Transport Costs and North-South Trade

Didier Laussel* Raymond Riezman†

June 15, 2006

Abstract

We develop a simple two country model of international trade that assumes that there is a fixed cost associated with transporting goods across national boundaries. We show that this leads to multiple equilibria that can be Pareto-ranked. One of these equilibria is autarky. We argue that the existence of fixed costs in transport can help explain the low volume of North-South trade.

*GREQAM, University of Aix-Marseille II, email: laussel@univ-aix.fr
†Department of Economics, University of Iowa, email: raymond-riezman@uiowa.edu

1 Introduction

The lack of trade between rich countries (the North) and poor countries (the South) has been widely documented and discusssed. In this paper we offer a new explanation for this lack of international trade. In a recent empirical paper, Hummels and Skiba (2002) argue that economies of scale in transport are important and in part, these economies may derive from large fixed costs of trade. Our purpose here is to explore a model in which there are economies of scale in transport to determine what effects these fixed costs have. For simplicity, we do this by introducing fixed costs of transportation into a model of international trade and work out the implications. We show that once fixed transport costs are introduced there is a low trade (autarky) equilibrium and that poor countries could be "trapped" at autarky. That is, if they consider small changes from autarky equilibrium they will conclude it does not pay to move from autarky.

Generally, transportation costs has received relatively little attention in the international trade literature. Samuelson (1954), in an analysis of the transfer problem, developed what has become known as the "iceberg" model of transport costs. In the iceberg model, transporting goods costs some proportion of either the goods' value or the physical quantity. The advantage of this approach is that transportation costs simply act as a kind of simple tax for which there is no revenue produced. In international trade models, its like there is a tariff that produces no revenue. In these models the standard trade theorems hold.

The next major theoretical advance in modeling transportation costs was by Falvey (1976). He treats transportation as services that need to be consumed in order for international trade to take place. Falvey explicitly models a transportation sector and shows that in a Heckscher-Ohlin framework the main trade theorems go through and the analysis is modified in straightforward ways. Despite these theoretical developments recent empirical work on transportation costs point in another direction.

Hummels and Skiba (2004) in a paper about whether high or low quality goods are more likely to be exported find that, "...we provide strong evidence against a widely used assumption in the trade literature: that transportation costs are of the 'iceberg' form, proportional to goods prices."

We develop a simple two country model of international trade that assumes that there is a fixed cost of doing international trade. We show that this leads to multiple equilibria that can be Pareto-ranked. There are high volume of trade, medium volume of trade and no trade (autarky) equilibria. The high trade equilibrium is best and autarky is worst. We argue that poor countries could be in an autarky trap since in the neighborhood of autarky, because of the fixed transportation cost, they would have no incentive to engage in international trade.

The model is developed in section 2, offer curves are derived in section 3, equilibrium solved for in section 4, efficiency is discussed in section 5, and policy conclusions are discussed in section 6.

2 The General Model

We consider a model in which two goods, labelled 1 and 2, are exchanged between two countries, a home country and a foreign country. All foreign country variables are indicated by asterisks (*). The two goods are produced within each country under perfect competition and with constant returns to scale production functions with the help of $m \geq 1$ internationally immobile factors. The domestic (respectively foreign) prices of the goods 1 and 2 are denoted by p_1 and p_2 (respectively p_1^* and p_2^*). Assuming that the production functions exhibit the usual properties (such as the Inada conditions in the two-factor case) the *autarkic* supply functions (i.e. when no resources are used for transportation) are written as $S_i(\frac{p_i}{p_j})$ and $S_i^*(\frac{p_i^*}{p_j^*})$, $i, j = 1, 2$, $i \neq j$, respectively in the home and foreign countries with $S_i' > 0$ and $S_i^{*\prime} > 0$.

The role of transportation costs is central in our model. In particular, we are interested in the effect of fixed costs of transportation that may be associated with international trade. These may include the costs of shipping goods from one country to the other or costs of setting up distribution and marketing networks. We focus here on the case when the transportation costs include only fixed (but not sunk) costs[1]. For simplicity, we suppose that shipping goods from the home (respectively foreign) country to the foreign (respectively home) country requires investing a fraction β (respectively β^*) of all the domestic (respectively foreign) factor resources whatever the (strictly positive) volume of trade. Together with constant returns to scale (CRS), this assumption allows us to rule out any effect of transportation activities on factor prices. The effect of opening the economy is simply to reduce proportionally by a factor β (β^*) the stocks of factors available for production activities. Since the CRS assumption rules out size effects, it is clear that at given domestic (respectively foreign) prices the factor prices are the same in free trade as in autarky. It follows that the total domestic (respectively foreign) factor income Y (respectivelyY^*) equals its autarkic value, itself equal to the value of the *autarkic* domestic (respectively foreign) output valued at (the same) domestic (respectively foreign) prices:

$$Y = p_1 S_1(\frac{p_1}{p_2}) + p_2 S_2(\frac{p_2}{p_1}) \tag{1}$$

$$Y^* = p_1^* S_1^*(\frac{p_1^*}{p_2^*}) + p_2^* S_2^*(\frac{p_2^*}{p_1^*}) \tag{2}$$

We assume average cost pricing in transportation activities. These fixed transport costs could be financed in a variety of ways, and while we acknowledge that the method of financing these activities is potentially important, we wish to keep the model as simple as possible in order to focus on the effects of the fixed costs. Accordingly, we assume that when there is international trade the difference between the foreign and the domestic prices of the exported

[1] Adding variable costs would not change the results in any significant way.

goods times the volume of exports exactly covers the fixed transportation cost expenditures. This can be thought of as an equilibrium condition: the home (respectively foreign) firms must be indifferent between selling on the home and on the foreign markets.

The equilibrium profits are zero and the total domestic (respectively foreign) income is then equal to the factor income Y (respectively Y^*). Finally the domestic and foreign *free trade* supply functions may be written respectively as $(1-\beta)\ S_i(\frac{p_i}{p_j})$ and $(1-\beta^*)\ S_i^*(\frac{p_i}{p_j})$, $i,j=1,2,\ \ i\neq j$, i.e. as fixed fractions of the autarkic supplies.

The consumption demands in the home and foreign countries are derived from the maximization of two thrice continuously differentiable concave utility functions $U(C_1,C_2)$ for the home country and $U^*(C_1^*,C_2^*)$ for the foreign country subject to the budget constraints which are respectively

$$p_1C_1+p_2C_2=Y \tag{3}$$

and

$$p_1^*C_1^*+p_2^*C_2^*=Y^* \tag{4}$$

We obtain twice-continuously differentiable demand functions:

$$C_i=D_i(\frac{Y}{p_i},\frac{p_j}{p_i}),\ i,j=1,2,\ \ i\neq j \tag{5}$$

and

$$C_i^*=D_i^*(\frac{Y^*}{p_i^*},\frac{p_j^*}{p_i^*}),\ i,j=1,2,\ \ i\neq j \tag{6}$$

We assume that the first derivatives of these demand functions are strictly positive, i.e. that the two goods are normal. Notice that, given equations (1) and (2) these demands depend only on relative good prices and that they are more conveniently written as

$$D_i(\frac{Y}{p_i},\frac{p_j}{p_i})=d_i(\frac{p_j}{p_i}) \tag{7}$$

$$D_i^*(\frac{Y^*}{p_i^*},\frac{p_j^*}{p_i^*})=d_i^*(\frac{p_j^*}{p_i^*}) \tag{8}$$

As is well known the income and substitution effects have the same sign in the case of exports so that, if i is an exported good, $d_i'(\frac{p_j}{p_i})>0\ \ (d_i^{*'}(\frac{p_j}{p_i})>0)$. The signs of the two effects are opposite in the case of imports so that one cannot say a priori anything on the sign of the above derivatives.

Notice that for given relative prices, these demand functions do not depend on β or β^*. This means that transportation costs have no direct effect on demand.

For convenience, we assume that if trade takes place the home country exports good 1. Hence,

$$X_1(p,\beta) = (1-\beta)S_1(p) - d_1(p)$$

and

$$M_2(p,\beta) = d_2(p) - (1-\beta)S_2(p)$$

are the export supply and import demand functions of the home country. For the foreign country

$$X_2^*(p^*,\beta^*) = (1-\beta^*)S_2^*(p^*) - d_2^*(p^*)$$

and

$$M_1^*(p^*,\beta^*) = d_1^*(p^*) - (1-\beta^*)S_1^*(p^*)$$

are the export supply and import demand functions, respectively.

Average cost pricing in the transportation industries implies that

$$(p_1^* - p_1)X_1(p,\beta) = \beta\ (p_1 S_1(p) + p_2 S_2(p)) \tag{9}$$

and

$$(p_2 - p_2^*)X_2^*(p^*,\beta^*) = \beta^*(p_1^* S_1^*(p^*) + p_2^* S_2^*(p^*)) \tag{10}$$

From equations (1) and (3) we obtain

$$p_1 X_1(p,\beta) = p_2 M_2(p,\beta) + \beta(p_1 S_1(p) + p_2 S_2(p))$$

Together with equation (9) we now obtain

$$v\ X_1(p,\beta) = M_2(p,\beta) \tag{11}$$

where $v = \frac{p_1^*}{p_2}$ denotes the ratio between the c.a.f. prices of the two goods. By a similar argument equations (2), (4) and (10) imply that

$$v\ M_1^*(p^*,\beta^*) = X_2^*(p^*,\beta^*) \tag{12}$$

It is worth noting that these "balance of trade" equilibrium conditions (equations (11) and (12)), contrary to the standard model of international trade without transportation costs, do not simply follow from the domestic and the foreign budget constraints. In order to derive them, we have assumed condition (9) and condition (10). These two conditions already have an equilibrium interpretation: they imply that the domestic (respectively foreign) firms are indifferent between selling on the domestic or the foreign market. If they hold, then international trade is possible and that means that essentially there is now one world market for each good.

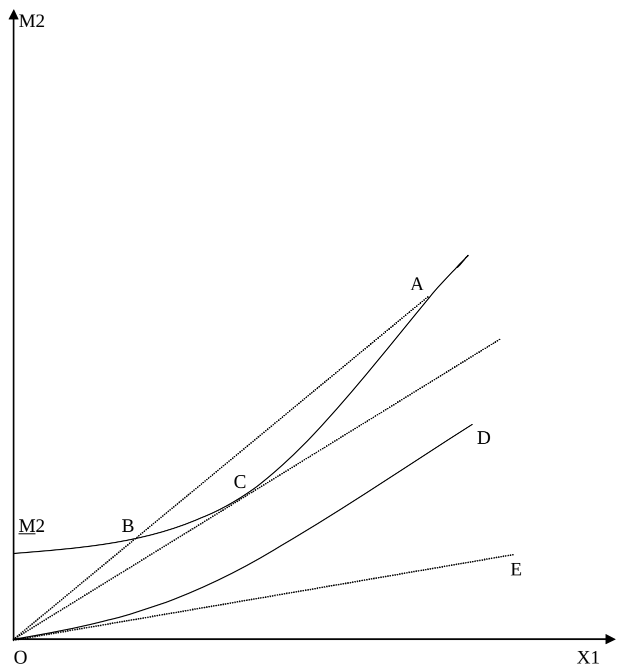

Figure 1:

3 The Offer Curves

We are now able to construct the home and foreign "offer curves" that specify the amount of exports a country is willing to supply in exchange for each possible level of imports. Given our previous assumptions if there is international trade then, the home country exports good 1 and exports good 2 while this is the reverse for the foreign country.

In order for international trade to take place each country has to gain enough from trade to cover the fixed transportation costs. For example, the home country is willing to trade if and only if the home *domestic* relative export price p is not lower than the critical value $\underline{p}(\beta)$ which is unambiguously defined by $X_1(\underline{p}(\beta), \beta) = 0$[2]. This critical price is easily proved to be an increasing function of β. Accordingly, the minimum volume of imports below which the home country is not willing to trade at all is $\underline{M}_2(\beta) = M_2(\underline{p}(\beta), \beta)$ where $\underline{M}_2$ is itself strictly increasing in β. Since M_2 is a strictly increasing function of p we may use the Inverse Function Theorem which guarantees the existence of an

[2]given equation (15) it is easy to show that $\underline{p}(\beta) \geq p^A$.

inverse function $\rho \equiv M_2^{-1}$. The offer curve of the home country is now simply defined as

$$X_1 = f(M_2, \beta) = \max\{0, X_1(\rho(M_2, \beta), \beta)\} \tag{13}$$

Obviously, $f(M_2, \beta) = 0$ for all $M_2 \leq \underline{M}_2(\beta)$. Moreover $\frac{\partial f(M_2,\beta)}{\partial \beta} < 0$.To see how the offer curve is affected by fixed transportation costs consider Figure 1. The usual domestic offer curve with no fixed transportation costs ($\beta = 0$) is OD. It is convex since to a given domestic price ratio p must correspond under the usual assumptions to one and only one couple (X_1, M_2). We assume that it is *strictly* convex[3]. The slope of the tangent OE to OD at the origin is equal to the autarkic equilibrium price ratio p^A.

Now consider the home country offer curve when there are fixed transport costs. The home country offer curve corresponding to some $\beta > 0$ is $O\underline{M}_2A$. At any point A on the home country offer curve we deduce from equation (11) that the value of the international relative price v equals the slope of OA. For sufficiently low values of β it must be *convex* for all $M_2 > \underline{M}_2(\beta)$ as pictured above. A necessary condition for the home country being willing to trade is obviously that the international relative price v of good 1 be larger than a value $\underline{v}(\beta)$ equal to the slope of OC which is itself strictly larger than the autarkic equilibrium price ratio p^A. Thus, with fixed transportation costs the domestic country requires more gains from trade (a higher relative price for good 1) before it is willing to engage in international trade. Of course $\underline{v}(\beta)$ tends toward p^A as β tends toward 0. Notice that for any value of v larger than $\underline{v}(\beta)$ there correspond two points on the home offer curve and hence two possible trade vectors and two possible values of the domestic relative price p.

The foreign offer curve is affected in the same way. The foreign country is willing to trade if and only if the foreign domestic relative price of imports p^* is not larger than a critical value $\overline{p}^*(\beta^*)$ unambiguously defined by $X_2^*(\overline{p}^*(\beta^*), \beta^*) = 0$. Accordingly, the minimum volume of imports below which the foreign country is not willing to trade is $\underline{M}_1^*(\beta^*) = M_1^*(\overline{p}^*(\beta^*), \beta^*)$ and is strictly increasing in β^*. M_1^* being a strictly decreasing function of p^* we may use the Inverse Function Theorem which guarantees the existence of $M_1^{*\,-1} \equiv \sigma$. The offer curve of the foreign country is then simply

$$X_2^* = f^*(M_1^*, \beta^*) = \max\{0, X_2^*(\sigma(M_1^*, \beta^*), \beta^*))\} \tag{14}$$

Notice that $f^*(M_1^*, \beta^*) = 0$ for all $M_1^* \leq \underline{M}_1^*(\beta^*)$ and that $\frac{\partial f^*(M_1^*,\beta^*)}{\partial \beta*} < 0$.

Figure 2 shows foreign country offer curves for $\beta^* = 0$ and $\beta^* > 0$. At any point A on this curve it follows from equation (12) that the corresponding international price ratio v equals the slope of OA. By the same argument used above for establishing the convexity of the home offer curve, the foreign offer

[3]This amounts to ruling out *flat* parts of the usual offer curves as occur in the Ricardian case. This assumption ensures that for low transport costs and a volume of imports above a given minimum the home offer curve is convex. However as shown in Section 5 for the Ricardian case, this assumption is too strong: in this case indeed the home offer curve is unambiguously convex for any value of β provided that $M_2 > \underline{M}_2(\beta)$.

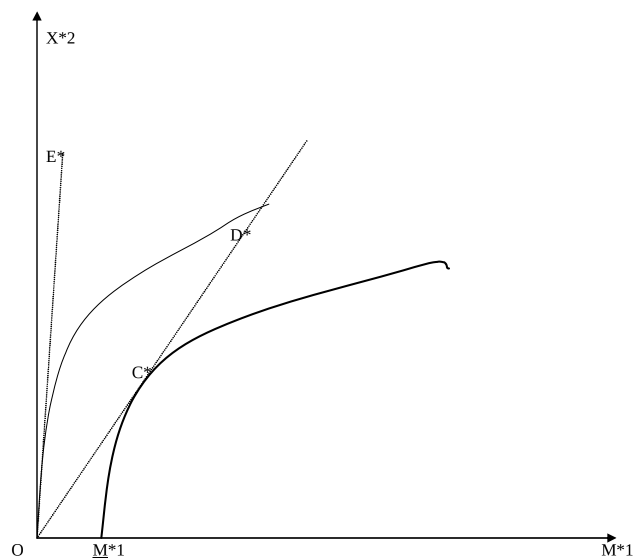

Figure 2:

curve is concave for sufficiently low values of β^* and for values of M_1^* larger than $\underline{M}_1^*(\beta^*)$. The foreign country is willing to trade if and only if the international price ratio v is lower than the critical value $\overline{v}(\beta^*)$ corresponding to the slope of the tangent OC^* to the offer curve from the origin. Of course $\overline{v}(\beta^*)$ is lower than the foreign autarkic price ratio p^{A*} given by the slope of OE*.

4 The Equilibria

The **autarkic equilibrium** (relative) prices p^A and p^{*A} (notice that $p = \frac{p_1}{p_2}$ and $p^* = \frac{p_1^*}{p_2^*}$) satisfy the market-clearing conditions (from Walras Law equilibrium on the first market entails equilibrium on the second market) :

$$\begin{aligned} S_1(p^A) &= d_1(\frac{1}{p^A}) \\ S_1^*(p^{A*}) &= d_1(\frac{1}{p^{A*}}) \end{aligned} \tag{15}$$

We assume without loss of generality that $p^A < p^{A*}$, i.e. that the home country has a comparative advantage in good 1.

Whenever the fixed transportation costs are both strictly positive (i.e. whenever $\beta > 0$ and/or $\beta^* > 0$) *autarky is an equilibrium of our model*. When the volume of trade is arbitrarily low no firm expects to be able to cover the fixed cost expenditures which it would have to make in order to enter the transportation industry. Put another way, at autarky, the prices of transportation services per unit of good shipped are so large as to discourage any trade[4]. This looks like a "low level equilibrium trap": there is no trade because at the margin transportation costs are very large but the transportation costs are large because there is no trade. However, it remains to show that there may also exist equilibria with positive volumes of trade.

An **international** (i.e. with positive trade) **equilibrium** of this model is formally a triple of relative prices (p, p^*, v) such that (i) the two goods markets clear and (ii) the two transportation industries break even. As usual, owing to Walras Law, one of these conditions is redundant so that one is left with three equations in three unknowns. Interestingly enough the two goods market clearing equations are

$$(1-\beta)S_1(\widehat{p}) + (1-\beta^*)S_1^*(\widehat{p}^*) = d_1(\frac{1}{\widehat{p}}) + d_1^*(\frac{1}{\widehat{p}^*}) \tag{16}$$

and

$$(1-\beta)S_2(\frac{1}{\widehat{p}}) + (1-\beta^*)S_2^*(\frac{1}{\widehat{p}^*}) = d_2(\widehat{p}) + d_2^*(\widehat{p}^*) \tag{17}$$

[4] They indeed tend toward infinity.

These equations determine the domestic relative prices in the home and foreign countries and thereby all the relevant quantities (output, consumption, import and export levels) *independently of the budget balance conditions for the transportation industries.* Then either condition (11) or condition (12) determines the international price ratio v so as to satisfy budget balance in the transportation industry.

To see how the model works it helps to first consider the classical case without transportation costs ($\beta = \beta^* = 0$). Here, at free trade, the two relative prices, home and foreign, must coincide in equilibrium ($p = p^* = v$) and conditions (11) and (12) are automatically satisfied. Moreover, from Walras Law, the second market clears if the first one does (and reciprocally) so that we are left with only one equilibrium condition, say equation (16), which may be written as $E_1(v) = d_1(\frac{1}{v}) + d_1^*(\frac{1}{v}) - S_1(v) - S_1^*(v) = 0$. Under standard assumptions the excess demand for good 1 (E_1) is a continuous function of v, is positive when $v = 0$, and tends toward a strictly negative value when v tends toward infinity. This ensures the existence of at least one equilibrium, i.e. of a value $\widehat{v}$ such that $E_1(\widehat{v}) = 0$. As is well-known, this equilibrium is unique whenever the condition below is satisfied.

Condition 1 (*Marshall-Lerner*) $\varepsilon(v) + \varepsilon^*(v) > 1$

Where $\varepsilon(v)$ and $\varepsilon^*(v)$ are respectively the home and foreign price-elasticities of imports. Recalling that home imports of good 2 are $M_2 = C_2 - S_2$ and foreign imports of good 1 are $M_1^* = C_1^* - S_1^*$, then $\varepsilon(v) = \frac{vM_2'(v)}{M_2(v)}$ and $\varepsilon^*(v) = -\frac{vM_1^{*\prime}(v)}{M_1^*(v)}$.

We next turn to determining equilibrium. Equilibrium occurs when the two offer curves intersect since that is where import demands are equal to export supplies. In the case without transportation costs (dotted curves in Figure 3), the Marshall-Lerner Condition ensures that the offer curves cut only twice, at O (autarky) and at E (free trade equilibrium.) However, only E corresponds to an equilibrium since at O the relative prices p^A and p^{A*} differ, giving rise to the possibility of costless and profitable trade.

When there exist small but strictly positive transportation costs a simple continuity argument shows that there now exist two international equilibria with positive amounts of trade, a "high" equilibrium at H , near E, and an "intermediate" equilibrium at I, near O with an international equilibrium price ratio respectively equal to the slopes of OH and of OI. Moreover as shown above autarky now becomes an equilibrium with equilibrium home and foreign autarkic relative prices equal to the slopes of OE and OE*.

Proposition 1 *For small enough values of β and β^*, such that at least β or $\beta^* > 0$, there exist three equilibria which are ranked by increasing volumes of trade: autarky, an "intermediate trade" equilibrium and a "high trade" equilibrium.*

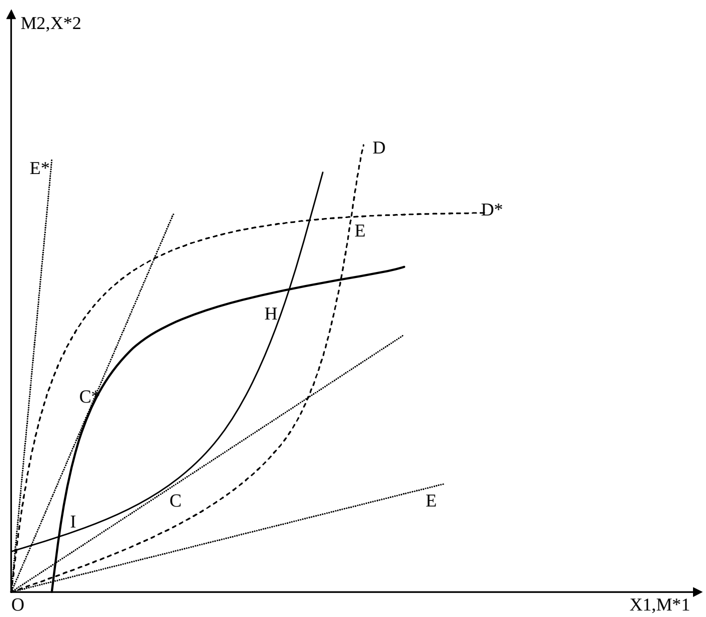

Figure 3:

5 Efficiency

We next consider efficiency. The central question we ask is whether the three equilibria can be ranked? We are able to show that in fact, all three equilibria can be Pareto-ranked.

Proposition 2 *(Efficiency) With fixed costs of transportation the three equilibria can be Pareto-ranked. The high trade equilibrium Pareto-dominates the intermediate trade equilibrium which in turn, Pareto-dominates the autarkic equilibrium.*

Proof. *First, consider the home offer curve. It follows from convexity assumptions made earlier that, moving from the left to the right on the home offer curve means M_2 is increasing as is p. So, M_2 is increasing in p. By the same argument M_1^* is decreasing in p^* moving from the left to the right on the foreign offer curve. It follows then, that at the high equilibrium point H, p is higher and p^* is lower than at the intermediate equilibrium point I. This means that the wedge between the internal home and foreign relative prices is lower at H than at I. This reasoning also shows that the wedge is lower at I than it is at O. The second step is now to show that the home welfare $W(p) = U(C_1(p), C_2(p))$ is increasing in p while the foreign welfare $W^*(p^*) = U^*(C_1^*(p^*), C_2^*(p^*))$ is decreasing in p^*. We obtain* ■

$$W'(p) = U_1'(C_1(p), C_2(p))C_1'(p) + U_2'(C_1(p), C_2(p))C_2'(p)$$

and then, using the first-order conditions of the home consumer's problem

$$W'(p) = U_2'(C_1(p), C_2(p)) \left[pC_1'(p) + C_2'(p)\right]$$

From equations (1) and (3)

$$pC_1'(p) + C_2'(p) + C_1(p) = pS_1'(p) + S_2'(p) + S_1(p)$$

Since at equilibrium the home national income is maximized $pS_1'(p)+S_2'(p) = 0$ *and we can safely conclude that*

$$W'(p) = U_2'(C_1(p), C_2(p)) \left[S_1(p) - C_1(p)\right] > 0$$

By the same argument

$$W^{*'}(p^*) = -\frac{U_1^{*'}(C_1^*(p), C_2^*(p))}{p^{*2}} \left[S_2^*(p^*) - C_2^*(p^*)\right] < 0$$

Remark: Though the "high trade equilibrium", when it exists, Pareto-dominates both the intermediate and the autarkic equilibrium it is not Pareto-efficient. Efficiency would indeed require that prices equal marginal costs. Specifically, since the marginal transport costs are zero in this model there should be no difference between home and foreign prices. This is not the case here owing to *average* cost pricing in the transportation industries: import prices are above marginal costs in both countries and the levels of consumption of imported (respectively exported) goods are accordingly below (respectively above) their optimal levels.

6 Conclusion

The basic message of this paper is clear. While there may exist some scope for mutually profitable North-South (interindustry) trade based on comparative advantage the world may well be trapped in some low level equilibrium (here the autarkic one) where, due to the existence of fixed transportation costs, low trade volumes lead to large unit transport prices which themselves induce in turn low trade volumes. The dimension of this ”trap” can be informally measured by the distance between this low level equilibrium and the intermediate equilibrium, a distance which is increasing in the fixed transportation costs.

One could think that getting out of this trap may require some kind of ”big push”, for instance some public investments in transport infrastructure: by doing so one could expect the emergence of a "high trade" equilibrium. Moreover, if these investments be financed by lump-sum taxation, an additional source of inefficiency, the divergence between the home and foreign relative prices, could be eliminated. Notice, however, that such a move would require some knowledge about what the high trade equilibrium looks like as well as some coordination between the governments of the two countries.

References

[1] Hummels, David and Alexandre Skiba, (2002), "A Virtuous Circle? Regional Tariff Liberalization and Scale Economies in Transport," mimeo.

[2] Hummels, David and Alexandre Skiba, (2004) "Shipping the Good Apples Out? An Empirical Confirmation of the Alchain-Allen Conjecture," forthcoming *Journal of Political Economy.*

[3] Falvey, Rodney, (1976), "Transport Costs in the Pure Theory of International Trade," *The Economic Journal,* 86, 536-550.

[4] Samuelson, Paul, (1954), "The Transfer Problem and Transport Costs, II: Analysis of Effects of Trade Impediments," *The Economic Journal,* 64, 264-289.