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Economic, environmental and congestion impacts of trucking

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Abstract

In this paper, two different measures of economic linkage are derived for various segments of the trucking industry and compared against the indicators of two types of negative externalities: congestion and greenhouse gas emissions. Overall, the correlation between economic linkages and the negative externality measures is not very strong, indicating there may be many economically inefficient movement (e.g. transport of low value goods over a long distance) of freight.
The analysis seems to point out that mixed freight and construction-related material and equipment are some of the most economically important commodities that are moved by trucks. Although those commodities rank high on the list of negative externalities, to a degree, the burden associated with the movements of those goods is justified from the economic point of view. On the other hand, transportation of goods such as miscellaneous manufactured products, paper and paper products, vehicle and parts, and electronic equipment put undue burden on the road network and emit disproportional amount of CO_2 that may not be justified in light of the relatively weak economic importance as measured in this study.

Keywords: Trucking ; externality of trucking; economic linkages; social cost

1. Introduction

Freight transportation has profound impacts on the social and economical well being of the U.S. in many dimensions. For example, on some of the major expressways, trucks can account for as much as 40% of total traffic, and also the user costs (i.e. excluding passenger vehicles) of delays to trucks alone exceeds $7.8 billion a year (Cambridge Systematics, 2005). More than 10 million people, one out of every 14 jobs in this country, works in the transportation-related industries (Federal Highway Administration, 2002). For many communities that have lost manufacturing jobs, the freight industry is regarded by policy makers and business communities as the potential economic base for the future.

Nevertheless, as indicated by the local resistance to the building of large intermodal facilities in the Chicago area and the public battle between the supporters and opponents of the proposal by the Canadian National Railroad to detour rail traffic through Chicago suburbs, transport of freight is widely perceived as a nuisance rather than an

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economic opportunity. While it is true that package pick-up and delivery activities are one of the key causes of congestion in urban areas, behind only vehicular crashes and road construction (Han et al., 2005), there seems to be a disconnection between the movement of freight and the consumption of the necessities for day-to-day living that includes commercial goods, services and energy. The same can be said for the economic contribution in the form of job creation. In the policy discussions regarding the movement of freight in urban areas, the focus is almost always exclusively on how to manage the negative impacts of truck activities using restrictions on their movement and access. A long-standing ban on the night-time truck delivery in the city of Chicago is such an example. However, what is missing from such discussions is the fact that not all trucking activities cause the same level of impacts, negative or positive, to society. For example, undoubtedly, transporting certain types of commodities is more economically beneficial (or detrimental) than others. It follows then that applying blanket restrictions on trucking activities based on vehicle types without considering the variations in the total impacts of different types of trucking activities is not a prudent public policy approach.

Currently, there is no reliable information for the government and decision makers to evaluate the impacts separately for different types of trucking activities. The overarching aim of this study is to fill such knowledge gap by comparing the economic contributions that come from the trucking of various types of commodities with the usage of road capacity. We will start with the forward linkage analysis framework of Rasmussen-Hirschman, which is designed to capture the economic impact of each additional unit of intermediate supply (of trucking) (Rasmussen, 1957, Hirschman, 1958). We will also use the analysis techniques based on the "supply-side" input-output framework, first developed by Chenery and Watanabe (1958). Without the explicit representation of the private (or "in-house") transportation sector in the SAM, the model does not accurately estimate all transport-related economic impacts. We use the Transportation Satellite Account (TSA) (1997), developed by the Bureau of Transportation Statistics (BTS) and the Bureau of Economic Analysis (BEA), to extract the information on the inter-industry transactions involving private trucking. Connecting freight activities to the economic sectors presents arguably the greatest challenge. The data from Vehicle Inventory and Use Survey (VIUS) (2002) are used to obtain the passenger-car-equivalent vehicle miles-of-travel (PCE VMT) figures for various types of commodities carried by trucks in urban areas.

2. Analysis of Economic Linkages - Theory

Measurements of the direct contributions made by freight activities include, final demand, jobs, and wages that are attributed to the freight industry including warehousing. Indirect contributions can be measured by the overall increase/decrease in the regional gross domestic product for a given amount of change in final demand for freight transport and the value of commodity transported.

The use of Input-Output (I-O) framework for analyzing the economic structure, including interdependence, or linkages, between sectors, was first established in the 1950's by the works of Rasmussen, Hirschman, Chenery and Watanabe, and others. While Hirschman is credited with recognizing the potential of identifying the key sectors of economy from the I-O data based on the linkages and establishing the conceptual foundation, Rasmussen and Chenery and Watanabe developed the analytical approach that is widely used to this date, for example, Claus and Li (2003), Andreosso-O'Callaghan and Yue (2004), Aydın (2007). Over the years, a number of modifications and improvements to the linkage analysis have been proposed by researchers such as Augustinovics (1970), Jones (1976), Cella (1984), Himler (1991), Sonis et al. (1995), and Dietzenbacher and van der Linden (1997).

There are two general types of inter-industry linkage measures that are commonly used. The backward linkage captures the relationship between an increase in the final demand of one sector and the increase in the outputs of other sectors of the economy. On the other hand, the forward linkage measures the change in the output of a sector that supplies intermediate products or services associated with a change in the final demands for other sectors. As far as the freight activity is concerned, forward linkage is of greater interest since the final demand for freight transportation is quite small relative to its total output.

In the present paper, the Chenery and Watanabe technique and also the direct requirement coefficients will be used with some modifications. The framework of Chenery-Watanabe uses, for the forward linkage, the "supply-side" I-O technique, in which changes in the output of the intermediate product or service are "pushed" forward through the economy to generate the multiplier effect. The following sections give the description of Chenery-Watanabe forward linkage measures and also the direct requirement coefficient.

2.1. Chenery-Watanabe forward linkage measure

In the approach based on the "supply-side" I-O technique, first proposed by Chenery and Watanabe, the forward linkage measure captures the direct effect of an increase in the output of the intermediate product or service provided by a sector on the outputs of the other industry sectors. Let x_{ij} be the elements of the industry-to-industry transaction table. In the demand-side I-O analysis, the total input coefficient matrix (often referred to as "**A** matrix") is calculated by dividing each element by the total output of the corresponding sector, i.e.

$$a_{ij} = \frac{x_{ij}}{\sum_i x_{ij} + V_j}, \text{ and } \mathbf{A} = \begin{bmatrix} x_{11} \Big/ \sum_i x_{i1} + V_1 & \cdots & x_{1n} \Big/ \sum_i x_{in} + V_n \\ \vdots & \ddots & \vdots \\ x_{n1} \Big/ \sum_i x_{i1} + V_1 & \cdots & x_{nn} \Big/ \sum_i x_{in} + V_n \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

Where V_j is the value added input for sector j. The Leontief inverse, $(\mathbf{I}\text{-}\mathbf{A})^{-1}$, where I is an identity matrix, gives the "multiplier" often used in the economic impact analysis.

On the other hand, in the supply-side I-O, the direct output coefficient matrix, often referred to as "B-matrix", is calculated by dividing x_{ij} by the row total, i.e.

$$b_{ij} = \frac{x_{ij}}{\sum_j x_{ij} + Y_i}, \text{ and } \mathbf{B} = \begin{bmatrix} x_{11} \Big/ \sum_j x_{1j} + Y_1 & \cdots & x_{1n} \Big/ \sum_j x_{1j} + Y_1 \\ \vdots & \ddots & \vdots \\ x_{n1} \Big/ \sum_j x_{nj} + Y_n & \cdots & x_{nn} \Big/ \sum_j x_{nj} + Y_n \end{bmatrix} = \begin{bmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{n1} & \cdots & b_{nn} \end{bmatrix} \quad (2)$$

Where Y_i is the final demand for sector i excluding the imports.

The Chenery-Watanabe forward linkage measure for industry sector i, FL_i^C , is calculated by the row sum of the B-matrix, i.e.,

$$FL_i^C = \sum_j b_{ij} \quad (3)$$

In essence, FL_i^C represents the portion of the total output for sector i that is used as intermediate inputs. Thus, the greater the FL_i^C, the higher the dependence of other industry sectors on the product or services provided by the sector i is.

The causal interpretation of the Chenery-Watanabe measure, as described by Jones and also Miller and Blair (1985), is easier when the linkage is understood in the context of constraints especially when considering the cases such as transportation and utility. For example, let the sectors 1 and 2 be for-hire trucking and construction, respectively. If b_{12} is 0.044, then a \$1 reduction in the total output of the for-hire trucking industry would reduce the supply of for-hire trucking, in the form of intermediate input into the construction sector, by \$0.044, which obviously affects the sector's production. FL_1^C represents the sum of the reductions in the intermediate supply of for-hire trucking for all sectors associated with each dollar of reduction in the total output of for-hire trucking. For transportation and utility, the effect of an *increase* in the total sector output does not provide an intuitive case since the demand for those sectors are derived from other sectors' needs. In other words, it is difficult to argue that an increase in transportation or electricity output generates additional intermediate purchases.

2.2. Direct requirement coefficients

Another measure of interdependence among industry sectors can be calculated from the Industry-by-Commodity Use Matrix, which shows the use of different commodities as intermediate inputs by other sectors and also the final demand. The direct requirement coefficients, which is calculated by dividing each element of the Use Matrix by the column sum shows, for each industry, amount of each commodity required to produce one dollar of output.

Let u_{ij} be the intermediate use of commodity i by the industry j. Then, the direct requirement coefficient for i by j, c_{ij} is calculated by

$$c_{ij} = \frac{u_{ij}}{\sum_{i} u_{ij} + V_j} \tag{4}$$

The interpretation of the direct requirement coefficient is straightforward. For example, c_{ij} of 0.2 indicates that for each dollar of output produced by j, \$0.2 of the commodity i is required as an input. By examining the direct requirement coefficient for the trucking "commodity" (the service provided by trucking industry), it is possible to identify the industries that rely heavily on trucking as inputs.

3. Analysis of Economic Linkages - Application

3.1. Economic data

The data used for the analysis is the 1997 Transportation Satellite Accounts (TSA) from the Bureau of Transportation Statistics (BTS) and the Bureau of Economic Analysis (BEA) (BTS, 1999). While a more recent set of I-O accounts are available from the BEA, for example, annual I-O accounts or the Benchmark I-O accounts, they do not separate the in-house (or "private") trucking as a separate economic sector (or commodity). As private trucking is estimated to account for 40% or more of the total trucking activity in the U.S., it is critical that those activities are not integrated into the primary industry sectors, e.g. retail, that perform private trucking as a part of the business activity.

The TSA consists of four separate tables. They are: Make Matrix, Use Matrix, Direct Requirement Matrix, and Total Requirement Matrix. The TSA matrices are all expressed in industry-by-commodity or commodity-by-industry format. There are 95 industry sectors, including seven separate transportation sectors, and 97 commodities. In the commodity definition, one of the transportation sectors, passenger transit services provided by the government, is not treated as a separate commodity. In the TSA, private trucking is categorized as "own account transportation". For-hire trucking is included in the "Motor freight transportation and warehousing" industry, because in the less-than-truckload industry, many of the firms operate warehouses, making it difficult to distinguish the trucking operation and warehousing operations.

3.2. Analysis 1. Chenery -Watanabe linkage

Analysis of the Chenery-Watanabe forward linkage measures, FL_i^C , showed that the private trucking has the highest possible value, 1.0. This is because .FL_i^C measures the share of the output used as the intermediate inputs for other sectors. Since private trucking has no final demand by definition, it should produce the index of 1.0. The forward linkage of the for-hire trucking is 0.7111, which ranks only 35th among the 97 industries. The linkage for the trucking as a whole, i.e. both for-hire and private combined, is 0.855, which is the 18th highest. As mentioned earlier, this figure only represents the direct effect, and does not reflect the broad impact such reductions would have on the total output of the economy. More interesting insights can be obtained by examining how the trucking services are used by other industries.

Table 1 shows the top 20 commodities measured by the direct output coefficients, b_{ij}, for the trucking as a whole. The value of b_{ij} shows the change in the supply of the commodity/service from industry "i" to "j" if the output of "i" were to increase by $1. This table also shows the rankings separately for private and for-hire trucking industries. It shows that the trucking industry is linked most closely with its own, scoring the highest output coefficient. This suggests a wide spread of intra-industry purchases of for-hire trucking services. Other industries that are strongly linked to trucking include: construction (both new and repair), wholesale, retail, and food-related sectors. The comparison of the rankings clearly shows that the economic linkages of the for-hire and private trucking sectors differ significantly. While the construction industry has strong linkages with both for-hire and private trucking, some of the industries that have a strong linkage with private trucking, such as retail, maintenance and repair construction, and eating and drinking places, have only a modest linkage with for-hire trucking. For some of the industries, the linkage is through financial transactions, as seen in the case of finance and various service sectors.

Table 1 Direct output coefficients (B_{ij}) - top 20 industries

Top 20 Industries by B_{ij} (for-hire & private)	B_{ij}	B_{ij} rank	
		For-hire	Private
Motor freight transportation and warehousing	0.101	1	N/A
New construction	0.101	2	1
Wholesale trade	0.081	10	2
Retail trade	0.068	20	3
Maintenance and repair construction	0.053	5	4
Eating and drinking places	0.038	13	5
Food and kindred products	0.031	3	10
Other agricultural products	0.028	24	6
Educational and social services, and membership organizations	0.028	28	7
Other business and professional services, except medical	0.026	17	8
Health services	0.023	19	9
Rubber and miscellaneous plastics products	0.013	6	22
Finance	0.013	4	33
Automotive repair and services	0.012	29	11
Motor vehicles (passenger cars and trucks)	0.012	9	16
Livestock and livestock products	0.011	15	15
Stone and clay products	0.011	8	26
Paper and allied products, except containers	0.010	7	37
Personal and repair services (except auto)	0.010	42	12
Primary iron and steel manufacturing	0.009	12	27

3.3. Analysis 2. Direct requirement coefficients

The second measure of inter-industry linkage is the direct requirement coefficient (DRC). Table 2 shows the 20 industries with the highest coefficients for the trucking, including both for-hire and private. The DRCs capture the shares that trucking represent within the inputs for producing the primary commodity or service of each industry. Not surprisingly, both lists mostly include the industries that involve transportation of heavy or bulky goods. Essentially, these are the industries that are most vulnerable to the price or productivity changes in trucking, both for-hire and private. For example, in the non-metallic minerals mining industry (e.g. mining of lime stone, etc.)

9.2% of all the input, including the value added, is spent on trucking. The motor freight transportation and warehousing, or "for-hire trucking" industry spend nearly 20% of input on purchasing services from other trucking companies, by far the highest figure.

Table 2 Direct requirement coefficients - top 20 industries

Top 20 Industries by DRC (for-hire & private)	DRC	DRC Rank	
		For-hire	Private
Motor freight transportation and warehousing	0.185	1	N/A
Non-metallic minerals mining	0.092	17	1
Other agricultural products	0.079	49	2
Stone and clay products	0.077	2	20
Maintenance and repair construction	0.076	24	5
Agricultural, forestry, and fishery services	0.069	53	4
New construction	0.069	25	6
Forestry and fishery products	0.068	91	3
Agricultural fertilizers and chemicals	0.055	3	81
Coal mining	0.048	23	11
Livestock and livestock products	0.047	10	15
Eating and drinking places	0.045	58	9
Metallic ores mining	0.044	29	12
Wholesale trade	0.042	80	7
Paperboard containers and boxes	0.041	4	70
Furniture and fixtures	0.041	26	14
Retail trade	0.040	87	8
Educational and social services, and membership organizations	0.038	81	10
Primary iron and steel manufacturing	0.037	8	35
Rubber and miscellaneous plastics products	0.036	7	36

The rankings of DRC by for-hire and private trucking sectors show considerable differences. As the rankings indicate, non-metallic minerals mining industry tend to rely heavily on their own trucks to satisfy the transportation needs. The same can be said for the "other agricultural" sector that include food grains as the major commodity and also the industries related to construction (New construction and Maintenance and repair construction). The industries that rely heavily on for-hire trucking instead of their own transport tend to deal with commodities that require expertise to transport, for example, stone and clay products, Agricultural fertilizers and chemicals, and paperboard containers and boxes.

4. Environment and Capacity Impacts

4.1. Road capacity usage

We use passenger-car-equivalent vehicle miles travelled (PCE VMT) to measure the impact of truck activities on the road capacity. To estimate the PCE VMT, the miles that trucks travel annually carrying various groups of commodities were obtained from the 2002 Vehicle Inventory and Use Survey (VIUS).

In order to estimate the PCE VMT by commodity for the urban areas, only the vehicles that are based in the Metropolitan Statistical Area (MSA) were extracted first. Then, the data were split into vehicles belonging to for-hire and private businesses. Using the vehicle body type provided in the VIUS data set, the records were classified into four groups: passenger cars, single-unit trucks less than 19,500 pounds of gross-vehicle weight, single-unit trucks exceeding 19,500 pounds, and tractor-trailer combinations. Elefteriadou et al. (1997) determined the appropriate conversion factors to translate the presence of the latter three types of trucks in the traffic stream using micro simulation models. Based on their findings, conversion factors of 1, 2, and 3, respectively, were used for those three types of heavy vehicles in order to convert the recorded VMT into PCE VMT. For this study, the VMT recorded by passenger cars with business plates was excluded from the calculation. Finally, the PCE VMTs were calculated for each of the 51 commodity types for for-hire, private, and the total of both private and for-hire trucks.

Table 3 shows, in order, top 15 commodities carried by trucks in terms of total PCE VMT of both for-hire and private. This table also shows the rankings of each commodity within for-hire and private trucking. The commodity with the highest PCE VMT, Mixed freight, includes containerised merchandizes.

Mixed freight accounts for almost 10% of truck-related PCE VMT in the urban areas in the U.S. Combined with the prepared food, top two commodities account for almost 20% of the total PCE VMT. Somewhat surprisingly, food-related items including: Prepared food and Bakery products, and Meat and seafood, account for nearly 16% of the total PCE VMT. Non-power and Power tools are transported by the vehicles that are operated by the construction businesses. Together, they account for about 6% of the total PCE VMT.

Table 3 Estimated passenger car equivalent VMT

Top 15 commodities by PCE VMT (for-hire & private)	Accumulative share of total PCE VMT	PCE VMT rank	
		For-hire	Private
Mixed freight	0.097	1	51
Prepared foodstuffs	0.184	2	1
Non-power tools	0.227	28	2
Misc. manufactured	0.267	10	4
Paper or paperboard articles	0.305	7	5
Bakery products	0.342	6	10
Power tools	0.377	32	3
Vehicle, including parts	0.412	4	20
Meat, seafood	0.446	5	18
Mail and parcels	0.479	3	42
Electronic equipment	0.509	18	6
Plastic and rubber	0.538	17	9
Wood prod.	0.567	11	15
Non-metallic mineral	0.594	16	13
Animal feed	0.619	26	7

4.2. CO_2 emissions

The CO2 emissions from the trucks carrying different commodities were estimated also using the VIUS data. First, the average fuel efficiencies (gallons per VMT) for gasoline and diesel engine equipped vehicles were estimated for each of three aforementioned truck body types based on the fuel efficiency, fuel type, and truck body type variables contained in the VIUS data set for each record. Next, the fuel efficiencies were converted into CO2 emissions per VMT using the average CO2 emission rate published by the U.S. Environmental Protection Agency (2005). Finally, the average CO2 emissions per VMT for each of three body types was calculated using the total annual VMT recorded for each body type as weights. The average CO2 emission rates were: 0.908, 1.494, and 1.731 for single-unit trucks less than 19,500 pounds of gross-vehicle weight, single-unit trucks exceeding 19,500 pounds, and tractor-trailer combinations, respectively. The estimated amount of CO2 emissions for each commodity, shown in Table 4, was calculated by multiplying the VMT of the truck body type carrying respective commodity by the average CO2 emissions per VMT.

The commodities shown in Table 3 are almost identical to those in Table 4 except for the Base metal that ranks 15th. The top 15 commodities account for over 62% of total CO_2 emitted in urban areas. The top three commodities are the same as the capacity impact case. However, the construction-related commodities, Power and Non-power tools account for nearly 10% of the total, compared against 6% for the PCE VMT, because they rely more heavily on smaller single unit vans than other commodities.

Table 4 Estimated CO_2 emissions

Top 15 commodities by CO_2 emission (for-hire & private)	Accumulative share of total CO_2 emission	CO_2 emission rank	
		For-hire	Private
Mixed freight	0.089	1	51
Prepared foodstuffs	0.170	3	2
Non-power tools	0.225	28	1
Power tools	0.269	31	3
Misc. manufactured	0.307	10	4
Mail and parcels	0.344	2	42
Bakery products	0.380	6	8
Vehicle, including parts	0.415	4	21
Paper or paperboard articles	0.450	7	6
Meat, seafood	0.482	5	18
Electronic equipment	0.511	17	7
Wood prod.	0.540	11	14
Non-metallic mineral	0.568	16	9
Plastic and rubber	0.595	18	12
Base metal	0.622	19	13

5. Discussion

So far, the impacts of trucking activities in three categories: economic, congestion and greenhouse gas, have been estimated. For the latter two categories, the list of commodities/services that impart most impacts through truck trips in urban areas are nearly identical. They include: Mixed Freight, construction-related activities, food deliveries, and miscellaneous manufactured products. For the analysis of economic impacts, two contrasting indicators, the direct output coefficients (b_{ij}) that captures how the supply of trucking services are absorbed by various industries, and direct requirement coefficients (DRC) that measures the degree to which various industries use trucking as input ingredient in the production, were examined. Not surprisingly, the results were quite different. In fact, there are only four industries that appear on the top 10 of both lists. They are: Motor freight transportation and warehousing, New construction, Maintenance and repair construction, and Other agricultural products. Non-metallic minerals mining, which is the second highest in terms of DRC, does not even appear in the top 20 of the B_{ij} (34th). Food and kindred products that is ranked 7th in terms of B_{ij} is ranked 28th in terms of the DRC. While the lists of industries that appear in the DRC and B_{ij} tables can be intuitively understood in the context of what the respective measures are designed to capture, this discrepancy underscores the difficulty of developing a clear-cut list of commodities that can be considered economically most critical. However, it is safe to say that the following trucking activities can be considered the most obvious: for-hire trucking, construction-related activities, and transport of grains and various agricultural products.

It should be noted that in contrast to the capacity and environmental impacts that were estimated for the urban areas, the economic impacts were estimated for the nation as a whole. Thus, the economic importance of industries such as grain production and processing, which is a large part of Other Agricultural Products industry, may not apply to the urban areas. However, insofar as the trucking activities that accrue as a part of the activities of such industry take place in the urban areas, they are impacted by the policies and also efficiencies of the roadway systems in the urban areas.

In order to compare the congestion, environment, and economic impacts in relation to each other, the rankings of the commodities within each category are summarized in Table 5. It should be noted that the industry/commodity definitions used in TSA and the commodity types in VIUS are not consistent. The 97 TSA commodities had to be reconciled with the 51 commodity type definitions used by VIUS based on the similarity of the definitions used in both data sets. In most cases, the right matches were found, but in some instances, finding the appropriate matches were challenging. Since there are more commodities in the TSA, some of the matches were one-to-many. In such situation, the highest rank of the TSA commodities are listed in the table.

Table 5 Comparison of impact measure ranks

Top commodities by PCE VMT and CO_2 Emissions	Rankings			
	PCE VMT	CO_2 Emission	b_{ij}	Direct requirement coefficients
Mixed freight	1	1	3	14
Prepared foodstuffs	2	2	7	28
Non-power tools	3	3	5	5
Misc. manufactured	4	5	35	49
Paper or paperboard articles	5	9	18	21
Bakery products	6	7	7	28
Power tools	7	4	2	7
Vehicle, including parts	8	8	15	32
Meat, seafood	9	10	16	8
Mail and parcels	10	6	1	1
Electronic equipment	11	11	50	45
Plastic and rubber	12	14	12	20
Wood prod.	13	12	21	24
Non-metallic mineral	14	13	34	2
Animal feed	15	19	8	3
Base metal	19	15	20	19

A comparison of the rankings indicates that the intensity of physical transporting of goods that are captured by the PCE VMT and CO2 rankings is not a good predictor of the economic importance. There are many commodities in the table that rank high in both PCE VMT and CO2 emissions, but whose economic contributions, as measured by both or at least one of the two measures, do not match. For example, Miscellaneous manufactured products, which includes items such as fabricated metal parts, toys, glass products, and appliances, is ranked 4th and 5th on VMT and CO2 emissions, respectively. However, it is ranked 35th and 49th in bij and DRC, respectively. This is a case where the burden of externality in the forms of congestion and greenhouse gas emission seem to outweigh the economic importance of the goods being transported at least according to the measures used here. Paper products, Vehicles and parts, and Electronic equipment are other examples. In contrast, construction-related trucking activities and as well as mail and parcel deliveries rank high in all measures.

6. Conclusion

In this paper, two different measures of economic linkage were derived for the trucking industry and compared against the indicators of two types of negative externalities: congestion and greenhouse gas emissions. Overall, the correlation between economic linkages and the negative externality measures are not very strong, indicating there may be many economically inefficient movements (e.g. transport of low value goods over a long distance) of freight.

The analysis seems to point out that mixed freight and construction-related material and equipment are some of the most economically important commodities that are moved by trucks. Although those commodities rank high on the list of negative externalities, to a degree, the burden that is placed on the road network by accommodating the movement of those goods is justified from the economic point of view. On the other hand, transportation of goods such as miscellaneous manufactured products, paper and paper products, vehicle and parts, and electronic equipment seem to put undue burden on the road network and emit disproportional amount of CO_2 that may not be justified in light of the relatively weak economic importance as measured in this study.

It is clear that treating all the trucking activities under the uniform policy and management strategy is not justified from an efficiency standpoint. The policy measures to correct this for the externalities may include commodity-specific fees or taxes, trucking restrictions of certain goods (e.g. time of day restrictions to avoid most congested time periods), and delivery consolidation. In particular, delivery consolidation may serve an important role for food and related products that have been shown to account for a significant share of the total VMT and CO_2 emissions.

It should be noted however that this study is still preliminary, and there are many aspects of the analysis and data that need to be improved. For example, the use of output inverse, (I-B)-1, instead of the B-matrix, will provide the measure of forward linkage that better represents the broad economic impacts.

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