a theoretical point of view, our contribution is modest as it merely implements ideas that have been around quite some time. A reference is the theoretical introduction of Ginsburgh & Waelbroeck (1981, pp. 30–31) where they consider the maximization of consumption subject to commodity and factor input constraints. In the empirical part, however, Ginsburgh & Waelbroeck (1981, p. 176) note that such a model could not be handled with available means. We carry out the program they suggested. No statistics or constructs beyond the fundamentals of the economies are used. In particular, we employ no price statistics. Nor do we admit artifical limitations on the direction of trade. The model provides a truly general equilibrium determination of the commodity pattern of trade.

The paper is organized as follows. Section 2, we present the model used to set up the competitive benchmark. In Section 3, we determine the comparative advantages of the two economies and compare the factor contents of net bilateral trade with the factor endowments. In Section 4, we compute the magnitude of gains to free bilateral trade. In Section 5, we relate details of our model to the literature. We conclude by summarizing the main features of our model and the results in Section 6.

2. Locating Comparative Advantages

We set up a single neoclassical model of international trade with fixed domestic endowments, with tradeable and non-tradeable commodities, used for intermediate or final consumption, and with Leontief functions for the technologies and preferences, i.e. with fixed input coefficients and fixed proportions of final consumption and investment in each economy. The efficient allocation of resources is obtained by maximizing the level of domestic final demand (including consumption and investment) in one economy, subject to a given proportion of final consumption in the two economies. We posit the latter to be such that the outcomes preserve the actual bilateral balance of payments. We will find this balanced, efficient allocation by scanning the final consumption frontier for the two economies. Thus, let c denote the level of final consumption in Europe and $c^\star$ the same for Canada. Star superscripts represent Canadian items. We scan the (c, $c^\star$)-frontier with the Canadian–European final consumption ratio, γ, by putting $c^\star = \gamma c$. For every ratio γ, a linear program will determine the maximum level of final consumption, c, subject to material balance and endowment constraints.[1] Apart from c itself, the variables are the vectors of gross outputs, $\mathbf{x}$ for Europe and $\mathbf{x}^\star$ for Canada. The linear program is

$$\max_{\mathbf{x},\mathbf{x}^\star,c\geqslant 0} \mathbf{e}^\top \mathbf{y}c + \mathbf{e}^\top \mathbf{y}^\star \gamma c \tag{1}$$

subject to the following constraints. For tradeable commodities:

$$(\mathbf{I} - \mathbf{A})\mathbf{x} + (\mathbf{I} - \mathbf{A}^\star)\mathbf{x}^\star \geqslant (\mathbf{y} + \mathbf{y}^\star\gamma)c + \mathbf{z} + \mathbf{z}^\star \tag{2}$$

for non-tradeable commodities:

$$(\mathbf{I} - \mathbf{A})\mathbf{x} \geqslant \mathbf{y}c, \; (\mathbf{I} - \mathbf{A}^\star)\mathbf{x}^\star \geqslant \mathbf{y}^\star\gamma c \tag{3}$$

and for factor inputs:

$$\mathbf{k}^\top\mathbf{x} \leqslant K, \mathbf{l}^\top\mathbf{x} \leqslant L, (\mathbf{k}^\star)^\top\mathbf{x}^\star \leqslant K^\star, (\mathbf{l}^\star)^\top\mathbf{x}^\star \leqslant L^\star \tag{4}$$

The expression 'for (non)tradeable commodities' restricts the announced vector in equality to the respective components.[2] In the objective function, $\mathbf{e}^\top = (1\ldots 1)$. The program features the following European parameters:

$\mathbf{y}$ = domestic final demand vector (including consumption and investment, excluding trade)
$\mathbf{z}$ = net exports vector (except for bilateral trade)
$\mathbf{A}$ = commodity input coefficients matrix
$\mathbf{k}$ = capital input coefficients row vector
$\mathbf{l}$ = labor input coefficients row vector
K = capital stock
L = labor force.

The Canadian variables are denoted with a star superscript. Variable c acts as an expansion factor. The solution is not affected by the monotonic transformation of the objective function. For normalization of the supporting price system, we have included a positive constant in the objective function. For every value of the final consumption ratio, $\gamma = c^\star/c$, denote the optimum (European) consumption level by $c(\gamma)$ and the outputs in the two countries by $\mathbf{x}(\gamma)$ and $\mathbf{x}^\star(\gamma)$, respectively. For low values of γ, Canadian consumption is unimportant and the bulk of net output is exported to Europe. Similarly, the trade balance shows a European surplus for high values of γ. For tradeable commodities, European *net exports* to Canada are given by the vector:

$$(\mathbf{I} - \mathbf{A})\mathbf{x}(\gamma) - \mathbf{y}c(\gamma) - \mathbf{z} \tag{5}$$

In a general equilibrium framework like the above, the supporting competive prices are given by the shadow prices of the linear program. Denote those for tradeable commodities by $\mathbf{p}(\gamma)$. By the dual constraint associated with the c-coefficients in equations (2) and (3), the value of final consumption, $\mathbf{y}+\mathbf{y}^{\star}\gamma$, under the shadow prices, is equal to its nominal value, the coefficient in (1). In other words, the coefficient in the objective function has been selected such that only relative prices change. This is the normalization rule. By the dual constraint associated with the $\mathbf{x}$-coefficients in (2) to (4), European profits are non-positive. Similarly, by the dual constraint associated with the $\mathbf{x}^{\star}$-coefficients in equations (2) to (4), Canadian profits are non-positive. Sectors with negative profits are inactive by the phenomenon of complementary slackness.

European surplus on the bilateral trade account is equal to the (inner) product of $\mathbf{p}(\gamma)$ and (5) and will be denoted by $s(\gamma)$. For γ low, $s(\gamma)$ is negative, and for γ high, $s(\gamma)$ is positive. For some intermediate value, $s(\gamma)$ will match the observed surplus on the bilateral trade account,

$$s^0 = \mathbf{e}^{\mathsf{T}}(\mathbf{x}^0 - \mathbf{A}\mathbf{x}^0 - \mathbf{z}) \tag{6}$$

where $\mathbf{x}^0$ is the observed value of gross output vector $\mathbf{x}$. We find the intermediate value of γ by the Newton algorithm,

$$\gamma_{n+1} = \frac{[s(\gamma_n) - s^0]\,\gamma_{n-1} - [s(\gamma_{n-1}) - s^0]\,\gamma_n}{s(\gamma_n) - s(\gamma_{n-1})} \tag{7}$$

with initial values $\gamma_0 = 0$ and $\gamma_1 = 1$. The limit of process (7) solves $s(\gamma) = s^0$ and is, therefore, the general equilibrium value of the Canadian–European final consumption expansion ratio, $\gamma = c^{\star}/c$. For this value, the linear program determines the levels, $c(\gamma)$ and $c^{\star}(\gamma)$, the allocations, $\mathbf{x}(\gamma)$ and $\mathbf{x}^{\star}(\gamma)$ and the bilateral trade vector, (5).

The sign pattern of bilateral trade locates the comparative advantages of the two economies. Notice that this is accomplished solely on the basis of parameters for Europe and similar parameters for Canada. The parameters represent *taste* ($\mathbf{y}$), *technology* ($\mathbf{A}$, $\mathbf{k}$ and $\mathbf{l}$) and *endowments* (K and L), and fix the rest of the world ($\mathbf{z}$). In other words, we have located the comparative advantages on the basis of the fundamentals of the economies, without recourse to exogenous prices. All prices are endogenous. Prices of the tradeable commodities $\mathbf{p}(\gamma)$ are shadow prices associated with constraint (2). The prices of the non-tradeable commodities, associated with constraints (3), and those of the factor inputs, associated with constraints (4), are specific to the individual economies.

By comparing the expansion of final demand under the autarky and free trade scenarios we can assess the gains of free trade. By letting consumption and input proportions represent taste and technology, we make a short-cut. Strictly speaking, technology is a blue-book of techniques and the choice of techniques depends on the relative prices. The observed input–output coefficients reflect the techniques prevailing under the observed prices. Now, if the prices change to the general equilibrium values, the choice of technique and hence the input–output coefficients may be different. An induced change of techniques within the technology blue-book thus prompts further reallocations of endowments and gains to specialization. The same holds for consumption: taste is a blue-book of consumption coefficients and the latter may adjust. By restricting the blue-book of technology and consumption to a single page for each economy, our model ignores the further reallocations and, therefore, the results will be conservative. Since the point of this paper is to demonstrate how endogenous patterns of productive activity create significant gains to free trade, it suffices to do so in the context of the narrow Leontief framework that underlies the above model.

3. Canadian Advantages Compared with Europe

If bilateral trade were completely free and the national economies were perfectly competitive, the free trade pattern of Table 1 would emerge, if we ignore the ramifications of the trade with the rest of the world. The first two columns of the table contrast the actual and the optimum trade figures (Statistics Canada, 1983 and equation (5)). By construction, the observed European trade deficit with Canada is the same.[3] The second column reveals that the Canadian comparative advantage *vis-à-vis* Europe given the trade with the rest of the world rests in *minerals*, *machines*, and *clothing & footwear*.

The resulting comparative advantage contrasts with observed trade (first column of Table 1). In reality, Canada exports chiefly minerals, metal products, consumption goods, and other manufactures, and imports machines, transportation equipment, and clothing & footwear. The endogenous comparative advantages may also conflict with intuition. For example, agricultural exports are not taken up by Canada, but by Europe. To some extent this is due to model limitations: land is not modeled as a separate factor and the rest of the world is not included. However, we also note that Canada has only a slight edge in agricultural value added per worker (10 110 versus 8884 ECU per worker), whereas agricultural value added per unit of capital is the same in the two economies. Because of the scarcity of Canadian capital, it does not pay to exploit the mild Canadian technological edge in this sector. It will, however, when access to technology is free, as we shall see at the end of this section.

Bilateral trade liberalization would multiply the volume of trade and let the small economy (Canada) specialize in only a few sectors. Note, however, that these sectors continue to feature two-way trade under perfectly competitive conditions. This is due to product differentiation. For example, in minerals the (dominant) Canadian export is in mining, but it is countered by European exports in petroleum

Table 1. Observed, free and superfree exports minus imports from Europe to Canada (millions ECU)

		Observed exports minus imports		Free exports minus imports		Superfree exports minus imports	
1	Agriculture	30	−174	6405	−0	9413	−0
2–4	Minerals	196	−1394	4178	−65734	6830	−0
5	Chemical Products	315	−433	2161	−0	6099	−0
6	Metal Products	265	−804	14294	−0	8648	−0
7–8	Machines	915	−337	6828	−12222	6483	−5163
9	Transportation Equipment	598	−162	11081	−0	10534	−0
10–12	Consumption Goods	316	−799	21964	−0	21557	−0
13–15	Clothing & Footwear	270	−125	9864	−22373	4920	−97040
16–18	Other Manufactures	263	−1718	20776	−0	24491	−0
Total		3168	−5946	97551	−100329	99425	−102203

Note: For sector aggregation, see Table A-1 in Appendix A. Observed exports and imports are at observed prices and (super) free exports and imports are at endogenous prices.

& natural gas and non-metallic minerals. Similarly, Canadian exports of machines are countered by European exports of electrical goods. And in clothing and footwear, Canada picks up the footwear.

The revelation of product differentiation in the phenomenon of two-way trade is limited by the level of disaggregation. In our model, where we want to determine comparative advantages on the basis of the fundamentals of the economies, we choose the most disaggregated classification of products that we could reconcile with the Eurostat and Statistics Canada production units (see Table A.1 in Appendix A). In this approach, footwear is footwear, be it European or Canadian. At this level of aggregation, there is no two-way trade, because according to the logic of the model each economy specializes in what it is best at. Seminar participants have suggested that Italian footwear is different from Canadian and that, therefore, trade should be two-way even at the disaggregated level. We admit that this is true, but in our opinion the only correct way of modeling this is to disaggregate the data. Our view deviates from the dominant one in the literature where product differentiation is imposed by taking into account the origin of commodities (the so-called Armington assumption, Harris, 1984, and Srinivasan & Whalley, 1986). Such an imposition of two-way trade may be a practical device to obtain a good fit, but it is useless for the location of comparative advantages, particularly when they are not assumed to be revealed by the international trade statistics.

Let us give some idea of the relative importance of the determinants of comparative advantage. As is common in the literature, we will focus on the role of endowments by holding technology and taste constant across the economies. This is implemented in neoclassical fashion by assuming free access to each other's technology and, similarly, by introducing substitutability between the mean consumption vectors in either economy. The modification yields a model of free trade between economies with free access to technology in production and consumption. This so-called superfree model is presented in Appendix B and the consequent pattern of superfree trade is reported in the last column of Table 1. The Canadian comparative advantages in machines and clothing & footwear persist when technology differences in production and consumption are eliminated, but the minerals production is picked up by Europe. The initial conclusion is, therefore, that the Canadian comparative advantage is determined by endowments (for machines and clothing & footwear) and technology (for minerals). A qualification of the technology determinant seems in order. It turns out that Europe adopts the Canadian technology to produce minerals. The Canadian input coefficients are relatively small in this sector. Note, however, that our model does not account for natural resources separately. The Canadian abundance or quality of the ores is reflected in the level of the input coefficients. The superfree scenario, by moving this technology to Europe, sort of endows Europe with the Canadian edge in minerals. This peculiar role of input coefficients in minerals is known. Carter (1970) showed that it is the only sector where input–output developments indicate technical regress and that the underlying problem is not a deterioration of knowledge, but a reduction of the quality of the unaccounted resource. In so far as the Canadian edge in mineral production is a reflection of the abundance of natural resources, the transfer of Canadian technology to Europe would not be supportable by a more detailed model. We therefore speculate that a fuller model, accounting for natural resources as a third endowment in addition to capital and labor, would ascribe the Canadian comparative advantage in minerals to the natural resource

Table 2. Capital–labor ratios (ECU per worker)

		Europe	Canada
Endowments		96 096	38 101
Endowments plus net imports:	Observed	96 060	37 730
	Free	96 404	36 802
	Superfree	94 334	55 501

endowment, rather than technology. We are thus inclined to conclude that the Canadian comparative advantage is determined by endowments.

Now let us shift attention from the product nature of trade to the factor contents. Are differences in European and Canadian factor endowment proportions leveled out by trade? We have calculated the factor contents embodied in the net trade vectors (actual, free, and superfree), see Table 2. The technique is due to Leontief (1953), but now the pattern of the comparative advantage revealing trade is endogenous.

The first line of Table 2 shows the capital/labor endowments ratios of the two economies. (These figures are obtained by simple divisions of the data at the bottom of Table A-2 in Appendix A. Europe is endowed with relatively much capital. The second and third lines of Table 2 show agreement between the effects of observed and free trade. We focus on trade augmented endowment ratios rather than exports and imports factor intensities to make the analysis Leamer (1980) proof. The capital–labor ratio in the big economy, Europe, is not affected. The capital–labor ratio of Canada deteriorates further. Obviously, the Heckscher–Ohlin theorem does not work here. There are numerous reasons for this, as pointed out by Batra & Casas (1973), Deardorff (1984), and Bowen *et al.* (1987). Perhaps the most important one is that the theorem assumes free access to technology and common preferences. Now these conditions are precisely the ones of the superfree trade scenario. Hence the last line of Table 2 is a more appropriate test of the Heckscher–Ohlin theorem. The results show that with common access to technology and consumption patterns free trade would indeed level out factor intensity differences.

That factor abundance theory is reflected in net exports between Europe and Canada is not a trivial result. In our high-dimensional model (with more commodities than factors), the Heckscher–Ohlin theorem need not hold. Factor prices are not equalized in the solution to our linear program. In the superfree trade model, the difference in relative factor prices may induce the two economies to select different techniques of production and different consumption patterns, and hence the direction of trade may be the result of relative factor abundance, but also of differential production and consumption input coefficients. Yet, a dominant technique is adopted for each output (except for one non-tradeable commodity, where two techniques coexist), and the Canadian consumption pattern is preferred in both countries. Differences in input structures (in production and consumption) are neutralized and trade is driven by differences in endowments.

At the suggestion of a referee, we have included results on the production structures in the free and superfree trade scenarios. Table 3 shows the sign patterns of the solution in either scenario. Since Canada is small compared with Europe, Europe must produce nearly everything. Leather and footwear is the only activity that can be taken up wholy by Canada, in the free trade scenario, where the two

Table 3. Activities sustaining the free and superfree trade scenarios, tradeables only (E = Europe, C = Canada, $E^{\star}$ = Europe using Canadian technology)

Sector	Free trade	Superfree trade
1 Agriculture	E	$E^{\star}$
2 Mining	E, C	$E^{\star}$
3 Petroleum & Natural Gas	E	E
4 Non-metallic Minerals	E	$E^{\star}$
5 Chemical Products	E	$E^{\star}$
6 Metal Products	E	$E^{\star}$
7 Machines	E, C	$E^{\star}$
8 Electrical Goods	E	$E^{\star}, C$
9 Transportation Equipment	E	E
10 Food	E	$E^{\star}$
11 Beverages	E	E
12 Tobacoo Products	E	E
13 Textiles & Clothing	E	C
14 Leather and Footwear	C	$E^{\star}$
15 Rubber & Printing	E	E
16 Wood Products	E	E
17 Paper & Printing	E	$E^{\star}$
18 Other Manufactures	E	E

economies stick to their own techniques of production. Canada is also active in mining and machines. Turning to the superfree trade scenario, the pattern of specialization changes to electrical good and textiles & clothing for Canada, with the latter being the inactive sector in Europe. The shift to the neoclassical paradigm of free access to technology has dramatic ramifications and, in particular, explains the differences in factor contents we encountered in Table 2. It is particularly noteworthy that Canadian technology is superior in the majority of sectors, including agriculture. In ten sectors, Europe adopts it, while Canada employs no European technology.

4. Gains to Free Trade

The solutions to (1)–(4) and (7) yield $\gamma = c^{\star}/c$ and c. The consequent expansion factors for European and Canadian final consumption are

$$c = 1.075 \text{ and } c^{\star} = 1.40 \tag{8}$$

respectively. Perfect competition and free bilateral trade would hence boost the European and Canadian economies by 7.5% and 40%, respectively. The difference reflects the relative importance of bilateral trade to the two economies. Gains accrue to both. Parts of the efficiency gains, however, are obtained by the elimination of the domestic waste of resources from misallocation and less than full utilization of resources. To isolate the gains to free trade, we must determine the domestic efficiency gains that the program can achieve without departing from the observed bilateral trade vector.

The domestic expansion factor for Europe, given the full net exports vector, $\bar{\mathbf{z}}$, is obtained by

$$\max_{\mathbf{x},d\geqslant 0} \mathbf{e}^{\mathsf{T}}\mathbf{y}d \text{ subject to} \tag{9}$$

$$(\mathbf{I}-\mathbf{A})\mathbf{x} \geqslant \mathbf{y}d+\bar{\mathbf{z}} \tag{10}$$

$$\mathbf{k}^{\mathsf{T}}\mathbf{x} \leqslant K,\ \mathbf{l}^{\mathsf{T}}\mathbf{x} \leqslant L \tag{11}$$

In star superscript, this would be the domestic expansion factor program for Canada. The consequent allocations of production and consumption are feasible with respect to the free trade program, (1)–(4), with $\gamma = d^{\star}/d$, for the following reason. The domestic material balances, (10), and the same but starred for Canada, sum to (2) and (3) because the bilateral net exports cancel out. The solutions to (9)–(11) and its Canadian version are

$$d = 1.073 \text{ and } d^{\star} = 1.18 \tag{12}$$

The bulk of the European efficiency gain can thus be ascribed to the elimination of domestic waste of capital and labor. Comparison of results in (8) and (12) shows that Europe would gain only 0.2% in free trade with Canada. This underscores the insignificance of the Canadian economy to Europe. For Canada, however, the picture is different. Half of the efficiency gain of 40%, in fact 22%, can be ascribed to free trade with Europe, as seen by subtraction of the second figures of (8) and (12).

5. Discussion of the Model

Linear programming yields a high degree of specialization. This is merely a reflection of the dimensionality of the issue. A key test for the factor-endowments approach is whether it can accommodate reality in a context simple enough (i.e. of low enough dimensionality) to be theoretically tractable. Indeed, a distinctive feature of our attempt is to determine the disaggregated pattern of comparative advantage on the basis of only a *few* fundamentals, namely the primitives suggested by neoclassical theory. Consequently, we face many more goods than factors and specialization is natural. Contrary to what Krueger (1984, p. 545) suggests, this property does not depend on the input–output assumption of fixed coefficients. As a matter of fact, input substitutability would widen the scope for specialization. To avoid the latter, one must resort to brute force.[4]

As is well known, estimates of inefficiencies of trade restrictions are modest when the patterns of trade are taken for granted. Within a framework of goods that agrees with the observed outputs, exports, and imports, the welfare losses are given by the Harberger triangles. The size of a triangle is half the base times the height and the two are related to each other by the elasticity of demand. In short, the welfare losses are quadratic in either the price or the quantity distortion, hence small. Romer (1994) shows that gains to free trade are of a higher order if the list of goods that defines the framework of an economy is endogenous, namely the outcome of profit maximization involving fixed costs. Free trade would lengthen the list and create new areas of consumer surplus. We have shown that one does not have to go as far as Romer, questioning the observed categories of goods, to suggest high welfare stakes of free trade. It suffices to endogenize the direction of trade in order to show the existence of efficiency gains of a higher order than the ones implied by Harberger calculations.

All market imperfections and departures from the simple perfectly competitive model are ignored when the benchmark is calculated. Some departures from the competitive benchmark cannot be separated from the fundamentals, but are grounded in the physical structure of the economies, particularly product differentiation and scale economies. Harris (1984) builds a real trade general equilibrium model to assess trade liberalization effects. This purpose, as well as the requirement that some historical data set is produced as an equilibrium, infringe on the 'pureness' of the model.[5]

In our opinion, product differentiation is an aggregation phenomenon. If products are differentiated, they constitute different commodities and the efficient pattern of trade must be determined at the most disaggregated level. Aggregating back to the level of differentiated products, intra-industry trade emerges. Cross-hauling actually represents different commodity components at the more detailed level of classification. Scale economies are a more intrinsic phenomenon. Since the related monopoly power is *a priori* excluded from our model, as noted above, only the scale-induced changes in technical coefficients could be relevant for the detection of comparative advantages. This effect is ignored in this study. Its inclusion would reinforce the gains to free trade. In fact, it is interesting to note that we can explain significant gains to free trade without using scale economies. In principle, scale economies might change the locational pattern of comparative advantages, but we do not expect them to be that high.

Our methodology differs from Bowen *et al.* (1987), Trefler (1993, 1995) and Davis *et al.* (1997) in the following sense. An exact equation is 'net exports equals net output minus domestic consumption'. In the cited papers the terms on the right-hand side of the equation are replaced by theoretical constructs, namely a linear function of endowment and a share of world net output. The authors then test whether the net exports predicted by the modified Heckscher–Ohlin model are close to the observed net exports. They introduce an error term in what should be an accounting identity and they check the magnitude and variation of the error term. Instead, we use actual data on endowments, input–output coefficients and consumption patterns and we check whether, were there free trade, countries would specialize according to factor abundance. In other words, we preserve the accounting identity and check if free competition would let the economies pick the same techniques and consumption pattern and then trade on the basis of factor abundance.

Ideally, the rest of the world is to be included as the third economy. Our method of detecting comparative advantages would remain perfectly valid. The detected comparative advantages from a bilateral trade model might differ from those obtained from a multilateral model, when we make stringent assumptions. We could, for instance, assume that the rest of the world has the same technologies as those in Europe and Canada and factor allocations similar to those in Europe. Canada, the smallest country, would continue to specialize in the same two activities that make abundant use of the factors it is comparatively better endowed with. Such assumptions are not more unrealistic than those of separability or extreme symmetry made by Helpman (1984) and Ethier (1984) to predict trade from factor endowments.

6. Conclusions

We locate the comparative advantages of two economies linked by international trade by computing a competitive benchmark on the basis of fundamentals only.

No assumption is made about prices, and the direction of the trade is endogenously determined. We use independent and country specific data on the three fundamentals: endowments, preferences and technologies. Instead of testing whether the Heckscher–Ohlin–Vanek model fits observed trade data, we ignore actual trade and derive it from the competitive benchmark. The factor contents of that trade are compared with factor endowments to test the Hecksch–Ohlin model in the presence of different technologies and preferences. The gains to free bilateral trade can also be computed.

The observed allocation is well within the frontier. The difference between observed and optimal allocations can be ascribed to domestic inefficiencies and to gains to free trade. The Canadian comparative advantage *vis-à-vis* Europe is in minerals, machines and clothing & footwear. The gains to free trade would be 0.2% for Europe and 22% for Canada. The pattern of comparative advantage persists when we allow for free access to technology and consumption coefficients and, therefore, it can be ascribed to the endowments. This free access would alter, however, the movement of factor contents, in agreement with the Heckscher–Ohlin theorem.

Notes

1. The location of comparative advantages in a system of more than two economies would involve a vector scanner, γ, and a fixed point alogrithm to find the value such that the consequent vector of national surpluses for all economies but one is mapped into the observed surpluses. (Walras' law would take care of the remaining economy.)
2. Tradeable commodities are those for which Statistics Canada (1983) reports data of foreign trade.
3. In fact, algorithm (7) stopped after only six iterations and the difference between the computed and actual deficits was only 24 ECU, an incredibly small fraction of the deficit.
4. In linear programming, artificial constraints are used (e.g. trade and activity restrictions as in Williams, 1978). In a neoclassical study, Diewert & Morrison (1986) assume a form of jointness of output which is conditioned by the pattern of trade and preserves it. Chipman & Tian (1992) also bar trade reversals.
5. The theoretical requirement that supply and demand are derived from the fundamentals of the economy is sacrificed by installing CES-'muffles' (make 'Armington') at four interfaces of supply and demand (Harris, 1984, pp. 1020, 1022 and 1026). 'Muffles' limit substitutability between commodities which differ by origin. These components are combined in a non-additive formula that is minimized to determine their shares. For example, to determine exports (E for domestic and $E^\star$ for all other countries exports) CES-muffle $[\beta E^{-\lambda} + (1 - \beta)E^{\star -\lambda}]^{-1/\lambda}$ is supposed to be 'produced' at minimum cost. Exports are thus 'determined' as a smooth function of domestic and foreign prices. A Cobb–Douglas version of the muffle divides intermediate demand between domestic supply and imports. One might think of goods and services supplied by different countries or industries as being differentiated not only in transportation costs, but also in terms of intrinsic product characteristics. When the purpose of study is the location of comparative advantage, however, the procedure is unnecessary and unwanted. From an econometric perspective, the evidence is no longer indirect (estimates of muffle parameters β and λ), but direct (observations of endowments, technology, and preferences). A second, related difference is that we are not plagued by the need to manipulate price formation. Harris averages Chamberlanian prices with the more oligopolistic ones of Eastman-Stijkolt. Deardorff (1986) shows that this element introduces a theoretical inconsistency, but is necessary to get effects of tariff reductions.

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Appendix A: Data

The European database comprises Denmark, the Federal Republic of Germany, France, Belgium, the Netherlands, Italy and the United Kingdom. The transactions matrix and final demand tables are from Eurostat (1989), the capital stock data from Eurostat (1990a) and the employment figures from Eurostat (1986). The capacity utilization rate is the EC manufacturing rate from the Commission of the European Communities (1984). The labor force figure is from Eurostat (1985). Non-market services in Europe, which correspond to non-business activities in Canada, are treated as exogenous. The labor and capital requirements from these sectors are substracted from the total labor and capital availabilities, and their intermediate input requirements are added to exogenous final demand.

The Canadian database, involving one country only, is straightforward. The use and make tables are directly available from Statistics Canada (1987). They relate to business activities only. Sectoral capital stock and labor employment data were kindly released to us by Statistics Canada (1990a and 1990b). The capital utilization rates are from Government of Canada (1984), and from Bank of Canada (1983) for the construction sector. The commodity input coefficients matrix is given by $\mathbf{A} = \mathbf{U}\mathbf{V}^{-\mathsf{T}}$ (see Kop Jansen & ten Raa, 1990; superscript $-\mathsf{T}$ denotes the composition of transposition and inversion, two commuting operations), where $\mathbf{U}$ is the commodity by sector input matrix (use table) and $\mathbf{V}$ is the sector by commodity output matrix (make table). The capital and labor input coefficients row vectors are obtained in the same way by postmultiplication of the row vector of sectoral utilized capital stocks and of the row vector of sectoral labor employments with $\mathbf{V}^{-\mathsf{T}}$.

Eurostat (1976, p. 162–167) uses 44 sectors in the input–output classification and 25 sectors in the capital accounts. Statistics Canada (1987, 1990b) uses 50 industries and 92 commodities in the M-level input–output classification and 29 industries in the capital accounts. In either economy, the labor accounts follow basically the input–output classifications, but slightly more aggregated. The so-called R-44 and M-level classifications have been aggregated into a common base of 26 sectors. The sectors are listed 1 to 26 throughout this study. These codes and the names we have assigned to the sectors are listed in the first column of Table A-1. The second column shows how they can be obtained by aggregating the R-44 sectors. The third column relates them to the European capital sector classification. The fourth and fifth columns show how the sectors can be obtained by aggregating the M-level industries and commodities, respectively. The sixth column relates them to the Canadian capital sector/classification.

Table A-2 lists the sectoral and labor and capital inputs and their overall availability. The total labor force figures are taken from Eurostat (1985) and Statistics Canada (1989). The exchange rate used to convert Canadian dollars to ECU is from IMF (1985). More detailed information on the construction of the

Table A-1. Classification of sectors and European and Canadian (dis)aggregations

Present Study 26 sectors	R-44 44 sectors	EC capital 25 sectors	M-level 50 industries	M-level 92 commodities	Canadian capital 29 industries
1 Agriculture	010	1	1,2,3	1,2,3,4,5,6	1,2,3
2 Mining	030,050,110,130	2,5	4,7	7,8,9,13	4
3 Petroleum & Natural Gas	070	2	5,26	10,11,62,63	4,21
4 Non-metallic Minerals	150	6	6,25	12,60,61	4,20
5 Chemical Products	170	7	27	64,65,66,67	22
6 Metal Products	190	8	20,21	45,46,47,48,49,50,51,52	15,16
7 Machines	210,230	9,10	22	53,54	17
8 Electrical Goods	250	11	24	58,59	19
9 Transportation Equipment	270,290	12	23	55,56,57	18
10 Food	310,330,350	13	8	14,15,16,17,18,19,20,21,22	5
11 Beverages	370	13	9	23,24	6
12 Tobacco Products	390	13	10	25,26	7
13 Textiles & Clothing	410	14	14,15	31,32,33,34,35	10
14 Leather & Footwear	430	14	13	30	9
15 Rubber & Plastic	490	16	11,12	27,28,29	8,9
16 Wood Products	450	17	16,17	36,37,38,39	11,12
17 Paper & Printing	470	15	18,19	40,41,42,43,44	13,14
18 Other Manufactures	510	17	28	68,69	23
19 Construction	530	19	29	70,71,72	24
20 Wholesale & Retail	510	20	35,36	80,81	28
21 Lodging & Catering	590	23	44	88	30
22 Transportation	610,630,650	24,25,26	30,31,32,50	73,74,90	25
23 Communication	670	27	33	75,76,77	25
24 Utilities	090	2	34	78,79	27
25 Finance	690,730	28	37,38,39,40	82,83	29
26 Service	790	20,29	41,42,43	84,85,86,87,89	30
	550,710,750,770		45,46,47,48,49	91,92	

Note: R-44 sectors 810, 850, 890 and 930 and EC capital sector 22 pertain to non-market services, which are excluded from sector 26 and modeled as exogenous in the present study.

Table A-2. Capital and labour, 1980

	Europe		Canada	
Sector	Utilized gross stock (millions ECU)	Employment (1000 persons)	Utilized gross stock (millions dollars)	Employment (persons)
1	255 339	7 278	47 127	735 518
2	131 252	2 006	19 355	118 192
3	335 647	199	35 010	62 383
4	70 347	1 539	4 912	64 444
5	141 435	1 729	13 642	87 284
6	65 256	2 806	20 016	305 501
7	89 933	3 859	1 793	98 423
8	59 177	2 901	2 531	141 608
9	94 758	2 957	5 823	195 028
10	115 891	2 502	7 749	204 892
11	12 127	370	2 868	33 323
12	3 116	107	453	7 622
13	55 449	2 960	4 677	182 166
14	15 655	1 015	764	27 410
15	37 657	1 109	1 642	62 642
16	26 868	1 553	5 635	177 202
17	58 342	1 870	21 977	245 841
18	8 980	504	1 028	68 201
19	90 170	8 265	5 605	726 220
20	333 574	141 616	20 120	1 713 967
21	65 645	3 368	9 276	433 900
22	94 553	5 887	53 712	499 772
23	160 684	1 806	35 659	210 192
24	116 174	978	91 924	94 176
25	253 540	7 045	25 892	522 077
26	246 610	187 388	33 309	1 003 204
Total	8 159 849	97 512	471 499	8 021 276
Force	10 049 079	104 573	563 382	9 450 655
			Exchange rate	1.5646 $/ECU
			Total stock	360 081 millons ECU

dataset (harmonization aggregation, disaggregation and handling of missing data) can be found in the appendix of ten Raa & Mohnen (1997).

Appendix B: The Superfree Trade Model

The superfree trade model is obtained by the following modification of linear program (1)–(4).

$$\max_{\mathbf{x}, \tilde{\mathbf{x}}, \mathbf{x}^\star, \tilde{\mathbf{x}}^\star, c, \tilde{c}, c^\star \geqslant 0} \mathbf{e}^\mathsf{T}\mathbf{y}\,(c+\tilde{c}) + \mathbf{e}^\mathsf{T}\mathbf{y}^\star\gamma(c+\tilde{c}) \tag{B-1}$$

subject to the following constraints. For tradeable commodities:

$$(\mathbf{I}-\mathbf{A})\mathbf{x} + (\mathbf{I}-\mathbf{A}^\star)\tilde{\mathbf{x}} + (\mathbf{I}-\mathbf{A}^\star)\mathbf{x}^\star + (\mathbf{I}-\mathbf{A})\tilde{\mathbf{x}}^\star \geqslant \tag{B-2}$$
$$\mathbf{y}c + \frac{\mathbf{e}^\mathsf{T}\mathbf{y}}{\mathbf{e}^\mathsf{T}\mathbf{y}^\star}\mathbf{y}^\star\tilde{c} + \mathbf{y}^\star c^\star + \frac{\mathbf{e}^\mathsf{T}\mathbf{y}^\star}{\mathbf{e}^\mathsf{T}\mathbf{y}}\mathbf{y}\tilde{c}^\star + \mathbf{z} + \mathbf{z}^\star$$

with $\tilde{c}^\star$ determined by

$$c^\star + \tilde{c}^\star = \gamma(c + \tilde{c}) \tag{B-3}$$

for non-tradeable commodities:

$$(\mathbf{I} - \mathbf{A})\mathbf{x} + (\mathbf{I} - \mathbf{A}^\star)\tilde{\mathbf{x}} \geqslant \mathbf{y}c + \frac{\mathbf{e}^\top \mathbf{y}}{\mathbf{e}^\top \mathbf{y}^\star}\mathbf{y}^\star \tilde{c} \tag{B-4}$$

$$(\mathbf{I} - \mathbf{A}^\star)\mathbf{x}^\star + (\mathbf{I} - \mathbf{A})\tilde{\mathbf{x}}^\star \geqslant \mathbf{y}^\star c^\star + \frac{\mathbf{e}^\top \mathbf{y}^\star}{\mathbf{e}^\top \mathbf{y}}\mathbf{y}\tilde{c}^\star$$

and for factor inputs:

$$\mathbf{k}^\top \mathbf{x} + (\mathbf{k}^\star)^\top \tilde{\mathbf{x}} \leqslant K, \;\; \mathbf{1}^\top \mathbf{x} + (\mathbf{1}^\star)^\top \tilde{\mathbf{x}} \leqslant L, \tag{B-5}$$

$$(\mathbf{k}^\star)^\top \mathbf{x}^\star + \mathbf{k}^\top \tilde{\mathbf{x}}^\star \leqslant K^\star, \;\; (\mathbf{1}^\star)^\top \mathbf{x}^\star + \mathbf{1}^\top \tilde{\mathbf{x}}^\star \leqslant L^\star,$$

European net output $(\mathbf{I} - \mathbf{A})\mathbf{x}$ has been augmented with $(\mathbf{I} - \mathbf{A}^\star)\tilde{\mathbf{x}}$, the net output in Europe using Canadian technology. Any European gross output component is generated by European or Canadian technologies with activity levels x_i, and $\tilde{x}_i$, respectively. The same kind of substitutability is introduced in the consumption section. European consumers are assumed to be indifferent between European final consumption, y, and Canadian final consumption scaled up to the European level $(\mathbf{e}^\top \mathbf{y}/\mathbf{e}^\top \mathbf{y}^\star)\mathbf{y}^\star$. 'These alternative life style vectors are multiplied by the consumption expansion factors, c and $\tilde{c}$, respectively. Finally, premultiplication by the unit row vector yields the European terms in the objective function, (B-1). The Canadian terms are analogous, $\mathbf{e}^\top \mathbf{y}^\star(c^\star + \tilde{c}^\star)$. We force them to trace the European consumption level by means of constraint (B-3).