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Theory of Comparative Advantage: Do Transportation Costs Matter?

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Abstract

The paper presents a formal analysis which incorporates returns to transportation into a Ricardian framework to predict trade patterns. The important point to be gained from this analysis is that increasing returns to transportation, coupled with appropriate distances between trading partners can be shown to reverse Ricardian predictions even when there are no international differences in tastes, technology, or factor endowments. Additional gains from trade may emerge from reductions in aggregate delivery costs owing to scale economies.

Keywords: Comparative advantage, Ricardian model, transportation costs, increasing returns, reasons for trade

JEL Classification: F010, F100, R100

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1 Introduction

The theory of comparative advantage is one of the most fundamental insights economics is providing to explain actual patterns of international trade. The standard model of comparative advantage that relies on differences in labour productivity was introduced by David Ricardo in 1817 and is generally referred to as the Ricardian model (see Ricardo, 1963). There are two key contributions of the Ricardian model to trade theory. First, it shows that trade can arise because of international differences in technology. More specifically, it establishes that in a one-factor world with two-traded goods produced under CES and perfect competition, the pattern of trade is determined by international differences in relative costs with each country exporting the good in which it has a relative labour productivity advantage. Second, it makes clear that voluntary trade cannot be welfare reducing for any of the parties involved. Typically, the analysis is conducted in a two–good, two–country, one–factor model and assumes zero transportation costs between the countries. The role of transportation costs is a major theme in regional science. Because transport costs pose obstacles to the movement of goods and services, they have important implications for the way a trading world economy is affected (see, e.g. Isard and Peck, 1954). Nonetheless, transportation costs have received little attention from formal trade theory. The main reason for this neglect seems to be that it has appeared difficult to deal with the implications of increasing returns to transportation in formal models.

This paper attempts to introduce the idea of increasing returns to transportation into a two–good Ricardian model to trade theory. It helps to establish that the presence of returns to transportation, coupled with appropriate distances between trading partners, gives rise to new possibilities. First, trade patterns may differ from those predicted by the classical theory of comparative advantage. Second, additional gains from trade may emerge from reductions in aggregate delivery costs owing to scale economies.

The paper is organized as follows: In Section 2 the classical two–country two–good Ricardian model is extended to a three-country version in a world characterized by increasing returns to transportation. This is followed by a discussion in Section 3 that the presence of increasing returns to transportation may cause trade between identical countries and this trade is beneficial to all. Section 4 continues to provide a formal justification for the argument that in a three–country world increasing returns to transportation may reverse Ricardian trade pattern predictions. Finally, Section 5 summarizes the results and suggests some conclusions.

2. The Modified Ricardian Model: Assumptions and Equilibrium

A. Assumptions of the model

The structure of this model is closely related to the classical two–good Ricardian model, but departs from traditional analysis through the combination of a three–country version of the model along with the introduction of iceberg transport costs. We consider a world of three countries, say A, B, *and* C. *To make the point most clearly we follow the simplifications made in the two–good Ricardian model. We assume a one–factor two–good economy. Each of the three countries has only one scarce factor of production, labour, available in quantities* L^A, L^B, *and* L^C, *and can produce two goods, say* z *and* w. *The technology of each country can be described by the productivity of labour in each industry. It is convenient to express productivity in terms of the unit labour requirement, the number of hours required to produce one unit of each. We label country's* $J \in \{A, B, C\}$ *unit labour requirement for a particular good* $i \in \{z, w\}$ *as* a_{Li}^J. *In general, the unit labour requirements can follow any pattern, but we are assuming that country* A *has a comparative advantage in producing* z *relative to the other two countries considered, that is*

$$(1) \qquad a_{Lz}^A / a_{Lw}^A < a_{Lz}^J / a_{Lw}^J \quad (J \in \{B, C\}).$$

To make the point most strongly, the countries are assumed to have identical tastes and share the same utility function from which the consumption pattern may be derived

$$(2) \qquad U(Z_J, W_J) = Z_J^{1-\alpha} W_J^{\alpha} \quad (J \in \{A,B,C\}),$$

where Z_J *and* W_J *denote respectively quantities of commodity* z *and* w, α *is a fixed coefficient* $(0<\alpha<1)$ *so that relative demand in country* J *is given by*

$$(3) \qquad Z_J/W_J = [(1-\alpha)/\alpha]/P_J \quad (J \in \{A,B,C\})$$

where P_J *denotes the relative price of* z, P_z/P_w, *in country* J.[1] *The functional form of the utility function chosen gives the model a simplified structure which makes the analysis easier.*

Transportation costs will be assumed to take Samuelson's (1954) "iceberg" form in which transport costs are incurred in the goods transported. Of each unit of good shipped from one country to another only a fraction $g \leq 1$ *arrives. This is a strong assumption that has to be made for tractability. But in contrast to Dornbush, Fisher and Samuelson (1977) the idea of increasing returns to transportation is introduced so that a step closer to reality is made by considering the effects of transport costs.*

Let $g_{J,K}(q_i)$ *denote the transportation costs of the quantity* q *of good* i *from country* J *to country* K *with* $J,K \in \{A,B,C\}$, $J \neq K$. *Specifically, we assume that* $g_{J,K}(q_i)$ *with* $q_i \geq 0$ *is a continuous and increasing function of* q_i, *inversely proportional to* $d_{J,K}$, *the distance between* J *and* K *[that is,* $g_{J,K}(q_i) > g_{M,N}(q_i)$, *iff* $d_{J,K} < d_{M,N}$*], and identical for shipments in either direction [that is,* $g_{J,K}(q_i) = g_{K,J}(q_i)$*]. Finally, for the sake of simplicity let us assume that there exists a set of model* *parameters, such that if free trade is allowed in the three–country world the differences in productivity lead to full specialization in the countries. Country* A *specializes in production of good* z *and countries* B *and* C *in production of commodity* w.[2]

It seems useful to represent the three countries as discrete points in space exogenously defined, for example, as shown in figure 1. We consider two distinct cases as illustrated in figure 1: direct trade (case I*) and indirect trade (case* II*). Countries* B *and* C *are identical in every respect. Country* A *has different opportunity costs of producing* z*. Its distance from* B *is smaller than from* C*. In case* I *countries* B *and* C *trade directly with* A *(see figure 1(a)); in case* II, B *and* C *form a new integrated economy that trades as a unit with* A *(see figure 1(b)).*

POSITION FIGURE 1 ABOUT HERE

B. Equilibrium in the model

Let us denote the quantities of goods *z* and *w* exported from country *J* to country *K* ($J,K \in \{A,B,C\}$) as $Z_{J,K}$ and $W_{J,K}$, respectively. If $K=J$, then $Z_{J,K}$ and $W_{J,K}$ denote quantities supplied in the domestic market. Then we can easily characterize the world economy's equilibrium in the case of direct trade (case *I*) by means of the following ten equations. The superscript *I* serves to indicate the unknown variables in case *I*.

(4) $$L^A/a_{Lz}^A = Z_{A,A}^I + Z_{A,B}^I + Z_{A,C}^I$$

(5) $$L^B/a_{Lw}^B = W_{B,B}^I + W_{B,A}^I$$

(6) $$L^C/a_{Lw}^C = W_{C,C}^I + W_{C,A}^I$$

(7) $$Z_{A,A}^{I} / [W_{B,A}^{I}\, g_{A,B}(W_{B,A}^{I}) + W_{C,A}^{I}\, g_{A,C}(W_{C,A}^{I})] = [(1-\alpha)/\alpha] / P_{A}^{I}$$

(8) $$Z_{A,B}^{I}\, g_{A,B}(Z_{A,B}^{I}) / W_{B,B}^{I} = [(1-\alpha)/\alpha] / P_{B}^{I}$$

(9) $$Z_{A,C}^{I}\, g_{A,C}(Z_{A,C}^{I}) / W_{C,C}^{I} = [(1-\alpha)/\alpha] / P_{C}^{I}$$

(10) $$Z_{A,B}^{I}\, g_{A,B}(Z_{A,B}^{I})\, P_{B}^{I} = W_{B,A}^{I}$$

(11) $$W_{B,A}^{I}\, g_{A,B}(W_{B,A}^{I}) / P_{A}^{I} = Z_{A,B}^{I}$$

(12) $$Z_{A,C}^{I}\, g_{A,C}(Z_{A,C}^{I})\, P_{C}^{I} = W_{C,A}^{I}$$

(13) $$W_{C,A}^{I}\, g_{A,C}(W_{C,A}^{I}) / P_{A}^{I} = Z_{A,C}^{I}$$

Equations (4)–(6) characterize the production possibilities in the three–country one–factor two–good world, while equations (7)–(9) describe market equilibria in the countries, that is, equalize relative supply with relative demand. Equations (10)–(13) exclude the possibility of the gain from buying goods in one market and selling them in another. The solution to the system of equations (4)–(13) determines values of the ten unknown variables: $W_{B,B}^{I}$, $W_{B,A}^{I}$, $W_{C,C}^{I}$, $W_{C,A}^{I}$, $Z_{A,A}^{I}$, $Z_{A,B}^{I}$, $Z_{A,C}^{I}$, P_{A}^{I}, P_{B}^{I}, P_{C}^{I}.

In the case of indirect trade (case *II*) the equilibrium – under full specialization – is described as follows where the superscript *II* denotes the unknown variables:

$$(14)\qquad L^A/a_{Lz}{}^A = Z_{A,A}{}^{II} + Z_{A,B}{}^{II}$$

$$(15)\qquad L^B/a_{Lw}{}^B = W_{B,B}{}^{II} + W_{B,A}{}^{II}$$

$$(16)\qquad L^C/a_{Lw}{}^C = W_{C,C}{}^{II} + W_{C,B}{}^{II}$$

$$(17)\qquad Z_{A,A}{}^{II} / [(W_{B,A}{}^{II} + W_{C,B}{}^{II}\, g_{C,B}(W_{C,B}{}^{II}))\, g_{A,B}(W_{B,A}{}^{II} + W_{C,B}{}^{II}\, g_{C,B}(W_{C,B}{}^{II}))] = [(1-\alpha)/\alpha]/P_A{}^{II}$$

$$(18)\qquad [Z_{A,B}{}^{II}\, g_{A,B}(Z_{A,B}{}^{II}) - Z_{B,C}{}^{II}] / W_{B,B}{}^{II} = [(1-\alpha)/\alpha]/P_B{}^{II}$$

$$(19)\qquad Z_{B,C}{}^{II}\, g_{B,C}(Z_{B,C}{}^{II}) / W_{C,C}{}^{II} = [(1-\alpha)/\alpha] / P_C{}^{II}$$

$$(20)\qquad [Z_{A,B}{}^{II}\, g_{A,B}(Z_{A,B}{}^{II}) - Z_{B,C}{}^{II}]\, P_B{}^{II} = W_{B,A}{}^{II}$$

$$(21)\qquad [W_{B,A}{}^{II} + W_{C,B}{}^{II}\, g_{C,B}(W_{C,B}{}^{II})]\, g_{A,B}(W_{B,A}{}^{II} + W_{C,B}{}^{II}\, g_{C,B}(W_{C,B}{}^{II})) / P_A{}^{II} = Z_{A,B}{}^{II}$$

$$(22)\qquad Z_{B,C}{}^{II}\, g_{B,C}(Z_{B,C}{}^{II})\, P_C{}^{II} = W_{C,B}{}^{II}$$

$$(23)\qquad W_{C,B}{}^{II}\, g_{C,B}(W_{C,B}{}^{II}) / P_B{}^{II} = Z_{B,C}{}^{II}$$

Equations (14)–(16) characterize the production possibilities in the three countries *A*, *B* and *C*, and equations (17)–(19) the market equilibria. Equations (20)–(23) exclude the possibility of the gain from buying goods in one market and selling them in another. The solution to the system of equations (14)–(23) specifies the values of $W_{B,B}{}^{II}$, $W_{B,A}{}^{II}$, $W_{C,C}{}^{II}$, $W_{C,B}{}^{II}$, $Z_{A,A}{}^{II}$, $Z_{A,B}{}^{II}$, $Z_{B,C}{}^{II}$, $P_A{}^{II}$, $P_B{}^{II}$, $P_C{}^{II}$.

In particular, quantities of goods are determined in the cases of direct trade (*I*) and indirect trade (*II*) as:

(24) $W_{B,B}{}^{I} = W_{B,B}{}^{II} = \alpha L^{B} / a_{Lw}{}^{B}$,

(25) $W_{B,A}{}^{I} = W_{B,A}{}^{II} = (1\text{-}\alpha) L^{B} / a_{Lw}{}^{B}$,

(26) $W_{C,C}{}^{I} = W_{C,C}{}^{II} = \alpha L^{C} / a_{Lw}{}^{C}$,

(27) $W_{C,A}{}^{I} = W_{C,B}{}^{II} = (1\text{-}\alpha) L^{C} / a_{Lw}{}^{C}$,

(28) $Z_{A,A}{}^{I} = Z_{A,A}{}^{II} = (1\text{-}\alpha) L^{A} / a_{Lz}{}^{A}$,

(29) $Z_{A,B}{}^{I} = (\alpha L^{A} / a_{Lz}{}^{A}) / \{1+ (L^{C} / a_{Lw}{}^{C})\, g_{A,C}((1\text{-}\alpha) L^{C} / a_{Lw}{}^{C}) / [(L^{B} / a_{Lw}{}^{B})\, g_{A,B}((1\text{-}\alpha)L^{B} / a_{Lw}{}^{B})]\}$,

(30) $Z_{A,C}{}^{I} = (\alpha L^{A} / a_{Lz}{}^{A}) / \{1+ (L^{B} / a_{Lw}{}^{B})\, g_{A,B}((1\text{-}\alpha) L^{B} / a_{Lw}{}^{B}) / [(L^{C} / a_{Lw}{}^{C})\, g_{A,C}((1\text{-}\alpha) L^{C} / a_{Lw}{}^{C})]\}$,

(31) $Z_{A,B}{}^{II} = \alpha L^{A} / a_{Lz}{}^{A}$,

(32) $Z_{B,C}{}^{II} = \alpha L^{A} / a_{Lz}{}^{A}\ g_{A,B}(\alpha\ L^{A} / a_{Lz}{}^{A}) / \{1 + (L^{B} / a_{Lw}{}^{B}) / [(L^{C} / a_{Lw}{}^{C})\ g_{C,B}((1-\alpha) L^{C} / a_{Lw}{}^{C})]\}$;

and relative prices in the countries as

(33) $P_{A}{}^{I} = [W_{B,A}{}^{I}\ g_{A,B}(W_{B,A}{}^{I}) + W_{C,A}{}^{I}\ g_{A,C}(W_{C,A}{}^{I})] / [Z_{A,A}{}^{I}\ \alpha /(1\text{-}\alpha)]$,

(34) $P_{A}{}^{II} = [(W_{B,A}{}^{II} + W_{C,B}{}^{II}\ g_{C,B}(W_{C,B}{}^{II}))\, g_{A,B}(W_{B,A}{}^{II} + W_{C,B}{}^{II}\ g_{C,B}(W_{C,B}{}^{II}))] / [Z_{A,A}{}^{II}\ \alpha / (1\text{-}\alpha)]$,

(35) $P_{B}{}^{I} = W_{B,A}{}^{I} / [Z_{A,B}{}^{I}\, g_{A,B}(Z_{A,B}{}^{I})]$,

(36) $P_{B}{}^{II} = [W_{B,A}{}^{II} + W_{C,B}{}^{II}\ g_{C,B}(W_{C,B}{}^{II})] / [Z_{A,B}{}^{II}\, g_{A,B}(Z_{A,B}{}^{II})]$,

(37) $P_{C}{}^{I} = W_{C,A}{}^{I} / [Z_{A,C}{}^{I}\, g_{A,C}(Z_{A,C}{}^{I})]$,

(38) $$P_C^{II} = W_{C,B}^{II} / [Z_{B,C}^{II}\, g_{B,C}(Z_{B,C}^{II})];$$

so that, free trade equlibria in both cases are fully specified.

3. INTERNATIONAL TRADE BETWEEN IDENTICAL COUNTRIES

If commodities *z* and *w* can be traded either directly (case *I*) or indirectly (case *II*) then indirect trade prevails in the three–country world that all three countries are better off than under direct trade. Recall from the standard course of international economics that a rise in terms of trade (the price of country's exports divided by the price of its imports) increases a country's welfare, while a decline in terms of trade reduces its welfare (see, e.g., Krugman and Obstfeld, 1991, for details). Thus, all three countries considered are always better off under indirect trade iff (a) $P_A^{I} < P_A^{II}$, (b) $P_B^{I} > P_B^{II}$, and (c) $P_C^{I} > P_C^{II}$.

The proposition below states that under increasing returns to transportation there exists a spatial configuration such that indirect trade prevails, and, consequently, international trade between two countries identical in all respects (*B* and *C*) can be observed.

PROPOSITION 1: The presence of increasing returns to transportation may cause trade between identical economies in a three–country world and increase bilateral welfare.

Proof of PROPOSITION 1: We proceed in two stages. *Stage 1*: Consider countries *B* and *C* which are identical in every respect and the distance $d_{B,C}$ between them is zero. Next introduce country *A* in which (i) the opportunity cost of producing a particular good differs from the other two, and (ii) its distance from *B* and *C* is the same, that is $d_{A,B}=d_{A,C}$. Now consider two possibilities. In the first, countries *B* and *C* trade directly with *A*; in the second, *B* and *C* form a new integrated economy that trades as a unit with *A*. The latter case is a superior alternative for all countries because – by the built in symmetry in transportation costs over the two traded goods, and the decline of these costs due to larger traded volumes – all countries can enjoy an improvement in their terms of trade, if countries *B* and *C* exploit economies of scale in transportation. The formal proof is straightforward: $P_A^{I} < P_A^{II}$, $P_B^{I} > P_B^{II}$ and $P_C^{I} > P_C^{II}$, since $g_{B,C}(\cdot)=1$, $W_{B,A}^{II} + W_{C,B}^{II} = 2\, W_{B,A}^{I}$, $Z_{A,B}^{II} = 2\, Z_{A,B}^{I}$, and $W_{C,A}^{I} = W_{C,B}^{II}$[3].

Stage 2: We raise the distance and, thus, the transportation costs between *B* and *C*. Country *C* becomes located further from both trading partners. Specifically, let us assume that country *A* is located in point *O* and country *B* in point *X* as illustrated in figure 2. Let us shift now country *C* along line *OX* further apart from *O* and *X*. If the distance between *B* and *C* increases then the terms of trade of all three countries change under direct trade. In particular, P_A^{II} and P_B^{II} decrease (since $g_{C,B}(\cdot)$ decreases), and P_C^{II} increases (since both $Z_{B,C}^{II}$ and $g_{C,B}(\cdot)$ decrease). Thus, the terms of trade of *A* and *C* deteriorate (countries *A* and *C* are worse off) and those of country *B* improve (country *B* is better off)[4]. Consequently, due to continuity of space, there exists a location of country *C* (say, at point *Y*, in figure 2) such that at least one country *C* or *A* is indifferent between direct and indirect trade, but for all location points, say V_i, such that $|XV_i| < |XY|$ and $|OV_i| > |OX|$ (see figure 2) all three countries prefer indirect trade. Thus, for any location point of country *B* there exists a non-empty set of location points of country *C*, such that, even if countries are identical in all respects, and there is no any natural pattern of comparative advantage between countries *B* and *C*, both countries will benefit from international trade.

It is important to note that indirect trade prevails only in the area where economies of scale from transportation exceed increased distance cost required for shipment between countries *A* and *C*.

POSITION FIGURE 2 ABOUT HERE

4. REVERSING BILATERAL PATTERN OF TRADE

Consider the model presented in Section 2 and assume that countries *B* and *C* differ in productivities. In particular, assume that country *B* has comparative advantage in producing good *w* and country *C* in producing of good *z* (suppose that $a_{Lz}^{B} = a_{Lz}^{C}$ and $a_{Lw}^{B} < a_{Lw}^{C}$, so that $a_{Lw}^{B}/a_{Lz}^{B} < a_{Lw}^{C}/a_{Lz}^{C}$). In a two–country world, according to the theory of comparative advantage, country *B* would export good *w* and import good *z*, and country *C* would export good *z* and import good *w*. Suppose, as above, that there is a third country *A* which is much more than all other countries productive in *z* and much less in *w*, so that in the three–country world *A* specializes in production of *z* and countries *B* and *C* in production of *w*. Similarly, as in the analysis above, under free trade regime commodities can be exchanged between countries *A* and *B* as well as *A* and *C* directly (see figure 1(a)) or indirectly (see figure 1(b)). Assume that country *B* is located closer to *A*. When goods are traded indirectly it can serve as an intermediary (i.e., country *B* imports good *z* from country *A* and exports it to country *C*). Note, however, that if this is the case then the pattern of trade between countries *B* and *C* is just opposite to one which follows from the Law of Comparative Advantage, i.e., country *B* exports (to *C*) good *z* and imports good *w*, and country *C* exports to *B* good *w* and imports good *z*, even though country *B* has comparative advantage in the production of good *w* and country *C* in the production of good *z*. In the analysis below we will show that if transportation costs face increasing returns to scale, there exists a spatial configuration of countries *A*, *B* and *C* such that the pattern of trade described above prevails.

PROPOSITION 2: In a one–factor world with three countries and two-traded goods increasing returns in transportation, coupled with appropriate distances between trading partners, may reverse Ricardian trade pattern predictions in so far that free trade does not reflect bilateral comparative advantages between pairs of countries.

Proof of PROPOSITION 2: The proof the proposition includes the same stages as that of PROPOSITION 1. *Stage 1*: Consider the hypothetical situation where *B* and *C* are identical in every aspect and $d_{B,C} = 0$. Compare case *I* (direct trade) and case *II* (indirect trade).

Since $g_{B,C}(\cdot) = 1$, $a_{Lw}^{B} < a_{Lw}^{C}$, $W_{B,A}^{II} = W_{B,A}^{I}$, $W_{C,B}^{II} = W_{C,A}^{I}$, the proof that $P_A^{I} < P_A^{II}$ is straightforward. $P_B^{I} > P_B^{II}$ if the following inequality is satisfied

$$W_{B,A}^{I} / [Z_{A,B}^{I}\, g_{A,B}(Z_{A,B}^{I})] > [W_{B,A}^{II} + W_{C,B}^{II}\, g_{C,B}(Z_{C,B}^{II})] / [Z_{A,B}^{II}\, g_{A,B}(Z_{A,B}^{II})] \tag{39}$$

Taking into account equations (25) and (27) and rearranging, we get

$$[Z_{A,B}^{II}\, g_{A,B}(Z_{A,B}^{II})] / [Z_{A,B}^{I}\, g_{A,B}(Z_{A,B}^{I})] > 1 + a_{Lw}^{B} / a_{Lw}^{C}. \tag{40}$$

If countries *B* and *C* are identical the inequality above is surely satisfied (since $a_{Lw}{}^{B}/a_{Lw}{}^{C} = 1$, and $Z_{A,B}{}^{II} = 2\ Z_{A,B}{}^{I}$) [5]. To show that there exist unit labour requirements $a_{Lw}{}^{B}$ and $a_{Lw}{}^{C}$, such that $a_{Lw}{}^{B}<a_{Lw}{}^{C}$ (i.e., that $a_{Lw}{}^{B}/a_{Lw}{}^{C} < 1$) which satisfy the inequality above consider left hand side of (40). Since $Z_{A,B}{}^{II}$ does not depend on the ratio $a_{Lw}{}^{B}/a_{Lw}{}^{C}$ and $Z_{A,B}{}^{I}$ increases if $a_{Lw}{}^{B}/a_{Lw}{}^{C}$ becomes smaller (see equation (29)), the left hand side of (40) decreases if $a_{Lw}{}^{B}/a_{Lw}{}^{C}$ decreases. Taking into account that the left hand side of (40) can be expressed as

(41) $$\frac{g_{A,B}(Z^{II}_{A,B})}{g_{A,B}(Z^{I}_{A,B})}[1+\frac{a^{B}_{Lw}}{a^{C}_{Lw}}\frac{g_{A,C}((1-\alpha)L^{C}/a^{C}_{Lw})}{g_{A,B}((1-\alpha)L^{B}/a^{B}_{Lw})}],$$

if $a_{Lw}{}^{B}/a_{Lw}{}^{C}$ goes to zero it goes to a certain positive value smaller than $g_{A,B}(Z_{A,B}{}^{II}) < 1$. On the other side the right hand side of inequality (40) goes to one if $a_{Lw}{}^{B}/a_{Lw}{}^{C}$ goes to zero. Since, both sides of inequality (40) can be considered as continuous functions of $a_{Lw}{}^{B}/a_{Lw}{}^{C}$ ($a_{Lw}{}^{B}/a_{Lw}{}^{C}\in(0,1]$), and for $a_{Lw}{}^{B}/a_{Lw}{}^{C} = 1$ the inequality (40) is always satisfied while for sufficiently small ratio $a_{Lw}{}^{B}/a_{Lw}{}^{C}$ is not, there exists an interval, say $(\theta,1]$ $(0 < \theta < 1)$, such that for all $a_{Lw}{}^{B}/a_{Lw}{}^{C}\in(\theta,1]$, inequality (40) is fulfilled, and, consequently, $P_{B}{}^{I}>P_{B}{}^{II}$.

To show that $P_{C}{}^{I}>P_{C}{}^{II}$ consider inequality[6]:

(42) $$W_{C,A}{}^{I} / Z_{A,C}{}^{I}\ g_{A,C}(Z_{A,C}{}^{I}) > W_{C,B}{}^{II} / Z_{B,C}{}^{II}.$$

Since $W_{C,B}{}^{II}=W_{C,A}{}^{I}$ (see equation (27)) the inequality above is surely satisfied if $Z_{A,C}{}^{I}\ g_{A,C}(Z_{A,C}{}^{I}) < Z_{B,C}{}^{II}$. Taking into account that[7]

(43) $$Z^{I}_{A,C}=\frac{\alpha L^{A}/a^{A}_{Lz}}{1+\frac{a^{C}_{Lw}g_{B,A}((1-\alpha)L^{B}/a^{B}_{Lw})}{a^{B}_{Lw}g_{C,A}((1-\alpha)L^{B}/a^{C}_{Lw})}},$$

and (since $L^{B} = L^{C}$ and $g_{B,C}(\cdot) = 1$)

(44) $$Z^{II}_{B,C}=\frac{g_{A,B}(\alpha L^{A}/a^{A}_{Lz})\alpha L^{A}/a^{A}_{Lz}}{1+a^{C}_{Lw}/a^{B}_{Lw}},$$

we get

(45) $$\frac{g_{A,C}(Z^{I}_{A,C})\alpha L^{A}/a^{A}_{Lz}}{1+\frac{a^{C}_{Lw}g_{BA}((1-\alpha)L^{B}/a^{B}_{Lw})}{a^{B}_{Lw}g_{BA}((1-\alpha)L^{C}/a^{C}_{Lw})}}<\frac{g_{AB}(\alpha L^{A}/a^{A}_{Lz})\alpha L^{A}/a^{A}_{Lz}}{1+a^{C}_{Lw}/a^{B}_{Lw}}.$$

The inequality above is always fulfilled, since

(46) $$1+\frac{a^{C}_{Lw}g_{BA}((1-\alpha)L^{B}/a^{B}_{Lw})}{a^{B}_{Lw}g_{BA}((1-\alpha)L^{C}/a^{C}_{Lw})}>1+a^{C}_{Lw}/a^{B}_{Lw}$$

and

(47) $$g_{A,C}(Z^{I}_{A,C}) < g_{A,B}(\alpha L^{A} / a^{A}_{Lz}) .$$

Stage 2: This proof is identical as in the proof of PROPOPSITION 1. We focus on indirect trade since this case is a superior alternative for all countries. Country *C* now becomes further located from countries *B* and *A*, then P_A^{II} and P_B^{II} decrease since $g_{C,B}(\cdot)$ decreases, and P_C^{II} increases since both $Z_{B,C}^{II}$ and $g_{C,B}(\cdot)$ decrease. Thus, terms of trade of *A* and *C* deteriorate while those of country *B* improve. Consequently, there exists at least one location point for which *C* or *A* is indifferent between direct and indirect trade, but for all location points closer to *B*, such that $d_{C,A}>d_{C,B}$ all three countries prefer indirect trade. Hence, for any location of country *B* there exists a non-empty set of location points of country *C* such that the pattern of trade (between countries *B* and *C*) opposite to one predicted by the theory of comparative advantage can be observed.

Note that if transportation costs face increasing returns the pattern of trade predicted by the theory of comparative advantage can be reversed even if transportation costs are identical in either direction (i.e., symmetric). If transportation costs are asymmetric then in addition to comparative advantage (disadvantage) in productivities, countries have also comparative advantage (disadvantage) in transportation, which has to be taken into account when the pattern of trade based on overall comparative advantage is determined, but this case is beyond the scope of the present analysis.

5. SUMMARY AND CONCLUSIONS

It has been widely recognized that differences in technology or factor endowments create a base for international trade. Differences in transportation costs have been usually neglected in formal trade theory. Such costs are either assumed to be zero, as in classical Ricardian or Heckscher-Ohlin models, or infinite, as in the case of domestic goods, and rather exceptionally there is something in between. In reality, however, they always exist. Since they can change the predictions of the classical models their integration appears to be useful in understanding trade among industrial countries.

The paper introduces increasing returns to transportation into a three-country version of the Ricardian model to trade theory in a one-factor world with two-traded goods. The model presented relies on restrictive assumptions. But this enables us to show that bilateral trade needs not to be the result of international differences in technology. Trade between two countries may also result from economies of scale to transportation.

It is important to recognize that increasing returns to transportation alone are not responsible for the main results of the paper. The results do depend on distance and the particular differences in technology assumed across countries. They should be viewed as complementary rather than as being in conflict with the theory of comparative advantage. We hope that the paper will stimulate further research to give economies of scale in transportation a more prominent place in trade theory in future.

ENDNOTES

1 It follows from the solution to the following optimization problem:

$$\max_{Z_J, W_J} Z_J^{1-\alpha} W_J^{\alpha}, \quad \text{s.t. } Z_J P_z^J + W_J P_w^J = M,$$

where P_z^J, P_w^J denote market prices of commodities *z* and *w* in country *J*, and *M* denotes the income of a single worker.

2 One can check that for $a_{Lz}^A = 1$, $a_{Lw}^A = 2$, $a_{Lz}^B = a_{Lz}^C = 6$, $a_{Lw}^B = a_{Lw}^C = 3$, $\alpha = 1/4$, $L_A = 100$, $L_B = L_C = 50$, and small transportation costs country *A* produces only commodity *z* and exchange it for commodity *w* that is produced in countries *A* and *B* (countries *B* and *C* produce only commodity *w*).

3 Assuming that countries *B* and *C* are identical implies that $L^B = L^C$, $a_{Lw}^B = a_{Lw}^C$ and $a_{Lz}^B = a_{Lz}^C$.

4 Since $Z_{A,B}^{II}$ is constant and $Z_{B,C}^{II}$ decreases if the distance $d_{B,C}$ between countries *B* and *C* increases, the difference $Z_{A,B}^{II} - Z_{B,C}^{II}$ increases, i.e., country *B* consumes more of commodity *w* for the same volume of commodity *z* exported.

5 See equations (29) and (31) and note that $d_{A,B} = d_{A,C}$.

6 See equations (37) and (38), and set $g_{B,C}(Z_{B,C}^{II}) = 1$.

7 See equations (30) and set $L^B = L^C$.

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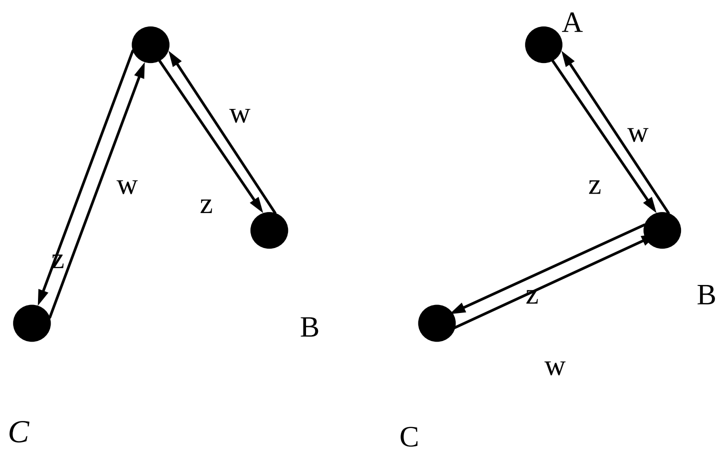
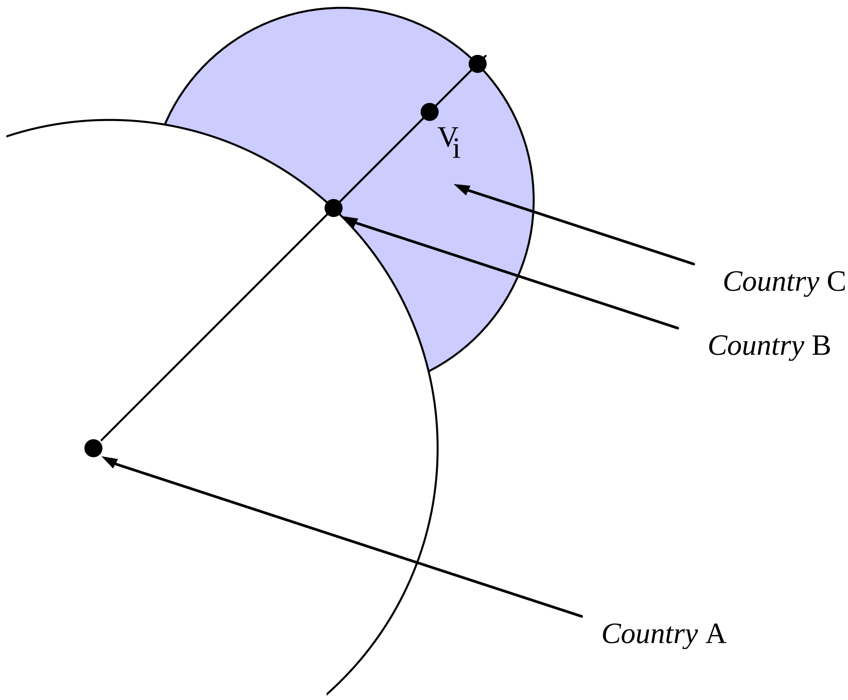


(a) Case I *(b) Case* II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TITLES OF FIGURES

Abstract

The paper makes a modest attempt to shed some light on the role of space in the creation of technological knowledge in Austria. The study is exploratory rather than explanatory in nature and based on descriptive techniques such as *Moran's I* test for spatial autocorrelation and the Moran scatterplot. Clusters of the knowledge 'output' [measured in terms of patent counts] are compared with spatial concentration patterns of two input measures of knowledge production: private R&D and academic research. In addition, employment in manufacturing is utilised to capture agglomeration economies. The analysis is based on data aggregated for two digit SIC industries and at the level of Austrian political districts. It explores the extent to which knowledge spillovers are mediated by spatial proximity in Austria. A time-space comparison makes it possible to study whether divergence or convergence processes in knowledge creation have occurred in the past two decades. As in the case of any exploratory data analysis, the findings need to be treated with caution and should be viewed only as an initial pre-modelling stage in the enterprise. Future research activities will be devoted to further exploring the issue of local university knowledge spillovers within a refined production framework (see Griliches 1979).

1 Introduction

2 Methodology and Data

In this current study *Moran's I* statistic is used. *Moran's I* is based on cross-products to measure value association:

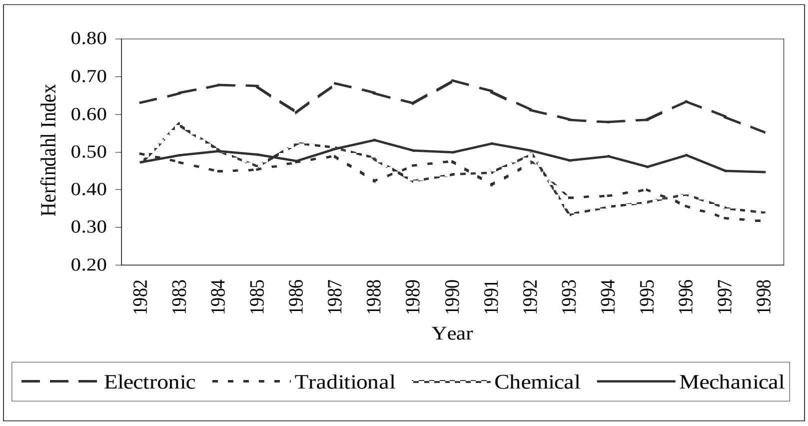
$$I = (n/S_0)\ \Sigma_i\ \Sigma_j\ w_{ij}\ (x_i - \mu)(x_j - \mu)\ /\ \Sigma_i(x_i - \mu)^2 \qquad (1)$$

Tab. 1: Sectotral distribution of Austrian patent applications in the periods 1982-1989 and 1990-1997

	Time Period 1982-1989	*1990-1997*	*Percentage Change from 1982-1989 to 1990-1997*
Sectoral Share of Patents in Total Patents in Manufacturing			
Machinery	26.02	24.52	-5.75
Metal Products excluding Machines	18.18	19.97	9.87
Instruments	9.48	10.64	12.27
Transportation Vehicles	9.23	8.47	-8.29
Chemistry and Pharmaceuticals	8.33	7.30	-12.39
Electrical Machinery	6.86	6.54	-4.73
Construction	5.53	5.26	-4.88
Stone, Clay and Glass Products	3.73	3.39	-9.1
Paper, Printing and Publishing	2.53	3.29	30.07
Electronics	2.61	2.78	6.46
Basic Metals	2.62	2.52	-3.73
Textiles and Clothes	1.87	1.38	-26.49
Computers and Office Machines	0.77	1.35	75.95
Food, Beverages, Tobacco	0.83	1.12	34.05
Rubber and Plastics	0.94	1.03	9.87
Oil Refining	0.29	0.25	-11.77
Wood and Furniture	0.18	0.19	5.39
Correlation Coefficient	0.99		
Total Number of Patent Application in Manufacturing	15,019	14,251	-5.11
Normalised Herfindahl Index of Sectoral Concentration	0.30	0.29	
Share of Vienna in Manufacturing Total [as percentage]	32.16	34.05	

Source: Austrian Patent Office

Fig. 2: Geographical concentration of patents for four manufacturing areas, measured by the normalised Herfindahl index [1982-1998]



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Endnotes

[1] Traditional sectors include food, beverages and tobacco [ISIC 15-16], construction [ISIC 45], stone, clay and glass [ISIC 25], textiles and clothing [ISIC 17 and 18], paper, printing and publishing [ISIC 21 - 22] and wood and furniture [ISIC 20 and 36]. The mechanical sectors include basic metals [ISIC 27], instruments [ISIC 33], transportation vehicles [ISIC 34 - 35], machinery [ISIC 29] and metal products [ISIC 28]. The chemical sectors consist of rubber and plastics [ISIC 25], chemistry and pharmaceuticals [ISIC 24] and oil refining [ISIC 23], whereas the electronic sectors include electronics [ISIC 32], electrical machinery [ISIC 31] and computers and office machines [ISIC 30].

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