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Transportation Costs and International Trade in the Second Era of Globalization

David Hummels

From 1950–2004, world trade grew at a rapid average rate of 5.9 percent per annum. The annual growth rate of manufacturing trade was even faster, at 7.2 percent. For the world as a whole, the ratio of trade relative to output more than tripled over the last five decades (World Trade Organization, International Trade Statistics, 2005). Similarly, the sum of U.S. imports and exports rose from 6.5 percent of GDP in 1960 to about 20 percent of GDP in the early 2000s (based on data at ⟨http://www.bea.gov⟩).

One prominent possible explanation for the rise in international trade is a decline in international transportation costs. Economic historians have documented how technological change led to substantial reductions in shipping costs from 1850–1913 (Harley, 1980, Harley, 1989; North, 1958, 1968; Mohammed and Williamson, 2004). Econometric evidence has subsequently linked shipping cost declines to rapid growth in trade during that first era of globalization (Estevadeordal, Frantz, and Taylor, 2003). The decades since World War II have also witnessed significant technological change in shipping, including the development of jet aircraft engines and the use of containerization in ocean shipping. However, documentation of the actual decline in shipping costs in recent decades has been lacking. This paper will draw on an eclectic mix of data to characterize the patterns of international ocean and air transportation costs in the last few decades.

Understanding modern changes in transportation costs turns out to be unexpectedly complex. Shifts in the types of products traded, the intensity with which they use transportation services, and whether these goods are shipped by ocean or air freight all affect measured costs. At various times, improvements in transportation technology have been partially offset by significant changes in input costs and

■ *David Hummels is Associate Professor of Economics, Purdue University, West Lafayette, Indiana. His e-mail address is ⟨hummelsd@purdue.edu⟩.*

in the nature of what is traded. Moreover, the economic effects of improved transportation are apparent not only in *how much* trade has grown, but also in *how* trade has grown. Improvements in the quality of transportation services—like greater speed and reliability—allow corresponding reorganizations of global networks of production and new ways of coping with uncertainty in foreign markets.

I begin with an overview of how goods are transported across international borders, with an emphasis on ocean and air transport. I discuss different ways of placing transportation costs in economic context and then discuss patterns of technological changes and price indexes for international air and ocean shipping. I employ regression analysis to sort out the role of cost shocks and technological and compositional change in shaping the time series in transportation costs and then draw out implications of these trends for the changing nature of trade and integration. Much of the data employed here can be difficult to find, but of great use to researchers going forward. An appendix at the end of the paper describes where to find data and offers links to a website that provides all of the data underlying this paper's tables and figures.

How Goods Move

Roughly 23 percent of world trade by value occurs between countries that share a land border. This proportion has been nearly constant over recent decades, though it varies significantly across continents. For Africa, the Middle East, and Asia, between 1 and 5 percent of trade by value is with land-neighboring countries; for Latin America, trade with land neighbors is 10 to 20 percent of the whole, and for Europe and North America it is 25–35 percent of trade. Detailed data on the value of trade by different modes of transportation are sparse, but U.S. and Latin American data suggest that trade with land neighbors is dominated by surface modes like truck, rail, and pipeline, with perhaps 10 percent of trade going via air or ocean, based on my calculations using data from United Nations Commodity Trade Statistics Database (UN Comtrade), the U.S. Census Bureau's *U.S. Exports/ Imports of Merchandise,* and the Economic Commission for Latin America and the Caribbean's International Transport Database (Base de datos de Transporte Internacional), or the ECLAC BTI, all discussed in more detail in the appendix.

For trade with nonadjacent partners, nearly all merchandise trade moves via ocean and air modes. Bulk commodities like oil and petroleum products, iron ore, coal, and grains are shipped almost exclusively via ocean cargo. Bulk cargoes constitute the majority of international trade when measured in terms of weight, but are a much smaller and shrinking share of trade when measured in value terms.

Manufactured goods are the largest and most rapidly growing portion of world trade. To illustrate how they are transported, Table 1 reports worldwide data on ocean and air shipping of non-bulk-traded goods. Air shipments represent less than 1 percent of total tons and ton-miles shipped, but are growing rapidly. Between 1975 and 2004, air tonnages grew at 7.4 percent per annum, much faster than both

Table 1A
World Trade

	World trade			*World trade*			
	All goods		*Manufactures*	*Quantities of nonbulk cargoes*			
	(2000 US$bn)	*Million tons*	*(2000 US$bn)*	*Million tons*		*Billion ton-miles*	
Year				*Ocean*	*Air*	*Ocean*	*Air*
1951			179				0.2
1955	505	880	222				0.3
1960	623	1080	301	307			0.7
1965	844	1640	453	434		1537	1.8
1970	1152	2605	684	717		2118	4.3
1975	2341	3072	1307	793	3.0	2810	7.7
1980	3718	3704	2009	1037	4.8	3720	13.9
1985	2759	3382	1683	1066	6.5	3750	19.8
1990	4189	4008	2947	1285	9.6	4440	31.7
1995	5442	4651	4041	1520	14.0	5395	47.8
2000	6270	5983	4688	2533	20.7	6790	69.2
2004	8164	6758	6022	2855	23.4	8335	79.2
Annualized growth rates							
Whole sample	7.40	5.37	7.04	5.20		4.43	11.72
1975–2004	4.40	2.76	5.41	4.52	7.37	3.82	8.35

Table 1B
U.S. Air Trade

	U.S.: Air share of trade value (excluding North America)	
Year	*Imports*	*Exports*
1951		
1955		
1960		
1965	8.1	11.9
1970	12.1	19.5
1975	12.0	19.3
1980	13.9	27.6
1985	19.8	36.3
1990	24.6	42.3
1995	33.1	44.3
2000	36.0	57.6
2004	31.5	52.8
Annualized growth rates		
Whole sample	3.55	3.89
1975–2004	3.40	3.53

Sources: World trade data from the World Trade Organization's "International Trade Statistics, 2005," and authors calculations. World air shipments from the International Air Transport Association's (IATA's) *World Air Transport Statistics.* World ocean shipments from United Nations Conference on Trade and Development's *Review of Maritime Transport.* U.S. data from the U.S. Census Bureau's *Statistical Abstract of the United States, U.S. Imports of Merchandise,* and *U.S. Exports of Merchandise.*

ocean tonnage and the value of world trade in manufactures in this period. The relative growth of air shipping is even more apparent in looking at ton-miles shipped, with 11.7 per annum growth rates going back to 1951.

Because the heaviest goods travel via ocean, weight-based data on international trade significantly understate the economic importance of air shipping. Table 1B reports the value share of air shipments in U.S. trade with nonadjacent partners. In the past 40 years, air shipments have grown to represent a third of the value of U.S. imports and more than half of U.S. exports with countries outside North America. Data on mode of transport for international trade are not broadly available for other countries, but the increased U.S. reliance on air shipping does not appear to be an anomaly. Excluding land neighbors, the air share of import value in 2000 exceeded 30 percent for Argentina, Brazil, Colombia, Mexico, Paraguay, and Uruguay (based on author's calculations using data from *U.S. Exports/Imports of Merchandise* and ECLAC BTI).

Why has air transport grown so rapidly? As the next sections show, a major factor has been a sharp decline in the relative cost of air shipping. Less obviously, but perhaps as important, Table 1 shows that a dollar of traded merchandise weighs much less today than in previous years. From 1960–2004, the real value of trade in manufactures grew about 1.5 percent per year faster than the weight of nonbulk cargoes. If bulk commodities are included in the calculation, the real value of all trade grew 1.8 percent faster per year than the weight of all trade.

A fall in the weight/value ratio of trade leads to more air transport for two reasons. First, the marginal fuel cost of lifting a 100 kilogram package into the air is considerably higher than the cost of floating it on water. Second, consumers are sensitive to changes in the delivered price of merchandise, not to changes in the transportation price. If transportation is but a small fraction of the delivered price, then when choosing transport mode, the explicit costs of transportation may be trumped by implicit costs such as timeliness or reliability.

Consider this example. I want to import a $16 bottle of wine from France. Air shipping costs of $8 are twice ocean shipping costs of $4. Going from ocean to air increases the delivered cost by $4 or 25 percent of the original price. Now I want to import a $160 bottle of wine from France. The shipping costs are the same, but the $4 cost to upgrade to air shipping represents just a 2.5 percent increase in the delivered price. The consumer is much more likely to use the faster but more expensive shipping option when the percentage effect on delivered price is smaller.

Similarly, the gains from employing air rather than surface shipping are more pronounced on longer routes. Choosing air transport from the United Kingdom to France might save a shipper five hours, while choosing air transport from China to France might save five weeks. Further, as I show below, the marginal cost of air shipping cargo an additional mile is falling rapidly. These insights help explain a final interesting pattern in the Table 1 data: over time, the average air shipment is getting longer and the average ocean shipment is getting shorter. Combining the tons and ton-miles data (for example 8,335 billion ton-miles/2855 million tons in 2004), ocean-shipped cargo traveled an average of 2,919 miles in 2004, down from

3,543 miles in 1975. In contrast, air-shipped cargo traveled 3,383 miles on average in 2004, up from 2,600 miles in 1975.

Transportation Costs in Perspective

There are three ways to put the economic importance of transportation costs in perspective: by examining 1) transportation costs relative to the value of the goods being moved; 2) transportation costs relative to other known barriers to trade, like tariffs; and 3) the extent to which transportation costs alter relative prices.

Ad Valorem Measures of Transportation Costs

International trade economists typically express transportation costs in ad valorem terms, that is, the cost of shipping relative to the value of the good. This is equivalent to the percentage change in the delivered price as a result of paying for transportation.[1]

The best data for evaluating the ad valorem impact of transportation costs over time comes from a few importers such as New Zealand and the United States that collect freight expenditures as part of their import customs declarations.[2] These data enable us to examine ad valorem transportation costs for an individual good, or to calculate aggregate expenditures on transportation divided by aggregate import value. This aggregate measure is equivalent to an average of ad valorem transport costs for each good, after weighting each good by its share of value in trade.[3]

The New Zealand data cover 1963–1997, a period in which aggregate transportation expenditures fluctuated between a low of 7 percent of import value (in 1970) and a high of 11 percent (in 1974) but exhibited no clear trend. The U.S. data cover 1974–2004, a period in which aggregate expenditures on freight

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[1] Transportation costs drive a wedge between the price at the place of origin and the price at the destination. Denoting the origin price as p, destination price as p^*, and per unit shipping costs as f, $p^* = p + f$. Then the ad valorem percentage change in prices induced by transportation is $p^*/p = 1 + f/p$. A common but inaccurate approach is to model the f term as a constant percentage τ of value shipped, in which case the ad valorem cost is $p^*/p = 1 + \tau p/p = 1 + \tau$ and is independent of the goods price.

[2] Several authors investigating trade growth have employed indirect measures of transportation costs constructed using a "matched partner" technique. In principle, exporting countries report trade flows exclusive of freight and insurance and importing countries report flows inclusive of freight and insurance. If measured without error, comparing the valuation of the same flow reported by both the importer and exporter yields a difference equal to transport costs. However, Hummels and Lugovskyy (2006) show that the "matched partner" technique is subject to enormous measurement error and in fact produces time series variation that is orthogonal to actual variation in shipping costs.

[3] F^k represents transportation expenditures for a single good k. Summing F^k over goods and dividing by the total value of imports gives aggregate expenditures, τ^{agg}, on transportation as a share of trade, $\tau^{\text{agg}} = \Sigma_k F^k / \Sigma_k (pq)^k = \Sigma_k \tau^k s^k$. This is the same as averaging the ad valorem transportation expenditure for each good, $\tau^k = F^k/(pq)^k$, after weighting each good by its share in trade, $s^k = (pq)^k / \Sigma_k (pq)^k$.

declined steadily from about 8 percent of the value of total imports in 1974 down to about 4 percent in 1997 before leveling off. However, the apparent downward trend in the U.S. data may be misleading. The contrast with the New Zealand data and evidence in the next section makes clear that much of the apparent decline in aggregate U.S. transport expenditures in this period is an artifact of the 1974 starting point and the large effect of the oil shock on prices in that year.

Aggregate freight expenditures can paint an incomplete picture of transportation costs. Since the share of trade in a particular product or from a particular exporter tends to be low when shipping costs are high, goods with high transportation costs tend to receive low weights when aggregating. A switch toward more proximate trading partners, or toward more transportable goods, can lower the aggregate value of expenditures on transportation even if true shipping costs are unchanged. Similarly, an increase in transport service quality can raise aggregate expenditures considerably. In the sections below, I provide measures that control for these important compositional shifts.

Transportation Costs vs. Tariffs

Studies examining customs data consistently find that transportation costs pose a barrier to trade at least as large as, and frequently larger than, tariffs. Trade negotiations have steadily reduced tariff rates, with average U.S. import tariffs dropping from 6.0 to 1.5 percent since 1950 (U.S. International Trade Commission) and worldwide average import tariffs dropping from 8.6 to 3.2 percent between 1960 and 1995 (Clemens and Williamson, 2002). As tariffs become a less important barrier to trade, the contribution of transportation to total trade costs—shipping plus tariffs—is rising.

Transport expenditures on the median good were half as much as tariff duties for U.S. imports in 1958 (Waters, 1970) and equal to tariff duties in 1965 (Finger and Yeats, 1976). By 2004, aggregate expenditures on shipping for total imports were three times higher than aggregate tariff duties paid. For the median individual shipment in U.S. imports in 2004, exporters paid \$9 in transportation costs for every \$1 they paid in tariff duties. Moreover, the United States is actually a notable outlier in that it pays *much less* for transportation than other countries. In 2000, aggregate transportation expenditures for major Latin America countries were 1.5 to 2.5 times higher than for the United States (based on author's calculations using *U.S. Imports of Merchandise* and ECLAC BTI data).

Transportation Costs and the Relative Prices of Goods

Ad-valorem transportation costs for a particular product depend on how far the good is shipped, the quality of the transport service offered, and the weight/value ratio of the good. Because all three factors vary considerably across shipments, transportation costs significantly alter relative prices and patterns of trade.

Transportation costs play an especially large role in altering relative prices across exporters and determining bilateral variation in trade. This pattern can be seen by calculating ad-valorem transportation costs for each product in U.S. imports in 2004 and sorting exporters from most to least expensive. For a typical product, exporters in the 90th percentile of costs faced shipping charges that were 11 times greater than those faced by exporters in the 10th percentile. This bilateral variation is considerably more than is found in tariff rates.

Fixing origin and destination, transportation costs also change the relative prices of different goods in the export bundle. The weight/value ratio of a good is a useful summary statistic both for the intensity of transportation services it consumes, and of the impact that transportation costs will have on its delivered price. Compare the cost of shipping $100 of coal (weighing a metric ton) to $100 of computer microchips (weighing a few ounces). The greater weight and bulk of the equivalent value of coal requires greater stowage space and fuel expenditures to move, which means that transportation increases the delivered price of coal relative to microchips. Similarly, compare the impact of transportation costs on the delivered price of a $10 wristwatch and a $1,000 wristwatch of similar weight and size. The $1,000 watch will typically require higher quality transportation services such as more insurance, greater care in handling, and more rapid delivery, but these services are not 100 times more expensive than those demanded for the $10 watch. Hummels and Skiba (2004) estimate that a 10 percent increase in product price leads to an 8.6 percent fall in the ad-valorem transport cost. That is, transportation lowers the delivered price of high-quality relative to low-quality goods.

Air Transport

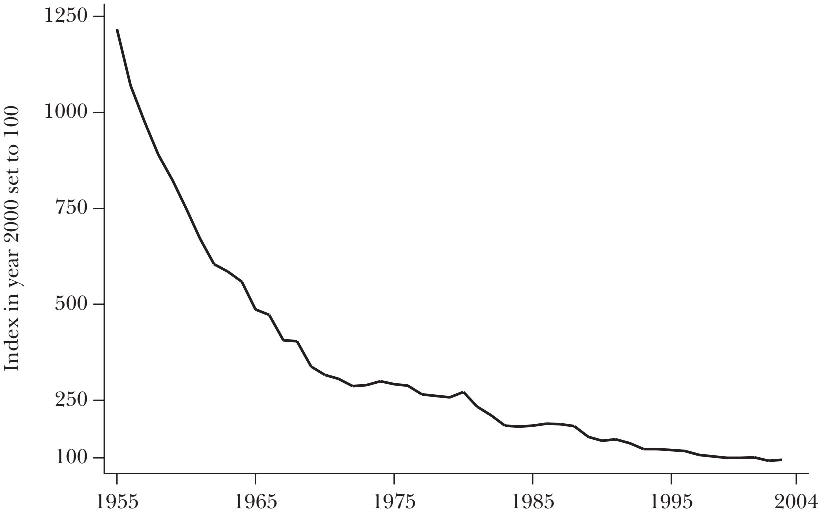
Commercial aviation has undergone rapid technological change, including improvements in avionics, wing design, materials, and most importantly the adoption of jet engines. Jet engines are faster, more fuel efficient and reliable, and require much less maintenance compared to the piston engines they replaced. Gordon (1990) calculates price indices for aircraft that adjust for these quality changes and finds dramatic declines in real prices of aircraft after jet engines were introduced. From 1957–1972, the period in which jet engine usage became widespread, quality-adjusted real prices for aircraft fell at a rate of 12.8 to 16.6 percent per year, depending on the method of calculation. Quality change in commercial aviation slowed considerably after 1972, but quality-adjusted aircraft prices were still dropping by 2.2 to 3.8 percent per year from 1972–1983.

Air Transportation Prices

Data on international air transportation prices are sparsely reported. However, the limited data do paint a clear portrait of decline over time in air shipping prices.

The International Air Transportation Association surveys international air carriers and reports worldwide data on revenues and quantities shipped in their annual *World Air Transport Statistics* (WATS). Figure 1 shows average revenue per ton-kilometer shipped for all air traffic worldwide, indexed to 100 in 2000. Over this 50-year period, this measure of costs per ton fell more than ten times that much.

Figure 1
Worldwide Air Revenue per Ton-Kilometer



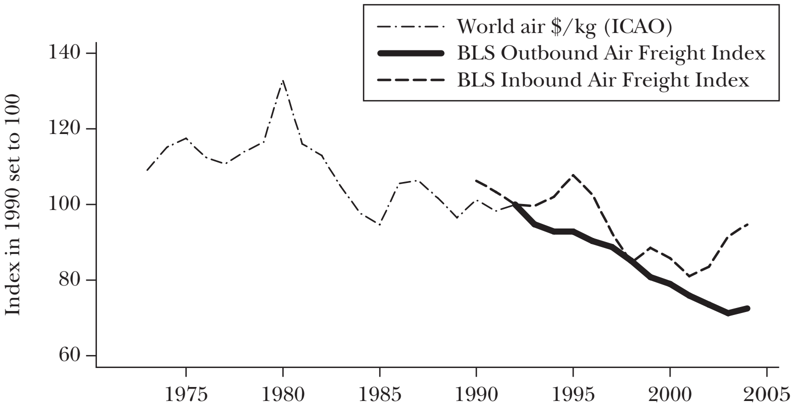
Source: International Air Transport Association, *World Air Transport Statistics,* various years.

Expressed in 2000 U.S. dollars, the price fell from $3.87 per ton-kilometer in 1955 to under $0.30 from 1955–2004. As with Gordon's (1990) measure of quality-adjusted aircraft prices, declines in air transport prices are especially rapid early in the period. Average revenue per ton-kilometer declined 8.1 percent per year from 1955–1972, and 3.5 percent per year from 1972–2003.

The period from 1970 onward is of particular interest, as it corresponds to an era when air transport grew to become a significant portion of world trade, as shown in Table 1. In this period, more detailed data are available. The U.S. Bureau of Labor Statistics reports air freight price indices for cargoes inbound to and outbound from the United States for 1991–2005 at ⟨http://www.bls.gov/mxp⟩. The International Civil Aviation Organization (ICAO) published a "Survey of International Air Transport Fares and Rates" annually between 1973 and 1993. These surveys contain rich overviews of air cargo freight rates (price per kilogram) for thousands of city-pairs in air travel markets around the world. The "Survey" does not report the underlying data, but it provides information on mean fares and distance traveled for many regions as well as simple regression evidence to characterize the fare structure. Using this data, I construct predicted cargo rates in each year for worldwide air cargo and for various geographic route groups.

I deflate both the International Civil Aviation Organization and Bureau of Labor Statistics series using the U.S. GDP deflator to provide the price of air shipping measured in real U.S. dollars per kilogram, and normalize the series to equal 100 in 1992. The light dashed lines in Figure 2 report the ICAO time series on worldwide air cargo prices from 1973–1993 (with detailed data on annual rates of change for each ICAO route group reported in the accompanying note).

Figure 2
Air Transport Price Indices



Source: International Civil Aviation Organization (ICAO), "Survey of Air Fares and Rates," various years; U.S. Department of Labor Bureau of Labor Statistics (BLS) import/export price indices, http://www.bls.gov/mxp/.

Notes: ICAO Data on Route Groups:

Annualized growth rates for 1973–80 of shipping price per kg (in year 2000 dollars): All routes 2.87; North Atlantic 1.03; Mid Atlantic 3.45; South Atlantic 3.98; North and Mid Pacific −3.43; South Pacific −2.49; North to Central America 3.63; North and Central America to South America 2.34; Europe to Middle East 4.80; Europe and Middle East to Africa 1.84; Europe/Middle East/Africa to Asia/Pacific 3.32; Local Asia/Pacific 0.97; Local North America 1.63; Local Europe 4.51; Local South America 2.53; Local Middle East 1.92; Local Africa 4.94.

Annualized growth rates for 1980–93 of shipping price per kg (in year 2000 dollars): All routes −2.52; North Atlantic −3.59; Mid Atlantic −3.36; South Atlantic −3.92; North and Mid Pacific −1.48; South Pacific −0.98; North to Central America −0.72; North and Central America to South America −1.34; Europe to Middle East −3.02; Europe and Middle East to Africa −2.34; Europe/Middle East/Africa to Asia/Pacific −2.78; Local Asia/Pacific −1.52; Local North America −1.73; Local Europe −2.63; Local Central America 0.97; Local South America −2.25; Local Middle East −1.46; Local Africa −2.43.

Pooling data from all routes, prices increase 2.87 percent annually from 1973 to 1980 and then decline 2.52 percent annually from 1980 to 1993. The increases in the first period largely reflect oil price increases. The timing of the rate reduction also coincides well with the WATS data, which show little price change in the 1970s and more rapid declines in the 1980s. The post-1980 price declines vary substantially over routes, with longer routes and those involving North America showing the largest drops.

Bureau of Labor Statistics data on air freight outbound from the United States for 1992–2004 are plotted with the solid line in Figure 2, while inbound data to the United States for 1991–2004 are plotted with the thick dashed line. The real price of outbound air freight fell consistently at a rate of 2.1 percent per year in this period. The real price of inbound air freight fell 2.5 percent per year from 1990–2001 and then rose sharply (4.8 percent per year) thereafter, perhaps reflecting greater security costs after September 11, 2001.

Whether looking at quality-adjusted prices for aircraft, simple average revenue measures of air transportation prices, or more carefully constructed air freight price indices, one sees a clear picture. Prices drop precipitously after the introduction of jet engines, and at a slow, steady pace in the three decades thereafter.

Ocean Transport

Ocean transport of dry (non-oil) cargo consists of two distinct markets: tramp and liner shipping. Tramps have traditionally been used for shipping large quantities of bulk commodities on a charter basis, with shipping prices set in spot markets. In recent years, a small fraction of containerized tramps have been employed to lift general cargoes. Liners are used for "general" cargoes—that is, all but large quantity bulk cargoes—and ply fixed trade routes in accordance with a predetermined timetable. The liner trade is organized into cartels, or conferences, which discuss, and perhaps collude in, the setting of prices and market shares. The extent to which these cartels are able to charge monopoly markups is an open question in the literature. Davies (1986) argues that, despite apparent collusive behavior by the liner conferences, the general cargo market is contestable and that this prevents incumbent firms from colluding to raise rates. Sjostrom (1992) reviews an older empirical literature that links shipping prices to product prices as evidence for market power. More recently, Hummels, Lugovskyy, and Skiba (2007) show that liners charge shipping prices that are much higher for goods whose import demand is relatively inelastic, which is precisely what one would expect if shipping firms were exercising market power.

Ocean shipping has undergone several important technological and institutional changes in the postwar era: the growth of open registry shipping, scale effects from increased trade volumes, and the introduction of containerization. Open registry shipping is the practice of registering ships under flags of convenience—for example, Liberia or Panama—to circumvent higher regulatory and manning costs imposed by wealthier nations. Open registry fleets comprised 5 percent of world shipping tonnage in 1950, 31.1 percent in 1980, and 48.5 percent in 2000 (OECD, *Maritime Transport,* for 1950; UNCTAD, *Review of Maritime Transport,* various years). Tolofari (1986) estimates that vessel operating costs for open registry ships are from 12 to 27 percent lower than traditional registry fleets, with most of the estimated savings coming from manning expenses.

The rise in world trade may have had significant impacts on shipping prices through scale effects. In periods of rapidly rising demand, shipping capacity becomes scarce and spot shipping prices rise quickly. Over longer periods however, rising demand for shipping may actually lower shipping prices. The reason is that the capacity of a modern ocean-going liner vessel is large relative to the quantities shipped by smaller exporting nations. As a consequence, vessels may stop in a dozen ports and in many different countries to reach capacity. As trade quantities increase, it is possible to realize gains from several sources more effectively. First, trade growth along a route promotes entry with rival liner companies competing away transportation markups. This effect is not trivial; in 2006, one in six importer-exporter pairs was served by a single liner service, and over half were served by three or fewer (Hummels, Lugovskyy, and Skiba, 2007). Service also becomes more frequent, with days rather than weeks elapsing between vessel calls in port. Second, a densely traded route allows for effective use of hub-and-spoke shipping economies—small container vessels move cargo into a hub where containers are aggregated into much larger and faster containerships for longer hauls. Examples include the European hub of Rotterdam, as well as Asian hubs in Singapore and Hong Kong. Third, the movement of some goods, like bulk commodities, crude oil, refrigerated produce, and automobiles requires specialized vessels. Increased quantities of trade allow introduction of these specialized ships along a route. Similarly, larger ships will be introduced on heavily traded routes, and these ships enjoy substantial cost savings relative to older smaller models still in use.

An example of these effects in combination can be seen in the introduction of containerized shipping. Containerized shipping is thought by many specialists to be one of the most important transportation revolutions in the twentieth century; Levinson (2006) provides an excellent and accessible popular history of containerization and its effects. The use of standardized containers provides cost savings by allowing goods to be packed once and moved over long distances via a variety of transport modes—truck, rail, ocean liner, rail, then truck again—without being unpacked and repacked. In this way, containerization reduces direct port costs such as storage and stevedoring (port labor) as well as indirect costs incurred during lengthy port stops (the rental rate on unused capital while a ship sits idle in port). The indirect costs are critical: estimates place break-bulk (noncontainer) cargo ships' time in port at one-half to two-thirds of the ship's life (UNCTAD, *Unitization of Cargo,* 1970). Containerization also creates savings on the ocean leg. Larger and faster ships substantially reduce the price per ton-mile while the ship is steaming, but they incur higher indirect port costs (idle time) in proportion to their increased capital expense (Gilman, 1983). Because containerships spend more time steaming, investments in larger, faster ships become feasible.

Containerized shipping was first introduced in the United States in the 1960s, then on U.S.–Europe and U.S.–Japan routes in the late 1960s and into the 1970s, then to developing countries from the late 1970s onward. The reason behind this seemingly slow pattern of diffusion lies in the large fixed costs of adoption, and the differential cost savings that containers yield. To make full use of containerization requires container-ready ocean liners and ports adapted to container use, which require specialized cranes, storage areas, and rail-heads. As a result, containerization was first adopted on the most heavily traded routes. Developing nations were especially slow to adopt, both because of lower scale and because of factor prices. In countries where capital is scarce and labor abundant, the capital cost of building container ports is higher, and the port labor cost savings of containers much lower.

Price Indices

Have technological and institutional changes resulted in lower ocean shipping prices? To answer this I examine price indices, based on U.S. dollars per quantity shipped, for tramp and liner shipping. Many such indices exist, but two stand out for their length of coverage.

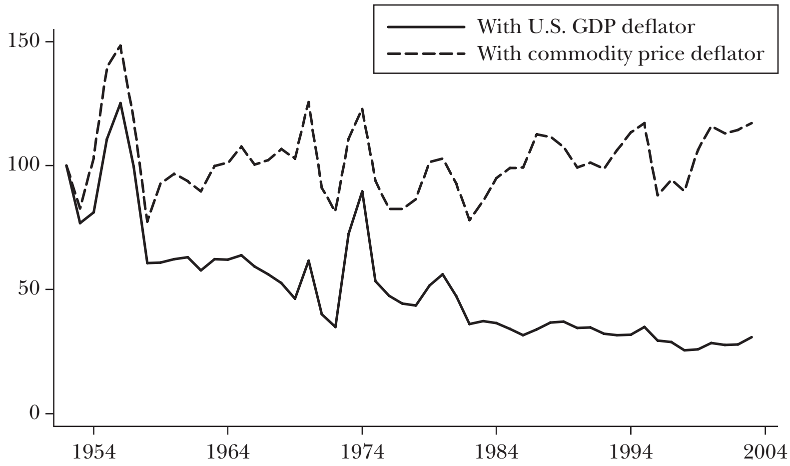
For the price of tramp trip charters, I will focus on the index originally constructed by the *Norwegian Shipping News (NSN)* and later continued by *Lloyd's Shipping Economist.* A trip charter is a contract to ship a large quantity of a dry bulk commodity between specific ports, and may include some minimal loading and/or unloading expenses. The trip charter price index represents a weighted bundle of spot market prices, measured in U.S. dollars per ton, for shipping major bulk commodities on several important routes worldwide.

For the price of liner shipping, I will focus on an index constructed by the German Ministry of Transport. The liner index emphasizes general cargoes, including containerized shipping and manufactured merchandise of all sorts, and so is more representative of the commodity composition of the majority of world trade. It also covers loading and unloading expenses, which are particularly relevant since reductions in cargo handling costs are thought to be a major source of gains from containerization. This index does not offer comprehensive geographic coverage, focusing only on liners loading and unloading in Germany and the Netherlands.

To evaluate the real costs of shipping over time, an appropriate deflator must be chosen. Tramp prices are set in competitive markets and quoted in U.S. dollars. I deflate these indices using the U.S. GDP deflator, and also using a price index for bulk commodities typically shipped via tramps. This commodity index includes the price of iron ore and various grains, based on the price series taken from *International Financial Statistics* published by the IMF. Using the U.S. GDP deflator provides a constant dollar value for the unit price of tramp shipping a given quantity of merchandise. Using the bulk commodity price index yields the price of shipping a bundle of goods relative to the price of that bundle, a crude measure of the ad valorem barrier posed by shipping costs. The liner index is deflated using the German GDP deflator, and a composite traded goods price index for Germany.

Figure 3 displays the price series for trip charters and shows several price spikes. The price spikes in the 1970s are clearly attributable to oil price shocks, and the price spike in the 1954–1957 period is probably due to a combination of high demand from unexpectedly large U.S. grain exports to Europe and the Suez Canal Crisis. The latter led to sharply increased war premiums and expensive rerouting of ships on Asia–Europe trade routes when the Suez Canal was closed. Setting aside these spikes, we can see two clear trends. The price of bulk shipping measured in real dollars per ton (the solid line) has declined steadily over time so that it is now half as much as in 1960 and a third the price in 1952. However, when measured relative to the commodity price deflator (the dashed line), there are large fluctuations but no downward trend. While the cost of shipping a ton of wheat or iron ore

Figure 3
Tramp Price Index
(with U.S. GDP deflator and with commodity price deflator)



Source: United Nations Conference on Trade and Development, *Review of Maritime Transport,* various years.
Note: Tramp prices deflated by a U.S. GDP deflator and tramp prices deflated by commodity price deflator.

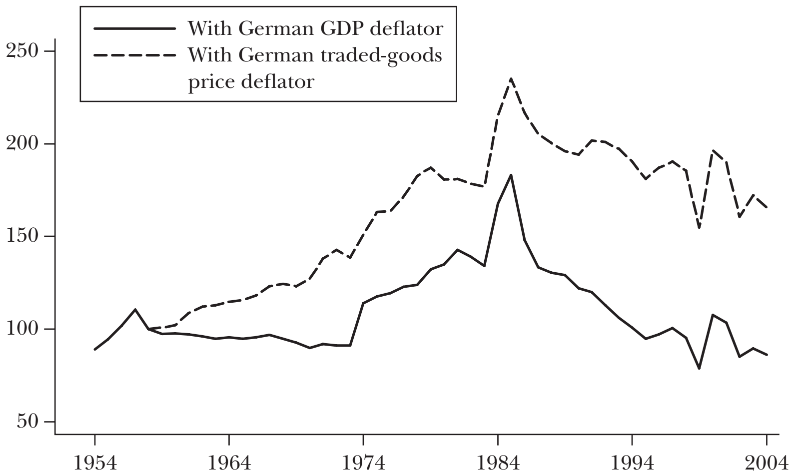
has steadily declined, the cost of shipping a dollar value of wheat or iron ore has not.

Figure 4 displays the liner price time series. Measured relative to traded goods prices, liner prices rise steadily against German import prices before peaking in 1985. Measured relative to the German GDP deflator (solid line), liner prices decline until the early 1970s, rise sharply in 1974 and throughout the late 1970s, spike in the 1983–1985 period, then decline rapidly thereafter.

The very sharp increases in the German cost of shipping from 1983–1985 is likely due to the rapid real depreciation of the German deutschemark in this period, which made German purchases of all international goods and services more expensive. Accordingly, the 1983–85 spike is probably not representative of what happened worldwide in this short period.

However, the rapid liner price increases facing Germany in the 1970s did occur more broadly. Throughout the 1970s, UNCTAD's annual *Review of Maritime Transport* reported in some detail price changes announced by shipping conferences, with annual nominal increases of 10–15 percent being common across nearly all routes. The same publication also reports the ad valorem shipping rates for a small number of specific commodities and routes from 1963–2004. Examples include rubber shipped from Malaysia to Europe, cocoa beans shipped from either Ghana or Brazil to Europe, and tea shipped from Sri Lanka to Europe. Converted to real dollars per quantity shipped, these liner prices increased by 67 percent in the 1970s.

Figure 4
Liner Price Index
(with German GDP deflator and with German traded goods price deflator)



Source: United Nations Conference on Trade and Development *Review of Maritime Transport,* various years.
Note: Liner prices deflated by a German GDP deflator and liner prices deflated by a German traded-goods price deflator.

Why Didn't Containerization Reduce Measured Ocean Shipping Rates?

These liner rate increases reported in Figure 4 are especially surprising given that they occurred shortly after the introduction of containerization to European liner trades. If containerization and the associated productivity gains led to lower shipping prices, as is widely believed and as Levinson (2006) qualitatively argues, the effect should appear in the liner series. Yet liner prices exhibit considerable increases, both in absolute terms and relative to tramp prices after containers are introduced. Further, data series that span the introduction of containerization, such as the New Zealand imports data and the UNCTAD *Review of Maritime Transport* series measuring costs for specific goods and routes, show no clear decline either.

One possible explanation for this puzzling finding is that the real gains from containerization might come from unmeasured quality change in transportation services. Containerships are faster than their predecessors, and for loading and unloading are much quicker than with break bulk cargo. In addition, containers allow cargo tracking, so that firms know precisely where goods are en route and when they will arrive. As I describe in more detail below, speed improvements are of substantial and growing value to international trade. To the extent that these quality improvements do not show up in measured price indices, the indices understate the value of the technological advance.

Still, many of the purported improvements of container shipping should have lowered explicitly measured ocean shipping costs, and apparently did not. Why?

Levinson (2006) argues that the historical data series are inadequate for capturing the true cost savings of containerization. Measuring the true impact of containers requires data on freight prices for similar goods and routes, with some shipments using containers while others do not. The U.S. Waterborne Trade Database has such data for 1991–2003. Blonigen and Wilson (2006) use these data to estimate the dependence of shipping costs on container usage in the cross-section. They show that, at a point in time, increasing the share of trade that is containerized by 1 percent lowers shipping costs by only .05 percent. If these cost estimates apply equally well to the introduction of containerization in the longer time series, the quantitative impact of containers on reducing shipping costs may have been modest, even if all else were held equal.

But all else was not equal. In the period during which containerization was spreading, input costs, including fuel, ship prices, and port costs, were skyrocketing. Sletmo and Williams (1981) report that liner operating costs rose 14–18 percent per annum in the 1970s as a result of the oil price shocks, with an especially large impact for more fuel-hungry containerships. They further report that while shipbuilding prices increased fleetwide, they rose twice as fast for containerships as for conventional freighters, attributing the difference to a more intensive use of steel and labor in containerships. A UNCTAD (1977) study, "Port Problems," revealed port cost increases in the 1970s ranging from 10 to 40 percent per annum, resulting in an overall increase in liner conference costs of as much as 7.5 percent per annum.

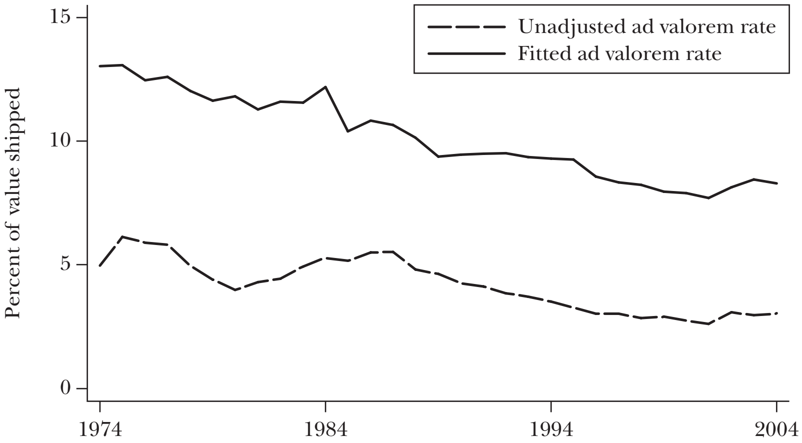
The Role of Technology, Composition, and Cost Shocks: Evidence from U.S. Customs Data

My discussion to this point has told a number of plausible stories about the causes of the changing costs of international transportation over time, but given the fragmented and partial international evidence on these transportation costs, it has not tested these hypotheses. In this section, I offer some regression evidence on how changes in technology, composition of trade, and cost shocks affect international transportation costs. I will rely here on *U.S. Imports of Merchandise* data for 1974–2004, which report value of imports from each exporter with commodities disaggregated to the five-digit SITC level. These data provide extremely detailed shipment characteristics including transport mode (air, ocean, land); weight; value; freight and insurance charges; and duties.

The first step is to construct data series on ad valorem transportation costs for air shipping and ocean shipping. The dashed line in Figure 5 reports an unadjusted measure of ad valorem air shipping costs: that is, aggregate expenditures on air shipping divided by the value of airborne imports. This line trends down slowly, dropping only 2 percentage points over 30 years.

As discussed earlier, measures of aggregate transportation expenditures calcu-

Figure 5
Ad Valorem Air Freight



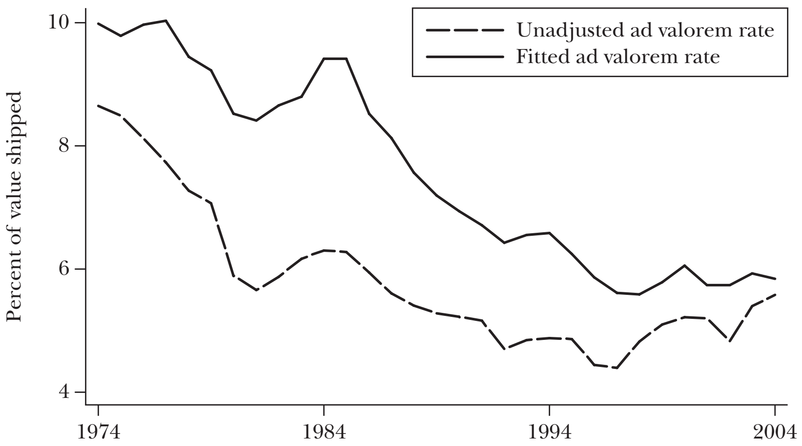
Source: Author's calculation based on U.S. Census Bureau *U.S. Imports of Merchandise.*
Note: The unadjusted ad valorem rate is simply expenditure/import value. The fitted ad valorem rate is derived from a regression and controls for changes in the mix of trade partners and products traded.

lated in this way do not take into account changes in the mix of trade partners or products traded. Thus, the next step is to construct a value for ad valorem air shipping costs that controls for these changes in composition. I use a regression in which the dependent variable is the ad valorem air freight cost in logs for commodity k shipped from exporter j at time t. The independent variables include a separate intercept for each exporter-commodity shipped, the weight/value ratio in logs for each shipment, and year dummy variables. The exporter-commodity intercepts control for the fact that iron-ore from Brazil has higher transportation costs in every period than shoes from Taiwan, and the weight/value ratio controls for compositional change over time within an exporter-commodity, for instance, Taiwan shipping higher quality shoes.

The resulting fitted trend (the solid line) in Figure 5, is the value of the dummy variable for each year and is equivalent to ad valorem transportation expenditures after controlling for compositional change. Once changes in the trade partner and product mix have been taken into account, the fitted ad valorem cost exhibits a greater absolute decline in air transportation costs.

Figure 6 provides a parallel picture for ocean shipping. Again, the dashed line shows aggregate expenditures on ocean shipping divided by total value of ocean shipping in each year. It shows an initially rapid decline in transportation expenditures, followed by a 25-year period in which rates fluctuate but do not otherwise decline. To control for compositional change, I use the same regression as with air shipping only now the dependent variable is the ad valorem ocean freight cost in logs for commodity k shipped from exporter j at time t. The solid line shows the

Figure 6
Ad Valorem Ocean Freight



Source: Author's calculations based on the U.S. Census Bureau's *U.S. Imports of Merchandise.*
Note: The unadjusted ad valorem rate is simply expenditure/import value. The fitted ad valorem rate is derived from a regression and controls for changes in the mix of trade partners and products traded.

coefficient on the dummy variables by year, which represents ad valorem ocean shipping costs after controlling for exporter-commodity composition and changing weight/value ratios. The fitted rates decline initially, then increase through the mid-1980s, then decline for the subsequent 20 years.

Figures 5 and 6 reveal a seeming paradox in the data. Even though the aggregate weight/value ratio of trade is falling, the weight/value ratio for both air and ocean shipping is increasing. How can this be? If we arrange goods along a continuum from heaviest to lightest, goods at the heaviest part of the continuum tend to be ocean shipped, and those at the lightest part tend to be air shipped. This pattern can be seen in the level of the ad valorem freight expenditures (dashed lines) in Figures 5 and 6, where ocean shipping appears to be more expensive than air shipping. It is not: the higher costs incurred for ocean shipping are due to the fact that the average ocean-shipped manufactured good is 25 times heavier than the average air-shipped manufactured good. As the relative price of air/ocean shipping falls, goods at the margin shift from ocean to air shipping (Harrigan, 2005, provides a formal model of this process). Relative to the set of air-shipped goods, these marginal goods are heavy, and the average weight of air-shipped goods rises. But relative to the set of ocean-shipped goods, these marginal goods are light, and by losing them the average weight of ocean-shipped goods rises as well. The difference between the unadjusted and the fitted lines in Figures 5 and 6 show this compositional shift in effect. Fitted costs for air and ocean shipping that control for this shift exhibit larger declines for both ocean and air shipping than aggregate expenditures, which fail to control for the shift.

The U.S. import data can also be used to examine what determines the level

Table 2

Determinants of Transportation Costs over Time

(dependent variable is the ad valorem freight cost in logs for commodity k *shipped from exporter* j *at time* t*)*

Elasticity of ad-valorem freight costs with respect to:	*Air shipments* (1)	*Air shipments* (2)	*Ocean shipments* (3)	*Ocean shipments* (4)
Weight/Value	0.492*	0.494*	0.410*	0.374*
Fuel costs	0.263*	0.055*	0.327*	0.232*
Distance	0.269*	0.436*	0.151*	
Distance × Trend		−0.009*		
Trend		0.060*		
Containerized share of trade			−0.029*	−0.134*
N	777966	777966	763997	787418
R^2	0.51	0.52	0.37	0.33

Source: Authors' calculations based on data from the U.S. Census Bureau's *U.S. Imports of Merchandise.*
Note: The dependent variable is the ad valorem air freight cost in logs for commodity *k* shipped from exporter *j* at time *t*. In column one, the independent variables (all in logs) are the weight/value ratio of each shipment, fuel costs in each year, and the distance shipped between the exporter and the U.S. entry port. Column two adds a yearly trend, and an interaction between distance shipped and the yearly trend. Regressions for columns 1, 2, and 3 include commodity (SITC 5 digit) fixed effects. Regressions for Column 4 includes exporter-commodity fixed effects.
* Significant at 1% confidence level.

of shipping costs and what causes shifts in transportation costs over time. For the first two columns of Table 2, the dependent variable is the ad valorem air freight cost in logs for commodity *k* shipped from exporter *j* at time *t*. In column one, the independent variables (all in logs) are the weight/value ratio of each shipment, fuel costs in each year, and the distance shipped between the exporter and the U.S. entry port. Column two adds a yearly trend as well as an interaction between distance shipped and the yearly trend. In both columns, I include separate intercepts for each commodity to control for differences in shipping expenses across goods that do not change over time.

Ad-valorem air transportation costs are increasing in the weight/value ratio of the good, jet fuel expenses, and the distance shipped. Interestingly, the effect of distance is steadily eroding over time. In 1974 the elasticity of air transportation costs with respect to distance was 0.43, but had dropped to 0.16 by 2004. To better understand the impact of this change, we can calculate the air shipping price paid by an exporter 14,000 kilometers from the United States compared to an exporter 2,000 kilometers away. The distant exporter would have paid air shipping prices that were 2.3 times that of the proximate exporter in 1974, but only 1.3 times that of the proximate exporter in 2004.

If we measure prices in units of price/kilogram, we can use the coefficient on weight/value to calculate the freight charges faced by high- and low-priced goods.

For example, a volume of shoes that is worth \$100 per kilogram will face much lower ad valorem costs of air shipping than shoes worth \$10 per kilogram:

$$f^{\$100}/f^{\$10} = \left(\frac{\$100/kg}{\$10/kg}\right)^{0.494-1} = .31.$$

As Schott (2003) notes, the variance of U.S. import prices within a particular product category has grown over time. As the spread between high-priced and low-priced goods in each product category widens, the cost advantage enjoyed by high-end goods is growing over time.

In column three of Table 2, the dependent variable is the ad valorem ocean freight cost in logs for commodity *k* shipped from exporter *j* at time *t*. As before, the independent variables include the weight/value ratio of the shipment, fuel costs, distance shipped, and a separate intercept for each commodity. To this, I add the exporter's share of trade that is containerized in that year. This regression allows me to see whether exporters who containerize their trade enjoy lower shipping expenses after we control for the composition of trade and fuel costs in each year. Finally, some exporters may have systematically higher transportation costs in all years. If this is related to the prices (value/weight) of goods they trade, or the likelihood that they will adopt containerized cargoes, it will lead to biased estimates of these coefficients. In column four, I include separate intercepts for each exporter-commodity so that the regression only uses time series changes to identify each effect.

Ocean shipping costs are increasing in the shipment's weight/value ratio, fuel costs, and distance shipped. The measured effect of container usage is quite a bit different when comparing columns three and four. When using cross-country information in column three, we find a very small effect—doubling the share of trade that is containerized lowers shipping costs by only 2.9 percent. But when controlling for cross-country differences and looking at growth in container usage over time in column four, we find that doubling container usage lowers shipping costs by 13.4 percent.

Figures 5 and 6 show steady downward trends in U.S. ocean and air shipping prices. However, part of this apparent decline may be due to the fact that the U.S. data series starts in 1974 when oil prices—a critical transportation input—were unusually high. The elasticity of transportation costs with respect to fuel prices reported in Table 2 is especially useful as it enables us to approximate what costs might have been prior to the 1974 oil shock. Ocean bunker fuel prices rose four-fold in real terms between 1973 and 1974. Combining this with the measured elasticity of 0.232 in the fourth column of Table 2 implies a 92 percent increase in ocean shipping costs in this year. That estimate matches very closely the estimates of fuel-related cost increases constructed from shipping fleet microdata (Sletmo and Williams, 1981). Taking the average fitted value of ocean shipping costs in 1974 from Figure 6 (9.9 percent ad valorem) and using this implied cost shock gives 1973 ad valorem ocean costs of 5.2 percent—a level comparable to rates in 2000.

Taken together, the evidence from Table 2 supports the qualitative and anecdotal evidence on ocean transportation described above. Containerization significantly reduced ocean shipping costs, but evidence of this effect in aggregate data was originally overshadowed by the dramatic increases in input costs in the 1970s. As Figures 4 and 6 clearly show, it was only when crude oil prices began to drop in the mid 1980s that ocean shipping costs really began to fall.

Implications: Transportation and the Changing Nature of Trade

Transportation Quality and Speed of Delivery

To this point, I have focused on the cost of shipping a good while taking the quality of the transportation service as fixed. However, the quality of international transport has improved over the past 30 years, with the most notable gain being shorter transportation time. Ocean liner service itself has become much faster than in years past, both because the ships are larger and faster, and because their loading and unloading time is dramatically lowered by containerization. But even after these improvements, ocean shipping is still a slow process. Shipping containers from Europe to the U.S. Midwest requires 2–3 weeks; from Europe to Asia requires five weeks. In contrast, air shipping requires a day or less to most destinations. Consequently, the ten-fold decline in air shipping prices since the late 1950s means that the cost of speed has fallen dramatically.

The economic effect of the declining cost of speed depends on how valuable timeliness is in trade. In Hummels (2001), I estimate a demand for timeliness by examining the premium that shippers are willing to pay for speedy air shipping relative to slow ocean shipping. There are two effects. First, every day in ocean travel time that a country is distant from the importer reduces the probability of sourcing manufactured goods from that country by 1 percent. Second, conditional on exporting manufactures, firms are willing to pay just under 1 percent of the value of the good per day to avoid travel delays associated with ocean shipping. Falling air transportation costs can then help explain trade growth: those goods with the highest estimated time sensitivity have exhibited the most rapid growth in trade.

Time in transit doesn't matter much for bulk commodities and simple manufactures. But for goods like fresh produce and cut flowers, lengthy travel times lead to spoilage. More generally, if there is uncertainty in demand plus lags between production and final sales, firms may face a mismatch between what consumers want and what the firm has available to sell. In the case of apparel, for example, firms are unable to predict in advance which fashions will be especially popular, making the ability to respond quickly to revelation of market information an important advantage. Evans and Harrigan (2005) show that clothing lines with high restocking rates are more likely to be obtained from exporters closest to the U.S. market. Aizenman (2004) argues theoretically and Schaur (2006) shows empirically that the use of airplanes is an alternative solution to the timeliness problem when foreign demand is uncertain. By using a mix of ocean and air shipping, firms can respond rapidly to demand shocks, essentially using airplanes as a real hedge for market volatility.

There are several factors that may explain increases in time sensitivity in the past decades. As the composition of trade has shifted from commodities to more complex manufactures, time sensitivity grows. Also, as consumer incomes rise, their willingness to pay for precise product characteristics grows. That in turn puts pressure on manufacturers to produce to those specifications and to be rapidly adaptable. Finally, Harrigan and Venables (2004) examine a model of location choice with industrial demand for inputs and the presence of uncertainty (in demand, in production costs, and in the timing of delivery). Their model shows that the need to respond to uncertainty in a timely way creates an important force for agglomeration—for locating firms producing industrial inputs near the downstream firms that will use those inputs. However, as an empirical matter, recent decades have seen rapid growth in international vertical specialization, a process by which firms separate the stages of production (R&D, component production, assembly) across countries according to comparative advantage (Hummels, Ishii, and Yi, 2001). How can a growing need for timeliness in industrial demands coincide with a growing dispersal of operations around the globe? Faster transport provides an answer.

Distance and Trade

Transportation costs co-vary with distance and are larger and exhibit much greater variability across exporters than do tariffs. This provides a plausible explanation for one of the most robust facts about trade: countries trade primarily with neighbors. Roughly a quarter of world trade takes place between countries sharing a common border, and half of world trade occurs between partners less than 3,000 kilometers apart (Berthelon and Freund, 2004). Even after controlling for other plausible correlates such as country size, income, and tariff barriers, the distance between partners explains much of bilateral trade volumes.

Recent changes in transportation would seem to suggest that the grip of distance should be weakening. Air transport tends to be preferred to ocean transport on especially long-distance shipments (Harrigan, 2005). As the level of air transport costs drop relative to the level of ocean transport, long distance trade becomes relatively more attractive. Further, as Table 2 shows, the marginal cost of an additional mile of air transport is dropping rapidly. Strangely then, the distance profile of world trade is little changed over the past 40 years (Berthelon and Freund, 2004; Disdier and Head, 2004). This pattern presents a significant puzzle for future research.

Conclusions

Changes in international transportation in the second half of the twentieth century are more than just a story of declining costs. For air shipping, to be sure, advances in technology have propelled a sharp decline in costs: average revenue per ton-kilometer shipped dropped by 92 percent between 1955 and 2004. As a result, air shipping grew in this period from an insignificant share of trade to a third of U.S. imports by value and half of U.S. exports outside of North America.

Ocean shipping, which constitutes 99 percent of world trade by weight and a majority of world trade by value, also experienced a technological revolution in the form of container shipping, but dramatic price declines are not in evidence. Instead, prices for ocean shipping exhibit little change from 1952–1970, substantial increases from 1970 through the mid-1980s, followed by a steady 20-year decline. That is not to say that the container revolution is unimportant; after all, estimates in this paper show that increasing the share of trade that is containerized lowers shipping costs from 3 to 13 percent. However, these savings were trumped in the 1970s by sharp increases in fuel and port costs. Indeed, ocean freight costs in recent years have again begun to increase with the cost of crude, and port congestion has become an especially severe problem in those countries with rapidly growing trade volumes (Bajpai, Carruthers, and Hummels, 2003).

Economic historians have argued that technological change in ocean shipping was the critical input to growing trade in the first era of globalization during the latter half of the nineteenth century. I would argue that technological change in air shipping and the declining cost of rapid transportation has been a critical input into a second era of globalization during the latter half of the twentieth century. There is perhaps a third era in cross-border trade unfolding even now, again driven by rapid improvements in a technology for connecting people across great distances. Clearly, the telecommunication and Internet revolution has already affected international integration, leading to growing trade in information and technology, in services outsourcing, and in migration of highly skilled professionals. The impact of these changes and the extent to which they displace older forms of integration bear close watching in the years to come.

Appendix
Notes on Data Sources

Much of the data used in this paper, including the New Zealand customs data, some transportation-focused extracts of the U.S. customs data, and data series collected from various issues of paper publications of the International Civil Aviation Organization's *Survey of International Air Transport Fares and Rates,* the International Air Transport Association's (IATA's) *World Air Transport Statistics,* and United Nations Conference on Trade and Development's (UNCTAD's) *Review of Maritime Transport,* can be most easily obtained directly from the author's website at ⟨http://www.mgmt.purdue.edu/faculty/hummelsd/research/jep/data.html⟩. Going forward, the IATA and UNCTAD publications are updated annually and an excellent source of ongoing information.

The best source of customs data that includes transportation costs is *US Imports of Merchandise,* available on CDs for 1990–2006. These can be obtained directly from the U.S. Census Bureau, and many university libraries have monthly and/or annual data CDs back to 1990. Rob Feenstra has posted annual extracts of these data (including freight expenditures, but lacking transportation mode or entry port detail) from 1974 to 2001 at ⟨http://www.nber.org/data/⟩. Similar data have been collected for the last 10 years for many Latin American countries by the Economic Commission for Latin America and the Caribbean ECLAC in the form of the International Transport Database (Base de datos de Transporte Internacional), or BTI (see ⟨http://www.eclac.cl/transporte/perfil/index.htm⟩). The U.S. Maritime Administration provides a great deal of useful data at its website ⟨http://www.marad.dot.gov⟩, including the U.S. Waterborne Trade Database. It contains much of the same detail as the *U.S. Imports of Merchandise* data, but with more information on port usage, whether cargo is containerized, and whether it is shipped by liner or tramp.

Finally, several private and public organizations provide detailed data on international trade and transportation issues. Among the best are the U.S. Bureau of Transportation Statistics at ⟨http://www.bts.gov⟩ and the Air Transport Association at ⟨http://www.airlines.org/economics⟩.

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