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Toward Consistent Cross-Hauling Estimation for Input-Output Regionalization *

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Abstract

Although the literature has provided steps in the right direction, conceptual shortcomings still exist in the cross-hauling adjustment methods that are currently being applied in the literature. This paper represents an attempt to 1) characterize the cross-hauling adjustment methods that exist in the literature; 2) identify the shortcomings that exist with the most widely applied method, CHARM; 3) provide an empirical analysis to tackle the notion of just how ubiquitous cross-hauling is and the potential impact it has on input-output multiplier estimates; and 4) suggest directions for future conceptual and theoretical development that will lead to consistent cross-hauling measures for use.

Keywords: Input-output; Cross-hauling; CHARM; Regional Economics
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Introduction

Cross-hauling, also known as two-way trade, is defined as the simultaneous import and export of identical or similar products. In a theoretical context, there are arguments both for and against the existence of cross-hauling under different assumptions. Samuelson (1953) argues that cross-hauling should not exist in a world of perfect competition. However, Brander (1981) explains its existence through imperfect competition. In applied research related to economic systems, cross-hauling has been shown to occur due to product differentiation and product mix that inevitably result from the need to group and aggregate similar commodities in statistical classification schemes such as the North American Industrial Classification System (NAICS) and the Standard Industrial Classification (SIC) system. Aggregation of data in terms of geography and time are also factors in the existence of cross-hauling within static representations of economic systems.

Recognition of the critical role of cross-hauling in economic systems and its critical impact on input-output regionalization method results has become the focus of an increasing level of attention in the input-output literature. This is appropriate, because the underestimation of cross-hauling leads to an overestimation of regional input-output multipliers based on overestimated input-output coefficient values. Impacts assessments based on these multipliers would consequently lead to inflated impact estimates as well. This well-established fact was recognized in Jackson (1998), which also provided a cross-hauling adjustment mechanism for supply-demand pooling, commodity balance regionalization methods. However, because that paper did not provide any guidance or insight as to how levels of commodity-specific cross-hauling should be estimated, Kronenberg (2009) developed a method for estimating cross-hauling levels, resulting in a cross-hauling adjusted regionalization method with the memorable acronym CHARM. Thissen et al. (2013) use another method based on microeconomic foundations of the Krugman (1991) model of international trade. There are a multitude of current or recent working papers and conference presentations on the topic as well demonstrating the recognition of the critical impact that cross-hauling estimation has on input-output regionalization method results and the inclination of researchers to make these estimates more accurate.

Although the literature has provided steps in the right direction, conceptual shortcomings still exist in the cross-hauling adjustment methods that are currently being applied in the literature. This paper represents an attempt to 1) characterize the cross-hauling adjustment methods that exist in the literature; 2) identify the shortcomings that exist with the most widely applied method, CHARM; 3) provide an empirical analysis to tackle the notion of just how ubiquitous cross-hauling is and the potential impact it has on input-output multiplier estimates; and 4) suggest directions for future conceptual and theoretical development that will lead to consistent cross-hauling measures for use. Section 2 gives a brief description of the cross-hauling adjustment methods that exist in the literature to date. Section 3 provides an overview of the conceptual issues that exist in the CHARM method in particular. The results from an initial empirical analysis are discussed in section 4, and section 5 provides concluding remarks and offers directions for future research.

1 Existing Cross-hauling Adjustment Methods

Jackson (1998) noted the issues with assuming that there was no cross-hauling during input-output regionalization procedures and provided some simple suggestions for ad hoc or mechanical adjustments to account for cross-hauling within a supply-demand pooling, commodity balance regionalization methods. These suggestions however, did not provide any guidance or insight as to how levels of commodity-specific cross-hauling should be estimated.

Kronenberg (2009) developed a method for estimating commodity specific cross-hauling levels, resulting in a cross-hauling adjusted regionalization method (CHARM). CHARM is founded on the premise that cross-hauling is due primarily to product heterogeneity. This is a reasonable assumption if product heterogeneity is defined in such a way as to include both product mix due to aggregation and product differentiation in more conventional usage. Kronenberg's reduced form expression for heterogeneity, h, for a commodity is as follows:

$$h = \frac{v - |b|}{x + c + d} \quad (1)$$

where, v is trade volume, b is trade balance (exports less imports), x is commodity output, c is intermediate commodity use, and d is commodity final demand. Kronenberg then states:

> The national input-output table contains data for all the variables on the right-hand side of equation 22. We can use these data to acquire an estimate of h_i^R. Note that we allow the degree of product heterogeneity to be different in every sector (that is why h carries the subscript i), but we are imposing the assumption $h_i^R = h_i^N$. In words, the heterogeneity of commodity i is the same in the region as in the nation. This assumption is reasonable, because product heterogeneity is a characteristic of the commodity, not of a specific geographical location. (Kronenberg, 2009, p. 51)

Applications of the CHARM method have been appearing in working papers and conference presentations in greater numbers over the last few years, making it the most often applied cross-hauling adjustment method in the literature. Although application of this method is likely better than no adjustments for cross-hauling, significant conceptual issues exist with this method, which we highlight in the next section.

Thissen et al. (2013) use another method based on microeconomic foundations of the Krugman (1991) model of international trade and other classical trade assumption in their estimation of European Regional Trade Flows for the PBL Netherlands Environmental Assessment Agency. This method is detailed in a current working paper (Diodato and Thissen, 2011).

2 Conceptual Issues in the CHARM Method

We disagree with the assertion in Kronenburg (2009) that equality of national and regional heterogeneity is a reasonable assumption. Although product differentiation might well be a characteristic of the commodity – though even the level of differentiation within a regionally produced commodity might also vary geographically – product mix most assuredly is a function of geographical location. Product mix will vary geographically for many reasons, including the simple fact that not all commodities within an aggregate commodity group will be produced everywhere. Consider the example of, say, commodity 7 in a simple two-region nation. At a finer level of detail – which can almost always be defined – region one produces commodities 7.1, 7.3, 7.5, and 7.7 while region two produces commodities 7.2, 7.4, 7.6, and 7.8. The national heterogeneity measure will reflect a composite commodity comprising all sub-types, which will be different from either region's composite commodity. Likewise, either region-specific heterogeneity measure will be expected to be different from its national counterpart.

Contrary to claims that cross-hauling is uniquely a function of the commodity and not the region, regional differences in tastes and preferences, the nature of commodity classification schemes, and differences in regional production structures and intermediate demand are critical to the determination of cross-hauling levels. Hence, the consequences of aggregation are fundamentally different from those uniquely based upon variation within a well-defined and narrow commodity class. The severity of consequence of this assumption will depend upon a) the level of aggregation in the classification scheme used, b) the unique character of different commodities, and c) the economic size of the subnational regions in the system.

A straightforward extension of the CHARM framework to a multi-regional system would be characterized by the use of the CHARM to identify the cross-hauling shares, implying that cross-hauling totals will comprise both domestic (interregional) and foreign trade. It would also have the implication, however, that since heterogeneity varies only across commodities and not geographical regions, regional cross-hauling shares for each commodity would be equal to their national cross-hauling share counterpart. But this gives rise to very peculiar conclusions.

Jackson (2014) demonstrates that subnational cross-hauling shares should not all be expected to equal their national cross-hauling share counterparts by simply generalizing the assumption to apply to a hierarchy of regional systems. For example, begin with country cross-hauling shares being the same as the counterpart EU shares. If the general sub-region super-region relationship holds, then all cross-hauling shares for all continents also would be equal to a global cross-hauling share; but of course there is no cross-hauling in the global economic system. Again following the CM relationships among sub-regions and super-regions (i.e., regions and nations), if global cross-hauling shares are equal to zero, then all geographical subdivisions of the global system would have expected cross-hauling shares of zero. Of course, we know this not to be the case.

These issues lead us to believe that cross-hauling estimation methods in input-output regionalization techniques are in need of a great deal more conceptual and theoretical development. The next section contains a preliminary analysis to determine whether cross-hauling really matters to accurate input-output multipliers and how prevalent it is.

3 Empirical Observations: Does Cross-hauling Really Matter?

Does cross-hauling really matter? Is it simply error around the edges, or is it prevalent enough to fully justify the attention and effort it has been attracting recently? In the absence of a strong theoretical alternative to existing estimation methods, we turn to empirical observation to begin to develop a better understanding of how cross-hauling varies, and a better appreciation for the extent to which accurate cross-hauling estimates really matter in the context of input-output modeling and results. This section aims to provide a preliminary analysis to demonstrate empirically the extent to which cross-hauling occurs, and to provide some quantitative evidence for potential impact it has on input-output multiplier estimates. How sensitive are IO results to variations in cross-hauling estimates?

3.1 Multiplier Sensitivity

The questions we pose here are whether IO models and multipliers are sensitive to enough to cross-hauling estimates to justify focusing additional attention on improving estimation accuracy, and if so, what is the relative magnitude of that sensitivity? Impacts on a region's interindustry structure, calculated multipliers, or other summary indicators will depend the region's distribution of industrial activity and demand, and the level of industrial disaggregation. While these results are not generalizable, they are intended only as a mechanism for demonstrating an example of multiplier sensitivities, providing a point of reference.

Without a closed form expression of multiplier cross-hauling sensitivity, we present below the empirical implications of modifying cross-hauling estimates for a specific regional model generated using Jackson's (1998) regionalization method, which incorporates a mechanism for embedding varying cross-hauling estimates explicitly. Jackson's regionalization method is a form of supply-demand pooling applied systematically to commodity-by-industry accounts. The key to estimating regional supply relationships in this framework is the inclusion of a Rest-of-World industry in the Supply table, representing the source of commodity imports. As cross-hauling increases, exports and imports of the cross-hauled commodity both increase, and the additional imports increase the cross-hauled commodity value in the Rest-of-World Supply table row. As a consequence, values in the corresponding column of the standardized Supply matrix decrease in proportion to the total commodity supply increment, which has the effect of decreasing the corresponding commodity regional supply percentage.

The database used for this empirical example is drawn from a recent study focusing on the Appalachian Regional Commission (ARC). The 2007 ARC table used in that analysis comprises 414 counties including all of West Virginia and parts of 12 other states, and is aggregated to 11 industries for this simulation exercise. The accounts used were adapted from the Benchmark Input-Output Accounts of U.S. for 2007 using 2007 county level employment and earnings data from the U.S. Bureau of Economic Analysis (BEA), along with BEA estimates of personal consumption expenditures and Census estimates of Federal and State and Local government final demands. Cross-hauling estimates for the simulation are estimated as a proportion of exports, with those proportions ranging from zero to 1.0. This is implemented by first estimating a value for exports absent of cross-hauling, then adding the increasingly large percentages of those exports values to the zero-cross-hauling value. All commodities cross-hauling levels are increased at each simulation step. For reference, initial exports as percentages of gross output are shown in Table 1.

Table 1: Export Percentages of Gross Output

	Output ($M)	Exports ($M)	Exports (%)
Farm	32,161	3,516	10.9%
Ag Svcs, For, & Fishing	3,759	344	9.20%
Mining	64,318	2,093	3.30%
Construction	110,336	7	0.00%
Manufacturing	559,502	85,819	15.3%
Transp & Public Utilities	163,614	7,632	4.70%
Trade	190,240	9,794	5.10%
F.I.R.E.	473,404	11,398	2.40%
Services	419,706	8,205	2.00%
Federal, Civilian	50,626	19	0.00%
State and Local	115,288	-	-
Total	2,182,954	128,827	5.90%

Table 2 shows the impact of varying cross-hauling levels (rows) on regional model estimation of output multipliers using the unadjusted 2007 ARC table as a reference. Output multipliers by industry are shown in each row, with the columns corresponding to sequentially increasing cross-hauling. The two right-most columns show the range of multipliers for each industry as cross-hauling increases from zero to one, and the range of cross-hauling multiplier changes as a proportion of the multiplier spinoff effects (the Type II multiplier in column one less 1.0). The largest absolute multiplier change is a decrease of .17 from an initial value of 2.27 in Manufacturing, while a somewhat larger percentage change of 13.4% is in the Construction sector. The average percentage impact on multiplier effects of increasing cross-hauling from zero to 100% of exports is just under 9%.

Table 2: Impact of Varying Cross-hauling Levels on Regional Model Estimation of Output Multipliers

CH Proportion	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	Range	Range %
Farm	2.16	2.15	2.14	2.13	2.11	2.10	2.09	2.08	2.07	2.06	2.05	0.12	10.13%
Ag Svcs, For, & Fishing	1.52	1.52	1.51	1.50	1.50	1.49	1.48	1.48	1.47	1.47	1.46	0.06	10.98%
Mining	1.58	1.57	1.57	1.56	1.56	1.55	1.55	1.54	1.54	1.53	1.53	0.05	8.82
Construction	1.88	1.87	1.86	1.84	1.83	1.82	1.81	1.79	1.78	1.77	1.76	0.12	13.44%
Manufacturing	2.27	2.26	2.24	2.22	2.20	2.18	2.16	2.15	2.13	2.12	2.10	0.17	13.35%
Transp & Public Utilities	1.86	1.85	1.85	1.84	1.83	1.82	1.82	1.81	1.80	1.80	1.79	0.06	7.72%
Trade	1.57	1.57	1.57	1.57	1.56	1.56	1.56	1.56	1.55	1.55	1.55	0.02	4.32%
F.I.R.E.	1.66	1.66	1.66	1.65	1.65	1.65	1.65	1.64	1.64	1.64	1.64	0.02	3.57%
Services	1.69	1.69	1.68	1.68	1.67	1.67	1.67	1.66	1.66	1.65	1.65	0.04	6.31%
Federal, Civilian	1.63	1.62	1.62	1.61	1.60	1.60	1.59	1.59	1.58	1.58	1.57	0.05	9.19%
State and Local	1.67	1.67	1.66	1.65	1.64	1.64	1.63	1.62	1.62	1.61	1.61	0.06	9.50%
Average	1.77	1.77	1.76	1.75	1.74	1.73	1.73	1.72	1.71	1.71	1.70	0.07	8.85%

Note that because of their direct and indirect linkages with other industries, the impact on some sectors can be large even when they are not directly involved in cross-hauling.

These results, of course, are specific to the trade characteristics of Appalachian Region for the selected year, specific to the level of aggregation, and representative only of a hypothetical context. Further, although a 9% impact on multiplier effects is substantial, it is reached only when cross-hauled exports equal non-cross-hauled exports.

Given the potential for substantial impact on multiplier values suggested by the simulation results, we turn to sources of secondary data that can provide an indication of how prevalent and substantial cross-hauling actually is.

3.2 U.S. Trade Statistics

There are extensive data on interstate trade for the states of the United States. State trade data by origin and destination are compiled and published by the Department of Transportation, Bureau of Trade Statistics (BTS), and selected supplemental data are available from the U.S. Department of Census. Sectoral detail is limited, however. The interstate trade data provide detail on 44 commodities. Through selective aggregation, 16 commodity sectors have directly comparable Bureau of Economic Analysis sectors for which annual input-output accounts data are available. The list of common sectors on which the remainder of analysis will be based appears in Table 3.

3.2.1 National Data

The first and most direct indicator of the extent to which cross-hauling occurs, We begin with U.S. national foreign trade data drawn from the 2007 benchmark accounts identified earlier. To be consistent with data available for commodities by state of origin and destination used in a later section, we aggregated the U.S. data to sixteen sectors listed above in Table 3.

Table 3: Sectoral breakdown for Empirical Analysis

1	Farms, Forestry, Fishing, and Related Activities
2	Food, Beverage, and Tobacco Products Manufacturing
3	Mining
4	Petroleum and Coal Products
5	Chemical Products
6	Plastic and Rubber Products
7	Wood Product Manufacturing
8	Paper Products Manufacturing
9	Printing and Related Support Activities
10	Textile, Apparel, Leather, and Related Products
11	Nonmetallic Mineral Product Manufacturing
12	Primary Metal Manufacturing
13	Fabricated Metal Product Manufacturing
14	Machinery Manufacturing
15	Electronic Equipment, Furniture, and Related Products Manufacturing
16	Motor vehicles and Other Transportation Equipment and Parts Manufacturing

Table 4 reports U.S. foreign imports and foreign exports for each of the 16 sectors, and identifies. Excluding re-exports from consideration for the moment, we can define cross-hauling as the minimum of the exports and imports values for each commodity. Because the U.S. imports more than it exports for each of these commodities, we see that the cross-hauling value is defined by exports for every sector. This corresponds conceptually to highest value used in the simulation exercise above.

3.2.2 State Data

Commodity domestic trade data by state of origin and destination are available for 2007 for 44 commodity categories (U.S. DOT/BTS). We compiled the data on state inflow and outflow for each commodity, and identified cross-hauling by state as the minimum of inflow and outflow values. We then aggregated to the 16 sectors available of the national data, resulting in 816 values (16 commodities $\times$ 51 regions – 50 states plus Washington DC). Nearly 95% of the cross-hauling estimates were defined by exports; that is, cross-hauling almost always equals exports.

Table 4: U.S. National Trade and Cross-hauling Summary, 2007

U.S. Trade, 2007	Foreign Exports	Foreign Imports	CH share of Gross Trade
Farms, Forestry, Fishing, and Related Activities	37,477.00	37,790.00	0.50
Food, Beverage, and Tobacco Products Manufacturing	41,753.00	59,279.00	0.41
Mining	14,150.00	285,740.00	0.05
Petroleum and Coal Products	40,098.00	102,285.00	0.28
Chemical Products	130,038.00	178,482.00	0.42
Plastic and Rubber Products	20,172.00	34,604.00	0.37
Wood Product Manufacturing	4,599.00	19,758.00	0.19
Paper Products Manufacturing	18,392.00	24,352.00	0.43
Printing and Related Support Activities	2,159.00	2,551.00	0.46
Textile, Apparel, Leather, and Related Products	13,525.00	152,280.00	0.08
Nonmetallic Mineral Product Manufacturing	7,372.00	23,131.00	0.24
Primary Metal Manufacturing	28,986.00	85,718.00	0.25
Fabricated Metal Product Manufacturing	23,924.00	50,617.00	0.32
Machinery Manufacturing	104,222.00	119,679.00	0.47
Electronic Equipment, Furniture, and Related Products Manufacturing	150,204.00	368,023.00	0.29
Motor vehicles and Other Transportation Equipment and Parts Manufacturing	177,724.00	274,631.00	0.39
Total	814,795.00	1,818,920.00	0.31

Given that foreign exports are not included in the BTS, this result might not be too surprising. Were we to add foreign trade to domestic trade, the totals would be expected to exceed imports with more regularity. While comparable foreign trade data were not immediately available, we generated crude estimates of foreign exports by state by commodity by multiplying state shares of commodity production by national commodity export values (Census Foreign Trade Statistics). After adding the resulting exports estimates to domestic values, 71.1% of the 816 cross-hauling values were still defined by their exports estimates. Adding foreign imports could only increase this percentage, since imports values already exceed exports.

3.3 Systematic Variation

Based on earlier discussion, we expect systematic variation in cross-hauling estimates. Specifically, we expect cross-hauling as a percent of gross industry product to decrease with increasing gross industry product, and to decrease with size of regional economy, as measured by gross regional product. As we work to obtain more accurate data to support rigorous statistical analysis, we present in the interim the results of descriptive analysis of the data on hand, followed by what amounts to a curve fitting exercise.

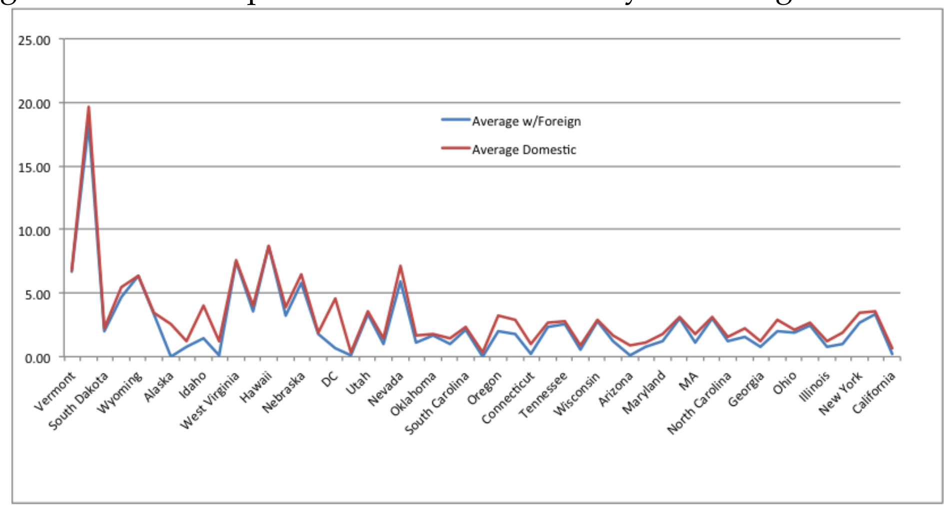
3.3.1 Raw Comparisons

As a preliminary exploration, we compute the average of the ratios of cross-hauling (CH) to gross industry product, and plot these by state in decreasing order of regional size. The results with and without the foreign exports estimates included are presented in Figure 1, and show a generally decreasing relationship, at least through roughly half of the states. Note that in some of the smaller states, CH for some industries will be zero, which decreases that state's average value.

3.3.2 Regression Results

To establish stronger support from a descriptive stance, we conducted a curve-fitting exercise. Here, we regressed sequentially the cross-hauling

Figure 1: Raw Comparison of States ordered by Gross Regional Product



proportion for each commodity on an intercept and the logs of gross product (lgrp) and gross industry product (lgip). The results are shown in Table 5. While this is more of a curve fitting than a statistical exercise, those coefficients that were significant were generally consistent with expectations.

To provide a summary view of these results, we averaged the individual models and created a composite predictive equation that we plotted along with observation based cross-hauling estimates in Figure 2. While there is considerable noise and variation around the predicted values, the trend in cross-hauling proportions seems clear: there is an inverse relationship between cross-hauling proportion and gross regional product.

4 Research Directions

Much remains to be done. The following tasks are planned or in process:

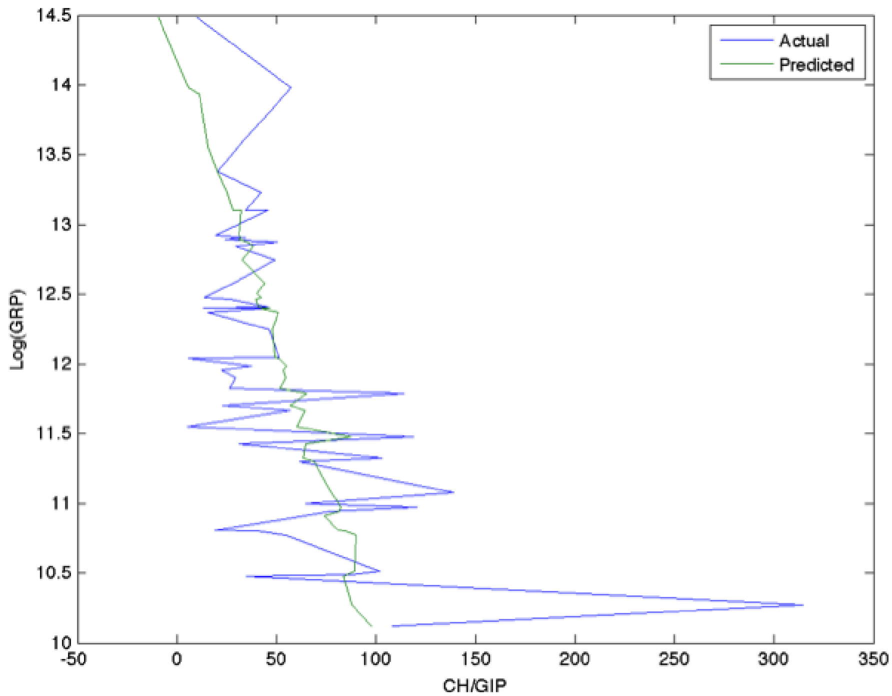
- Refine or replace foreign exports data for states
- Identify a good source for foreign imports data

Table 5: Regression Results (CH/gip)=f(intercept, lgrp, lgip)

Sector	Beta Values			T-statistics		
	intercept	lgrp	lgip	intercept	lgrp	lgip
1	-1.70	0.72	-0.84	-1.26	5.57	-9.01
2	4.29	0.36	-0.93	1.61	1.42	-5.04
3	14.69	-0.10	-1.60	1.10	-0.08	-1.74
4	45.83	-3.92	1.01	2.46	-2.20	0.78
5	18.148	-1.44	0.29	3.09	-2.57	0.70
6	11.544	0.16	-1.40	2.26	0.32	-3.96
7	4.35	0.21	-0.68	1.64	0.82	-3.73
8	15.89	-0.24	-1.42	2.77	-0.43	-3.57
9	0.96	0.02	-0.05	0.79	0.21	-0.57
10	31.80	-1.60	-0.47	1.80	-0.94	-0.38
11	1.25	0.04	-0.13	1.57	0.59	-2.43
12	127.10	-13.35	5.81	2.31	-2.53	1.53
13	5.31	-0.34	0.00	3.41	-2.31	0.04
14	37.76	-1.14	-2.60	1.95	-0.61	-1.94
15	6.09	-0.10	-0.31	1.42	-0.25	-1.05
16	8.72	-0.22	-0.39	1.30	-0.35	-0.85
Averages	20.75	-1.31	-0.23			

- Manipulate regional definitions
- Group states by twos and threes to assess impacts of varying geographical scope
- Aggregate to Census regions
- Aggregate to Mega regions
- West, Central, East
- West, East
- Explore potential empirical regularities
- Are there relationships with other ?own-region? characteristics
- Does industrial diversity shape cross-hauling propensities?

Figure 2: Relationship between cross-hauling proportion and gross regional product



- What are the implications of aggregation?
- What are the implications of using state data vs data for functional economic areas
- Further conceptualization
- Are there fundamental theoretical determinants that can carry us further than Kronenberg's basic formula?
- Are there implications concerning centrality and relative location?

5 Conclusions

Given that cross-hauling behavior is so important to accurate input-output table estimation, its estimation methods also are in need of a great deal more conceptual and theoretical development. Despite the fact that this paper presents only preliminary and tentative analyses, we are confident that

- Cross-hauling is substantial and likely to be defined by a substantial proportion of exports
- Cross-hauling levels can be expected to vary by size of region (although the precise relationships have yet to be established)
- Cross-hauling increases with increasing levels of aggregation (if for no other reason than that sectoral heterogeneity increases with aggregation)

Any new or refined methods for estimating cross-hauling will need to incorporate or at least reflect these relationships.

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