The Impact of Distance on U.S. Agricultural Exports: An Econometric Analysis

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Introduction

Overcoming distance has always been an important issue in marketing agricultural products. Agricultural economists have examined the role of distance intermittently (Thompson, 1981). International trade economists have long ignored distance until recently as described by Paul Krugman:

> [T]he analysis of international trade makes virtually no use of insights from economic geography or location theory. We normally model countries as dimensionless points within which factors of production can be instantly and costlessly moved from one activity to another, and even trade among countries is usually given a sort of spaceless representation in which transport costs are zero for all goods that can be traded.
> (Paul Krugman, *Geography of Trade,* 1996)

There are three types of costs in shipping agricultural products: physical shipping costs, time-related costs, and the costs of unfamiliarity (Linnemann, 1966). Collectively, these costs represent a natural tariff that limits trade. The removal or reduction of these costs would have an impact on trade similar to the impact of the removal or reduction of a tariff.

While income growth and trade liberalization around the world are generally believed to be key determinants in the expansion of global food and agricultural trade, advances in technology that have lowered transportation and communication costs have also contributed to this expansion.

One way of measuring the trade effects of distance is the distance elasticity, which describes the change in trade with respect to a change in distance. The expectation is the greater the distance, the more inhibiting effect it has on trade, all other variables constant. A larger elasticity implies that distance has a greater impact on the trade of a particular item than would be the case with a smaller elasticity. A declining distance elasticity over time implies that distance is having less impact on trade with the passage of time. According to the literature, however, the estimated trade effects of distance, a proxy for transportation costs, are not diminishing over time. Using a gravity model, Leamer (1993) estimated a distance elasticity in 1985 not dramatically smaller than one estimated for 1970. Boisso and Ferrantino (1997) generated similar findings for their year-by-year estimates between 1950 and 1988. Eichengreen and Irwin (1997) showed that the effects of distance on trade did not diminish during the inter-war period, nor in 1949, 1954, and 1964. Frankel (1997) concluded from a survey of gravity model results that there was no statistical evidence of a decline in the distance elasticity for trade in the past century.

Most of the above results, however, were obtained from aggregated data, often total bilateral trade among trading countries, not based on specific commodities such as detailed food and

agricultural products. Recent developments in transportation and communication technology may have played an important role in reducing shipping costs, particularly for perishable products and possibly for other food products. We believe it is, therefore, important to let the empirical analysis inform us about the impact that distance has had on specific agricultural goods.

A key distinguishing characteristic of many food and agricultural products is perishability, which requires refrigeration and prompt delivery to the consumer to assure quality. Marketing prime-quality perishable products abroad was either prohibitively expensive or simply not feasible until 30 years ago. The adoption of modern technologies has facilitated trade of many high-value agricultural products in recent years. Examples of such technologies include:

❑ Improved communication systems allowing for better monitoring of quality, tracking of shipments, and coordinating of steps through the marketing chain of time-sensitive food products.

❑ Greater use of intermodal systems and the reefer box, a mobile refrigerated warehouse, from the point of production to the point of consumption combined with modern container terminals, allowing for quicker turnaround in ports and faster delivery of product over greater distances.

❑ Developments in refrigeration, controlled atmosphere (CA) and humidity control that reduce spoilage and allow the substitution of cheaper ocean shipping for air transport for some of the more perishable items.

❑ Packaging innovations, fruit and vegetable coatings, bioengineering, and other techniques that reduce deterioration of food products and help shippers extend the marketing reach of U.S. perishable products.

❑ Development of infrastructure linkages for making ocean shipping of perishable products not only technologically feasible but also profitable for all players. Providing sufficient crane capacity, adequate storage space, and ready access to highway and rail connections. Developing efficient inspection and customs services by government agencies, as well as port-to-market distribution systems, critical for fresh produce that often must arrive quickly on store shelves.

To assess the role of distance on the performance of exports of U.S. food and agricultural products and evaluate how that role has changed over time with new transportation technologies and logistical systems, we use a simple gravity model to estimate distance elasticities and their time trends for both aggregate categories and specific food and agricultural products, using pooled cross-section and time-series data for more than 100 destinations over 30 years. The results for the aggregate categories were similar to previous research. But we often found statistical evidence of a declining effect of distance when disaggregated data were used. Examples include most meats, eggs, and certain processed foods.

Distance and U.S. Food and Agricultural Exports

To benefit from growing overseas demand, U.S. agriculture has had to meet the challenge of delivering food products to purchasers thousands of miles away with no substantial loss in freshness and quality. Two of the largest U.S. markets, Japan and the European Union, are thousands of miles beyond the shores of the United States (figure 8).

It is evident from the trade data that U.S. food and agricultural products are traveling greater and greater distances. East Asia, which surpassed the EU in the 1980's as the most important regional market for U.S. food and agricultural products, is about 50 percent further away than the EU (from Chicago, Tokyo is 10,200 kilometers and The Netherlands is 6,660 kilometers) (figure 9). Until recently, East Asia was even larger than the combined nearby markets of Canada and Mexico. It is also evident that non-bulk and perishable products are coming to dominant U.S. agricultural exports in recent years.

Over time, the mean distance traveled by many commodities has risen. U.S. bulk exports traveled an average of 8,000 kilometers in 1962 to 1964; roughly the distance from the United States to Brazil. This distance rose to 8,700 kilometers in 1993 to 1995, an increase of 9 percent. In the case of U.S. horticultural exports the rise was greater, from 4,400 kilometers in 1962 to 1964 to 6,300 in 1993-95, an increase of more than 40 percent (figure 10). This occurred despite relatively high transportation costs, accounting for 30 to 40 percent of fob values for a variety of horticultural products (figure 11).

U.S. meat exports, with the exception of poultry meat (whose production is not bound the way beef and pork are to space and land resources), are also traveling greater distances now compared with 1979 to 1981. U.S. beef exports, for example, averaged 8,200 kilometers in 1993 to 1995, compared with 7,500 kilometers in 1979-81, thanks to market-opening measures in East Asia and advances in logistics and transportation technology. A larger share of Japanese beef imports is chilled rather than frozen, reflecting greater sophistication in shipping technology and handling techniques. Meats are one of the fastest growing components of U.S. food and agricultural exports, traveling as far or further than more storable products like corn.

What are the underlying reasons for such differential growth in trade for U.S. bulk versus perishable food products?

Part of the explanation is attributable to the unevenness in technological innovation as it applies to specific food and agricultural commodities. For example, transport costs may have declined more rapidly for meats than for feed grains with the advent of and increased sophistication and speed of containerized versus bulk shipping.

Another reason is that more significant cuts in protection may have taken place for perishable products than for bulk commodities in the last 10 to 15 years. In Japan, for example, liberalization of meats has been far more dramatic in recent decades than for feed grain, which has been relatively freely traded for some time.

Finally, unbalanced economic growth across countries may be an explanation. The economic and income growth in far away countries was faster than in neighboring countries. The so-called shift of gravity to East Asia, Japan, Korea, Taiwan, and Hong Kong, may account for a larger share of our meat and horticultural exports traveling a longer distance than before.

Since there are several possible explanations, we need an analytical model to determine the relative importance of transportation costs as one possible factor in explaining the bulk-to-perishable shift in U.S. agricultural exports.

Model Specification and Data Sources

The gravity model is a commonly used empirical tool to assess the role of distance (a proxy for transportation costs) in international trade that has gained growing theoretical acceptance in recent years (Hummels and Levisohn, 1995, and Deardorff, 1995). In this study, we apply a simple double logarithmic version of the gravity equation as follows:

$$\text{Ln } X_{isrt} = \alpha_{isr} + (\beta_{0i} + \gamma_i T)\text{Ln } DIS_{sr} + \beta_{1i}\text{Ln } GDP_{st} + \beta_{2i}\text{Ln } GDP_{rt} + \beta_{3i}\text{Ln } \frac{GNP_{st}}{POP_{st}} + \beta_{4i}\text{Ln } \frac{GNP_{rt}}{POP_{rt}}$$

$$+ \beta_{5i}\text{Ln } LAN_r + \beta_{6i}\text{Ln } AGLAND_{rt} + \beta_{7i}\text{Ln } RCA_{rt} + \beta_{8i}\text{Ln } EXC_{rt} + \beta_{9i} ADJ_r + \mu_{irst}$$

Where X_{irst} is the value of exports of commodity i from country s (the United States) to country r at time t, measured at country r's cif price. GDP_{st} and GDP_{rt} stand for real GDP (in 1987 U.S dollars) of the United States and the importing country, respectively, and measures the size effect of the two economies. The next two items in the equation are per capita real GNP for the United States and for the importing country, respectively. Importer per capita income gauges the income effect on imports. The variable LAN_r is an index ranging from 0 to 10,000, which measures the percentage of people that speak English in both the United States and the importing country. $AGLAND_{rt}$ and RCA_{rt} are arable land and Balassa's Revealed Comparative Advantage index (Balassa, 1965), respectively. EXC_{rt} is a real exchange rate variable measured by the units of the importing country's home currency per U.S. dollar. The variable ADJ_r is an adjacent dummy variable equal to one when the importing country shares a common border with the United States and zero when it does not. T_t is a time trend variable, μ_{isrt} represents the error terms (their structure will be discussed later), and α_{isr} and β_{0i} - β_{9i} are parameters that need to be estimated.

Since only exports from the United States to its trading partners are considered in this study, the coefficient of U.S. real GDP acts as a time-varying shift parameter measuring the impact of economic growth in the United States on its agricultural exports. This is expected to be positive because the United States has a strong comparative advantage in agriculture. Since growth in U.S. food demand generally is slower than growth in demand for other products and services, the export market for agricultural products becomes relatively more important over time. The coefficient of real GDP for the importing country reflects the size effects and is expected to have a positive effect on U.S. agricultural exports. The coefficient of per capita real GNP is an income

elasticity for the importing country: its sign depends on whether the commodity is a necessity or luxury. By using real GDP variables, we have taken aggregate price changes over time into account. Since data on real, effective exchange rates are not available for all countries and years in our sample, the price-level-deflated exchange rate is used, which is the yearly average market exchange rate deflated by the CPI in the importing country. An increase in the dollar value of an importing country's currency implies an appreciation of the U.S dollar and is expected to have a negative impact on U.S agricultural exports. The coefficient of the exchange variable β_{6i}, therefore, should have a negative sign. The distance variable (DIS) is a proxy for the transportation cost and expects to be negatively correlated with U.S. exports.

There are a number of theoretical justifications for the above specification. Bergstrand (1989), for example, derives a similar specification from a microeconomic model of differentiated products, incorporating factor endowment variables of the Heckscher-Ohlin type and nonhomothetic tastes along the lines of Linder (1961). In his derivation, the importing countries' per capita GDP enters directly while the exporting countries' per capita GDP is a proxy for the exporting countries' capital-labor ratio. In such an explanation, the coefficient of U.S. per capita GDP measures the impact of capital intensity in the United States on U.S. agricultural exports.

The physical distance measure used in this study is the great-circle route measured in kilometers between Chicago and the most populous cities in the importing countries as calculated in Fitzpatrick and Modlin (1986). It does not change with time and therefore only varies across export destinations. Because of the progressive decline in international transportation and communication costs due to advances in technology, we expect the effect of distance on U.S. exports to decline over time. To formally test this hypothesis statistically, a linear time trend is used to capture the change in the distance elasticity over the sample period. Since the elasticity of distance is expected to be negative, a positive γ indicates a declining trend in the effect of distance on U.S. agricultural exports.

The measure of linguistic similarity we use was generated by Boisso and Ferrantino (1997). They first calculated the percentage of people in each country who speak each individual language as their preferred language and then constructed a linguistic similarity index for the two trading countries by multiplying together their language shares. The index has a maximum value of 10,000 when everyone in the two countries speaks the same language and zero when the native languages are totally dissimilar. It is superior to the linguistic dummies typically used. The language similarity index takes into account linguistic diversity within countries. In theory, as more and more people in the importing country speak the same language as in the exporting country, communication costs decline, thus facilitating trade. A positive coefficient is expected for this variable.

The gravity model specified in the equation is estimated by pooling time series and cross-sectional data. We use U.S. agricultural export data for more than 100 trading partners over 30 years (1966 to 1995). The export data are taken from United Nations Commodity Trade Statistics database and are based on cif prices. We first aggregate agricultural trade data into five broad categories: 1) bulk commodities; 2) intermediate processed goods; 3) horticultural products; 4) consumer-

ready processed goods; and 5) other agricultural products.[1] The first four categories add up to the official USDA definition for total agriculture (FATUS). The fifth category includes distilled spirits, fish and marine products, and forestry products. In order to assess the role of distance on specific agricultural products and more narrowly grouped commodities, the data were further disaggregated into more detailed commodities based on the International Bilateral Agricultural Trade (IBAT) classification, an international classification scheme designed by ERS specifically for agricultural trade. The IBAT classification condenses over 250 SITC four-digit commodities into 110 commodity groups. The data for real GDP, real GNP, and population are from the World Development Indicators 1998 CD-ROM (The World Bank, 1998), while the nominal exchange rates and CPI are from the IMF International Financial Statistical online database.

Since we estimate the gravity model at a very disaggregated level, there may be a fairly strong Coals to Newcastle effect.[2] This effect biases upward the distance parameters. It occurs when region's exports of commodity i to region r are negatively correlated with region r's comparative advantage in commodity i, because of geographical clustering of comparative advantages. For example, a gravity model of Saudi Arabia's export in oil would find that it does not export much to other nearby Persian Gulf countries because their neighboring countries also export oil. To circumvent the possible bias from a geographic clustering of comparative advantage, we introduce arable land area and Balassa's RCA index[3] as an alternative explanatory variables into our gravity equation specification focusing on U.S. exports of agricultural goods. The Balassa index captures not only the comparative advantage associated with land but also other factors. We expect the coefficient estimates for both of these two variables to have a negative sign, the more arable land

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[1] Bulk commodities are unpackaged products which include grains, oilseeds, plant-based fibers such as cotton, raw rubber and unmanufactured tobacco. These commodities are usually directly linked with extensive use of arable land for production. Processed intermediate goods are derived from bulk commodities and need further processing for human consumption, such as flour, feed, live animals, and animal fats and oils. Horticultural products are consumer-ready, unprocessed fresh commodities such as fresh fruit, vegetables, and flowers. They often require special handling such as containerization and refrigeration. Consumer-ready processed products are commodities that have been significantly transformed such as prepared and preserved vegetables, fruits and nuts, chilled and frozen meats, eggs, dairy products, processed meats and beverages.

[2] We are very grateful to Michael Ferrantino for his comments in this regard and his suggestion to use Balassa's RCA index as a repressor.

[3] RCA is the share of each commodity group in an economy's total exports divided by that commodity group's share of world exports (See Balassa, 1965). If the economy's export specialization has not been distorted by government policies, the ranking of RCA values indicates comparative advantage relative to the rest of the world. Formally, denoting E_{ij} to be the export of good i of country j, and assuming that there are n commodities and m countries engaged in trade, then the RCA can be defined as:

$$RCA_{jr} = (\Sigma_{jr} / \Sigma^n_{j?1} \Sigma_{jr}) \ / \ (\Sigma^m_{s?1}\Sigma_{sj} / \Sigma^n_{j?1}\Sigma^s_{j?1}\Sigma_{js})$$

Share of good j   Good j's share
in country r's   in world exports
total exports

In practice, the ranking of the RCA index usually not only reflects fundamental comparative advantage, but also government policy distortions, which may subsidize or restrict exports of particular commodities.

the importing country has (or the stronger the comparative advantage they have), the less its demand for U.S. agricultural exports. The data on arable land was downloaded from the FAO Website, while the RCA indices were calculated from the United Nations Commodity Trade Statistics database. Data on total agricultural exports were used in calculating the RCA indices for the 110 disaggregated food and agricultural commodities, and data on total merchandise exports were used in the indices for the five aggregated agricultural commodities.

Econometric Issues

In pooling cross-section and time series data, we have to take into account variations (i) across time, (ii) across export destinations, and (iii) joint disturbance in both dimensions. Therefore, the error term in the equation can be decomposed as follows:

$$\mu_{isrt} = \sigma_{ir} + \lambda_{it} + \nu_{isrt}$$

Where σ_{ir} is the importing country effect, λ_{it} is the time effect, and ν_{isrt} is a white-noise disturbance term. Such an error structure leads to the use of a two-way error component model. In such models, both the importing country's specific error σ_{ir} and time error λ_{it} is assumed to be normally distributed random effects. An estimated generalized least square (EGLS) procedure will be used to estimate such models. It involves estimating each of the variance components in the first stage and applying generalized least squares (GLS) to the data in the second stage by incorporating the estimated variance-covariance matrix obtained in the first stage.

There are three reasons to make such an assumption on the error structure. First, both the physical distance and the linguistic similarity index are time-invariant measures.[4] Assuming σ_{ir} to be fixed would make it impossible to estimate their coefficients. Second, some computational advantages accrue from using a random-effect model rather than a fixed-effect specification when the number of importing countries is as large as in our sample. Finally, since there is incomplete data on real GDP and exchange rates for importing countries, our sample does not include all trading partners of the United States (only about two-thirds). Thus, σ_{ir} should be considered as being randomly distributed when making inferences about parameters of the population.

Another econometric issue is how to deal with those countries with which the United States has zero exports. There are a large number of such observations, especially in the detailed commodity data. Alternative methods have been proposed (Frankel, 1997). An observation with zero export value can be simply omitted, which may lead to selectivity bias. Arbitrary small numbers may be used in place of zeros. A semi-logarithmic formulation and Tobit estimator can be used with the loss of interpreting the estimated coefficients as elasticities (Havrylyshyn and Pritchett, 1991). The approach used in this study is based on Eichengreen and Irwin (1995). It preserves the double-log form, and yields results similar to the Tobit model.

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[4] The linguistic index is invariant because it changes slowly and because of serious data constraints in constructing a time series of such an index.

In such an approach, the dependent variable is transformed as Ln (1+ exports). When the value of exports is large, the dependent variable is roughly equal to Ln (exports) and the constant elasticity relationship is preserved. For small export values, the dependent variable is roughly equal to exports itself, approximating the semi-log Tobit relationship. After the data transformation, the equation is estimated by a scaled OLS estimator in which the least squares estimates are divided by the share of observations of U.S. exports not equal to zero (Eichengreen and Irwin, 1995), and the Tobit method, which allows simultaneous modeling of the threshold effect of zero versus positive trade and estimation of the elasticities of the dependent variable with respect to the various regressors (Boisso and Ferrantino, 1997).

Major Estimation Results

1) Estimation results at aggregate level

The estimation results from the three methods are quite similar, especially for the scaled OLS and Tobit models. The estimated coefficients for major explanatory variables such as distance, United States and importing country's GDP, the real exchange rate, and arable land endowment in the importing country, all have the expected sign and most are statistically significant.

The estimated coefficients of U.S. GDP are highly significant regardless of the estimation procedure. This shows that economic growth in the United Sates has a strong impact on U.S. agricultural exports. Bulk, intermediate and horticultural products have elasticities greater than one while consumer-ready and other agricultural products have elasticities less than one. This indicates that the exports of bulk and intermediate products expanded at a more rapid rate relative to U.S. GDP growth than exports of consumer-ready products, with the latter having relied more heavily on the domestic market. However, U.S. aggregate agricultural exports grew faster than GDP, indicating that the international food and agricultural market is an important source of growth for the U.S. economy.

The elasticity of the importer's GDP is also significant (with consumer-ready products in the error-component model the only exception) and greater than one for U.S. bulk, intermediates, and total agricultural exports, but less than one for horticultural, consumer-ready and other agricultural commodities. The estimated elasticity of the importer's per capita income indicates U.S. bulk and intermediate exports are necessities for the importing country while horticultural, consumer-ready and other agricultural products are luxuries, consistent with our a priori expectations.
The elasticities of real exchange rates are all negative and statistically significant (except other agriculture in the error component model). The magnitude of these estimates shows that U.S. exports of horticultural and consumer-ready products are more sensitive to changes in exchange rates than bulk products since the former are relatively more elastic with respect to price than the latter.

All the coefficient estimates of arable land in importing countries have the expected negative sign and are statistically significant, indicating a strong negative correlation between U.S. agricultural

exports and importing countries agricultural land endowment. The Balassa index is not used in the aggregate equations because the land variable appears to be a sufficient proxy for comparative advantage for the broad commodity aggregates. The elasticities of agricultural land in importing countries are relatively larger for bulk commodities than other products, indicating land endowment in the importing countries has a stronger impact on U.S. bulk exports than other commodities. This is consistent with intuition. However, the coefficients of the adjacency dummy are all negative, which contradicts the conventional wisdom that a common border will boost trade. The negative coefficient may be explained by the fact that the NAFTA countries are all net agricultural exporters. The use of land as an explanatory variable to represent comparative advantage in the model may not be sufficient to fully isolate the geographic effects from the Coals to Newcastle effects we discussed earlier.

The impacts of language similarity are all positive and statistically significant for horticultural, consumer-ready, and other agricultural products but insignificant for bulk and intermediate products in the scaled OLS and Tobit models. This may be explained by the notion that marketing horticultural and consumer-ready products demands more language proficiency than bulk products. Possessing a common language enables U.S. suppliers to be more effective with promotional activities and enables them to better understand how to differentiate products that suit the tastes of foreign consumers. Note, that all estimates for the effect of language similarity in the random effect model are statistically insignificant. However, their signs being positive conform with our expectations.

The estimated distance elasticities are always negative and statistically significant in each of our estimated models. The estimated coefficients on the log of distance for the five major categories of U.S. agricultural exports range from -1.5 to -2, which means that when the distance between the United States and the importing country increases by 1 percent, U.S. total agricultural exports will decline by 1.5 to 2 percent. The negative impacts of distance on horticultural products and bulk commodities are relatively larger than for the other agricultural commodity groupings. The stronger negative effect of distance on horticultural products is consistent with the fact that horticultural products are the most expensive to transport because of their bulkiness relative to value and the higher handling costs given their high degree of perishability. However, the larger distance elasticity for bulk commodities is somewhat surprising. Perhaps this can be explained by differences in the rate of technological change characterizing the various agricultural subsectors. In recent years, rapid technological innovations have taken place in the way agricultural perishables are shipped. By contrast, little has changed in the way in which bulk commodities are transported.
The coefficients for the time trend of the distance elasticity at the aggregate commodity level are generally not statistically significant. However, the estimates for bulk exports have significant negative signs from the scaled OLS model and the estimates for horticultural exports have significant positive signs from the error component model. These results are consistent with findings elsewhere in the empirical literature, which found no clear-cut statistical evidence of a declining role for distance in aggregate trade (Boisso and Ferrantino, 1997, Frankel, 1997).

The significant variation in the proportion of transportation-costs-to-export-value for different U.S. agricultural exports, with ratios rising for some products but falling for others, tend to

average or cancel out in the broad aggregate categories. The desire to explore the role of distance at a more detailed commodity level motivates us to undertake more detailed, disaggregate analysis.

2) Estimation results at detailed commodity level

Among the 104 commodities whose distance elasticity have the expected negative sign, 43 have a statistically significant positive sign for the time trend, indicating that distance may have had a declining effect on U.S. exports. Thirty-five of the categories have a statistically significant negative sign, indicating that distance has become more of an impediment to trade with time. Finally, the other 26 are statistically insignificant, implying that the effect of distance has not changed over the sample period.

To construct the three tables, we first ran two regressions for each detailed product using two different measures of comparative advantage, one that used the importing country's arable land as a proxy and the other that used the RCA index to represent comparative advantage. All the regressions with a wrong sign for the variable representing comparative advantage were deleted. For those commodities with a statistically significant negative sign for both arable land and the RCA index, reported estimates were selected on the basis of adjusted R squares, the sign and t-statistics of other explanatory variable such as common border and language similarity index, as well as intuition. For those commodities that did not have a statistically significant coefficient estimate for either variable, additional regressions were run without any comparative advantage variables.

Many of the commodities for which distance has become less of an impediment to trade over time includes such perishable products as fresh and chilled meat, fresh eggs, flowers, fruit, vegetables and other processed products. Only a couple of bulk commodities, namely cotton seed and sugar, show diminishing effects for distance.

Commodities in the second group for which distance may have had an increasing effect are mixed. This group includes important bulk products such as wheat, soybeans, tobacco, natural rubber, barley and oats, but also quite a few processed commodities. Seventeen of the 35 commodities in this group still have a negative sign for their adjacent dummy variable, 12 of which are statistically significant, indicating that Coals to Newcastle effects may have biased the empirical estimates (compared with the first group of commodities, their estimated coefficients of the adjacent dummy are positive with only four exceptions). The adjacency variable should be positive, reflecting lower costs of doing business in a familiar, nearby market. When it is negative, it may indicate that the strong effects from comparative advantage are not being fully isolated.

The empirical results support the notion that the cost of shipping processed products such as various meats may have declined faster than the cost of shipping feed grains such as corn. The distance elasticities for most meats have a statistically significant declining trend, while the coefficient for corn is not significantly different from zero. In addition to income growth and trade liberalizing measures, transportation costs for meat may have declined relatively more than for feed grain, thus leading to a substitution of meat for feed grain in trade.

The regression model performed better at the individual agricultural product level than at the aggregate level. Most commodity- and product-specific equations had correct signs on the estimated coefficients and were statistically significant. The coefficients of language similarity, for example, were almost always positive and statistically significant for most commodities. Moreover, the results at the detailed level often clarified ambiguous results obtained from the broad aggregate groups. For example, the estimated border effect was positive for most processed and consumer-ready products; but the border effect was negative for most bulk products. This demonstrates that adjacency facilitates trade in high-value products. It also shows that similarities in arable land endowment reduce trade between neighboring countries in specific land-intensive bulk commodities. Such offsetting effects can confuse the results when highly aggregated data are used.

Conclusions

This study represents the first attempt to estimate the effects of distance on U.S. exports of specific food and agricultural commodities. By using a simple gravity model and pooling cross-section and time-series data, we found that the impact of distance on U.S. agricultural exports varies significantly for different products.

Similar to most previous gravity model estimations, we also found almost no statistical evidence to support a diminishing trend in the effect of distance on aggregate groups of commodities. Generally speaking, the gravity model performed better using more detailed, disaggregate data. The specific commodity and product approach enables us to more precisely determine the impact of technology-induced reductions in transportation costs and the role of distance. For example, the empirical evidence shows a declining impact of distance on U.S. agricultural exports for certain perishable and processed products. These findings are contrary to previous studies that have not found that the distance effect is diminishing. They are also at odds with our more aggregate results.

Two caveats need to be mentioned. Because of many missing values in the detailed disaggregated trade data, the sample size for many commodities was reduced. This could lead to possible estimation bias when using the RCA index as an explanatory variable representing an importing country's comparative advantage. To further isolate geographic effects from the impact of comparative advantage, it may be necessary to exclude Canada from the sample, especially for bulk commodities. In addition, the robustness of the coefficient estimates need to be further tested by filling those missing values in the RCA index and applying a similar model to other countries export data.

There are many factors that explain the differential growth in U.S. bulk versus perishable product exports. In this paper, we focus on one of the most important determinants, distance. When technological advances in transportation and logistics dominate, lower transaction costs reduce the elasticity of distance. However, the distance elasticity may remain unchanged or even increase over time in response to differential rates of growth in different parts of the world. More research is needed to better understand this "shift in gravity" phenomenon.

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