EXPLANATORY VARIABLES FOR ROAD FREIGHT RATES IN BRAZIL: EVIDENCE FROM AGRIBUSINESS SUPPLY CHAINS

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ABSTRACT
This article sought to explain the complex nature of the principles of the formation of transport prices, focusing on certain dysfunctions and the limited efficiency of the negotiation of freight rates for the supply chains of Brazilian Agribusiness. Statistical and econometric techniques were used to identify the systematic behavior of the freight rates of the selected products, and, where possible, this procedure was allied to other market evidence. The influence of some of the variables affecting freight rates was found with a reasonable degree of certainty, in spite of the lack of systematic behavior between regions and periods of time and other factors that reflected the overloading of the infrastructure. It was concluded that the strength of these variables in the formation of freight rates lies in the fact that they make it possible both to develop negotiation strategies and minimize conflicts in negotiations to the extent that the costs are identified by the parties concerned

Keywords: Agribusiness Logistics, Transport Costs, Freight Rates

INTRODUCTION

According to what Mason *et al.* (2003) report, for example, empirical studies demonstrate that transport costs comprise from 2 to 4% of earnings and from 30 to 60% of a company's total logistic costs.

Transport is one of the logistic activities that is directly involved in logistic planning and, for this reason, it is one of the key factors in of supply chain performance. Therefore, transport should be organized so that it is integrated with supply, production, distribution and consumption processes in the sequence of business operations (Pedersen, 2001; Nielsen *et al*, 2003). Thus the logistic management of transport implies numerous trade-offs within the logistic system as a whole, such as

decisions whether or not to centralize stocks in the supply chain, stocking policies and the number, location and size of logistic installations, among others.

One of the most frequently used forms of drawing up the parameters for supply chain performance involves the costing process. In this case, the transport companies add the direct freight costs deriving from actual transport of the goods to the indirect costs from operational efficiency which flow over into other activities and operations of the logistic system.

However, the specificities of this economic activity and of the local, short-term and external variables make the freight market an extremely complex structure that is difficult to manage according to the logistics of the chain of business operations.

In the case of Brazil, these difficulties have special characteristics because of the serious deficiencies in the transport system. As a general rule, the country has had the same size of rail network for the last 80 years; only a small number of roads are surfaced (approximately 10%) and, according to the National Confederation of Transport Companies (NCTC), most of these are in a precarious state of repair; the railways provide a slow service with low productivity, using a network that has remained practically unchanged for eighty years; development of the existing potential for river transport is impaired by two factors. First of all, there is the geographical location of the rivers, which are far from the main economic centers and have no direct link to the sea, and, in second place, the fact that hydroelectric stations have been built without paying due attention to the construction of locks; the port system is, technologically, very out of date, all of which results in expensive services with low productivity.

The aim of this article is to investigate the evidence of the effect of variables and the relative importance of drivers for the formation of road freight rates of agribusiness supply chains in Brazil.

PRINCIPLES OF THE FORMATION OF TRANSPORT PRICES

According to the Department of Transportation (1995), the formation of transport service prices, ie, freight rates, is relatively complex because, in addition to the costs of the activity itself, local and general factors are involved. These have a direct effect through events that cause variations in demand for the service: the performance of the economy (demand for transport is “derived demand”); certain business strategies such as, location, production management, stocking and policies regarding centralization of warehouses; international commercial agreements, such as Mercosur and Nafta; packing materials (innovations in lighter materials along wiht innovations in cargo containers); and reverse flows (for example, for recycling purposes). And an indirect effect through factors which effect the costs of providing the service, such as: regulation/deregulation; variations in fuel prices; innovations in vehicles and cargo containers; congestion; and weight limits for movement of goods and the strictness of enforcement of these limits

Castro (2002) mentions that Samuelson (1977) developed a simple theoretical model to calculate the freight rate in situations where a transport company enjoys a monopoly. If we assume that the this company will try to maximize profits, the freight rate can be calculated as follows:-

$$t = \frac{dC}{dD} + p\left(\frac{1}{Ed} + \frac{1}{Es}\right) \qquad (1)$$

that is, the company sets a price equal to the marginal transport cost (***dC/dD***) plus the price (***p***) of the goods times the sum of the inverse elasticities of demand ($\boldsymbol{E_d}$) and supply ($\boldsymbol{E_S}$), where both values are taken as being positive.

Samuelson derived some guidelines from this equation, regarding the formation of transport costs, namely:

1) transport tariffs tend to increase in accordance with the unit value of the goods transported;
2) goods that have a greater elasticity of supply or demand tend to pay lower tariffs;
3) the structures of the supply and demand market for the goods hauled has an effect on the transport tariffs paid for the goods;

4) the closer the market structure comes to perfect competition, the nearer transport tariffs approach the marginal costs of production.

However, within this set of factors there are complex relations that influence freight costs. According to McCann (2001), the variables of "distance" and "quantity" to be transported together determine the appropriate vehicle, depending on its capacity, and the behavior of the freight rate, depending on the distance the cargo is to be hauled. This has been proved by an equation for logistic costs which states that:

1) the theoretical optimum size of the vehicle is not always positively related to the distance traveled, in spite of the fact that such a relation is normally found empirically.
2) the relationships between the value of the freight per ton and the distance traveled produce a concave curve, except in the case where the optimum type of vehicle does not vary according to the distance traveled.
3) the relationships between the value of the freight per ton and the amount transported produce a convex curve.

There is an apparently paradoxical relationship between transportation costs and freight rates. Whereas the cost curve has a linear rising shape, the freight rate/distance relationship has a falling shape which produces a concave curve and the freight rate/quantity relationship produces a convex curve, implying that the optimum capacity of the vehicle to be used tends to increase in line with the increase in distance and quantity and vice-versa.

These relationships can be explained by the fact that there are economies of scale and distance which have a predominant effect on freight costs. The economies of scale were discovered from an examination of the elasticity of cost-production (E_c), shown in (2) as

$$E_c = \frac{\Delta C/C}{\Delta Q/Q} \qquad (2)$$

which measures the proportional variation in the costs of production (C), occurring as a result of the proportional variation in the quantities produced (Q). There are economies of scale in cases where the proportional variations in costs are smaller than those which occur as a result of the quantities transported.

One way to obtain these parameters is demonstrated by McCann (2001), who deduced that the freight would be as shown by

$$t_i = \frac{v_i}{Q} \qquad (3)$$

where

t_i = the value of the freight in relation to the quantity transported times the distance traveled ($/t.km);
v_i = the value of the freight in relation to the distance traveled ($/km);
Q = the quantity of cargo to be transported per vehicle.

Therefore, economies of scale in transport can be associated with reductions in ***t***, and the extent to which there is an increase in quantity, ***q***, as shown in Figure 1. Thus, Savage (1997) found such economies in rail transport in the United States. According to McCann (2001), this relationship takes place at the rate of $1/\sqrt{m_i}$, where $\boldsymbol{m_i}$ is the total quantity to be transported. In this case, it is preferable to use higher capacity vehicles for hauling large quantities.

On the other hand, it can be seen from equation (3) that where the vehicle remains the same, as the distance increases, the relative cost of the journey decreases ($/km), $\boldsymbol{v_i}$. McCann (2001) estimated that this relation occurs at the rate of $1/\sqrt{d_i}$, where $\boldsymbol{d_i}$ is the distance traveled.

Other studies have looked for evidence of explanatory variables for the market freight rates. In general, a concentration of approaches has been found that hold distance to be the primary factor determining values, independently of the mode of transport used. Correa Júnior *et al.* (2001) also state that, in general, studies that seek to identify the determinants of road freight costs, first of all make use of the distance as the principal factor and then make adjustments in the light of other factors. The distance traveled influences the unit costs of transport, that is, the cost per ton (US$/t), which suggests that the value is sensitive to the mileage hauled.

Still using the costs of providing the service as the basis, the market freight rates also reflect the investments made in order to provide the service, taking into account the specific features of the cargo, which implies more expensive assets and cargos with either a higher level of risk or which require special handling. For example, shippers of soybean oil and refrigerated cargo require special types of truck which results in sunk costs for the service provider. The suppliers take this necessity and the associated risk into account and, so the freight rates reflect the demands imposed by the cargo, since it is necessary to obtain a return for the specific asset involved, for example, a tanker truck. In the case of fragile goods which have a high loss rate, there is a specific cost for the more specialized service required.

Once the basic costs of providing the transport service have been established, the transporter may be inclined to offer discounts or prizes, depending on the actual and potential levels of competition in the market and on the (Davies, 1986). The discounts and prizes may be offered in certain situations, such as the quantity and frequency of the business offered by the shipper, the geographical features of the route, the probability of obtaining backhauling and the overall demand in the economy and seasonal peaks for some of the main types of cargo, among other factors.

Negotiations are always very intense. The shipper is concerned about the impact of transport costs on the profit margin provided by the difference between costs of production and market price, while the transporter takes average cost as the minimum reference value.

METHODOLOGY

This research is of an essentially empirical and exploratory nature, seeking to analyze market evidence in order to explain the formation of road freight rates in Brazil in agribusiness supply chains. Statistical and econometric techniques were used to identify the systematic behaviors of the freight rates for selected products, and where possible, this was associated with other types of market evidence.

The Effect of Distance on Freight Rates

According to the literature, distance is, theoretically, the main explanatory variable for freight costs. By means of regression analysis, it was intended to demonstrate the explanatory power of distance alone on the freight rates charged for soybean, according to distance traveled in the different Brazilian regions,. Consequently, the different freight rates were organized region by region in accordance with the point of origin and/or destination of soybean.

The basic texts in econometrics show some of the common functional forms which seek to explain the relationship between the variables under consideration. In the specific case of this study, the relevant variables are the freight rates in operation in different regions (v) and the different distances (x). The functional forms normally used are those shown in Figure 3.

The Effect of Seasonal Demand

It is therefore to be expected that different agricultural products will exhibit seasonal behavior as a result of the seasonal production of the products under study. The value of the freight rates varies in

intensity depending on the time of year and the volume to be hauled, due to the low fixed storage capacity at the cooperative and cereal producers' properties.

The investigation into seasonality carried out in this research is based on a time series of the freight rates for coffee, soybean, soybean meal and wheat for different routes in the State of Paraná and other routes that either originate or terminate in the same state. It was aimed to find out if the freight costs for these products were subject to cyclic variations that constituted more than just a tendency. If these elements were found to be present, it was aimed to discover when they predominated, since this information would allow prices to be forecast.

Type	Statistical Model	Angular Coefficient
1. Linear	$v_i = a + b\ X_i + e_i$	b
2. Recíprocal	$v_i = a + b\ \frac{1}{X_i} + e_i$	$-b\ \frac{1}{X_i^2}$
3. Logarithmic	$\ln(v_i) = a + b \ln(X_i) + e_i$	$b\ \frac{v_i}{X_i}$
4. Log-linear (Exponential)	$\ln(v_i) = a + b\ X_i + e_i$	$b\ v_i$
5. Linear-log (Semi-log)	$v_i = a + b \ln X_i + e_i$	$b\ \frac{1}{X_i}$
6. Log-inverse	$v_i = a - b\ \frac{1}{X_i} + e_i$	$b\ \frac{1}{X_i^2}$
7. Quadratic	$v_i = a + b\ X_i + c\ X_i^2 + e_i$	$b\ e\ c$

Figure 3 – Alternative Functional Forms for Econometric Estimates

The test for seasonality was made by means of regression analysis from the Proc Reg of the Statistical Analysis System (SAS), and by using the harmonic analysis model to determine the amplitude of the phasic angles of prices

The Influence of Other Variables

The specific freight rates for agribusiness products from the State of Paraná were also investigated vis-a-vis the relative influence of corridors and of such products as sugar, coffee, soybean meal, corn, soybean and wheat.

The average test was used for the statistical analyses to back up these investigations. This formulation was used to test the statistical significance of the freight rates charged in the different corridors under study. Therefore, when the hypothesis that H_0: $\delta = 0$ is accepted, it may be concluded that the averages of the freight rates of two corridors are equal. However, when this hypothesis is rejected, the averages of the freight rates are different, or, in other words, the freight rates charged for the same length of journey are different.

The Source and Nature of the Data

The freight rates used in the above studies, and for the evidence presented in this article, were obtained from the Freight System for Agricultural Cargo, at the Luiz de Queiroz - Centre for Applied Economics at the University of São Paulo, which compares freight rates from a very large number of origin-destination points, for the period 1998 to 2004, organized according to mileage.

EVIDENCE OF HOW FREIGHT RATES ARE ESTABLISHED

The Role of Distance in the Formation of Freight Rates

The parameters estimated for the linear model had values close to those obtained by Castro (2002) e Correia Júnior (2001) for different regions and distances. However, as expected, no significant differences were observed between the functional forms. The results obtained for the regressions had very similar values and it was not possible to decide which functional forms was best for estimating freight rates in Brazil.

In any case, the fact that distance behaved like an explanatory variable, and was statistically significant in all of the models, means that mileage should be taken to be an important variable in the formation of freight rates. However, it is also necessary to take into consideration the fact that the significance of distance varies as much with the detailed characteristics of the cargoes as it does with the regions.

In the case of Brazilian agribusinesses, it can be seen from Table 1 that greater distances do, indeed, mean higher unit freight costs ($/t). However, it can also be seen that the return per kilometer traveled (US$/t.km) moves in the opposite direction. This is the effect of the principle of economies of distance which was theoretically proven by McCann (2001) and which occurs to a greater or lesser degree according to the levels of competition and the actual and potential levels of market competition (Davies, 1986). Taking the transport of soybean in Brazil as a basis, the drop in returns is relatively abrupt and makes it possible for road transport to be competitive. This reflects the excess of supply in a road transport market dominated by independent carriers.

Table 1 – Road Freight for Transport of Soybean in November 2005

Origin	Destination	km	US$/ton	US$/ton.km
Quirinópolis – State of Goiás	São Simão – State of Goiás	75	5.78	0.077
Sorriso – State of Mato Grosso	Santos – State of São Paulo	2.030	65.77	0.032

Source: sifreca.esalq.usp.br.

The low return per kilometer ($/t.km) accepted by agents providing this mode of transport for distances above 1,000 kilometers has the effect of inhibiting the demand for and the viability of rail transport for distances at which, theoretically, this mode is more competitive. This has a harmful effect on decisions about investment in mealch lines and expansion of the network. In the case of river transport, demand is repressed by the poor availability of storage and the irregular supply of the service, along with situation imposed by geography, in that the geographical location of our river basins do not serve the main centers of consumption.

In other words, the historical restrictions on investment for the expansion of transport systems and the lack of a logistic system of terminals and warehouses have combined to favor the predominance of road transport. Therefore, road transport is the main method for moving products with low added value over large distances, which conflicts with the principles of transport economies (McCann, 2001), as far as the transport model for countries of our size is concerned and, specifically for cargos of agricultural commodities.

The deficiencies of the infrastructure affect practically all sectors of the economy. Given that freight rates are an important factor in the establishment of prices for goods using export) corridors and result from negotiations between shippers who pay great attention to the volume of cargo and other features associated with the specific characteristics required by transport assets) and transporters and agents, some agribusiness cargos, such as corn, actually pay the market freight rate for soybean, even though not having the same market value as this product.

In other words, the role of distance in the establishment of freight rates in Brazil is distorted by the structural features of the transport systems and by other factors belonging specifically to the road freight market.

The Seasonality of Freight Rates

If the significant volumes of soybean transported in Brazil are taken into consideration, which gives those who ship this cargo special prominence, the lack of infrastructure means that the whole system is overburdened at harvest time. Because of the seasonal nature of demand and the lack of adequate provision of public (transport systems) and private (storage systems) logistics, the freight rates follow the peaks in the demand for the service. For example, in Brazil, at harvest time, freight rates rise significantly in comparison with the period between harvests, as Table 2 shows.

In order to statistically identify seasonality, adjustments were made to all the equations described in the section on methodology; both the observed values and the logarithmic transformation of the dependent variables. The best adjustments occurred in the case of logarithmic transformation. The results are presented with the anti-log of all the variables.

It should be emphasized that the models for points of origin or destination in the State of Paraná for coffee and bulk wheat on routes between 400 and 700 kilometers and for soybean and soybean meal on routes above 700 kilometers were not significant at levels of significance with a probability of less than 10%.

Tabel 2 – Road Freight for the transport of Soybean between Canarana (State of Mato Grosso) and Paranaguá (State of Paraná), in November 2004 and March 2005

Months	US$/ton	US$/ton per km
Nov/04	34,96	0,018
Mar/05	60,53	0,031

Source: Basic Data from sifreca.esalq.usp.br

Figure 4 shows the comparative behavior of the real and estimated values for soybean freight rates for distances of between 400 and 700 kilometers inside and outside the State of Paraná.

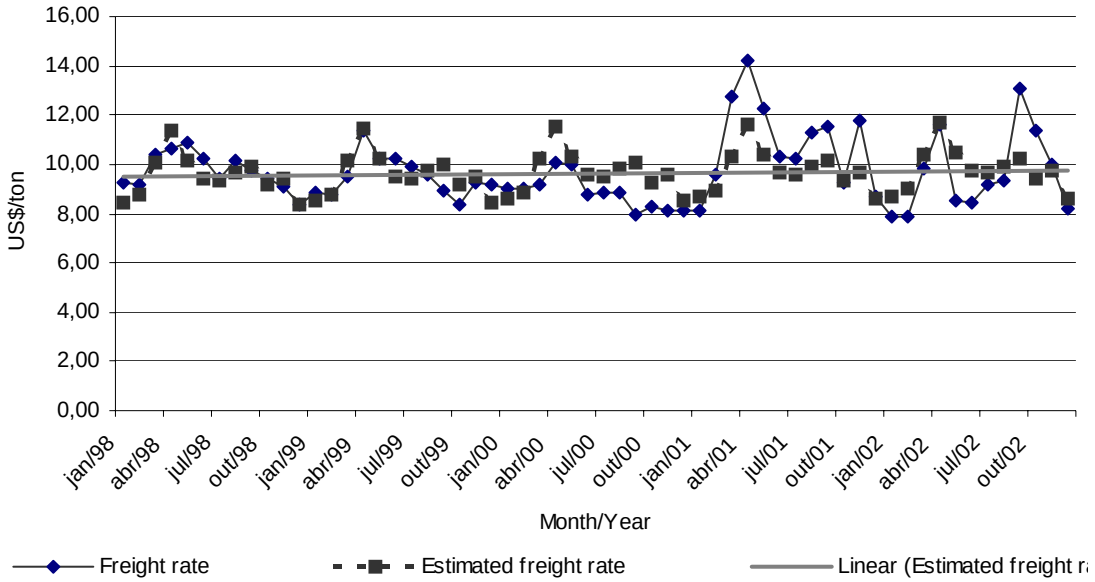

Figure 4 – Real, Estimated and Tendential Freight Rates – Soybean on Road Routes from 400-700 kilometers long within and outside the State of Paraná

It was found that none of the coefficients associated with pairs of harmonic components had a significant value. In this case, it was not possible to state with certainty that these data show the

presence of annual cycles. An important factor that may have contributed to this unfavorable result is the size of the data series, since the freight rates that were obtained for soybean on road routes within and outside the State of Paraná for distances of 400 to 700 kilometers, were for a period of only 3 years and this is a particularly low number when attempting to evaluate cyclical or seasonal variations. There was found to be a large variation in the residuals with extreme values, which varied from -7.78 to 11.44. In spite of the fact that, at first sight, the estimates for the parameters of the three harmonic components appear to indicate that there were seasonal cycles, the low number of observations may have distorted this result.

The tendencial variable, however, was positive and significant, indicating that, in real terms, the freight rates for this product and this specific distance have been rising and, as Correa Júnior *et al* (2001) highlighted, this implies the impact of variables which interfere in the establishment of the price of transport, such as increases in operational costs, mainly diesel fuel, and market instability, where soybean competes with industrialized products in the transport market.

Although the graph shows successive peaks in freight rates in April, the statistical proof of seasonality in this period may have been distorted by the alterations recently observed in this market.

One of these alterations has to do with the very unstable state of affairs that caused the emergence of different market strategies in negotiations for the sale of crops. Periods of good harvests that are not fully expected ("bumper harvests") mean a significant increase in the demand for transport, as in 2001, and, due to the low fixed storage capacity, the excess production has to be sold as soon as it is harvested, and this overloads the market.

On the other hand, harvests which meet expectations although with rising prices or a favorable foreign exchange situation, cause the product to be withheld, waiting for the selling prices to continue to improve and this means strategies of holding on to stocks of different crops, such as corn or meal, and not selling until it becomes clear which one has the most favorable price , as was the case in 2002 in the State of Paraná.

The large shipping companies, which operate on a national scale, define the strategy of logistic investment in storage for crops, mainly in the West-Central Region. These shippers stock the harvest locally or regionally and as a result, greater and greater volumes of cargo are being transported on shorter routes

These companies also determine new strategies for freight contracts. General increases in costs, including freight rates and toll charges, along with the inflexibility of international prices and lack of storage structure at the ports, led the shipping companies to create a new system for managing freight contracts which sought more formally established service providers and less direct negotiation with truck owners and which also offered cargos more evenly distributed over the whole year in return for a contractual relationship made viable by the logistic strategy implemented.

As a result of this new method of management, there are signs that freight rates will be less unstable in coming years, with fewer peaks, except when there are unforeseen bumper harvests.

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Other Evidence of Variables that are Important in the Formation of Freight Rates

Differences in freight rates can also be seen in cases where the cargo requires special packing, such as when more expensive assets are involved, or due, for example, to the characteristics of the cargo, because of the risk of loss of quality or the need for special care to prevent damage. Shippers of soybean oil and refrigerated cargo require special trucks for transport, which results in sunk costs for the service provider. The suppliers consider this requirement and the associated risk, and, therefore, the freight rates reflect the requirements of the cargo, as shown in Table 3, because there is the need to obtain a return on the specific assets involved, the tanker truck. In the case of fragile cargo, which has a high rate of loss, there is also a charge for this more specialized service.

There may be important differences between the economies provided by specific service providers (modal or even unimodal providers) and the way the service is carried out [performance

of the business] (freight contract). This occurs because, in addition to its strictly economic attributes, the freight market is sensitive to other variables concerning the level of service required/desired by the shipper. For example, shippers of perishable goods, with a low turnover, high aggregate value and rigid delivery dates, tend to show preference for more expensive transport service, since this price is compensated by the security and speed offered.

Table 3 – Road Freight Rates for the Transport of Selected Products – February 2006

Product	Origin	Destination	Distance	US$/t
Cargo with low asset specificity				
Sugar (sacks)	Sud Menucci (State of São Paulo)	Santos (State of São Paulo)	663	27.18
Soybean (bulk)	Medianeira (State of Paraná)	Paranaguá (State of Paraná)	632	16.66
Refrigerated Cargo				
Beef	Bataiporã (State of Mato Grosso do Sul)	São Paulo (State of São Paulo)	763	63.06
Fragile Cargo				
Papaya	Linhares (State of Espírito Santo)	Rio de Janeiro (State of Rio de Janeiro)	672	70.78
Tomatoes	Itaperuna (State of Rio de Janeiro)	São Paulo (State of São Paulo)	640	51.18
Bulk Liquids				
Soybean Oil (bulk)	Uberlândia (State of Minas Gerais)	São Paulo (State of São Paulo)	587	29.42

Source: Sifreca Bulletin, 10(106), February 2006.

FINAL CONSIDERATIONS

It was possible to identify the influence of many variables on the formation of freight rates, such as distance, seasonality of production, the corridors along which the cargo is transported, its specific characteristics and the resulting demands made by customers. These are fairly plausible, in spite of the fact that there is lack of systematic behavior between regions and time periods. However, as a result of overloading of the infrastructure, some products were found to be affected by the transportation of soybean, even though it was transported outside the peak period for harvesting the grain.

It was also concluded that the difficulties of transport management in supply chains has a significant impact on the relationship between the links in the chains. The fact that it is difficult to understand the set of explanatory variables for the formation of freight rates and the respective weight to be given to shippers and transportation companies constitutes an important hindrance to the full development of competitiveness in supply chains, since the incompletely formalized mechanisms for creating more simple forms of remuneration have not shown themselves to be capable of either managing more complex relationships between shippers and logistic service providers or of reducing to a significant degree the amount of shared earnings derived from productivity increases and improvements in the quality of logistic operations supplied by logistic service providers.

One limitation of the research has to do with the fact that the evidence used was restricted to agribusiness. It is certain that more definite conclusions would demand wider sectorial analyses. However, this was not a feasible proposition in this research, due to the temporary lack of a freight rate data base.

Thus, future research on the basic factors in the formation of freight rates will require to find a means of carrying out a sectorial investigation that takes into account the relevant analyses of supply chains in the formation of freight rates and the history of performance and service providers' costs and returns, among other possibilities.

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