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# Airplanes and Comparative Advantage

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Abstract

Airplanes are a fast but expensive means of shipping goods, a fact which has implications for comparative advantage. The paper develops a Ricardian three-country model with a continuum of goods which vary by weight and hence transport cost. Comparative advantage depends on relative air and surface transport costs across countries and goods, as well as stochastic productivity. In the model, countries that are far from their export markets will have low wages and tend to specialize in high value/weight products, which will be shipped on airplanes. Less remote exporters will have higher wages, and will tend to specialize in low value/weight products which will be sent by ship, train, or truck. These implications are confirmed using detailed data on U.S. imports from 1990 to 2003. Distance from the US and air shipment are associated with much higher import unit values.

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## 1 Introduction

Countries vary in their distances from each other, and traded goods have differing physical characteristics. As a consequence, the cost of shipping goods varies dramatically by type of good and the route that it is shipped. A moments reflection suggests that these facts are probably important for understanding international trade, yet they have been widely ignored by trade economists. In this paper I focus on one aspect of this set of facts, which is that airplanes are a fast but expensive means of shipping goods.

The fact that airplanes are fast and expensive means that they will be used for shipping only when timely delivery is valuable enough to outweigh the premium that must be paid for air shipment. They will also be used disproportionately for goods that are produced far from where they are sold, since the speed advantage of airplanes over surface transport is increasing in distance. In this paper I build a simple model that illustrates some implications of these observations for specialization and wages: remote countries will have lower wages, and will specialize in lightweight goods which are air shipped. Using a highly disaggregated database on all U.S. imports from 1990 to 2003, I show empirically that distance generally and airplanes in particular make a big difference in the composition of U.S imports.

There is a small, recent literature that looks at some of the issues that I analyze in this paper. Limao and Venables (2002) model the interaction between specialization and trade costs, illustrating how the equilibrium pattern of specialization involves a tradeoff between comparative costs and comparative transport costs. Deardorff (2004) elegantly shows how relative distance affects the trade pattern, arguing that local comparative advantage (defined as autarky prices in comparison to nearby countries rather than the world as a whole) is what matters in a world with trade costs. Evans and Harrigan (2005) develop a model of the demand for timeliness, and show how the pattern of US apparel imports is influenced by the interaction between relative distance and the relative value of timely delivery. Harrigan and Venables (2004) further develop microfoundations for the demand for timely delivery, and show how timeliness can lead to an incentive for agglomeration.

David Hummels has written a series of important empirical papers that directly motivated this paper, as well as motivating Evans and Harrigan (2005) and Harrigan and Venables (2004). Hummels (1999) shows that ocean freight rates have not fallen on average since World War 2, and have often risen for substantial periods. By contrast, the cost of air shipment has fallen dramatically. Figure 1 shows that these trends have continued since 1990, with the relative price of air shipping falling 40% between 1990 and 2004. Hummels (2001a) shows that shippers are willing to pay a large premium for faster delivery, a premium that has little to do with the interest cost of goods in transit[1]. Hummels (2001b) analyzes the geographical determinants of trade costs, and decomposes the negative effect of distance on trade into measured and unmeasured costs.

## 2 Airplanes and trade: theory

In the model there are three countries, *1, 2*, and *3*, which can be thought of as "United States", "Mexico" and "China". Country *1* has a large technological advantage in a homogeneous numeraire good, so in the equilibria that I examine it specializes in this good, which it produces with a unit labor requirement of one. With *1*'s wage as the numeraire, the FOB export price of *1*'s good is also one[2]. *1* consumes the numeraire and imports from *2* and *3*. Demand for the numeraire and imports comes from a Cobb-Douglas utility function with expenditure share $\alpha$ on total imports.

Countries *2* and *3* are identical except for distance from *1* and the size of their labor forces. Both countries produce $x$, which they don't consume, exporting all their output to *1*, and using the export revenues to buy the numeraire from *1*. Producers in *2* and *3* face a choice of shipping mode (air or surface). Air shipment is more costly, and depends on the weight of the product being shipped. Despite its cost, air shipment may be profitable because goods shipped by air can be sold for a premium over surface shipped goods. To formalize this tradeoff, let an index $z \in [0,1]$ order goods by increasing weight (and therefore increasing value/weight, though this will be endogenous): good 0 is the lightest (computer chips), while good 1 is the heaviest (oil). Surface shipping costs are the same for all goods, but airfreight iceberg costs $\omega(z) > 1$ are increasing in weight and, therefore, increasing in $z$: good 0 is the cheapest to send by air, while good 1 is the most expensive. Furthermore, the cost of air freight is the same regardless of where

[1] By "the interest cost of goods in transit", I mean the financial cost of having goods in transit before they can be sold. This opportunity cost equals the value of the good × daily interest rate × days in transit.

the flight originates, and to make the problem interesting assume

$$\omega(z) > \tau_3 > \tau_2 > 1 \text{ for all } z. \tag{1}$$

Why would anybody pay for airfreight? The answer is, consumers like speedy delivery for some reason, so that demand is higher for the same good when it is shipped by air. Some of the reasons for such a preference are analyzed by Evans and Harrigan (2005) and Harrigan and Venables (2004), but for the purposes of this model I will simply suppose that utility is higher for goods that arrive by air. Let the set of goods shipped by air be $A$, with measure also given by $A$. Subutility for imports is

$$U(x(z)) = \int_{z\in A} a \ln x(z)dz + \int_{z\notin A} \ln x(z)dz \tag{2}$$

where $a > 1$ is the air-freight preference. The resulting demand functions are generalizations of constant-expenditure-share Cobb-Douglas:

$$\begin{aligned} x(z) &= \frac{a}{aA+(1-A)} \cdot \frac{\alpha L_1}{\omega(z)p(z)} \qquad z \in A \\ x(z) &= \frac{1}{aA+(1-A)} \cdot \frac{\alpha L_1}{\tau p(z)} \qquad z \notin A \end{aligned} \tag{3}$$

The relevant prices are inclusive of transport costs, which will depend on where the good is produced and perhaps on weight.

Given these demands and the structure of transport costs, the next task is to determine the equilibrium location of production. Perfect competition ensures FOB price = unit cost, but there is a choice of shipping mode and consequent CIF price paid. When buying from location $c$, consumers are willing to pay for airfreight as long as the relative marginal utility from timely delivery exceeds the relative shipping cost, or

$$\frac{\omega(z)}{\tau_c} \leq a, \qquad c = 2, 3 \tag{4}$$

Since FOB production costs are the same, competition among sellers means that they will ship by air just in case this inequality is satisfied. I choose parameter values so that this never happens for country 2 and sometimes does for country 3:

[2] FOB stands for "free on board", and refers to the price of the good before transport costs are added. CIF stands for "cost, insurance, and freight", and refers to the price after transport costs

$$a\tau_2 < \omega(z) \qquad z \in [0,1]$$
$$a\tau_3 < \omega(z) \qquad z \in [\bar{z},1] \tag{5}$$
$$\omega(z) \le a\tau_3 \qquad z \in [0,\bar{z}]$$

The cutoff $\bar{z}$ is an endogenous variable which is determined by the relative cost of air and surface shipping in country 3 only, given implicitly by

$$a\tau_3 = \omega(\bar{z}), \tag{6}$$

and its determination is illustrated in Figure **2**. Goods $z \in [\bar{z},1]$ will never be shipped by air, regardless of where they are produced, and I call these goods heavy. Light goods, $z \in [0,\bar{z}]$, will be shipped by air if they are produced in *3*, otherwise they will be shipped by surface from *2*. The boundary between heavy and light goods will change when surface or air transport costs change, but it does not depend on comparative cost advantage, since it reflects only the decision facing a producer in one country.

Production location and shipping mode are determined jointly. Define relative surface transport costs, relative wages, and relative unit labor requirements respectively as

$$w \equiv \frac{w_2}{w_3}, \quad \tau \equiv \frac{\tau_2}{\tau_3}, \quad b(z) = \frac{b_2(z)}{b_3(z)} \tag{7}$$

For heavy goods, consumers in *1* buy from the lowest cost source, where costs are inclusive of wages and transport costs. Therefore, goods are produced in *2* if and only if

$$\tau_2 b_2(z) w_2 \le \tau_3 b_3(z) w_3$$

or

$$\tau w b(z) \le 1 \qquad z \in [\bar{z},1]. \tag{8}$$

For light goods, we know that if they are produced in *3* they'll be shipped by air, so the relevant cost comparison is between surface in *2* and air in *3*. But production cost is not the only consideration, since consumers are willing to pay more for goods shipped by air. The relevant cost comparison needs to be adjusted for this, and becomes

$$\tau_2 b_2(z) w_2 \le \frac{\omega(z) b_3(z) w_3}{a} \qquad z \in [0,\bar{z}]$$

so production takes place in *2* if and only if

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have been added.

$$\frac{\tau_2 wb(z)}{\omega(z)} \leq \frac{1}{a} \qquad z \in \left[0, \bar{z}\right] \tag{9}$$

These inequalities define the sets of heavy and light goods produced in each country:

$$z_2^H = \left\{ z \in \left[\bar{z}, 1\right] \mid \tau wb\left(z\right) \leq 1 \right\}, \quad z_3^H = \left\{ z \in \left[\bar{z}, 1\right] \mid \tau wb\left(z\right) > 1 \right\}$$

$$z_2^L = \left\{ z \in \left[0, \bar{z}\right] \mid wb\left(z\right) \leq \frac{\omega(z)}{\tau_2 a} \right\}, \quad z_3^L = \left\{ z \in \left[0, \bar{z}\right] \mid wb\left(z\right) > \frac{\omega(z)}{\tau_2 a} \right\} \tag{10}$$

Obviously, the set of goods produced in each country is the union of light and heavy goods produced there. Note also that light goods produced in *3* are air shipped, so $z_3^L = A$. In an abuse of notation, let the labels of these sets also denote their measure, so

$$z_2^H + z_3^H = 1 - \bar{z} \qquad z_2^L + z_3^L = \bar{z}$$

$$z_2^H + z_2^L = z_2 \qquad z_3^H + z_3^L = 1 - z_2 \tag{11}$$

I will treat labor productivity in good *z* as a random variable, and I adopt the modeling strategy of Eaton and Kortum (2002). I simplify the Eaton-Kortum framework by focusing on just two countries that have identical distributions of labor productivity (the inverse of the unit labor requirement) drawn from a Fréchet distribution with parameters $T > 0$ and $\theta > 1$. With this distribution, the log of productivity has mean $\frac{\gamma + \log T}{\theta}$ and standard deviation $\frac{\pi}{\theta\sqrt{6}}$, so that smaller values of $\theta$ imply greater dispersion in productivity[3].

With random productivity, the low-cost producer is probabilistic. Adapting Eaton and Kortum's equation (8) for my purposes gives a particularly simple expression for the probability that country 2 is the supplier of heavy good *z*:

$$\pi_2^H(z) = \pi_2^H = \frac{\left(w_2\tau_2\right)^{-\theta}}{\left(w_2\tau_2\right)^{-\theta} + \left(w_3\tau_3\right)^{-\theta}} = \frac{1}{1 + \left(w\tau\right)^{\theta}} \qquad z \in \left[\bar{z}, 1\right] \tag{12}$$

This expression is quite intuitive: the probability that country 2 will supply any given heavy goods is decreasing in 2's relative wages and transport costs. The problem is slightly more complex for lightweight goods for two reasons. The first is that country 3's optimal shipping mode for lightweight goods is air, and the transport cost for these goods depends on weight. The second is that consumers in 1 are willing to pay a premium $a > 1$ for goods shipped by air. Using equation (9) with the Fréchet distribution for productivities implies that the probability that country 2 is the supplier of light good $z$ is

$$\pi_2^L(z) = \frac{(\tau_2 w_2)^{-\theta}}{(\tau_2 w_2)^{-\theta} + \left(\frac{\omega(z) w_3}{a}\right)^{-\theta}} = \frac{1}{1 + (w\tau)^{\theta}\left(\frac{a\tau_3}{\omega(z)}\right)^{\theta}} \qquad z \in [0, \bar{z}) \tag{13}$$

The term $\left(\frac{a\tau_3}{\omega(z)}\right)^{\theta}$ in equation (13) is strictly greater than one, which implies $\pi_2^L(z) < \pi_2^H$ for all $z \in [0, \bar{z})$. This result says that country *2* has a greater chance of supplying heavy goods than lightweight goods, and the lighter the good the lower the chance that *2* will be the supplier. The law of large numbers implies that for any interval of goods the average probability will be the share of goods supplied by country 2, so I'll refer to the $\pi$'s from now on as market shares. The market shares for country 3 are of course just one minus the shares for country 2:

$$\pi_3^H = \frac{1}{1 + (w\tau)^{-\theta}}, \qquad \pi_3^L(z) = \frac{1}{1 + (w\tau)^{-\theta}\left(\frac{a\tau_3}{\omega(z)}\right)^{-\theta}} \tag{14}$$

Figure **3** illustrates equations (12) and (13). Country *2*'s market share is increasing in the weight of the good $\omega(z)$ for all $z \in [0, \bar{z})$. In this range, if a good is supplied by country *2* it is sent by surface at a cost of $\tau_2$ while if it is supplied by *3* it is sent by air at a cost of $\omega(z)$. For heavy goods $z \geq \bar{z}$, both countries use surface transport, and country *2* has a transport cost advantage since $\tau_3 > \tau_2$. Equation (12) implies that if wages are the same, country *2* will have a greater than 50% market share in heavy goods, but that within heavy goods *2*'s market share is constant.

To close the model I make wages endogenous. Factor market clearing requires that FOB export revenue equals national income in country *2* and *3*. For both countries, FOB revenue from good $z$ is the probability that it produces the good times country 1's CIF expenditure on that

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[3] In terms of the Eaton-Kortum model, I assume that both countries have the same comparative advantage parameter $T_c$. The constants are $\gamma = 0.577...$ and $\pi = 3.14159....$ See Eaton and Kortum

good, divided by the iceberg transport cost. Expenditure levels for good $z$ are found by multiplying equations (3) by $p(z)$. Total expenditure on light goods is then the integral of expenditure on each good over the range $\left[0,\bar{z}\right)$, and expenditure on heavy goods is the integral over the range $\left[\bar{z},1\right]$. Using these expenditure levels and the probabilities from (12) and (13), the factor market clearing condition for country 2 becomes

$$w_2L_2 = \frac{\alpha L_1}{aA+(1-A)}\left[\int_0^{\bar{z}}\frac{\pi_2^L(z)}{\tau_2}dz + \int_{\bar{z}}^1\frac{\pi_2^H}{\tau_2}dz\right]$$

$$= \frac{\alpha L_1}{aA+(1-A)}\left[\frac{1}{\tau_2}\int_0^{\bar{z}}\frac{1}{1+(w\tau)^{\theta}\left(\dfrac{a\tau_3}{\omega(z)}\right)^{\theta}}dz + \frac{1}{\tau_2}\frac{1-\bar{z}}{1+(w\tau)^{\theta}}\right] \tag{15}$$

Similarly for country 3, export revenue is the sum of FOB revenue from air- and surface-shipped goods:

$$w_3L_3 = \frac{\alpha L_1}{aA+(1-A)}\left[a\int_0^{\bar{z}}\frac{\pi_3^L(z)}{\omega(z)}dz + \int_{\bar{z}}^1\frac{\pi_3^H}{\tau_3}dz\right]$$

$$= \frac{\alpha L_1}{aA+(1-A)}\left[a\int_0^{\bar{z}}\frac{\omega(z)^{-1}}{1+(w\tau)^{-\theta}\left(\dfrac{a\tau_3}{\omega(z)}\right)^{-\theta}}dz + \frac{1}{\tau_3}\frac{(1-\bar{z})}{1+(w\tau)^{-\theta}}\right] \tag{16}$$

The market clearing equations (15) and (16) along with equation (6) that defines $\bar{z}$ are three equations in the three unknowns $w_2$, $w_3$, and $\bar{z}$. With a solution to these three equations, the other endogenous variables of the model (national income and trade flows) are obtained by substitution.

The three equation system given by equations (6), (15) and (16) is highly nonlinear but fairly simple economically. Intuitive results can be obtained by using a convenient functional form for $\omega(z)$,

$$\omega(z) = \beta\tau_3 a^{1+z} \tag{17}$$

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(2002) for more on the Fréchet distribution and its interpretation.

where the shift parameter $\beta$ has a range of $[a^{-1}, 1]$[4]. Recall that the condition for airfreight to be profitable for country 3 in good $z$ is $\omega(z) \leq a\tau_3$. For low values of $\beta$ air freight is always profitable for country 3,

$$\beta = a^{-1} \rightarrow \qquad \omega(0) = \tau_3 \qquad \omega(1) = a\tau_3$$

while for high values it is never profitable:

$$\beta = 1 \rightarrow \qquad \omega(0) = a\tau_3 \qquad \omega(1) = a^2\tau_3$$

Substituting (17) into (6) gives the solution for $\bar{z}$ :

$$\bar{z} = -\frac{\log \beta}{\log a} \in [0,1]$$

By varying $\beta$ I can do comparative statics on the model's equilibrium. Finding an analytical solution for equilibrium wages is impossible, as the integrals in (15) and (16) can not be evaluated analytically. Consequently, I solve the model for a numerical example (details of the computations are in the Appendix).

As noted in the introduction, the long-term trend is for air transport costs to decline relative to the cost of surface shipping (Figure 1). I model this as a proportionate shift down in the cost of air transport $\omega(z)$. Figure **4** shows that falling air transport costs expand the range of goods which are potentially shipped by air. The increase in $\bar{z}$ creates excess supply for country 2's labor, as some goods formerly produced in 2 are now profitable to produce in 3 and send by air. In the new equilibrium relative wages in 2 decline, and the resulting effects on market shares are illustrated in Figure **5**. Country 2 increases its market share in all heavy goods, where 2's now-lower wage improves its competitiveness, and loses market share in light goods, where the lower cost of air shipping more than offsets the drop in 2's wages.

Equilibrium wages as a function of the cost of air shipment are illustrated in Figure **6**. The figure is normalized so that wages in 2 are equal to one at $\beta = 1$, where air freight is prohibitively expensive even for the lightest goods. As expected, a fall in air freight costs (declining $\beta$) lowers the wage of 2 in both absolute and relative terms. Surprisingly, the initial effect of a decline in air freight costs on $w_3$ is negative. This is an instance of immiserizing technological improvement: the increased supply of goods from 3 lowers their price by more

[4] A further parameter restriction for this functional form is $\tau_3 > a\tau_2$, which guarantees that airfreight is never profitable for country 2.

than the improvement in technology. As technology improves further, this terms of trade effect is outweighed by the efficiency gain on inframarginal goods, so $w_3$ increases. This result is partly an artifact of the assumption of Cobb-Douglas expenditure by country 1, and with a more elastic aggregate demand for imports the negative terms of trade effect of technological improvement would diminish.

Whatever the effect on the absolute level of wages in 3, lower air freight costs inevitably lower wages in 2. This happens because 2 faces greater competition from 3 but has no use for the improved air shipping technology. The unambiguous winner is country 1, which gets lower prices on all its imports from 2 and gets a wider range of air shipped goods from 3. In the case where $w_3$ actually falls, country 1 gets more than 100% of the global welfare gain from improved technology: 1 gets both lower prices on all the goods it imports by surface and a wider selection of air shipped goods.

**2.4 The model's prediction for trade data**

For any given level of wages, the model delivers predictions about the cross-section of goods imported by 1, and it is these predictions which will be the focus of the empirical analysis. The first prediction has already been illustrated in Figure **3** : country 2 will have lower market share in light-weight goods, and these light goods will be shipped by air when produced by 3. More generally, the message of the model is that nearby countries will specialize in heavy goods and faraway countries will specialize in light goods.

In the model all non-weight-related determinants of specialization are treated as random. This is a useful modeling device but ignores what is known about the systematic influence of factor endowments, development, country size, industry-level technology differences, etc on comparative advantage. A transparent example is oil: the reason that Mexico exports oil to the US and Japan does not has nothing to do with the fact that oil is heavy. In taking the model to the data other determinants of specialization must be taken into account, at least statistically. The prediction of the theory then acquires a *ceteris paribus* clause: all other things equal, nearby countries will specialize in heavy goods.

Most import records report quantities as well as FOB values, which makes it possible to construct unit values, defined as the dollar value of imports per physical unit. Since shipping costs depend primarily on the physical characteristics of the good rather than on its value, low value goods will be "heavy" in the sense of having a higher shipping cost per unit of value[5]. For example, consider shoes. Quantities of shoes are reported in import data, and the units are "number" as in "number of shoes". Expensive leather shoes from Italy and cheap canvas sneakers from China weigh about the same, but the former will have a much higher unit value. In the context of the model, Italian leather shoes are "lighter" than Chinese fabric sneakers, in the economically relevant sense that the former have lower transport costs as a share of value. The model's prediction can then be translated into a prediction about unit values: within a given product category, nearby countries will tend to specialize in low-value goods. High-value goods will tend to be produced in more distant locations and will be shipped by air.

**3 Airplanes and trade: empirical evidence**

The data used in this paper are derived from detailed import statistics collected by the U.S. Customs Service and reported on CD-ROM. For each year from 1990, the raw data includes information on the value, quantity (usually number or kilograms), and weight (usually in kilograms) of U.S. imports from all sources. The data also include information on transport mode and fees, including total transport charges broken down by air, vessel and (implicitly) other, plus the quantity of imports that come in by air, sea, and (implicitly) land.[6]

The data are reported at the 10-digit Harmonized System (HS) level, which consists of almost 17,000 separate categories in 2003. I aggregate this data for analysis in various ways. For most of the descriptive charts and tables, I work with a broad aggregation scheme that updates Leamer's (1984) classification, which is reported in Table 1. For the regression analysis, I work with the 6-digit HS categories, of which there were over 14,000 in 2003.

The unit value of imports is defined as the value of imports divide by the physical quantity. The units measuring physical quantity vary by commodity, with the most common being "number" (as in, number of cars) and kilograms (as in, kilograms of steel). For the majority of records, there are two units reported, the first often number and the second invariably weight; this makes it possible to distinguish between unit value and value to weight for a particular import value.

[5] The relationship between shipping cost and shipment value is estimated by Hummels and Skiba (2004), Table 1. They find that shipping costs increase less than proportionately with price.

### 3.1 Data description

Table 1 illustrates the great heterogeneity in the prevalence of air freight, as well as some important changes over the sample. Many products come entirely or nearly entirely by surface transport (oil, iron and steel, road vehicles) while others come primarily by air (computers, telecommunications equipment, cameras, medicine). Scanning the list of products and their associated air shipment shares hints at the importance of value to weight and the demand for timely delivery in determining shipment mode.

Charts 1 to 10 illustrate the variation in air freight across regions and goods (the regional aggregates are defined in Table 2, while the product aggregates correspond to the headings in Table 1). Chart 1 shows that the about a quarter of US (non-oil) imports arrived by air in 2003, up from 20% in 1990 (for brevity, in what follows I'll call the proportion of imports that arrive by air "air share"). Chart 2 shows that this average conceals great regional variation, which is related to distance: essentially no imports come by air from Mexico and Canada, while Europe's air share is almost half by 2003, up from under 40% in 1990. East Asia's air share increased by about half from over the sample, from 20 to 30%. The airshare from the Caribbean and South America was about one-fifth over the sample. Chart 3 shows that air shipment is concentrated in manufactured goods, particularly labor-intensive manufactures and machinery (as Table 1 shows, the capital-intensive aggregate is mainly steel and other metals, which are very heavy). The biggest increase in air share came in chemicals, which (as Table 1 reveals) is accounted for by the increasing importance of pharmaceuticals, which had an 80% air share in 2003.

The remaining Charts 4 through 10 show the evolution of air share by major regions and product aggregates. The most notable fact about Chart 4 is the sharp increase in machinery's air share from East Asia, to levels similar to Europe's by 2003 (Chart 5). Western and South Asia (which is mainly the Indian subcontinent), shows a puzzling drop in the air share for labor intensive manufactures, a drop also seen in the Caribbean (Chart 7). This may have to do with the phenomenon documented by Evans and Harrigan (2005): as apparel production moved to Mexico during the 1990s, the shift was concentrated in goods where timely delivery is important. Essentially, U.S. apparel retailers who wanted timely delivery replaced air shipments from South Asia and the Caribbean for surface shipments from next-door Mexico.

[6] "other" transport modes include truck and rail, and are used exclusively on imports from Mexico and Canada.

Heavy capital-intensive goods have not shown any increase in air-share from any source since 1990 (Chart 8), but lighter machinery imports became increasingly air shipped from East Asia (Chart 9). Finally, the shift toward air shipment in chemicals from major suppliers was world-wide, with the obvious exception of NAFTA (Chart 10).

Chart 11 shows import-weighted average transport charges for total imports and for air shipped imports. There has not been much of a change in these numbers over the sample period, with overall transport charges equal to about 5% of import value and air charges about 10%. But as Hummels (2001b) emphasizes, these averages underestimate the true level of transport charges facing importers, since they reflect a cost-minimizing equilibrium. Tables 3 and 4 illustrate how weighted average transport costs vary by region and product category. Not surprisingly, the products that have the highest air share, Machinery and Chemicals, have the lowest air freight costs. In some of the categories, the average transport cost is lower for air than overall, which of course reflects selection: very low value/weight items, which cost a lot to move even by ship, don't get put on planes.

### 3.2 Statistical results

The theory model of section 2 makes a number of predictions. The one I focus on here concerns the price of imports across source countries: the model predicts that imports from faraway countries will weigh less, and will have higher f.o.b. prices, than goods shipped from nearby countries. Statistically, I investigate this by looking at variation in unit values across exporters within 10-digit HS categories. The econometric model I use is

$$v_{ict} = \alpha_{it} + \beta_t d_c + other\ controls + residual \qquad (18)$$

where

$v_{ict}$ = log unit value of imports of product $i$ from country $c$ in year $t$

$\alpha_{it}$ = fixed effect for 10-digit HS code $i$ in year $t$

$d_c$ = distance of $c$ from United States

Note that import values are measured f.o.b, so they do not include transport charges. The model predicts $\beta_t > 0$ in equation (18): across exporters within a 10-digit commodity category, more distant exporters will sell products with higher unit values, controlling for other observable country-specific factors which might affect unit values. When the units are kilograms, then the prediction for unit values is a prediction about the value-weight ratio.

In the model, the effect of distance on unit values comes through a sorting effect which leads to higher-valued goods being produced at greater distance and then shipped by air. To test for the direct effect of air shipment on unit values, I estimate the model

$$v_{ict} = \alpha_{it} + \beta_{1t} a_{ict} + \beta_{2t} d_c + other\ controls + residual \qquad (19)$$

where

$a_{ict}$ = share of imports of $i$ from $c$ that came by air in $t$.

Strictly speaking, the model predicts $\beta_{1t} = 0$ and $\beta_{2t} > 0$ in equation (19): controlling for transport mode, distance should have no further effect on unit values. But if non-air transport costs per unit are increasing in distance (as they are in the world, though not in the model), then the sorting effect of distance will be operative for all goods, whether air-shipped or not, and $\beta_{1t} > 0$ in equation (19) would be expected.

I measure distance by five indicator variables:

1. adjacent to the US (Mexico and Canada).
2. between 1 and 4,000 kilometers (Caribbean islands and the northern coast of South America).
3. between 4,000km and 7,800km (Europe west of Russia, most of South America, a few countries on the West Coast of Africa)
4. between 7,800km and 14,000km (most of Asia and Africa, the Middle East, and, Argentina/Chile)
5. over 14,000km (Australia/New Zealand, Thailand, Indonesia, Malaysia/Singapore)

In some of the regressions, I aggregate the distance classes into near (less than 4,000km ) and far. I also include a dummy for if a country is landlocked.

There are many other factors that could affect unit values, and I control for some of these. *Other controls* include

1. trade cost variables (shipping cost and tariff, both measured as *ad valorem* percentages), which should have negative signs to the extent that trade costs are passed on to consumers.
2. macro indicators of comparative advantage (log aggregate real GDP per worker and log overall price level, both measured relative to the US, from the Penn-World Tables). My model is silent on how these aggregate measures might affect prices, but if more advanced countries specialize in more advanced and/or higher quality goods, we would expect positive effects of these variables on log unit values. Evidence of such effects is reported by Schott

(2004) and Hummels and Klenow (2005).

Tables 5 and 6 report the results of estimating equation (18). For each year, log unit value is regressed on the controls as well as fixed effects for 10-digit HS codes. Each column shows results for a single year's regression, with *t*-statistics in *italics*. Table 5 takes a broad definition of unit value, and includes all observations for which units are reported, whether those units are number, barrels, dozens, kilos, or something else. Differences in units across 10-digit codes are controlled for by the 10-digit fixed effects. Table 6 includes only observations for which weight in kilos is reported, so the unit value in the Table 6 regressions is precisely the value-weight ratio for all of the observations. In the interest of reducing the quantity of numbers presented, I report results for only four selected years (1990, 1995, 2000, and 2003), although all regressions were estimated on all 14 years from 1990 to 2003 (complete results available on request).

Tables 5 and 6 show that the effect of distance on unit values is large, robust, and statistically significant. The first four columns of Tables 5 and 6 have a single indicator for distance greater than 4000km from the United States. As the first row of Table 5 shows, for the full sample unit values are between 19 and 37 percent higher when they come from more distant locations. The effect is even larger when the sample is restricted to observations with units in kilos, with the distance effect between 35 and 51 percent (first row, Table 6). The second four columns of Tables 5 and 6 break down distance into a larger number of categories, with Mexico/Canada as the excluded category. The effect of being less than 4000km but not adjacent to the US is positive and significant in each year in Table 5, and for all but one year in Table 6, but the effect is fairly small, at between 7 and 30 percent for the full sample and between -15 and 9 percent in the restricted sample. The effect of being more than 4000km from the US is much larger, though it is not monotonic in distance, with larger effects in the 4000-7800km range than in more distant categories. The additional effect of being landlocked is also large, ranging between 15 and 40 percent across specifications in Tables 5 and 6.

The non-monotonicity of the distance effect on unit values probably reflects imperfectly measured country characteristics that are correlated with distance, since the 4000-7800 range includes many of the most developed countries. The importance of development in affecting unit values was found in Schott (2004) and Hummels and Klenow (2005), and is confirmed here: a higher aggregate price level (which is associated with development) raises unit values with a large and significant elasticity, between 0.4 and 0.8, in every regression in Tables 5 and 6. The effect of aggregate productivity is inconsistent across specifications, but this merely reflects the very high correlation between aggregate productivity and price level.

Although the tariff and transport cost effects are not the focus of the paper, it is interesting that they are consistently estimated to be small, negative and mostly statistically significant (ranging from 0 to -0.016 across specifications). These negative effects are consistent with the US being a large market for most exporters, and are suggestive of a terms of trade gain from protection.

Tables 7 and 8 report the results of estimating equation (19), which is the same specification as in equation (18) but with air share included as an explanatory variable. Airshare is measured as a continuous variable, but almost all the observations on 10-digit codes are either zero or one, so it is very close to a dummy variable for air shipment. The coefficient on air share is large and statistically significant in every specification, ranging between 1.06 and 1.6. This implies very large price effects, ranging between 290 and 500 percent. As expected, the distance effect is much smaller when directly controlling for airshare, but is still generally positive and statistically significant for distances greater than 4000km. This suggests that the sorting mechanism of the model operates for surface-shipped as well as air-shipped goods, though the air shipment sorting effect is more powerful.

## 4 Conclusion

This paper has focused on the interaction between trade, distance, product characteristics, and the choice of shipping mode. In the theory model, I showed how the existence of airplanes implies that distant countries have a comparative advantage in lightweight goods. In the empirical section, I documented the heterogeneity across regions and goods of the prevalence of air shipment in US imports. The statistical analysis uncovered a large and robust relationship between distance and unit values: U.S. imports from remote suppliers have unit values on the order of a third higher than those from nearby countries. Goods which are shipped by airfreight have unit values that are much higher than those shipped by surface, even after controlling for distance.

## References


Deardorff, Alan, 2004, "Local Comparative Advantage: Trade Costs and the Pattern of Trade", http://www.econ.lsa.umich.edu/~alandear/writings/

Eaton, Jonathan and Samuel Kortum, 2002, "Technology, Geography, and Trade", *Econometrica 70*(5): 1741-1779 (September).

Evans, Carolyn E., and James Harrigan, 2005, "Distance, Time, and Specialization: Lean Retailing in General Equilibrium", forthcoming, *American Economic Review*.

Harrigan, James, and A.J. Venables, 2004, "Timeliness, Trade, and Agglomeration", NBER Working Paper 10404.

Hummels, David, 1999, "Have International Transportation Costs Declined?", http://www.mgmt.purdue.edu/faculty/hummelsd/

Hummels, David, 2001a, "Time as a Trade Barrier", http://www.mgmt.purdue.edu/faculty/hummelsd/

Hummels, David, 2001b, "Toward a Geography of Trade Costs", http://www.mgmt.purdue.edu/faculty/hummelsd/

Hummels, David, and Alexandre Skiba, 2004, "Shipping the Good Apples Out? An Empirical Confirmation of the Alchian-Allen Conjecture", *Journal of Political Economy 112(6)*: 1384-1402 (December).

Hummels, David, and Peter Klenow, 2005, "The Variety and Quality of a Nation's Exports", forthcoming, *American Economic Review*.

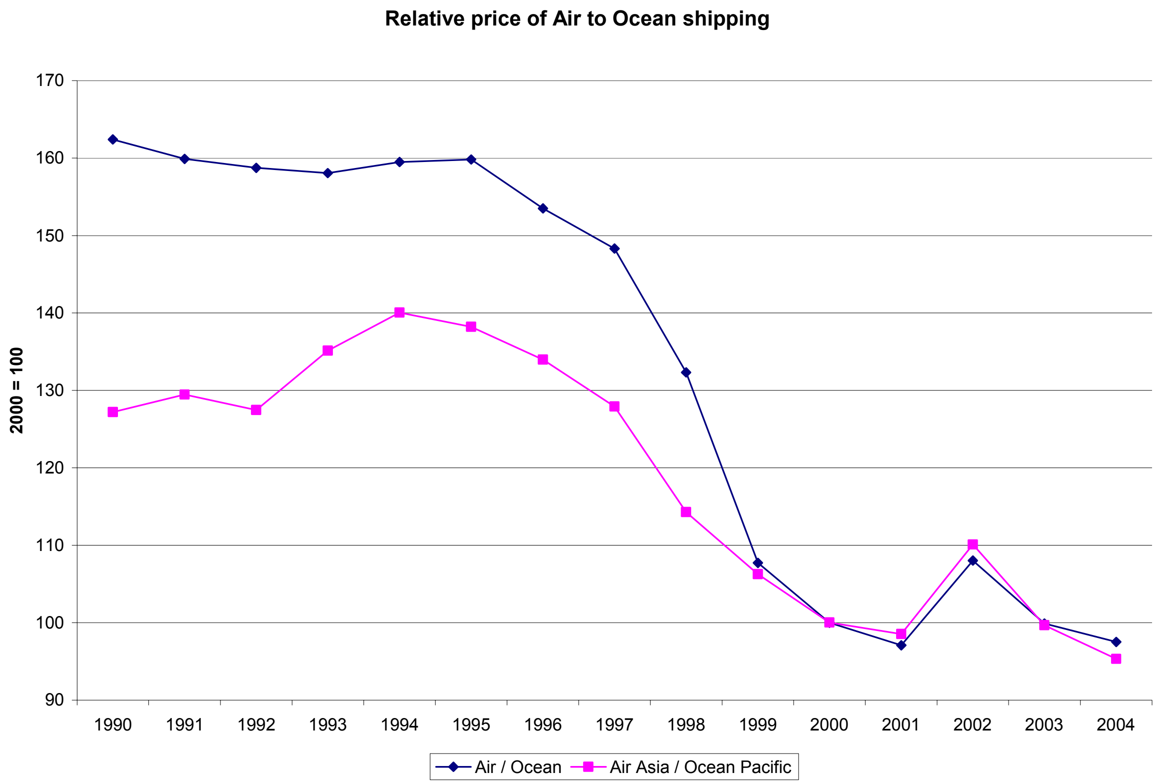
Leamer, Edward, 1984, *Sources of International Comparative Advantage*, Cambridge, MA: MIT Press.

Limão, Nuno, and A.J. Venables, 2002, "Geographical Disadvantage: a Hecksher-Ohlin-Von-Thunen Model of International Specialisation," *Journal of International Economics* 58(2): 239-63 (December).

Redding, Stephen, and A.J. Venables, 2004, "Economic Geography and International Inequality", *Journal of International Economics 62(1)*: 53-82.

Schott, Peter K., 2004, "Across-product versus within-product specialization in international trade", *Quarterly Journal of Economics119(2):*647-678 (May).

**Figure 1**




Notes to Figure 1: Data are price indices for U.S. imports of air freight and ocean liner shipping services from the Bureau of Labor Statistics, www.bls.gov/mxp. The "Air/Ocean" series divides all US imports of air freight services by all imports of ocean liner services, while the "Air Asia / Ocean Pacific" series divides the index for air freight imports from Asia by the index for ocean liner imports from the Pacific region.

**Figure 2 - the air shipping decision**

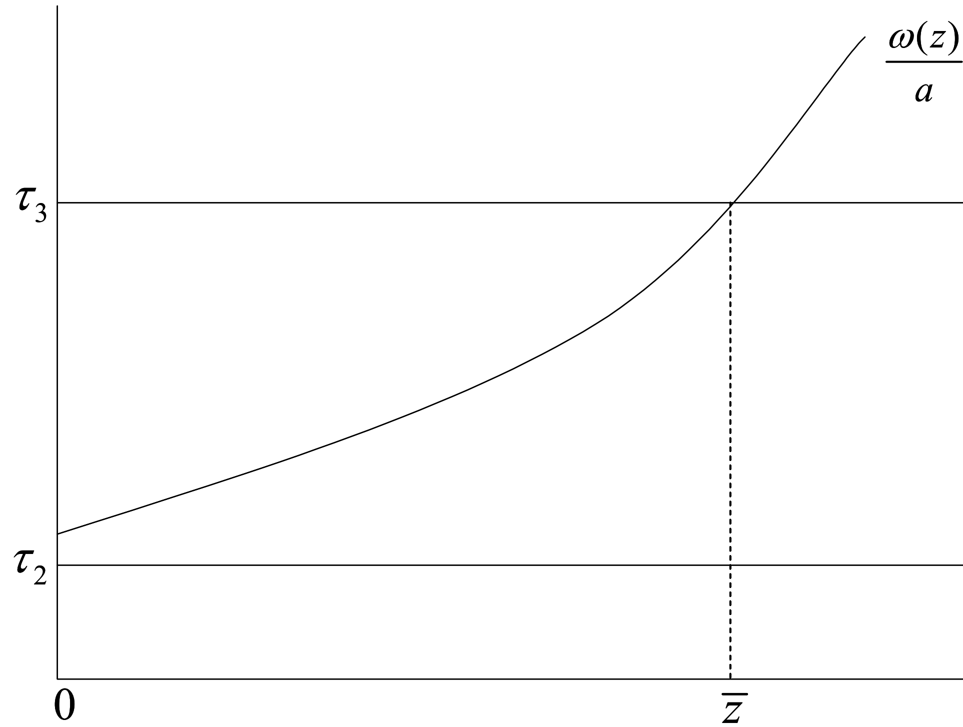



**Figure 3 - Market shares for country 2**

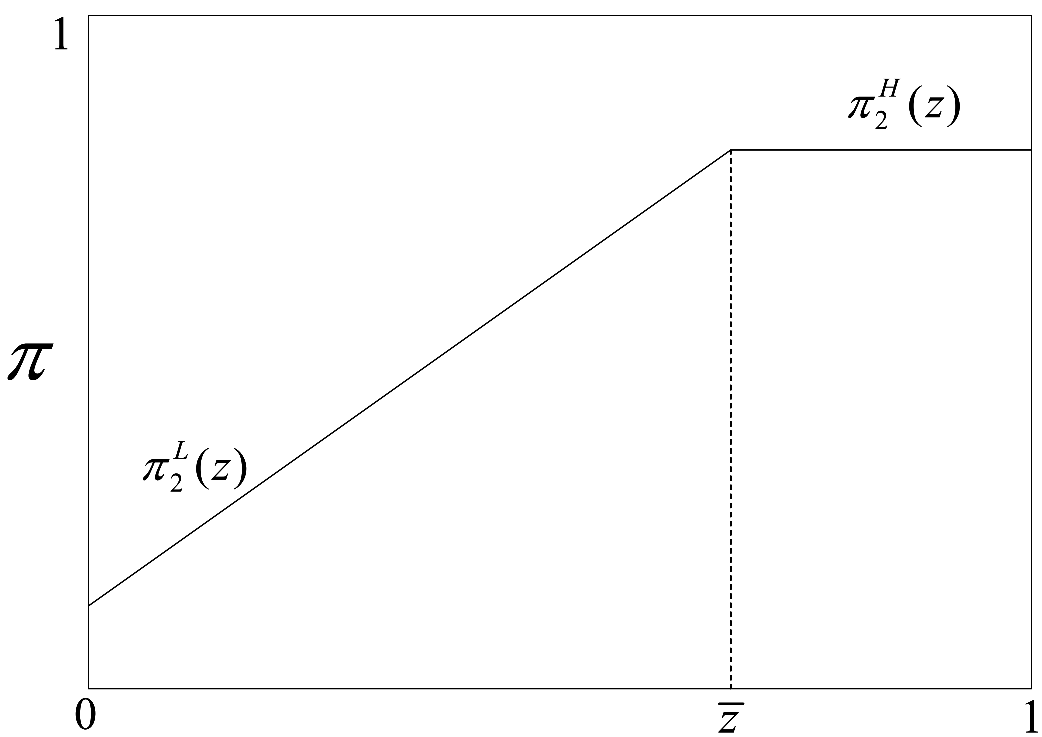


**Figure 4 - Change in $\bar{z}$ when air freight costs fall**

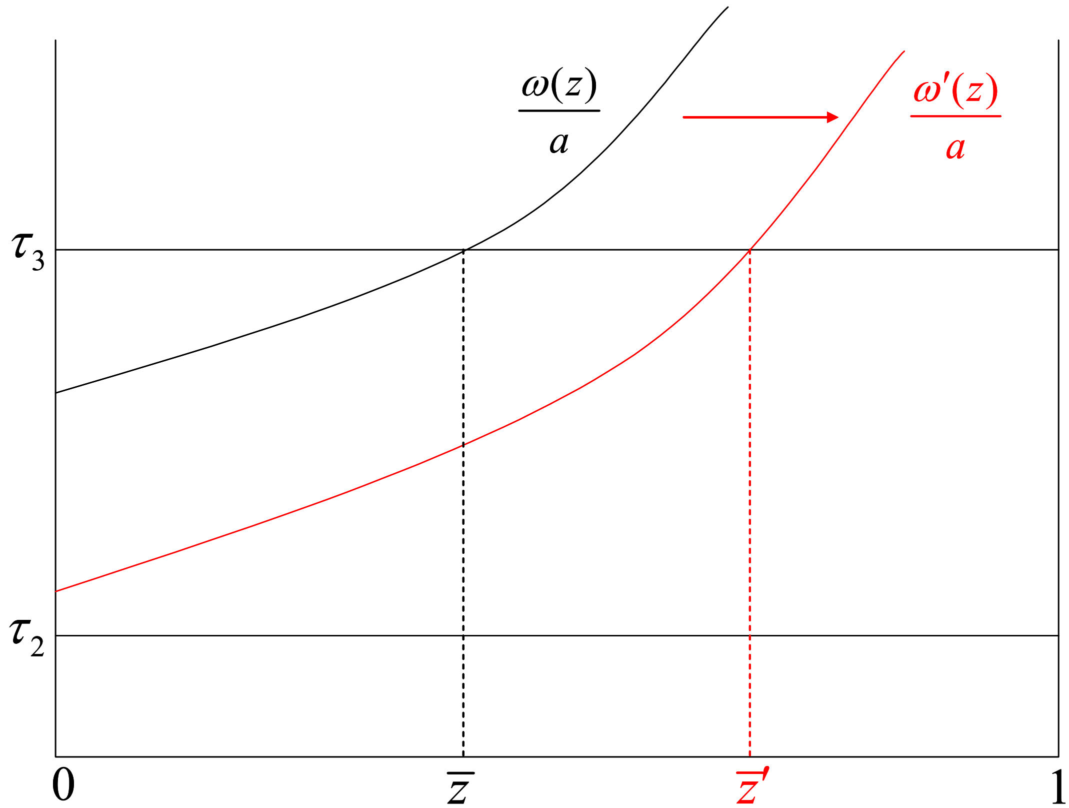



**Figure 5 - Change in equilibrium market shares when air freight costs fall**

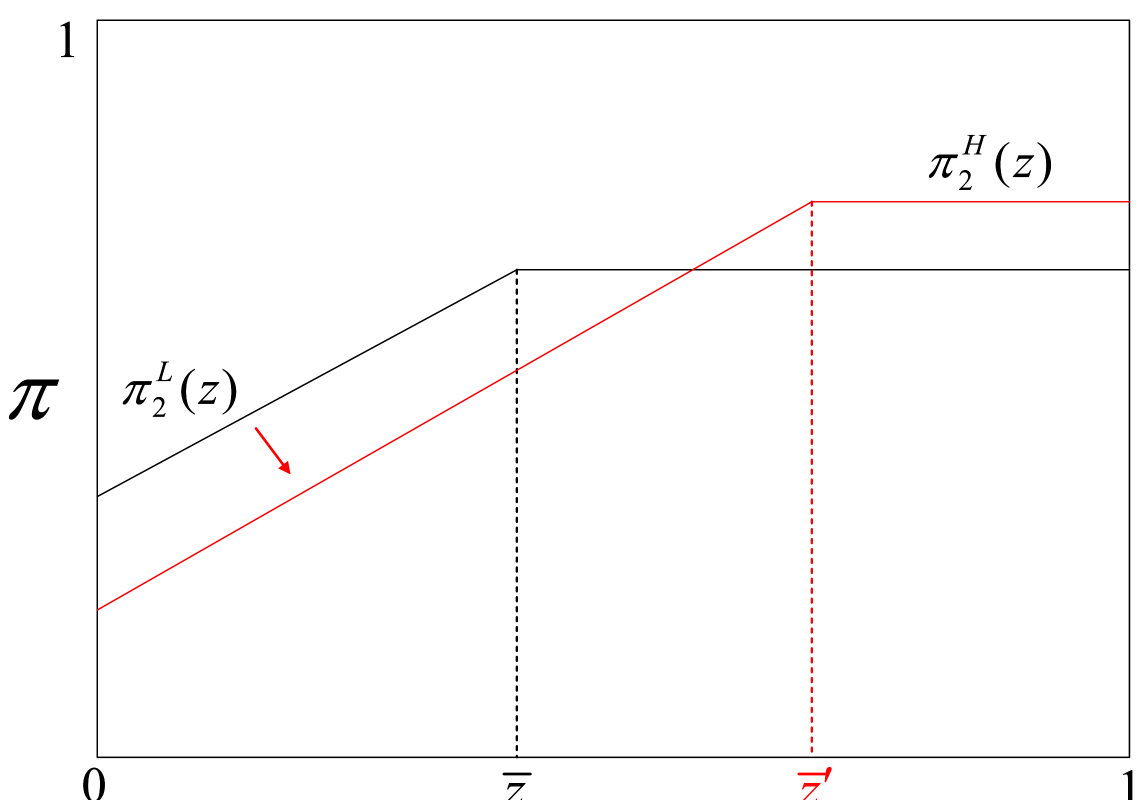
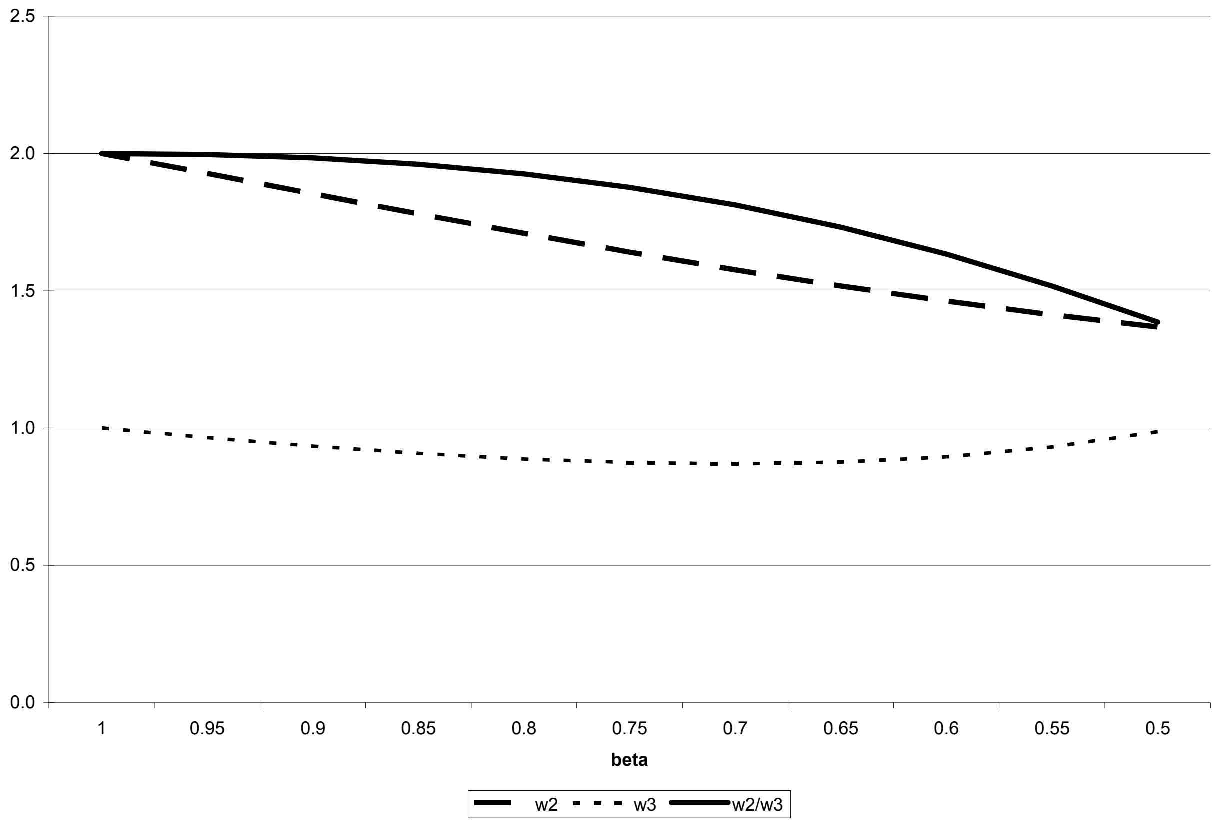
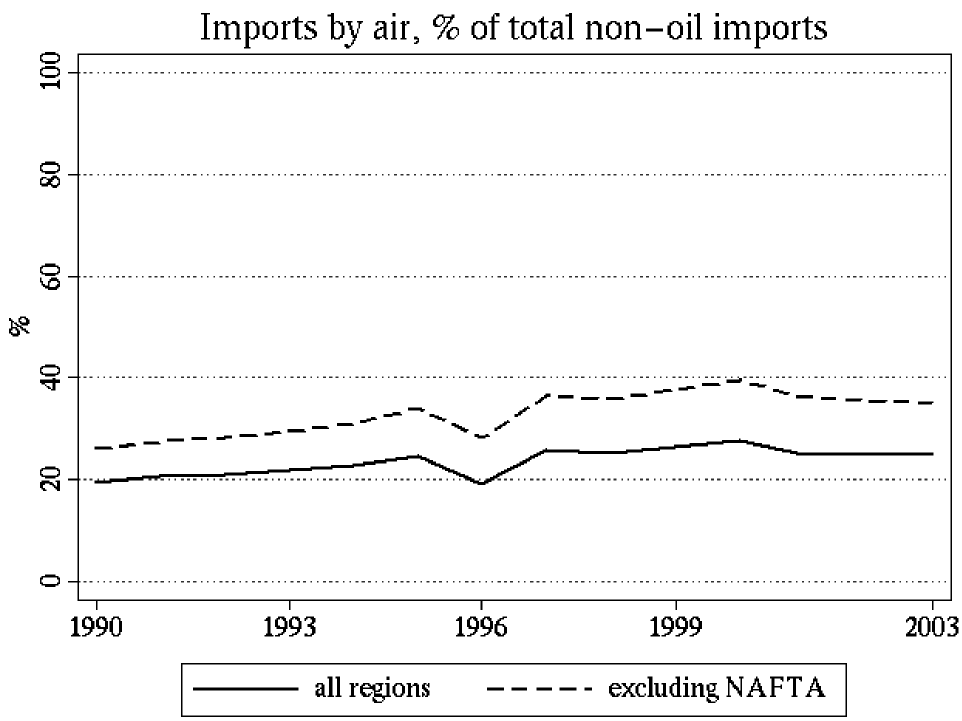


**Figure 6- Wages as a function of air freight costs**



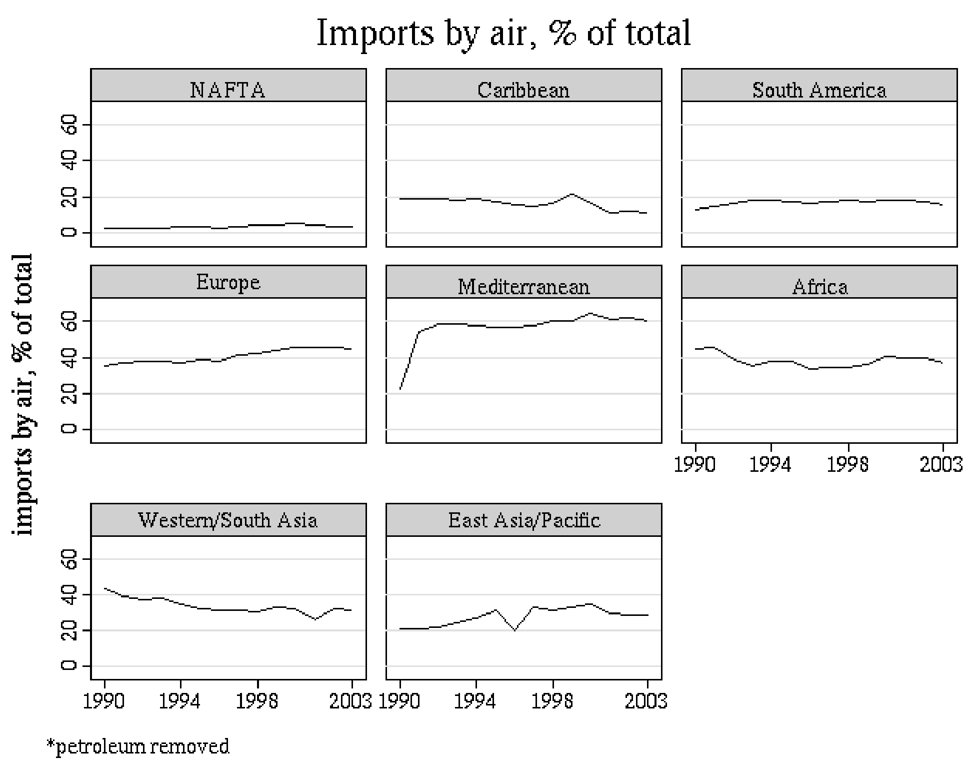

**Notes to Figure 6:** Illustrates equilibrium wages as a function of air freight costs for a numerical example, with air freight costs varying from prohibitive (left axis) to low enough so that country 3 always uses air freight (right axis). Wage in country 3 is normalized to 1 when air transport cost is prohibitive. For parameter values used in numerical example, see appendix.

Chart 1




*petroleum removed

Chart 2



Imports by air, % of total
NAFTA
Caribbean
South America
Europe
Mediterranean
Africa
Western/South Asia
East Asia/Pacific
imports by air, % of total
0
20
40
60
1990
1994
1998
2003
*petroleum removed

Chart 3

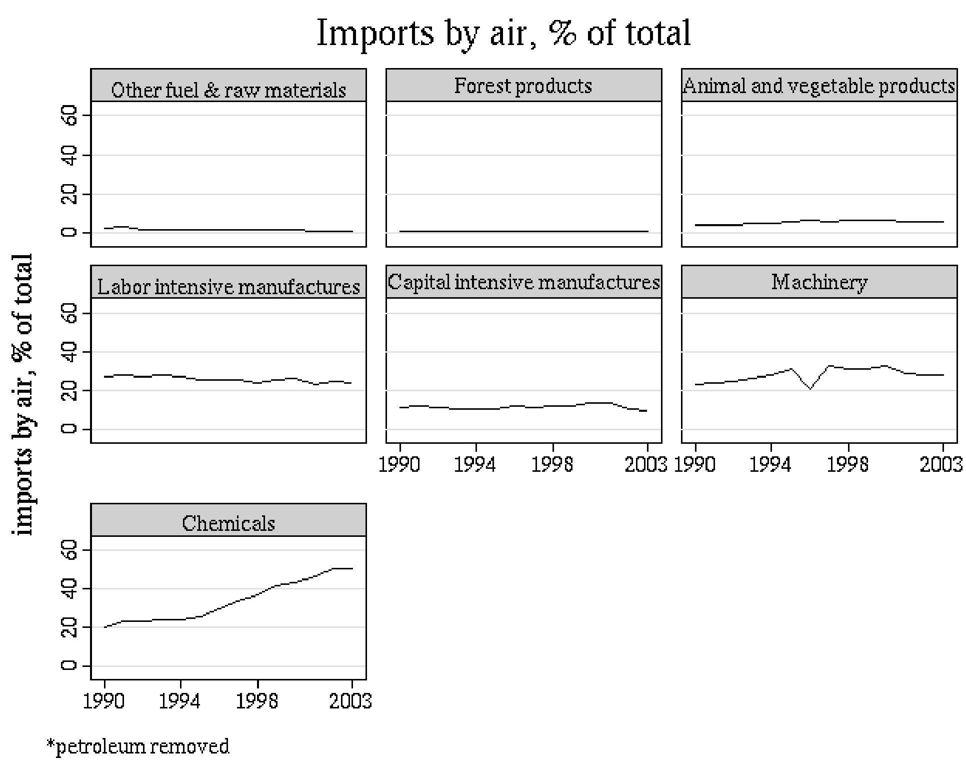
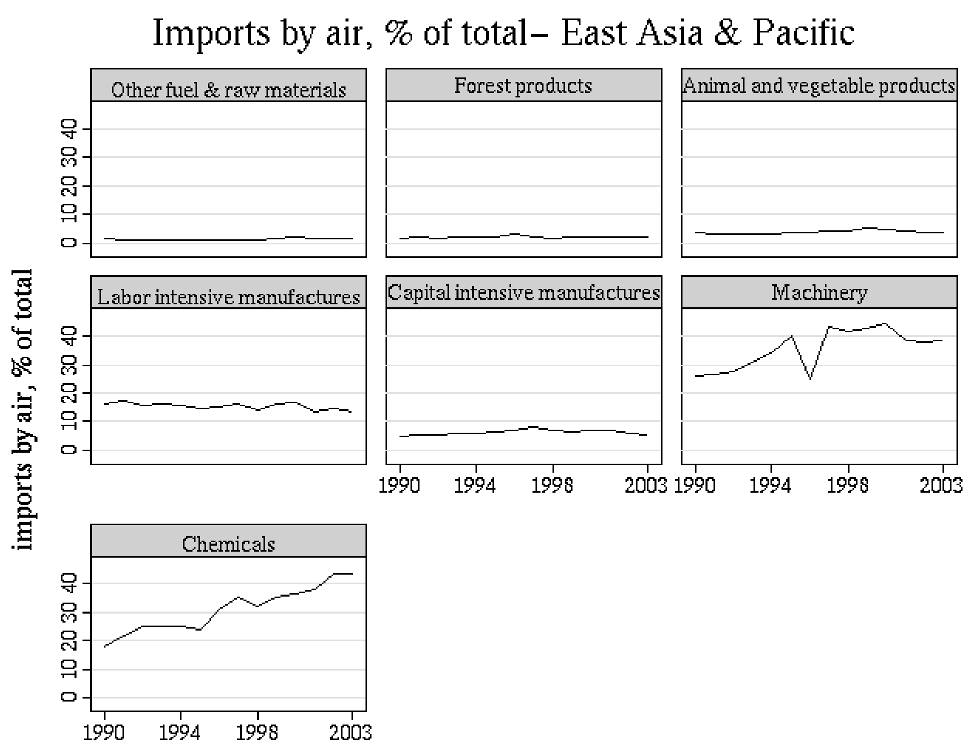
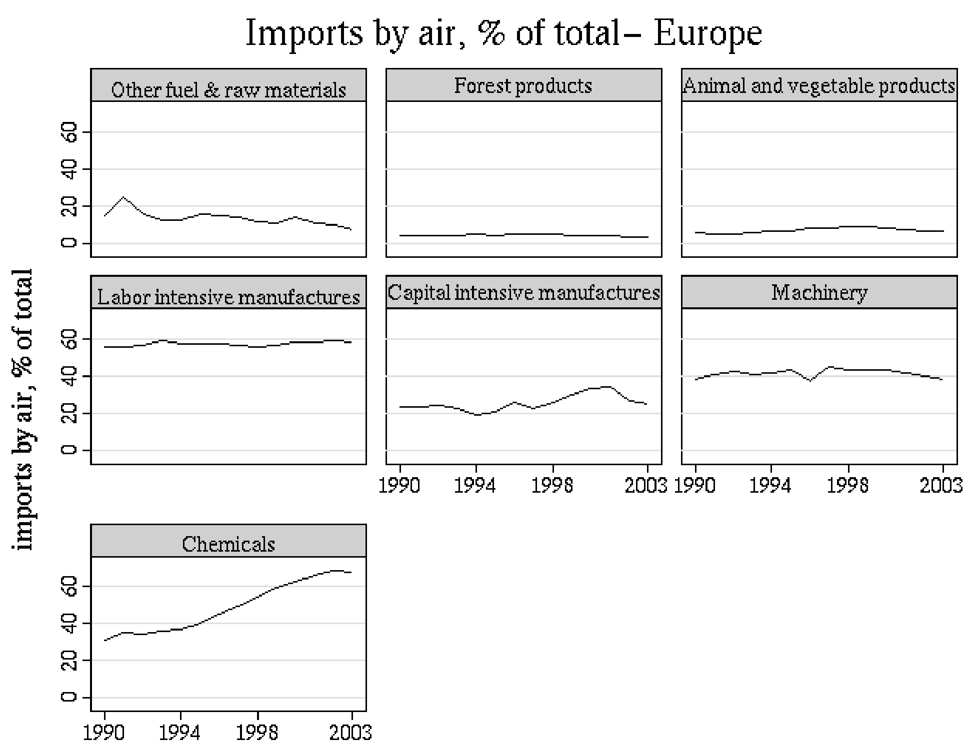

Imports by air, % of total
imports by air, % of total
Other fuel & raw materials
Forest products
Animal and vegetable products
Labor intensive manufactures
Capital intensive manufactures
Machinery
Chemicals
0
20
40
60
1990
1994
1998
2003
*petroleum removed

Chart 4



Imports by air, % of total– East Asia & Pacific
Other fuel & raw materials
Forest products
Animal and vegetable products
Labor intensive manufactures
Capital intensive manufactures
Machinery
Chemicals
imports by air, % of total
0 10 20 30 40
1990 1994 1998 2003

Chart 5



Imports by air, % of total– Europe
Other fuel & raw materials
Forest products
Animal and vegetable products
Labor intensive manufactures
Capital intensive manufactures
Machinery
Chemicals
imports by air, % of total
0
20
40
60
1990
1994
1998
2003

Chart 6

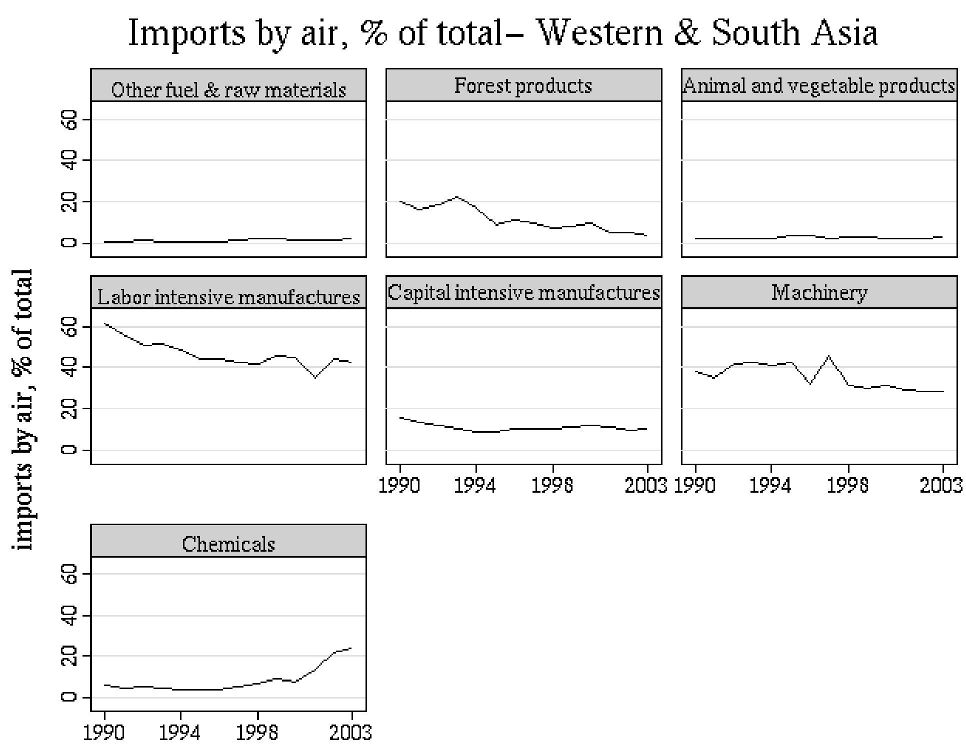

Imports by air, % of total– Western & South Asia
Other fuel & raw materials
Forest products
Animal and vegetable products
Labor intensive manufactures
Capital intensive manufactures
Machinery
Chemicals
imports by air, % of total
0
20
40
60
1990
1994
1998
2003

Chart 7

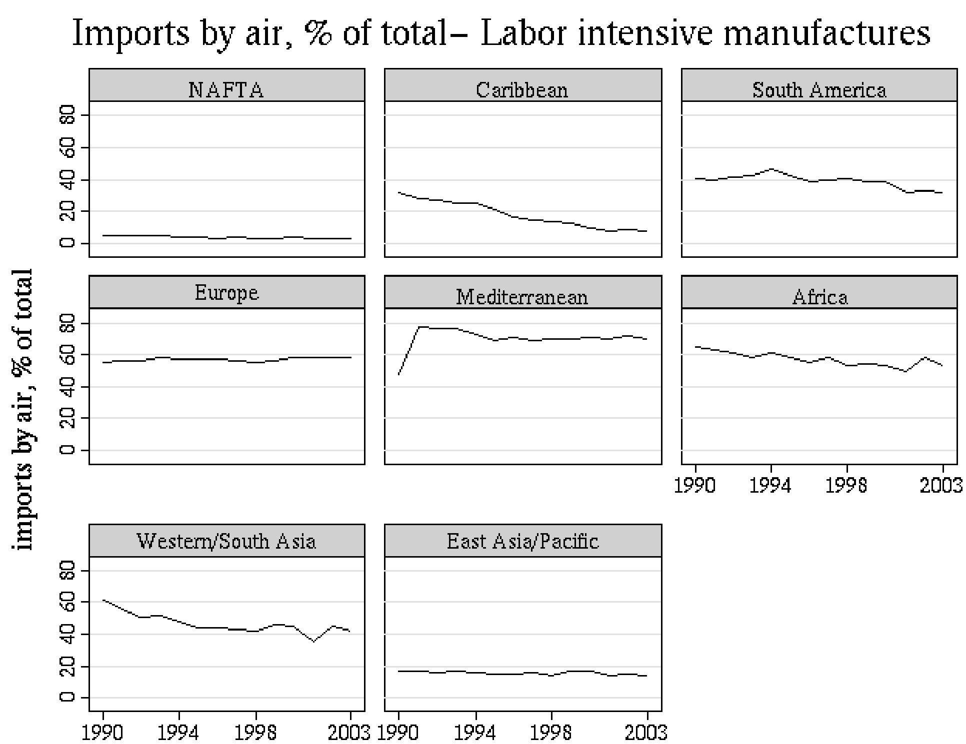
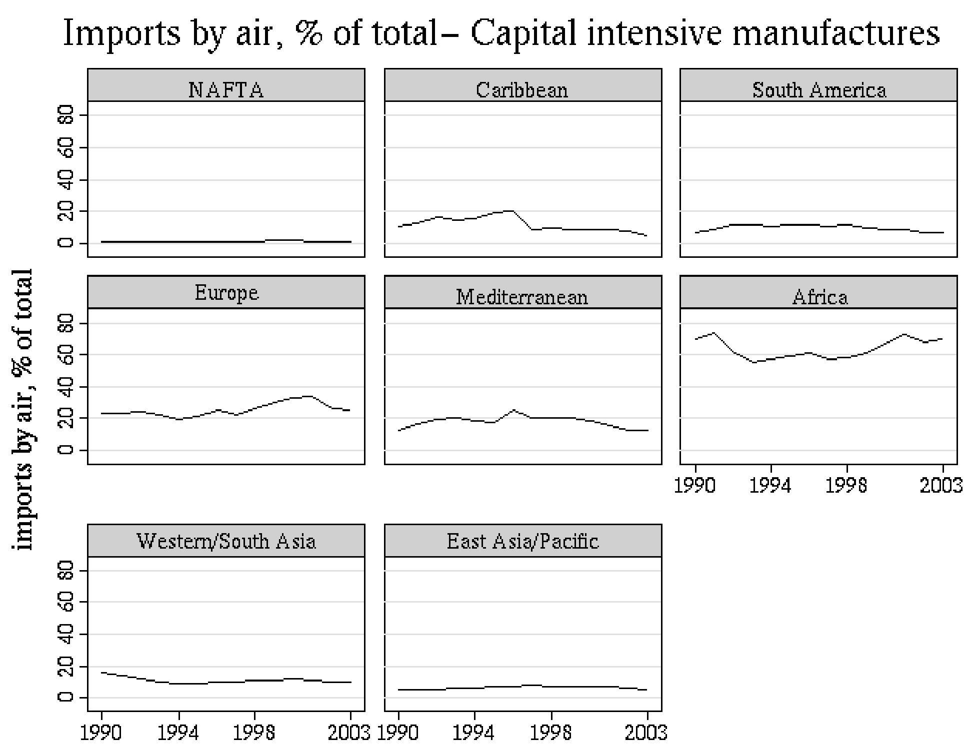
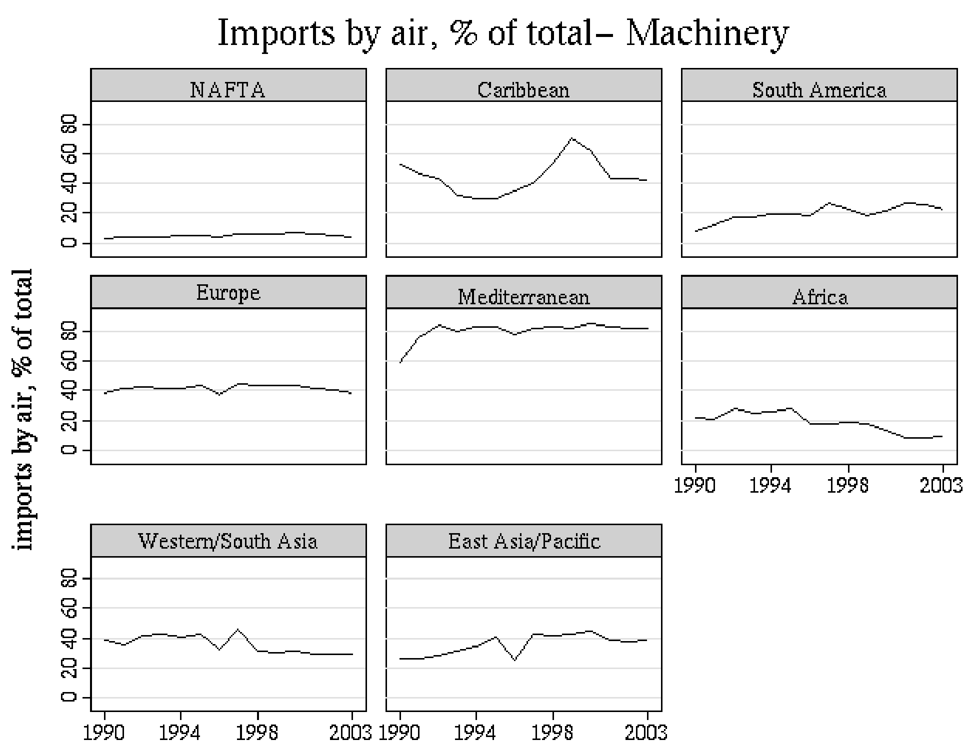

Imports by air, % of total– Labor intensive manufactures
imports by air, % of total
NAFTA
Caribbean
South America
Europe
Mediterranean
Africa
Western/South Asia
East Asia/Pacific
0
20
40
60
80
1990
1994
1998
2003

Chart 8



Imports by air, % of total– Capital intensive manufactures
NAFTA
Caribbean
South America
Europe
Mediterranean
Africa
Western/South Asia
East Asia/Pacific
imports by air, % of total
0
20
40
60
80
1990
1994
1998
2003

Chart 9



Imports by air, % of total– Machinery
imports by air, % of total
NAFTA
Caribbean
South America
Europe
Mediterranean
Africa
Western/South Asia
East Asia/Pacific
0 20 40 60 80
1990 1994 1998 2003

Chart 10

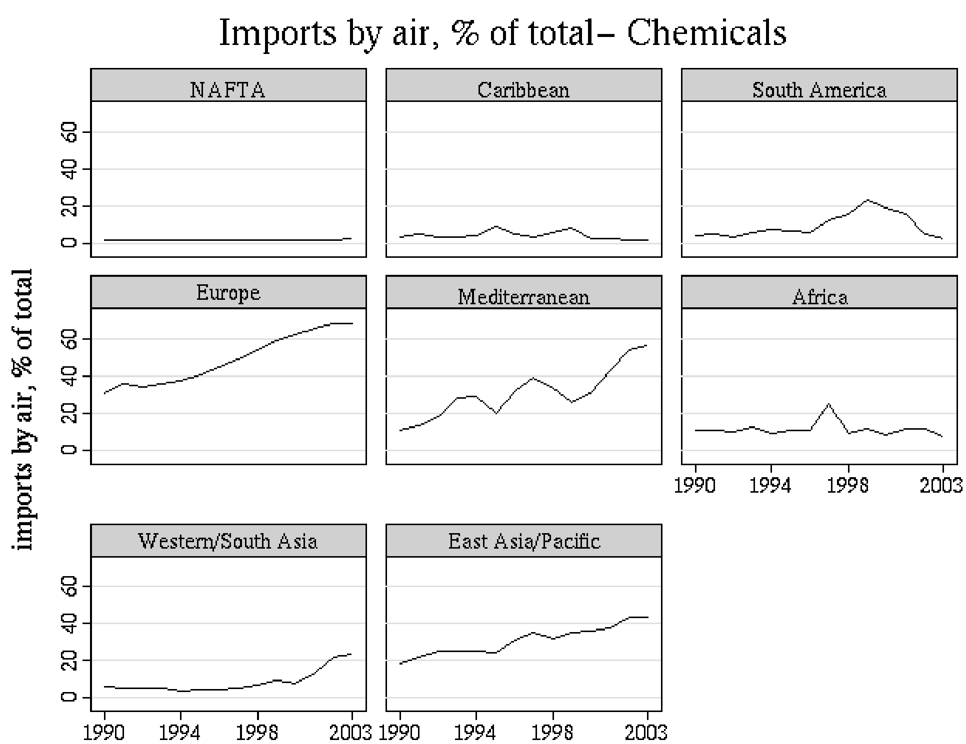

Imports by air, % of total– Chemicals
NAFTA
Caribbean
South America
Europe
Mediterranean
Africa
Western/South Asia
East Asia/Pacific
imports by air, % of total
0
20
40
60
1990
1994
1998
2003

Chart 11

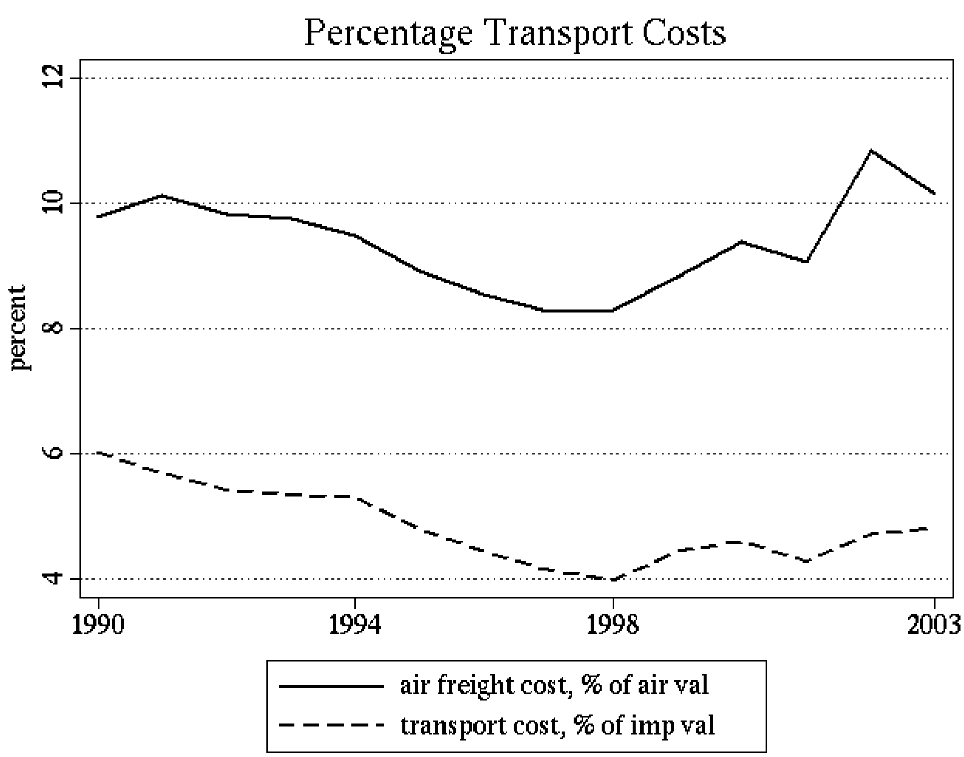

Percentage Transport Costs
percent
12
10
8
6
4
1990
1994
1998
2003
air freight cost, % of air val
transport cost, % of imp val

**Table 1 Imports by product and percent air shipped, 1990 and 2003**

| Share of total 1990 | Share of total 2003 | SITC2 | Share of category 1990 | Imports by air, % of total 1990 | Share of category 2003 | Imports by air, % of total 2003 | SITC description |
|---|---|---|---|---|---|---|---|
| **12.2** | **8.9** | **Petroleum** | | | | | |
| | | 33 | 100.0 | 2.4 | 100.0 | 2.9 | Petroleum, petroleum products and related materials |
| **2.2** | **3.3** | **Other fuel & raw materials** | | | | | |
| | | 28 | 35.0 | 9.1 | 7.5 | 13.6 | Metalliferous ores and metal scrap |
| | | 34 | 30.6 | 1.4 | 74.3 | 7.6 | Gas, natural and manufactured |
| | | 23 | 11.2 | 6.8 | 4.5 | 10.0 | Crude rubber (including synthetic and reclaimed) |
| | | 27 | 10.6 | 19.4 | 5.7 | 19.6 | Crude fertilizers, other than those of division 56, and crude minerals |
| | | 26 | 5.5 | 7.7 | 1.6 | 29.1 | Textile fibres (other than wool tops and other combed wool) and their wastes |
| | | 35 | 4.3 | 0.0 | 3.4 | 0.0 | Electric current |
| | | 32 | 2.7 | 1.7 | 2.9 | 0.3 | Coal, coke and briquettes |
| **3.4** | **2.8** | **Forest products** | | | | | |
| | | 64 | 51.2 | 23.8 | 43.5 | 19.5 | Paper, paperboard and articles of paper pulp, of paper or of paperboard |
| | | 24 | 18.9 | 4.9 | 21.2 | 4.0 | Cork and wood |
| | | 25 | 17.3 | 12.3 | 7.6 | 9.5 | Pulp and waste paper |
| | | 63 | 12.6 | 18.3 | 27.7 | 13.0 | Cork and wood manufactures (excluding furniture) |
| **5.7** | **4.7** | **Animal and vegetable products** | | | | | |
| | | 5 | 19.8 | 7.4 | 19.5 | 5.8 | Vegetables and fruit |
| | | 3 | 18.5 | 31.2 | 17.4 | 26.6 | Fish (not marine mammals), crustaceans, molluscs and aquatic invertebrates |
| | | 11 | 12.7 | 4.7 | 17.9 | 2.7 | Beverages |
| | | 7 | 12.0 | 6.2 | 9.0 | 8.2 | Coffee, tea, cocoa, spices, and manufactures thereof |
| | | 1 | 10.5 | 15.0 | 7.6 | 14.7 | Meat and meat preparations |
| | | 29 | 4.4 | 36.8 | 4.8 | 40.6 | Crude animal and vegetable materials, n.e.s. |
| | | 6 | 4.3 | 3.0 | 3.7 | 3.9 | Sugars, sugar preparations and honey |
| | | 0 | 4.3 | 86.6 | 2.8 | 83.8 | Live animals other than animals of division 03 |
| | | 4 | 3.2 | 5.6 | 5.6 | 4.0 | Cereals and cereal preparations |
| | | 12 | 2.3 | 16.2 | 2.2 | 14.1 | Tobacco and tobacco manufactures |
| | | 42 | 2.3 | 3.7 | 2.3 | 6.6 | Fixed vegetable fats and oils, crude, refined or fractionated |
| | | 2 | 1.7 | 18.9 | 1.9 | 14.2 | Dairy products and birds' eggs |
| | | 9 | 1.4 | 6.9 | 3.2 | 7.9 | Miscellaneous edible products and preparations |
| | | 8 | 1.2 | 9.6 | 1.2 | 5.2 | Feeding stuff for animals (not including unmilled cereals) |
| | | 22 | 0.7 | 11.8 | 0.5 | 10.8 | Oil-seeds and oleaginous fruits |
| | | 21 | 0.6 | 44.2 | 0.2 | 61.1 | Hides, skins and furskins, raw |
| | | 43 | 0.2 | 3.1 | 0.3 | 10.3 | Animal or vegetable fats and oils, processed; waxes of animal or vegetable origin |
| | | 41 | 0.1 | 13.4 | 0.1 | 18.7 | Animal oils and fats |

Table 1, continued

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **15.3** | **15.9** | Labor intensive manufactures | | | | | |
| | | 84 | 33.3 | 56.5 | 31.4 | 47.5 | Articles of apparel and clothing accessories |
| | | 89 | 32.9 | 47.0 | 32.6 | 46.4 | Miscellaneous manufactured articles, n.e.s. |
| | | 85 | 12.8 | 46.3 | 7.7 | 50.1 | Footwear |
| | | 66 | 11.6 | 28.9 | 13.7 | 24.5 | Non-metallic mineral manufactures, n.e.s. |
| | | 82 | 6.6 | 12.8 | 12.2 | 12.3 | Furniture, and parts thereof; bedding, mattresses, mattress supports, cushions |
| | | 83 | 2.9 | 60.9 | 2.3 | 58.2 | Travel goods, handbags and similar containers |
| **8.1** | **7.0** | **Capital intensive manufactures** | | | | | |
| | | 67 | 24.5 | 3.3 | 14.5 | 7.1 | Iron and steel |
| | | 68 | 23.4 | 17.0 | 19.4 | 25.2 | Non-ferrous metals |
| | | 69 | 22.2 | 24.2 | 28.5 | 29.4 | Manufactures of metals, n.e.s. |
| | | 65 | 15.8 | 45.8 | 19.7 | 46.3 | Textile yarn, fabrics, made-up articles, n.e.s., and related products |
| | | 62 | 8.7 | 14.6 | 9.7 | 27.0 | Rubber manufactures, n.e.s. |
| | | 81 | 3.1 | 18.4 | 6.9 | 20.0 | Prefabricated buildings; sanitary, plumbing, heating and lighting fixtures and |
| | | 61 | 2.2 | 59.1 | 1.3 | 65.3 | Leather, leather manufactures, n.e.s., and dressed furskins |
| **45.2** | **45.0** | **Machinery** | | | | | |
| | | 78 | 34.2 | 14.7 | 31.1 | 19.4 | Road vehicles (including air-cushion vehicles) |
| | | 77 | 15.0 | 55.3 | 14.6 | 60.9 | Electrical machinery, apparatus and appliances, n.e.s., and electrical parts the |
| | | 75 | 12.3 | 73.6 | 14.5 | 74.5 | Office machines and automatic data-processing machines |
| | | 76 | 9.7 | 57.6 | 12.7 | 74.5 | Telecommunications and sound-recording and reproducing apparatus |
| | | 74 | 6.4 | 31.5 | 6.8 | 34.7 | General industrial machinery and equipment, n.e.s., and machine parts, n.e.s. |
| | | 72 | 5.9 | 30.2 | 3.7 | 35.7 | Machinery specialized for particular industries |
| | | 71 | 5.8 | 40.1 | 5.7 | 43.9 | Power-generating machinery and equipment |
| | | 79 | 3.3 | 42.0 | 3.6 | 42.8 | Other transport equipment |
| | | 88 | 3.0 | 68.2 | 2.1 | 73.7 | Photographic apparatus, equipment and supplies and optical goods, watches |
| | | 87 | 2.7 | 64.0 | 4.2 | 75.5 | Professional, scientific and controlling instruments and apparatus, n.e.s. |
| | | 73 | 1.7 | 28.9 | 1.0 | 41.4 | Metalworking machinery |
| **4.5** | **8.3** | **Chemicals** | | | | | |
| | | 51 | 32.7 | 23.4 | 33.5 | 32.2 | Organic chemicals |
| | | 52 | 14.0 | 11.1 | 7.1 | 16.8 | Inorganic chemicals |
| | | 54 | 11.7 | 54.6 | 31.2 | 65.0 | Medicinal and pharmaceutical products |
| | | 59 | 9.2 | 10.9 | 6.7 | 21.6 | Chemical materials and products, n.e.s. |
| | | 57 | 8.9 | 7.2 | 7.1 | 19.5 | Plastics in primary forms |
| | | 58 | 8.0 | 24.2 | 4.6 | 27.2 | Plastics in non-primary forms |
| | | 53 | 5.9 | 10.4 | 2.4 | 18.4 | Dyeing, tanning and colouring materials |
| | | 55 | 5.3 | 28.3 | 5.4 | 22.7 | Essential oils and resinoids and perfume materials; toilet, polishing and cleanser |
| | | 56 | 4.2 | 8.7 | 2.0 | 6.9 | Fertilizers (other than those of group 272) |

**Table 2 Country categories**

| distance | country | region | country | region |
|---|---|---|---|---|
| 1-4000 km from USA | Canada | NAFTA | Mexico | NAFTA |
| | Bahamas | Caribbean | Barbados | Caribbean |
| | Belize | Caribbean | Costa.Rica | Caribbean |
| | Dominican.Republic | Caribbean | El.Salvador | Caribbean |
| | Guatemala | Caribbean | Haiti | Caribbean |
| | Honduras | Caribbean | Jamaica | Caribbean |
| | Nicaragua | Caribbean | Panama | Caribbean |
| | Trinidad.And.Tobago | Caribbean | Colombia | South America |
| | Venezuela | South America | | |
| 4000-7800 km from USA | Bolivia | South America | Brazil | South America |
| | Ecuador | South America | Guyana | South America |
| | Paraguay | South America | Peru | South America |
| | Suriname | South America | Austria | Europe |
| | Belgium-Lux | Europe | Czechoslovakia | Europe |
| | Denmark | Europe | Finland | Europe |
| | France | Europe | Germany | Europe |
| | Hungary | Europe | Iceland | Europe |
| | Ireland | Europe | Italy | Europe |
| | Netherlands | Europe | Norway | Europe |
| | Poland | Europe | Portugal | Europe |
| | Spain | Europe | Sweden | Europe |
| | Switzerland | Europe | United.Kingdom | Europe |
| | Yugoslavia | Europe | Algeria | Mediterranean |
| | Malta | Mediterranean | Morocco | Mediterranean |
| | Tunisia | Mediterranean | Gambia | Africa |
| | Guinea | Africa | Guinea.Bissau | Africa |
| | Liberia | Africa | Mali | Africa |
| | Mauritania | Africa | Senegal | Africa |
| | Sierra.Leone | Africa | | |

Table 2, continued

| distance | country | region | country | region |
|---|---|---|---|---|
| 7800-14000 km from USA | Argentina | South America | Chile | South America |
| | Uruguay | South America | Bulgaria | Europe |
| | Romania | Europe | Russian.Federation | Europe |
| | Cyprus | Mediterranean | Egypt | Mediterranean |
| | Greece | Mediterranean | Israel | Mediterranean |
| | Syrian.Arab.Republic | Mediterranean | Turkey | Mediterranean |
| | Angola | Africa | Benin | Africa |
| | Burkina.Faso | Africa | Burundi | Africa |
| | Cameroon | Africa | Central.African.Republic | Africa |
| | Chad | Africa | Comoros | Africa |
| | Congo | Africa | Cote.D'Ivour | Africa |
| | Djibouti | Africa | Ethiopia | Africa |
| | Gabon | Africa | Ghana | Africa |
| | Kenya | Africa | Malawi | Africa |
| | Mozambique | Africa | Niger | Africa |
| | Nigeria | Africa | Rwanda | Africa |
| | Somalia | Africa | South.Africa | Africa |
| | Sudan | Africa | Tanzania | Africa |
| | Togo | Africa | Uganda | Africa |
| | Zaire | Africa | Zambia | Africa |
| | Zimbabwe | Africa | Afghanistan | Western/South Asia |
| | Bahrain | Western/South Asia | Bangladesh | Western/South Asia |
| | Bhutan | Western/South Asia | India | Western/South Asia |
| | Iran | Western/South Asia | Iraq | Western/South Asia |
| | Jordan | Western/South Asia | Kuwait | Western/South Asia |
| | Mongolia | Western/South Asia | Myanmar | Western/South Asia |
| | Nepal | Western/South Asia | Oman | Western/South Asia |
| | Pakistan | Western/South Asia | Qatar | Western/South Asia |
| | Saudi.Arabia | Western/South Asia | United.Arab.Emirates | Western/South Asia |
| | Yemen | Western/South Asia | China | East Asia/Pacific |
| | Fiji | East Asia/Pacific | Hong.Kong | East Asia/Pacific |
| | Japan | East Asia/Pacific | Korea.RP.(S) | East Asia/Pacific |
| | Laos | East Asia/Pacific | Phillipines | East Asia/Pacific |
| | Solomon.Islands | East Asia/Pacific | Taiwan | East Asia/Pacific |
| over 14000 km from USA | Madagascar | Africa | Mauritius | Africa |
| | Seychelles | Africa | Reunion.Islands | Western/South Asia |
| | Sri.Lanka | Western/South Asia | Australia | East Asia/Pacific |
| | Indonesia | East Asia/Pacific | Malaysia | East Asia/Pacific |
| | New.Zealand | East Asia/Pacific | Papua.New.Guinea | East Asia/Pacific |
| | Singapore | East Asia/Pacific | Thailand | East Asia/Pacific |

Table 3- Transport costs by region

| Region | transport cost, % of import value 2003 | air freight cost, % of air value 2003 |
|---|---|---|
| NAFTA | 1.50 | 5.17 |
| Caribbean | 2.34 | 6.47 |
| South America | 9.17 | 7.04 |
| Europe | 4.45 | 4.96 |
| Mediterranean | 5.09 | 10.18 |
| Africa | 7.02 | 14.57 |
| Western/South Asia | 7.12 | 15.38 |
| East Asia/Pacific | 6.17 | 12.76 |

Table 4- Transport costs by product

| Product | transport cost, % of import value 2003 | air freight cost, % of air value 2003 |
|---|---|---|
| Petroleum | 5.00 | 22.37 |
| Other fuel & raw materials | 4.74 | 3.76 |
| Forest products | 6.44 | 20.88 |
| Animal and vegetable products | 7.30 | 23.77 |
| Labor intensive manufactures | 5.71 | 4.43 |
| Capital intensive manufactures | 5.48 | 6.97 |
| Machinery | 1.97 | 2.37 |
| Chemicals | 2.73 | 1.04 |

**Table 5** - Regression of U.S. import unit values on distance and other controls

| | 1990 | 1995 | 2000 | 2003 | 1990 | 1995 | 2000 | 2003 |
|---|---|---|---|---|---|---|---|---|
| more than 4000km | 0.260 | 0.190 | 0.371 | 0.362 | | | | |
| | *21.6* | *15.3* | *32.8* | *31.9* | | | | |
| 1-4000km | | | | | 0.056 | -0.148 | 0.092 | 0.047 |
| | | | | | *2.4* | *-6.6* | *4.2* | *2.2* |
| 4000-7800km | | | | | 0.446 | 0.390 | 0.517 | 0.530 |
| | | | | | *31.4* | *27.4* | *40.4* | *41.3* |
| 7800-14,000km | | | | | -0.023 | -0.133 | 0.139 | 0.078 |
| | | | | | *-1.5* | *-8.9* | *9.8* | *5.5* |
| more than 14,000km | | | | | 0.239 | 0.074 | 0.355 | 0.290 |
| | | | | | *12.6* | *4.3* | *20.6* | *17.0* |
| log Y/L | -0.051 | -0.056 | 0.200 | 0.276 | -0.130 | -0.202 | 0.031 | 0.081 |
| | *-4.0* | *-4.7* | *18.7* | *25.7* | *-9.6* | *-16.1* | *2.5* | *6.6* |
| log price level | 0.829 | 0.769 | 0.403 | 0.364 | 0.760 | 0.768 | 0.485 | 0.445 |
| | *46.0* | *52.3* | *28.7* | *25.7* | *39.9* | *50.3* | *31.6* | *29.0* |
| landlocked | 0.294 | 0.322 | 0.337 | 0.443 | 0.178 | 0.154 | 0.217 | 0.291 |
| | *14.8* | 16.96 | 19.41 | 25 | *9.0* | *8.2* | *12.4* | *16.3* |
| tariff | -0.014 | -0.011 | -0.001 | -0.003 | -0.013 | -0.013 | -0.002 | -0.002 |
| | *-18.5* | *-8.7* | *-0.8* | *-3.0* | *-18.1* | *-9.9* | *-1.5* | *-1.9* |
| transport cost | -0.012 | -0.004 | -0.013 | -0.011 | -0.012 | -0.004 | -0.013 | -0.011 |
| | *-25.4* | *-18.2* | *-33.5* | *-30.1* | *-25.9* | *-18.3* | *-32.7* | *-29.4* |
| *N* | 88,984 | 108,837 | 121,830 | 127,602 | 88,984 | 108,837 | 121,830 | 127,602 |
| HS codes | 11,815 | 13,131 | 13,788 | 14,103 | 11,815 | 13,131 | 13,788 | 14,103 |
| $R^2$ within | 0.145 | 0.135 | 0.119 | 0.132 | 0.168 | 0.162 | 0.131 | 0.149 |

**Notes to Table 5**: Estimates of equation (18) in the text. For each year, log U.S. import unit value is regressed on indicators for exporter distance from the US, other controls, and fixed effects for 10 digit HS codes. Y/L is aggregate real GDP per worker of the exporter, price level is the exporters aggregate price level, landlocked is an indicator for the exporter having no port, and tariff and transport costs are ad valorem percentages. "$R^2$ within" is the $R^2$ after removing HS10 means from the data.

**Table 6** - Regression of U.S. import value/kilo on distance and other controls

| | 1990 | 1995 | 2000 | 2003 | 1990 | 1995 | 2000 | 2003 |
|---|---|---|---|---|---|---|---|---|
| more than 4000km | 0.400 | 0.353 | 0.551 | 0.510 | | | | |
| | *36.1* | *30.2* | *50.2* | *45.8* | | | | |
| 1-4000km | | | | | 0.296 | 0.069 | 0.160 | 0.165 |
| | | | | | *14.5* | *3.4* | *8.0* | *8.3* |
| 4000-7800km | | | | | 0.571 | 0.508 | 0.657 | 0.656 |
| | | | | | *41.6* | *36.5* | *51.4* | *50.8* |
| 7800-14,000km | | | | | 0.339 | 0.229 | 0.461 | 0.345 |
| | | | | | *23.3* | *15.7* | *32.8* | *24.1* |
| more than 14,000km | | | | | 0.443 | 0.334 | 0.598 | 0.494 |
| | | | | | *24.3* | *19.8* | *35.1* | *28.9* |
| log Y/L | -0.057 | -0.096 | 0.058 | 0.151 | -0.056 | -0.153 | -0.016 | 0.042 |
| | *-4.9* | *-8.6* | *5.8* | *14.7* | *-4.5* | *-12.6* | *-1.4* | *3.6* |
| log price level | 0.718 | 0.746 | 0.523 | 0.488 | 0.643 | 0.721 | 0.550 | 0.511 |
| | *43.4* | *53.3* | *39.2* | *35.7* | *36.7* | *49.1* | *37.8* | *34.9* |
| landlocked | 0.362 | 0.327 | 0.374 | 0.478 | 0.310 | 0.249 | 0.320 | 0.384 |
| | *18.9* | *18.0* | *22.2* | *27.2* | *16.2* | *13.7* | *18.7* | *21.6* |
| tariff | -0.013 | -0.009 | -0.002 | -0.001 | -0.014 | -0.010 | -0.003 | -0.001 |
| | *-10.8* | *-7.7* | *-2.4* | *-1.5* | *-11.5* | *-8.8* | *-3.7* | *-1.1* |
| transport cost | -0.014 | -0.004 | -0.015 | -0.014 | -0.015 | -0.004 | -0.016 | -0.014 |
| | *-33.9* | *-21.8* | *-41.9* | *-39.2* | *-35.2* | *-22.2* | *-42.1* | *-39.3* |
| *N* | 52,028 | 66,366 | 74,271 | 78,910 | 52,028 | 66,366 | 74,271 | 78,910 |
| HS codes | 7,422 | 8,518 | 8,910 | 9,139 | 7,422 | 8,518 | 8,910 | 9,139 |
| $R^2$ within | 0.219 | 0.212 | 0.197 | 0.213 | 0.230 | 0.225 | 0.202 | 0.225 |

**Notes to Table 6**: Estimates of equation (18) in the text. For each year, log U.S. import value/kilo is regressed on indicators for exporter distance from the US, other controls, and fixed effects for 10 digit HS codes. Y/L is aggregate real GDP per worker of the exporter, price level is the exporters aggregate price level, landlocked is an indicator for the exporter having no port, and tariff and transport costs are ad valorem percentages. "$R^2$ within" is the $R^2$ after removing HS10 means from the data.

**Table 7** - Regression of U.S. import unit values on distance, air share and other controls

| | 1990 | 1995 | 2000 | 2003 | 1990 | 1995 | 2000 | 2003 |
|---|---|---|---|---|---|---|---|---|
| more than 4000km | 0.121 | 0.028 | 0.153 | 0.122 | | | | |
| | *10.5* | *2.4* | *13.8* | *11.1* | | | | |
| 1-4000km | | | | | -0.220 | -0.386 | -0.105 | -0.187 |
| | | | | | *-9.8* | *-17.9* | *-4.9* | *-9.0* |
| 4000-7800km | | | | | 0.183 | 0.101 | 0.211 | 0.202 |
| | | | | | *13.0* | *7.2* | *16.6* | *16.0* |
| 7800-14,000km | | | | | -0.100 | -0.224 | 0.010 | -0.061 |
| | | | | | *-6.9* | *-15.6* | *0.8* | *-4.5* |
| more than 14,000km | | | | | 0.099 | -0.058 | 0.193 | 0.109 |
| | | | | | *5.4* | *-3.5* | *11.6* | *6.7* |
| air share | 1.137 | 1.133 | 1.161 | 1.290 | 1.075 | 1.058 | 1.122 | 1.238 |
| | *88.9* | *98.7* | *102.3* | *114.7* | *81.3* | *89.4* | *96.9* | *108.1* |
| log Y/L | -0.086 | -0.084 | 0.135 | 0.215 | -0.148 | -0.215 | 0.012 | 0.067 |
| | *-6.9* | *-7.4* | *13.2* | *21.0* | *-11.4* | *-17.8* | *1.0* | *5.7* |
| log price level | 0.718 | 0.659 | 0.309 | 0.241 | 0.694 | 0.708 | 0.404 | 0.339 |
| | *41.7* | *46.9* | *22.9* | *17.8* | *37.9* | *48.3* | *27.2* | *23.1* |
| landlocked | 0.113 | 0.134 | 0.167 | 0.253 | 0.055 | 0.032 | 0.105 | 0.166 |
| | *6.0* | *7.4* | *10.0* | *15.1* | *2.9* | *1.7* | *6.2* | *9.8* |
| tariff | -0.012 | -0.013 | -0.006 | -0.006 | -0.012 | -0.015 | -0.007 | -0.006 |
| | *-17.7* | *-10.7* | *-5.9* | *-5.8* | *-17.8* | *-12.6* | *-6.6* | *-6.2* |
| transport cost | -0.019 | -0.007 | -0.020 | -0.019 | -0.019 | -0.006 | -0.019 | -0.018 |
| | *-42.5* | *-31.2* | *-51.7* | *-53.9* | *-41.2* | *-30.1* | *-50.6* | *-52.5* |
| N | 88,956 | 108,804 | 121,627 | 127,432 | 88,956 | 108,804 | 121,627 | 127,432 |
| HS codes | 11,814 | 13,130 | 13,784 | 14,097 | 11,814 | 13,130 | 13,784 | 14,097 |
| $R^2$ within | 0.225 | 0.215 | 0.197 | 0.223 | 0.234 | 0.227 | 0.201 | 0.229 |

**Notes to table 7:** Estimates of equation (19) in the text. For each year, log U.S. import value/kilo is regressed on indicators for exporter distance from the US, other controls, and fixed effects for 10 digit HS codes. Y/L is aggregate real GDP per worker of the exporter, price level is the exporters aggregate price level, landlocked is an indicator for the exporter having no port, and tariff and transport costs are ad valorem percentages. "$R^2$ within" is the $R^2$ after removing HS10 means from the data.

**Table 8** - Regression of U.S. import value/kilo on distance, air share, and other controls

| | 1990 | 1995 | 2000 | 2003 | 1990 | 1995 | 2000 | 2003 |
|---|---|---|---|---|---|---|---|---|
| more than 4000km | 0.266 | 0.187 | 0.292 | 0.221 | | | | |
| | *27.0* | *17.9* | *30.2* | *23.0* | | | | |
| 1-4000km | | | | | 0.000 | -0.184 | -0.033 | -0.089 |
| | | | | | *0.0* | *-10.3* | *-1.9* | *-5.2* |
| 4000-7800km | | | | | 0.251 | 0.159 | 0.257 | 0.234 |
| | | | | | *20.1* | *12.5* | *22.5* | *20.6* |
| 7800-14,000km | | | | | 0.254 | 0.125 | 0.319 | 0.198 |
| | | | | | *19.7* | *9.6* | *26.1* | *16.2* |
| more than 14,000km | | | | | 0.340 | 0.209 | 0.445 | 0.332 |
| | | | | | *21.0* | *13.8* | *30.1* | *22.7* |
| air share | 1.274 | 1.260 | 1.443 | 1.599 | 1.292 | 1.271 | 1.476 | 1.606 |
| | *114.4* | *124.1* | *147.5* | *164.6* | *111.3* | *120.7* | *147.5* | *161.9* |
| log Y/L | -0.084 | -0.112 | -0.025 | 0.081 | -0.072 | -0.157 | -0.043 | 0.028 |
| | *-8.1* | *-11.2* | *-2.8* | *9.2* | *-6.6* | *-14.6* | *-4.2* | *2.8* |
| log price level | 0.574 | 0.604 | 0.390 | 0.303 | 0.557 | 0.641 | 0.441 | 0.363 |
| | *39.3* | *48.3* | *33.5* | *26.0* | *35.9* | *48.8* | *34.9* | *28.9* |
| landlocked | 0.144 | 0.108 | 0.150 | 0.216 | 0.147 | 0.087 | 0.161 | 0.198 |
| | *8.5* | *6.6* | *10.2* | *14.4* | *8.7* | *5.3* | *10.9* | *13.0* |
| tariff | -0.010 | -0.012 | -0.011 | -0.006 | -0.009 | -0.014 | -0.012 | -0.008 |
| | *-8.9* | *-12.4* | *-13.6* | *-7.8* | *-8.9* | *-14.5* | *-14.9* | *-10.1* |
| transport cost | -0.023 | -0.006 | -0.025 | -0.025 | -0.024 | -0.006 | -0.026 | -0.026 |
| | *-61.3* | *-39.9* | *-77.4* | *-83.5* | *-61.5* | *-40.1* | *-79.0* | *-84.2* |
| N | 52,023 | 66,359 | 74,210 | 78,855 | 52,023 | 66,359 | 74,210 | 78,855 |
| HS codes | 7,422 | 8,517 | 8,908 | 9,136 | 7,422 | 8,517 | 8,908 | 9,136 |
| $R^2$ within | 0.396 | 0.378 | 0.398 | 0.433 | 0.398 | 0.381 | 0.402 | 0.437 |

**Notes to table 8:** Estimates of equation (19) in the text. For each year, log U.S. import value/kilo is regressed on indicators for exporter distance from the US, other controls, and fixed effects for 10 digit HS codes. Y/L is aggregate real GDP per worker of the exporter, price level is the exporters aggregate price level, landlocked is an indicator for the exporter having no port, and tariff and transport costs are ad valorem percentages. "$R^2$ within" is the $R^2$ after removing HS10 means from the data.