Impact of Risk Sharing on Competitive Bidding in Truckload Transportation

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ABSTRACT

The purpose of this research was to evaluate whether a shipper's fuel surcharge (FSC) program affected its per-load transportation costs in the United States full-truckload (TL) transportation industry. In this study, we restricted transportation costs to line-haul charges and fuel surcharge premiums. Using ordinary least squares (OLS) regression, we examined the effect of a shipper's FSC program on its line-haul charges. We controlled for well-established transportation cost drivers, including distance and geography. We found that carriers discounted their line-haul rates according to a shipper's FSC program. The more a shipper paid in FSC premiums, the less it paid in line-haul charges. For fuel prices above $2.08 per gallon, however, the fuel surcharge premiums dwarfed the line-haul discount. This effect was most pronounced for shippers with low efficiency values. Shippers with lower efficiency values paid higher per-load transportation costs than shippers with higher efficiency values.

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1 Introduction

Trucking is the dominant transportation mode in the United States. In 2009, trucking accounted for 68 percent of total U.S. freight tonnage and 82 percent of total U.S. freight spend. Interestingly, trucking serves as the sole delivery source for over 80 percent of American communities (American Trucking Associations, 2011).

1.1 Industry basics

There are three main players in the trucking industry: shippers, carriers, and third party logistics (3PL) firms. Shippers have product which needs to be transported from an origin to a destination; carriers have equipment, such as trucks and trailers, capable of performing this transportation. Some shippers prefer to outsource their transportation management to a 3PL. In these cases, the 3PLs assume the role of the shipper in shipper-carrier interactions.

Depending on factors such as the volume and weight of the product being moved, the shipper will rent all or part of the carrier's trailer. The first case is called full-truckload (TL) transportation, and the second case is called less-than truckload (LTL) transportation. The TL and LTL industries differ substantially in size, number of competing carriers, and contract terms. The TL industry is exponentially larger than the LTL industry. In fact, the TL industry has 45,000 carriers and makes up 80 percent of U.S. transportation spend. By comparison, the LTL industry has only 150 carriers (Standard & Poors, 2012). In our research, we considered only the TL transportation industry.

1.2 Transportation costs

The shipper pays the carrier a fee for moving its product. This fee has three components: a line-haul charge, an accessorial charge, and a fuel surcharge (FSC).

$$\textit{Total transportation cost} = \textit{line-haul} + \textit{accessorials} + \textit{FSC} \tag{1}$$

The line-haul charge equals the carrier-set rate per distance multiplied by the distance. Most often, the line-haul charge is reported in terms of a rate per mile (RPM).

$$\textit{Line-haul} = \textit{carrier rate per distance} \times \textit{distance} \tag{2}$$

In most cases, the line-haul charge is the most substantial portion of total transportation cost. The accessorial charge is an optional fee for extra services performed by the carrier, for instance extra driver wait time. Finally, the fuel surcharge is a premium to compensate carriers for fuel expenditures. We explain how FSCs are calculated in detail in the next section. We ignored accessorial charges in this research, and consequently our revised total transportation cost equaled:

$$\textit{Total transportation cost} = \textit{line-haul} + \textit{FSC} \tag{3}$$

1.3 Calculating fuel surcharge

In a perfect world, carrier rate per mile would cover the carrier's operating costs, including fuel, and a markup for profit. Unfortunately, this situation is impossible since fuel prices are volatile. From 2008 to 2011, diesel fuel prices ranged from \$2.02 per gallon to \$4.76 per gallon. The median fuel price was approximately \$3.12 per gallon. A carrier cannot know what the price of fuel will be when it finally moves the shipper's product. In most cases, the carrier sets a contracted long-haul rate for the entire year.

While the line-haul charge is set by the carrier ahead of time during contracting, the fuel surcharge is determined by the shipper based on the prevailing fuel price at the time of the actual shipment. Once the shipment is complete, the shipper pays the carrier for all charges. How the cost of fuel is shared between the shipper and the carrier depends on the shipper's own fuel surcharge program and the prevailing price of fuel.

Figure 1 illustrates how fuel prices varied from 2008 to 2011. The figure also shows how line-haul and total cost rates moved with fuel prices over this period. Fuel costs represent about 30 percent of a carrier's total operating cost (American Transportation Research Institute, 2011). In general, in order to secure carrier capacity when fuel prices rise, a shipper must pay its carrier higher rates to compensate for higher fuel costs.

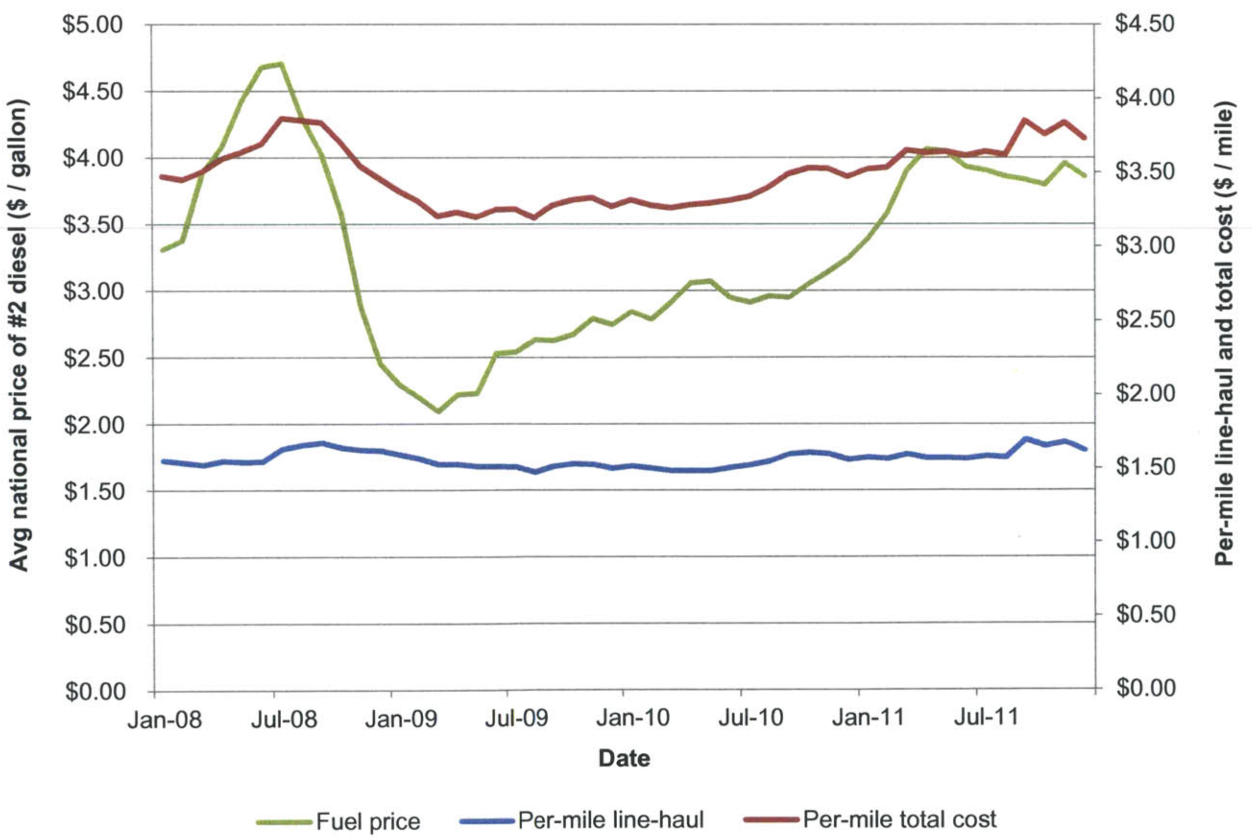

Figure 1. Volatility of fuel prices and transportation rates

1.3.1 A typical fuel surcharge program

Shippers report their FSC programs to carriers in a table outlining how much the shipper will pay at different fuel prices. A shipper's FSC program table is defined by three important values: the peg price, the premium, and the escalator. Table 1 gives an example FSC table.

Table 1. Example FSC program table

Fuel price between		Premium
$1.020 / gallon	$1.079 / gallon	$(0.030) / mile
1.080	1.139	(0.020)
1.140	1.199	(0.010)
1.200	1.259	0.000
1.260	1.319	0.010
1.320	1.379	0.020
...	...	...
3.600	3.659	0.400
3.660	3.719	0.410
...	...	...

The peg price is the threshold fuel price above which the shipper pays the carrier a fuel surcharge premium. In this example, the peg price of $1.20 per gallon. When the price of fuel is below the peg price, the shipper pays the carrier a negative premium by discounting the total rate. Most FSC programs were set by shippers decades ago when fuel prices were low and have since been left unchanged. It is quite unusual for the price of fuel to be less than the peg price, and so although negative surcharges exist in almost all FSC programs, they are rarely triggered (Heartson, 2012).

The premium is the per mile amount paid by the shipper to the carrier for fuel. The escalator is the difference between two consecutive fuel prices in the FSC program table. The escalator determines the rates at which the premium increases with the price of fuel. The efficiency variable is a manipulation of this escalator term and represents the shipper's estimate of an equitable carrier equipment fuel economy in miles per gallon.

$$Efficiency = \frac{escalator}{\Delta\, premium} = \frac{\frac{\$}{gallon}}{\frac{\$}{mile}} = \frac{miles}{gallon} \tag{4}$$

From the first row, we see that the escalator value is \$1.080 - \$1.020 = \$0.06 per gallon. We calculate the efficiency value using the efficiency equation:

$$Efficiency = \frac{1.260 - 1.200}{0.010 - 0.000} = \frac{0.060\, \frac{\$}{gallon}}{0.010\, \frac{\$}{miles}} = 6\, \frac{miles}{gallon}$$

Suppose the prevailing price of fuel is \$3.60 per gallon. In this case, the shipper will pay the carrier \$0.40 per mile for fuel. For a 300 mile route, the shipper will pay the carrier a \$120 fuel surcharge. Most shippers determine the prevailing fuel price by referencing the U.S. Department of Energy weekly average national price of #2 diesel (EIA, 2012).

Each shipper sets its own peg, premium, and escalator value to create its FSC program.

1.3.2 Modeling an FSC program

An FSC program table, like the one shown above, provides the premium paid by the shipper at every fuel price. FSC program tables are discontinuous, because they allow for only a finite number of premium values. We can represent this table by using an integer function to create the following step equations:

$$Per\text{-}mile\ FSC\ premium = INT\left[\frac{fuel\ price - peg}{escalator}\right] \times 0.01 \tag{5}$$

$$Total\ FSC\ premium = INT\left[\frac{fuel\ price - peg}{escalator}\right] \times 0.01 \times distance \tag{6}$$

For simplicity, we can approximate these step equations with the continuous linear equations given below.

$$Per\text{-}mile\ FSC\ premium = \left(\frac{fuel\ price - peg}{efficiency}\right) \tag{7}$$

$$Total\ FSC\ premium = \left(\frac{fuel\ price - peg}{efficiency}\right) \times distance \tag{8}$$

Consider the case where fuel price equals \$3.60 per gallon and the lane is 300 miles. Using the above equation to calculate FSC premium, we get:

$$Total\ FSC\ premium = \left(\frac{(1.26 - 1.20)\dfrac{\$}{gallon}}{6\dfrac{miles}{gallon}}\right) \times 300\ miles = \$120 \tag{9}$$

In this case, the discontinuous and continuous equations yield the same FSC premium.

Figure 2 shows the difference between the step and continuous equations.

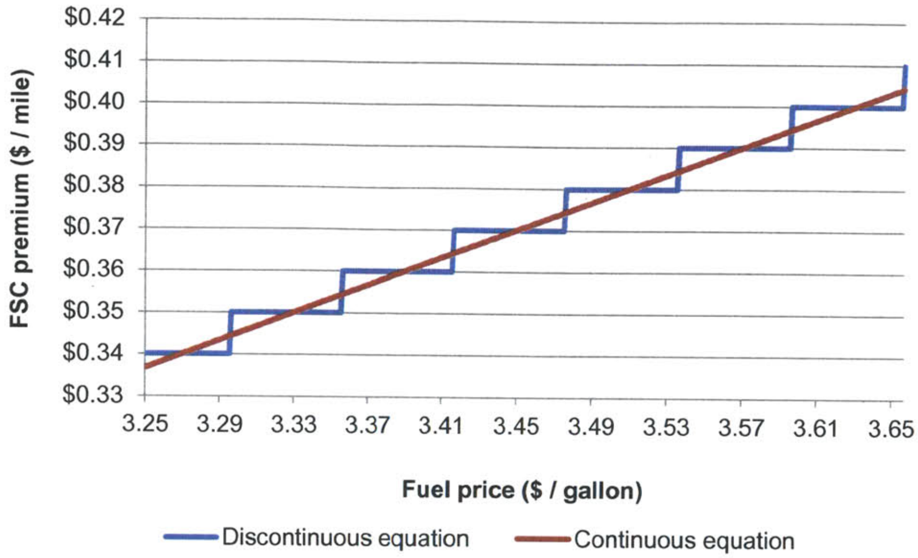

Figure 2. Modeling an FSC program

The step function and can only take on whole cent premiums, while the continuous linear function can take on all real premiums.

1.3.3 Comparing shipper FSC programs

Together, the peg and efficiency determine a shipper's fuel surcharge premiums. To show the effect of different peg and efficiency values on per-mile FSC premiums, we give three hypothetical FSC programs in Table 2.

Table 2. Comparing shipper FSC programs

Shipper	Peg ($ / gallon)	Efficiency (miles per gallon)
A	0.90	7
B	1.15	6
C	2.15	5

Figure 3 shows the shippers' FSC premiums at different fuel prices. Each line represents a different shipper's FSC payouts. The x-intercept represents the peg. The slope equals the rate at which FSC premium changes for a one unit increase in fuel price and represents the reciprocal of the efficiency value.

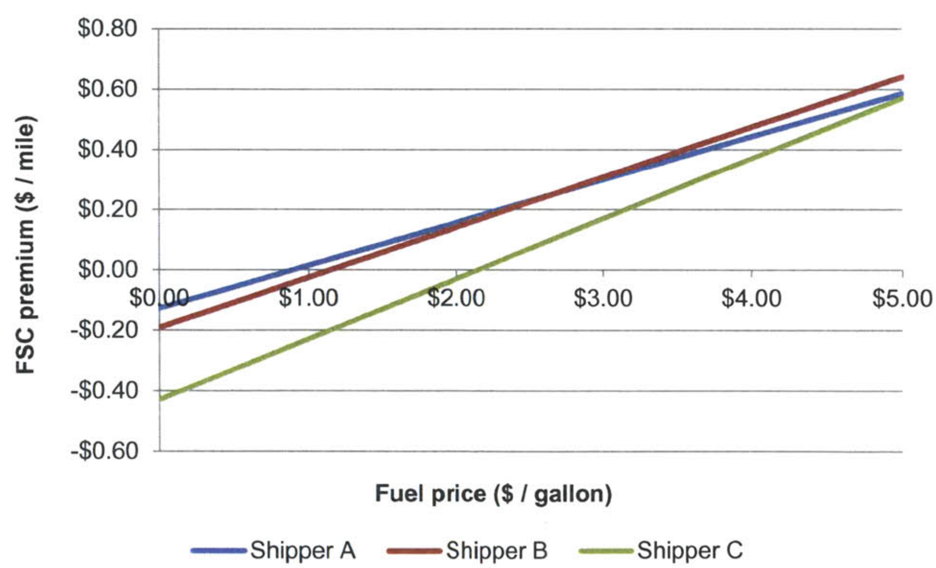

Figure 3. Comparing shipper FSC programs

Shipper A and Shipper B pay carriers the same fuel surcharge premium when the price of fuel is $2.60 per gallon. For fuel prices above $2.60 per gallon, Shipper B pays carriers a higher fuel surcharge premium than does Shipper A. The reverse is true for fuel prices below $2.60 per gallon. Shipper C pays carriers the lowest fuel surcharge premium for all fuel prices.

1.3.4 Impact of efficiency

In the fuel surcharge equation, efficiency represents the shipper's estimate of a fair carrier fuel economy. In almost every case, the shipper's estimate differs from the carrier's true efficiency. In fact, a carrier's true efficiency varies with traffic congestion, the lane, and the time of year, among other factors.

Consider an example, illustrated in Figure 4, with one shipper and two carriers. One carrier has a relatively efficient mileage of seven miles per gallon, and the other carrier has a relatively inefficient mileage of five miles per gallon. The shipper assumes a carrier efficiency of six miles per gallon and has a peg value of $0.90 per gallon.

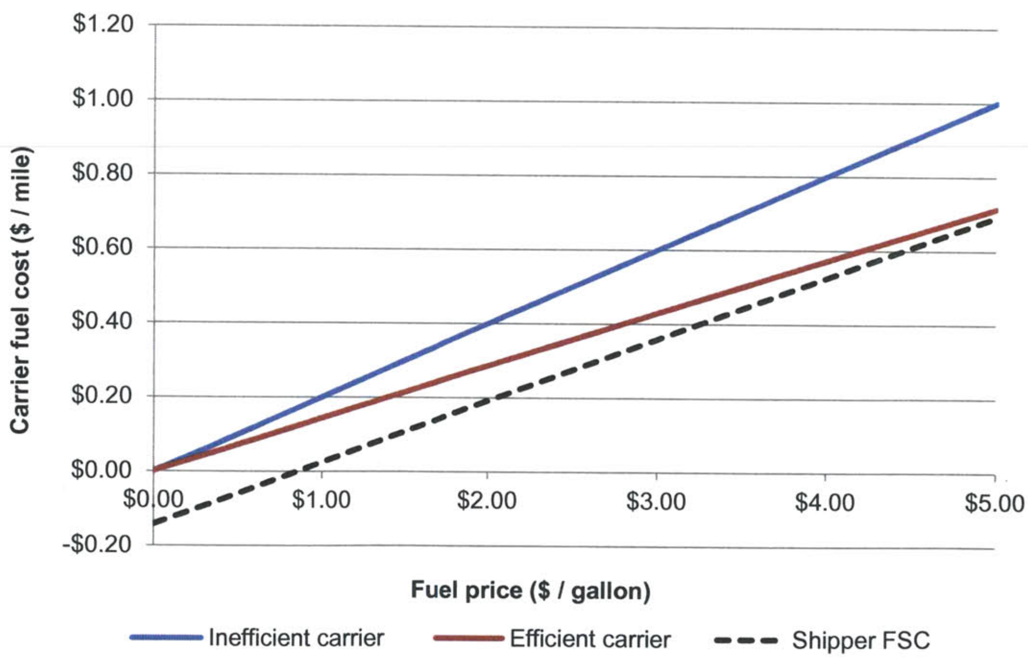

Figure 4. Understanding the effect of efficiencies

The graph shows how much the shipper pays in FSC premiums at each fuel price. It also shows each carrier's fuel cost, in dollars per mile. Fuel cost is calculated by dividing the prevailing fuel price by the carrier's true efficiency. Though the shipper's FSC premium is less than the carrier's fuel cost at all fuel prices due to the shipper's peg price, the efficient carrier is comparatively better off than the inefficient carrier because it is able to recover a larger portion of its fuel cost. For example, when the price of fuel is $2.00 per gallon, the efficient carrier recovers about 70 percent of its fuel cost from the FSC premium, while the inefficient carrier recovers only 50 percent of its fuel cost. When the price of fuel is $5.00 per gallon, the efficient carrier recovers 100 percent of its fuel cost from the FSC premium, while the inefficient carrier recovers only 70 percent of its fuel cost. This graph does not consider the fuel costs associated with a carrier's return trip from the shipper's destination, called a backhaul, which is not paid for by the shipper.

Assuming a constant peg price and price of fuel, the lower a shipper sets its efficiency, the more it pays to carriers in fuel surcharge premiums. Because carriers do not want shippers to raise their FSC program efficiencies, carriers with high efficiencies do not freely distribute their efficiency information to shippers (Kanteti, Levine, 2011).

1.4 Two key transportation processes: procurement and tendering

Recall that shippers hire carriers to move product. To facilitate the hiring process, shippers identify a group of preferred carriers in advance of need, and rank them in order of preference. This activity is called procurement, and it typically occurs every year or every other year. Later, when the shipper needs to move a load, the shipper offers the load to its preferred carriers. This process is called tendering, and it can happen several times a week. We explain procurement and tendering in more detail below.

1.4.1 Procuring carriers

The process of identifying and ranking carriers is called procurement or bidding exercise. The exercise has three steps: shipper RFP distribution, carrier bid submission, and shipper selection.

(1) **Shipper RFP distribution.** In the first step, the shipper distributes a request for proposal (RFP) to preselected carriers. Hundreds of carriers can be included in this process. The RFP contains several pieces of information, including the FSC program information, lane information, and sometimes the anticipated volume for each lane.

(2) **Carrier bid submission.** The carrier responds to the shipper's RFP by submitting a bid for each lane.

(3) **Shipper selection.** In the final step, the shipper selects its primary and backup carriers for each lane. This ranking of carriers for each lane is the shipper's routing guide. Shippers rank carriers primarily on cost, on-time delivery performance, and tender acceptance rate.

1.4.2 Tendering a load

Under normal circumstances, when the shipper needs to move a load, it offers the load to carriers on its routing guide, starting with the primary carrier. This process is called tendering a load. The primary carrier can either accept or reject the load. If the carrier rejects the load, the shipper offers the load to the first backup carrier on the routing guide. This process repeats until a carrier accepts the load. Sometimes no routing guide carrier accepts the load. In such cases, the shipper offers the load on the spot market and the total transportation cost is negotiated in real time.

The term "bid depth" is defined as the number of times a shipper tenders a load before the load is accepted by a carrier. The term "tender lead time" refers to the amount of time between when a shipper tenders the load and when the carrier transports the load. For most firms, the tender process is automated through a transportation management system (TMS).

In the TL industry, shipper-carrier contracts are binding with respect to rates but non-binding with respect to volume. This means that while a carrier can refuse a shipper's load during tendering, if the carrier accepts the shipper's load, it must charge the contracted line-haul rate established during procurement. Carriers avoid rejecting too many tenders, however, because a shipper will stop using a carrier if the carrier's rejection rate becomes too high.

1.5 Our research question

Shippers have different fuel surcharge programs. Consequently, at a given fuel price, some shippers pay higher FSC premiums than others. We wanted to know if higher fuel surcharge premiums translated into higher total transportation costs for shippers. We hypothesized that carriers would offset higher shipper fuel surcharge premiums by offering lower line-haul rates. We tested our hypothesis through a cost model which evaluated how a shipper's FSC program affected its total cost.

1.6 Partner company

To conduct our research, we partnered with C.H. Robinson Worldwide, a 3PL serving clients in freight transportation, logistics, and outsourcing. Our dataset came from C.H. Robinson's Transportation Management Center (TMC), a division which provides outsourced transportation management. Our dataset contained single-mode freight transportation records from 17 shippers and 1,458 carriers in the United States over the years 2008 to 2012.

1.7 Chapter summary

This chapter introduced the truckload transportation industry, its players, and its primary costs. It also introduced the concept of a fuel surcharge program and described how it is used by shippers and carriers to split fuel price risk.

1.8 Looking ahead

The next chapter summarizes previous research on both the use of fuel surcharge programs and the use of quantitative models for predicting transportation costs. The third chapter profiles our dataset and looks for meaningful trends and patterns in the data. The fourth chapter describes how we analyzed our data and what conclusions we were able to draw from our analysis. The final chapter discusses the implications of our results for the TL transportation industry. It also suggests topics for further research.

2 Literature review

The purpose of this literature review is twofold: (1) to better understand how fuel surcharge programs are used in the TL transportation industry, and (2) to explore how past researchers have modeled transportation costs.

2.1 FSC programs in the TL transportation industry

The shipper compensates the carrier for fuel expenditures according to the shipper's fuel surcharge program. Both the shipper and the carrier prefer to calculate fuel costs separately from all other charges. By calculating fuel independently, the shipper can more easily track and manage those transportation costs that are under its control, such as line-haul charges. Likewise, the carrier can more easily set long-term rates without having to account for volatile fuel prices.

In the TL transportation industry, shipper-set FSC programs vary significantly. In general, efficiency values range from five to seven miles per gallon. Peg values range from \$1.00 to \$1.50 per gallon. Most peg values were set decades ago when fuel prices were stable between \$1.00 and \$2.00. Transportation managers at C.H. Robinson believe shippers have left pegs unchanged because (1) no shipper wants to move first in setting a new peg value, and (2) shippers are unsure how carriers will respond to updated peg values. CHR reasons that a shipper would feel comfortable updating its peg value if a large group of shippers acted simultaneously (Raetz, 2008).

In their previous research, Kanteti and Levine (2011) surveyed carriers to determine how they would respond to updated shipper FSC programs. Of the surveyed carriers, 52 percent believed that they could seamlessly adjust their rates to a new FSC peg price, without affecting revenues. Another 30 percent of carriers felt that a new FSC program would cause only administrative challenges (Kanteti, Levine, 2011). Importantly, the surveyed carriers believed that shipper-set FSC programs did not affect carrier revenues -

and by extension - shipper cost. Our research quantitatively tests the claim that a shipper's FSC program does not affect its total transportation cost.

2.2 Modeling transportation costs

There has been much research done on the drivers of total transportation cost in the TL transportation industry. We can split these cost drivers into two categories: core and non-core. Core cost drivers explain a large portion of the total cost, while non-core drivers explain only a marginal portion of total cost.

Well-established, core cost drivers include geographic factors, such as load origin and destination, and distance. Non-core cost drivers include carrier size, tender lead time, tender day of week, and procurement exercise frequency. In determining how a shipper's fuel surcharge program affects its transportation cost, we had to account for core and - whenever possible - non-core drivers. We discuss these cost drivers in more detail below.

2.2.1 Core cost drivers

Core cost drivers include load origin and destination and distance. Together, load origin and destination form a lane. Carriers consider some lanes more attractive than others; they offer shippers lower rates for more attractive lanes (Caplice, Sheffi, 2006). In general, carriers consider high-volume lanes to be more attractive than low-volume lanes. It is very expensive for carriers to perform a backhaul with an empty truck. Carriers prefer to secure a new load for their backhaul trip, and they have a better chance of doing so on a high-volume lane. In addition to lane volume, carriers may simply prefer to operate in certain states.

Distance, in miles, is also an important cost driver. Among other things, distance dictates how long it will take a carrier to perform the shipment, how many drivers are required, how much wear-and-tear the truck will incur, and how much fuel will be needed.

2.2.2 Non-core cost drivers

Non-core cost drivers include carrier rank, carrier size, tender lead time, tender day of week, and procurement event frequency. Carrier rank refers to the carrier's position in the shipper's routing guide. Most shippers assign low-cost carriers to the top of their guides. Consequently, as carrier rank increases, rates tend to rise.

Carrier size refers to the number of trucks a carrier has. Caldwell and Fisher (2008) found that rates increase with carrier size. Larger carriers had higher rates. The researchers reasoned that large carriers have higher overhead expenses but no cost savings at the individual truck level. Caldwell and Fisher also hypothesized that larger carriers might have higher rates because they tend to serve more remote parts of the country (Caldwell and Fisher, 2008).

Caldwell and Fisher also showed that tender lead time - or the difference between tender date and ship date - negatively affects total cost. Loads with longer lead times tend to have lower rates. This trend makes sense as carriers naturally prefer to have more advance notice before transporting a load. If a shipper waits until the last minute to hire a carrier, it is likely that many low-cost carriers will already be booked. Indeed, Caldwell and Fisher found that carrier acceptance rate increased for loads with longer tender lead times. An industry paper, based on Caldwell and Fisher's work, stressed the importance of tender lead time (C.H. Robinson, 2008):

> Increasing lead time from less than two days to over three days would improve the carrier acceptance rate and save an average of $15.34 per load. While this might seem a modest savings, if applied to a shipper's 40,000 loads per year, the shipper would save $613,000 on their annual transportation costs.

The day of the week that a load is shipped also affects total cost. Most organizations are structured around a Monday through Friday work week. Consequently, rates tend to be higher for loads that are tendered or shipped during the weekends (Caldwell and Fisher, 2008). It is important to note that Caldwell and Fisher also used TMC data, but from earlier years.

Recall that most shippers engage in procurement exercises every year or every other year. During a procurement exercise, a shipper requests bids from preselected carriers and creates its routing guide. We say a shipper has 'stale rates' if they have not engaged in a recent procurement exercise. In their 2012 research, Martens and Suzuki showed that shippers that engage in frequent, semi-annual procurement exercises enjoy lower rates than shippers that engage in infrequent annual procurement exercises (Martens and Suzuki, 2012).

2.3 Chapter summary

This chapter emphasized the importance of FSC programs in TL transportation. It also laid the groundwork, in terms of relevant cost drivers, for our quantitative cost model. We now turn to organizing and analyzing our dataset.

3 Profiling the dataset

Before we conducted our quantitative analysis, we cleaned and organized the dataset and looked for meaningful patterns and trends in the data. We explain both of these processes in the subsequent sections.

3.1 Data preparation

In this research, we were interested in quantifying the impact of a shipper's FSC program on its TL transportation costs. We eliminated records with overly-complicated rates, such as records from refrigerated, multi-modal, or cross-border freight. We also eliminated short-haul records in which the distance traveled was less than 300 miles. Short-hauls have highly variable and unpredictable transportation costs; they are not in the scope of this research. Finally, we restricted our data to loads from shippers for which we had fuel surcharge program information.

In addition to the above restrictions, we also eliminated flawed or highly unusual records because we suspected them to be either data entry errors or outliers. Leaving these records in the dataset would inaccurately skew our analysis. Specifically, we deleted records with (1) missing values for Line-haul or Distance, (2) negative values for Total Rate, Line-haul, or Tender Lead Time, (3) a RPM less than $0.8 per mile or greater than $2.5 per mile, and (4) distances greater than 3,000 miles. In our dataset, most RPMs fell between $1.2 per mile and $2.0 per mile. Records with RPMs below $0.8 per mile and above $2.5 per mile were well outside this normal range. Records with reported distances greater than 3,000 miles were most likely the results of data entry errors.

Our last dataset modification was updating the Fuel Surcharge value for all records. Due to difficulties procuring data, the TMC dataset had inconsistent or missing FSC values for many records. To correct this problem, we recalculated the FSC value for each record by using the appropriate shipper's FSC program information and the prevailing fuel price at the time of shipment as reported by the U.S. Department of Transportation for # 2 diesel.

After cleaning and organizing the data, we had records of over one million tenders and 600,000 loads distributed across the continental United States. Together, the total dollar value of these 600,000 loads was $826,321,347. Our dataset also contained information about 17 shippers in diverse industries and 698 carriers. This sizeable and evenly-distributed dataset was representative of the TL transportation industry.

3.2 Data characteristics

In the literature review, we discussed well-established behaviors in the trucking industry. By analyzing our dataset, we were able to confirm many of these behaviors. For example, our data revealed that RPM decreased with length of haul and tender lead time and increased with bid depth.

The first step in uncovering these insights was to summarize the data. The second step was to look for trends in the data.

3.2.1 Data summary

3.2.1.1 Shipper profile

Our data contained records from 17 shippers, all with different FSC programs. Peg values ranged from $0.90 to $1.90, well below prevailing fuel prices. Efficiency values ranged from 4.62 miles per gallon to 7.00 miles per gallon. Shipper 1 had an unusual efficiency value of 12.00 miles per gallon. Shipper 14, with a significantly lower efficiency value of 4.62 miles per gallon, paid carriers the largest per-mile fuel surcharge premium. For example, Shipper 14 offered carriers $0.39 per mile at a fuel price of $3.00 per gallon and $0.60 per mile at a fuel price of $4.00 per gallon. Conversely, Shipper 1 paid carriers the lowest per-mile premium, offering only $0.15 per mile at $3.00 per gallon and $0.24 per mile at $4.00 per gallon. Figure 5 shows how much each shipper paid in FSC premiums at different fuel prices. When the price of fuel was $3.50 per gallon, the majority of shippers paid carriers between $0.30 and $0.45 per mile for fuel.

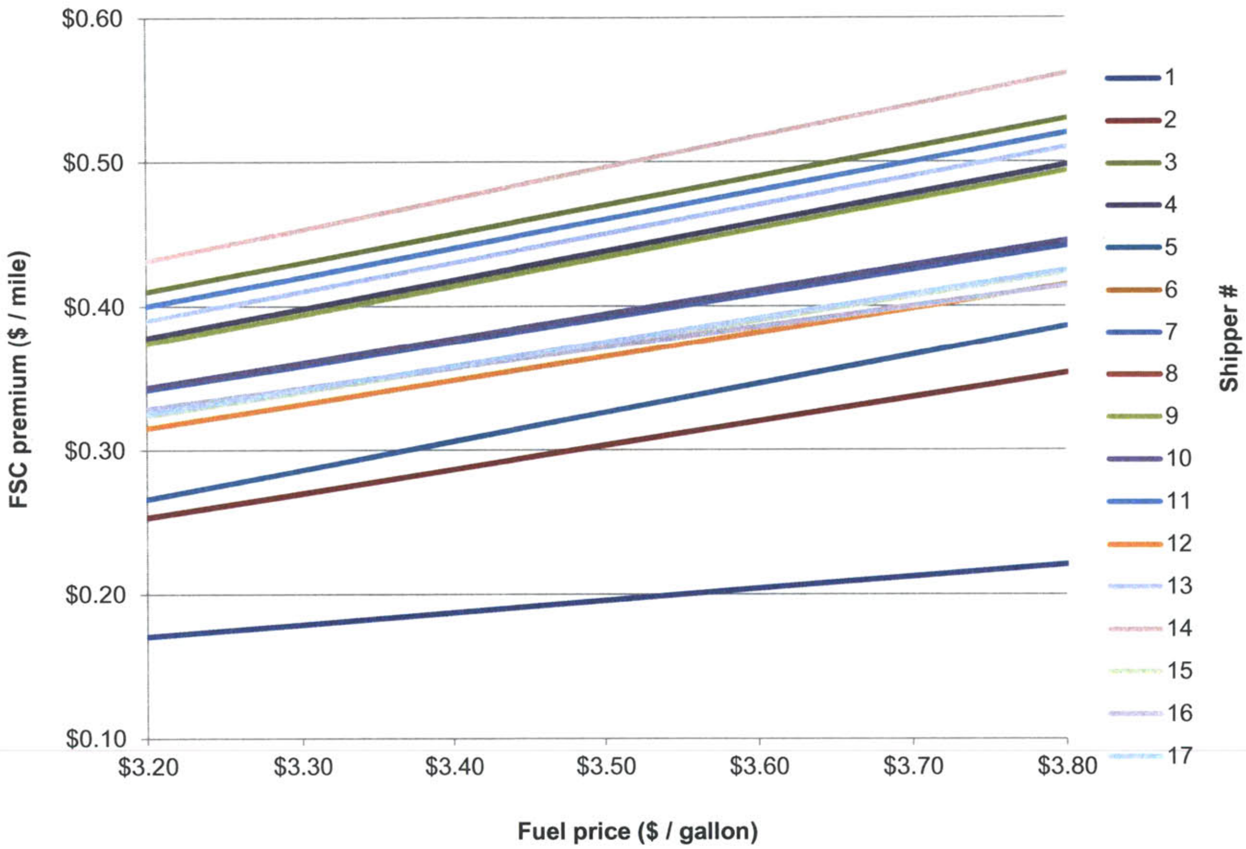

Figure 5. Distribution of shipper FSC programs

The shippers also differed in terms of load count, average length of haul, and average line-haul RPM paid. Shipper 7 was the largest shipper with over 57 percent of the loads, or 359,249 loads. Shippers 13, 2, and 5 were all very small, with only seven, nine, and 36 loads respectively. The average line-haul RPM paid by each shipper ranged from $1.17 to $1.90 per mile.

Table 3 summarizes shipper data.

Table 3. Summary of shipper data

	General information			FSC program inputs		FSC per-mile premium	
Shipper	**# Loads**	**Avg miles**	**Avg RPM**	**Peg**	**Efficiency**	**@ $3/gal**	**@ $4/gal**
7	359,249	678	$1.63/mi	$1.15/gal	6.00 mpg	$0.31/gal	$0.48/gal
10	81,183	631	1.55	1.18	5.88	0.31	0.48
9	67,648	714	1.48	1.33	5.00	0.33	0.53
15	41,237	693	1.45	1.26	6.00	0.29	0.46
17	33,939	663	1.50	1.25	6.00	0.29	0.46
11	17,824	777	1.54	1.20	5.00	0.36	0.56
4	14,718	553	1.47	1.31	5.00	0.34	0.54
16	6,211	1,045	1.30	0.90	7.00	0.30	0.44
1	4,818	926	1.34	1.15	12.00	0.15	0.24
12	4,480	1,047	1.50	1.31	6.00	0.28	0.45
3	972	771	1.17	1.15	5.00	0.37	0.57
14	391	1,496	1.34	1.21	4.62	0.39	0.60
8	168	517	1.67	1.33	5.00	0.33	0.53
6	163	1,364	1.29	1.20	5.00	0.36	0.56
5	36	1,100	1.42	1.87	5.00	0.23	0.43
2	9	805	1.31	1.68	6.00	0.22	0.39
13	7	525	1.90	1.25	5.00	0.35	0.55
Range	**7 - 359,249**	**517 - 1,496**	**1.17 - 1.90**	**0.90 - 1.87**	**4.62 - 12.00**	**0.15 - 0.39**	**0.24 - 0.60**

3.2.1.2 Geographic distribution

Figure 6 shows how loads were distributed throughout the United States. We divided the continental U.S. into six regions: Northwest, Southwest, North Central, South Central, Northeast, and Southeast. The Northeast and Southeast had the greatest percentage of loads by far, accounting for 57 percent of load origins and 52 percent of load destinations. The Northwest had the lowest percentage of loads, with only 3 percent of load origins and 4 percent of load destinations.

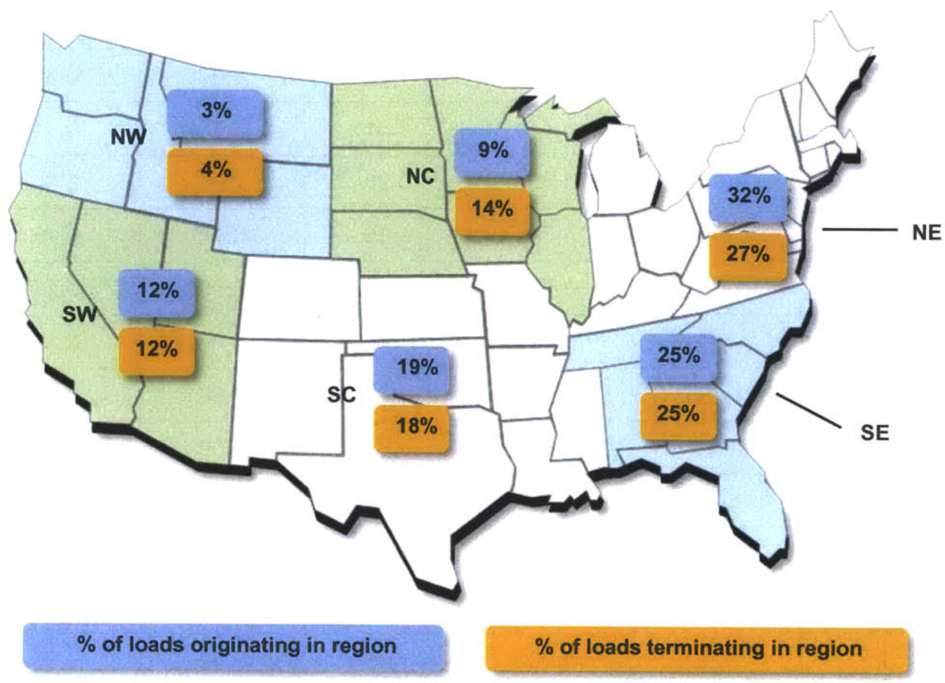

Figure 6. Geographic distribution of loads

3.2.1.3 Tender profile

In analyzing our data, we looked at three characteristics of shipper tenders: (1) bid depth, (2) tender lead time, and (3) tender and ship date distribution. Recall that bid depth refers to the number of times a shipper tenders a load before the load is accepted by a carrier. Tender lead time quantifies how much advance warning a carrier has before having to transport the shipper's goods. Tender date and ship date refer to the day of the week that the load was tendered or shipped.

In our dataset, roughly 75 percent of loads were accepted by the first carrier in the routing guide. Almost all loads were accepted by one of the first seven carriers in the guide. A few unusual loads had bid depths of up to 50 tenders; however the average bid depth was 1.15 tenders per load. Figure 7 gives the bid depth distribution for loads with more than one tender.

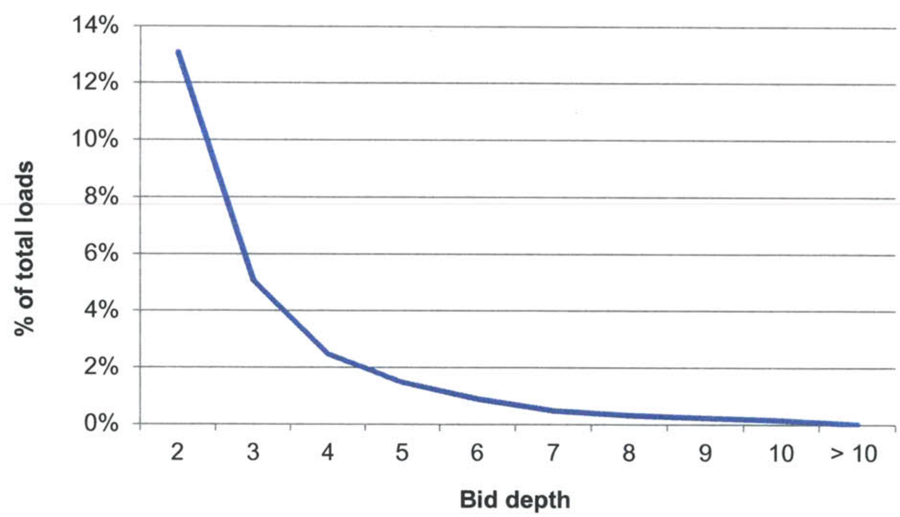

Figure 7. Distribution of bid depth for loads with more than one tender

The graph shows that 13 percent of all loads were hauled by the first backup carrier in the shipper's routing guide. Less than one percent of loads was hauled by a carrier ranked seventh or lower in the guide.

Tender lead time ranged from less than one hour to more than several months. Approximately 67 percent of tenders had lead times of three days or less. Less than one percent of tenders had lead times of more than 14 days. Figure 8 gives the tender lead time distribution.

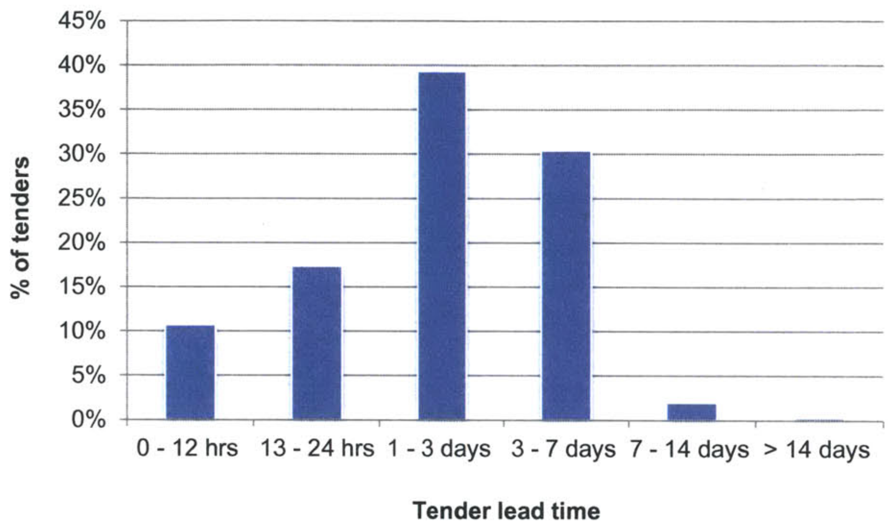

Figure 8. Distribution of tender lead time

As expected, most loads were tendered during the business week, with almost no loads being tendered on the weekends. Similarly, most loads were shipped during the business week, with the greatest percentage of shipped loads occurring on Friday. Almost seven percent of loads were shipped on Saturday. Figure 9 give the tender and ship day distribution.

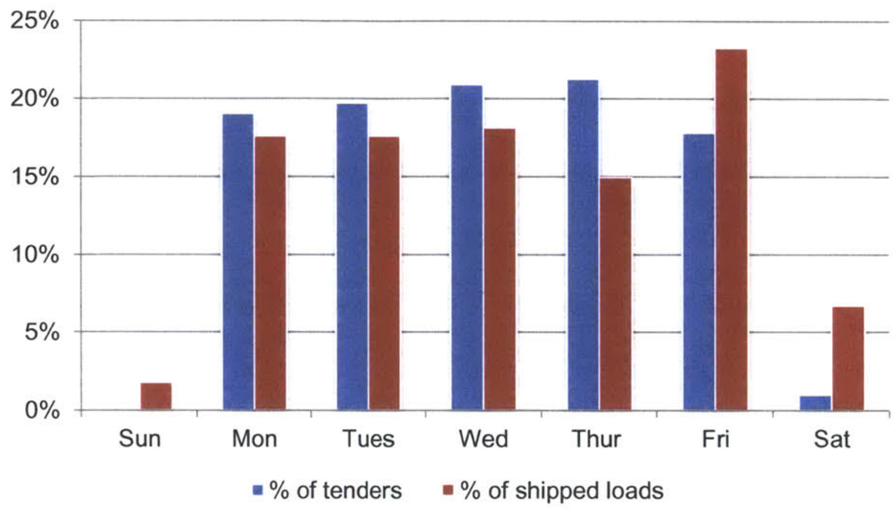

Figure 9. Distribution of tender and ship day of week

3.2.2 Trends

By profiling our data, we were able to confirm several widely-held beliefs in the trucking industry. Specifically, we confirmed that average line-haul RPM decreases with length of haul and tender lead time and increases with bid depth. Our data also showed that shipper volume does not affect average line-haul RPM paid.

In our dataset, average line-haul RPM decreased with length of haul with a correlation of -0.90. This relationship makes logical sense. When a carrier transports a load, it incurs some fixed costs. As the length of haul increases, the carrier can spread these fixed costs over more miles. As a result, carriers tend to quote lower RPMs for longer hauls. Figure 10 shows the relationship between average line-haul RPM and length of haul.

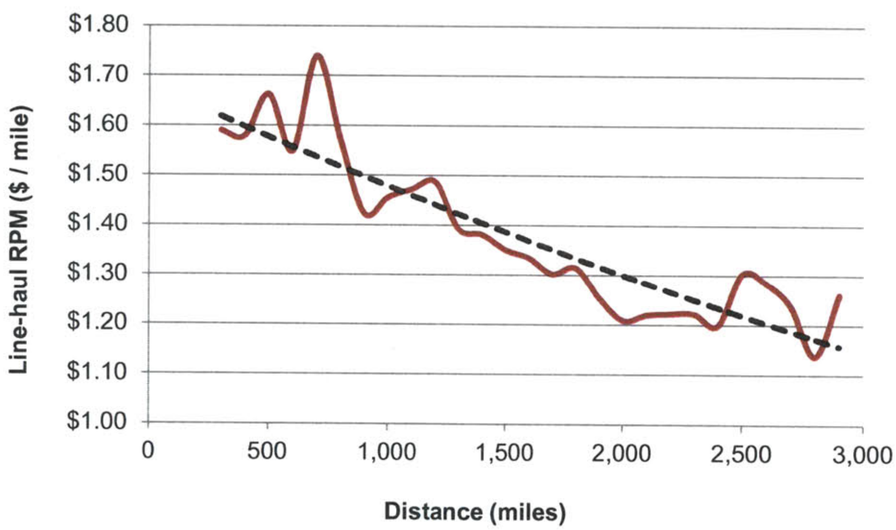

Figure 10. Average line-haul RPM versus distance

Loads with a distance of 500 miles had an average line-haul RPM of $1.65 per mile, while loads with a distance of 2,000 miles had a substantially lower RPM of $1.20 per mile.

We also observed that average line-haul RPM increased with bid depth with a correlation of 0.89. When shippers rank carriers in the guide, they tend to put low-cost carriers at the top of the guide, except in the case where an inexpensive carrier has very limited capacity. Therefore, when a load is rejected, the shipper must offer the load to a deeper, more expensive carrier in the routing guide. Therefore, it is reasonable that average line-haul RPM increases with bid depth. Figure 11 shows the relationship between average line-haul RPM and bid depth in blue and also gives the bid depth distribution from Figure 7.

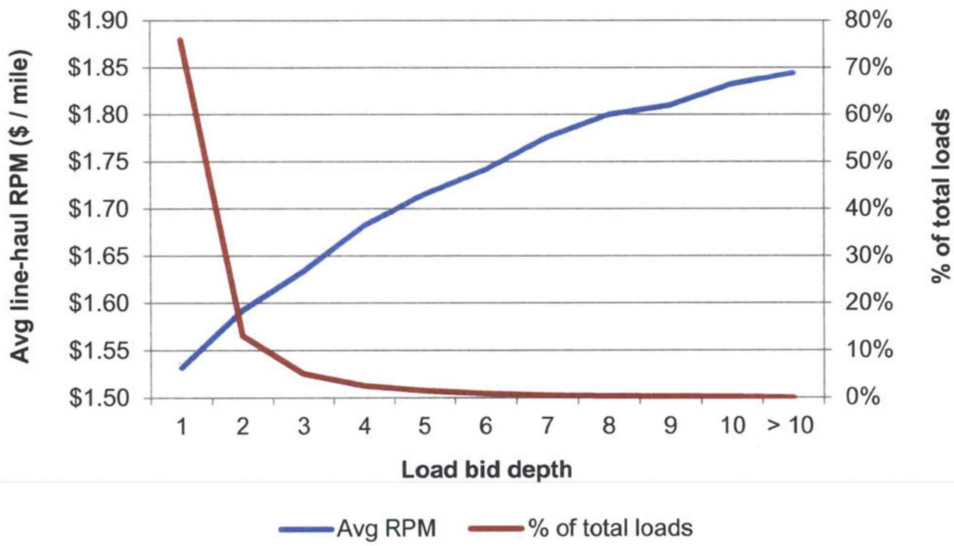

Figure 11. Average line-haul RPM versus load bid depth

The graph shows that 76 percent of loads have a bid depth of one; the corresponding average line-haul RPM for these loads is $1.53 per mile. Less than one percent of loads have a bid depth of 10; the corresponding average line-haul RPM for these loads is 30 cents higher at $1.83 per mile.

Our dataset showed that as tender lead time increases, trucking rates decrease. Consider a situation where a shipper has a load that must be shipped on the following day. As usual, the shipper will tender the load to carriers in its routing guide however, because of the last-minute nature of the tender, many routing guide carriers will already be booked. Consequently, to move the load on time, the shipper will have to hire a lower-ranked, more expensive carrier. In our data, shippers with shorter average lead times had higher average line-haul RPMs, and vice versa. We verified this relationship in our regression analysis. Figure 12 shows that shippers can lower their transportation costs by reserving capacity with their most preferred carriers early. This graph ignores the confounding effect of length of haul on average RPM.

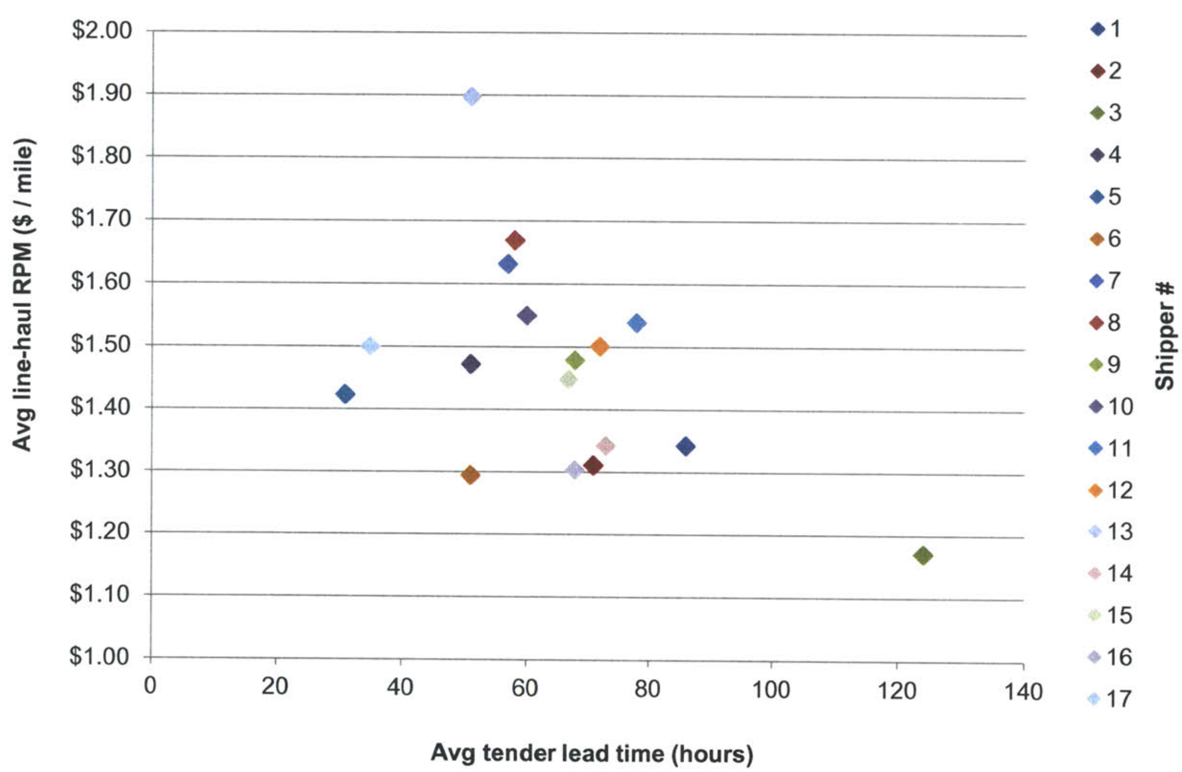

Figure 12. Average tender lead time and average line-haul RPM by shipper

Finally, our dataset revealed that shippers of all sizes in the TL industry pay similar transportation rates. This situation is very different from the situation in other industries, in which large players can command lower prices on inputs. Figure 13 gives shipper size, in load count, versus the average line-haul RPM paid by each shipper. Interestingly, the graph shows no correlation between load count and average line-haul RPM. For example, Shipper 1, the median shipper with respect to load count, had an average rate of $1.34 per mile, while Shipper 7, the largest shipper with respect to load count, had an average rate of $1.63 per mile.

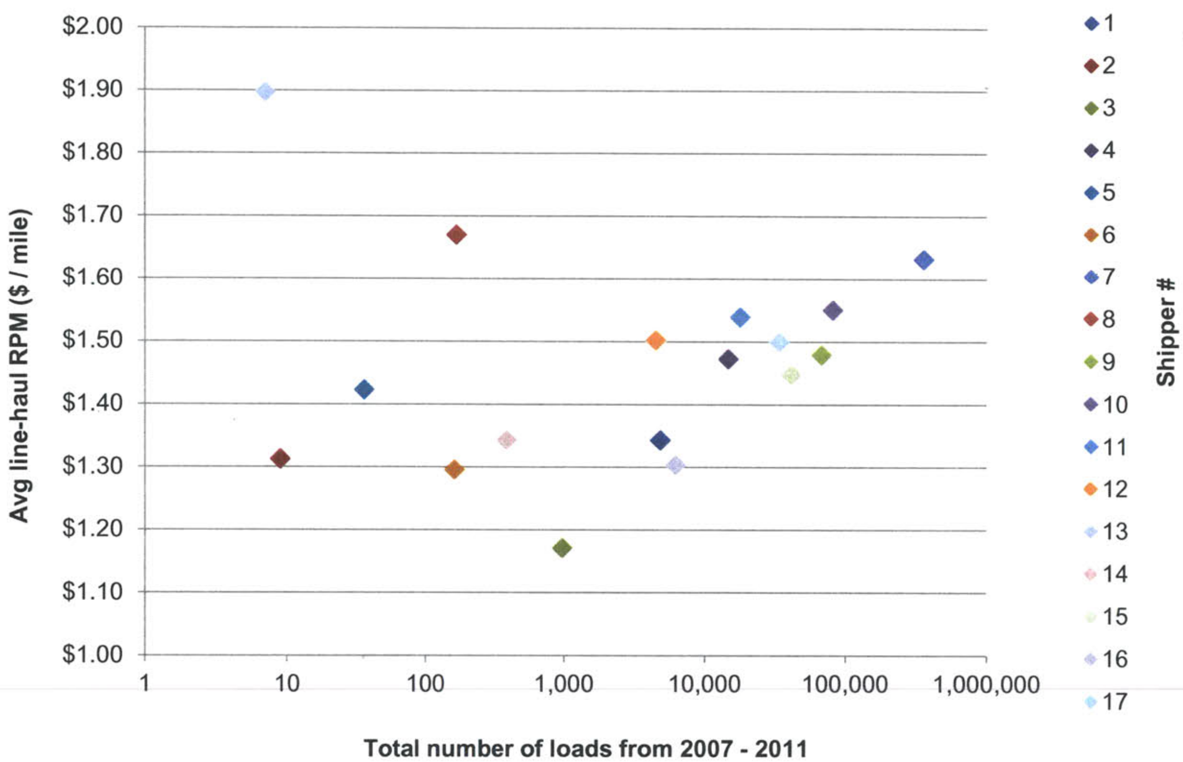

Figure 13. Load count and average line-haul RPM by shipper

3.3 Chapter summary

In this chapter, we described the steps that we took to generate our final dataset. We also discussed correlations in the dataset, including (1) the negative correlation between average line-haul RPM and distance, (2) the positive correlation between average line-haul RPM and load bid depth, (3) the negative correlation between average line-haul RPM and tender lead time, and (4) the lack of correlation between average line-haul RPM and shipper volume.

4 Data analysis and results

This research explored whether a shipper's FSC program affects its total transportation cost. In this study, we defined total transportation cost to be the sum of the line-haul charge and the fuel surcharge. We hypothesized that a shipper which pays higher than average FSC premiums pays lower than average line-haul charges.

4.1 Building the cost model

Using ordinary least squares (OLS) regression analysis in SAS JMP Pro statistical software, we tested the effect of a shipper's FSC program on its total transportation cost. In OLS regression, a series of independent variables are used to predict the value of a dependent variable. Independent variables can be either continuous or discrete. A continuous variable can assume any real value, while a discrete variable can take on only a finite number of values. One special type of discrete variable is called a dummy variable, which can assume a value of either zero or one. A value of one indicates the presence of some categorical characteristic. To avoid model "over-specification", there should always be one less dummy variable than category in the model. For example, suppose we wanted to include dummy variables for the seasons. We would include a dummy variable for Fall, Winter, and Spring. The condition Summer would exist when the three other dummy variables equaled zero.

The following example describes OLS regression in its simplest form.

$$y = 3x - 2w + \varepsilon \tag{10}$$

In this basic example, the independent variables x and w predict the value of the dependent variable y. Epsilon, ε, is the error term, and it represents the difference between the actual and predicted value of y. The numbers in front of the independent variables are called coefficients. Coefficients indicate how the independent variables affect the dependent variable. In this case, the positive coefficient on the x variable means that if the value of x increases by one unit, the value of y increases by three units. In OLS regression, the coefficients are derived such that they minimize the sum of the squared error terms.

Other important regression concepts include the R^2 term, the coefficient t-statistics, the coefficient *p*-values, the mean squared error (MSE) term, the mean absolute percent error (MAPE) term, and the mean percent error (MPE) term. The R^2 term represents the proportion of variation in the dependent variable that is explained by the independent variables. Because R^2 is a proportion, its values range from zero to one or zero percent to 100 percent. The higher the R^2 term, the better the model is at predicting the value of the dependent variable.

$$R^2 = 1 - \frac{\sum(y_i - \hat{y}_i)^2}{\sum(y_i - \bar{y})^2} = 1 - \frac{SSR}{SST} \tag{11}$$

In this equation, SSR equals the sum of squared residuals or error terms, and SST equals the total sum of squares. Together, SSR divided by SST equals the proportion of variation in the dependent variable that is unexplained by the model. Consequently, one minus this proportion equals the proportion of variation in the dependent variable that is explained by the model. The Adjusted R^2 term is a modification of the R^2 term which accounts for the number of independent variables in the model.

Along with coefficients, OLS regression generates t-statistics and *p*-values for each independent variable. Both calculations measure the statistical significance of an independent variable. If an independent variable is statistically significant, it indicates that the predictive power of the variable is unlikely to be due to chance alone. Larger t-statistics and smaller *p*-values imply stronger statistical significance. In our research, we considered an independent variable to be statistically significant if the *p*-value was less than 0.05. Under normal circumstances, insignificant variables should not be included in a regression equation. That said, in a few cases we retained variables with insignificant *p*-values for model completeness. For example, we included variables for all 48 continental states, even though some state variables were insignificant.

The mean squared error (MSE) and the mean absolute percent error (MAPE) both measure model accuracy. MSE measures total model error and does not normalize the error terms for the size of the observed values. The MAPE term, on the other hand, gives the average absolute error as a proportion of the observed value. The mean percent error (MPE) measures the bias of the model. A MPE of zero means the model is perfectly unbiased. A non-zero MPE, however, means that the model has either positive or negative bias.

The following equations give the equations for MSE, MAPE, and MPE.

$$Mean\ squared\ error\ (MSE) = \frac{\sum_{t=1}^{n} e_t}{n} \tag{12}$$

$$Mean\ absolute\ percent\ error\ (MAPE) = \frac{\sum_{t=1}^{n} \frac{|e_t|}{a_t}}{n} \tag{13}$$

$$Mean\ percent\ error\ (MPE) = \frac{\sum_{t=1}^{n} \frac{e_t}{a_t}}{n} \tag{14}$$

Here, a_t represents an observed value from the dataset, e_t represents the error term of that value, or the difference between the observed value and the value predicted by the model, and n represents the number of observations in the dataset.

4.2 Model variables

OLS determines how independent variables explain or affect a dependent variable. In our study, we wanted to evaluate how a shipper's FSC program affected its line-haul cost. Therefore, we created a dependent variable to represent a shipper's line-haul cost and an independent variable to represent a shipper's FSC program. Figure 14 gives our dependent line-haul variable and our independent FSC variable. We explain this breakdown next.

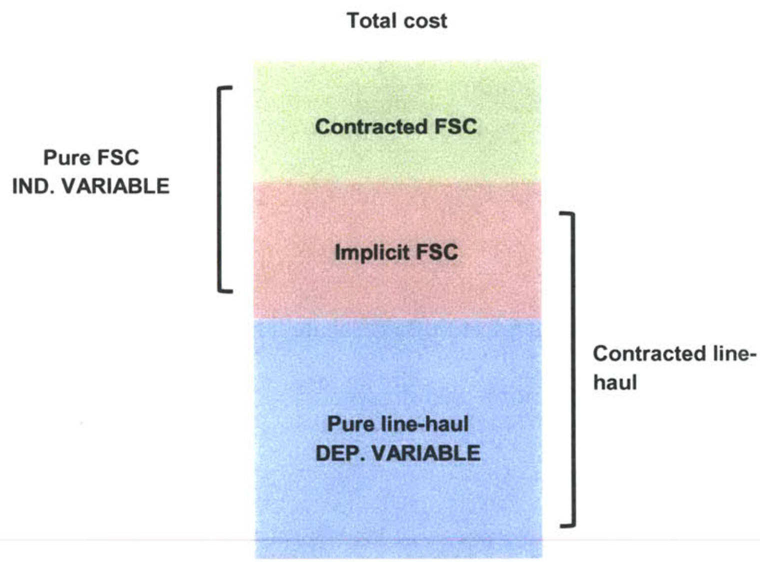

Figure 14. Dependent and independent variables

4.2.1 Dependent variable

When the price of fuel drops below a shipper's peg price, the shipper levies a negative fuel surcharge on the carrier. Carriers take into account the likelihood of a negative fuel surcharge when setting their line-haul rates. As a result, the line-haul charge has two components: (1) a pure line-haul component which is independent of the peg price, and (2) an implicit fuel surcharge which accounts for the likelihood of a negative fuel surcharge.

Our goal was to determine if a shipper's FSC program affected its line-haul costs. Consequently, we had to separate variables which depended on the shipper's FSC program from variables that did not. We set our dependent variable equal to *pure line-haul* (*PLH*).

We calculated *pure line-haul*, which is measured in dollars per load, as follows:

$$Pure\ line\text{-}haul = quoted\ line\text{-}haul - \frac{peg}{efficiency} \times distance \tag{15}$$

$$= \frac{\$}{haul} - \frac{\frac{\$}{gallon}}{\frac{miles}{gallon}} \times miles = \frac{\$}{haul}$$

4.2.2 Independent variables

Our cost model contained an independent variable to measure a shipper's FSC program. It also contained independent variables for other transportation cost drivers.

4.2.2.1 Fuel surcharge variable

We set our independent FSC variable, called *pure FSC* (*PFSC*), equal to the implicit fuel surcharge plus the actual FSC paid. We calculated *pure FSC*, which is measured in dollars, as follows:

$$Pure\ FSC = FSC\ paid + implicit\ FSC \tag{16}$$

$$= \left[\left(\frac{assumed\ fuel\ price - peg}{efficiency}\right) + \left(\frac{peg}{efficiency}\right)\right] distance$$

$$= \left(\frac{assumed\ fuel\ price}{efficiency}\right) \times dist$$

$$= \frac{\frac{\$}{gallon}}{\frac{miles}{gallon}} \times miles = \$$$

Pure FSC measures the total fuel surcharge paid by the shipper to the carrier and is dependent on the prevailing price of fuel. However, when the carrier submits its line-haul rates to the shipper during bidding, the carrier does not know what the price of fuel will be in the coming period. Instead, the carrier must submit its rate based on its expectation of future fuel prices. In our study, we assumed a fuel price expectation of $3.30 per gallon, which was the mean price of fuel between 2008 and 2011. Later, we show that our results did not change when we tested our model with different assumed fuel prices.

4.2.2.2 Other independent variables

In the literature review, we discussed drivers of transportation cost. We incorporated these drivers in our cost model. As in the literature review, we split the independent variables into two groups: core and non-core variables. Core variables had substantial power in explaining the total cost, while non-core variables had only marginal explanatory power. Core variables included the lane geography and the distance traveled. In our study, we also considered the time of year, expressed in quarters, to be a core variable in order to capture seasonality and macroeconomic effects in the TL industry. Non-core variables included carrier rank, carrier size, tender lead time, tender day of week, and procurement exercise frequency. Of these, we did not consider carrier size and procurement exercise frequency in our model, however, due to insufficient data. We describe how we modeled each variable below.

Core variables:

(1) ***Geography.*** We modeled the geography by including origin and destination dummy variables for the continental states plus Washington D.C. For example, suppose a lane originated in California and terminated in Texas. In this case, O_CA and D_TX would both equal one. All other state dummy variables would equal zero. Because carriers have diverse lane preferences, we expected variable coefficients for the geography variables.

(2) ***Distance.*** We modeled distance as a continuous variable, representing the number of miles traveled. We expected the distance variable to have a positive coefficient since longer hauls tend to have higher total costs.

(3) ***Quarters.*** We modeled the time of year with dummy variables for each quarter. Given the volatile macroeconomic conditions present between 2008 and 2012, we expected diverse coefficients for the quarter variables.

Non-core variables:

(1) ***Primary carrier.*** We modeled carrier rank by adding a dummy variable to indicate if the carrier was the shipper's top-ranked carrier in the routing guide. The dummy variable equaled 1 when the carrier was the top-ranked carrier in the guide; it equaled 0 in all other cases. Approximately 70 percent of loads were accepted on the first tender by the top-ranked carrier. The remaining 30 percent of loads were rejected by the top-ranked carrier and were subsequently accepted by a lower-ranked carrier in the guide. We expected a negative coefficient on the carrier rank variable since top-ranked carriers tend to have lower rates.

(2) ***Tender lead time.*** We modeled tender lead time by grouping our records into different tender lead time brackets. A dummy variable was created for each bracket. We grouped records into the following brackets: 0 - 12 hours, 13 - 24 hours, 1 - 3 days, 4 - 7 days, 8 - 14 days, and greater than 14 days. Less than one percent of records had lead times longer than 14 days. Because rates tend to increase as tender lead time decreases, we expected large, positive coefficients on the short lead time brackets.

(3) ***Tender day of week.*** We modeled tender day of week by including dummy variables for each day of the week. We expected positive coefficients for Saturday and Sunday since it likely costs more to tender loads outside of the business week.

4.3 Analyzing the cost model

Our goal was to determine if a shipper's FSC program affected its line-haul rate. To answer this question, we built four regression models with the pure FSC variable and different combinations of the other independent variables. Table 4 summarizes the four models.

Table 4. Summary of regression models

Model	Dependent variable	Independent variables
1	*Pure line-haul*	*Pure $FSC_{3.30}$, geography, distance, quarters*
2	*Pure line-haul*	*Pure $FSC_{3.30}$, geography, distance, quarters, primary carrier*
3	*Pure line-haul*	*Pure $FSC_{3.30}$, geography, distance, quarters, tender lead time*
4	*Pure line-haul*	*Pure $FSC_{3.30}$, geography, distance, quarters, tender day of week*

All four models explained the dependent variable *pure line-haul* and included the *pure FSC* variable, evaluated at an assumed fuel price of $3.30 per gallon, and the core variables. Models 2, 3, and 4 each contained one non-core independent variable.

After each iteration, we examined how the incremental independent variable affected the *pure FSC* variable's coefficient and significance. The purpose of this step was to ensure that the sign and magnitude of the FSC coefficient did not change by adding an incremental variable. Adding incremental non-core variables to the primary model boosted the adjusted R^2 term by less than one percent. We performed all initial regressions on the 2008 to 2011 data, reserving the 2012 data to test model accuracy.

4.3.1 Model 1: *pure FSC, geography, distance,* and *quarters*

The first model, which we refer to as our primary model, explained the *pure line-haul* dependent variable with the independent variables *pure FSC, geography, distance*, and *quarters*. Table 5 gives the results from this regression.

Table 5. Model 1 regression results

	Total spend FSC		
Variable	**Coefficient**	**t-statistic**	***p*-value**
Intercept	950.73	15.67	<.0001
Geography (unitless)			
Origin	-623.22, -32.45	-	-
Destination	-763.01, 90.60	-	-
Quarter (unitless)	-90.85, -11.26	-	-
Distance (miles)	1.38	548.07	<.0001
$PFSC_{3.30} \cdot dist$ (\$)	-0.63	-144.5	<.0001
Fit statistics			
Adjusted R^2	88.99%		
Mean squared error	25,672		

The second column gives the coefficient for each independent variable. In the case of the *geography* and *quarter* variables, we reported the range of coefficients since there were too many coefficients to report in the table. We give the complete regression output in the Appendix. Five of the geographic and quarter dummy variables had statistically insignificant *p*-values greater than 0.05, however we retained these variables for model completeness. For example, the geography dummy variable O_AZ had a *p*-value of 0.0663, which means that there was a 6.63 percent chance of there being no real effect on pure-line haul by O_AZ. The distance variable had a positive coefficient of 1.38. This coefficient indicates that as the distance travelled increased by one mile, the pure line-haul charge increased by $1.38.

As expected, the *PFSC* variable had a statistically significant negative coefficient of -0.63. This coefficient indicates that if a shipper paid an additional dollar in fuel surcharge premium, the shipper paid \$0.63 less in pure line-haul charges. In other words, shippers that pay higher FSC premiums tend to pay lower pure line-haul charges.

Why did this line-haul discounting phenomenon occur? Did high-FSC shippers have lower bid depths than low-FSC shippers? As we have discussed, line-haul rates increase with bid depth. Or did carriers adjust their line-haul bids during procurement to account for a shipper's FSC program?

Figure 15 shows the relationship between a shipper's FSC program and its percentage of first-tender acceptances. The correlation between the average per-mile FSC premium paid and the percentage of first-tender acceptances was a low -0.44.

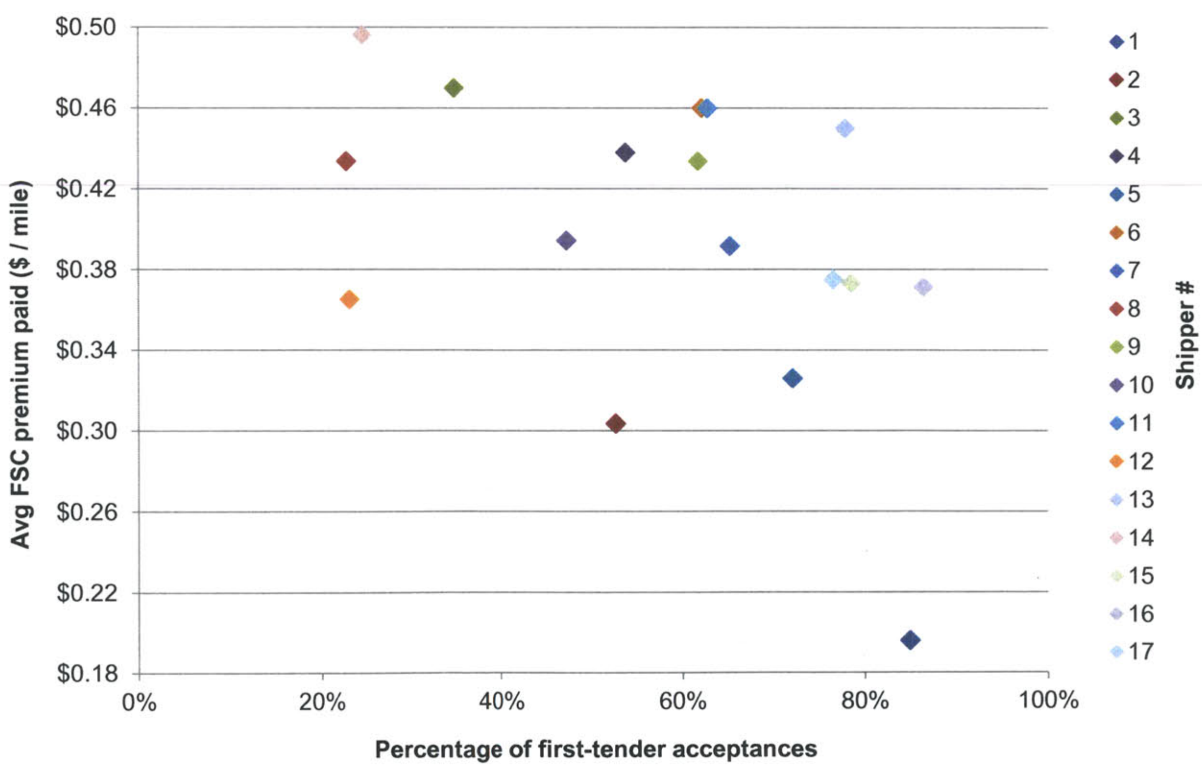

Figure 15. Relationship between FSC program and bid depth

The lack of correlation between a shipper's FSC program and its bid depth performance suggests that differences in line-haul rates were the result of carrier bidding behavior. Carriers modified their line-haul charges according to a shipper's FSC program.

From the regression output, we know that a carrier discounts its pure line-haul charge by $0.63 for every additional dollar spent by the shipper in fuel surcharge premiums. This does not mean that all shippers paid the same total transportation cost, however. Because shippers have different fuel surcharge programs, they pay different fuel surcharge premiums at different fuel prices. We define "net fuel payment" to equal the amount the shipper pays the carrier in per-mile fuel surcharge payments minus the per-mile pure line-haul discount extended by the carrier. Table 6 calculates the net fuel payments paid by three hypothetical shippers with different efficiency values.

Table 6. Net fuel payment to carriers

	Shipper efficiency		
	5 mpg	**6 mpg**	**7 mpg**
PFSC premium			
$2.50 / gallon	0.50	0.42	0.36
$3.00	0.60	0.50	0.43
$3.50	0.70	0.58	0.50
$4.00	0.80	0.67	0.57
***PFSC* coefficient**	-0.63	-0.63	-0.63
PLH discount	-0.42	-0.35	-0.30
Net fuel payment			
$2.50 / gallon	0.08	0.07	0.06
$3.00	0.12	0.15	0.13
$3.50	0.28	0.23	0.20
$4.00	0.38	0.32	0.27

In the table above, the per-mile pure FSC premium is calculated as follows:

$$PFSC\ premium = \frac{fuel\ price}{efficiency} \tag{17}$$

The pure line-haul discount, at an assumed fuel price of \$3.30 per gallon, is calculated as follows:

$$PLH\ discount = PFSC\ coefficient \times \frac{assumed\ fuel\ price}{efficiency} \tag{18}$$

$$= -0.63 \times \frac{3.30}{efficiency} = \frac{-2.079}{efficiency}$$

The net fuel payment is the difference between the pure FSC premium and the pure line-haul discount.

Figure 16 gives the net fuel payments for these three hypothetical shippers. For fuel prices above $2.079 per gallon, the greater fuel surcharge premiums dwarfed the line-haul discount. This effect was most pronounced among low-efficiency shippers. The shipper with the low efficiency value of five miles per gallon paid higher net fuel payments to carriers than the shipper with the high efficiency value of seven miles per gallon.

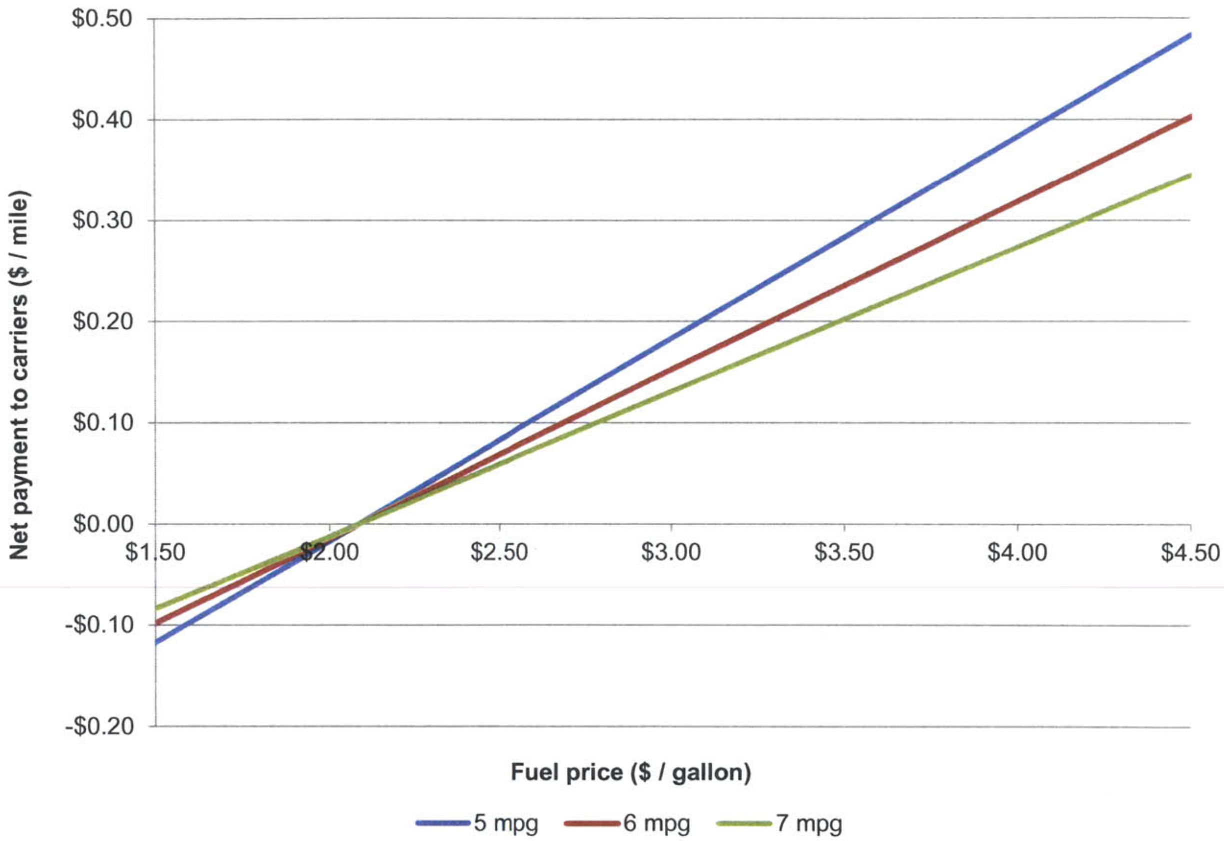

Figure 16. Effect of efficiency on net fuel payment to carriers

The tipping point of $2.079 per gallon did not change when we varied the assumed fuel price. Table 7 gives the tipping point for five different assumed fuel prices. In every case, the tipping point remains at around $2.08 per gallon. This means that the pure line-haul discount extended by carriers is independent of the fuel price assumed by carriers during bidding.

Table 7. PFSC coefficients at different assumed fuel prices

Assumed fuel price	*PFSC* coefficient	Tipping point
$3.00 / gallon	-0.69	-2.07
3.30	-0.63	-2.08
3.50	-0.59	-2.07
4.00	-0.52	-2.08
4.50	-0.46	-2.07

4.3.2 Model 2: *pure FSC, geography, distance, quarters,* and *primary carrier*

The second model explained the *pure line-haul* dependent variable with the independent variables *pure FSC, geography, distance, quarters,* and *primary carrier.* We had two forms of the *primary carrier* variable: (1) a primary flag variable which equaled one when the carrier was the top-ranked carrier in the routing guide and zero in all other cases, and (2) the primary flag variable multiplied by the distance variable. The first variable form allowed us to calculate the per-load savings from using a primary carrier. The second variable form allowed us to calculate the per-mile savings from using a primary carrier.

Table 8 gives the results from the second regression.

Table 8. Model 2 regression results

	(2a) Per-load			(2b) Per-mile		
Variable	**Coefficient**	**t-stat**	***p*-val**	**Coefficient**	**t-stat**	***p*-val**
Intercept	984.53	16.37	<.0001	973.65	16.25	<.0001
Geography (unitless)						
Origin	-620.53, -49.94			-629.85, -58.04		
Destination	-757.10, 86.98			-758.37, 84.94		
Quarter (unitless)	-82.75, -2.00			-83.08, -2.56		
Distance (miles)	1.39	556.46	<.0001	1.44	573.04	<.0001
$PFSC_{3.30}$ (\$)	-0.65	-150.3	<.0001	-0.67	-155.30	<.0001
Primary flag (unitless)	-45.27	-131.6	<.0001	-	-	-
Primary flag · dist (miles)	-	-	-	-0.07	-160.00	<.0001
Fit statistics						
Adjusted R^2	89.17%			89.25%		
Mean squared error	25,248			25,049		

In the first case, the coefficient on the primary flag variable was -45.27. This coefficient means that pure line-haul charges were $45.27 less per load when a shipper uses its top-ranked carrier. In the second case, the coefficient on the primary flag · distance variable was -0.07. The interpretation of this coefficient is that the primary carrier was $0.07 cheaper per mile than lower-ranked carriers. The coefficient on the *PFSC* independent variable remained statistically significant when we added both *primary carrier* variables.

4.3.3 Model 3: *pure FSC*, *geography*, *distance*, *quarters*, and *tender lead time*

The third model explained the *pure line-haul* dependent variable with the independent variables *pure FSC*, *geography*, *distance*, *quarters*, and *tender lead time*. Table 9 gives the regression results for the third regression. We left out the bracket for tender lead time greater than 14 days to prevent over-specifying the model.

Table 9. Model 3 regression results

Variable	**Coefficient**	**t-stat**	***p*-val**
Intercept	918.48	15.14	<.0001
Geography (unitless)			
Origin	-629.66, -26.56		
Destination	-759.85, 96.02		
Quarter (unitless)	-92.06, -11.21		
Distance (miles)	1.38	546.43	<.0001
$PFSC_{3.30} \cdot dist$ ($)	-0.63	-143.70	<.0001
$TLT_{0\text{ - }12\ hrs}$	46.03	14.71	<.0001
$TLT_{13\text{ - }24\ hrs}$	32.71	10.51	<.0001
$TLT_{1\text{ - }3\ days}$	29.60	9.55	<.0001
$TLT_{4\text{ - }7\ days}$	21.04	6.78	<.0001
$TLT_{8\text{ - }14\ days}$	4.49	1.36	0.17
Fit statistics			
Adjusted R^2	89.01%		
Mean squared error	25,609		

All *tender lead time* variables, except the 8 - 14 day bracket, were statistically significant. Shorter lead time brackets had larger coefficients, indicating that last-minute tenders were more expensive than tenders scheduled in advance. The 41.54 difference between the 0 - 12 hour bracket and the 8 - 14 day bracket indicates that a shipper paid $41.54 more on average to tender a load with less than 12 hours of lead time as opposed to a load with between one to two weeks of lead time. A shipper can decrease its total cost by increasing its tender lead time. Adding the *tender lead time* variable did not meaningfully alter the *PFSC* variable coefficient or significance.

4.3.4 Model 4: *pure FSC, geography, distance, quarters,* and *tender day of week*

The fourth model explained the *pure line-haul* dependent variable with the independent variables *pure FSC*, *geography*, *distance*, *quarters*, and *tender day of week*. Table 10 gives the results from the fourth regression. As in the third model, we left out one tender day to prevent over-specifying the model.

Table 10. Model 4 regression results

Variable	Coefficient	t-stat	*p*-val
Intercept	874.71	14.39	<.0001
Geography (unitless)			
Origin	-623.23, -33.07		
Destination	-762.60, 90.79		
Quarter (unitless)	-90.15, -10.33		
Distance (miles)	1.38	547.59	<.0001
$PFSC_{3.30} \cdot dist$ ($)	-0.63	-144.00	<.0001
$Tender_{Mon}$	71.97	16.35	<.0001
$Tender_{Tues}$	73.73	16.75	<.0001
$Tender_{Wed}$	75.88	17.24	<.0001
$Tender_{Thurs}$	76.54	17.39	<.0001
$Tender_{Fri}$	79.13	17.97	<.0001
$Tender_{Sat}$	107.07	23.00	<.0001
Fit statistics			
Adjusted R^2	89.00%		
Mean squared error	25,649		

All *tender day* variables were statistically significant. Saturday had the highest tender day coefficient. The 35.10 difference between the Saturday and Monday coefficients indicates that a shipper paid $35.10 more on average to tender a load on Saturday than on Monday. This finding agreed with our expectation that shippers pay more to conduct business outside the standard work week. Adding the *tender day* variables did not meaningfully alter the *PFSC* variable coefficient or significance.

4.4 Summary of regression results

Table 11 summarizes the regression results from the four models. All models had very similar explanatory power, accuracy, and *pure FSC* coefficients.

Table 11. Summary of regression results

Model	**Adjusted R^2**	**MSE**	***PFSC* coefficient**
1	88.99%	25,672	-0.63
2a	89.17%	25,248	-0.65
2b	89.25%	25,049	-0.67
3	89.01%	25,609	-0.63
4	89.00%	25,649	-0.63

4.5 Results validation

We validated our results in three ways. First, we checked the accuracy and bias of our four models. Next, we tested our primary model on load data. Finally, we tested our primary model on 2012 data. We explain each of these validation methods below.

4.5.1 Validating the regressions

To begin, we verified that our regression models were reasonable, accurate, and unbiased. We checked that all variable coefficients were of the sign and magnitude that we expected. Next, we checked the mean absolute percent error (MAPE) and the mean percent error (MPE). MAPE refers to the accuracy of the model, and MPE refers to the bias in the model. Our primary model had a MAPE of 13 percent and a MPE of negative two percent. These values mean that our model had 87 percent accuracy with a bias of only two percent. MAPE and MPE values for the secondary models were similar.

Finally, we looked at the distribution of the error terms for each model. Unbiased models should have error term distributions that are normally distributed with a mean value of zero. In all cases, our error term distributions met this requirement.

Figure 17 gives the distribution of error terms for the primary model.

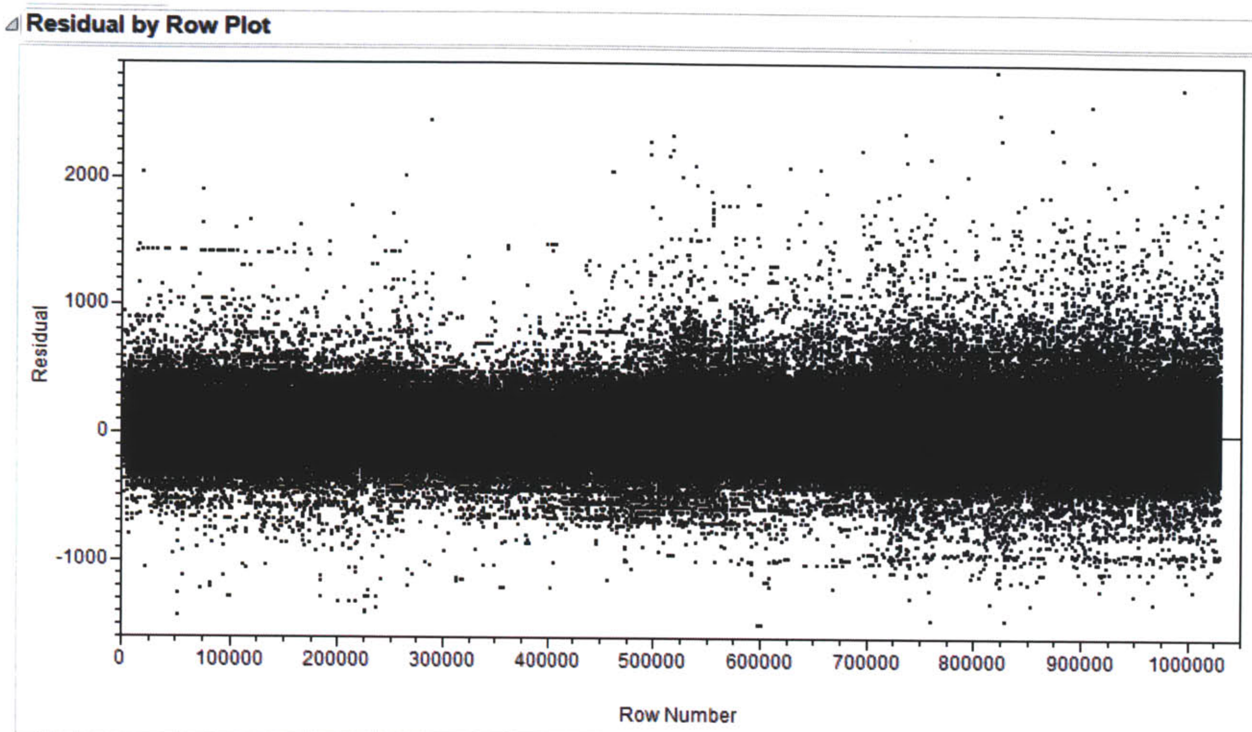

Figure 17. Distribution of primary model error terms

4.5.2 Testing the primary model on load data

In the above four models, we used tender data to generate our results. Tender data included tenders that were both accepted and rejected by carriers. We wanted to make sure that we would get similar results if we used only load data, which included only tenders accepted by carriers. Load data reflected the actual transportation price paid by shippers.

When we ran the primary model using tender data, we got a coefficient of -0.63 for the *pure FSC* variable. When we re-ran the primary model using load data, we got a coefficient of -0.48.The load model had an adjusted R^2 of 89.34 percent. While the *PFSC* coefficient differed slightly between the two models, the load regression results still confirm that shippers which paid higher fuel surcharge premiums paid lower pure line-haul charges.

4.5.3 Testing the primary model on 2012 data

Our regression models were generated using 2008 to 2011 data. We reserved 2012 data to test the accuracy of the regression models. We predicted 2012 pure line-haul rates with the regression model coefficients, excluding quarter variables. Next we compared the predicted 2012 values to the actual 2012 values. We checked the accuracy and bias of our predicted values.

When we ran our primary model with 2012 data, we calculated a MPE of 1.5 percent and a MAPE of 14 percent. The values indicate that our model had a very low bias of 1.5 percent and a high accuracy of 86 percent.

4.6 Chapter summary

In this chapter, we described how we built and analyzed our transportation cost model. We also presented and discussed our regression results.

Primary findings:

(1) Carriers implicitly discounted their line-haul rates according to a shipper's FSC program. The more a shipper paid in FSC premiums, the more the carrier discounted the line-haul.

(2) For fuel prices above $2.079 per gallon, greater fuel surcharge premiums dwarfed the line-haul discount. This effect was most pronounced among low-efficiency shippers.

(3) Shippers with lower efficiency values had higher per-load costs than shippers with higher efficiency values on a given lane.

Secondary findings:

(1) Line-haul rates increased the deeper a shipper reached down its routing guide.

(2) Line-haul rates increased as tender lead time decreases.

(3) Line-haul rates were higher for weekend tenders.

These secondary findings agree with patterns observed in our dataset and with previous research done on drivers of transportation cost.

5 Insights and conclusion

The purpose of this research was to determine if a shipper's FSC program affected its total per-load transportation cost. Using regression analysis, we found that carriers implicitly discounted their line-haul rates according to a shipper's FSC program. Shippers with higher FSC premiums had lower line-haul charges; however for fuel prices above $2.079 the larger FSC premiums overpowered the lower line-haul charges.

5.1 Management insights

Our analysis showed that a shipper's FSC program affected its total per-load transportation cost. Shippers with lower efficiency values paid higher per-load transportation costs than shippers with higher efficiency values. These findings suggest that shippers can minimize their transportation costs by increasing their efficiency values. Of course, if enough shippers switch to a high-efficiency fuel surcharge program, carriers will likely adjust their line-haul rates so as to diminish any potential cost savings for shippers.

5.2 Future research

We ran our regression using data from 2008 to 2011. From this dataset we generated our *PFSC* variable coefficient of -0.63 and our tipping point of $2.079 per gallon. Future research should test whether these values change over time. Furthermore, in our dataset, fuel prices ranged from $2.02 per gallon to $4.76 per gallon. Within this range, we did not notice any difference in bid depth performance among shippers with different FSC programs. Still, we might wonder if these findings hold for skyrocketing fuel prices. Additional research is needed to evaluate whether carriers strongly prefer one type of FSC program over another at substantially higher fuel prices. Because this research must look ahead using speculative fuel prices, it may need to be qualitative in nature. Finally, future research could consider how a carrier manipulates its rates in response to a peg price change, an efficiency change, or both a peg price and efficiency change. This information is critical for a shipper considering an adjustment to its FSC program.

Appendix

Table 12 gives the complete regression results for the first regression model at an assumed fuel price of $3.30 per gallon. These results correspond to the regression results in Table 5.

Table 12. Complete regression results for model 1

Variable	Coefficient	t-stat	*p*-val
Intercept	950.73	15.67	<.0001
Distance	1.38	548.07	<.0001
$PFSC_{3.30}$	-0.63	-144.5	<.0001
O_AL	-254.35	-4.20	<.0001
O_AZ	-111.28	-1.84	0.070
O_AR	-201.95	-3.32	0.001
O_CA	-124.92	-2.06	0.040
O_CO	-497.92	-8.19	<.0001
O_CT	-585.01	-9.00	<.0001
O_DE	-420.36	-6.90	<.0001
O_DC	-560.42	-6.76	<.0001
O_FL	-531.83	-8.77	<.0001
O_GA	-305.44	-5.04	<.0001
O_ID	-305.21	-5.03	<.0001
O_IL	-110.43	-1.82	0.070
O_IN	-155.48	-2.57	0.010
O_IA	-127.96	-2.11	0.030
O_KS	-124.61	-2.05	0.040
O_KY	-230.64	-3.81	0.001
O_LA	-347.16	-5.73	<.0001
O_ME	-610.00	-9.72	<.0001
O_MD	-522.89	-8.60	<.0001
O_MA	-623.22	-10.14	<.0001
O_MI	-216.91	-3.58	0.001
O_MN	-32.45	-0.54	0.590

O_MS	-245.03	-4.04	<.0001
O_MO	-106.68	-1.76	0.080
O_MT	-125.91	-1.98	0.050
O_NE	-139.94	-2.30	0.020
O_NV	-173.77	-2.86	0.001
O_NH	-575.77	-9.45	<.0001
O_NJ	-569.81	-9.41	<.0001
O_NM	-478.33	-7.56	<.0001
O_NY	-473.82	-7.82	<.0001
O_NC	-269.33	-4.45	<.0001
O_ND	-154.60	-2.54	0.010
O_OH	-208.65	-3.44	0.001
O_OK	-264.18	-4.36	<.0001
O_OR	-391.52	-6.46	<.0001
O_PA	-482.82	-7.97	<.0001
O_RI	-577.84	-8.69	<.0001
O_SC	-238.59	-3.94	<.0001
O_SD	-143.08	-2.35	0.020
O_TN	-138.15	-2.28	0.020
O_TX	-358.60	-5.92	<.0001
O_UT	-425.81	-7.02	<.0001
O_VT	-574.67	-7.42	<.0001
O_VA	-407.18	-6.72	<.0001
O_WA	-438.30	-7.23	<.0001
O_WV	-247.56	-4.02	<.0001
O_WI	-54.68	-0.90	0.370
D_AL	-601.62	-188.70	<.0001
D_AZ	-444.17	-137.20	<.0001
D_AR	-602.26	-152.20	<.0001
D_CA	-763.01	-249.50	<.0001
D_CO	-285.93	-86.19	<.0001
D_CT	-71.27	-19.02	<.0001

D_DE	-215.40	-55.24	<.0001
D_DC	-341.28	-4.26	<.0001
D_FL	-158.78	-50.39	<.0001
D_GA	-572.76	-178.90	<.0001
D_ID	-311.43	-72.89	<.0001
D_IL	-673.36	-210.00	<.0001
D_IN	-688.76	-204.20	<.0001
D_IA	-720.93	-225.10	<.0001
D_KS	-643.20	-188.40	<.0001
D_KY	-568.06	-168.80	<.0001
D_LA	-479.15	-137.30	<.0001
D_ME	73.05	20.61	<.0001
D_MD	-267.79	-75.22	<.0001
D_MA	8.79	2.56	0.010
D_MI	-574.60	-167.00	<.0001
D_MN	-684.78	-210.80	<.0001
D_MS	-581.72	-166.30	<.0001
D_MO	-629.90	-199.20	<.0001
D_MT	90.60	16.64	<.0001
D_NE	-623.52	-173.10	<.0001
D_NV	-505.72	-119.60	<.0001
D_NH	15.75	3.89	0.0001
D_NJ	-214.29	-66.16	<.0001
D_NM	-123.81	-29.48	<.0001
D_NY	-154.89	-48.13	<.0001
D_NC	-522.52	-167.50	<.0001
D_ND	-462.50	-99.14	<.0001
D_OH	-606.95	-193.30	<.0001
D_OK	-526.63	-140.20	<.0001
D_OR	-363.35	-113.50	<.0001
D_PA	-280.39	-89.27	<.0001
D_RI	36.93	4.97	<.0001

DISCLAIMER

MISSING PAGE(S)

Page 66 is missing from the original document submitted by the author.

D_SC	-499.98	-137.70	<.0001
D_SD	-464.74	-77.15	<.0001
D_TN	-591.56	-179.10	<.0001
D_TX	-428.30	-138.20	<.0001
D_UT	-301.86	-93.84	<.0001
D_VT	37.25	5.89	<.0001
D_VA	-354.38	-104.60	<.0001
D_WA	-209.09	-66.08	<.0001
D_WV	-443.38	-95.68	<.0001
D_WI	-700.83	-215.40	<.0001
Q1_2008	-35.58	-39.77	<.0001
Q2_2008	-29.74	-32.17	<.0001
Q3_2008	-21.10	-24.83	<.0001
Q4_2008	-11.26	-12.58	<.0001
Q1_2009	-26.71	-26.89	<.0001
Q2_2009	-60.21	-60.43	<.0001
Q3_2009	-90.85	-98.60	<.0001
Q4_2009	-89.17	-106.80	<.0001
Q1_2010	-84.61	-97.72	<.0001
Q2_2010	-66.81	-78.90	<.0001
Q3_2010	-49.19	-61.96	<.0001
Q4_2010	-32.74	-41.59	<.0001
Q1_2011	-36.99	-45.52	<.0001
Q2_2011	-21.47	-26.18	<.0001
Q3_2011	-12.37	-16.10	<.0001
Fit statistics			
Adjusted R^2		88.99%	
Mean squared error		25,672	