Incorporating Port-Level Foreign Trade Data into IMPLAN's Gravity Model to Estimate Region-Specific Foreign Trade Rates by Country Trading Partner

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Abstract

Understanding regional participation in international trade is important for state and local policymakers, but useful empirical estimates are often unavailable. This paper describes a new method that incorporates foreign trade data tabulated by customs port into a gravity model of regional trade in order to allow for regionally-specific foreign trade rates and identification of foreign country-level trading partners by commodity at the subnational (county and state) level. The paper begins by describing the methods used to incorporate the port-level foreign trade data into the gravity model and to decompose these U.S.-region-specific foreign trade data by country-specific trading partner. The paper then compares results to existing alternative methods and concludes with suggestions for additional work.

This paper uses port-level data, as reported by the United States Census Bureau, on foreign exports and imports of shippable goods (aggregated to 345 commodities) to decompose known national foreign import and export values to the county level while maintaining consistency with estimated county gross supply and demand by commodity.[1] It then further decomposes those county-level foreign trade estimates by country-level trading partner.

[1] The United States had 3,141 counties in 2015, the year of data used in this paper

Estimates of county-level gross commodity supply and demand, as well as gravity model calibration parameters, are based on IMPLAN's 2015 dataset for the United States. U.S. national-level estimates of supply, demand, and foreign trade of commodities are derived from U.S. national accounts published by the Bureau of Economic Analysis.

The results of this method are compared to two common alternatives: 1) subnational decompositions of foreign trade that rely on fixed import and export rates (the method currently used by IMPLAN, in which, for example, each county that produces a given commodity would export that commodity abroad at the same rate as the U.S.), which may be overly simplistic, and 2) Census Bureau's published state-level data tabulated by origin of movement or state of destination, which may not coincide with place of production or consumption (or intermediate use).

Introduction

By capturing the market and non-market flows within an economy, IMPLAN's social accounting matrices (SAMs) describe the structure and function of an economy and can be used to analyze changes in that economy.[2] An important component in the creation of a regional SAM is the estimate of local vs. non-local purchasing behavior, which can be encapsulated by regional purchase coefficients (RPCs). RPCs are commodity- and region-specific, and describe the proportion of each dollar of local demand (final and intermediate) for a given commodity that is purchased from local producers. A number of techniques for estimating RPCs have been explored and utilized (Miller and Blair, 2009).

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[2] Examples of non-market transactions include taxes and unemployment benefits.

While RPCs provide valuable information on local purchasing behavior, they do not provide any information about trading partners or gross flow values. Thus, the development of inter-regional trade flow data (i.e., gross commodity imports and exports between regions) not only allows for the calculation of RPCs, but it also allows for the development of multi-regional input-output (MRIO) models and SAMs.

Since 2005, IMPLAN has used a double-constrained gravity model to estimate intra- and inter-county flows of goods and services.[3] However, the model does not currently estimate foreign imports and exports, and instead assumed that each county that produced a given commodity would export that commodity abroad at the same rate as the U.S. as a whole; for example, if the U.S. exports 10% of its supply of grains, then each county in the U.S. that produces grain is assumed to export 10% of its production abroad. While this assumption is internally consistent (the sum of county-level foreign exports equals the U.S. total), has been employed by other researchers, and is a reasonable assumption when lacking raw data on subnational foreign trade, it may not be realistic in some cases, particularly in the case of perishable goods, where time and transport can damage the good.[4] In such cases, it may be more likely that counties closer to a U.S. Customs port will export and import internationally at a higher rate than counties further away, all else equal.

This paper describes the incorporation of port-level foreign trade data into IMPLAN's gravity model in order to allow for county-specific and country –trading-partner-by-county-

[3] The double constraints are that 1) the sum of domestic exports of a commodity equals the sum of domestic imports of that commodity and 2) each county's sum of local consumption and exports (foreign and domestic) = total local supply of that commodity.
[4] See Joseph Parilla and Nick Marchio, 2017, "Brookings export database methodology," Export Monitor, https://www.brookings.edu/research/export-nation-2017/, accessed May 14, 2018.

specific foreign trade rates. The paper begins with a brief overview of the gravity model, the details of which are described in the appendix. It then describes the methods used to incorporate the port-level foreign trade data into the gravity model. This is followed by a discussion of preliminary results, including a decomposition of trade by country-trading partner, and a comparison of results aggregated to the state level to alternative regional foreign trade estimation methods. The last section includes conclusions and plans for future research.

The Gravity Model

A gravity model stems from, and is named for, Newton's Law of Gravity, whereby the attraction between two masses is directly related to the size of the masses and inversely related to the distance between them:

$$Gravity = G\left[\frac{(Mass_i * Mass_j)}{Distance^2}\right] \qquad [1]$$

where G is a constant representing the force of gravity. Spatial interaction systems model the gross flows between nodes, such as the import and export flows between regional economies.

Leontief and Strout (1963) recommended gravity models for input-output analysis, and others recommended it in related contexts around the same time (see Chaney 2018). Subsequently, this model has been used, with much success, to predict trade flows (see, for example, Anderson and van Wincoop, 2003; Gómez Herrera, 2012; Anderson, 2011). While Anderson (2011) explains that despite empirical success, gravity-based models of trade have lacked robust theoretical foundations, Anderson (1979) and Chaney (2018), among others, have developed a stronger theoretical apparatus for explaining the structure of a gravity-based model of trade. Finding the relevant trade theory not only helps estimation, but also provides a framework for prediction and for estimating welfare effects of trade. Hewings and Oosterhaven (2014) provide an overview of economic trade theory and its relevance to regional trade, giving attention to the role of international trade in interregional trade, which is the topic of this paper.

Most of the gravity literature explores international trade, and of the literature that explores interregional trade, e.g., from state to state, almost all of it directly uses data from movement-based surveys, in which origins are not necessarily places of production, destinations are not necessarily places of use, and each leg of a journey that a good takes counts as a shipment. So, goods moving through wholesale and retail channels likely have longer physical journeys than "economic" journeys from producer to user (see Miller and Blair, 2009, for a review of several such papers). Using movement-based data is almost inescapable, however; this paper and IMPLAN's gravity method in general use adjusted distance-traveled data from a movement-based survey (U.S. Commodity Flow Survey) as a calibrator of the expected average physical distance a good should travel, while not using these data outright.

Whereas existing literature focuses on estimating parameters of a general gravity model, given known trade values, the goal of this paper is to estimate actual trade flows without the benefit of any known trade values. Gravity models, of course, are not the only way to estimate gross flows of traded commodities. Miller and Blair (2009) review several competing non-survey methods, which include location-quotient-based methods, variations on gravity models, constrained optimization methods, and hybrid methods that combine non-survey methods with survey data. For example, Boomsma and Oosterhaven (1992) describe a "DEBRIOT" model that surveys firms' exports, complemented with input-output techniques, to avoid some of the biases inherent in other regionalization methods, such as location quotients (LQs). For a case in which survey-based data are available, Riddington et al. (2006) find that a gravity-based approach, combined with a balancing RAS algorithm, compares favorably to a LQ approach. Gravity models have the benefit of allowing cross-hauling, an important feature of international and interregional trade (Miller and Blair, 2009; Kronenberg, 2009).

This paper, and IMPLAN's data in general, implement a double-constrained calibrated gravity model, in which the mass variables consist of estimated gross supply and demand by county and commodity, with distance consisting of an index for the cost of moving goods from one location to another by the mix of modes of transport specific to each commodity. The solution gives a result in which all supplies are used and all demands are met, minimizing, over the distance exponent, the difference between model-implied average miles traveled and adjusted external observations of average miles traveled by commodity.[5] Our work clearly relies on and derives from the initial gravity model work pursued by our past colleagues and the creators of IMPLAN software and data: Lindall, Olson, and Alward (2006). We are particularly indebted to Greg Alward for inspiring this research effort and doing preliminary foundational work for it.

Data and Methods

Data

This project depends critically on commodity-specific port-level foreign import and export data from the U.S. Census Bureau. These data are for shippable commodities only; thus, the standing

[5] Ready-mix concrete, for example, is observed to travel shorter distances than microchips.

methods are used for non-shippable commodities; that is, counties are assumed to import and export those commodities internationally at the same rate as the U.S. as a whole. These data are categorized by 6-digit harmonized schedule codes (HSC), compared with the national-level foreign trade data, which serve as controls for the port-level data and are categorized at the 10-digit HSC level. Thus, it is necessary to first split the port-level data among the various 10-digit HSC codes that pertain to a given 6-digit HSC code, after which the data are then bridged to North American Industry Classification System (NAICS) codes, at which point they can finally be bridged to IMPLAN commodity codes.

National-level foreign trade data, which are also from the U.S. Census Bureau and are available at the more-detailed 10-digit HSC level, serve as controls for the port-level data prior to their use in the gravity model. The raw data also are adjusted to remove transshipments in accordance with the Bureau of Economic Analysis's (BEA) input-output guidelines and IMPLAN's treatment of the national-level foreign trade data.[6] We further adjust the data to be consistent with IMPLAN's balanced national-level input-output model, which can adjust the magnitudes of some imports and exports. Data from the BEA's National Income and Product Accounts (NIPA) serve as top-level control totals.

Methods and Assumptions

In order to incorporate the port-level data into the gravity model, it is necessary to give each port a set of impedance values between the port and each county in the U.S. (including the county in which the port lies); this was a simple matter of assigning each port impedance values based upon the state and

[6] Transshipments represent the shipment of goods to an intermediate destination without being consumed or altered, to then be shipped to yet another destination. They do not contribute to supply or demand.

county in which it is located.[7] Thus, while each port is treated as its own geographic area, with its own "demands" (i.e., the value of exports coming to it from the counties to be shipped abroad) and "supplies" (i.e., the value of foreign imports entering it to be distributed to the counties), each port is given the same impedance values as the county in which it lies. Relatedly, within the gravity formulation, we explicitly disallow trade between ports. The foreign trades are solved simultaneously with the domestic county-to-county trades, yielding an internally consistent solution.

Preliminary Results

Assessing the quality of estimates of empirically unavailable data is difficult. To borrow language from econometrics, we have only "y-hat"s and no "y"s; accordingly, beyond ensuring there are no constraint violations, we are left with comparisons to other methods and subjective assessments of reasonability. While empirical measurements of imports and exports by commodity by location of production or use (final and intermediate) are not available, we compare the estimates from this project ("port-gravity solution") to the prior working assumption ("constant national rates") and to a common alternative that uses "origin of movement" (OM) and "ultimate destination" (UD) by state.

Quality Control Checks

To ensure the proper functioning of the model after the changes, several tests were performed. Among them, we confirmed that the foreign import and export rates remained unchanged for all non-shippable commodities. We ensured that any county lacking lack of demand for a commodity had zero imports and that any county lacking supply had zero exports. Finally, it was confirmed that the sum of all

[7] This is accomplished by assigning each port code its corresponding FIPS code, at which point the impedance values are known, since the impedances between all FIPS codes are known. Federal Information Processing Standards (FIPS) codes uniquely identify counties and county equivalents in the U.S. and U.S. territories. The 5-digit codes consist of a 2-digit state code and a 3-digit county code.

counties' foreign exports and imports of each commodity remained unchanged – and equal to the U.S. control total.

Comparisons to Alternative Methods

The OM and UD data are available directly from the U.S. Census Bureau and are tabulated by U.S. state. Although the origin of movement could coincide with the place of production, it is only the "transportation" origin. This commonly is a packaging or shipping location. Similarly, though the ultimate destination might coincide with place of use, it commonly is an unpacking or wholesale location.[8] While this paper's estimates are prepared at the county level, we aggregate them to the state level for comparison purposes. To maintain consistency, we applied the same bridging and controlling adjustments to the state OM and UD data as we did for the other two methods. Overall, we find the agreement between the state OM/UD method and port-gravity solution surprising.

Tables 1 and 2, in the appendix, show total foreign exports and imports, respectively, of goods by state. Ex ante, we expect both the port-gravity solution and state movement solutions to show relatively more trade for coastal and border states, and relatively less for inland states, versus the constant national solution, which is generally the case. Rhode Island is a notable exception.

Tables 3 and 4 present the same data, but as shares of estimated goods supply and demand (as calculated by IMPLAN for purposes of solving the gravity model consistently with its county- and state-level input-output models). Note that for any given commodity in the constant national rate method, each state has the same foreign import share of demand as every other state, and similarly for foreign export shares of supply, but the overall rates are different due to differing levels of supply and demand by

[8] See https://www.census.gov/foreign-trade/aip/elom.html#definitions, accessed May 14, 2018.

commodity in each state. The state OM and UD data could show a rate in excess of 100%, since they are not subject to the gravity model's supply- and demand-constraints. This does not happen for all shippable commodities in total, but frequently occurs (for more than 1,000 state-commodity pairs, in a scheme using 345 shippable commodities) on a commodity-by-commodity basis. Any rate in excess of 100% indicates a problem with the demand and supply estimates, the data bridging and controlling, or with the practice of treating the state OM/UD data as a valid proxy for place of production or use, or a combination thereof. It is difficult to tell which, except in some cases when the state OM/UD data show implausible numbers (when interpreted as a proxy for place of production or use).

The state commodity-level data cannot productively be represented by in-line tables, so they are available as an attachment upon request. Evaluating the port-gravity solution's accuracy is most valuable, and probably most feasible, on a commodity-level basis, especially for exports (there likely will be more diverse users of a commodity than producers). For better or worse, considerations of exports tend to drive more policy and planning than do considerations related to imports. Some discussion of exemplary commodity-level foreign trade by state is included below.

While the state OM/UD solution data are not necessarily a good proxy for production- and use-based export and import estimates, we may be able to place more confidence in commodity trade estimates when the port-gravity solution and state OM/UD solutions yield similar results, simply for the reason that fewer alternative estimates exist. The results from each solution should be most similar when the origin and destination of the packaged goods for transportation are located near the place of production and consumption, respectively. If asked to choose those commodities for which we would implement the port-gravity method, a decision rule might be to use the constant national rates solution (the default, and preference of many other researchers) except when the correlation between the port-gravity solution and state OM/UD solution is above an arbitrary threshold.

Accordingly, we tested the correlation by commodity between the solutions of the port-gravity method and state OM/UD method at the state level, for total exports (Table 5) and total imports (Table 6). Some perishable commodities, e.g., fruit, fish, seafood products, appear high on the list in Table 5, as expected, since we would expect that packaging and transportation for export would occur near the place of production. The import of perishable products does not adhere as closely to this trend.

Although the OM/UD data do not provide any county-level information, a strong correlation between the state OM/UD solution and the port-gravity solution gives us confidence in the port-gravity solution and increases our confidence in the county-level port-gravity data (of which the state data are simple aggregates).

Figures 1-4 show the exports and imports of seafood products, a commodity with high correlation (for both imports and exports) between the two solutions, for each solution. Although most of the activity is near bodies of water, it's entirely reasonable that some would not be; seafood products are processed and are distinct from the commodity "fish," which are unprocessed. Note that the state UD data show some states without any demand of imported seafood products, which likely is inaccurate but to be expected given that the destinations may be unpacking and wholesale locations.

Figure 1.

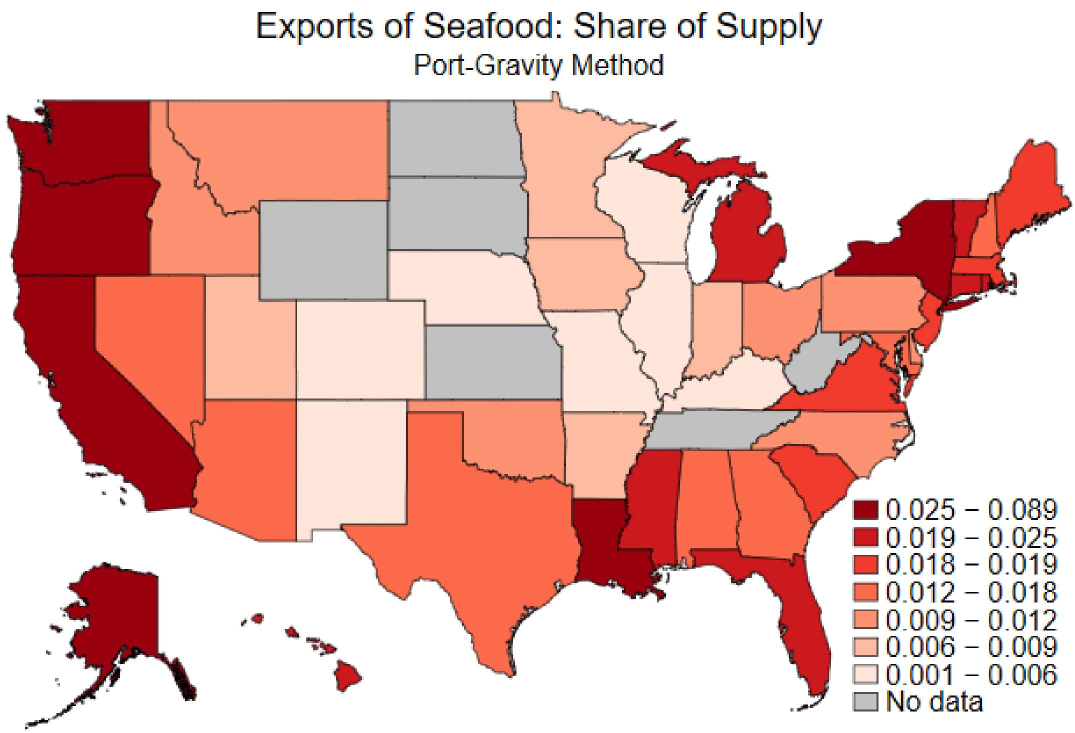


Figure 2.

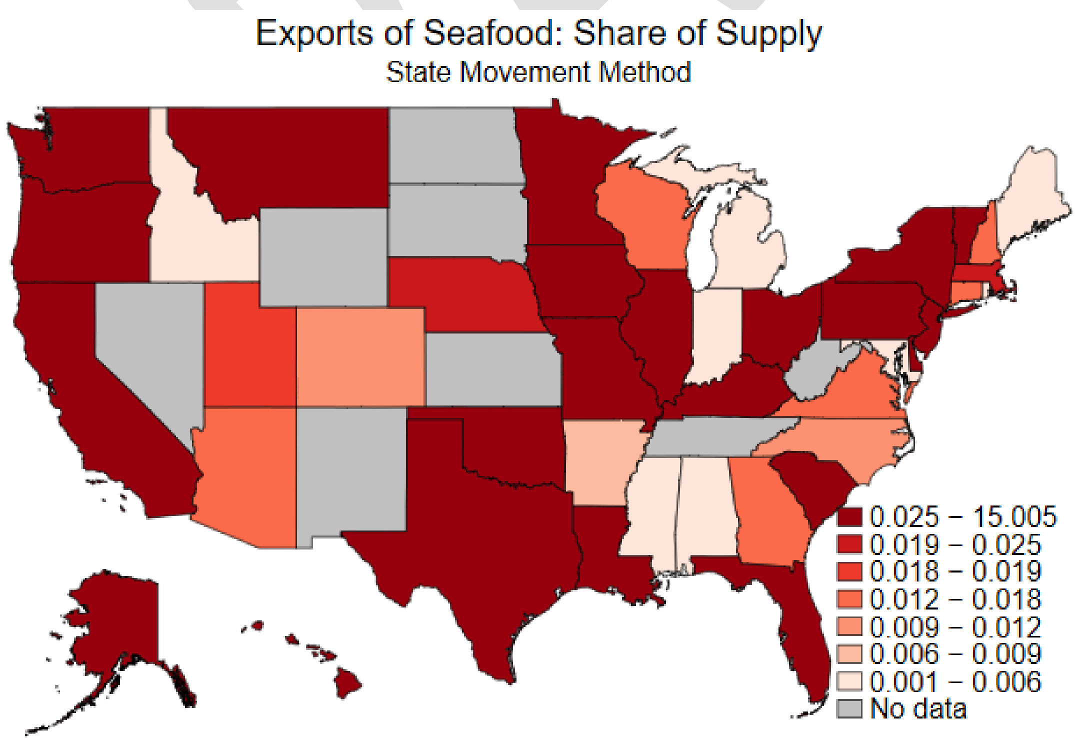


Figure 3.

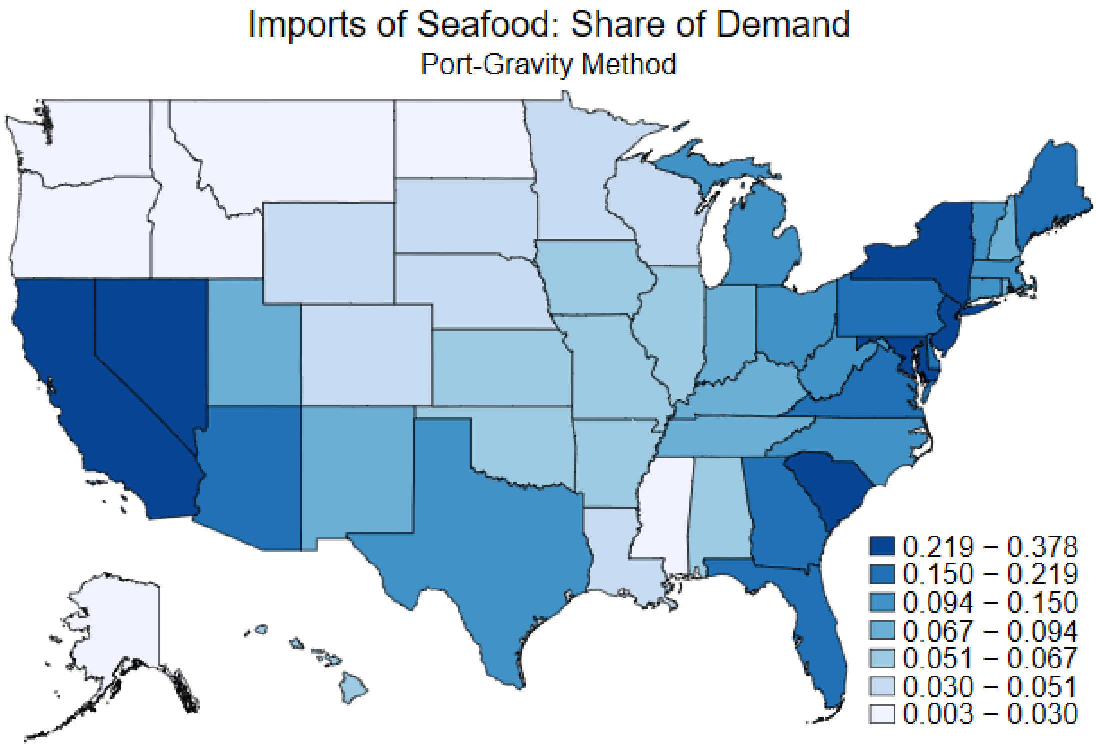
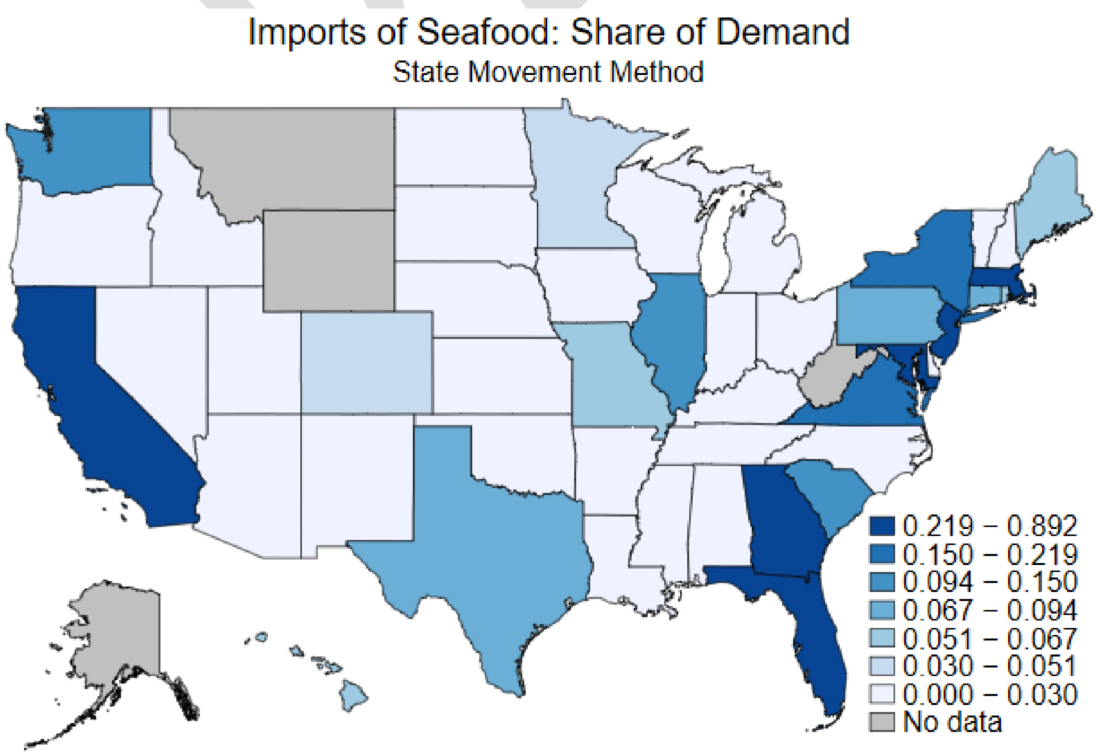


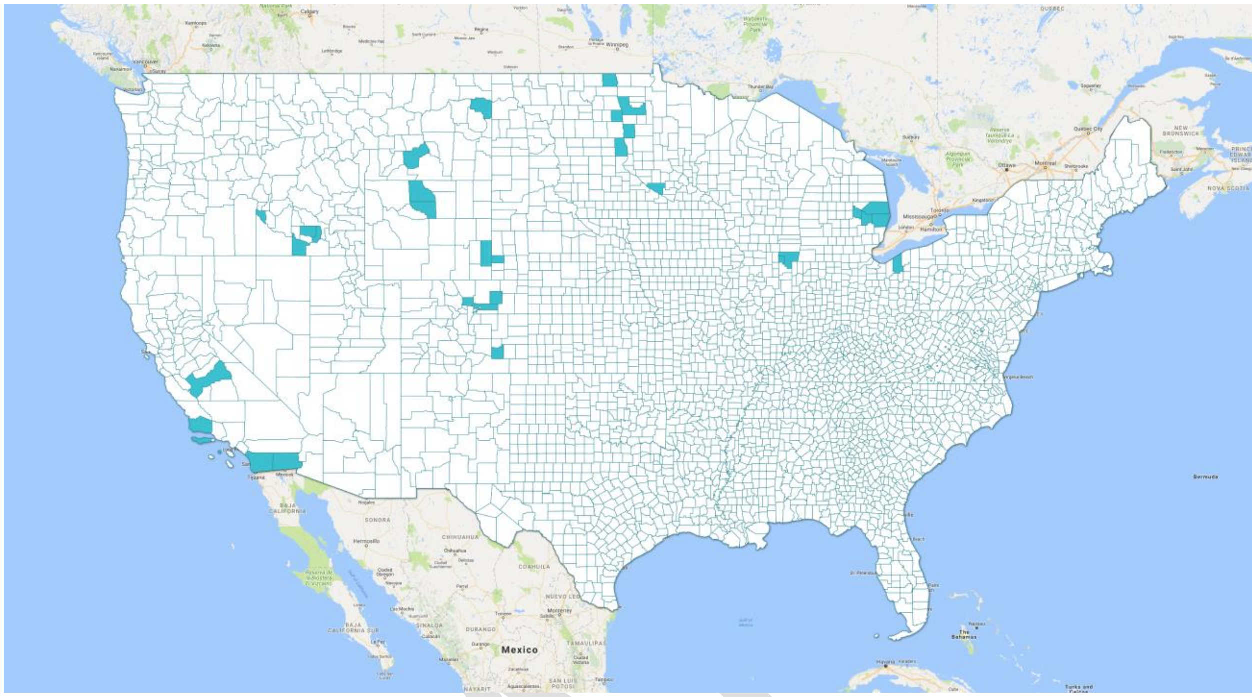
Figure 4.



Illustrative Examples of County-Level Foreign Trade by Commodity

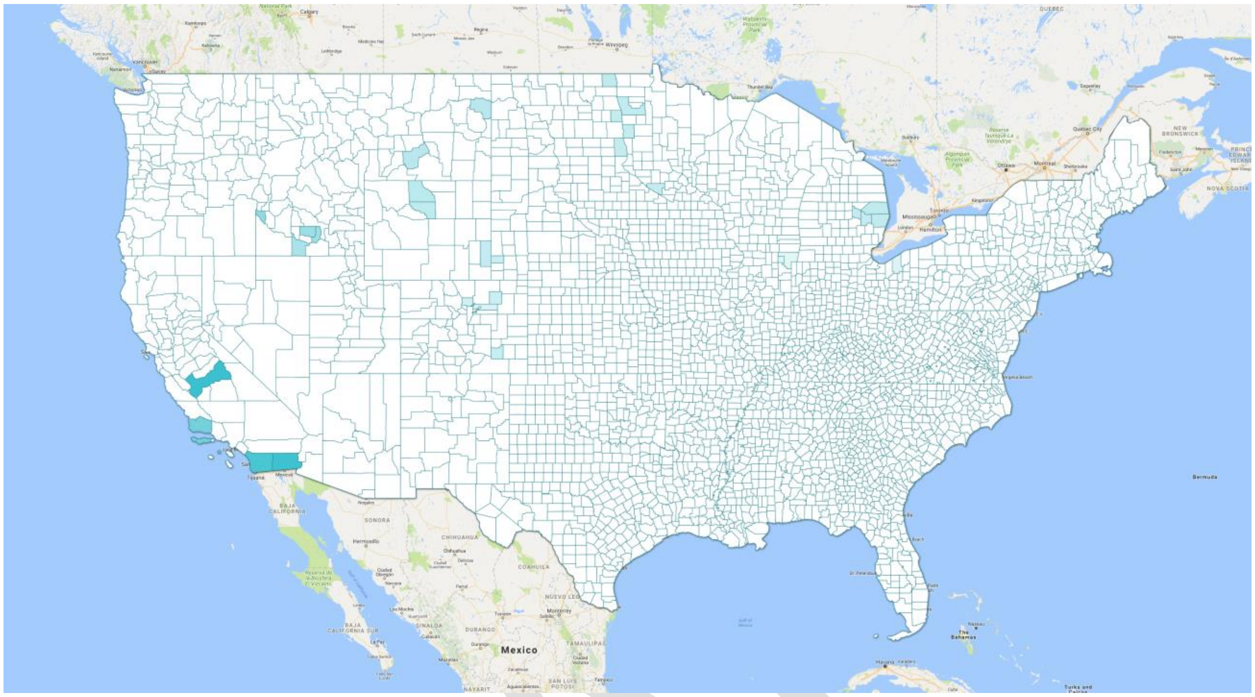
With over 340 shippable commodities and over 9 million county-county combinations, it is hard to summarize the results of the new method compared to the old method. One way to help visualize and understand the changes is to focus on shippable commodities for which there are relatively few producing counties (when looking at foreign exports) or relatively few demanding counties (when looking at foreign imports). One such commodity is beet sugar, which is produced in just 31 U.S. counties. The U.S. foreign export rate for this commodity in 2015 was 2.24 percent, meaning that the U.S. as a whole exported 2.24 percent of its total value of production of this commodity. This means that in the constant national rates method, each of these 31 counties that produced beet sugar in 2015 exported 2.24 percent of the value of their production to foreign destinations (Figure 16). Therefore, the foreign export value varied by county solely as a function of output level of each county and was not influenced by the counties' relative proximity (in terms of cost of transport of the commodity) to a customs port.

Figure 5. Beet sugar foreign export rates – old methodology.



Under the new treatment, the county-level foreign export rates, which now depend on both output level and relative proximity to customs ports, range from 0.83 percent (DuPage County, IL) to 6.52 percent (Fresno County, CA) (Figure 5). Whereas previously the county with the largest value of foreign exports of this commodity was Polk County, MN due to its being the county with the largest output value, followed by Canyon County, ID, which has the second-largest output value, under the new treatment these places are switched, with Canyon County taking first place due to its closer proximity (in terms of distance and cost) to a customs port. In terms of foreign export *rates*, Polk County took occupies fifteenth place, with a new rate that is lower than the U.S. average, at just 1.99 percent, while Canyon County occupies fifth place, with a new rate that is above the U.S. average, at 2.68 percent.

Figure 6. Beet sugar foreign export rates – new methodology.

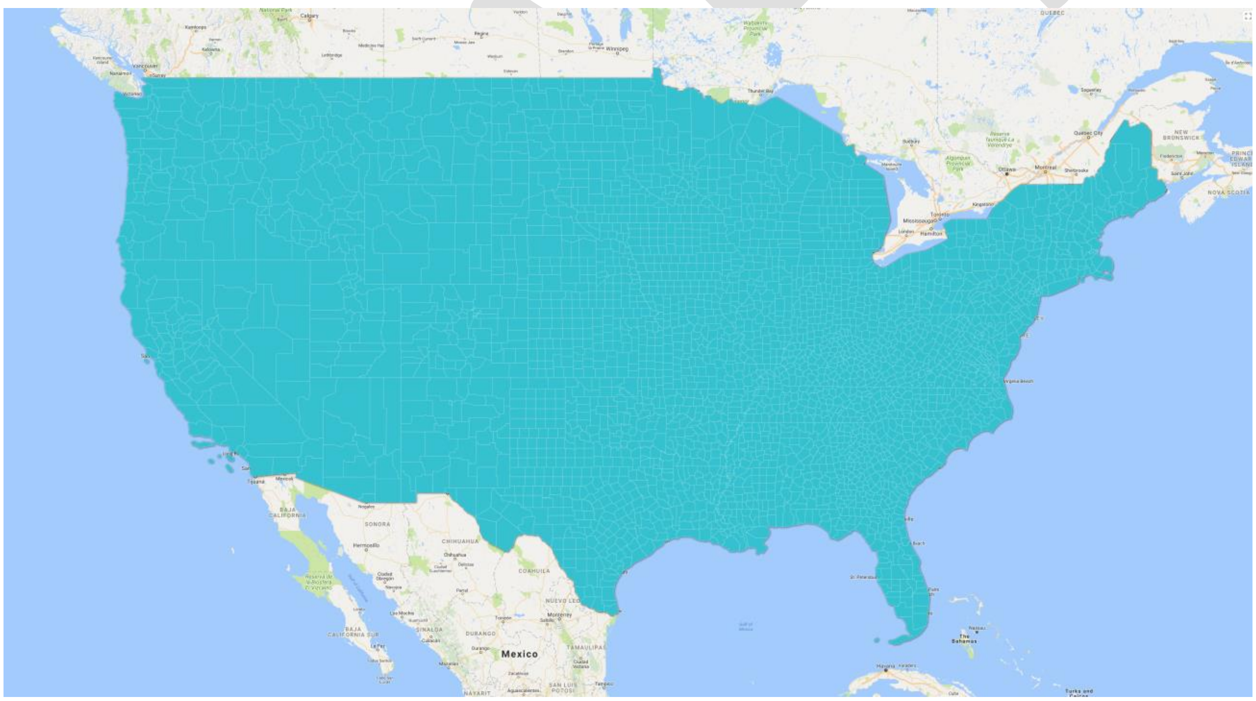


Turning our attention to foreign imports, an interesting commodity for investigation is motor vehicle stamped metal, a commodity for which there is no institutional demand.[9] The U.S. foreign import rate for this commodity in 2015 was 3.03 percent, meaning that the U.S. as a whole imported 3.03 percent of its total demand for this commodity from non-U.S. sources. This means that in the old methodology, each county that had demand for motor vehicle stamped metal in 2015 imported 3.03 percent of the value of their demand from foreign sources (Figure 6); therefore, the total foreign import value varied by county solely as a function of level of demand, and was not influenced by the counties' relative proximity (both geographically and in terms of cost of travel) to a customs port. Under the new treatment, the foreign import rates, which now depend on both the level of demand and relative proximity to customs ports, range from 0.96 percent to 3.15 percent.

[9] Institutional demand refers here to household demand, fixed capital, and government demand.

The county with the largest total demand for this commodity is Wayne County, MI, followed in descending order by Jefferson County, KY, Clay County, MO, Rutherford County, TN, and Macomb County, MI. Therefore, under the old treatment, Wayne County, MI also had the largest magnitude (value) of foreign imports of this commodity, followed in descending order by Jefferson County, KY, Clay County, MO, Rutherford County, TN, and Macomb County, MI, since foreign imports were a function of demand levels only, with no consideration for location of the county relative to customs ports. Each of these counties (and every other county with demand for this commodity) imported 3.03 percent of its demand from foreign sources.

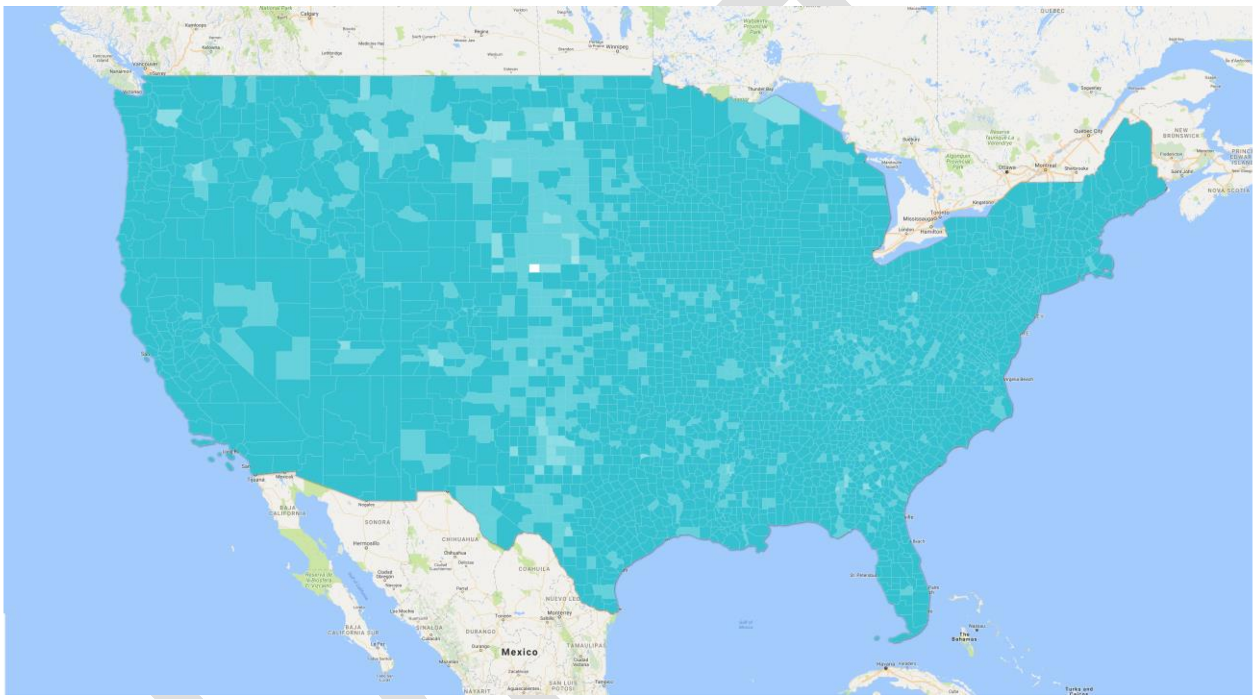
Figure 7. Motor vehicle stamped metal foreign import rates – old methodology.



Under the new treatment, the foreign import rates vary from 1.00 percent (Loup County, NE) to 3.15 percent (Orange County, CA) (Figure 7). Wayne County, MI is still the largest importer of motor vehicle stamped metal <u>by value</u>, but its foreign import <u>rate</u> is actually a bit below the national average, at

3.00 percent. Jefferson County, KY has a foreign import rate of 3.00, Clay County, MO has a rate of 3.06, Rutherford County, TN has a rate of 3.02, and Macomb County, MI has a rate of 3.01. The new leaders in terms of foreign import rates are Orange County, CA (3.15 percent), Ventura County, CA (3.14 percent), Webb County, TX, (3.14 percent) Riverside County, CA 3.14 percent), and Los Angeles County, CA (3.13 percent).

Figure 8. Motor vehicle stamped metal foreign import rates – new methodology.



The changes are more drastic than those for beet sugar at least a couple reasons. First, the average miles target for beet sugar is 885 miles, which renders the proximity to a customs port less important compared to motor vehicle stamped metal, which has an average miles target of 504 miles. In other words, in order to meet the average miles target for motor vehicle stamped metal, fewer foreign trades involving counties far from customs ports (i.e., long-distance shipments within the U.S.) can be permitted. Second, there are more counties that import motor vehicle stamped metal than export beet sugar, thereby allowing a greater range of foreign import rates. In fact, while no county has institutional demand for this commodity, every county has intermediate demand for it due to the variety of industries and government enterprises that use it as an input, from the auto, truck, and motor home manufacturing industries to the motor vehicle parts manufacturing industry, state and local government passenger transit, and even the scientific research and development industry.

Summary Findings of County-Level Foreign Trade by Commodity

The largest reduction in foreign export rate was for the export of other fabricated metals from Ozaukee County, WI, which fell from the U.S. average of 18.41 percent to 3.52 percent. This commodity is transported almost entirely by truck, with the remaining 1.67 percent transported by rail, rendering the water ports in WI (none of which is located in Ozaukee County) useless as far as this commodity is concerned.

The largest increase in foreign export rate was for the export of grains from Koochiching County, MN, which rose from the U.S. average of 15.72 percent to 37.19 percent. Koochiching County lies on the international border with Canada, is the location of the International Falls Port of Entry, and is a major thoroughfare for the Canadian National Railway. Grains are one of just seven commodities that are transported more than 10 percent by truck, more than 10 percent by rail, and more than 10 percent by water, all three of which are possible in Koochiching County.

The largest reduction in foreign import rate was for the import of other fabricated metals into Ozaukee County, WI, which fell from the U.S. average of 42.85 percent to 9.10 percent. As mentioned previously in the case of foreign exports, this commodity is transported almost entirely by truck, with the remaining 1.67 percent transported by rail, rendering the water ports in WI (none of which is located in Ozaukee County) useless as far as this commodity is concerned.

The largest increase in foreign import rate was for the import of grains to Koochiching County, MN, which rose from the U.S. average of 5.76 percent to 95.39 percent. As mentioned previously in the case of foreign exports, Koochiching County lies on the international border with Canada, is the location of the International Falls Port of Entry, and is a major thoroughfare for the Canadian National Railway. Grains are one of just seven commodities that are transported more than 10 percent by truck, more than 10 percent by rail, and more than 10 percent by water, all three of which are possible in Koochiching County.

Decomposition by Trading Partner

Each of the three trade solutions (national foreign trade rates, port-gravity model solution, and state OM/UD solution) provides a straightforward method of ascertaining a state's country-level trading partners by commodity.[10] The national-level foreign trade data include identifiers by country of origin and country of destination, as do the port-level import and export data and the state OM/UD data. We estimate levels of foreign trade by commodity by trading partner by applying country shares of imports and exports from each of the respective raw trade datasets. For example, in the port-gravity solution, if a port supplies $100 of grains to Mecklenburg County, North Carolina, and imports of grain from China to that port make up 50% of total grain imports from that specific port, then we estimate that Mecklenburg County imports $50 of grains from China. These data can then be aggregated to the state-level. The state OM/UD data also show country trading partner detail. The constant national rates method assigns the same country shares for a given commodity to every county and every state.

Tables 7 and 8 show the top country trading partner when summed across all shippable commodities for each state and for each method, also indicating the estimated value of trade and share of

[10] As noted above, we perform comparisons at the state level, since the state OM/UD data are available only at the state level.

gross supply of all shippable commodities or gross demand for all shippable commodities. China, Canada, and Mexico comprise the top trading partners for both imports and exports in both the constant national rates and port-gravity solutions. The state OM/UD data prominently feature those same countries, but have more variety. In this view, the state OM/UD data appear less reliable, as it is unlikely that Washington D.C. exports more goods to the United Arab Emirates than to anywhere else, and that those goods exported to the UAE represent 54% of Washington D.C.'s total supply of goods. Among the goods exported from Washington D.C. for which the UAE is the top importer, the exports-to-supply ratio ranges from 0.03 to 1,679, with many observations in the tens or hundreds, which is implausible.[11] In another notable departure of the state OM/UD method, Saudi Arabia appears to supply most of Louisiana's imports according to the state OM/UD data. The commodity-level data reveal that oil imports, which often go to Louisiana for pipeline distribution, are the primary factor. While some of the oil may be used in Louisiana, much of it likely is transported via pipeline to other states. When moving from the constant national rates solution to the port-gravity solution, the top trading partner for southern border states often switches from Canada to Mexico, as might be expected

By providing state- and county-level detail on country trading partners by commodity, the port-gravity method produces data that can serve many purposes. Notably, they provide direct information about a region's exposure to foreign goods markets, which can help quantify the risks and opportunities associated with changing tariff regimes. As of the writing of this paper, for example, the U.S. and China have expanded or levied new tariffs on imports from the other country.

Trade data are estimated as part of IMPLAN's regular process of producing data to build MRIO

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[11] There are 12 commodities for which the UAE is Washington D.C.'s top export destination.

models of any combination of counties and states within the U.S. (there are currently 3,141 counties in the U.S., and 51 states including the District of Columbia). Expanding the data to include country trading partners, for any of the methods explored here, facilitates nesting an (MR)IO model of U.S. regions in an international MRIO model, opening the door to the rich analyses that MRIO enables.

Illustrative Examples of State-Level Foreign Trade by Commodity by Country Trading Partner

In light of the escalating trade tensions in the first half of 2018 between the United States and China, we provide some illustrative examples of regional trade with China based on the port-gravity solution and state OM/UD solution. Figures 9 and 10 show the destinations of U.S. imports of household laundry machines from China, which have been subject to increased tariffs and align well with IMPLAN commodity classifications. As the maps show, the two methods align reasonably well here; the correlation coefficient is 0.94. Comparing these maps of Chinese imports to a map of U.S. production of household laundry machines, as in Figure 11, shows considerable overlap. In the short-term, at least, there often are clear "winners" and "losers" from a change in trade policy; this comparison shows that, in contrast to a commodity where consumption and production are spatially divergent, the new tariffs on laundry machines may not segregate winners and losers geographically.

Figure 9.

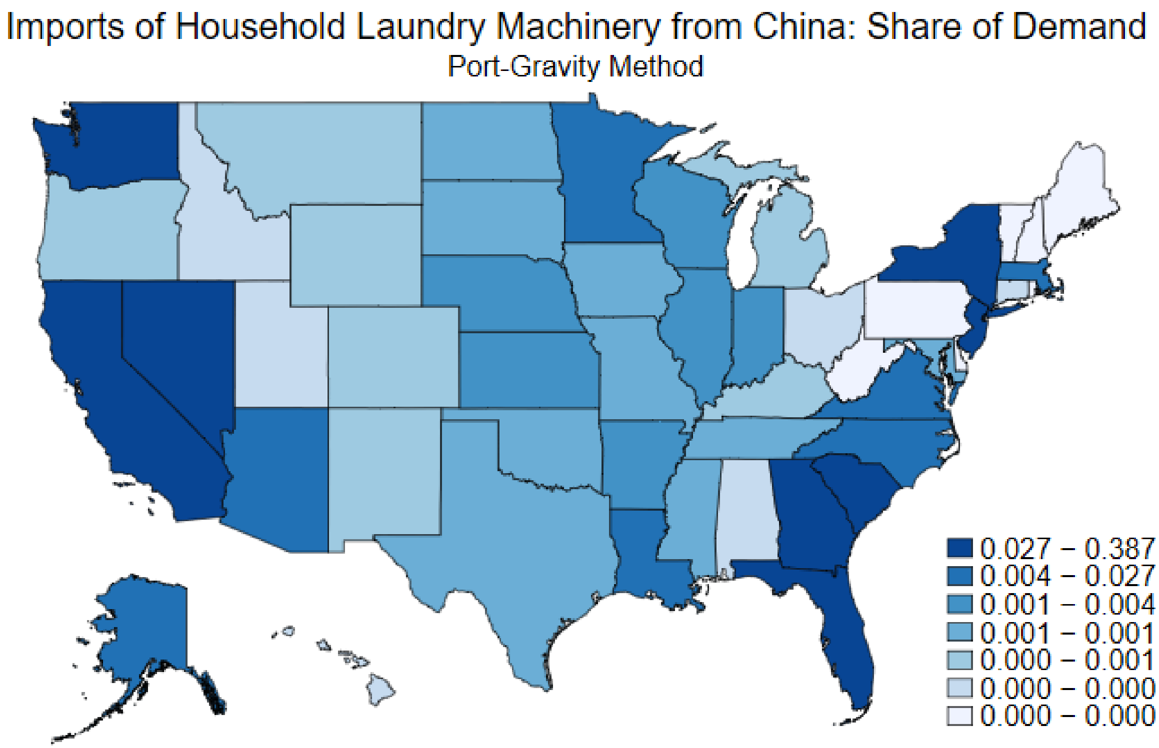


Figure 10.

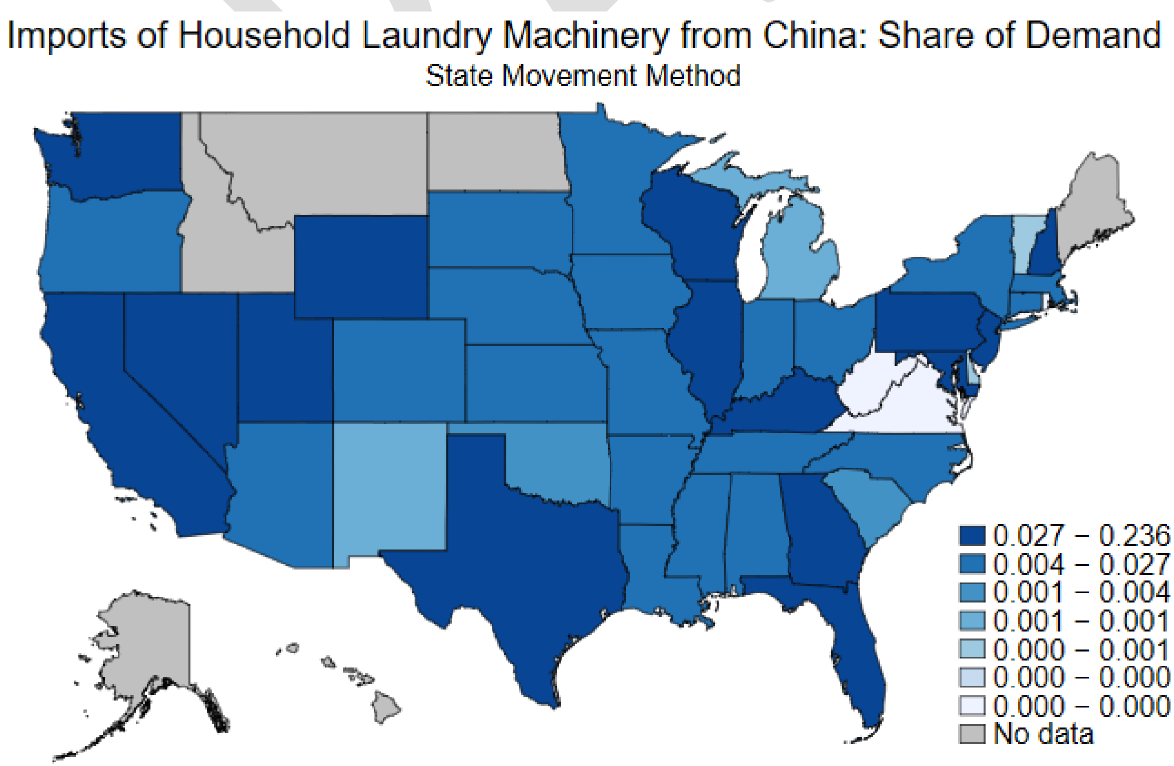
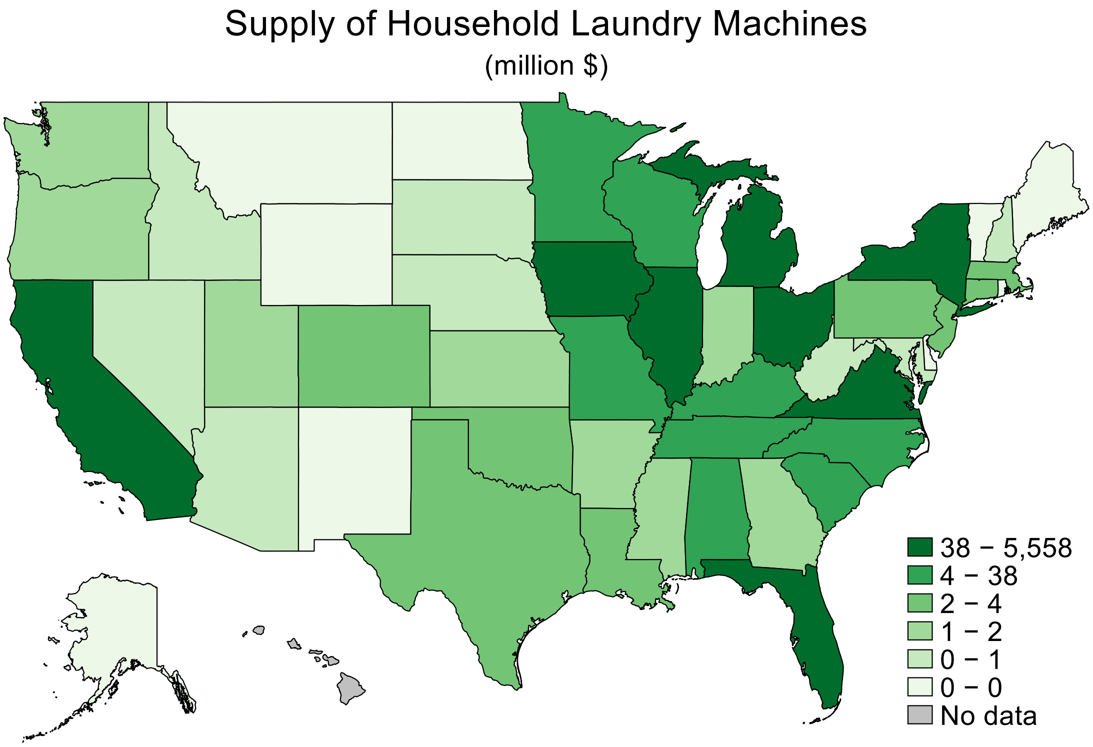


Figure 11.



The U.S. government has also subjected steel to increased tariffs. "Steel" crosses many IMPLAN commodities, not each of which consists exclusively of steel; thus, for Figures 12-14, we have aggregated three IMPLAN commodities: 217, 220, and 231 corresponding to "Iron and steel and ferroalloy products," "Steel wire," and "Iron and steel forgings," respectively. Here, there is more divergence between states that import Chinese steel versus states that produce steel, perhaps implying regionally distinct winners and losers from this policy.

Figure 12.

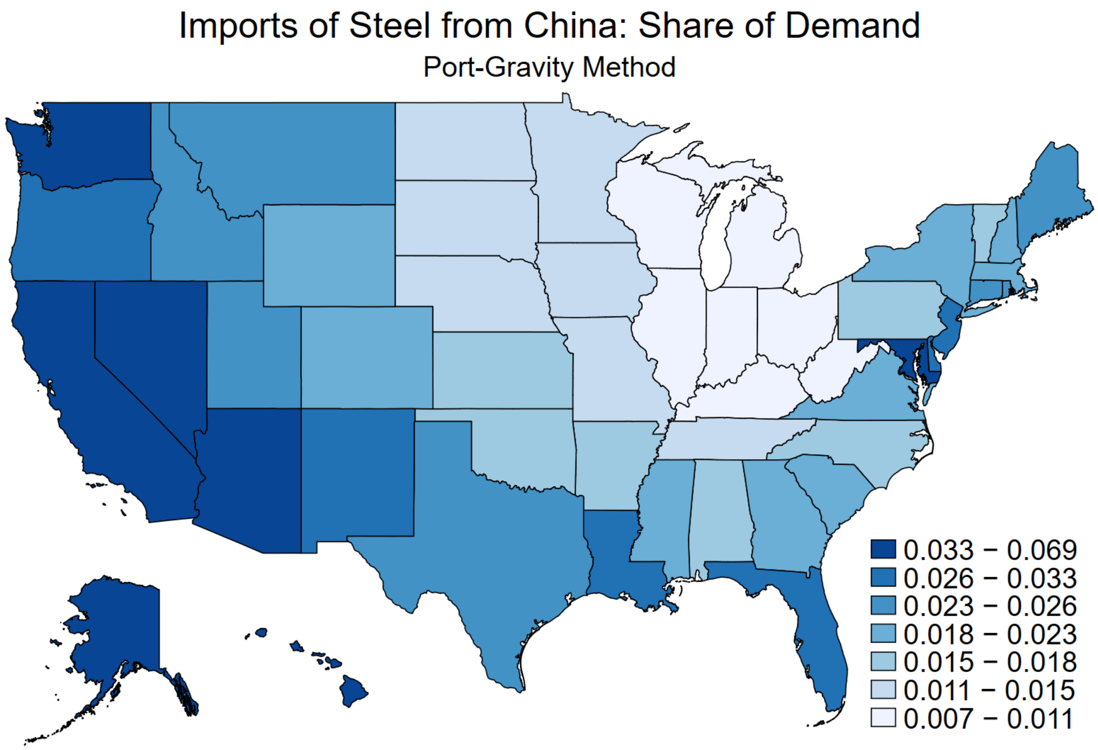


Figure 13.

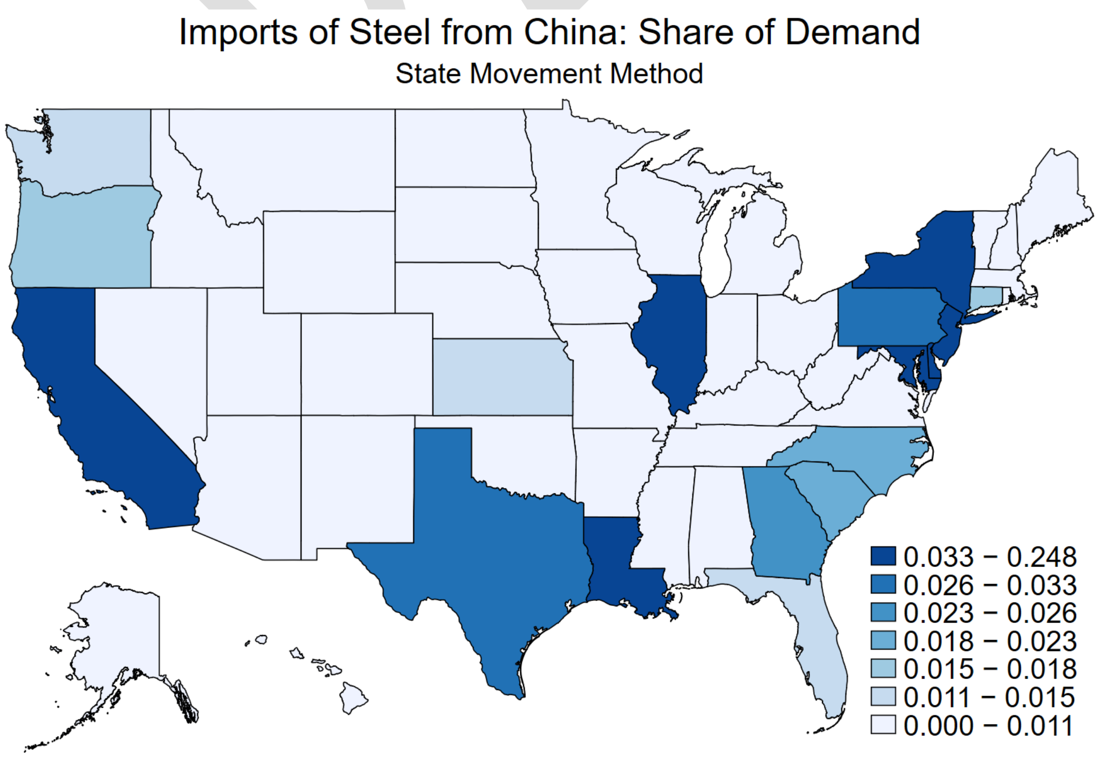
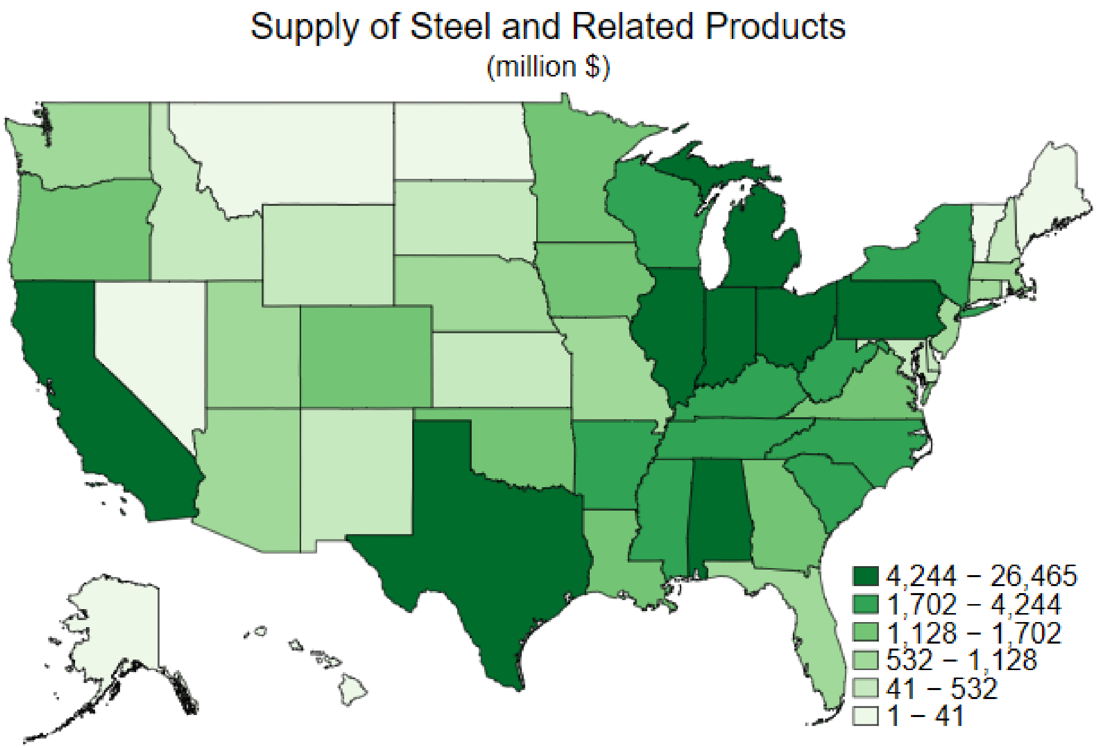


Figure 14.



Figures 15-18 show state exports of oilseeds to China, as shares of state supply and in absolute dollar amounts, across the various methods. Soybeans compose the majority of oilseeds, and have been subject to Chinese tariffs on imports from the United States. According to the port-gravity solution, the highest estimated dollar values of oilseed foreign exports to China occur in the states with the highest production levels, including Illinois, Iowa, and Minnesota; however, a relatively small share of these states' supply of oilseeds consists of exports to China. Louisiana, on the other hand, has high dollar-value exports to China that account for a relatively large percentage of its total supply, according to both the port-gravity and state OM methods, indicating that Chinese tariffs may be especially harmful to the producers there.

Figure 15.

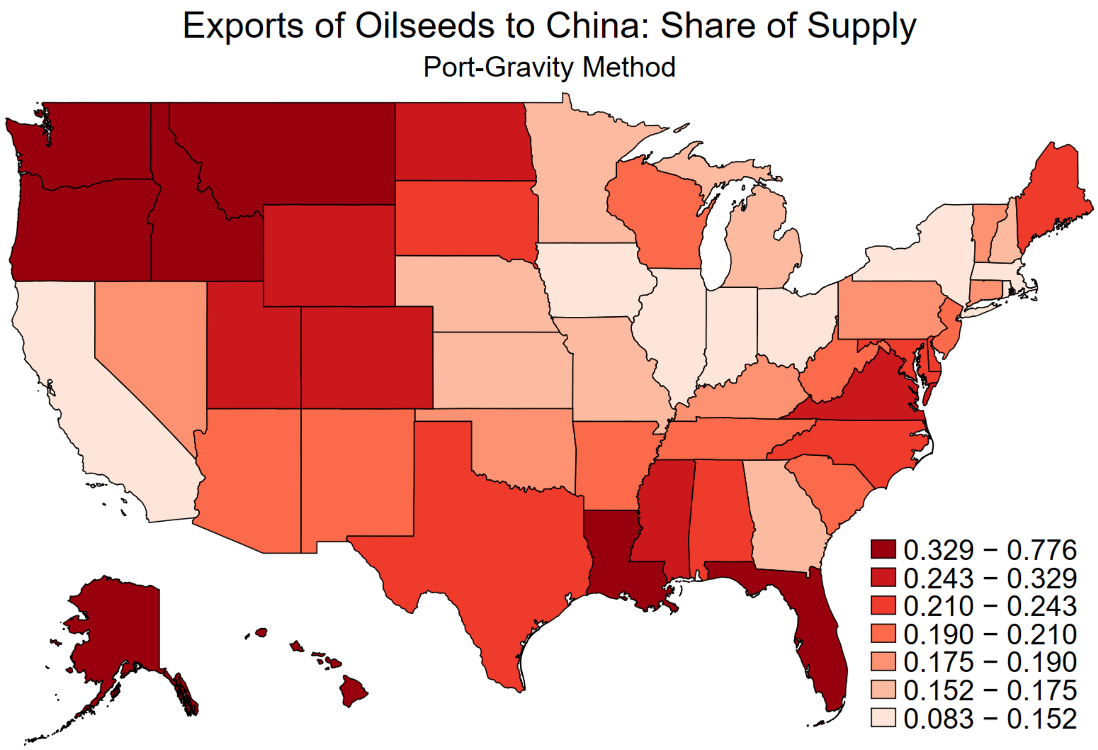


Figure 16.

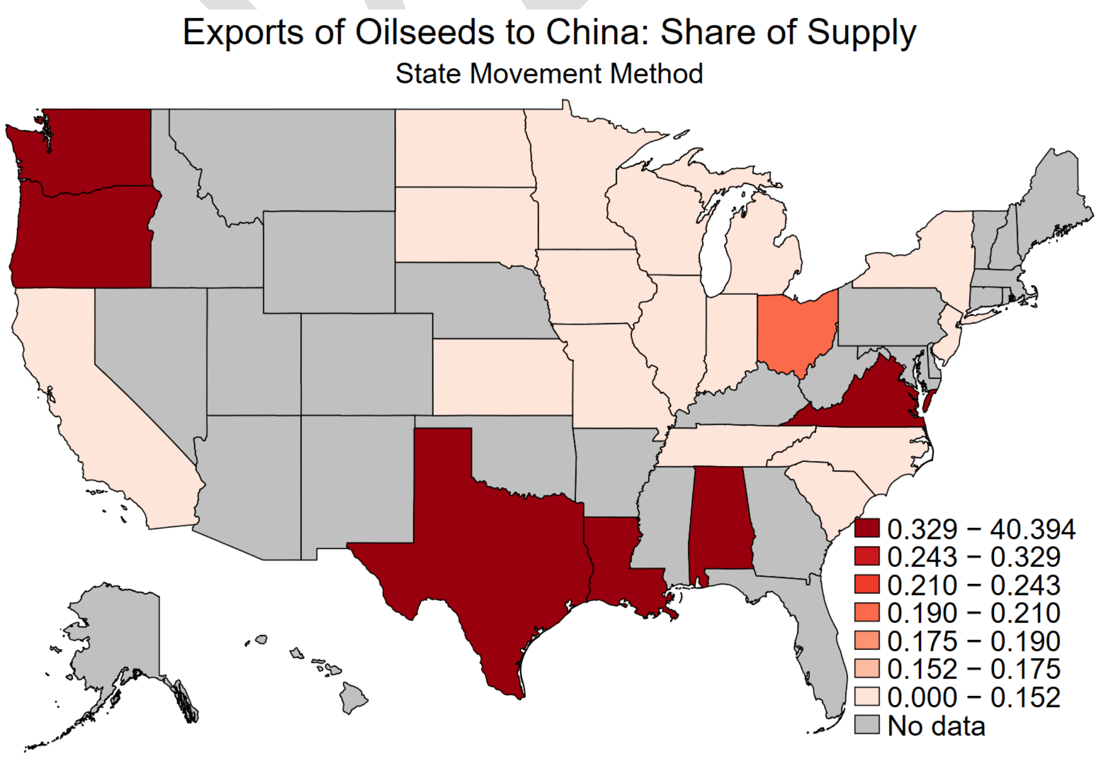


Figure 17.

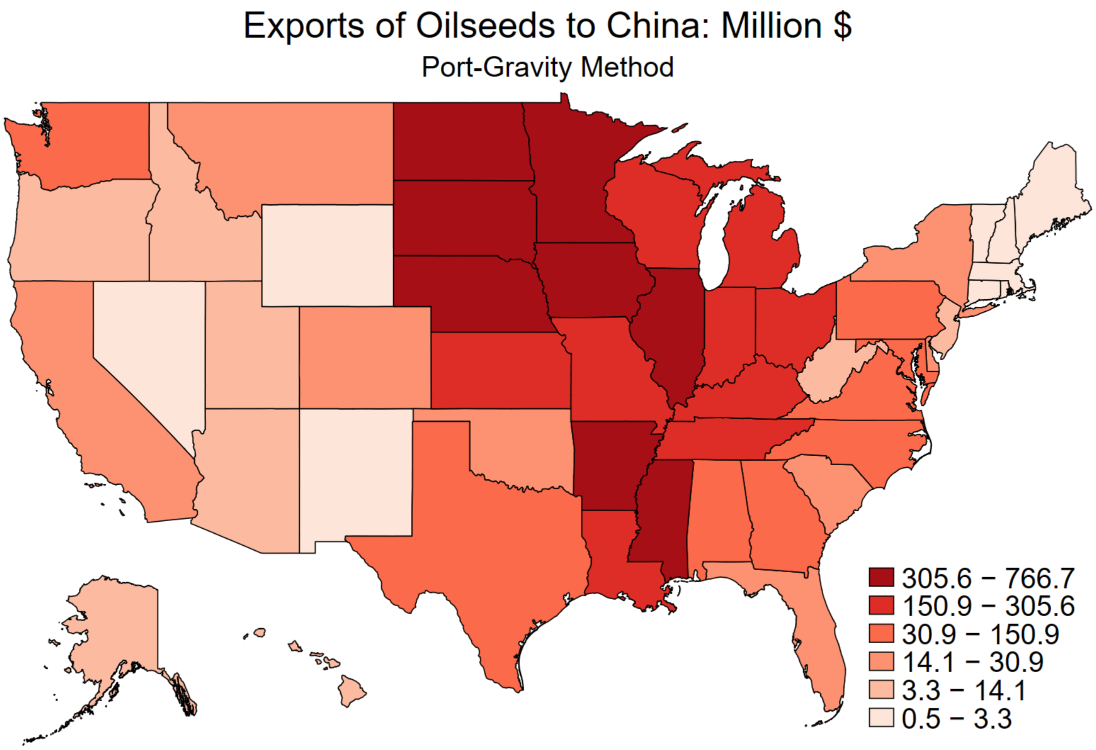
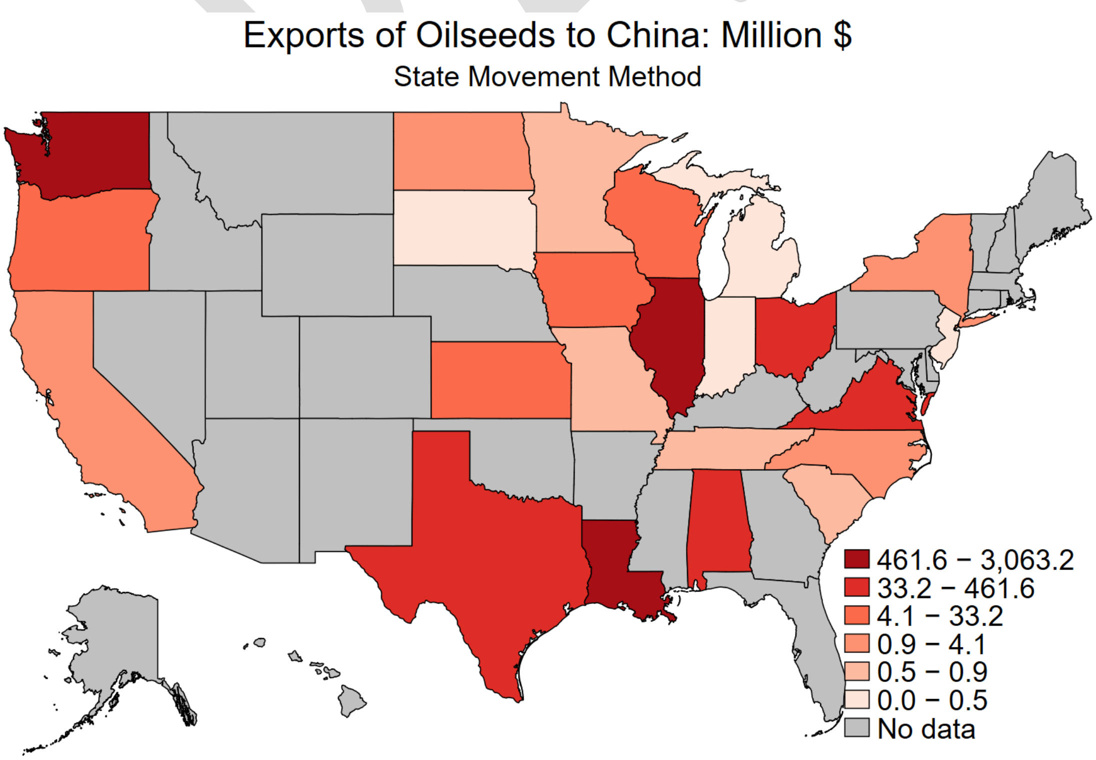


Figure 18.



The purpose of the above examples is not to analyze U.S.-Chinese trade relations but rather to illustrate the importance and one potential use of these data.. Finally, to demonstrate that the port-gravity solution provides county-by-country partner data, we add Figure 19, showing oilseed exports to China by county, as a share of county supply.

Figure 19.

Conclusions and Remaining Questions

While the assumption that a county's proximity to a customs port (in terms of cost of transport to and from it) influences that county's foreign import and export rates is logical, a question that remains is whether this assumption holds for all shippable commodities. It is reasonable to think that this assumption (and thus the new gravity treatment) holds for perishable commodities for which time is a factor; however, proximity to a port, while still providing cost savings, may be relatively less important for non-perishable commodities for which time is much less of a factor. That being said, with the rise of custom orders and real-time manufacturing, the proximity to ports may still be a significant factor for some non-perishable goods.

The results of the gravity model cannot be interpreted as necessarily reflecting differing tastes and preferences for international varieties of goods versus domestic varieties. For example, the result that a swath of Colorado counties have among the lowest foreign import rates of the commodity *beer, ale, malt liquor and nonalcoholic beer* makes intuitive sense in light of the thriving brewery industry throughout the state and the many "buy local" movements taking place not only in Colorado but across the country; however, these results are due solely to a combination of these counties' supply relative to demand, other counties' supplies relative to their demands, and the relative ease with which these Colorado counties can trade this commodity with other counties and ports, all of which are exogenous inputs into the gravity model. In other words, while the results are intuitive and within expectations for a state with a vibrant brewing industry, they cannot be interpreted to suggest that Colorado residents have a stronger preference for domestic beers, ales, and malt liquors relative to residents of other states; while they very well might, the results of the gravity model cannot identify the effect of tastes and preferences on import rates. St. Louis City, MO had a similarly low foreign import rate of this commodity; this result is not unexpected given that this county is the headquarters of the American operations of Anheuser Busch and leads the nation in the value of production of this commodity. The county with the lowest foreign import rate of this commodity under the new treatment was Harrisonburg City, VA. This result is not entirely unexpected given that Harrisonburg has a relatively high supply-to-demand ratio for this commodity and is surrounded by several counties with the highest supply-to-demand ratios in the country for this commodity.

Also, car manufacturers sometimes locate car manufacturing plants in the U.S. for the purpose of serving only U.S. markets; in such a case, one would not expect that manufacturer to have any foreign exports. However, if there is a non-zero impedance between the county in which the manufacturing plant is located and a port that exports cars, the gravity model will overestimate foreign exports of cars from that county, all else equal.

It should also be noted that, aside from the quality control checks to ensure the proper functioning of the model (i.e., that the model was programmed as intended), the systematic testing of these results is hampered by the lack of empirical data against which they can be compared. As explained, data that track imports from port-of-entry to destination, and exports from origin of transportation movement, exist at the state level, but these origins and destinations often are not places of production, intermediate, or final use for the goods, which is the economic concept of trade that we are modeling. We have created comparable estimates using the state OM/UD method, which, along with an in-depth review of certain commodity trading patterns certainly provides some insight into the validity of the new treatment; however, it does not preclude the possibility of unexpected or suspect results for commodities and geographies that have not received in-depth inspection.

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Appendix

IMPLAN's Gravity Model Implementation for Inter-regional trade

If distance is ignored, we may expect that for a given commodity, the percentage of supply of that commodity from region *i* going to satisfy demand in region *j* will be equal to the ratio:

$$P_{ij} = \left[{}^{D_i}\!/_{D} \right] \; for\ all\ i, j \qquad [2]$$

where D_j = region *j*'s total demand for the commodity and $D = \sum_j D_j$. That is, if region *j* makes up 10% of U.S. demand for the commodity, then each county that produces the commodity will send 10% of their supply of that commodity to region *j*. In this case, trade between regions *i* and *j* depends solely upon supply and demand in each region – supply from region *i* will go to meet the demand in region *j* based on *i*'s total production of the commodity and *j*'s proportion of all region's demands for the commodity:

$$T_{i,j} = O_i \left[{}^{D_i}\!/_{D} \right] \; for\ all\ i, j \qquad [3]$$

where O_i = total supply of the commodity originating in region *i.*

More realistically, the attractiveness of a region decreases across distance as a result of time and cost to deliver the goods:

$$T_{ij} = O_i \left[\frac{{}^{D_i}\!/_{D}}{d_{ij}} \right] for\ all\ i, j \qquad [4]$$

where d_{ij} = the "distance" between regions *i* and *j*. Experience has shown that Equations [3] and [4] overestimate the volume of shorter hauls (Isard, 1960; Carroll and Bevis, 1957); thus, the denominator is modified to account for all competing sources of demand:

$$P_{ij} = {\left[\frac{\left[{}^{D_i}/_{D}\right]}{d_{ij}}\right]} \Big/ {\sum_i \left[\frac{\left[{}^{D_i}/_{D}\right]}{d_{ij}}\right]} \; for\ all\ i, j \quad [5]$$

and

$$T_{ij} = O_i \left({\left[\frac{\left[{}^{D_i}/_{D}\right]}{d_{ij}}\right]} \Big/ {\sum_i \left[\frac{\left[{}^{D_i}/_{D}\right]}{d_{ij}}\right]} \right) for\ all\ i, j \quad [6]$$

We can simplify Equation [6] by recognizing that D cancels out:

$$T_{ij} = O_i \left({\left[\frac{D_i}{d_{ij}}\right]} \Big/ {\sum_i \left[\frac{D_i}{d_{ij}}\right]} \right) for\ all\ i, j \quad [7]$$

We can simplify further by setting:

$$Z_i = \sum_j D_j d_{ij}^{-1} \quad [8]$$

Therefore:

$$T_{ij} = O_i D_j d_{ij}^{-1} Z_i^{-1} \quad [9]$$

Note from Equation [5] that the sum of all probabilities (P_{ij}) is 1; therefore, we can derive a singly-constrained model where the sum of all trade from region i to all regions is equal to the total supply in region:

$$\sum_j T_{ij} = O_j \sum_j \left(D_j d_{ij}^{-1} Z_i^{-1} \right) \quad [10]$$

But we also need to constrain the system so that the sum of all trade flows into a region is equal to that region's total demand. Trade flows from each region into region *j* are summed to obtain a first estimate of total inflows to region *j*: $T_j = \sum_i T_{ij}$.

The known D_j is then divided by the estimated total inflows, yielding the ratio:

$$B_j = \frac{D_j}{T_j} \qquad [11]$$

Each first-round *supply-constrained* estimate of T_{ij} to destination *j* is then multiplied by Bj to obtain the first-round *demand-constrained* estimates of T_{ij}:

$$T_{ij}^D = B_j O_i D_j d_{ij}^{-1} Z_i^{-1} \qquad [12]$$

Then, for each origin region *i*, the known O_i is divided by the new *demand-constrained* estimates of T_i, yielding the ratio:

$$A_i = \frac{O_i}{T_i} \qquad [13]$$

Each *demand-constrained* T_{ij} for origin *i* is then multiplied by A_i to obtain the next round of *supply-constrained* estimates of T_{ij}:

$$T_{ij}^S = A_i B_j O_i D_j d_{ij}^{-1} Z_i^{-1} \qquad [14]$$

This iterative process is repeated until the trade estimates are double-constrained; that is, until all supplies go somewhere (including within the same county) and all demands are fulfilled. $A_i B_j$ may be thought of as a derived gravitational constant between two counties (Isard, 1998). This formulation assures that the following two constraints are satisfied:

$$\sum_j T_{ij} = O_i \qquad [15]$$

and

$$\sum_{i} T_{ij} = D_j \qquad [16]$$

Distance

There are a number of possible ways to define the distance (d_{ij}) between the masses of attraction, several of which are discussed below.

Great Circle Distance

The simplest concept is the straight-line distance or shortest possible route between two regions. This route can be determined through GIS programs and is known as the great circle distance.

Highway Distances

Once one has the great circle distances (GCDs) between regions, a simple rule-of-thumb could be used to estimate highway distance between regions – e.g., the highway distance between regions *i* and *j* is 1.2 times the GCD between regions *i* and *j*. One could also potentially extract highway distances from traffic and map data (e.g., Google Maps).

Impedances

Neither of the above approaches accounts for the relative advantages of rail and water transportation, nor impediments to travel. For example, the GCD or highway distance between Denver and New Orleans may be shorter than the highway distance between St Paul and New Orleans, but water transportation available on the Mississippi River means that grain shipments are more likely to travel from St. Paul to New Orleans than from Denver to New Orleans.

The Center for Transportation Analysis at Oak Ridge National Laboratory (ORNL) has developed an integrated, intermodal transportation network modeling system.[12] The system accounts for tolls, congestion, and other factors to derive travel impedances between each county centroid to every other county centroid in the U.S., by mode of transportation (truck, truck-rail multimodal, and truck-water multimodal). These impedances serve as the distances (d_{ij}) in the gravity model. ORNL also provides the great circle distances between county centroids – these are used to calibrate the gravity model to the Commodity Flow Survey data, as described next.

Model Calibration

The Commodity Flow Survey (CFS) and Freight Analysis Framework (FAF) contain information on the value, weight, distance traveled, transportation mode, and origin and destination state of the shippable commodities.[13] These commodities are classified according to the standard classification of transported goods (SCTG) system, and the survey data are typically reported at the two-digit SCTG level. The tables from the CFS and FAF provide three important pieces of information relevant to the gravity model:

1. Mode of transportation by commodity
2. Tons by distance shipped
3. Ton-miles[14] shipped

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[12] See County-to-County Distance Matrix, available https://cta.ornl.gov/transnet/SkimTree.htm, accessed May 15, 2018.

[13] The CFS is a joint effort by the Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics (BTS), and U.S. Census Bureau. The survey is conducted roughly every five years and the resulting data are published on the Census Bureau's website..

[14] Ton-miles = tons shipped x miles traveled.

Mode of Transportation

CFS and FAF tables show the proportion of total commodity value, tons, and ton-miles that were transported by the various transportation modes. This table of shipment mode provides the basis of our decision as to which of the impedances to use in calibration of the model or the weighting to give the various modes of transportation.

Ton-Miles

Finally, after determining the appropriate value and functional form for d_{ij}, perhaps the most important part of the calibration is determining an appropriate value for *b*. For this we rely on CFS and FAF data on value, tons, and total ton-miles moved by commodity. Dividing ton-miles by tons for a commodity yields the average movement for each ton of that commodity, which serves as the target for calibration – *b* is adjusted for each commodity until the sum of T_{ij}s for that commodity (for all *i* and *j*) are suitably close to the national average movement of that commodity as reported by the most recent CFS.

We start the calibration process by setting *b* to a value of 2 (the value of *b* in Newton's gravity formulation)[15] and solving the doubly-constrained model for initial estimates. If the average ton-miles exceeds the target from the calibration sources, *b* is increased, thereby decreasing the "distance" between *i* and *j*. Conversely, if the average ton-miles is less than the target value, *b* is decreased. This is done iteratively until the average ton-miles traveled by the commodity (across all counties) is within ten percent of what the calibration sources report as the national average movement of that commodity.

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[15] The value of 2 was used in the initial year of IMPLAN's use of the gravity model to estimate trade flows. In subsequent years and currently, the initial value of *b* is determined by the final *b* for that commodity from the previous year's solution.

Table 1.

	Total Goods Exports (million $)		
State	Constant National Rates	Port-Gravity Solution	State Origin of Movement
AK	2,349	2,751	3,370
AL	20,010	18,804	14,788
AR	10,306	9,250	4,611
AZ	15,102	15,991	16,085
CA	120,133	121,429	114,212
CO	10,766	8,460	6,228
CT	14,412	14,093	11,777
DC	183	133	860
DE	2,423	2,162	4,356
FL	22,975	25,660	38,453
GA	29,043	29,085	30,792
HI	974	857	1,478
IA	20,663	17,794	11,597
ID	4,689	4,132	3,172
IL	45,673	42,535	48,219
IN	41,782	36,488	27,234
KS	19,599	16,378	8,480
KY	21,977	18,179	21,682
LA	20,184	24,289	35,551
MA	20,062	18,774	18,067
MD	8,103	7,485	7,114
ME	2,964	3,029	1,920
MI	43,854	52,071	40,734
MN	22,517	18,908	15,595
MO	26,411	20,898	10,902
MS	9,055	9,878	7,525
MT	2,360	3,579	1,005
NC	36,770	31,637	23,105
ND	3,937	6,160	3,137
NE	9,931	9,081	5,692
NH	4,041	3,722	2,604
NJ	16,422	16,646	21,695
NM	3,344	2,665	2,214
NV	2,929	2,615	5,575
NY	33,080	39,038	37,024
OH	50,063	46,802	39,238
OK	13,415	10,990	4,218
OR	17,861	18,203	14,859
PA	39,466	36,189	29,747
RI	3,077	3,097	1,230
SC	19,661	19,810	24,571
SD	4,232	4,238	1,282
TN	25,004	21,280	25,261
TX	110,408	133,755	175,008
UT	10,400	8,603	9,637
VA	13,593	12,559	13,606
VT	1,919	2,116	2,300
WA	52,759	63,237	68,098
WI	27,730	24,953	18,158
WV	5,175	4,196	3,925
WY	1,983	1,086	819

Table 2.

	Total Goods Imports (million $)		
State	Constant National Rates	Port-Gravity Solution	State Ultimate Destination
AK	6,161	6,619	2,336
AL	34,939	31,218	22,215
AR	17,814	13,664	6,896
AZ	31,664	33,747	16,347
CA	233,453	273,107	356,076
CO	31,799	25,259	12,122
CT	24,096	26,943	23,119
DC	6,046	6,608	462
DE	5,591	6,892	9,295
FL	89,556	103,092	70,544
GA	56,195	52,601	82,325
HI	8,274	10,087	4,220
IA	25,842	19,497	8,951
ID	9,238	7,980	4,230
IL	84,619	74,100	115,158
IN	59,496	49,188	46,709
KS	25,876	17,355	9,294
KY	35,258	26,298	34,041
LA	46,134	56,274	43,609
MA	42,982	50,232	31,996
MD	33,776	38,129	30,190
ME	7,977	9,540	3,605
MI	73,986	72,835	120,262
MN	39,624	34,414	28,300
MO	41,009	31,493	18,271
MS	21,035	20,561	13,944
MT	7,733	8,971	4,771
NC	59,510	49,545	45,212
ND	6,752	6,185	3,241
NE	13,663	9,327	3,990
NH	8,660	9,339	11,304
NJ	49,702	61,261	122,407
NM	10,857	8,881	2,017
NV	12,757	12,814	7,035
NY	100,084	137,844	106,953
OH	86,594	71,230	64,753
OK	26,751	18,792	11,505
OR	23,355	23,062	13,046
PA	81,215	79,842	74,377
RI	6,138	7,522	8,502
SC	31,615	30,983	37,335
SD	5,801	4,539	1,047
TN	43,352	33,912	63,486
TX	209,956	208,153	237,865
UT	19,022	14,586	11,861
VA	47,221	47,363	22,806
VT	4,300	5,283	3,087
WA	54,997	68,012	49,092
WI	42,329	34,997	22,109
WV	10,926	8,033	3,728
WY	6,452	3,974	1,239

Table 3.

State	Goods Exports as a Share of Goods Supply (%)		
	Constant National Rates	Port-Gravity Solution	State Origin of Movement
AK	12.7%	14.8%	18.9%
AL	12.9%	12.1%	9.5%
AR	12.2%	10.9%	5.6%
AZ	18.2%	19.3%	19.3%
CA	15.8%	16.0%	15.0%
CO	11.7%	9.2%	6.7%
CT	19.6%	19.2%	16.0%
DC	14.5%	10.5%	80.3%
DE	13.5%	12.0%	25.0%
FL	14.1%	15.7%	23.4%
GA	14.5%	14.6%	15.4%
HI	10.6%	9.3%	17.7%
IA	13.3%	11.4%	7.5%
ID	12.3%	10.9%	8.5%
IL	13.3%	12.4%	14.0%
IN	13.0%	11.3%	8.4%
KS	17.1%	14.3%	7.4%
KY	13.2%	10.9%	13.0%
LA	10.5%	12.7%	18.7%
MA	16.7%	15.6%	15.0%
MD	14.6%	13.5%	12.8%
ME	12.9%	13.2%	8.4%
MI	13.3%	15.8%	12.3%
MN	13.3%	11.1%	9.2%
MO	15.9%	12.6%	6.6%
MS	11.3%	12.3%	9.5%
MT	10.5%	16.0%	4.6%
NC	13.9%	11.9%	8.7%
ND	14.7%	22.9%	11.8%
NE	11.9%	10.9%	6.9%
NH	16.2%	14.9%	10.5%
NJ	12.3%	12.5%	16.2%
NM	12.4%	9.9%	8.8%
NV	12.1%	10.8%	23.7%
NY	14.9%	17.6%	16.6%
OH	13.0%	12.2%	10.2%
OK	13.0%	10.6%	4.1%
OR	17.4%	17.7%	14.4%
PA	13.2%	12.1%	9.9%
RI	19.7%	19.8%	8.1%
SC	15.4%	15.5%	19.2%
SD	14.2%	14.2%	4.4%
TN	13.5%	11.5%	13.6%
TX	12.4%	15.1%	19.7%
UT	15.4%	12.8%	14.3%
VA	11.1%	10.3%	11.1%
VT	13.4%	14.7%	16.3%
WA	28.2%	33.7%	36.2%
WI	12.9%	11.6%	8.4%
WV	10.6%	8.6%	8.3%
WY	8.3%	4.6%	3.8%

Table 4.

State	Goods Imports as a Share of Goods Demand (final and intermediate use) (%)		
	Constant National Rates	Port-Gravity Solution	State Ultimate Destination
AK	30.2%	32.4%	12.2%
AL	23.1%	20.6%	14.5%
AR	21.1%	16.2%	8.3%
AZ	24.5%	26.1%	12.6%
CA	26.0%	30.4%	39.1%
CO	24.0%	19.0%	9.0%
CT	25.5%	28.6%	24.1%
DC	24.9%	27.2%	2.2%
DE	23.7%	29.2%	42.4%
FL	24.7%	28.4%	19.1%
GA	22.6%	21.1%	32.6%
HI	25.9%	31.6%	13.4%
IA	20.0%	15.1%	6.9%
ID	22.2%	19.2%	10.3%
IL	24.0%	21.1%	32.2%
IN	24.4%	20.2%	18.8%
KS	22.9%	15.4%	8.3%
KY	23.4%	17.4%	22.4%
LA	25.1%	30.6%	23.6%
MA	25.4%	29.7%	18.6%
MD	25.3%	28.6%	22.3%
ME	24.8%	29.7%	11.3%
MI	24.1%	23.7%	38.6%
MN	23.4%	20.3%	16.5%
MO	22.8%	17.5%	10.0%
MS	24.9%	24.4%	16.9%
MT	26.3%	30.5%	16.9%
NC	23.1%	19.2%	17.3%
ND	23.1%	21.2%	11.5%
NE	18.1%	12.4%	5.4%
NH	25.7%	27.7%	33.1%
NJ	25.1%	30.9%	60.8%
NM	25.6%	20.9%	4.9%
NV	24.8%	24.9%	13.6%
NY	25.3%	34.8%	26.5%
OH	23.9%	19.6%	17.6%
OK	25.2%	17.7%	11.0%
OR	24.8%	24.5%	13.7%
PA	24.3%	23.9%	21.9%
RI	25.8%	31.6%	36.5%
SC	23.1%	22.6%	27.2%
SD	20.1%	15.7%	3.9%
TN	23.3%	18.2%	33.8%
TX	23.9%	23.7%	26.8%
UT	25.2%	19.4%	16.2%
VA	24.0%	24.1%	11.5%
VT	23.9%	29.4%	17.2%
WA	25.3%	31.3%	22.3%
WI	22.3%	18.4%	11.5%
WV	22.1%	16.2%	8.2%
WY	28.1%	17.3%	5.9%

Table 5. Correlation of Export Values by State between Port-Gravity and State OM Methods, Sorted by Correlation Coefficient

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
34	Phosphate rock[16]	1.000	0.000
5	Tree nuts	0.999	0.000
156	Refined petroleum products	0.995	0.000
83	Dehydrated food products	0.995	0.000
109	Wine and brandies	0.993	0.000
349	Travel trailers and campers	0.993	0.000
20	Natural gas and crude petroleum	0.991	0.000
266	Oil and gas field machinery	0.990	0.000
4	Fruit	0.990	0.000
119	Carpets and rugs	0.989	0.000
26	Lead and zinc ore	0.980	0.000
27	Copper ore	0.979	0.000
161	Petrochemicals	0.977	0.000
10	All other crops	0.977	0.000
375	Office furniture, except wood	0.975	0.000
24	Gold ore	0.971	0.000
390	Musical instruments	0.965	0.000
93	Seafood products	0.965	0.000
170	Phosphatic fertilizer	0.964	0.000
166	Plastics materials and resins	0.961	0.000
129	Other cut and sew apparel	0.959	0.000
3	Vegetables and melons	0.959	0.000
254	Valve and fittings, other than plumbing	0.958	0.000
159	Petroleum lubricating oil and grease	0.958	0.000
364	Boats	0.957	0.000
126	Cut and sewn apparel from contractors	0.955	0.000
357	Aircrafts	0.953	0.000
130	Apparel accessories and other apparel	0.950	0.000
367	All other transportation equipment	0.948	0.000
188	Plastics packaging materials and unlaminated films and sheets	0.948	0.000
17	Fish	0.945	0.000
239	Plates	0.944	0.000
165	Other basic organic chemicals	0.943	0.000
202	Other pressed and blown glass and glassware	0.941	0.000
81	Canned fruits and vegetables	0.940	0.000
128	Women's and girls' cut and sew apparel	0.937	0.000
168	Artificial and synthetic fibers and filaments	0.937	0.000

[16] This commodity has very few observations without missing values.

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
305	Broadcast and wireless communications equipment	0.936	0.000
77	Chocolate and confectioneries from cacao beans	0.936	0.000
99	Roasted nuts and peanut butter	0.936	0.000
281	Machine tool	0.936	0.000
78	Confectioneries from purchased chocolate	0.934	0.000
146	Wood pulp	0.932	0.000
385	Sporting and athletic goods	0.930	0.000
238	Fabricated structural metal products	0.928	0.000
249	Machined products	0.927	0.000
320	Analytical laboratory instruments	0.925	0.000
79	Frozen fruits, juices and vegetables	0.924	0.000
355	Motor vehicle stamped metal	0.924	0.000
175	In-vitro diagnostic substances	0.923	0.000
107	Manufactured ice	0.920	0.000
309	Semiconductors and related devices	0.918	0.000
28	Uranium-radium-vanadium ore	0.917	0.028
272	Optical instruments and lenses	0.915	0.000
319	Electricity and signal testing instruments	0.914	0.000
279	Special tool, die, jig, and fixture	0.913	0.000
334	Switchgear and switchboard apparatus	0.910	0.000
350	Motor vehicle gasoline engines and engine parts	0.909	0.000
84	Fluid milk	0.908	0.000
190	Plastics pipes and pipe fittings	0.908	0.000
382	Ophthalmic goods	0.907	0.000
89	Meat (except poultry) produced in slaughtering plant	0.904	0.000
105	All other food products	0.903	0.000
182	Toilet preparations	0.903	0.000
360	Guided missiles and space vehicles	0.903	0.000
7	Tobacco	0.901	0.000
248	Spring and wire products	0.899	0.000
149	Paperboard containers	0.899	0.000
124	Hosiery and socks	0.898	0.000
76	Nonchocolate confectioneries	0.897	0.000
32	Other clay, ceramic, refractory minerals	0.897	0.000
224	Rolled, drawn, and extruded aluminum	0.897	0.000
384	Jewelry and silverware	0.896	0.000
92	Processed poultry meat products	0.895	0.000
312	Printed circuit assemblies (electronic assemblies)	0.894	0.000
187	Other miscellaneous chemical products	0.892	0.000
269	Sawmill, woodworking, and paper machinery	0.890	0.000
263	Lawn and garden equipment	0.890	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
242	Ornamental and architectural metal products	0.888	0.000
177	Paints and coatings	0.887	0.000
351	Motor vehicle electrical and electronic equipment	0.887	0.000
383	Dental laboratories	0.887	0.000
264	Construction machinery	0.886	0.000
6	Greenhouse, nursery, and floriculture products	0.885	0.000
217	Iron and steel and ferroalloy products	0.885	0.000
361	Propulsion units and parts for space vehicles and guided missiles	0.885	0.000
127	Men's and boys' cut and sew apparel	0.883	0.000
389	Gaskets, packings, and sealing devices	0.882	0.000
8	Cotton	0.881	0.000
326	Lighting fixtures	0.881	0.000
68	Rice	0.880	0.000
321	Irradiation apparatus	0.878	0.000
178	Adhesives	0.878	0.000
194	Plastics bottles	0.874	0.000
295	Welding and soldering equipment	0.873	0.000
352	Motor vehicle steering, suspension components (except spring), and brake systems	0.871	0.000
90	Meat processed from carcasses	0.871	0.000
16	Logs and roundwood	0.870	0.000
268	Semiconductor machinery	0.869	0.000
75	Sugar cane	0.866	0.000
86	Cheese	0.866	0.000
241	Sheet metal work (except stampings)	0.864	0.000
388	Signs	0.862	0.000
277	Air conditioning, refrigeration, and warm air heating equipment	0.859	0.000
394	All other miscellaneous manufactured products	0.859	0.000
103	Mayonnaise, dressings, and sauces	0.852	0.000
296	Packaging machinery	0.846	0.000
151	Stationery products	0.844	0.000
387	Office supplies (except paper)	0.843	0.000
147	Paper from pulp	0.843	0.000
330	Household laundry equipment	0.841	0.000
378	Blinds and shades	0.840	0.000
94	Bread and bakery products, except frozen	0.838	0.000
265	Mining machinery	0.837	0.000
347	Truck trailers	0.835	0.000
274	Other commercial service industry machinery	0.835	0.000
369	Upholstered household furniture	0.835	0.000
373	Wood office furniture	0.834	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
301	Electronic computers	0.834	0.000
122	Rope, cordage, twine, tire cord and tire fabric	0.834	0.000
338	Fiber optic cables	0.831	0.000
154	Printed materials	0.831	0.000
346	Motor vehicle bodies	0.825	0.000
342	All other miscellaneous electrical equipment and components	0.824	0.000
372	Institutional furniture	0.821	0.000
259	Small arms, ordnance, and accessories	0.820	0.000
112	Fiber filaments, yarn, and thread	0.819	0.000
267	Food product machinery	0.815	0.000
167	Synthetic rubbers	0.813	0.000
380	Surgical appliance and supplies	0.812	0.000
362	Railroad rolling stock	0.811	0.000
137	Engineered wood members and trusses	0.810	0.000
95	Frozen cakes and other pastries	0.810	0.000
288	Air and gas compressors	0.810	0.000
134	Dimension lumber	0.809	0.000
306	Other communications equipment	0.809	0.000
143	Manufactured homes (mobile homes)	0.808	0.000
23	Iron ore	0.808	0.000
297	Industrial process furnaces and ovens	0.807	0.000
91	Processed animal rendered byproducts	0.807	0.000
87	Dry, condensed, and evaporated dairy products	0.805	0.000
148	Paperboard from pulp	0.803	0.000
73	Breakfast cereal	0.798	0.000
133	Other leather and allied products	0.798	0.000
287	Pump and pumping equipment	0.797	0.000
315	Search, detection, and navigation instruments	0.795	0.000
232	Nonferrous forgings	0.795	0.000
227	Nonferrous metal, except copper and aluminum, shaping	0.793	0.000
164	Other basic inorganic chemicals	0.793	0.000
236	Handtools	0.791	0.000
31	Sand and gravel	0.790	0.000
228	Secondary processing of other nonferrous metals	0.788	0.000
313	Other electronic components	0.786	0.000
216	Miscellaneous nonmetallic mineral products	0.784	0.000
339	Other communication and energy wires	0.783	0.000
271	All other industrial machinery	0.781	0.000
333	Motors and generators	0.781	0.000
370	Nonupholstered wood household furniture	0.780	0.000
198	Other rubber products	0.778	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
392	Brooms, brushes, and mops	0.777	0.000
205	Cement	0.777	0.000
179	Soaps and other detergents	0.776	0.000
250	Turned products and screws, nuts, and bolts	0.774	0.000
262	Farm machinery and equipment	0.773	0.000
304	Telephone apparatus	0.770	0.000
120	Curtains and linens	0.770	0.000
278	Industrial molds	0.769	0.000
345	Heavy duty trucks	0.768	0.000
371	Other household nonupholstered furniture	0.765	0.000
123	Other textile products	0.760	0.000
155	Printing support services	0.755	0.000
199	Pottery, ceramics, and plumbing fixtures	0.754	0.000
379	Surgical and medical instruments	0.750	0.000
359	Other aircraft parts and auxiliary equipment	0.748	0.000
356	Other motor vehicle parts	0.747	0.000
195	Other plastics products	0.744	0.000
207	Concrete blocks and bricks	0.743	0.000
353	Motor vehicle transmission and power train parts	0.741	0.000
240	Metal windows and doors	0.741	0.000
121	Textile bags and canvas	0.741	0.000
229	Ferrous metals	0.739	0.000
220	Steel wire	0.739	0.000
286	Other engine equipment	0.739	0.000
136	Veneer and plywood	0.733	0.000
96	Cookies and crackers	0.733	0.000
221	Aluminum products	0.730	0.000
318	Totalizing fluid meters and counting devices	0.728	0.000
245	Metal cans	0.727	0.000
160	All other petroleum and coal products	0.724	0.000
196	Tires	0.724	0.000
65	Dog and cat food	0.723	0.000
131	Tanned and finished leather and hides	0.718	0.000
298	Fluid power cylinders and actuators	0.716	0.000
223	Aluminum sheets, plates, and foils	0.715	0.000
247	Hardware	0.714	0.000
215	Mineral wool	0.713	0.000
381	Dental equipment and supplies	0.712	0.000
104	Spices and extracts	0.706	0.000
100	Other snack foods	0.705	0.000
322	Watches, clockes, and other measuring and controlling devices	0.705	0.000
106	Bottled and canned soft drinks and water	0.705	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
237	Prefabricated metal buildings and components	0.703	0.000
261	Other fabricated metals	0.702	0.000
14	Animal products, except cattle and poultry and eggs	0.702	0.000
243	Power boilers and heat exchangers	0.701	0.000
324	Software and other prerecorded and record reproducing	0.700	0.000
325	Electric lamp bulbs and parts	0.700	0.000
209	Other concrete products	0.700	0.000
317	Industrial process variable instruments	0.697	0.000
150	Paper bags and coated and treated paper	0.696	0.000
311	Electronic connectors	0.693	0.000
300	Scales, balances, and miscellaneous general purpose machinery	0.692	0.000
291	Conveyor and conveying equipment	0.692	0.000
344	Light trucks and utility vehicles	0.690	0.000
386	Dolls, toys, and games	0.687	0.000
290	Elevators and moving stairways	0.680	0.000
293	Industrial trucks, trailers, and stackers	0.679	0.000
158	Asphalt shingles and coating materials	0.678	0.000
203	Glass containers	0.678	0.000
35	Other chemical and fertilizer mineral	0.677	0.000
153	All other converted paper products	0.676	0.000
183	Printing inks	0.676	0.000
308	Bare printed circuit boards	0.676	0.000
323	Blank magnetic and optical recording media	0.674	0.000
257	Small arms ammunition	0.672	0.000
358	Aircraft engines and engine parts	0.672	0.000
343	Automobiles	0.671	0.000
354	Motor vehicle seating and interior trim	0.669	0.000
113	Broadwoven fabrics and felts	0.668	0.000
97	Dry pasta, mixes, and dough	0.668	0.000
341	Carbon and graphite products	0.665	0.000
340	Wiring devices	0.664	0.000
294	Power-driven handtools	0.660	0.000
197	Rubber and plastics hoses and belts	0.660	0.000
391	Fasteners, buttons, needles, and pins	0.660	0.000
69	Malt	0.659	0.010
163	Synthetic dyes and pigments	0.659	0.000
162	Industrial gases	0.658	0.000
280	Cutting tool and machine tool accessory	0.657	0.000
145	All other miscellaneous wood products	0.655	0.000
116	Knitted fabrics	0.654	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
314	Electromedical and electrotherapeutic apparatus	0.653	0.000
201	Flat glass	0.650	0.000
101	Coffee and tea	0.650	0.000
328	Household cooking appliances	0.646	0.000
36	Other nonmetallic minerals	0.644	0.000
376	Showcases, partitions, shelvings, and lockers	0.640	0.000
327	Small electrical appliances	0.640	0.000
377	Mattresses	0.633	0.000
176	Biological products (except diagnostic)	0.630	0.000
244	Metal tanks (heavy gauge)	0.629	0.000
152	Sanitary paper products	0.624	0.000
138	Reconstituted wood products	0.620	0.000
273	Photographic and photocopying equipment	0.608	0.000
174	Pharmaceuticals	0.608	0.000
115	Nonwoven fabrics	0.608	0.000
270	Printing machinery and equipment	0.606	0.000
212	Abrasive products	0.600	0.000
110	Distilled liquors except brandies	0.595	0.000
374	Custom architectural woodwork and millwork	0.593	0.000
255	Plumbing fixture fittings and trims	0.592	0.000
80	Frozen specialties	0.591	0.000
336	Storage batteries	0.589	0.000
230	Nonferrous metals	0.586	0.000
307	Audio and video equipment	0.583	0.000
289	Measuring and dispensing pumps	0.577	0.006
180	Polish and other sanitation goods	0.571	0.000
169	Nitrogenous fertilizer	0.568	0.000
256	Balls and roller bearings	0.563	0.001
22	Coal	0.554	0.002
275	Air purification and ventilation equipment	0.553	0.000
70	Wet corn	0.549	0.007
365	Motorcycles, bicycles, and parts	0.544	0.000
85	Creamery butter	0.544	0.001
185	Compounded resins	0.540	0.000
184	Explosives	0.538	0.003
200	Bricks, tiles, and other structural clay products	0.536	0.000
186	Photographic films and chemicals	0.534	0.000
226	Rolled, drawn, extruded, and alloyed copper	0.527	0.000
299	Fluid power pumps and motors	0.524	0.000
246	Metal barrels, drums and pails	0.524	0.000
283	Turbine and turbine generator set units	0.515	0.000
135	Preserved wood products	0.510	0.000
181	Surface active agents	0.507	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
235	Cutlery, utensils, pots, and pans	0.505	0.000
66	Other animal food	0.497	0.000
284	Speed changers, industrial high-speed drives, and gears	0.493	0.000
88	Ice cream and frozen dessert	0.492	0.003
292	Overhead cranes, hoists, and monorail systems	0.490	0.001
213	Cut stone and stone products	0.487	0.001
303	Computer terminals and other computer peripheral equipment	0.487	0.000
368	Wood kitchen cabinets and countertops	0.486	0.001
139	Wood windows and doors	0.485	0.001
310	Capacitors, resistors, coils, transformers, and other inductors	0.479	0.001
140	Cut stock, resawn and planed lumber	0.476	0.000
204	Glass products made of purchased glass	0.473	0.001
30	Stone	0.453	0.001
206	Ready-mix concrete	0.453	0.004
15	Forest, timber, and forest nursery products	0.447	0.001
282	Rolling mill and other metalworking machinery	0.443	0.002
363	Ships	0.441	0.008
329	Household refrigerators and home freezers	0.441	0.076
332	Power, distribution, and specialty transformers	0.440	0.002
276	Heating equipment (except warm air furnaces)	0.438	0.002
118	Coated fabric coating	0.435	0.002
13	Poultry and egg products	0.431	0.004
189	Unlaminated plastics profile shapes	0.430	0.002
72	Fats and oils refining and blending	0.427	0.003
285	Mechanical power transmission equipment	0.423	0.002
82	Canned specialties	0.416	0.004
335	Relay and industrial controls	0.404	0.003
225	Nonferrous metal (exc aluminum) smelting and refining	0.403	0.005
114	Narrow fabrics and schiffli machine embroidery	0.399	0.020
234	Crowned and stamped metals	0.389	0.008
214	Ground or treated mineral and earth products	0.374	0.010
141	Other millwork, including flooring	0.372	0.008
302	Computer storage devices	0.371	0.014
210	Lime	0.370	0.090
2	Grains	0.363	0.011
142	Wood containers and pallets	0.337	0.017
29	Other metal ore	0.331	0.195
231	Iron and steel forgings	0.328	0.036
172	Pesticides and other agricultural chemicals	0.321	0.024

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
331	Other major household appliances	0.319	0.128
157	Asphalt paving mixtures and blocks	0.309	0.047
211	Gypsum products	0.307	0.060
67	Flour	0.302	0.052
316	Automatic environmental controls	0.287	0.045
102	Flavoring syrup and concentrate	0.282	0.045
173	Medicines and botanicals	0.274	0.072
111	Cigarettes, cigars, smoking and chewing tobacco, and reconstituted tobacco	0.246	0.181
132	Footwear	0.242	0.094
258	Ammunition, except for small arms	0.237	0.126
74	Beet sugar	0.221	0.567
71	Soybean and other oilseed processing	0.170	0.238
1	Oilseeds	0.164	0.293
366	Military armored vehicles, tanks, and tank components	0.152	0.331
11	Beef cattle	0.147	0.324
337	Primary batteries	0.141	0.397
144	Prefabricated wood buildings	0.134	0.358
108	Beer, ale, malt liquor and nonalcoholic beer	0.105	0.473
348	Motor homes	0.097	0.524
9	Sugarcane and sugar beets	-0.019	0.943
33	Potash, soda, and borate mineral	-0.086	0.840
25	Silver ore	-0.133	0.776

Table 6. Correlation of Import Values by State between Port-Gravity and State OM Methods, Sorted by Correlation Coefficient

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
26	Lead and zinc ore[17]	1.000	0.000
302	Computer storage devices	0.978	0.000
111	Cigarettes, cigars, smoking and chewing tobacco, and reconstituted tobacco	0.977	0.000
9	Sugarcane and sugar beets	0.976	0.000
161	Petrochemicals	0.971	0.000
312	Printed circuit assemblies (electronic assemblies)	0.969	0.000
142	Wood containers and pallets	0.968	0.000
7	Tobacco	0.962	0.000
68	Rice	0.953	0.000

[17] This commodity has very few matching records with non-missing observations.

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
121	Textile bags and canvas	0.952	0.000
303	Computer terminals and other computer peripheral equipment	0.947	0.000
342	All other miscellaneous electrical equipment and components	0.944	0.000
308	Bare printed circuit boards	0.940	0.000
313	Other electronic components	0.939	0.000
377	Mattresses	0.938	0.000
372	Institutional furniture	0.937	0.000
369	Upholstered household furniture	0.937	0.000
370	Nonupholstered wood household furniture	0.937	0.000
330	Household laundry equipment	0.936	0.000
145	All other miscellaneous wood products	0.935	0.000
204	Glass products made of purchased glass	0.934	0.000
153	All other converted paper products	0.933	0.000
16	Logs and roundwood	0.933	0.000
195	Other plastics products	0.930	0.000
20	Natural gas and crude petroleum	0.929	0.000
213	Cut stone and stone products	0.928	0.000
123	Other textile products	0.926	0.000
138	Reconstituted wood products	0.926	0.000
107	Manufactured ice	0.922	0.000
378	Blinds and shades	0.921	0.000
10	All other crops	0.917	0.000
6	Greenhouse, nursery, and floriculture products	0.911	0.000
368	Wood kitchen cabinets and countertops	0.910	0.000
359	Other aircraft parts and auxiliary equipment	0.909	0.000
394	All other miscellaneous manufactured products	0.909	0.000
261	Other fabricated metals	0.909	0.000
188	Plastics packaging materials and unlaminated films and sheets	0.909	0.000
199	Pottery, ceramics, and plumbing fixtures	0.908	0.000
268	Semiconductor machinery	0.908	0.000
300	Scales, balances, and miscellaneous general purpose machinery	0.905	0.000
241	Sheet metal work (except stampings)	0.905	0.000
329	Household refrigerators and home freezers	0.903	0.000
353	Motor vehicle transmission and power train parts	0.902	0.000
244	Metal tanks (heavy gauge)	0.900	0.000
371	Other household nonupholstered furniture	0.900	0.000
154	Printed materials	0.900	0.000
92	Processed poultry meat products	0.898	0.000
385	Sporting and athletic goods	0.897	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
83	Dehydrated food products	0.897	0.000
113	Broadwoven fabrics and felts	0.897	0.000
224	Rolled, drawn, and extruded aluminum	0.896	0.000
309	Semiconductors and related devices	0.896	0.000
238	Fabricated structural metal products	0.896	0.000
130	Apparel accessories and other apparel	0.895	0.000
335	Relay and industrial controls	0.895	0.000
217	Iron and steel and ferroalloy products	0.894	0.000
360	Guided missiles and space vehicles	0.892	0.000
311	Electronic connectors	0.892	0.000
317	Industrial process variable instruments	0.890	0.000
133	Other leather and allied products	0.889	0.000
149	Paperboard containers	0.889	0.000
205	Cement	0.888	0.000
194	Plastics bottles	0.887	0.000
288	Air and gas compressors	0.887	0.000
29	Other metal ore	0.886	0.000
392	Brooms, brushes, and mops	0.885	0.000
292	Overhead cranes, hoists, and monorail systems	0.884	0.000
229	Ferrous metals	0.884	0.000
393	Burial caskets	0.884	0.000
209	Other concrete products	0.883	0.000
272	Optical instruments and lenses	0.882	0.000
350	Motor vehicle gasoline engines and engine parts	0.881	0.000
319	Electricity and signal testing instruments	0.881	0.000
182	Toilet preparations	0.880	0.000
365	Motorcycles, bicycles, and parts	0.880	0.000
160	All other petroleum and coal products	0.880	0.000
33	Potash, soda, and borate mineral	0.879	0.000
305	Broadcast and wireless communications equipment	0.878	0.000
336	Storage batteries	0.878	0.000
81	Canned fruits and vegetables	0.877	0.000
126	Cut and sewn apparel from contractors	0.876	0.000
109	Wine and brandies	0.876	0.000
339	Other communication and energy wires	0.873	0.000
103	Mayonnaise, dressings, and sauces	0.872	0.000
120	Curtains and linens	0.871	0.000
93	Seafood products	0.869	0.000
79	Frozen fruits, juices and vegetables	0.869	0.000
247	Hardware	0.868	0.000
298	Fluid power cylinders and actuators	0.867	0.000
71	Soybean and other oilseed processing	0.866	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
356	Other motor vehicle parts	0.865	0.000
181	Surface active agents	0.863	0.000
235	Cutlery, utensils, pots, and pans	0.859	0.000
210	Lime	0.858	0.000
129	Other cut and sew apparel	0.858	0.000
97	Dry pasta, mixes, and dough	0.857	0.000
203	Glass containers	0.855	0.000
147	Paper from pulp	0.853	0.000
391	Fasteners, buttons, needles, and pins	0.851	0.000
127	Men's and boys' cut and sew apparel	0.847	0.000
136	Veneer and plywood	0.847	0.000
202	Other pressed and blown glass and glassware	0.847	0.000
388	Signs	0.846	0.000
307	Audio and video equipment	0.846	0.000
338	Fiber optic cables	0.843	0.000
326	Lighting fixtures	0.842	0.000
114	Narrow fabrics and schiffli machine embroidery	0.842	0.000
101	Coffee and tea	0.842	0.000
389	Gaskets, packings, and sealing devices	0.841	0.000
267	Food product machinery	0.841	0.000
105	All other food products	0.841	0.000
273	Photographic and photocopying equipment	0.840	0.000
240	Metal windows and doors	0.839	0.000
168	Artificial and synthetic fibers and filaments	0.836	0.000
196	Tires	0.836	0.000
355	Motor vehicle stamped metal	0.835	0.000
128	Women's and girls' cut and sew apparel	0.835	0.000
201	Flat glass	0.833	0.000
386	Dolls, toys, and games	0.831	0.000
277	Air conditioning, refrigeration, and warm air heating equipment	0.828	0.000
318	Totalizing fluid meters and counting devices	0.828	0.000
376	Showcases, partitions, shelvings, and lockers	0.827	0.000
283	Turbine and turbine generator set units	0.826	0.000
166	Plastics materials and resins	0.824	0.000
102	Flavoring syrup and concentrate	0.823	0.000
354	Motor vehicle seating and interior trim	0.823	0.000
243	Power boilers and heat exchangers	0.821	0.000
211	Gypsum products	0.820	0.000
374	Custom architectural woodwork and millwork	0.820	0.000
325	Electric lamp bulbs and parts	0.819	0.000
299	Fluid power pumps and motors	0.816	0.000
327	Small electrical appliances	0.814	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
373	Wood office furniture	0.814	0.000
137	Engineered wood members and trusses	0.814	0.000
200	Bricks, tiles, and other structural clay products	0.813	0.000
323	Blank magnetic and optical recording media	0.812	0.000
132	Footwear	0.810	0.000
230	Nonferrous metals	0.809	0.000
197	Rubber and plastics hoses and belts	0.809	0.000
95	Frozen cakes and other pastries	0.808	0.000
141	Other millwork, including flooring	0.808	0.000
306	Other communications equipment	0.805	0.000
150	Paper bags and coated and treated paper	0.805	0.000
328	Household cooking appliances	0.805	0.000
380	Surgical appliance and supplies	0.804	0.000
341	Carbon and graphite products	0.800	0.000
22	Coal	0.800	0.000
324	Software and other prerecorded and record reproducing	0.799	0.000
144	Prefabricated wood buildings	0.799	0.000
148	Paperboard from pulp	0.799	0.000
89	Meat (except poultry) produced in slaughtering plant	0.798	0.000
340	Wiring devices	0.797	0.000
387	Office supplies (except paper)	0.797	0.000
189	Unlaminated plastics profile shapes	0.793	0.000
190	Plastics pipes and pipe fittings	0.793	0.000
382	Ophthalmic goods	0.793	0.000
112	Fiber filaments, yarn, and thread	0.792	0.000
118	Coated fabric coating	0.792	0.000
239	Plates	0.792	0.000
290	Elevators and moving stairways	0.791	0.000
173	Medicines and botanicals	0.790	0.000
91	Processed animal rendered byproducts	0.789	0.000
140	Cut stock, resawn and planed lumber	0.787	0.000
274	Other commercial service industry machinery	0.785	0.000
216	Miscellaneous nonmetallic mineral products	0.784	0.000
364	Boats	0.784	0.000
220	Steel wire	0.780	0.000
82	Canned specialties	0.780	0.000
276	Heating equipment (except warm air furnaces)	0.780	0.000
320	Analytical laboratory instruments	0.779	0.000
169	Nitrogenous fertilizer	0.778	0.000
110	Distilled liquors except brandies	0.778	0.000
165	Other basic organic chemicals	0.778	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
72	Fats and oils refining and blending	0.778	0.000
345	Heavy duty trucks	0.775	0.000
116	Knitted fabrics	0.774	0.000
270	Printing machinery and equipment	0.771	0.000
332	Power, distribution, and specialty transformers	0.769	0.000
390	Musical instruments	0.766	0.000
31	Sand and gravel	0.764	0.000
178	Adhesives	0.762	0.000
297	Industrial process furnaces and ovens	0.761	0.000
348	Motor homes	0.759	0.000
316	Automatic environmental controls	0.757	0.000
179	Soaps and other detergents	0.755	0.000
74	Beet sugar	0.754	0.000
333	Motors and generators	0.754	0.000
254	Valve and fittings, other than plumbing	0.754	0.000
242	Ornamental and architectural metal products	0.753	0.000
284	Speed changers, industrial high-speed drives, and gears	0.752	0.000
310	Capacitors, resistors, coils, transformers, and other inductors	0.752	0.000
4	Fruit	0.751	0.000
275	Air purification and ventilation equipment	0.748	0.000
80	Frozen specialties	0.747	0.000
226	Rolled, drawn, extruded, and alloyed copper	0.747	0.000
321	Irradiation apparatus	0.746	0.000
234	Crowned and stamped metals	0.746	0.000
255	Plumbing fixture fittings and trims	0.745	0.000
177	Paints and coatings	0.745	0.000
237	Prefabricated metal buildings and components	0.745	0.000
381	Dental equipment and supplies	0.743	0.000
236	Handtools	0.742	0.000
151	Stationery products	0.742	0.000
379	Surgical and medical instruments	0.741	0.000
183	Printing inks	0.738	0.000
115	Nonwoven fabrics	0.737	0.000
271	All other industrial machinery	0.733	0.000
296	Packaging machinery	0.729	0.000
266	Oil and gas field machinery	0.727	0.000
152	Sanitary paper products	0.725	0.000
286	Other engine equipment	0.723	0.000
135	Preserved wood products	0.722	0.000
343	Automobiles	0.722	0.000
245	Metal cans	0.720	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
104	Spices and extracts	0.717	0.000
246	Metal barrels, drums and pails	0.714	0.000
17	Fish	0.713	0.000
250	Turned products and screws, nuts, and bolts	0.712	0.000
198	Other rubber products	0.711	0.000
334	Switchgear and switchboard apparatus	0.707	0.000
301	Electronic computers	0.705	0.000
76	Nonchocolate confectioneries	0.701	0.000
375	Office furniture, except wood	0.699	0.000
30	Stone	0.697	0.000
15	Forest, timber, and forest nursery products	0.696	0.000
285	Mechanical power transmission equipment	0.693	0.000
287	Pump and pumping equipment	0.692	0.000
352	Motor vehicle steering, suspension components (except spring), and brake systems	0.692	0.000
269	Sawmill, woodworking, and paper machinery	0.690	0.000
367	All other transportation equipment	0.689	0.000
70	Wet corn	0.687	0.000
212	Abrasive products	0.687	0.000
265	Mining machinery	0.685	0.000
186	Photographic films and chemicals	0.678	0.000
185	Compounded resins	0.677	0.000
134	Dimension lumber	0.673	0.000
65	Dog and cat food	0.672	0.000
73	Breakfast cereal	0.670	0.000
90	Meat processed from carcasses	0.670	0.000
331	Other major household appliances	0.668	0.000
215	Mineral wool	0.665	0.000
124	Hosiery and socks	0.660	0.000
383	Dental laboratories	0.654	0.000
99	Roasted nuts and peanut butter	0.652	0.000
88	Ice cream and frozen dessert	0.652	0.001
157	Asphalt paving mixtures and blocks	0.652	0.000
304	Telephone apparatus	0.651	0.000
314	Electromedical and electrotherapeutic apparatus	0.649	0.000
223	Aluminum sheets, plates, and foils	0.648	0.000
291	Conveyor and conveying equipment	0.647	0.000
351	Motor vehicle electrical and electronic equipment	0.646	0.000
322	Watches, clockes, and other measuring and controlling devices	0.645	0.000
75	Sugar cane	0.642	0.000
139	Wood windows and doors	0.638	0.000
94	Bread and bakery products, except frozen	0.630	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
347	Truck trailers	0.629	0.000
264	Construction machinery	0.629	0.000
280	Cutting tool and machine tool accessory	0.623	0.000
8	Cotton	0.621	0.006
155	Printing support services	0.620	0.000
184	Explosives	0.619	0.000
262	Farm machinery and equipment	0.619	0.000
232	Nonferrous forgings	0.617	0.000
34	Phosphate rock	0.616	0.015
281	Machine tool	0.615	0.000
295	Welding and soldering equipment	0.614	0.000
164	Other basic inorganic chemicals	0.614	0.000
119	Carpets and rugs	0.611	0.000
248	Spring and wire products	0.604	0.000
163	Synthetic dyes and pigments	0.600	0.000
86	Cheese	0.600	0.000
2	Grains	0.598	0.000
100	Other snack foods	0.597	0.000
344	Light trucks and utility vehicles	0.592	0.000
180	Polish and other sanitation goods	0.589	0.000
282	Rolling mill and other metalworking machinery	0.587	0.000
77	Chocolate and confectioneries from cacao beans	0.586	0.000
3	Vegetables and melons	0.586	0.000
357	Aircrafts	0.584	0.000
256	Balls and roller bearings	0.581	0.000
158	Asphalt shingles and coating materials	0.580	0.000
293	Industrial trucks, trailers, and stackers	0.579	0.000
187	Other miscellaneous chemical products	0.577	0.000
315	Search, detection, and navigation instruments	0.576	0.000
66	Other animal food	0.575	0.000
32	Other clay, ceramic, refractory minerals	0.575	0.000
67	Flour	0.567	0.000
106	Bottled and canned soft drinks and water	0.567	0.000
167	Synthetic rubbers	0.564	0.000
159	Petroleum lubricating oil and grease	0.562	0.000
361	Propulsion units and parts for space vehicles and guided missiles	0.557	0.000
337	Primary batteries	0.555	0.000
1	Oilseeds	0.547	0.000
23	Iron ore	0.532	0.011
358	Aircraft engines and engine parts	0.528	0.000
14	Animal products, except cattle and poultry and eggs	0.527	0.000

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
384	Jewelry and silverware	0.526	0.000
35	Other chemical and fertilizer mineral	0.519	0.000
36	Other nonmetallic minerals	0.518	0.000
294	Power-driven handtools	0.512	0.000
289	Measuring and dispensing pumps	0.511	0.000
69	Malt	0.509	0.001
146	Wood pulp	0.504	0.000
362	Railroad rolling stock	0.500	0.000
259	Small arms, ordnance, and accessories	0.492	0.000
221	Aluminum products	0.488	0.001
143	Manufactured homes (mobile homes)	0.472	0.000
122	Rope, cordage, twine, tire cord and tire fabric	0.469	0.001
175	In-vitro diagnostic substances	0.466	0.001
5	Tree nuts	0.450	0.002
278	Industrial molds	0.450	0.001
349	Travel trailers and campers	0.442	0.001
96	Cookies and crackers	0.436	0.001
156	Refined petroleum products	0.431	0.002
228	Secondary processing of other nonferrous metals	0.429	0.002
78	Confectioneries from purchased chocolate	0.424	0.002
206	Ready-mix concrete	0.410	0.003
174	Pharmaceuticals	0.407	0.003
257	Small arms ammunition	0.401	0.005
170	Phosphatic fertilizer	0.399	0.004
172	Pesticides and other agricultural chemicals	0.385	0.008
176	Biological products (except diagnostic)	0.377	0.007
84	Fluid milk	0.353	0.022
227	Nonferrous metal, except copper and aluminum, shaping	0.343	0.014
131	Tanned and finished leather and hides	0.335	0.016
225	Nonferrous metal (exc aluminum) smelting and refining	0.335	0.017
363	Ships	0.326	0.020
279	Special tool, die, jig, and fixture	0.318	0.023
87	Dry, condensed, and evaporated dairy products	0.310	0.027
11	Beef cattle	0.287	0.046
85	Creamery butter	0.268	0.152
263	Lawn and garden equipment	0.246	0.082
231	Iron and steel forgings	0.215	0.129
214	Ground or treated mineral and earth products	0.205	0.171
13	Poultry and egg products	0.204	0.227
366	Military armored vehicles, tanks, and tank components	0.193	0.234

Commodity Index	Commodity Name	Correlation	P-Value (rounded)
108	Beer, ale, malt liquor and nonalcoholic beer	0.163	0.259
258	Ammunition, except for small arms	0.144	0.409
207	Concrete blocks and bricks	0.141	0.378
24	Gold ore	0.129	0.705
346	Motor vehicle bodies	0.119	0.414
28	Uranium-radium-vanadium ore	0.093	0.762
162	Industrial gases	0.079	0.595
27	Copper ore	0.002	0.996
25	Silver ore	-0.551	0.628

Table 7.

	Top Trading Partner								
	Constant National Rates			Port-Gravity Solution			State Origin of Movement		
State	Partner	Export Value (million $)	Share of State Supply to Partner	Partner	Export Value (million $)	Share of State Supply to Partner	Partner	Export Value (million $)	Share of State Supply to Partner
AK	CANADA	598	3.2%	CHINA	706	3.8%	CHINA	973	5.4%
AL	CANADA	4,754	3.1%	MEXICO	3,307	2.1%	CANADA	3,209	2.1%
AR	CANADA	2,186	2.6%	MEXICO	2,795	3.3%	CANADA	986	1.2%
AZ	MEXICO	2,532	3.1%	MEXICO	5,126	6.2%	MEXICO	6,120	7.4%
CA	CANADA	19,635	2.6%	MEXICO	14,836	2.0%	MEXICO	18,183	2.4%
CO	CANADA	1,973	2.1%	MEXICO	1,744	1.9%	CANADA	1,174	1.3%
CT	CANADA	1,889	2.6%	CANADA	1,806	2.5%	FRANCE	1,601	2.2%
DC	CHINA	38	3.0%	CHINA	31	2.4%	UNITED ARAB EMIRATES	581	54.2%
DE	MEXICO	402	2.2%	CANADA	288	1.6%	UNITED KINGDOM	845	4.9%
FL	CANADA	4,486	2.8%	MEXICO	2,984	1.8%	CANADA	2,999	1.8%
GA	CANADA	5,592	2.8%	CANADA	3,953	2.0%	CANADA	5,121	2.6%
HI	CANADA	207	2.2%	CANADA	118	1.3%	AUSTRALIA	1,123	13.4%
IA	CANADA	4,310	2.8%	CANADA	4,167	2.7%	CANADA	3,551	2.3%
ID	CANADA	855	2.3%	CANADA	817	2.1%	CANADA	751	2.0%
IL	CANADA	9,848	2.9%	CANADA	9,291	2.7%	CANADA	13,182	3.8%
IN	CANADA	10,822	3.4%	CANADA	11,562	3.6%	CANADA	8,738	2.7%
KS	CANADA	2,803	2.4%	MEXICO	2,816	2.5%	CANADA	1,991	1.7%
KY	CANADA	6,231	3.7%	CANADA	4,654	2.8%	CANADA	5,536	3.3%
LA	CANADA	3,366	1.8%	MEXICO	4,548	2.4%	CHINA	4,906	2.6%
MA	CANADA	2,985	2.5%	CANADA	2,820	2.3%	CANADA	2,156	1.8%
MD	CANADA	1,376	2.5%	CANADA	1,086	2.0%	CANADA	1,078	1.9%
ME	CANADA	594	2.6%	CANADA	1,026	4.5%	CANADA	911	4.0%
MI	CANADA	13,000	3.9%	CANADA	28,083	8.5%	CANADA	17,628	5.3%
MN	CANADA	4,194	2.5%	CANADA	4,817	2.8%	CANADA	3,637	2.1%
MO	CANADA	5,874	3.5%	CANADA	3,873	2.3%	CANADA	3,735	2.2%
MS	CANADA	2,154	2.7%	MEXICO	1,691	2.1%	CANADA	1,486	1.9%
MT	MEXICO	365	1.6%	CANADA	2,028	9.1%	CANADA	382	1.8%
NC	CANADA	7,539	2.8%	CANADA	5,588	2.1%	CANADA	5,623	2.1%
ND	CANADA	693	2.6%	CANADA	2,984	11.1%	CANADA	2,137	8.0%
NE	MEXICO	1,611	1.9%	MEXICO	1,951	2.3%	CANADA	1,377	1.7%
NH	MEXICO	752	3.0%	CANADA	680	2.7%	CANADA	372	1.5%
NJ	CANADA	2,914	2.2%	CANADA	2,368	1.8%	CANADA	4,935	3.7%
NM	CANADA	552	2.0%	MEXICO	774	2.9%	MEXICO	749	3.0%
NV	CANADA	567	2.3%	MEXICO	452	1.9%	SWITZERLAND	1,526	6.5%
NY	CANADA	5,836	2.6%	CANADA	9,681	4.4%	CANADA	6,644	3.0%
OH	CANADA	12,677	3.3%	CANADA	18,822	4.9%	CANADA	15,608	4.0%
OK	CANADA	3,028	2.9%	CANADA	2,677	2.6%	CANADA	1,260	1.2%
OR	MEXICO	2,540	2.5%	CHINA	3,034	3.0%	CHINA	3,340	3.2%
PA	CANADA	8,111	2.7%	CANADA	8,498	2.8%	CANADA	8,886	3.0%
RI	CANADA	412	2.6%	CANADA	378	2.4%	CANADA	261	1.7%
SC	CANADA	4,467	3.5%	MEXICO	3,181	2.5%	GERMANY	3,312	2.6%
SD	CHINA	699	2.3%	CANADA	791	2.6%	CANADA	494	1.7%
TN	CANADA	6,288	3.4%	CANADA	4,622	2.5%	CANADA	6,617	3.6%
TX	CANADA	19,550	2.2%	MEXICO	34,909	3.9%	MEXICO	60,607	6.8%
UT	CANADA	1,529	2.3%	MEXICO	1,114	1.7%	UNITED KINGDOM	1,934	2.9%
VA	CANADA	3,048	2.5%	CANADA	2,391	2.0%	CANADA	2,549	2.1%
VT	CANADA	353	2.5%	CANADA	769	5.4%	CANADA	857	6.1%
WA	CHINA	5,792	3.1%	CHINA	8,100	4.3%	CHINA	15,130	8.0%
WI	CANADA	6,663	3.1%	CANADA	7,718	3.6%	CANADA	6,284	2.9%
WV	CANADA	1,017	2.1%	CANADA	1,094	2.2%	CANADA	1,118	2.4%
WY	CANADA	360	1.5%	CANADA	232	1.0%	CANADA	141	0.7%

Table 8.

	Top Trading Partner									
	Constant National Rates			Port-Gravity Solution			State Ultimate Destination			
State	Partner	Import Value (million $)	Share of State Demand from Partner	Partner	Import Value (million $)	Share of State Demand from Partner	Partner	Import Value (million $)	Share of State Demand from Partner	
AK	CHINA	1,137	5.6%	CHINA	1,757	8.6%	CANADA	643	3.4%	
AL	CHINA	6,671	4.4%	CHINA	5,409	3.6%	KOREA, SOUTH	4,695	3.1%	
AR	CHINA	3,385	4.0%	MEXICO	3,170	3.8%	CHINA	2,586	3.1%	
AZ	CHINA	6,920	5.4%	MEXICO	9,918	7.7%	MEXICO	7,214	5.6%	
CA	CHINA	49,993	5.6%	CHINA	82,991	9.2%	CHINA	116,054	12.7%	
CO	CHINA	7,198	5.4%	CHINA	6,514	4.9%	CANADA	3,612	2.7%	
CT	CHINA	5,073	5.4%	CANADA	4,636	4.9%	UNITED KINGDOM	4,580	4.8%	
DC	CHINA	1,805	7.4%	CHINA	1,615	6.6%	INDIA	127	0.6%	
DE	CHINA	1,066	4.5%	CHINA	938	4.0%	BELGIUM	1,249	5.7%	
FL	CHINA	20,465	5.6%	CHINA	19,156	5.3%	CHINA	10,804	2.9%	
GA	CHINA	11,959	4.8%	CHINA	10,677	4.3%	CHINA	18,763	7.4%	
HI	CHINA	1,673	5.2%	CHINA	2,021	6.3%	INDONESIA	1,063	3.4%	
IA	CHINA	4,907	3.8%	CANADA	3,983	3.1%	CANADA	2,911	2.2%	
ID	CHINA	1,906	4.6%	CHINA	2,055	4.9%	CHINA	1,372	3.3%	
IL	CHINA	16,611	4.7%	CANADA	21,638	6.1%	CANADA	35,059	9.8%	
IN	CHINA	10,583	4.3%	CANADA	14,692	6.0%	CANADA	7,659	3.1%	
KS	CANADA	4,483	4.0%	MEXICO	3,560	3.2%	CHINA	2,308	2.1%	
KY	CHINA	6,553	4.3%	CHINA	4,916	3.3%	CHINA	5,022	3.3%	
LA	CANADA	10,995	6.0%	MEXICO	8,862	4.8%	SAUDI ARABIA	7,587	4.1%	
MA	CHINA	9,951	5.9%	CANADA	10,579	6.2%	CANADA	8,488	4.9%	
MD	CHINA	8,154	6.1%	CHINA	7,527	5.6%	GERMANY	5,030	3.7%	
ME	CHINA	1,633	5.1%	CANADA	3,242	10.1%	CANADA	2,029	6.3%	
MI	CHINA	14,375	4.7%	CANADA	28,939	9.4%	MEXICO	44,036	14.1%	
MN	CHINA	8,041	4.8%	CANADA	12,437	7.3%	CHINA	9,977	5.8%	
MO	CHINA	8,166	4.5%	CHINA	6,466	3.6%	CHINA	4,869	2.7%	
MS	CANADA	3,746	4.4%	MEXICO	3,769	4.5%	CHINA	3,434	4.2%	
MT	CANADA	1,607	5.5%	CANADA	5,003	17.0%	CANADA	4,256	15.0%	
NC	CHINA	12,730	4.9%	CHINA	10,283	4.0%	CHINA	9,607	3.7%	
ND	CHINA	1,266	4.3%	CANADA	2,328	8.0%	CANADA	2,123	7.5%	
NE	CHINA	2,567	3.4%	CHINA	2,132	2.8%	CANADA	1,088	1.5%	
NH	CHINA	2,001	5.9%	CANADA	2,572	7.6%	CANADA	7,325	21.5%	
NJ	CHINA	10,630	5.4%	CHINA	10,758	5.4%	CHINA	17,892	8.9%	
NM	CHINA	2,107	5.0%	MEXICO	2,715	6.4%	CHINA	688	1.7%	
NV	CHINA	2,890	5.6%	CHINA	4,107	8.0%	CHINA	3,136	6.1%	
NY	CHINA	23,222	5.9%	CHINA	24,659	6.2%	CHINA	21,444	5.3%	
OH	CHINA	16,428	4.5%	CANADA	21,485	5.9%	CANADA	13,873	3.8%	
OK	CHINA	4,729	4.4%	MEXICO	4,633	4.4%	CANADA	5,399	5.2%	
OR	CHINA	4,931	5.2%	CHINA	6,073	6.4%	CANADA	2,519	2.6%	
PA	CHINA	16,043	4.8%	CHINA	13,382	4.0%	CHINA	15,242	4.5%	
RI	CHINA	1,277	5.4%	CANADA	1,172	4.9%	GERMANY	2,294	9.8%	
SC	CHINA	6,384	4.7%	CHINA	5,771	4.2%	GERMANY	7,270	5.3%	
SD	CHINA	1,166	4.0%	CHINA	1,004	3.5%	CANADA	598	2.2%	
TN	CHINA	8,929	4.8%	CHINA	6,965	3.7%	CHINA	17,417	9.3%	
TX	CANADA	38,066	4.3%	MEXICO	64,593	7.3%	MEXICO	72,172	8.1%	
UT	CHINA	3,619	4.8%	CHINA	3,873	5.1%	MEXICO	3,767	5.1%	
VA	CHINA	11,121	5.7%	CHINA	10,182	5.2%	CHINA	6,534	3.3%	
VT	CHINA	911	5.1%	CANADA	2,116	11.8%	CANADA	2,071	11.5%	
WA	CHINA	10,477	4.8%	CHINA	15,863	7.3%	CANADA	14,835	6.7%	
WI	CHINA	8,592	4.5%	CANADA	9,392	4.9%	CHINA	5,964	3.1%	
WV	CHINA	1,917	3.9%	CHINA	1,568	3.2%	JAPAN	1,213	2.7%	
WY	CANADA	1,580	6.9%	CANADA	1,363	5.9%	CANADA	947	4.5%	