EconomicLetter

Distance and the Impact of 'Gravity' Help Explain Patterns of International Trade

by Ananth Ramanarayanan

The gravity model of international trade takes its name from its similarity to the law of universal gravitation in physics and is known as one of the strongest observed relationships in economics.

United States trade with other countries declined dramatically during the recent recession, with the volumes of imports and exports each falling about 21 percent from third quarter 2008 to second quarter 2009. By comparison, real gross domestic product (GDP) contracted only 4 percent (*Chart 1*). A subsequent rebound in international trade flows is just as striking and has been one of the most robust indicators during the accelerating recovery.

International trade flows are typically among the most volatile economic variables over the business cycle, fluctuating far more than GDP.[1] This volatility represents a large degree of quarter-to-quarter variation in the amount of income that consumers and firms (both in the U.S. and abroad) spend on foreign goods relative to domestically produced ones. However, the geographic distribution of trade between the U.S. and the rest of the world is, by contrast, remarkably stable over short time horizons. The fractions of goods the U.S. imports from individual countries or regions change slowly, and the movements in these fractions over the business cycle are relatively small (*Chart 2*). For example, China's share of U.S. imports rose to 19 percent from 6 percent over the 15-year period from 1995 to 2010, though this figure changed by no more than about 4 percentage points during any single year, and typically much less.

One broad explanation is that this pattern of trade is determined by factors that are permanent, or at least slow to change, as well as by factors that vary over the business cycle. A framework known as the "gravity model" incorporates this idea to explain trade flows. Introduced in the 1960s, the gravity model of international trade takes its name from its similarity to the law of universal gravitation in physics and is known as one of the strongest observed relationships in economics.[2]
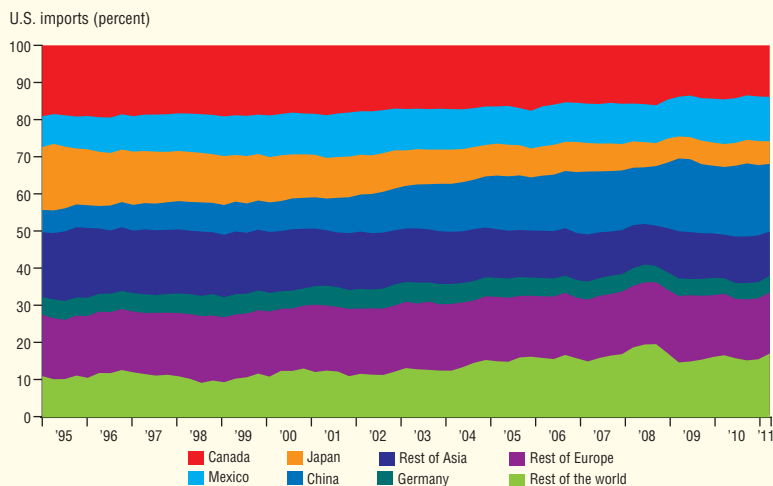
> *Trade may decline as the distance between two countries increases, reflecting transportation costs for goods.*

Chart 1
U.S. Trade Collapses and Rebounds

Volume index, 2008:Q3 = 100
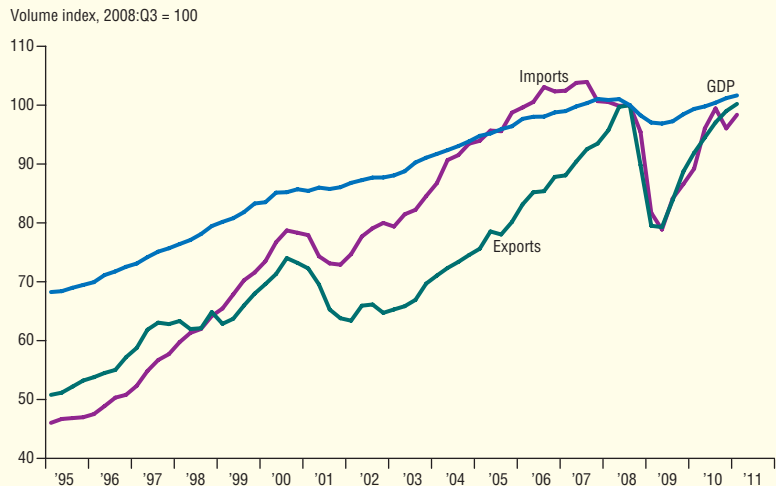
SOURCES: Bureau of Labor Statistics; Bureau of Economic Analysis; Census Bureau.

Chart 2
Geographic Distribution of U.S. Imports Changes Slowly

U.S. imports (percent)

Canada Japan Rest of Asia Rest of Europe
Mexico China Germany Rest of the world

SOURCE: Census Bureau.

these factors is simple. A large destination country has a lot of income to spend and so attracts imports, while a large source country has a lot of goods to sell, so it tends to export a lot. Trade may decline as the distance between two countries increases, reflecting transportation costs for goods.

Charts 3 and 4 depict how trade between pairs of countries is related to the three factors of the gravity model—the size of each of the two countries and the distance between them. Here, distance is measured as the great-circle arc length between the capital cities of the two nations. More generally, including other measures of distance—such as whether countries share a border, a language or a free-trade agreement—is economically relevant as well. Chart data cover bilateral trade flows among a set of 22 countries in the Organization for Economic Cooperation and Development (OECD).

Chart 3 confirms that bilateral trade flows are positively related to the importer's size and the exporter's size: Larger countries export more and import more than smaller countries.
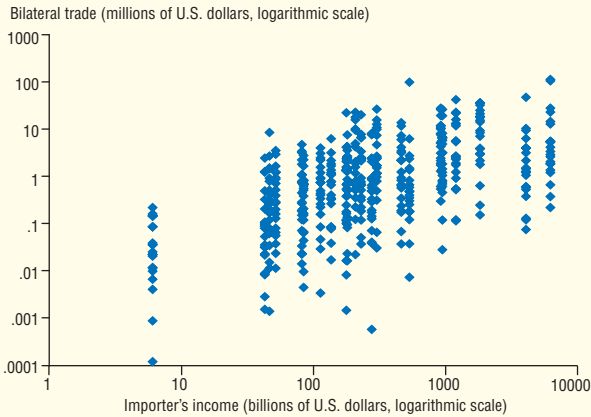
Chart 4 shows how *relative* trade

The simplest form of the gravity model relates trade flows between two countries to their sizes—typically measured by their GDPs—and some measure of the distance between them. The reasoning behind the relevance of
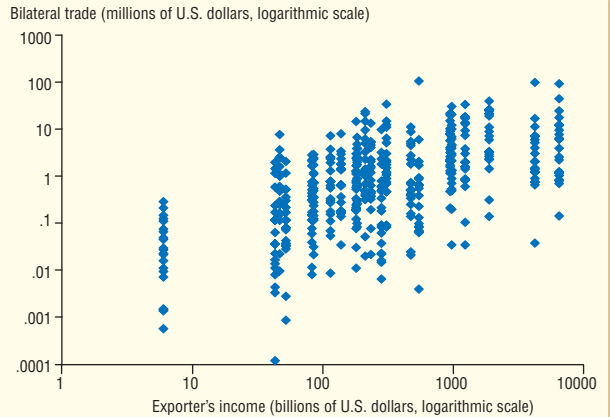
Chart 3
Country Size Influences Bilateral Trade

A. Measuring Import Income

Bilateral trade (millions of U.S. dollars, logarithmic scale)

Importer's income (billions of U.S. dollars, logarithmic scale)

B. Counting Export Income

Bilateral trade (millions of U.S. dollars, logarithmic scale)

Exporter's income (billions of U.S. dollars, logarithmic scale)

NOTES: Countries included are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, U.K. and U.S. Trade and GDP data are from 1993. Data are plotted for all pairs of these 22 countries.

SOURCE: Data on 22 OECD economies are from "Gravity with Gravitas: A Solution to the Border Puzzle," by James E. Anderson and Eric van Wincoop, *American Economic Review*, vol. 93, no. 1, 2003, pp. 170–92. Data available at www2.bc.edu/james-anderson/gravity.zip.
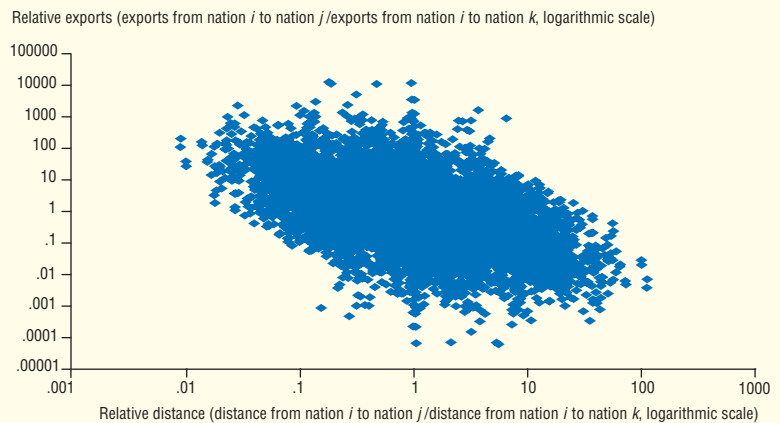
shares between different pairs of countries depend on relative distance. Each point on the graph represents the fraction of a country's exports to one destination relative to a second destination country, plotted against the ratio of the two distances involved. This relative measure is meant to isolate the impact of distance from that of country size, and indeed, the downward-sloping relationship in the chart suggests that distance is a significant factor in determining relative trade shares.

Among the factors affecting trade flows, the importance of distance is likely to remain relatively fixed over time, while the influence of country size fluctuates over the business cycle and contributes to trade-flow volatility. In this way, the gravity model helps explain why the pattern of relative trade shares across countries is fairly stable, as in Chart 2.

While the economic costs associated with distance—for example, shipping costs—vary over time, this has less impact on relative trade than on absolute levels of trade. As an example,

Chart 4
Assessing the Impact of Distance on Trade

Relative exports (exports from nation *i* to nation *j* /exports from nation *i* to nation *k*, logarithmic scale)

Relative distance (distance from nation *i* to nation *j* /distance from nation *i* to nation *k*, logarithmic scale)

NOTES: Countries included are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, U.K. and U.S. Trade and GDP data are from 1993. Data are plotted for all pairs of country pairs.

SOURCE: Data on 22 OECD economies are from "Gravity with Gravitas: A Solution to the Border Puzzle," by James E. Anderson and Eric van Wincoop, *American Economic Review*, vol. 93, no. 1, 2003, pp. 170–92. Data available at www2.bc.edu/james-anderson/gravity.zip.

high oil prices raise the cost of sending container ships between China and the U.S., so we may expect to see U.S. imports from China fall. But at the same time, the cost of shipping from Germany to the U.S. rises as well, so the fractions of total imports that come from China and from Germany may not change much.

The growth of any particular bilateral trading relationship relative to others is due to factors that change slowly. For example, China's economic reforms begun in the late 1970s and 1980s led to greater openness to international trade, and China's accession to the World Trade Organization in 2001 marked the beginning of its growing importance for U.S. trade.

If the pattern of trade is so strongly related to permanent and slow-moving factors such as distance and trade policy, why does overall trade as a fraction of GDP vary so much over the business cycle? That is, why do the relative amounts the U.S. imports from two different countries seem to behave differently than the amount the U.S. imports relative to what it buys from itself?

Perhaps the factors that determine whether a consumer or firm imports a certain product from one country or another are different from the factors determining whether it is imported at all rather than bought domestically. For example, exchange rate movements over the business cycle can change the purchasing power of the U.S. dollar and significantly alter the relative cost of importing a good from anywhere versus buying it domestically. At the same time, the relative cost of importing from one country versus another may not change much.

At present, though recovery from the recession is proceeding at various speeds in different parts of the world, we shouldn't expect drastic changes in the geographic pattern of U.S. trade. For example, for the past year, the prices of goods the U.S. imports from Canada are temporarily rising faster than the prices of items from China.

But the opposite happened from mid-2008 to early 2009, and the U.S.'s relative imports from these two countries remained fairly stable. While one country may gain a temporary advantage over another, it is costly to reallocate production between different locations. In the same way that permanent barriers such as distance significantly affect relative trade flows, so producers should be willing to reallocate production from one country to another only when there are extremely persistent or permanent changes to the relative benefits of doing so.

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Notes

[1] The volatility of trade flows over the business cycle has been mentioned in *Economic Letter* previously, in "Trade, Globalization and the Financial Crisis," by Mark A. Wynne and Erasmus K. Kersting, vol. 4, no. 8, 2009; and "Durable Goods and the Collapse of Global Trade," by Jian Wang, vol. 5, no. 2, 2010.

[2] The gravity model as an empirical model was first used by Jan Tinbergen in *Shaping the World Economy: Suggestions for an International Economic Policy*, New York: Twentieth Century Fund, 1962. Originally gaining popularity because of its success in explaining the pattern of trade in the data, the gravity model was later shown to be consistent with economic theories of international trade based on the costs and benefits of trade between different countries. See, for example, "Gravity with Gravitas: A Solution to the Border Puzzle," by James E. Anderson and Eric van Wincoop, *American Economic Review*, vol. 93, no. 1, 2003, pp. 170–92; and "Technology, Geography, and Trade," by Jonathan Eaton and Samuel Kortum, *Econometrica*, vol. 70, no. 5, 2002, pp. 1741–79.

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