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COMPARATIVE ADVANTAGE, GEOGRAPHIC ADVANTAGE, AND THE VOLUME OF TRADE

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ABSTRACT

A functional relationship between the degree of a country's comparative advantage in any good and the volume of its net exports of that good to its trading partner is established using a model with per-unit-distance transportation costs between countries' coasts and their interiors. The greater a country's comparative advantage, the greater the transportation cost it can overcome and hence the deeper its exports can penetrate geographically into its trading partner. The internal spatial structure of a country is modelled using cities as the basic spatial units. It is shown that the city closest to the coast will be the largest and have the highest wage rate and residential rental rates, and that population sizes, wage rates, and residential rental rates of cities all fall as one moves inland.

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The theory of comparative advantage, as embodied in the Ricardian and Heckscher–Ohlin models of trade, is capable of predicting the pattern of trade between countries in more than two commodities but not the volume of trade in each commodity. The Ricardian model predicts that a country will export those goods for which it has a comparative labor productivity advantage and import those for which it has a comparative labor productivity disadvantage, with the dividing line in this chain of comparative advantage being determined by the demand side of the model (see Haberler 1936). However, given that a country exports (imports) a good, the amount of exports (imports) is not influenced by the degree of its comparative advantage (disadvantage). The Heckscher–Ohlin model predicts that the country relatively well endowed with, say, capital per worker will export those goods that use capital intensively and import those goods that use labor intensively (assuming it is possible to rank goods in this way unambiguously), with the dividing line in this chain of comparative advantage again being determined by the demand side as in the Ricardian model (see Deardorff 1979). Also as in the Ricardian model, the amounts of exports and imports have nothing to do with comparative advantage.

The fundamental reason for the failure of the theory of comparative advantage to explain the volume of trade is simple. The country with the comparative advantage in a good can produce it more cheaply than its trading partner(s) for reasons that are unrelated to the volume of production. Thus potential domestic producers will never be able to gain a share of the domestic market for any importable no matter how slight is their comparative disadvantage or how great is domestic demand.[1] In other words, when the theory of comparative advantage predicts the pattern of trade it predicts complete specialization of a country's production in its exportables. When the theory of comparative advantage does not predict complete

[1]A country much smaller than its trading partner(s) may not be able to satisfy the demand of the partner(s) for the good in which it has the greatest comparative advantage even if it devotes all its resources to production of that one good. In this exceptional case the trading partner(s) does have positive production of one of the goods it imports.

specialization, as in the Heckscher-Ohlin case of factor-price equalization across countries, it does not predict the pattern of trade either (see Bhagwati 1972).[2] It is interesting to note that technology-based theories of the pattern of trade, the main competitors with the theory of comparative advantage, also predict complete specialization and hence are equally silent regarding the volume of trade. The Krugman (1979) formulation of the product cycle theory, for example, predicts that the innovating country will completely specialize in production of "new" goods while the non-innovating country will completely specialize in production of "old" goods.

This limitation of the standard trade models becomes especially noticeable when we attempt to test them empirically. Do we take the theory of comparative advantage at its word and test only for the direction of trade, using a limited dependent variable technique? This was the approach of Harkness and Kyle (1975) in testing the Heckscher-Ohlin model. Or do we throw theoretical caution to the winds and test using the volume of trade? This approach was pioneered by MacDougall (1951) for the Ricardian model and by Baldwin (1971) for the Heckscher-Ohlin model. If we take this latter approach, we confront several questions for which we have no theoretical guidance. For example, do we use net exports for our volume of trade variable, or do we use gross exports and imports separately? Do we measure volume by quantity or value? How do we scale the volume of trade variable to take account of the fact that the world's consumers allocate more of their income to some goods than to others?

One can sidestep these problems altogether by working with the implicit trade in factor services that is embodied in commodity trade rather than with the volume of commodity trade itself. This approach has been championed by Leamer, a recent example being Bowen, Leamer, and Sveikauskas (1987). However, as Deardorff (1984) states in a survey article, the results of the large body of literature using volume of trade as a dependent variable in

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[2]Of course in the two commodity case of the Heckscher-Ohlin model comparative advantage both predicts the pattern of trade <u>and</u> influences the volume of trade in each commodity, but this is of little help when we try to implement the Heckscher-Ohlin model empirically.

regression analysis are too strong and consistent to be dismissed. He goes on to suggest several modifications of the standard models that would allow for a functional relationship between autarky price differentials (determined by comparative advantage) and the volume of trade between countries. One of these suggestions looks at the role of per–unit–distance transportation costs:

> One might argue that as trade expands it is necessary for exports to penetrate deeper and deeper into the importing country and that this is increasingly costly. With this assumption it should follow that quantities traded would depend positively on autarky price differences, though in general equilibrium there would be room for many and perhaps ambiguous cross effects as well (pp. 472–473).

Deardorff's suggestion is lent plausibility by the fact that estimation of "gravity" models has shown international distance to be a very important predictor of bilateral trade volumes.[3] However, I choose to pursue this particular suggestion not because I think it is necessarily the best for establishing the functional relationship just mentioned, but because if it is rigorously implemented it yields unexpected dividends over and above the return to our understanding of international trade.

It is clear that in order to implement Deardorff's suggestion I will need to impose some spatial structure on what is normally a non–spatial theory. I must be concerned about the spatial location within a country of individuals' purchases for consumption. Moreover, since it would not be consistent to allow for transportation costs for goods but to ignore them for people, I will assume that people live and work near where they consume. Now add the fact that typically it is most efficient for international trade to proceed via coastal ports rather than through direct exchange between point of production and point of consumption. International trade will therefore tend to attract economic activity towards ports, with consequences for the spatial distribution of returns to both land and human resources. This is the "geographic

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[3]For evidence of the empirical importance of intercountry distance as a determinant of bilateral trade flows within Europe, see Aitken (1973). The driving force behind trade in gravity models is product differentiation by country of origin rather than comparative advantage.

advantage" to which the title of this paper refers.

As discussed in the next section, I choose cities as the basic unit of spatial organization for the trading countries in this paper. Previous work adding cities to an international trade model such as Henderson (1982) and Rauch (1989) has assumed away all transportation costs for goods, leaving only commutation costs within each city. The model developed in sections I and II, on the other hand, incorporates both intercountry and intracountry transportation costs for goods. It predicts that population sizes, wage rates, and residential rental rates of cities should all decline monotonically as one moves from a coast of a country into its interior. It is hoped that this model will be of interest to those working in the areas of regional and urban economics as well as to those working in international trade.

In the next section of this paper I assemble my basic model. Section II uses this model to derive results on the spatial–economic structure of countries that are engaged in international trade, under the assumption of per–unit–distance transportation costs. Section III uses the model to develop a relationship between the degree of comparative advantage and the volume of trade for any good. The concluding section summarizes the results of sections II and III and suggests directions for future research.

I. CITIES IN A CONTINUUM–OF–GOODS RICARDIAN MODEL

In order to compensate for the complexity added by spatial structure, I choose the more simple expression of the theory of comparative advantage, the Ricardian model. In particular, I will work with the continuum–of–goods Ricardian model developed by Dornbusch, Fischer, and Samuelson (1977). In this model goods are indexed by $z \in [0,1]$. The goods are ranked by diminishing home country comparative advantage which is measured by

$$A(z) = a^*(z)/a(z), \quad A'(z) < 0, \tag{1}$$

where $a^*(z)$ is the foreign country's labor requirement per unit of z output and $a(z)$ is the home country's labor requirement per unit of z output. (Labor is the only input to production.) The two countries have identical Cobb–Douglas social preferences, so that the proportion of its income that either country spends on any good z is fixed by the exponent, $b(z) = b^*(z)$, of that good in its Cobb-Douglas social utility function. Finally, I choose the convenient normalization $\int_0^1 b(z)dz = 1$.

Turning to the spatial side of our model, we note the well documented fact that people do not distribute themselves uniformly in space, even when that space is relatively undifferentiated in a geographic sense, but instead agglomerate around centers into cities, towns, and villages.[4] This fact points to the existence of increasing returns, perhaps resulting from positive externalities, since as Starrett (1974) points out, "in a world in which exogenous resources are uniformly distributed and the usual convexity assumptions are made, all economic activity should be spread out uniformly (this minimizes transport costs); there would be no concentrations of economic activity, hence no cities [p. 418]." Starrett constructs a general model for the optimum location choice problem given increasing returns, while here I follow the literature that takes what Starrett calls a partial equilibrium approach to the location problem, which is to impose some exogenous structure on the problem in order to facilitate empirical application. In particular, I borrow a simplified model of a city from Henderson (1985, Chapter 11). In his model all production and shopping take place in a central business district (CBD). The CBD is a dimensionless point--all urban land is used for residences. The size of residential lots is fixed at one unit of land. Costs of commuting to work and shopping rise with distance from the CBD. This leads to a rent gradient, with rents falling with distance from the CBD to reach an assumed value of zero at the city's edge. Urban land is undifferentiated so that cities form themselves into circles, which minimize commutation cost. Finally, it is assumed that land is owned collectively by all city residents through shares in a land bank company that efficiently manages the city's land. Each resident owns an equal share in the company. The land bank company pays out dividends, which equal average per capita land rents.

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[4]For an excellent empirical study of agglomeration in the U. S. state of Iowa, see Berry (1967).

Additional assumptions depart from the Henderson model with respect to some details. Consumers are identical in every respect except where they live. Each has Cobb-Douglas preferences as described above and each inelastically supplies N labor hours and requires one unit of land to live on. The consumer receives wage w, but some of his labor hours are lost due to time spent commuting. Hence his labor income is $w(N - \tau\ell^i)$, where τ is time lost commuting (there and back) per unit distance and ℓ^i is the distance of consumer i's residence from the CBD. Finally, some increasing returns are required to provide a force for agglomeration. Henderson assumes increasing returns resulting from a positive production externality. I choose instead to assume that people derive pleasure from interacting with each other while working and shopping in the CBD. In particular I let the logarithm of the ith consumer's utility function be

$$\log U^i = \int_0^1 b(z)\log C^i(z)dz + \log G(n),$$

where $C^i(z)$ is consumer i's consumption of good z, n is the size of the city population and G is increasing and concave.

We can now write the logarithm of the individual's indirect utility function as[5]

$$\log V^i = \int_0^1 b(z)\log[b(z)Y^i/p(z)]dz + \log G(n), \tag{2}$$

where p(z) is the price of good z that prevails in the CBD and $Y^i = w(N - \tau\ell^i)$ + per capita land rent - $r(\ell^i)$, $r(\ell)$ being the rent on one unit of land at distance ℓ from the CBD. In equilibrium, city residents must be equally happy regardless of where they live, so we must have $\partial V/\partial\ell = 0$. This gives us $\partial r(\ell)/\partial\ell = -w\tau$, which we integrate to get $r = k - w\tau\ell$, where k is a constant of integration. By assumption $r(\bar{\ell}) = 0$ where $\bar{\ell}$ is the radius of the city, so

$$r(\ell) = w\tau(\bar{\ell} - \ell).$$

Total land rents are then $\int_0^{\bar{\ell}} 2\pi\ell r(\ell)d\ell = (\pi\ell^2 w\tau\bar{\ell} - \frac{2}{3}\pi\ell^3 w\tau)\big|_0^{\bar{\ell}} = \frac{1}{3}\pi\bar{\ell}^3 w\tau$. We divide this figure

[5]It is possible for a more detailed model to generate endogenously an indirect utility function where city population enters in the positive, multiplicatively separable way assumed here. For example, Abdel-Rahman (1988) applies the Dixit-Stiglitz (1977) model of monopolistic competition and product differentiation to the provision of nontraded urban services. A larger city population is then shown to increase consumers' utility in a multiplicatively separable way by supporting the provision of a greater variety of differentiated services at lower cost.

by n to get per person rental income. But $n = \pi\bar{\ell}^2$ or $\bar{\ell} = \sqrt{n/\pi}$, so

$$\text{per person rental income} = \tfrac{1}{3}w\tau\sqrt{n/\pi}.$$

Thus income for the person on the edge of the city (necessarily equal to the income of any city resident in equilibrium) is

$$Y^{\bar{\ell}} = w(N - \tau\bar{\ell}) + \tfrac{1}{3}w\tau\sqrt{n/\pi} = wN - \tfrac{2}{3}w\tau\sqrt{n/\pi} = Y. \qquad (3)$$

We now show that there can be a unique optimum city size $\bar{n}$ that maximizes $\log V(n)$. Substituting equation (3) into equation (2) gives us

$$\log V(n) = \log w + \log(N - \tfrac{2}{3}\tau\sqrt{n/\pi}) + \int_0^1 b(z)[\log b(z) - \log p(z)]dz + \log G(n). \qquad (4)$$

The first–order condition that the optimum city size must satisfy is then $\partial \log V(n)/\partial n = -\frac{1}{3}\tau(n\pi)^{-1/2}/(N - \frac{2}{3}\tau\sqrt{n/\pi}) + G'(n)/G(n) = 0$. This is an example of Starrett's principle that one should organize spatial concentrations so as to balance the benefits of increasing returns against the costs of increasing average transport requirements (1974, p. 431). If G(n) takes a constant elasticity form then it is easily shown that for any values of the parameters N and τ a unique $\bar{n}$ satisfies this first–order condition, and that the second–order condition for a maximum is also satisfied. If we only assume that G(n) is concave, we may need to choose the parameters N and τ appropriately to assure that $\partial^2 \log V/\partial^2 n$ is negative. In either case, the unique optimum city size $\bar{n}$ depends only on these parameters and G(n). Note that $\partial^2 \log V(n)/\partial n \partial\tau$ is negative, so by the implicit function theorem $d\bar{n}/d\tau$ is negative and optimum city size shrinks as commuting cost increases, as we would expect.

II. CONSTRUCTING A "MAP" OF THE HOME COUNTRY

Having established the city as the basic unit of spatial organization in our country, I now need to discuss the spatial relation of cities to each other. I will make assumptions so as to simplify this relation as much as possible. The country has only one port of entry, which is the mouth of a river of zero width that runs perpendicular to the straight–line coast.[6] The river is the most efficient means of transporting goods in bulk quantity, so that the CBD of any city that engages in international trade will be located on the river. The river also contains natural deep–water ports that fix the locations of trading cities. For simplicity I assume that the distance between these ports (and, to maintain comparability across all cities, the distance between the first port and the coast) is large relative to the radius of a city. Unlike goods, people are most efficiently transported over land, so the river's presence does not affect commutation time.

Now I formally incorporate per–unit–distance transportation costs for goods into my model. I use the "ice" model of transport costs (see Samuelson 1954, p. 268), where a certain proportion $t(z) = t$ of every good "melts away" per unit distance: $dQ(z)/dD = -tQ(z)$, where $Q(z)$ is the quantity of good z and D is the distance it is transported. The virtue of the ice model is that it maintains the adding up property of general equilibrium models (factor income = expenditure) without complicating our model by introducing separate transportation "activities" and payments to factors that provide transportation services. Thus if producers exporting a good z ship it a distance D to where the price p(z) prevails, they receive an effective price of $p(z)e^{-tD}$ per unit of good z exported. Similarly, if consumers buying a good z ship it a distance D from where the price p(z) prevails, they pay an effective price of $p(z)/e^{-tD}$ or $p(z)e^{tD}$.

Let us index the cities in each country by designating the city closest to the river mouth as city 0 and letting the index increase as we move inland from the coast. We can assume without loss of generality that the importing country pays the price prevailing in city 0 of the country from which it imports and incurs the transportation costs thereafter. In this case producers in city j receive $p_j(z) = p_0(z)\exp(-tD_j)$ for their exportables, where $p_0(z)$ is the price

[6] It is possible to generalize our model to the case where there are many rivers of zero width running perpendicular to the same straight–line coast. However, this extension neither changes the results of the one–river case nor adds results of significant interest.

that prevails in city 0 and D_j = distance from the CBD of city j to the CBD of city 0, which is fixed by the location of the deep–water ports. It follows that for exportables of both city j and city j–x we have

$$p_j(z)/p_{j-x}(z) = \exp[-t(D_j - D_{j-x})], \tag{5}$$

where $D_j - D_{j-x} > 0$ by our indexing convention. Since under perfect competition we have $p_j(z) = a(z)w_j$ and $p_{j-x}(z) = a(z)w_{j-x}$ for all goods produced by both cities, we have $p_j(z)/p_{j-x}(z) = w_j/w_{j-x}$ or

$$w_j = \exp[-t(D_j - D_{j-x})]w_{j-x}. \tag{6}$$

Because of this equation, the price ratio between cities for goods that are not traded by either city equals the price ratio between cities for goods that are exported by both cities. Indeed, city j–x will always be indifferent between producing a good itself and importing it from city j. But of course it will prefer to import from abroad when that is cheaper. Following this reasoning the reader will quickly see that the price prevailing in any trading city for all exportables and nontradeables of its country will equal the cost of production in that city:

$$p_j(z) = a(z)w_j, \text{ z an exportable or a nontradeable, j a trading city.} \tag{7}$$

Prices consumers must pay for a country's importables rise, the deeper we penetrate into the country:

$$p_j(z) = \exp[t(D_j - D_{j-x})]p_{j-x}(z), \text{ z an importable for both cities.} \tag{8}$$

This price gradient for importables makes substitution of local production for imports increasingly possible as we move away from the coast. As hinted in the introduction, this effect will become the basis for a functional relationship between comparative advantage and the volume of trade. For the time being, however, we will concern ourselves with another effect of this import price gradient: it causes population sizes for trading cities to decrease monotonically as we move inland.

The intuition behind this result is straightforward. Holding city size constant, the purchasing power of wages falls as one moves inland due to the increasing cost of importables. This causes a city to be a more desirable place of residence the closer it is to the coast. If we make the same assumption for <u>inter</u>city residence that we did for <u>intra</u>city residence, i.e., that in equilibrium economically identical individuals must be equally happy regardless of where they live, then intercity migration must expand city size further beyond the optimum, the closer is the city to the coast. In this situation no one has an incentive to change his city of residence, since if he moves to another city the prevailing utility level there must fall while the prevailing utility level in the city he left must rise.

By formalizing this intuition we will not only deepen our understanding of the city size gradient result but also lay the foundation for the proof that in this economy a positive relationship exists between comparative advantage and the volume of trade. We begin by referring to the expression for the logarithm of the representative individual's indirect utility given by equation (4). By rearranging this equation we can see that in city j we have

$$\log V_j = [\log w_j - \int_0^1 b(z)\log p_j(z)dz] + \log[(N - \tfrac{2}{3}\tau\sqrt{n_j/\pi})G(n_j)] + \int_0^1 b(z)\log b(z)dz. \qquad (4')$$

The first term in brackets in equation (4′) gives the logarithm of the purchasing power of wages for the representative individual in city j, holding the size of city j constant. We will now prove that this term declines monotonically as our city index j increases (as we move away from the coast).

Let us define S as the distance from the CBD of foreign city 0 to the CBD of home city 0, and let t_S be the coefficient of melting for "sea" transportation. Home city j will import good z from the foreign country if and only if

$$w_j a(z) > w_0^* a^*(z)\exp(t_S S + tD_j), \qquad (9)$$

where the asterisk denotes the foreign country. Substituting from equations (1) and (6), this condition becomes

$$A(z) < \omega\exp[-(t_S S + t2D_j)],$$

where $\omega = w_0/w_0^*$. Given ω,

$$A(z) = \omega\exp[-(t_S S + t2D_j)] \qquad (9')$$

determines a $\bar{z}_j$ above which home city j will import from the foreign country. The further is city j from the coast, the larger is $\bar{z}_j$.

Following the discussion so far we have $p_j(z) = a(z)w_j$, $z \leq \bar{z}_j$, and $p_j(z) = w_0^* a^*(z)\exp(t_S S + tD_j)$, $z > \bar{z}_j$. Substituting these results into our expression for the logarithm of the purchasing power of wages given n_j yields

$$\log w_j - \int_0^{\bar{z}_j} b(z)\log[a(z)w_j]dz - \int_{\bar{z}_j}^1 b(z)\log[w_0^* a^*(z)\exp(t_S S + tD_j)]dz \qquad (10)$$

or

$$\log w_j[1 - \int_0^{\bar{z}_j} b(z)dz] - \int_{\bar{z}_j}^1 b(z)\log[w_0^* a^*(z)\exp(t_S S + tD_j)]dz - \int_0^{\bar{z}_j} b(z)\log a(z)dz. \qquad (10')$$

As j increases these expressions will change because D_j increases, which in turn causes w_j to decrease by equation (6) and $\bar{z}_j$ to increase by equation (9′). We can see from the second term in expression (10′) (third term in expression (10)) that as D_j increases the prices of importables increase, holding w_j and $\bar{z}_j$ constant. We can also see from the first term in expression (10′) that as w_j falls wages become lower in terms of importables, holding the range of goods imported and their prices constant. Finally, as $\bar{z}_j$ increases the logarithm of the overall price index (given by the negative of the second and third terms in expression (10)) increases by equation (9), holding w_j and the prices of importables constant. In short, purchasing power declines as we move inland because 1) the wage rate falls in terms of a given set of importables with given prices (while staying constant in terms of nontradeables and exportables), and 2) the prices of importables increase, though the full increase caused by transportation costs is not passed through to consumers because of substitution of local production for some of the importables.

We have now shown that if population size is the same across all trading cities, the utility level of the representative individual in a city must rise the closer is that city to the coast. In order to attain spatial equilibrium, population sizes must adjust so that the second term in brackets in equation (4′) eliminates this utility differential. As we saw at the end of section I, given appropriate parameter values this term would reach a unique maximum at some optimum city size $\bar{n}$. Therefore this term declines as a city expands beyond $\bar{n}$, allowing free migration to the most desirable city to equate the utility of the representative individual across cities by (in effect) causing greater overcrowding, the closer is a city to the coast.[7]

We are now ready to construct the country map promised in the title of this section. It is possible to draw two different types of maps. In the first type, transportation costs are sufficiently high and total country population is sufficiently large that some cities will form very far inland that find it profitable to substitute local production for all imports. The purchasing power of wages holding city size constant is the same for these autarkic cities as can be seen by setting $\bar{z}_j = 1$ in expression (10′), so our city size gradient ceases its monotonic decline once we have moved far enough inland to reach these cities. In the second type of map there are no autarkic cities, i. e., $\bar{z}_j < 1$ for all j so that our country never produces some goods. (Within this subset of goods, of course, the relationship we are trying to establish between comparative advantage and the volume of trade will not hold.) The gradient of city sizes that emerges as a result of trade will then encompass all cities, so that the city furthest inland will be strictly smaller than the next–to–furthest city. Since the type of map under discussion has little effect on the analysis of the remainder of this paper, in the interest of brevity we will deal with the second, more realistic type only. This map is shown for the home country in figure I. (Of course an analogous map could be drawn for the foreign country.)

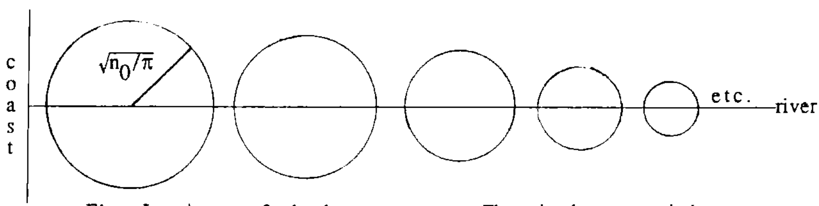

Fig. I. A map of the home country. The circles are cities.

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[7]Theoretically, there exists another equilibrium for any city where its size lies sufficiently below the optimum size $\bar{n}$ to just equate the utility of its representative individual with that prevailing in all other cities. This equilibrium is unstable, however, since if one person should migrate to this city its prevailing utility level would rise, causing a self–reinforcing flood of immigrants from all other cities, while if one person should leave this city its prevailing utility level would fall, causing a self–reinforcing flight of all its residents.

Now recall from the end of section I that in any city both the average residential rent and residential rents given distance from the CBD depend positively on the city's wage rate: the former is given by $\frac{1}{3}w_j\tau\sqrt{n_j/\pi}$ while the latter are given by $r_j(\ell) = w_j\tau(\sqrt{n_j/\pi} - \ell)$, where ℓ is distance from the CBD. Since the gradient of wage rates declining away from the coast given by equation (6) is matched by a city size gradient, it follows that residential rental rates (average or given distance from the CBD), wage rates and city sizes all decline monotonically as we move inland. It is worth noting that this prediction of a positive correlation between city size and residential rents is at odds with the standard prediction of models of wage and rent differentials based on differential amenities, where greater city population is considered to be a disamenity for which consumers have to be compensated in the form of higher wages and lower rents. We can check our prediction against recent United States data using a study by Beeson and Eberts (1987). From the Public Use Microdata Sample of the 1980 U. S. Census of Population they drew a subsample of individuals who lived and worked in the same Standard Metropolitan Statistical Area (SMSA) in 1980 and who changed addresses between 1975 and 1980. The subsample of recent movers was chosen because prices of more recently acquired or rented dwellings more accurately reflect current market conditions. The logarithms of weekly earnings and monthly housing expenditures were regressed on the relevant individual characteristics of workers and dwellings, respectively. The residuals from each regression were then averaged by SMSA in order to obtain quality–adjusted log wages and log rents for each city. Provided that the sample was selected at random with regard to distance from the CBD in each city, these quality–adjusted variables are appropriate for my theoretical model where all workers are homogeneous and all land within a city is homogeneous except for its distance from the CBD. Beeson and Eberts report quality–adjusted log wages and log rents for the 38 U. S. metropolitan areas for which 100 or more individuals in the sample were recorded as movers between 1975 and 1980. The correlation coefficients between the log of 1980 SMSA population and these two variables are .52 and .44, respectively. (The correlation coefficient between these two variables is .46.)

III. COMPARATIVE ADVANTAGE AND THE VOLUME OF TRADE

Since there is no intraindustry trade in our model, it does not matter whether we measure the volume of trade in any good by gross exports or imports or by net exports or imports. It is for convenience only, then, that we will choose net exports of the home country as our measure of the volume of trade.

The intuitive reason why our model generates a positive relationship between home country comparative advantage and the volume of its net exports was already indicated in the above proof that city sizes decline monotonically as one moves inland. We saw that the further inland was home city j, the smaller was the range of goods it imported—the higher was $\bar{z}_j$. From the foreign country's point of view, this means that the greater is its comparative advantage in a good (the higher is z), the deeper its exports will penetrate into the home country (the more home country cities will import the good). Since the same mechanism will work for home country exports to the foreign country, a positive relationship between the degree of home country comparative advantage in any good and its net exports of that good will result.

A more formal development of this argument will serve two purposes. First, it will help resolve some of the empirical issues mentioned in the introduction by providing a theoretical foundation for regressions of measures of the volume of trade on characteristics of goods indicating degree of comparative advantage. Second, we will be able to determine whether or not our model has a unique solution and thus whether it retains the usefulness for comparative static analysis that makes the continuum–of–goods formulation of the Ricardian model so valuable.

Following the discussion for home city j in section II, we can see that foreign city j will import a good from the home country if and only if

$$w_j^* a^*(z) > w_0 a(z) \exp(t_S S + t^* D_j^*), \tag{11}$$

or

$$A(z) > \omega \exp(t_S S + t^* 2D_j^*).$$

Given ω,

$$A(z) = \omega \exp(t_S S + t^* 2D_j^*) \qquad (11')$$

determines a $\bar{z}_j^*$ below which foreign city j will import from the home country. Clearly the further is city j from the coast the smaller is $\bar{z}_j^*$. By comparing equations (9′) and (11′), we can also see that $\bar{z}_0^* < \bar{z}_0$. Hence there is a range of nontraded goods given by $\bar{z}_0^* \le z \le \bar{z}_0$.[8]

Of course the volume of trade in any good will depend not only on how many cities import it but also on how much each city imports. This will in turn depend on the city's income, which needs to be adjusted for the labor hours lost due to commuting. (The reader can check that this procedure gives the same result for the city's income as does multiplying equation (3) by n_j.) The total labor employed in home city j is given by $n_jN - \int_0^{\sqrt{n_j/\pi}} 2\pi\ell\tau\ell d\ell = n_jN - \frac{2}{3}\pi\ell^3\tau|_0^{\sqrt{n_j/\pi}} = n_j(N - \frac{2}{3}\tau\sqrt{n_j/\pi})$. We can now write the volume of trade for any good z, given by the <u>value</u> of the home country's net exports, as

$$X(z) = -\Sigma_{j \text{ s.t. } z > \bar{z}_j} b(z)w_jn_j(N - \tfrac{2}{3}\tau\sqrt{n_j/\pi}) + \Sigma_{j \text{ s.t. } z < \bar{z}_j^*} b(z)w_j^*n_j^*(N^* - \tfrac{2}{3}\tau^*\sqrt{n_j^*/\pi}). \qquad (12)$$

The first term represents the value of our imports of z and the second term represents the value of our exports of z (equals the value of the foreign country's imports from us).

If we are to establish a relationship between comparative advantage and the volume of trade, we can immediately see the need, mentioned in the introduction to this paper, for <u>scaling</u> the trade variable to take account of the fact that some goods are desired more than others. This is best done by dividing equation (12) by the value of total world consumption of good z. Our scaled trade variable is then

$$T(z) = \frac{-\Sigma_{j \text{ s.t. } z > \bar{z}_j} w_jn_j(N - \tfrac{2}{3}\tau\sqrt{n_j/\pi}) + \Sigma_{j \text{ s.t. } z < \bar{z}_j^*} w_j^*n_j^*(N^* - \tfrac{2}{3}\tau^*\sqrt{n_j^*/\pi})}{\Sigma_{\text{all } j}\, w_jn_j(N - \tfrac{2}{3}\tau\sqrt{n_j/\pi}) + \Sigma_{\text{all } j}\, w_j^*n_j^*(N^* - \tfrac{2}{3}\tau^*\sqrt{n_j^*/\pi})}. \qquad (13)$$

T(z) varies with z <u>only as the number of cities that import good z varies</u>. The number of cities for which $z > \bar{z}_j$ ($z < \bar{z}_j^*$) in turn depends entirely on the comparative advantage function A(z)

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[8]This result also followed from the introduction of sea transport costs into the Dornbusch-Fischer-Samuelson model.

via equation (9′) (equation (11′)). The relationship between T(z) and A(z) is plotted in figure 2. The closer together the trading cities are and the smaller they are, the smoother will be the relationship because there will be narrower and shorter "steps". For the extreme goods (near 0 and 1) there is complete specialization (only one country produces them), so there is no relationship between T(z) and A(z) for these goods.

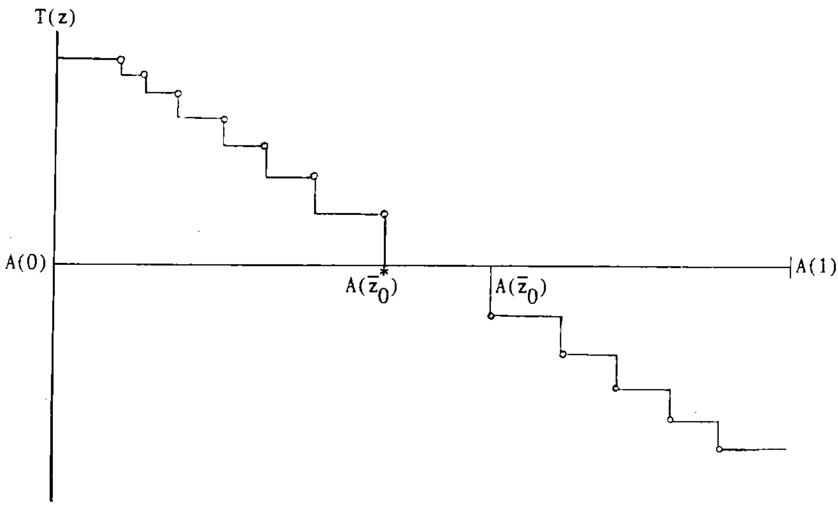

Fig. 2. Deflated home country net exports and comparative advantage.

We have now implicitly suggested two guidelines for empirical testing of trade models based on the theory of comparative advantage: 1) Use value rather than quantity data for net exports and 2) deflate the trade variable by value of world consumption. Both of these guidelines result from the fact that following them allows one to construct a trade variable whose variance depends <u>only</u> on the degree of comparative advantage, at least provided one assumes identical Cobb–Douglas preferences across countries. The reader can easily see that it would not have been possible to construct such a trade variable using quantity data because of the variance in the price of a good across cities and countries due to transportation costs.[9] It is also worth noting that A(z) is unobservable for the extreme goods, so the lack of a relationship between A(z) and T(z) for these goods is empirically irrelevant.

We turn now to the second purpose mentioned above for formal development of the relationship between comparative advantage and the volume of trade, which is to determine whether a unique solution (or any solution) to our model exists. To this end we close our model using the balanced trade condition

$$\Sigma_{\text{all } j}\, (1 - \lambda_j) w_j n_j (N - \tfrac{2}{3}\tau\sqrt{n_j/\pi}) = \Sigma_{\text{all } j}\, (1 - \lambda_j^*) w_j^* n_j^* (N^* - \tfrac{2}{3}\tau^* \sqrt{n_j^*/\pi}) \qquad (14)$$

where $\lambda_j = \int_0^{\bar{z}_j} b(z)dz$ and $\lambda_j^* = \int_{\bar{z}_j^*}^1 b(z)dz$, so that $1 - \lambda_j$ $(1 - \lambda_j^*)$ gives the proportion of home (foreign) city j's income that is spent on imports. Equation (14) states that the value of our imports equals the value of the foreign country's imports (equals the value of our exports). We can simplify this condition by substituting for w_j and w_j^* using equation (6) and its foreign counterpart:

$$w_0 \Sigma_{\text{all } j}\, (1 - \lambda_j)\exp(-tD_j) n_j (N - \tfrac{2}{3}\tau\sqrt{n_j/\pi}) = w_0^* \Sigma_{\text{all } j}\, (1 - \lambda_j^*)\exp(-t^* D_j^*) n_j^* (N^* - \tfrac{2}{3}\tau^* \sqrt{n_j^*/\pi})$$

or

$$\omega \Sigma_{\text{all } j}\, (1 - \lambda_j)\exp(-tD_j) n_j (N - \tfrac{2}{3}\tau\sqrt{n_j/\pi}) = \Sigma_{\text{all } j}\, (1 - \lambda_j^*)\exp(-t^* D_j^*) n_j^* (N^* - \tfrac{2}{3}\tau^* \sqrt{n_j^*/\pi}). \qquad (15)$$

We can note further that, from equations (9′) and (11′), we have

$$\bar{z}_j = A^{-1}(\omega\exp[-(t_S S + t2D_j)])$$

and

$$\bar{z}_j^* = A^{-1}(\omega\exp(t_S S + t^* 2D_j^*)),$$

where $(A^{-1})' < 0$. The question of existence of a (unique) solution to our model is thus reduced to the question of whether a (unique) ω exists that solves equation (15).

As ω increases it has a direct positive effect on the left–hand side of equation (15) that

[9] In the traditional model with zero transport costs the effect of price on the quantity–based volume of trade variable could be eliminated, but then of course the degree of comparative advantage would only determine the sign of this "variable" which would otherwise be identical for all goods.

reflects the effect of the change in relative incomes on home country demand for imports versus foreign country demand. It also has two indirect effects. First, $\bar{z}_j$ and $\bar{z}_j^*$ decrease for all j, increasing the range of goods imported by every home city and decreasing the range of goods imported by every foreign city. Second, in the home country the purchasing power of city's wages given its population size increases more, the greater the range of goods it imports (the closer it is to the coast) while in the foreign country this purchasing power decreases less, the smaller the range of goods it imports (the further it is from the coast). This is evident from the term $\log w_j[1 - \int_0^{\bar{z}_j} b(z)dz] = \log w_j(1 - \lambda_j)$ in expression (10′) (and the foreign counterpart to this term). Equation of utility across cities therefore causes population to be redistributed toward cities that import more in the home country and toward cities that import less in the foreign country. Thus all direct and indirect effects of the increase in ω work in the same direction: to increase the left–hand side of equation (15) and decrease the right–hand side. The right–hand side is therefore monotonically decreasing in ω while the left–hand side increases monotonically from 0 to ∞ as ω increases from 0 to ∞. It follows that there exists a unique ω that solves our model.

IV. SUMMARY AND CONCLUSIONS

This paper has developed a model where the direction of trade between countries in more than two commodities is determinate yet countries are incompletely specialized in production. The volume of trade in any good depends on the degree of comparative advantage in that good. In particular, if for each good in the model one deflates the value of a country's net exports by the value of world consumption, one obtains a variable which is an increasing function of that country's degree of comparative advantage. This suggests a procedure for constructing the dependent variable in empirical work when the volume of a country's trade is being regressed on characteristics of goods indicating its degree of comparative advantage. The model has a unique solution and can therefore be used for the same comparative static analyses as the Ricardian continuum–of–goods model that it generalizes.

The key difference between the model of this paper and standard international trade models is the existence of per–unit–distance transportation costs within a country. These costs, combined with the assumption that cities are the basic units of spatial organization in a country, lead the model to predict that population sizes, wage rates, and residential rental rates of cities will all decline monotonically as one moves inland from a coastal port. These new results are derived jointly with the relationship between comparative advantage and the volume of trade and thus add to the plausibility of the particular approach to establishing that relationship that is pursued here.

Two ways of extending the present work seem natural. One way is to enrich the trade side of the model, for example by using per–unit–distance transportation costs with another theory of comparative advantage such as the Heckscher–Ohlin theory. The other way is to enrich the spatial side of the model, for example by introducing land for agricultural production (which if the Ricardian properties of the model are to be preserved presumably requires allowance for Ricardo's "extensive [no–rent] margin"). The challenge is to enrich one side without reducing the interest that is held by the other.

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