



# Assessment of the Impact of the Level of Railway Tariffs on the Evolution of Cargo Supply Chains

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**Abstract.** The objective of the paper is to quantify the impact of rail tariff levels on the evolution of freight supply chains. The following methods were used: econometric modeling, comparative method, analysis, statistical method, systemic method. Using econometric modeling and comparative calculation, a quantitative assessment was made of the impact of the level of freight railway tariffs on the evolution of supply chains in terms of changing one mode of transport to another on the example of transportation of oil cargo and coal in the Russian Federation; additional comments were formulated to the conclusions of the obtained assessment; recommendations for further refinement of the results of the econometric assessment have been developed. The results of the research can be used to optimize tariffs for rail transport in the face of constrained supply chains of goods, as well as for further research in the field of the evolution of supply chains of goods and pricing in rail transport.

**Keywords:** Cargo supply chains · Rail tariffs · Pricing · Evolution · Oil cargo · Coal

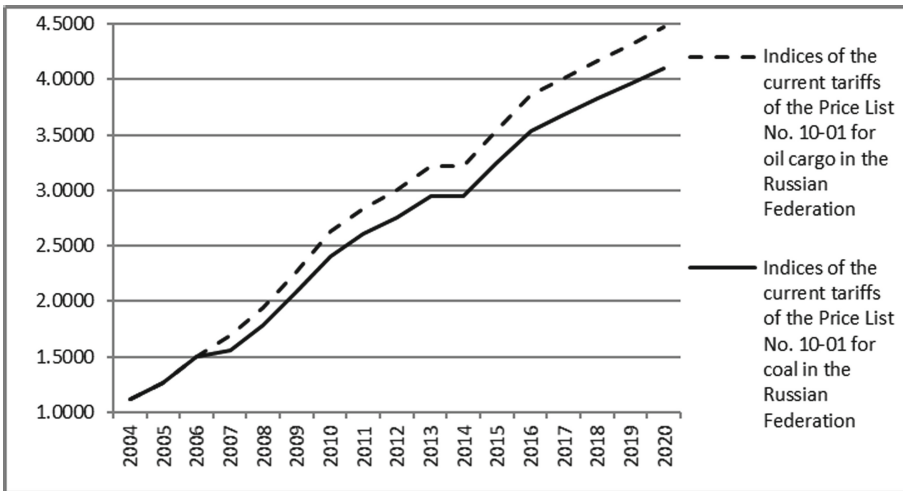
## 1 Introduction

Trends in cargo supply chains i.e. the evolution (transformation) of cargo supply chains is influenced by a variety of factors. For example, in terms of changing one mode of transport to another in the cargo supply chains, factors contributing to such a change include: the availability of the ability to transport large consignments of cargo, the availability of the possibility of exporting cargo in full, the presence of a developed transport infrastructure, the availability of the ability to carry out transportation in the near future after submitting an application for transportation, the timing of the vehicle's submission for loading, the availability of the ability to track the cargo along the route, the degree of safety of the cargo during transportation, compliance with the delivery time of the cargo, the delivery time of the cargo, the cost of transportation, the degree of flexibility in pricing for transport services, the ability to carry out door-to-door cargo transportation, the speed of response to customer requests, the ease of interaction with the carrier regarding the application for transportation, the level of development of

transport and logistics centers, the quality of preparation of the vehicle for transportation, assortment t of the services offered by the carrier and other factors.

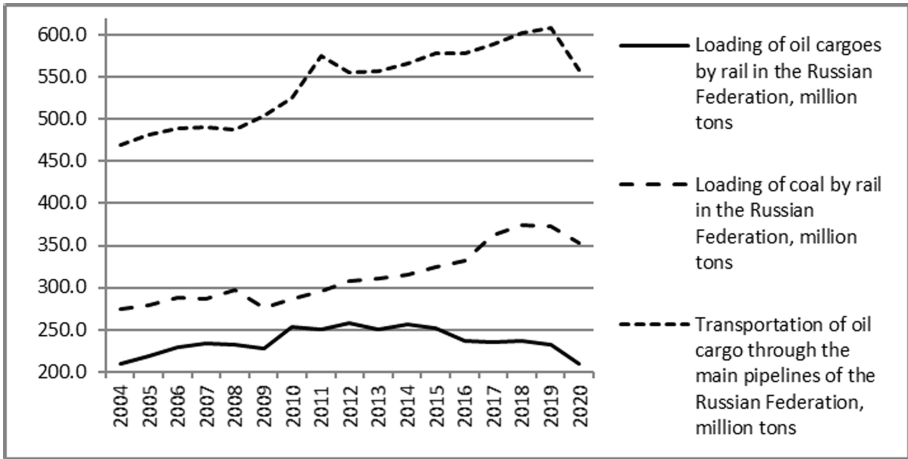
One of the most important of these factors is the cost of transportation, which is confirmed by the results of surveys of cargo owners, owners of rolling stock, representatives of transport and logistics companies, owners or operators of infrastructure. At the same time, the cost of transportation is determined by the level of transport tariffs applied for specific goods by various modes of transport. A particular case of the influence of the factor of the cost of transportation of goods on the transformation of supply chains in terms of changing one mode of transport to another is the case of freight rail tariffs.

Note that the problem of assessing the impact of the level of railway tariffs on the evolution (transformation) of freight supply chains is, including in terms of changing one mode of transport to another, a problem not only of a theoretical, but also of an important practical nature. Thus, the growth / value of the level of freight railway tariffs for the transportation of oil cargoes and coal in the Russian Federation (Fig. 1), a number of researchers name among the main factors of the transition of part of oil cargo from railway to pipeline transport and part of loading coal from railway to road transport in 2010–2020 (Fig. 2).



**Fig. 1.** Indices of the current tariffs of the Price List No. 10–01 for oil cargo and coal in the Russian Federation in 2004–2020. (according to Rosstat data [1]).

In 2020, the railway transport of the Russian Federation accounted for about 20% of the loading of coal in the domestic traffic, about 40% of the loading of coal for export, about 16% of the loading of oil cargo in the domestic traffic and about 20% of the loading of oil cargo for export [1]. Therefore, even a partial transfer of these cargoes from rail to other types of transport results in the loss of multibillion-dollar income for Russian Railways and rolling stock operators.



**Fig. 2.** Volumes of loading oil cargoes and coal by railway transport of the Russian Federation and transportation of oil cargoes through main pipelines of the Russian Federation in 2004–2020. (according to Rosstat data [1]).

Recent work on trends in cargo supply chains and drivers of these trends include publications by Macioszek et al. [2], Antún [3], Carlan et al. [4], Perboli et al. [5], Runhaar and van der Heijden [6], Taniguchi et al. [7], Schniederjans et al. [8]. In the field of theory and methodology of freight railroad tariffs, recent publications include the works of Pittman [9], Poliak et al. [10], Serfas et al. [11], Wilson and Wolak [12], Brewin et al. [13], MacDonald [14], Alises et al. [15], Boyer [16]. Also indirectly, the studied problem is affected by the works of Chechenova et al. [17], Guliy et al. [18], Tretyak et al. [19].

Recognizing the depth and thoroughness of the studies carried out on the problem under consideration, some of their limitations should be noted:

1. studies of the influence of the level of railway tariffs on the evolution (transformation) of freight supply chains are, as a rule, mainly of a qualitative nature; an exception is the work of Brewin et al. [13], in which an attempt was made to quantify the consequences of the abolition of the maximum tariff for the carriage of grain by rail in Canada on the grain supply chains in the country;
2. the researchers for the most part do not analyze the influence of the level of railway tariffs on the evolution of freight supply chains in terms of changing one mode of transport to another.

The foregoing substantiates the relevance of this research, and helps to formulate its objective: to quantify the impact of rail tariff levels on the evolution of freight supply chains.

## 2 Materials and Methods

### 2.1 Research Methodology

To quantify the impact of the level of railway tariffs on the evolution of cargo supply chains (for example, the transition of oil cargo and coal from railway transport to other modes of transport), a first-order autoregressive model of the following type is used:

$$y_t = a + b_0 * x_t + c_1 * y_{t-1} + \varepsilon_t, \quad (1)$$

where  $y_t$  – the resulting variable (volumes of cargo transportation by rail and pipeline) at time  $t$ ;

$y_{t-1}$  – resulting variable at time  $t-1$ ;

$x_t$  – indicators of the level of the current tariffs of railway transport (indices of the current tariffs of the Price List No. 10–01) at time  $t$ ;

$b_0, c_1$  – model coefficients;

$\varepsilon_t$  – residual term of autoregressive model.

This instrumental variable is defined using the view model:

The estimation of the coefficients of model 1 is carried out in 2 steps using the instrumental variable  $\widehat{y_{t-1}}$ , which is substituted into model 1 instead of the lag variable  $y_{t-1}$ . This instrumental variable is defined using a model of the form:

$$y_{t-1} = d_0 + d_1 * x_{t-1} + u_t, \quad (2)$$

where  $u_t$  – residual term of regression model 2;

$x_{t-1}$  – indicators of the level of the current tariffs of railway transport (indices of the current tariffs of the Price List No. 10–01) at time  $t-1$ ;

$d_0, d_1$  – coefficients of regression model 2 estimated using classical least squares method.

The assessment of the statistical significance of model 1 is carried out using the Fisher criterion, the assessment of the statistical significance of the coefficients of model 1 - using the student's test. Testing of model 1 for the presence of auto-correlation of residuals (if necessary) is carried out using the Darbin h test.

Also, the study uses a comparative method, analysis, statistical method, systemic method. These methods are used to generalize the provisions of published works on the problem under study, when conducting econometric modeling and for a comprehensive interpretation of the results of this modeling, to construct and interpret a comparative calculation of the average growth rates of indicators of the level of railway tariffs and transportation of goods by rail and pipeline transport, to generalize the - research results.

### 2.2 Theoretical Fundamentals

The autoregression model (in this study, the first-order autoregression model is used) was first applied for econometric analysis by Yule [20] and Slutsky [21] in the 1920s and 1930s. XX century Comparative method, analysis, statistical method, systemic method are general scientific methods used for scientific research since ancient times.

### 3 Results

The assessment of the influence of the level of railway tariffs on the evolution of freight delivery chains was carried out using the autoregressive model 1 on the example of the transportation of oil cargo and coal by rail and pipelines in the Russian Federation during 2003–2020 (the phenomenon of the transition of oil cargo and coal from railway transport to other modes of transport).

Table 1 presents the results of the assessment of model 1 of autoregression of the influence of the level of the current tariffs of Price List No. 10–01 for oil cargoes in the Russian Federation transported by rail (separately for the time intervals 2004–2020 and 2010–2020).

**Table 1.** The results of the assessment of model 1 of the autoregression of the influence of the level of the current tariffs of the Price List No. 10–01 for oil cargo in the Russian Federation (railway transport, the significance level  $\alpha = 0.05$ , estimated by the author on the basis of Rosstat data [1])

Resulting variable $y_t$	Statistical significance of model 1	Statistical significance of the coefficient $b_0$ of model 1	Statistical significance of the coefficient $c_1$ of model 1	Estimation of the coefficient $b_0$ of model 1	Estimation of the coefficient $c_1$ of model 1
Oil cargo handling (2004–2020), million tons	Insignificant	Insignificant	Insignificant	10,78	–1,37
Oil cargo handling (2010–2020), million tons	Significant	Insignificant	Insignificant	–26,78	–0,30

Table 2 shows the results of the assessment of model 1 of autoregression of the influence of the level of the current tariffs of Price List No. 10–01 for oil cargo and oil in the Russian Federation on the volumes of these cargoes transported by main pipeline transport in 2004–2020.

**Table 2.** The results of the assessment of model 1 of the autoregression of the influence of the level of the current tariffs of the Price List No. 10–01 for oil cargo and oil in the Russian Federation in 2004–2020. (pipeline transport, significance level  $\alpha = 0.05$ , estimated by the author on the basis of Rosstat data [1])

Resulting variable $y_t$	Statistical significance of model 1	Statistical significance of the coefficient $b_0$ of model 1	Statistical significance of the coefficient $c_1$ of model 1	Estimation of the coefficient $b_0$ of model 1	Estimation of the coefficient $c_1$ of model 1
Oil cargo transportation, million tons	Significant	Insignificant	Insignificant	5,44	0,75
Oil transportation, million tons	Significant	Insignificant	Insignificant	4,33	0,75

Table 3 presents the results of the assessment of model 1 of autoregression of the influence of the level of the current tariffs of Price List No. 10–01 for coal in the Russian Federation transported by rail in 2004–2020.

**Table 3.** The results of the assessment of model 1 of the autoregression of the influence of the level of the existing tariffs of the Price List No. 10–01 for coal in the Russian Federation in 2004–2020. (railway transport, significance level  $\alpha = 0.05$ , estimated by the author on the basis of Rosstat data [1])

Resulting variable $y_t$	Statistical significance of model 1	Statistical significance of the coefficient $b_0$ of model 1	Statistical significance of the coefficient $c_1$ of model 1	Estimation of the coefficient $b_0$ of model 1	Estimation of the coefficient $c_1$ of model 1
Loading of coal, million tons	Significant	Insignificant	Insignificant	–33,42	2,04

In addition to the results of the estimates of model 1 (Tables 1, 2 and 3), Table 4 presents a comparative calculation of the average chain growth rates of the indicators of the level of the current tariffs of the Price List No. 10–01 and the indicators of transportation of goods by rail and pipeline transport in the Russian Federation (for oil cargo and coal).

**Table 4.** Average chain growth rates of indicators of the level of the current tariffs of the Price List No. 10–01 and indicators of cargo transportation by rail and pipelines in the Russian Federation (for oil cargo and coal, calculated by the author on the basis of Rosstat data [1])

Indicator	Average chain growth rate of the indicator in 2005–2020, %	Average chain growth rate of the indicator in 2010–2020, %
Indices of the current tariffs of the Price List No. 10–01 for oil cargo in the Russian Federation	9,2	6,4
Indices of the current tariffs of the Price List No. 10–01 for coal in the Russian Federation	8,6	6,4
Loading of oil cargoes by railroad transport of the Russian Federation, million tons	0,1	–0,7
Transportation of oil cargo through the main pipelines of the Russian Federation, million tons	1,2	1,0
Loading of coal by railway transport of the Russian Federation, million tons	1,7	2,3

## 4 Discussion

An econometric assessment of the impact of the level of the current tariffs of Price List No. 10–01 for oil cargoes in the Russian Federation transported by rail did not reveal a statistically significant effect in terms of the coefficients of the model and the model itself as a whole for the time interval 2004–2020. (row 2 of Table 1). This influence was revealed for the interval 2010–2020. only in part of the model as a whole, but the coefficients of the model are still insignificant, Durbin’s h test is not applicable for testing the autocorrelation of the model residuals (row 3 of Table 1). That is, according to the results of the assessment of model 1, the growth of tariffs for the transportation of oil cargo in the Russian Federation by rail did not have a statistically significant effect on the volume of transportation of these goods by rail both in 2004–2020 and in 2010–2020.

An econometric assessment of the influence of the level of the current tariffs of Price List No. 10–01 for oil cargoes and oil in the Russian Federation on the volumes of these cargoes transported by pipeline transport revealed a statistically significant effect in terms of the model as a whole for the time interval 2004–2020. (Table 2). However, the coefficients of the model are statistically insignificant and Darbin’s h test is not applicable for testing the autocorrelation of the model residuals. Thus, according to the results of the assessment, the growth of tariffs for the transportation of oil cargo and

oil in the Russian Federation by rail did not have a statistically significant effect on the volume of transportation of these goods by pipeline in 2004–2020.

An econometric assessment of the impact of the level of the existing tariffs of Price List No. 10–01 for coal in the Russian Federation transported by rail has revealed a statistically significant effect in terms of the model as a whole for the time interval 2004–2020. (Table 3). However, the coefficients of the model are statistically insignificant and Darbin's h test is not applicable for testing the autocorrelation of the model residuals. Consequently, according to the results of the assessment, the growth of tariffs for the transportation of coal in the Russian Federation by rail did not have a statistically significant effect on the volume of transportation of these goods by rail in 2004–2020.

Thus, if we take into account only the results of econometric modeling, then the change in tariffs for railway transportation in 2004–2020. for oil cargo and coal (and in 2010–2020 for oil cargo) did not statistically significantly contribute to the partial transition of these cargoes from railway transport to other types of transport (pipeline, road) with a change in supply chains.

However, according to the results of a comparative calculation of the average chain growth rates of the indicators of the level of the current tariffs of Price List No. 10–01 and the indicators of cargo transportation by rail and pipeline transport in the Russian Federation (for oil cargo and coal), such an influence was still present at least for oil cargo (Table 4). Growth of the current tariffs index of Price List No. 10–01 for oil cargo in the Russian Federation by an average of 9.2% in 2005–2020. was accompanied by an almost zero average growth in the loading of oil cargo by rail (0.1%) and an average growth of 1.2% in the transportation of oil cargo via trunk pipelines. And the growth of the current tariffs index of Price List No. 10–01 for oil cargo in the Russian Federation by an average of 6.4% in 2010–2020. was accompanied by a negative average decrease in the loading of oil cargo by rail (–0.7%) and an average growth of 1.0% in the transportation of oil cargo via trunk pipelines.

Such dynamics of changes in oil supply chains is clearly visible in Figs. 1 and 3: after 2010, the base rate of growth in the loading of oil cargo by rail begins to gradually decline simultaneously with an increase in tariffs for the transportation of oil cargo by rail and an increase in the base rate of growth in the transportation of oil cargo by pipeline. This leads to a change in the structure of the oil cargo supply chains: if in 2010 railway transport accounted for 32.5% of the transportation of these cargoes, then in 2020 this figure dropped to 27.2% (Fig. 4).

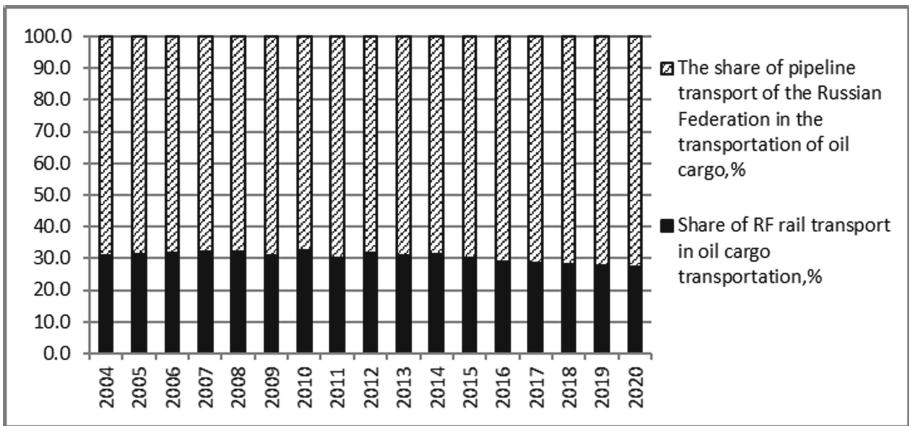
Note that such a picture was not observed for coal (the increase in tariffs was accompanied by an increase in loading on railway transport, Table 4), but this does not prove the thesis that the change in freight railway tariffs did not / does not have any effect on the supply chains of coal in the Russian Federation.

The statistical insignificance of the results of econometric modeling in Tables 1 and 2 against the background of the coincidence of the dynamics of the partial transition of oil cargo from railway transport to pipeline transport (Table 4, Figs. 1, 3, 4) can be explained by the complexity of a set of factors in the evolution of supply chains. The level of tariffs is an important factor in this population, which is recognized by researchers and participants in the transport market (based on surveys), but this level is not the only important factor. Also, the very evolution of supply chains is not limited





**Fig. 3.** Basic growth rates of oil cargo loading by rail in the Russian Federation and basic growth rates of oil cargo transportation via main pipelines of the RF in 2004–2020. (by 2004) (calculated by the author based on Rosstat data [1]).



**Fig. 4.** Shares of pipeline and rail transport in the transportation of oil cargo in the Russian Federation in 2004–2020. (calculated by the author based on Rosstat data [1]).

to the replacement of one mode of transport for another. Therefore, on the basis of the first-order autoregressive model 1, it is impossible to obtain a complete assessment of the picture of the influence of a complex of sometimes interrelated factors on the evolution of supply chains. To obtain such estimates in the future, it is necessary to use more complex econometric models (for example, a vector autoregression model) and use them to evaluate the influence of the whole complex of influencing factors simultaneously on a number of different indicators of the evolution of supply chains.

## 5 Conclusions

According to the results of the conducted econometric modeling using the first-order autoregressive model, the change in tariffs for railway transportation in the Russian Federation in 2004–2020. for oil cargo and coal (in 2010–2020 for oil cargo) did not statistically significantly contribute to the partial transition of these cargoes from railway transport to other types of transport (pipeline, road) with the transformation of the supply chains of these goods. However, according to the results of a comparative calculation of the average chain growth rates of the indicators of the level of existing freight railway tariffs and indicators of the transportation of these goods by rail and pipeline transport, such an influence was still present at least for oil cargo: an increase in the index of existing tariffs for oil cargo by an average of 9, 2% in 2005–2020 was accompanied by an almost zero average growth in the loading of oil cargo by rail and an average growth of 1.2% in the transportation of oil cargo via trunk pipelines (similar quantitative estimates were obtained for the period 2010–2020).

To clarify the results of quantitative econometric assessments of the effect of the level of railway tariffs on the evolution of freight supply chains in the future, it is necessary to use more complex econometric models (for example, a vector autoregression model), taking into account the need to simultaneously assess the entire range of influencing factors, and also taking into account a number of different indicators of the evolution of supply chains.

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