A Statistical Study of Commodity Freight Value/Tonnage Trends in the United States

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ABSTRACT

The last two decades have seen dramatic economic, technical and market changes in the United States including widespread internet adoption, rapid advances in information and communication technologies, outsourcing, and the globalization of supply chains. These changes are likely affecting the demand for freight transportation as well as the type and prominence products shipped by commodity group. This research focuses on the study of value/tonnage trends for some key commodities. Value/tonnage ratios are not only relevant because they can show aggregate trends for key commodity groups but also because they are utilized in many freight models at the freight generation stage. Statistical results indicate that some changes in value/tonnage ratios are statistically significant. Implications of these results for freight modeling efforts are discussed.

Keywords: Freight trends, Freight Generation, Commodity, Value/Tonnage

1- INTRODUCTION

Freight transportation has grown rapidly in the last decades (1). At the same time, radical changes have taken place in the US economy since the 1990's due to technological changes in information and communication technologies, outsourcing, the rapid growth of international trade, and the globalization of supply chains.

Value/tonnage ratios are not only relevant because they can show aggregate trends for key commodity groups but also because they are utilized in many freight models at the freight generation stage. According to the Quick Response Freight Manual (2), freight generation models can be categorized into two broad groups, first generation and second generation models.

The first generation of freight models adopts the well-known four-step passenger models to goods movements; first generation freight models can be broken into vehicle-based models or commodity-based models (i.e. freight movement can be measured in two basic forms, as flows of commodities or vehicles). The key difference between commodity and vehicle based models is found in the demand generation and mode split steps and the type of basic input data employed to generate flows (2). Vehicle-based models use employment, socio-economic, and household data to estimate trip rates. These models presuppose that the mode and vehicle selections were already done and do not require mode split models since trucking is implicitly assumed as the only available option. On the other hand, commodity based models tend to use economic models (e.g. input/output models) to generate tons or value per commodity type. Commodity-based freight models usually estimate or forecast freight flows between origins and destinations (OD matrices). Additionally, these models have a mode split step (i.e. commodities utilize the most suitable mode) (2, 3).

The second generation or more advanced freight models attempts to consider the role played by supply chains in the formation of freight shipments by including all relevant companies and agents making decisions about shipments and transportation related decisions. Adding supply chain structures and attributes to freight models can better capture the effects of changes in system performance or costs in one link/stage of the supply chain or on the overall economy (4).

Many freight models, in both generations, employ value-density functions (relationship of dollars per ton) to convert OD annual dollar commodity flows into tons of goods shipped. One example is the statewide transportation model for Oregon also called SWIM2 (second generation statewide integrated model). SWIM2 is an integrated model that captures the interactions between the land use, economy, and transportation systems. Complex connections and feedback loops among these three systems are modeled in SWIM2 and can be used to forecast the impact of policy decisions on Oregon's transportation system, land use and the economy. SWIM2 includes 20 industry sectors; 18 household income/size categories and 41 SCTG (Standard Classification of Transported Goods) commodities. Its integrated framework makes it ideal for analyzing the impacts of economic changes on commodity flows as well as travel and land use patterns at the state level.

SWIM2's Commercial Transport (CT) module is a hybrid micro-simulation model of freight travel demand (5).The CT module estimates and forecasts tons and vehicle freight flows between origins and destinations (OD commodity value matrices).The CT module employs value-density functions to convert annual dollar commodity flows between origins and destinations first into tons of freight moved and later into vehicle flows. The current value-density functions are derived from the 1997 Commodity Flow Survey (CFS) data.

One of the motivations of this paper is to study how value-density functions, or value/tonnage ratios, have changed over time. This research presents: (a) an evaluation of trends between 1997 and 2007 in mode split and commodity value/ton ratios using Commodity Flow Survey (CFS) and Freight Analysis Framework (FAF) data; (b) a comparison of trends, by mode and commodity, between Oregon and the U.S. key commodities; and (c) an analysis of value-density ratios for some commodities that are central to Oregon's economy.

2- TRENDS COMPARISON AND ANALYSIS

To provide the necessary context and background, this section presents a brief description of the CFS data and brief comparison between Oregon and the U.S. in terms of freight mode shares.

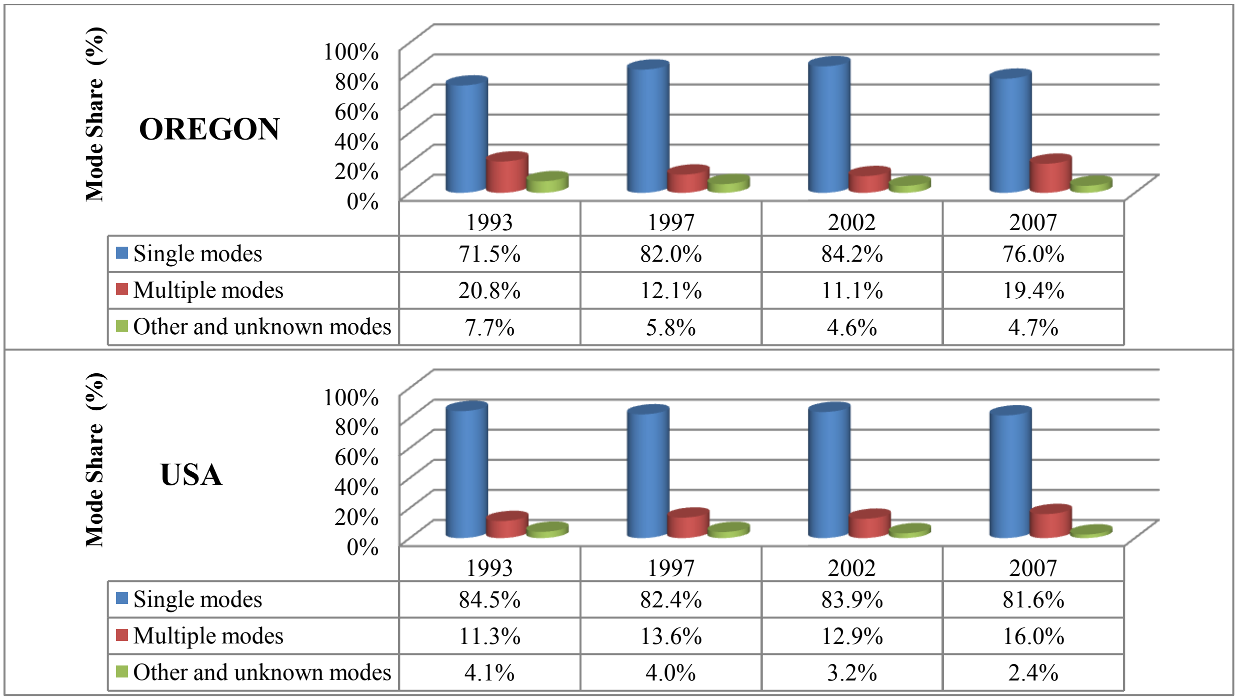
2.1 CFS

The Commodity Flow Survey (CFS) is a joint effort of the Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics (BTS), and the U.S. Census Bureau (part of the U.S. Department of Commerce). CFS data reports the value, weight, and ton-miles of goods shipped at national and state level by SCTG (standard classification of transported goods) commodity codes. The CFS is conducted approximately every 5 years (the last one was conducted in 2007) and is part of the U.S. Economic Census. In the 2007 CFS, surveyed commercial establishments including those located in the United States, having non-zero payroll in 2005, and the following sectors: mining (except oil and gas extraction), manufacturing, wholesale, electronic shopping and mail order, fuel dealers, and publishing industries, as defined by the 2002 North American Industry Classification System (NAICS) (6).

CFS provides aggregated freight shipment information at the national, state, and main metropolitan area levels. The CFS is a shipper-based survey which captures the shipments originating from selected business establishments. Therefore, data related to carriers, logistics systems, and routing (e.g., logistic chains, distribution patterns) are not captured. It is important to highlight that the CFS data presented in this paper reflects only the *origin* of the shipment and not the destination of the shipment. The CFS sample design, instrument design and data collection method have improved over the last 20 years. The CFS takes place every five years and unfortunately the sample size has changed over time. This research will utilize mostly 1997 and 2007 CFS data because they have similar sample size; 2002's simple size was significantly smaller.

2.2 General Trends

CFS data for Oregon and the United States (US) show some important similarities and differences in terms of freight movements by value, ton, or commodity (6). As shown in figure 1, single modes (Truck, Rail, Water, Air and Pipeline) dominate in both Oregon and in the US. Figure 1 also shows that the share of multiple modes (which include multimodal and package delivery) has experienced a noticeable growth in both the US and Oregon. Some of the changes in mode share may be attributable to changes in the survey form[1].



OREGON

	1993	1997	2002	2007
Single modes	71.5%	82.0%	84.2%	76.0%
Multiple modes	20.8%	12.1%	11.1%	19.4%
Other and unknown modes	7.7%	5.8%	4.6%	4.7%

USA

	1993	1997	2002	2007
Single modes	84.5%	82.4%	83.9%	81.6%
Multiple modes	11.3%	13.6%	12.9%	16.0%
Other and unknown modes	4.1%	4.0%	3.2%	2.4%

FIGURE 1 Freight mode shares, Oregon and the US (1993 to 2007)
Source: Commodity Flow Survey data (6)

Figure 2 shows Oregon and US top commodities by value in 2007. The five top commodities by value account for 42% of total freight movements in Oregon and 38% of freight movements in the US. The makeup of the top commodities by value differs significantly between Oregon and the US. Oregon has a unique mix of high tech products (e.g. electronics) and primary product s or commodities (e.g. wood products) that is significantly different from the composition of the US economy.

In terms of tons, the top five commodities by weight account for 64% of the total tonnage moved in Oregon; in the US, the top five commodities by weight account for 46% of the total. Mode split percentages show that trucking is the dominant mode for all top commodities by value in the US (Figure 3). As expected, multimodal and package delivery are significant for both electronics and pharmaceutical products (with over 30% of flows) whereas air mode is significant for electronics (with 10% of flows). Rail is only noticeable for long-haul motorized products and vehicle flows.

It is important to highlight that for 2007 values the FAF3 data is used since it is more reliable than CFS; FAF is not a survey as CFS. FAF3 integrates data from a variety of freight data sources to build a comprehensive picture of freight movement in US (7). However, to study trends, CFS data is used due to the unavailability of FAF data for 1997.

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[1] http://www.bts.gov/help/commodity_flow_survey.html

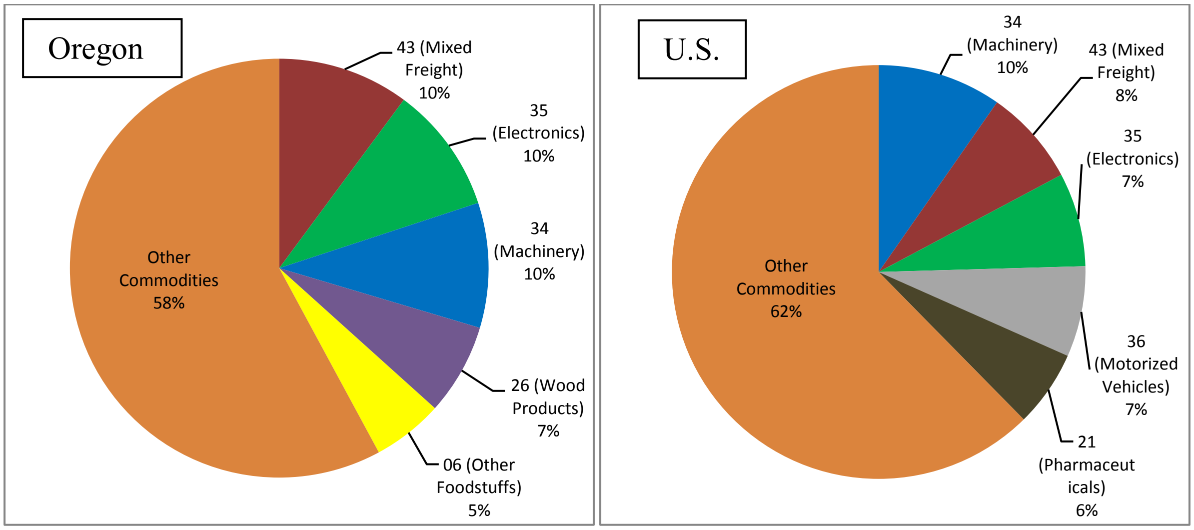
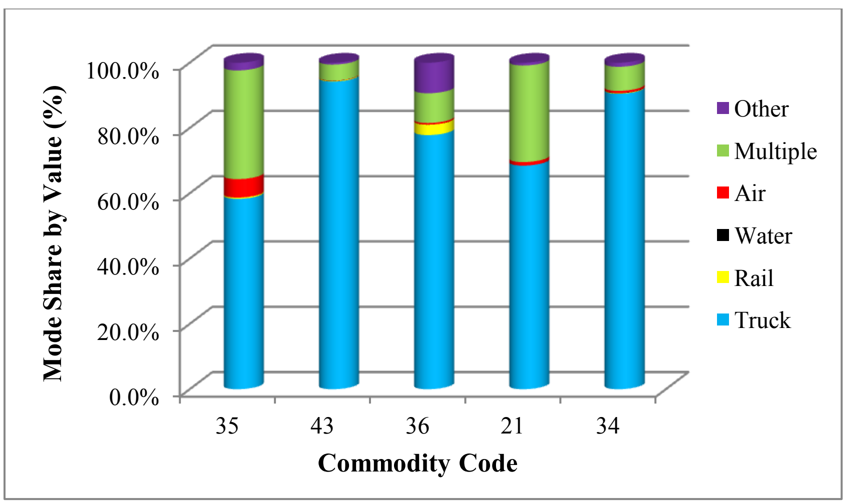


FIGURE2 U.S. and Oregon top commodities value shares, 2007
Source: Freight Analysis Framework (7)



35	Electronic & other electrical
43	Mixed freight
36	Motorized and other vehicles
21	Pharmaceutical products
34	Machinery

FIGURE 3 National top commodities mode shares (by value, 2007)
Source: Freight Analysis Framework (7)

Table 1 shows a comparison between Oregon and the US in terms of Oregon's top commodities mode shares by value in 2007. Significant mode differences can be observed for the commodity group "other prepared foodstuffs. Multiple modes (multimodal and package) and air represent over 60% of flows for commodity code 35 (Electronics) in Oregon whereas their share at the national level is only 45%. This may indicate that electronics shipped from Oregon tend to move over longer distances. Similarly, rail is more common for the movement of wood products shipments from Oregon than in the U.S (Oregon is a net "exporter" of wood products).

TABLE 1 Oregon top commodities' mode share by value-Oregon and United States: 2007

Top Commodities by VALUE (Oregon Tops)		Mode shares by value (%)									
		Truck		Rail		Water		Air		Multiple	
SCTG Code	Commodity Description	Oregon	U.S.	Oregon	U.S.	Oregon	U.S.	Oregon	U.S.	Oregon	U.S.
35	Electronic & other elec. equip	35.5	50.5	0.0	S	0.0	S	10.4	8.5	50.7	37.2
43	Mixed freight	90.1	92.9	0.0	0.2	0.0	0.0	S	0.2	5.6	5.5
26	Wood products	76.4	91.9	12.2	2.9	S	0.1	S	0.1	8.7	3.4
38	Precision instruments	23.3	35.4	0.0	0.0	0.0	S	S	10.8	46.1	52.0
07	Other prepared foodstuffs	92.0	92.7	2.0	2.5	0.0	0.2	S	0.1	3.4	3.1
36	Motorized and other vehicles	61.7	71.8	0.5	7.6	S	S	S	0.6	S	10.2

S: Data estimate does not meet publication standards because of high sampling variability or poor response quality.
Source: Commodity Flow Survey data (6)

TABLE 2 Oregon top commodities mode shares: by value, 2002 and 2007

SCTG Code	Commodity Description	Mode shares (%)									
		Truck		Rail		Water		Air		Multiple	
		2002	2007	2002	2007	2002	2007	2002	2007	2002	2007
35	Electronic & other elec. equip	S	35.5	0.0	0.0	0.0	0.0	S	10.4	15.0	50.7
43	Mixed freight	95.2	90.1	0.0	0.0	0.0	0.0	S	S	3.9	5.6
26	Wood products	61.1	76.4	32.8	12.2	S	S	S	S	2.2	8.7
38	Precision instruments	S	23.3	0.0	0.0	0.0	0.0	S	S	48.3	46.1
07	Other prepared foodstuffs	91.5	92.0	1.9	2.0	0.0	0.0	S	S	3.9	3.4
36	Motorized and other vehicles	36.2	61.7	S	0.5	0.0	S	0.5	S	12.5	S

S: Data estimate does not meet publication standards because of high sampling variability or poor response quality.
Source: Commodity Flow Survey data (6)

Table 2 shows mode shares, in 2002 and 2007, for Oregon; noticeable changes are observed for commodity code 26 (wood products) and can be related to changes in the product mix or mode competition. Due to high sampling variability or poor response quality, it is not possible to analyze mode share changes in other commodities. However, it is clear that trucking plays a central role in Oregon's shipments and economy.

3- Trends in Value Density Functions

3.1 Mode Trends

This section analyzes value/tonnage ratios at the individual commodity level. Mode-specific dollar values per ton have experienced notable changes over time. Table 3.a shows dollar per ton changes in Oregon for different modes. The dollar per ton ratio for the air mode has increased 600 percent, probably due to the growth of electronics manufacturing (Intel) in Oregon. Another interesting change is seen for the rail mode whose dollar per ton values have declined between 1997 and 2007. Some of these trends are still relevant even if the values are adjusted for inflation (see Table 3.b).

TABLE 3.aChanges in Oregon mode specific dollar/ton values (NOT inflation adjusted)

Mode	$/Ton			
	1993	1997	2002	2007
All modes	400	634	649	795
Single	334	605	570	674
Truck	329	648	557	674
Rail	442	520	307	465
Water	88	155	*S	220
Air	43,080	46,098	S	404,769
Multiple	S	4,276	5,974	3,423
Parcel, U.S.P.S	24,384	30,601	39,212	68,438

* S: Data estimate does not meet publication standards because of high sampling variability or poor response quality.

TABLE 3.b Changes in Oregon mode specific dollar/ton values (1997 dollars)

Mode	$/Ton			
	1993	1997	2002	2007
All modes	429	634	632	588
Single	358	605	555	498
Truck	353	648	542	498
Rail	474	520	299	344
Water	94	155	S	163
Air	46,232	46,098	S	299,238
Multiple	S	4,276	5,815	2,531
Parcel, U.S.P.S	26,168	30,601	38,165	50,595

* S: Data estimate does not meet publication standards because of high sampling variability or poor response quality.

Value-density functions, by each mode-commodity combination, can be derived from the CFS data utilizing shipment data at the state level. This was the approach employed to derive SWIM2 value/tonnage ratios by commodity. If there have been significant changes in these ratios, then there could be significant changes in the estimated number of freight vehicles.

3.2 Commodity Trends and Statistical Analysis

Using data from the 48 contiguous states, CFS state observations (shipments at the state level by truck) are employed to estimate linear regressions.

Employing SPSS software outliers were removed. For assessing outliers two measures were used: (a) Cook's Distance and (b) DFBETA. The former is a statistic measure that assesses the overall impact of an observation on the regression results and the latter is a statistic measure that assesses the specific impact of an observation on the regression coefficients. The outlier removing process started with removing the worst outlier (state) and continued until all outliers were removed.

Scatter-plots showing the relationship between value and weight for wood products (SCTC commodity 26) and electronics (SCTC commodity 35) are shown in Figures 4 and 5. Each state is represented as a single point and the estimated linear value-density function is shown in the graph (linear regression with no intercept). Ratios were adjusted for inflation to 1997 values using the aggregated Producer Price Index (PPI).

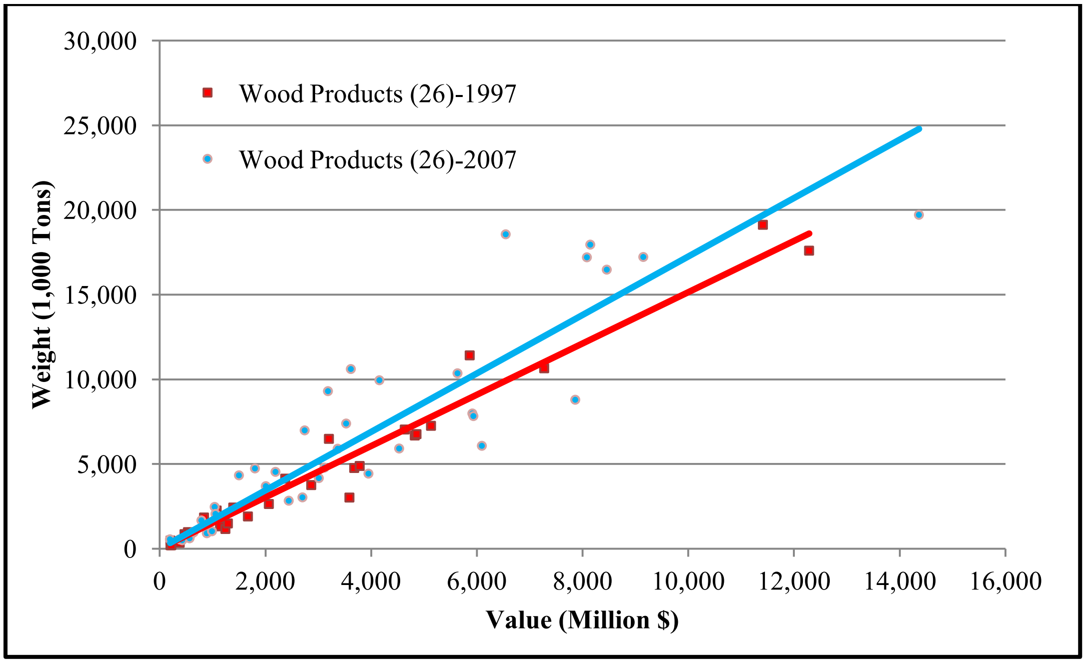


FIGURE4 Wood products (commodity 26), value-density function estimates

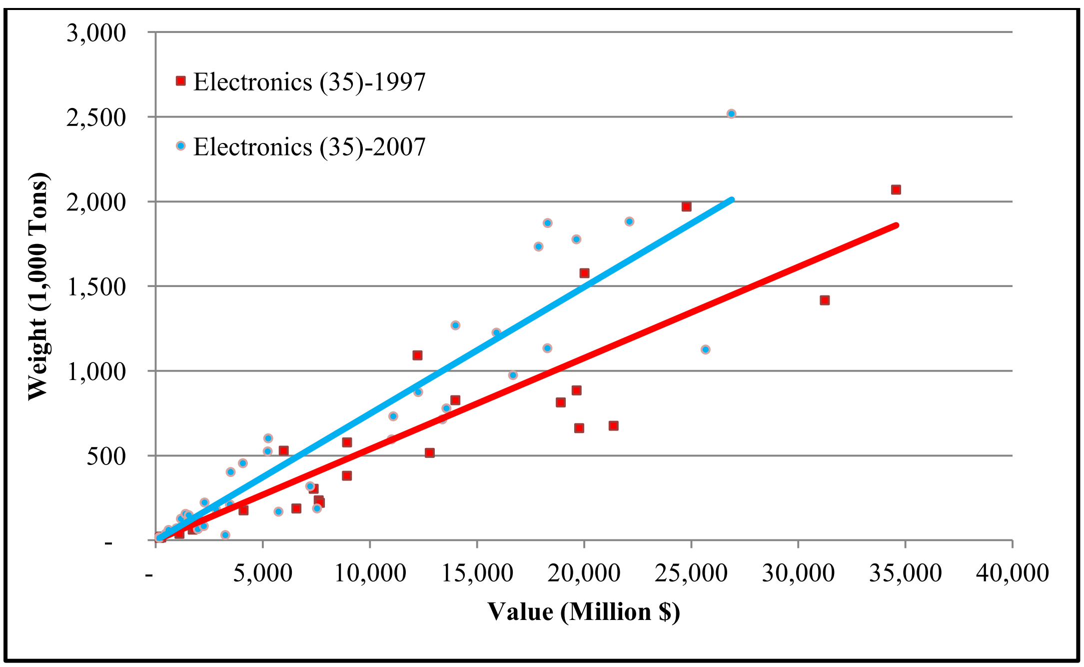


FIGURE 5 Electronics (commodity 35), value-density function estimates

Table 4 shows the changes in estimated slopes and adjusted R^2 for each regression. The changes in value/tonnage are important; for both commodities the value/tonnage ration has decreased. These changes can be the results of structural economic changes or the relative composition of each commodity group at the time of the CFS. The R^2 of each regression is high, with $R^2 > 0.77$.

TABLE 4 Value/Weight trends and Sample Statistical Analysis Results

Commodity	Slope		Change (%)	Adj. R^2		$/ton	
	1997	**2007**	**97 to 07**	**1997**	**2007**	**1997**	**2007**
Wood Product (26)	0.4020	0.3833	-5	0.88	0.88	402	383
Electronics (35)	10.147	8.424	-17	0.77	0.88	10,147	8,424

Note: Analysis based on Commodity Flow Survey data (6)

In order to statistically test whether the 1997 and 2007 linear coefficients are equal, the Chow test (8) was applied assuming homoscedasticity of errors (i.e. the same error variances in two groups). Assuming the following models for each year:

$$\begin{cases} \text{Value}_{1997} = \beta_1 \times \text{Weight}_{1997} \\ \text{Value}_{2007} = \beta_2 \times \text{Weight}_{2007} \end{cases}$$

The null hypothesis is $\beta_1 = \beta_2$. The null hypothesis is rejected with a 99% confidence level for both wood products and electronics using the Chow test. The Chow test is an econometric and statistical test to determine whether the coefficients in two linear regressions on different data sets are equal. In other words, for the same weight, the value of the commodities has *decreased* significantly for both wood and electronic products between 1997 and 2007.

The Chow test requires certain assumptions regarding the underlying distribution of the data. A non-parametric test was performed to compare the distribution of value/tonnage ratios between 1997 and 2007 data sets. Applying the Wilcoxon test, the null hypothesis can be expressed as follows:

$$\begin{cases} Value/tonnage\ ratio\ \text{Distribution}_{1997} = \text{A} \\ Value/tonnage\ ratio\ \text{Distribution}_{2007} = \text{B} \end{cases}$$

The null hypothesis is A = B (No difference in distributions)

The results of the test are shown in Table 5. The Wilcoxon test is the non-parametric equivalent of the paired samples t-test. The top two commodities by value in Oregon and US were compared in addition to wood products and electronics (which are in top five commodities by value in Oregon). These four commodities account for more than 35% and 25% of the freight shipments by value in Oregon and the US respectively.

TABLE 5 Top Commodities - Wilcoxon Test Results (1997 vs. 2007)

Commodity Description	Z-Score	P*	Test Result (for 0.05 significance level)
26 (Wood Product)	-0.584	0.560	The null hypothesis is **Accepted**
34 (Machinery)	-4.578	0.000	The null hypothesis is **Rejected**
35 (Electronics)	-3.945	0.000	The null hypothesis is **Rejected**
43 (Mixed Freight)	1.614	0.107	The null hypothesis is **Accepted**

*Two-tailed probability

As shown in Table 5, the result for wood products has changed (non-parametric tests are more general but less powerful). However, electronics and machinery still show significant differences between the 1997 and 2007 distributions.

4- Discussion

The results presented in the previous section indicate that for two important commodities, the changes that took place between 1997 and 2007 have resulted in significant changes in the value/tonnage ratio. Because data from all states was employed, the changes have taken place at the national level. A decrease in the value/tonnage ratio for electronics may result in an increase in the number of vehicles or trips generated. The same downward value/tonnage ratio is observed for machinery. Hence, utilizing 1997 values may underestimate the number of machinery or electronics related vehicles/trips at a national level.

The implications at the state level are potentially more serious. For example, at the national level there is a *decrease* in value/tonnage for electronics but at the state level there is an *increase* in the value per tonnage ration between 1997 and 2007. This increase in value can be related to the growing importance of the electronics sector in the Oregon economy. Intel Corporation is the largest private employer in the state and has been expending steadily since the early nineties. According to a new report it accounts for nearly five percent of the state economic activity[1]. The potential for freight generation error associated to the commodity are greater if the dollar per tonnage values diverge at the national and state level. Using data from CFS and FAF3, trends in $/ton ratios for key Oregon and US commodities moved by trucks are compared as shown in Table 6. Ratios were adjusted for inflation at 1997 dollars using the aggregated Producer Price Index (PPI).

TABLE 6 Dollar per ton Trends in Oregon and US (1997 dollars)

	US			
Commodity	**$/ton**			**CFS Changes (%)**
	CFS		**FAF3**	
	1997	**2007**	**2007**	**97 to 07**
26 (Wood Product)	404	427	420	6%
34 (Machinery)	7,269	5,896	5,845	-19%
35 (Electronics)	14,360	10,303	8,620	-28%
43 (Mixed Freight)	2,047	2,188	2,109	7%
	Oregon			
Commodity	**$/ton**			**CFS Changes (%)**
	CFS		**FAF3**	
	1997	**2007**	**2007**	**97 to 07**
26 (Wood Product)	441	380	361	-14 %
34 (Machinery)	9,303	7,369	6,223	-21%
35 (Electronics)	17,954	29,646	14,763	65%
43 (Mixed Freight)	S	2,297	2,064	S

S: Data estimate does not meet publication standards because of high sampling variability or poor response quality.

Source: Commodity Flow Survey data-CFS (6) and Freight Analysis Framework data-FAF3 (7)

According to Table 6, the value/tonnage ratios are close to Oregon ratios for top commodities except for "electronics" for which Oregon has significantly greater $/ton in both CFS and FAF cases. Other noticeable changes take place in the value/tonnage change of "wood products"

[1] http://www.oregonlive.com/silicon-forest/index.ssf/2011/10/intel_report_pegs_its_oregon_p.html

commodities (-14% and 6% for Oregon and the US respectively); machinery seems to have similar decreasing trends in terms at the Oregon and US level.

5- CONCLUSIONS

This paper has analyzed value/tonnage trends in the US and Oregon. Given the central role of trucking, the analysis has focused on value/tonnage trends by truck. The US economy and the state of Oregon have changed dramatically in the last two decades. Hence, it is not surprising that statistical tests show that there have been significant changes in some value/tonnage ratios even after adjusting for inflation.

There is a decline in value/tonnage ratios for electronics and machinery shipments from 1997 to 2007 in the USA. However, an increase in electronics value/tonnage ratio can be observed in Oregon. This can potentially produce serious errors at the freight generation step if 1997 values are not adjusted accordingly. Future research efforts will expand the analysis presented in this paper to include additional commodities and additional indicators that can potentially explain the trends observed in this paper.

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