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Deriving Multi-Regional Models Using the IMPLAN National Trade Flows Model

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1. Introduction

Development of multi-regional input-output or social accounting models has always been hindered by the lack of good estimates of the flows of goods and services between regions. Minnesota IMPLAN Group, Inc. (MIG) along with the U.S. Forest Service (USFS) has developed a National Trade Flows Model that estimates gross trade flows between counties.

The trade flows model is a doubly-constrained gravity model that uses IMPLAN's county level estimates of commodity supply and demand. The model is balanced so that domestic imports and exports "cancel out"; that is, when domestic imports and exports for all states are summed, they are equal for each commodity. In other words, all sources of supply and demand are accounted for.

This new trade flows model will be used for several purposes. First, it will be used as a new set of regional purchase coefficients (RPCs) for single region modeling. Second, the model will be used to allow estimates of model impacts on more than one study area. Third, it will be the basis for developing multi-regional social accounting system (SAM) models that can be incorporated into other software.

This paper will discuss the model and present some initial results along with comparisons to the original RPCs.

2. The Model

The base trade flows model is a double constrained gravity model where the import and export flows between regional economies are modeled as flows between county nodes. In general terms, the import and export flows between regions are thought to be proportional to the "mass", "attractiveness" or "size" of an economy and inversely proportional to the "distance" or cost of moving goods and services between them. Mass variables often are interpreted as gross supply and demand while distance is frequently equated with the cost of moving goods and services from one location to another.

The IMPLAN social accounting system offers a unique opportunity for modeling domestic trade flows between regions using a spatial interaction models. IMPLAN social accounting system is complete and consistent. Gross supply and demand for all regions add up to supply and demand on a (domestic) national basis.

This advantage can be exploited as follows. For gross domestic commodity supply,

$$M_r x_r + z_r = s_r \qquad (1)$$

where M is the byproducts matrix for region r, x is the industry output for region r, z is non-industry (institutional sales) output for region r, and s is the domestic commodity supply for region r.

Similarly, for gross domestic commodity demand,

$$A_r x_r + y_r - f_r = d_r \qquad (2)$$

where, A is the gross absorption matrix for region r, x is the industry output for region r, y is gross final commodity demand for region r, f is foreign export from region r, d is gross commodity demand for region r, and when summed over all regions (e.g., states or counties),

$$\sum_r s_r = \sum_r d_r \,. \qquad (3)$$

That is, all sources of supply and destinations of demand for commodities are accounted for by the system. Domestic trade flows between regions, of imports and exports are similarly closed.

Both supplies and demands for all commodities are known for the system, so an *interaction* model is required to estimate the trade flows between locations or regions of supply and demand. In general, the form of this model for a particular commodity is as follows.

$$T_{ij} = A_i B_j O_i D_j d_{ij}^{-b} \qquad (4)$$

Where T_{ij} is the trade flow between regions *i* and *j*; O_i is the total commodity supply originating in region i; D_j is the total commodity demand originating used in region *j*;

$$A_i = (\sum_j B_j D_j d_{ij}^{-b})^{-1}; \qquad (5)$$

$$B_j = (\sum_i A_i O_i d_{ij}^{-b})^{-1}; \qquad (6)$$

and d_{ij}^{-b} is the distance function.

We have introduced a new term *Bj*. This formulation assures that the two constraints

$$\sum_j T_{ij} = O_i \qquad (7)$$

and

$$\sum_i T_{ij} = D_j \qquad (8)$$

are satisfied; in other words both the known supplies (O_i) and demands (D_j) can be correctly obtained from the interaction data.

Notice that the expression for A_i includes the term B_j, while that for B_j includes A_i. This means that they must be computed by iteration. The iteration is accomplished by first setting $B_j = 2$ and solving for A_i (eq. 5). The resulting A_i is then plugged into equation 6. The process is iterated until Ai and Bj no longer change.

Ai and *Bj* are constants derived through the iteration process and incorporate the inverse distance relationship between regions *i* and *j*, as well as, force the constraints set by equations 7 and 8 to be true.

This model is documented in "Using a Double Constrained Gravity Model to Derive Regional Purchase Coefficients" (Olson and Alward ?date). Essentially, the model makes an estimate of the value of a commodity moved from one county to another.

2.1 Trade Flows Model Data

There are three main databases used in the IMPLAN Trade Flows Model (TFM). These are: the Oak Ridge National Labs (ORNL) county-to-county distances by mode of transportation, the Commodity Flows Survey (CFS) ton-miles data by commodity, the IMPLAN commodity supply and demand estimates by county.

The ORNL database consists of distances and travel times by zip code to zip code and mode of transportation. The modes are highway, rail, water, air, and pipeline. Highway transportation times are also varied by speed limit, toll ways, and other factors affecting the time of travel. ORNL combined the data to county level for this project using the employment centroid as the center point for the computations. The end result from the ORNL database is an impedance index as a combination of distance, time, and cost factor. This index is used in the IMPLAN Trade Flows Model. There is a separate index for each different mode. For county to same county distances, the county was turned into a concentric circle and a point was set 1/3 the distance to each edge and the distance computed between the two points.

The CFS data provided the distance in miles each commodity traveled on average. The ton-miles data is used in calibrating the Trade Flows Model as it is being processed. It also is also used to create one index out of the separate ORNL indexes.

2.2 Model Solution

In practical terms, the distance or impedance between region *i* and region *j* is essentially an "ease of transport index" obtained from Oakridge National Labs transportation model described above. The supply and demand for commodities is from the IMPLAN models.

For each commodity, the value of trade is solved by initially setting the b term in the distance function to 2 and iterating the *A* and *B* terms until there is no longer any change in *A* or *B*. Then, for each commodity, the average ton miles moved is computed and compared to the average ton-miles for that commodity as reported in the Commodity Flows data. The b term is then adjusted up or down by a small increment and the *A* and *B*s are recomputed. This process continues until the average ton miles moved in the system match that of the Commodity Flows data. The system is then solved for each of the 509 commodities and ultimately ends up with a 3140 by 3140 by 509 matrix of county to county trade flows.

Non-shippable commodities such as services were done by setting the b term to a high value. This does not allow the services to move very far, treating services more like a supply/demand model. The one exception is Hotels and lodging which were allowed to move. This is to account for the low local use of local the supply of hotels services.

3. Model Results

The end results provide an ability to compute a new Regional Purchase Coefficient (RPC). The new is simply the value of trade from a county back to itself divided by total local commodity demand. The definition of the RPC is "the proportion of local supply that satisfies local demand".

The trade flows database consists of 6 Microsoft Access tables that are about 2GB each. It is difficult to test the resulting model since we do not have any observed data to check it against. The results can be subject to examination and given a reality check to see if they make sense compared to local area knowledge.

Washington County Minnesota IMPLAN data for 2000 is used for this initial examination. The new RPC is compared to the RPC estimated from IMPLAN's econometric equation for six different cases. The export flows for each commodity are also mapped and checked for "reasonableness".

First the data will presented for commodity flows between Washington County Minnesota and the rest of the Twin Cities. Then maps showing the flows from Washington to the rest of the United States will be discussed.

The commodities examined are: Fluid Milk, Millwork, Petroleum Refining, Miscellaneous Plastics Products, Special Dies and Tools, and Magnetic & Optical Recording Media. These sectors were chosen because they are relatively important to the county and the businesses producing those commodities can actually be identified in most cases.

Fluid milk employment in 2000 is estimated by IMPLAN to have be 363 jobs and has total commodity supply of $115.6 million. Specific producers are not identified, but the flow of milk to consumers is interesting since milk tends not to travel very far from its production point.

The Millwork sector includes producers of wood windows and doors. The main player in the county is Anderson Windows. This company is one of the largest window producers in the United States and has national market coverage.

Petroleum refining is also a large sector in Washington County producing about $550 million in oil in 2000 according to IMPLAN estimates. There are two refineries in the county and we know that most of the gasoline sold in the Twin Cities is produced here. Mapping the exports of gasoline will give us an indication of the models ability to predict this flow.

Miscellaneous Plastics products and Special Dies and Tools are both relatively important sectors, but do not have an identifiable producer, but the trade flow estimate has an interested comparison between the old and new RPC.

Lastly, the Magnetic & Optical Recording Media is Imation. Imation is a spinoff of 3M and is a large producer of CD and DVD recording media. Here we can get a sense of both the local use and exports across the country and check it against local intuitive knowledge.

The calculations of commodity supply and demand for the six commodities are summarized in Table 1. It also has the current econometric RPC and the new RPC based on the IMPLAN Trade Flows Model. For the first three commodities, Fluid Milk, Mill Work, and Petroleum Refining, the RPCs are really pretty close.

The Fluid Milk RPC increases to almost 99 percent or $17.5 million, which makes sense that most local consumption of milk is supplied locally when the production is as large as it is. Exports to the rest of the Twin Cities 7 County Metropolitan area account for $30.6 million compared to demand of $250.5 million for the same area. This allows for domestic exports of $67.3 million to the rest of the country. What is happening here is we have additional suppliers of Fluid Milk in other areas of the Twin Cities and these other suppliers are filling the demand for milk in the rest of the Twin Cities.

The Millwork RPC is slightly lower than the econometric estimate, but passes the reasonability test since using Anderson Windows in housing construction is a selling point in this area. For Washington County, 86.9 percent of demand is satisfied by local production. For the rest of the Twin Cities, Washington county supplies $336.8 million of total demand of 2,702.8 million. There are other window producers in Minnesota likely satisfying that demand. Total domestic exports outside the Twin Cities are $543.3 million. Anderson does have a national market presence which becomes more apparent in the maps.

The Petroleum Refining RPC is also very similar to the econometrically estimated IMPLAN RPC. There is a large refinery in Washington County that supplies a large portion of county demand. Washington County production also supplies a relatively large portion of demand in the rest of the Twin Cities. As a result, there is very little left to export outside of the Twin Cities. Based on local knowledge, that makes sense.

Table 1. Comparison of Regional Purchase Coefficients

Description	Fluid Milk	Millwork	Petroleum Refining	Miscellaneous Plastics Products	Special Dies and Tools and Accessories	Magnetic & Optical Recording Media
Commodity Code	65	137	210	220	321	382
Total Commodity Supply	$ 115.619	$ 643.612	$ 551.679	$ 99.281	$ 105.085	$ 283.761
Net Commodity Supply	$ 115.401	$ 628.480	$ 532.762	$ 90.815	$ 91.524	$ 82.172
Intermediate Commodity Demand	$ 2.458	$ 9.508	$ 124.456	$ 93.600	$ 8.412	$ 1.711
Institutional Commodity Demand	$ 15.103	$ -	$ 76.304	$ 6.344	$ 75.931	$ 75.416
Total Gross Commodity Demand	$ 17.561	$ 9.508	$ 200.760	$ 99.944	$ 84.343	$ 77.127
Domestic Supply/Demand Ratio	1.0000	1.0000	1.0000	0.9087	1.0000	1.0000
Average RPC	85.12%	90.82%	88.61%	0.30%	84.90%	59.51%
New RPC	99.78%	86.98%	87.45%	2.95%	2.97%	22.12%
LocalUse	$ 17.522	$ 8.270	$ 175.566	$ 2.947	$ 2.504	$ 17.064
Imports From Rest of TC	$ 0.019	$ 0.195	$ 1.440	$ 19.545	$ 4.448	$ 6.649
Exports To Rest of TC	$ 30.611	$ 76.914	$ 336.885	$ 19.209	$ 5.416	$ 7.539
Rest Of TC Commodity Demand	$ 250.573	$ 148.748	$ 2,702.796	$ 1,938.362	$ 309.145	$ 62.403
Total Domestic Exports	$ 97.880	$ 620.209	$ 357.196	$ 87.868	$ 89.020	$ 65.108
Exports to outside TC	$ 67.268	$ 543.295	$ 20.311	$ 68.659	$ 83.604	$ 57.568

For the next three commodities, the trade flows estimate is quite different from the econometrically estimated RPC. First, for Miscellaneous Plastics Products, the Trade Flows RPC is 2.9 percent compared to 0.3 percent. The model does end up shipping about $19 million to the rest of the Twin Cities with the remaining $68.7 going outside the region. Miscellaneous Plastics Products is really a catch-all sector for many different things so it makes sense that the RPC should be small, the econometrically estimated RPC seems too low however.

The Special Tools and Dies sector trade flows RPC is 2.9 percent compared to 84.9 percent for the old RPC. This sector produces capital goods used when equipping or updating equipment in a factory. Again, this commodity sector is comprised of many different kinds of actual products so it makes sense that these products would be shipped all over the US. The RPC of 84.9 percent seems very high under this scenario.

Lastly, the Magnetic & Optical Recording Media sector is also quite important to the Washington County economy. There is $283.8 million in total commodity supply, but only $82.2 million in net commodity supply. That means that Foreign Exports have consumed a large portion of the supply. The trade flows RPC is 22.2 percent compared to 59.1 percent. Most commodity demand is from final consumers so the product is finished CDs or DVDs. This commodity again is produced by Imation, and according to the company website, sold all over the world. However, it is also very prominent in the Twin Cities market so the RPC of 22.2 percent seems reasonable. The large foreign demand also seems reasonable.

Even though we really have no definitive proof that the trade flows are correct, and in fact no one will, these cases cited above seem reasonable. Another way to examine the flows is to map them. In the next section are maps for each commodity showing the flow from Washington County, Minnesota to the rest of the US.

3.1 Trade Flow Maps

A map summarizing trade flows for the Fluid Milk sector is shown in Figure 1. The model is allocating some supply to a large number of counties. What is interesting here is the lack of demand in the Western half of the US as well as the New England states. California is the number one supplier of Raw Milk in the US and has a lot of processing. In New England, there is a compact that supports the Milk industry and shuts out most other suppliers. These maps are constructed using a log linear scale so the lighter areas represent very small flows.

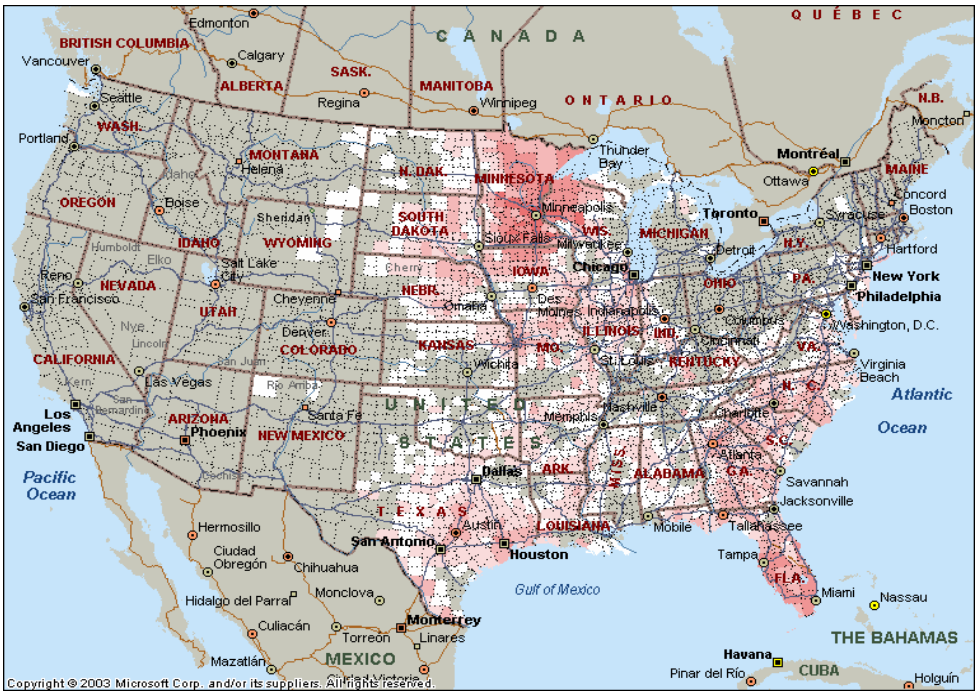


Figure 1. Fluid Milk Shipments from Washington County Minnesota

The shipment of wood windows from Anderson Windows in Washington County is illustrated in Figure 2. Anderson is a national window manufacturing company with about 4,000 employees in the county. The national demand is clear. Higher shipments to areas of the country with rapid population and thus housing growth are also evident.

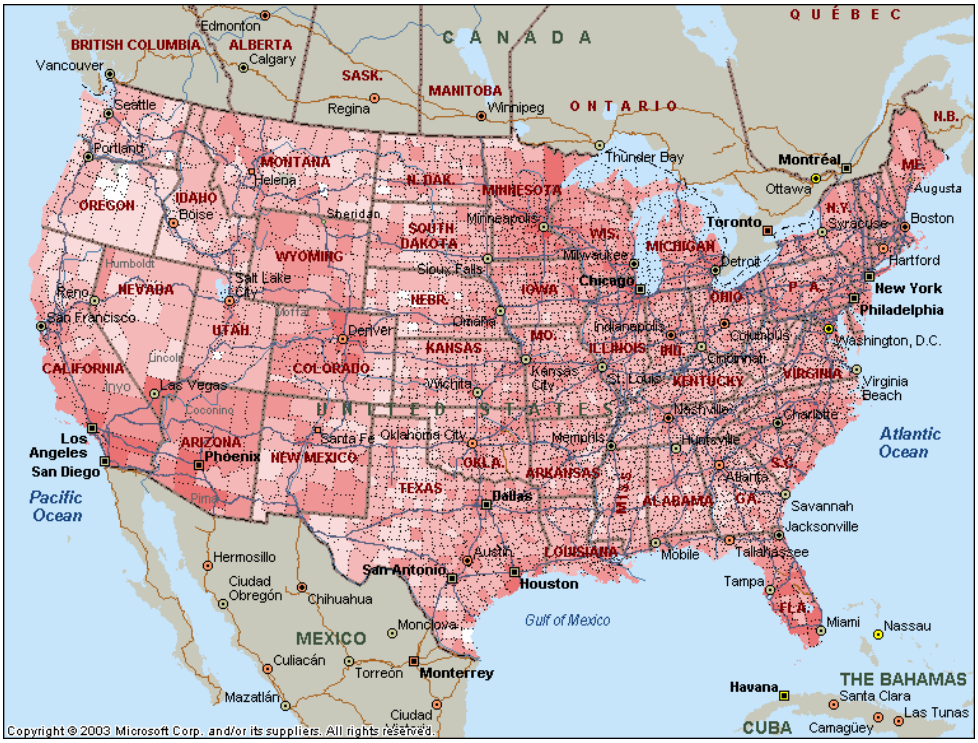


Figure 2. Millwork Shipments from Washington County Minnesota

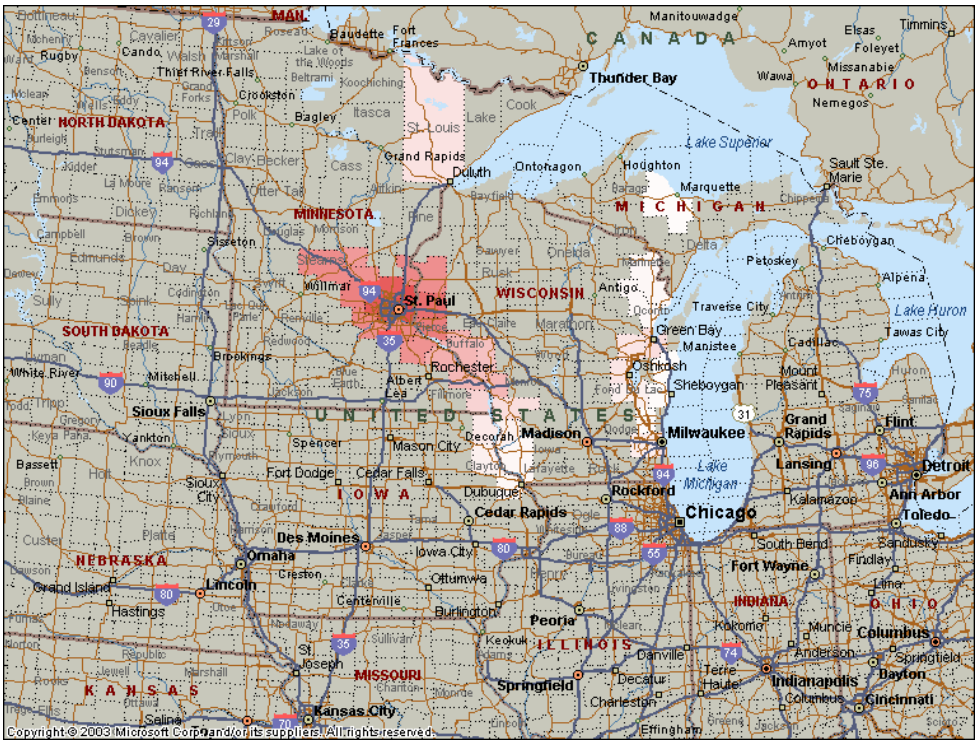


Figure 3. Petroleum Refining Shipments from Washington County, Minnesota

Petroleum Refining is shown in Figure 3. There are several refineries in Washington County and they supply about 80 percent of the gasoline used in the Twin Cities. This map clearly shows the very localized distribution of the gasoline product.

The flow of Miscellaneous Plastics Products from Washington County is shown if Figure 4.

The flow of Special Dies, Tools and Accessories is shown in Figure 5. This is a diverse industry and most of the flows are to areas of the country with a manufacturing base.

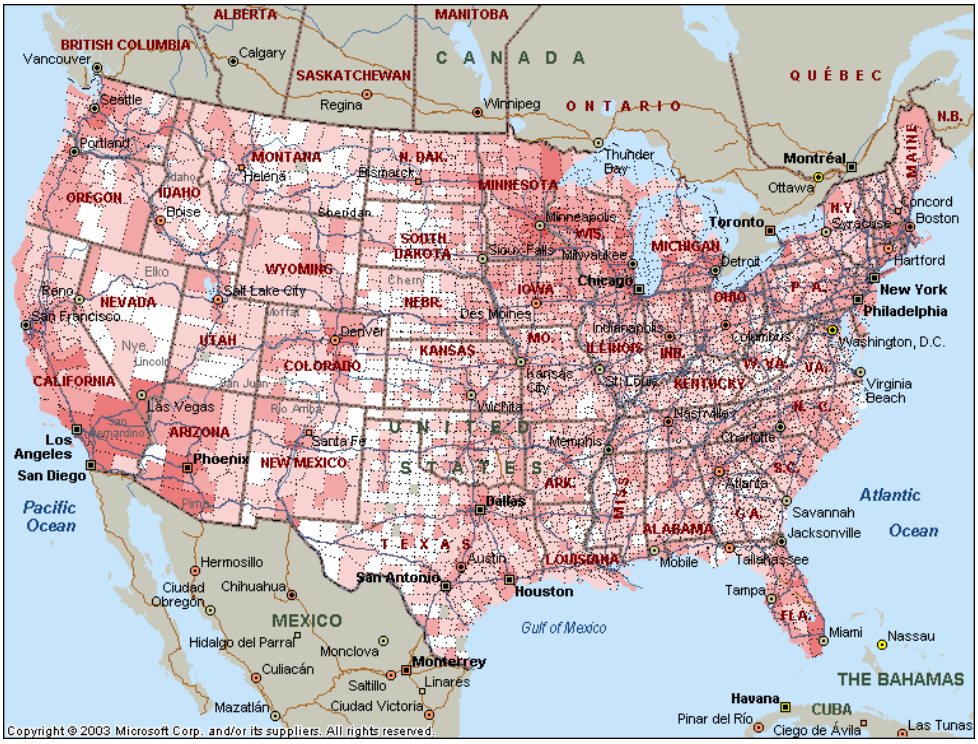


Figure 4. Miscellaneous Plastics Products

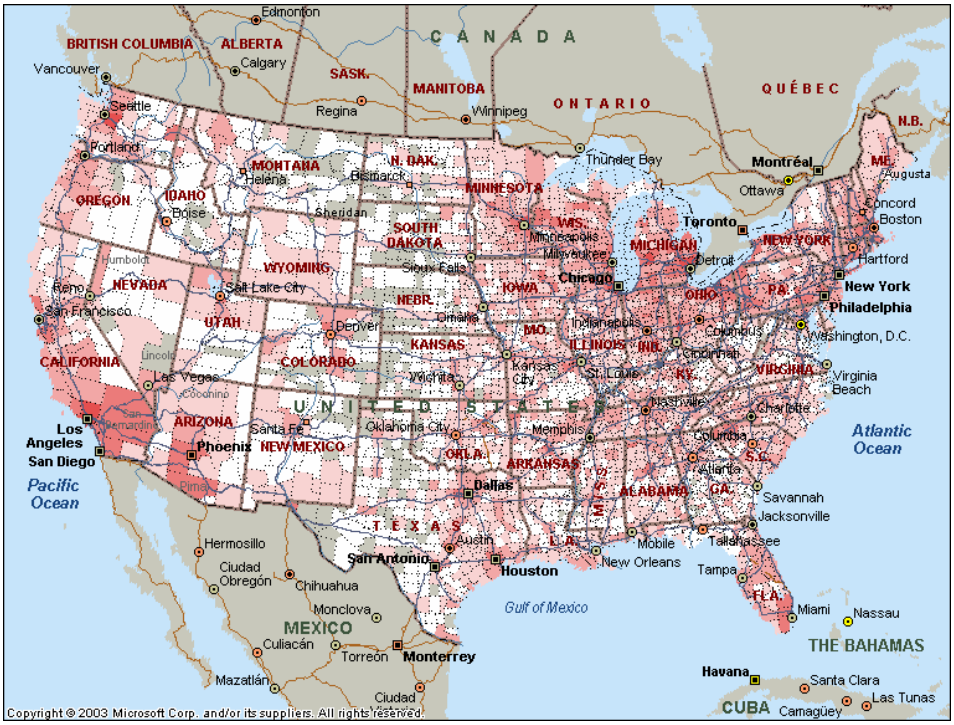


Figure 5. Special Dies Tools and Accessories

The flows of the Magnetic & Optical Recording Media commodity is shown in Figure 6. This commodity consists mostly of compact disks and digital video disks. The primary company producing this in Washington County is Imation a 3M spin-off company. This map shows fairly even distribution of the commodity.

Again, something one would expect since the primary consumer of this commodity is households. There is a larger flow to Los Angeles, California, perhaps due to the movie industry.



Figure 6. Magnetic & Optical Recording Media

4. Conclusions

Multi-regional modeling has always been hindered by the lack of good estimates of the flows of goods and services between regions. Minnesota IMPLAN Group, Inc. (MIG) along with the U.S. Forest Service (USFS) has developed a National Trade Flows Model that estimates gross trade flows between counties.

In summary, a double constrained gravity model was developed using IMPLAN's commodity supply and demand estimates along with data from Oakridge National Laboratory's national transportation model. This gravity model made estimates of the flows of commodities between all counties in the United States.

The IMPLAN National Trade Flows Model does seem to satisfy the reasonability test. Unfortunately, it is very difficult to "ground truth" any model such as this since there is no real data. One method of checking the model is to map the flows and then check for reasonability. This method might be extended by actually collecting data from commodity producers as to where their products are shipped, though this would be difficult to do on a large scale. There is significantly more testing to do and as we have more users looking at it, we can better calibrate the model with that experience.

The National Trade Flows Model will be used for policy analysis in numerous ways. The first use of it will be to incorporate the data into IMPLAN Version 3. This will allow researchers to estimate the impact of a county level economic event on the surrounding counties and actually see the individual county impacts results.

Another use will be in multi-regional Computable General Equilibrium (CGE). Current multi-regional CGE models have to manipulate the flows estimates within the program to achieve a balanced model. That will no longer be necessary.

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