THE DEMAND FOR U.S. RAILROAD FREIGHT SERVICE—SELECTED MANUFACTURED GOODS

by

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Abstract

Many of the railroad demand studies are out-dated, lacking the most recent data. We felt that it is time to re-evaluate the rail markets to determine if changes have occurred in the determinants of railroad demand. This paper examines the effects of industrial production and revenue per ton of railroads on the demand for railroad service for selected manufactured goods. Also there appears to be a fundamental shift in railroad pricing after 2004. Thus a dummy variable for the 2005-2010 period was included in the model. Although there is variation in the price elasticity of demand across the manufactured goods markets, all are price inelastic.

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Chapter 1 - Introduction

Since the Staggers Act of 1980, there has been a total restructuring of the U.S. rail industry. Through deregulation, firms were unrestricted in their ability to price their services which changed the relationship between railroads and shippers (Burton 1993). This can be seen through changes in composition of the demand for rail transportation. The objective of the thesis is to demonstrate through the use of linear regression modeling that fundamental differences have occurred in the post 2004 era in the demand for rail service.

Changes in policy have enabled railroads to become more efficient. The deregulation of the industry has decreased the variable costs by as much as 41 to 44 percent in 1989 (Wilson 1997). By being able to offer a lower price to shippers, the quantity demanded for rail transportation has increased in the post deregulation era.

Rail mergers also played a key part in the restructuring of the industry. In 1980, there were 40 Class I railroads compared to just seven in 2011. Through time there has been an increase in the efficiency of rail transportation by being able to capture more pronounced economies of scale and lower the cost per-ton mile for freight. Mergers have also allowed better service capabilities by being able to ship more commodities longer distances without have to interchange as much with other rail carriers (Association of American Railroads 2011). The merger between Union Pacific Railroad Co. and the Southern Pacific Transportation Co. in 1996 made it the largest rail transport firm at the time. The Interstate Commerce Commission (ICC) allowed the merger because of the cost savings and service quality that the merged railroad could provide to its customers in the western United States (Breen 2004). There were several occasions where multiple smaller railroads joined together to achieve a lower cost structure and provide greater levels of service to its customers.

The Staggers Act also allowed railroads to abandon or sell unprofitable sections of track in a timelier manner allowing them to focus on the areas that would provide the largest amounts of revenue (MacDonald and Cavalluzzo 1996). Many short line railroads formed through the abandonment of track by large Class I railroads providing much needed rail service in rural areas. They are crucial to rural areas to provide for the movement of commodities that would otherwise be impossible or impractical due the high costs of other modes of transportation. Short line railroads accounted for 43,003 miles of track in 2010 which is 31% of the national rail network (Association of American Railroads, *Railroad Facts* 2011).

Many of the studies of rail demand are outdated, lacking the most recent data in their calculations. It is time to re-evaluate the markets to see what has happened in recent years. The main objective is to measure the demand for railroad service in the following markets: food and kindred products, lumber and wood products, chemicals and allied products, petroleum and coal products, stone, clay, and glass products, primary metal products, and transportation equipment. These markets account for nearly 92% of rail manufactured goods tonnage in 2010. Another objective is to determine whether an OLS regression model can be applied to estimate rail demand. Lastly we examined whether there are structural breaks in the demand for rail service.

Chapter 2 - Literature Review

Levin (1979) examines the impact of ICC rate regulation on the allocation of surface freight traffic among the different modes. He uses a multinomial logit model to estimate the traffic in manufactured commodities among truck, rail boxcar, and piggyback. The author is trying to determine the amount of misallocation attributable to regulatory rate distortion in rail transportation.

The author makes the market share a function of the rate charged by transport mode, commodity value x mean transit time per mode, and the standard deviation of transit time for each mode. The market share is a ratio of either boxcar to truck or piggyback to truck.

He found that the total dead-weight loss attributed to the regulation of rail prices for 1972 to be between 53 and 135 million dollars. This was found by the difference in substituting marginal costs for boxcar and piggyback rates.

Oum (1979) formulates a demand model for intercity freight transport as an intermediate input to the production and distribution sectors of the economy, and to estimate the price elasticities and the elasticities of substitution between the major modes (rail, truck, and water).

The author uses a twice continuously differentiable production function relating the gross output to capital, labor, and freight transport. The data is from the Canadian economy 1945-1974 and it was transformed using a price index for each mode to calculate the revenue per ton mile.

The author finds that the demand for railway freight services is only slightly responsive to the change in railway freight rate; but the own-price elasticity has been increasing in absolute value over time. Also, railway and truck carriers exhibited a complementary relationship until 1955 when they started really competing with one another. There is also a highly competitive relationship between rail and water carriers that can be seen throughout all years of the data, but it has been decreasing slightly over time.

Babcock (1980) examines the impact of increasing fuel prices on the truck-rail competitive relationship in the intercity freight markets. Specifically he examines the impact of fuel price increases and speed restrictions that prevailed when the study was written. To achieve the objectives of the study Babcock uses both a micro study, which examined the impact of fuel price increases on the rail-truck distance crossover point, and a macro study that examines the effect of energy-related variables on rail tonnage originated.

The macro model makes rail freight originated a function of the ratio of rail price to truck price, value added by manufacture, and the ratio of average truck speed to average rail speed. The equations were estimated for three regions and nine commodities. In the micro model distance cost functions were estimated for 1973 for both modes. The line haul costs are modified to reflect 1980 fuel prices. Then the distance crossover point is recalculated to estimate the impact of fuel price increases.

The author found that railroads did not benefit from the 1970s energy crunch in terms of originated freight despite the improvement in the competitive position produced by fuel price increases. Babcock also found that the distance crossover point declined from 85 miles to 62 miles. Thus the increase in fuel prices substantially reduced the cost competitive distance of truck with rail.

Friedlaender and Spady (1980) analyze the demand for freight transportation with freight being a productive input in the firm and which should be treated like any other input and the full costs of transportation should include inventory costs as well as shipping and storage. The authors derive an explicit freight demand equation from a general cost function recognizing the interrelationship between rates and inventory cost through shipment characteristics.

The demand equation is generated from a cost function that uses labor, capital, materials and energy, rail transportation, and truck transportation to produce an aggregate output. Since firms are unable to adjust factor usage instantaneously, it is assumed that a short run cost function is desirable.

The authors find that commodities such as iron and steel products, electrical machinery, and food appear to have an elastic demand. By region, the demand for rail service in the southern region appears to be elastic. The cross price elasticities between rail and truck service are low in absolute value across all goods in all areas suggesting a large amount of independence between the two modes. The authors note that this is reasonable since most of the data for trucks that they used was for LTL shipments which are not a strong competitor for rail.

Winston (1981) notes that previous work in freight transportation has focused on the aggregate approach without considering the underlying behavior of the firms responsible for actually making the mode-choice decision. The author looks at these choices as it applies to intermodal competition. This was done by developing a random expected utility model that was suitable for econometric analysis comparing both regulated and un-regulated motor freight and rail.

The author makes expected utility a function of modal attributes and commodity and firm characteristics that has been divided into two different elements, observed and unobserved parts. This is further broken down into the observed part and a stochastic term representative of a random parameter, modal attributes, and an independent identically distributed disturbance.

It was found that the commodity groups most sensitive to service quality are perishable products or inputs to perishables products. Conversely, the commodity groups that are least sensitive to service quality are neither perishable nor likely to have storage problems such as storage costs or demand. Generally, freight charges and location have the most explanatory power with tangible shipping costs tending to play a dominant role in mode choice decisions.

Levin (1981) attempts to predict the impact of rate flexibility on rail prices, profitability, and economic welfare in a deregulated rail industry to ascertain whether it will restore the rail industry to financial viability by generating a cash flow large enough to maintain and improve high quality rail service. A secondary objective is to determine the presence of railroad market power sufficient to generate excessive increases in profits, prices, and the associated dead-weight losses.

The author uses a multinomial logit model where truck, piggyback, and rail in 1972 for 349 markets are explained by intermodal differences in rates, by the inventory costs of differences in speed and reliability, and unobserved attributes of modes and shippers. The author used 1972 data although 1977 Census of Transportation data was available at the time the study was written. This was based on the possibility that the results could be affected by initial steps to deregulate the railroads.

The author finds that for any given degree of inter-railroad competition, average rate increases on manufacturers are greater than for the primary bulk commodities and the amount of competition has a large influence on the level of rates. This shows that rail demand is more elastic in the sample markets than for bulk commodities. Also, truck deregulation will only provide a mild restraint on the increase of rail rates. With the amount of intermodal competition, it is unlikely that railroads will merge and form some sort of monopoly or a collusion of oligopolies, but the industry should be able to improve its capital stock by raising its rate of return.

Babcock and German (1983) forecast 1985 railroad market shares for 12 intercity manufactured goods freight markets. The authors note that the railroad share of these markets declined in the 1955-1980 period while the truck share rose. One of the principal objectives of the Staggers Rail Act of 1980 was to arrest the decline of rail market shares. Whether this would occur is the primary question addressed by this paper.

The authors employ a model in which railroad market share (measured by ratio of a rail tonnage index to an index of industrial production) is made a function of the ratio of the rail rate to the truck rate, the prime interest rate, and the ratio of truck service to rail service. Truck service is measured by interstate highway miles as a percent of total highway miles. Rail service is measured by an index of average daily freight car miles. The authors found the potential forecast performance of the estimated rail share equations to be excellent.

The authors also found that rail market shares would continue to decline in about half of the 12 markets if truck service improved relative to rail service. If the decline in rail service relative to truck service is arrested, railroad market shares increase in all 12 markets. The principal conclusion of the paper is that the secular decline of railroads was ending in most transport markets by the middle 1980s.

Harris and Winston (1983) try to estimate possible consequences of both parallel and vertical mergers. This is done by measuring the cost saving for firms and the improvements in rail service quality. The authors used an ordinary least squares regression of total cost as a function of loaded freight cars, loaded freight car miles, loaded freight car hours, loaded freight cars x urban dummy variable, route miles, and route miles x urban dummy variable. The data comes from the Association of American Railroads and includes 90% of rail movements in 51 major inter-urban markets for the month of October 1976. They simulated vertical mergers by decreasing the number of carriers on each route and horizontal mergers through decreasing the number of carriers and routes in each market.

The authors found that vertical mergers with a 33% reduction in the number of carriers per route have the potential to decrease the variable costs for firms by 9%-18%. With horizontal mergers, the anti-competitive effects outweigh the cost savings so the variable cost would increase. They also found that shippers would be significantly better off from vertical mergers, and worse off from the anti-competitive effects of parallel mergers. Vertical mergers result in several shipper advantages that are not present in horizontal mergers including faster transit times (and thus lower inventory costs), direct service to more markets, and less record keeping costs.

Morrison and Winston (1985) estimate a behavioral disaggregate model of intercity passenger transportation demand for vacation travelers with regards to multiple mode options: bus, rail, plane, and car.

The authors use a model that determines the indirect utility of travelers by maximizing their income minus price of destination, price of transportation mode, price of rental car x dummy, and a vector of explanatory variables including traveler, mode, and destination characteristics. The data came from the National Travel Survey covering 1,893 household vacation trips with 3,623 travelers and including 607 directional city pairs for the year 1977.

Both buses and rail could be successful in obtaining more demand through reducing their travel time and time between departures. Car could increase its market share from a decrease in its costs, such as the price of fuel, for short to medium length trips.

German and Babcock (1994) note that there has been comparatively little recognition and virtually no measurement of the effect of major socio-economic trends on rail traffic. The objective of the study is to develop a framework-procedure for measuring the impact of the decline of the U.S. middle class on U.S. railroad tonnage and employment. The specific objectives of the study are (1) measure the impact of income distribution on single family housing starts, (2) measure the impact of the change in single family housing starts on railroad lumber traffic, and (3) measure the impact of the change in railroad lumber traffic on railroad employment.

The first specific objective is achieved by formulation of a model of single family housing starts which are made a function of disposable personal income, the new home mortgage interest rate, and percent of U.S. adults age 25 to 50 in the high income class.

The second specific objective is development of a railroad lumber tonnage model which is made a function of single family housing starts from the first objective, railroad price relative to truck price, and the interest rate. The third objective is achieved through development of a railroad employment model which is made a function of an index of the cubic capacity of the average truck trailer manufactured in a given year, total railroad originated tonnage minus lumber, and railroad originated lumber tonnage.

Chapter 3 - Model and Data

The variables in the empirical model are suggested by results of previous freight demand models. The model is as follows:

$$\text{Ton}_i = \text{Rton}_i + \text{Ip}_i + \text{Prime} + \text{ExIm} + \text{Railspeed/Interstate} + \text{Dummy} + e_i$$

Where:
Ton_i – Railroad tons originated, industry i
Rton_i – Railroad revenue per originated ton, industry i
Ip_i – Industrial production, industry i
Prime – U.S. prime interest rate
ExIm – U.S. exports of non-agricultural products plus imports of non-petroleum products
Railspeed – U.S. freight train miles/train hours
Interstate – U.S. interstate highway miles
Dummy- Equal to 1.0 for 2005-2010; 0 in other years
e_i – disturbance term, industry i

The theoretically expected sign for $Rton_i$ is negative since an increase in railroad price would have a negative effect on rail tonnage.

Transportation demand is derived from the demand for production. Thus if industrial production increases the demand for rail transport would increase, resulting in an increase in rail tonnage. Accordingly the theoretically expected sign of industrial production is positive.

The theoretically expected sign of the interest rate variable is negative. If interest rates increase, industrial production would decrease. This would result in a negative effect on railroad tonnage. Also, a rise in interest rates would increase firm inventory costs. If firms react to this by reducing the shipment size of incremental additions to inventory, it would increase truck shipments since the average shipment size of truck is much less than railroads. Thus, the interest rate would have a negative effect on rail tonnage.

Goods are transported from the interior states to the coasts for export. In the opposite way, imports are transported from the coasts to the interior states. In both cases, increases in imports or exports will increase the demand for transportation of goods. So, the theoretically expected sign is positive for imports plus exports.

Transportation service is measured in relative terms with rail service in the numerator and truck service in the denominator. Transportation service is multi-dimensional, including, but not limited to the following: delivery time, dependability of delivery time, frequency of service, door-to-door delivery, flexibility, loss and damage record, and shipment tracking capability.

No transportation trade association or regulatory body has ever published any of these service factors. Thus, imperfect proxies must be used. The motor carrier service proxy is interstate highway miles. This variable does not directly measure any of the service parameters mentioned above. However, the interstate highway system facilitated gains in many aspects of motor carrier service such as delivery time, dependability of delivery time, and safety. Rail service is proxied by freight train speed (freight train miles/ train hours).

The theoretically expected sign of the relative service variable is positive since an increase in rail service relative to truck service would increase rail tonnage.

In the 2005-2010 period railroads increased their prices by more than they had previously, possibly due to a significant increase in railroad costs. Rail cost recovery index increased 39.2% between 2004-2010, but only 25.2% between 1995 and 2003. To account for this change a dummy variable equal to 1.0 in each year of the 2005-2010 period and zero for other years was included in the model. Since the cause of this change in pricing behavior is unknown, the theoretically expected sign of the dummy variable is indeterminate.

The model was estimated for the 1964-2010 period. The data for tons originated and revenue per ton was obtained from the Association of American Railroads *Freight Commodity Statistics*, various issues. The Association of American Railroads also provided the data for train speed (freight train miles/ train hours) from their *Railroad Facts*, various issues. Train hours were provided by the editor of *Railroad Facts*. Interstate highway miles came from the U.S. Federal Highway Administration, *Highway Statistics*, various issues.

It is desirable to include truck price in the model which is the principal intermodal competitor of railroads. Revenue per ton mile of LTL motor carriers was published in *Transportation in America 2000* for 1964-1999 and in *Transportation in America* 20th edition for 2000-2003. However railroads do not compete with LTL motor carriers, they compete with TL motor carriers. There is no time series data for TL motor carrier prices.

U.S exports of non-agricultural products plus imports of non-petroleum products was from President's Council of Economic Advisors, *Economic Report of the President, 2011*. Prime interest rate also is from President's Council of Economic Advisors, *Economic Report of the President, 2011*. Industrial production is from the Board of Governors of the Federal Reserve System.

Chapter 4 - Empirical Results

Some of the explanatory variables in the model had multicollinearity problems with other variables and were dropped from the final empirical model. The final model is:

$$\text{Ton}_i = \text{Rton}_i + \text{Ip}_i + \text{Dummy} + e_i$$

The empirical results are in Tables 1 and 2. In Table 1, the variables are in non-logs and in Table 2 expressed in logs. An examination of Table 1 reveals that all the explanatory variables have the theoretically expected sign and most of them are statistically significant at the 1% level. The only exceptions are industrial production in the food and kindred products equation and the dummy variable in the transportation equipment equation. All the equations have a good fit with adjusted R^2 ranging from a low of 0.61 for food and kindred products to a high of 0.97 for chemicals and allied products. All the equations in Table 1 initially had statistically significant auto correlation but this was corrected using Newey-West standard errors with a lag of 3.

The results for the log specification of the variables are displayed in Table 2 and are very similar to the results in Table 1. All the explanatory variables have the theoretically expected sign and most are significant at the 1% level. Variables that are non-significant include industrial production in the food and kindred products equation, the dummy variable in the petroleum products equation, and the dummy variable in the transportation equipment equation. Better statistical results were obtained without the dummy variable in the lumber and wood products equation. All the equations have a good fit with adjusted R^2 ranging from a low of 0.61 for food and kindred products to a high of 0.97 for chemicals and allied products. As was the case for the non-log specification, all the equations in Table 2 initially had statistically significant auto correlation but this was corrected using Newey-West standard errors with a lag of 3.

An examination of the rail price variable coefficients in Table 2 indicates that rail demand is price inelastic in all the markets. However, the elasticities vary across markets from a low of 0.23 for chemicals and allied products to a high of 0.78 for lumber and wood products.

The empirical evidence of a structural break in railroad demand in the 2005-2010 period is strong. In Table 1 the dummy variable is statistically significant in six of the seven equations, and in four of the seven cases in Table 2. Thus the dummy variable was statistically significant in 71.4 percent of the 14 equations.

Table 1: Empirical Results, Non-logged Specification

Variable	Coefficient	t-statistic	Probability
Food and Kindred Products (20)			
Rton	-1380.673	-4.24**	0.000
Ip	195.9641	1.44	0.157
Dummy	27646.8	4.58**	0.000
Constant	109764	15.52	0.000
R^2 (adjusted)	0.6165		
Lumber and Wood Products (24)			
Rton	-2765.741	-6.30**	0.000
Ip	375.5813	2.28*	0.027
Dummy	44871.69	3.44**	0.001
Constant	99595.96	12.00	0.000
R^2 (adjusted)	0.8895		
Chemicals and Allied Products (28)			
Rton	-699.1385	-2.96**	0.005
Ip	1318.974	16.92**	0.000
Dummy	12245.11	2.09*	0.043
Constant	42821.14	12.8	0.000
R^2 (adjusted)	0.9696		
Petroleum and Coal Products (29)			
Rton	-676.871	-3.76**	0.001
Ip	613.9369	6.50**	0.000
Dummy	6800.999	2.59*	0.013
Constant	1689.533	0.24	0.810
R^2 (adjusted)	0.7175		
Stone, Clay Glass, and Concrete Products (32)			
Rton	-2169.741	-16.80**	0.000
Ip	231.2307	5.07**	0.000
Dummy	21254.59	7.69**	0.000
Constant	74897.75	23.25	0.000
R^2 (adjusted)	0.9217		
Primary Metal Products (33)			

Rton	-1951.978	-5.77**	0.000
Ip	359.2521	4.14**	0.000
Dummy	34921.81	4.37**	0.000
Constant	59140.59	4.20	0.000
R^2 (adjusted)	0.7915		
Transportation Equipment (37)			
Rton	-142.5743	-6.41**	0.000
Ip	344.4825	15.29**	0.000
Dummy	-2138.688	-1.62	0.113
Constant	16912.31	6.60	0.000
R^2 (adjusted)	0.7870		

*significant at 5% level
** Significant at the 1% level
Numbers in parenthesis following the commodity name are the standard transportation industrial code numbers

Table 2: Empirical Results, Log Specification

Variable	Coefficient	t-statistic	Probability
Food and Kindred Products (20)			
Rton	-.3588928	-3.74**	0.001
Ip	.250355	1.76	0.086
Dummy	.2363098	5.02**	0.000
Constant	11.46102	29.22	0.000
R^2 (adjusted)	0.6126		
Lumber and Wood Products (24)			
Rton	-.7757609	-8.33**	0.000
Ip	.6589186	2.20*	0.033
Dummy			
Constant	10.51785	9.41	0.000
R^2 (adjusted)	0.8659		
Chemicals and Allied Products (28)			
Rton	-.2319248	-4.05**	0.000
Ip	.7965673	14.43**	0.000
Dummy	.1154938	2.93**	0.005
Constant	9.49064	76.73	0.000
R^2 (adjusted)	0.9682		
Petroleum and Coal Products (29)			
Rton	-.2800091	-3.56**	0.000
Ip	1.367995	6.83**	0.000
Dummy	.0658721	1.19	0.241
Constant	5.348242	9.94	0.000
R^2 (adjusted)	0.7268		
Stone, Clay Glass, and Concrete Products (32)			
Rton	-.6193791	-15.96**	0.000
Ip	.5671079	6.19**	0.000
Dummy	.1870066	6.17**	0.000
Constant	10.13612	32.86	0.000
R^2 (adjusted)	0.9296		

Primary Metal Products (33)			
Rton	-.5569052	-9.57**	0.000
Ip	1.136729	8.55**	0.000
Dummy	.3983874	5.31**	0.000
Constant	7.26892	11.70	0.000
R^2 (adjusted)	0.8703		
Transportation Equipment (37)			
Rton	-.327991	-4.34**	0.000
Ip	.8363946	9.43**	0.000
Dummy	-.0923239	-1.23	0.225
Constant	8.155372	23.57	0.000
R^2 (adjusted)	0.6336		

*significant at 5% level

** Significant at the 1% level

Numbers in parenthesis following the commodity name are the standard transportation industrial code numbers

Chapter 5 - Conclusion

This paper has attempted to use the most recent data in identifying the demand for railroad transportation of manufactured products. In doing so, it was shown how ordinary least squares regression can be used for the purposes of measuring the demand for rail transport, and it was observed that there are fundamental differences in the makeup of this demand in the post 2004 time period.

The initial explanatory variables in the model did not all turn out to be significant or have the theoretically correct sign, possibly due to multicollinearity. After dropping these from the model, we were able to develop an equation that can be used to measure railroad demand of manufactured goods.

Rail demand was price inelastic in all the markets. However, there was variation in the price elasticities across the seven markets. The price inelasticity is to be expected given the high level of aggregation of the model. As the level of aggregation becomes more disaggregated, the substitution possibilities increase for shippers. Thus the price elasticities for an individual railroad would be more price elastic then the elasticities estimated by the model which pertain to the entire rail industry.

As far as the changes in the structure of demand over time, this was addressed through the implementation of a dummy variable. The dummy variable was significant for most of the commodities that we investigated, indicating a structural break in rail demand in the 2005-2010 period.

The model developed in this thesis can be used to forecast railroad demand. Forecasts are useful for transportation policy makers. They could be used to assess the impact of regulatory changes on the relative shares of railroads in the various transportation markets. The model could also be used to measure the impact of increased fuel prices in truck-rail competition.

Forecasts of railroad transportation demand are essential for railroads. They can reveal which markets offer the greatest potential, and also opportunities for market penetration at the expense of rivals. Even if specific forecasts are eventually in error, the forecasting exercise is still worthwhile for the railroad. This is because forecasting forces a consideration of the major factors affecting transportation markets and can ultimately improve railroad investment planning strategy.

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