Computer Modeling of the Dynamics of Interregional Freight Transport Depending on Macroeconomic Indicators

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Abstract: The purpose of this research is to consider various macroeconomic indicators of world regions(North America, South America, Europe, Mediterranean, Persian Gulf, CIS, South Africa, Central America, West Africa, East Africa, East Asia, South Asia, Southeast Asia, Oceania, Australia) and federal districts in the Russian Federation (Central, North-western, Southern, North Caucasian, Volga, Ural, Siberian, Far Eastern), visualize the received data, determine their impact on the volume of freight traffic between the designated zones, identify patterns with the help of which we could carry out various kinds of forecasting. Further, it is necessary to carry out direct forecasting for several products of the selected industry, applying the necessary math model.

1 INTRODUCTION

It's no secret that interregional trade is important in the global economy. Even though each state is unique, the countries within certain zones have somewhat similar socio-economic and physical-geographical characteristics. Based on this kind of "kinship", 15 regions of the world can be conditionally defined: East Africa, West Africa, Central America, South Africa, Oceania, Mediterranean, CIS, Persian Gulf, South America, Southeast Asia, South Asia, Europe, Australia, East Asia, North America.

Each of these zones has completely different infrastructure, and, speaking directly about our topic, macroeconomic indicators that are very different from each other, which stimulate the active development of interregional trade.

In addition to the global dynamics in the field of freight traffic and their impact on the economic indicators of the regions, it is necessary to highlight trends and relationships in a country. The Russian Federation was chosen for the research as one of the most geographically vast and economically interesting countries in the world.

In a country of 8 major districts: Central Federal district, North-western Federal district, Southern Federal district, North Caucasian Federal district, Volga Federal district, Ural Federal district, Siberian Federal district and Far Eastern Federal district. For each of these regions, we selected key economic indicators for a detailed analysis and identification of various interesting patterns that allow us to draw concrete conclusions about the direct impact of macroeconomic indicators on the volume of cargo flows both in these zones and in the whole country

Thus, the article will consider: the dynamics of cargo flows between the selected regions, macroeconomic indicators of the regions, as well as their direct influence on each other; the relationship between freight turnover within the districts of the Russian Federation and their socio-economic characteristics. Another important task is to be able to predict in the short term how the volume of selected cargo will change in 2020. For this, a special mathematical algorithm will be used.

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2 IMPACT OF CARGO FLOWS ON THE MACROECONOMIC INDICATORS OF THE WORLD REGIONS

2.1 Analysis of the Mean Nominal GDP of the World Regions

Gross domestic product (GDP) is the most important macroeconomic indicator, which can be understood as the value of all goods and services produced on the territory of the country. There is another important characteristic that, along with GDP, reflects the degree of development of a country. Gross national income (GNI) is defined as the sum of GDP and the balance of primary income (summing up the income of citizens received from abroad, subtracting funds taken out of the country by foreigners). To analyse entire macro-regions, it is necessary to determine the characteristics by which these districts will be further investigated. So, the mean nominal gross domestic product and gross national income were selected. They were calculated as the arithmetic mean of the corresponding indicators of all countries located in this zone.

So, in Fig.1 shows a heat map of the world, where each of the 15 regions is highlighted in colour, reflecting the value of the average nominal GDP in this zone in comparison with others. Data for modelling was taken from. The most economically developed macro-regions are North America and East Asia with an average GDP of 5896 billion USDs and 2766 billion USD, respectively. Australia also ranks high with a GDP of 1376 billion $. Of course, you need to understand that there are countries that have a very developed economy, but due to the fact that the region is dominated by countries that have a low GDP, the average indicator is decreasing. For example, the United Kingdom, France and Germany have a GDP in 2019 more than 2,500 billion USD. but taking into account some other countries that have this indicator more than five times less, it turns out that Europe, as one of the most comprehensively developed parts of the world, in comparison with the leading macro-regions in this characteristic, has a nominal gross domestic product equal to $ 659 billion. But if we consider some other countries that have this indicator more than five times less, it turns out that Europe, as one of the most comprehensively developed parts of the world, in comparison with the leading macro-regions in this characteristic, has a nominal gross domestic product equal to 659 billion USD.

The situation of Africa is not surprising. Unfortunately, most of the countries of this continent have a very underdeveloped economy, which is proved by extremely low average GDP figures: South Africa - $ 82.5 billion, East - $ 26 billion, West - 34.5 billion $.Many CIS countries are economically developed at the same level. But the Russian Federation stands out a lot: its GDP is 1,638 billion $ in 2019.

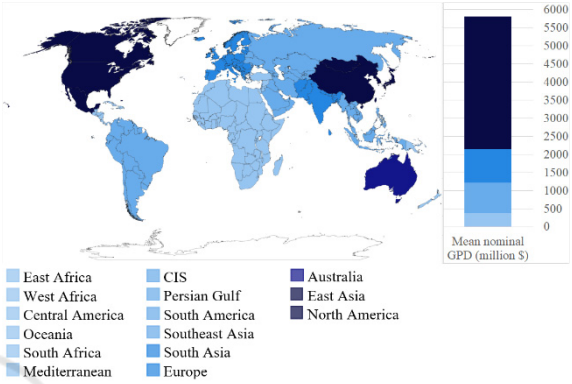

Figure 1: Mean nominal GPD of world regions (million $).

Python heat map implementation for East Africa:

```
pip install pygal
import pygal
import numpy
from pygal.style import Style
custom_style = Style( colors =
('#96c5f1'))
worldmap = pygal.maps.world.World(style
= custom_style)
worldmap.title = ' Mean nominal GPD of
world regions (million $).'
worldmap.add('East Africa',
['bi','dj','zm','zw','ke','mu','mg','mw
','mz','rw','sc','so','sd','tz','ug','e
r','et'])
```

2.2 Analysis of the Mean GNI of the World Regions

It is advisable to further consider the average GNI in different regions of the world (fig. 2) and understand how this characteristic differs from the previously considered indicator. The overall situation has not changed much: in the top three developed economic regions are still North America with an mean GNI of 5729 billion $, East Asia - 2764 billion $, and Australia - 1346 billion $.

Countries of Africa and Oceania have the worst indicators-less than 70 billion $. The initial conclusions before the analysis were as follows: in

countries where most of the income is exported abroad, GNI is less than GDP. On the contrary, if citizens of a country have high incomes in companies in other countries, then GNI will exceed GDP.

In practice, the previously made conclusions were confirmed. A while the difference between gross domestic product and gross national income may be significant in theory, in practice it turned out to be insignificant. For example, if the mean GDP in Europe is 659 billion USD, the mean GNI is 682.8 billion USD. Relative to these amounts, the difference is small, but noticeable and is the highest among all the districts considered.

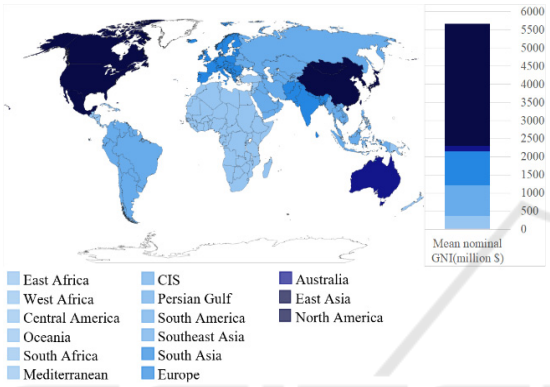

Figure 2: Mean GNI of world regions (million $).

2.3 Analysis of Cargo Flows between World Regions

In order not to be unfounded, let's move on to the analysis of freight traffic between the world macro-regions. Fig. 3 and Fig. 4 show graphs reflecting the import and export of all goods between the regions in monetary terms. The 15 regions into which we united all states earlier are now presented in the form of 5 larger zones.

The most promising is cooperation between America and Asia, which can be explained by their developed economic and trading system. Indeed, paying attention to the mean nominal GDP and mean GNI that we examined earlier, it becomes clear that they are indicators for high trade between these macro-regions. It should be noted that the import of products from Asia to America (1611million USD) is almost 2 times more than in the opposite direction (980 million USD). Why is this happening?

I propose to carefully consider Fig. 5. The total tonnage of freight turnover between Asian countries and the rest of the world tells us that China, Japan, India, Korea and other large manufacturing countries in Asia have a powerful resource base - no other macro-region has such a volume of goods supplied to other zones: In 2019, more than 350 million tons of agricultural products alone were supplied, fuel - more than 1.24 billion tons, metals and minerals - more than 700 million tons. And this is not all the products exported by Asia.

The trade partnership between the countries of Europe and America is no less interesting: fertilizers, metals and minerals, gas, oil are also in great demand here. The supply of various goods from Europe to Australia, as two economically developed regions of the world, is surprising: the weight of the transported goods in 2019 (Fig. 5) and its monetary equivalent (Fig. 3 and Fig. 4) is not large.

How can such a commodity exchange phenomenon be explained? Previously, the analysis could only be based on economic indicators, but now it is necessary to consider the geographical location of the regions: Europe and Australia are among the most distant trading partners. Therefore, it is much more profitable for them to look for suppliers in countries that are closer. This is what happens – Australia prefers to import goods mainly from Asia and Oceania. However, why are there deliveries from Australia to Europe and back at all? This question can be answered if you pay attention to the types of products delivered. The basis of trade is coal, which is not surprising: Australia is a major exporter of this type of raw material in the world.

It is interesting that African countries with low macroeconomic indicators supply a lot of goods, for example, to America (more than a billion tons in 2019). The most exported precious metals, ores and phosphorites. At the same time, African countries buy little cargo from other macro-regions. How can this be explained? The federal budget plays an important role here. Mauritania, Togo, Eritrea, Burundi, Lesotho, Swaziland, Liberia and other countries are among the poorest in the world (GDP less than US $ 10 billion). That's why many states do not have the ability to purchase goods from abroad.

Trade cooperation between Europe and Asia is no less important than the rest. Perhaps the most prominent is the cargo turnover between these macro-regions. The difference in the quantity of products delivered between these zones is very noticeable: 213 million tons from Asia to Europe, 721 million tons in the opposite direction. It is very important to understand why there are such strong differences in the volume of deliveries.

To do this, you need to consider the types of products. The most priority cargoes from Europe to Asia are forestry products, fossil fuels, agricultural products, gold, silver and other precious metals, palladium, platinum.

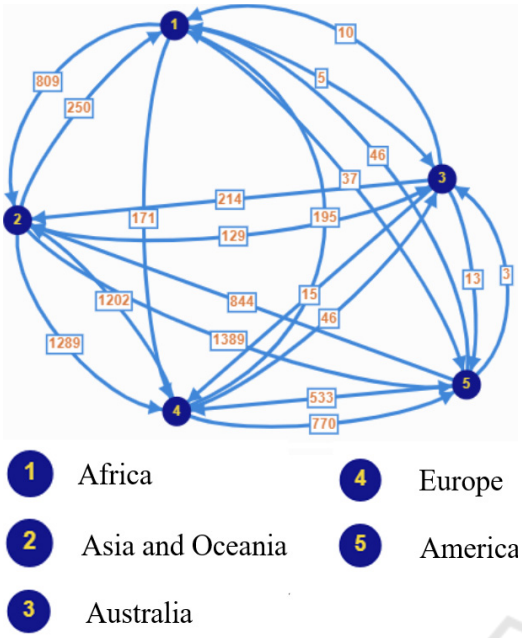

Figure 3: Import of all goods between world regions (million $).

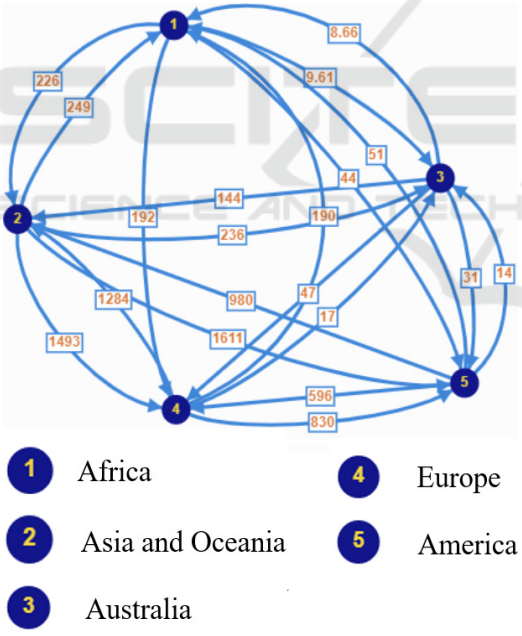

Figure 4: Export of all goods between world regions (million $).

If we talk about the opposite direction, the most common products here are fossil fuels and minerals, precious metals. Assuming that China is one of the world's largest gold, silver and other precious metals mining centers, it was assumed that this type of goods would occupy an impressive part of the total supply. In reality it turned out that precious metals are a small part of the total cargo turnover between the regions, but Asia places a great emphasis on the supply of this expensive resource. So, if we consider the monetary equivalent of exported goods, this indicator is comparable between both zones (from Asia to Europe, $ 1,288 million, in the opposite direction, $ 1,202 million).

After analyzing the obtained indicators, we can make a reasonable conclusion that cargo tonnage is not the only factor that should be considered when analyzing cargo flows. It is very important to consider what specific resource is being delivered, because each product has a different market value. For example, in our case, the supply of gold and other precious metals from Asia to Europe is not comparable in price with forestry products, which take up most of the supply in the opposite direction.

Thus, cargo turnover directly depends on the economic development of the cooperating regions, and the partner States in particular. However, it is necessary to take into account the geographical factor: trade relations between Europe and Australia show us that remote macro-regions can also cooperate with each other, but due to the strong remoteness of the zones, we cannot count on a high exchange of goods. When analyzing cargo transportation between regions, you need to consider the type of products delivered: regions that specialize in the production and processing of any product will always offer their range to those who need it. In international practice, this is confirmed by Asian countries, whose products are in demand on the world market.

3 MUTIAL IMPACT OF CARGO FLOWS ON MACROECONOMIC INDICATORS OF THE RUSSIAN DISTRICTS

The Russian Federation is a vast country with the big national resources which has a great economic potential. Key feature of the country - very convenient location for trade relations. The country consists of 8 districts: Central Federal district, North- western Federal district, Southern Federal district, North Caucasian Federal district, Volga Federal district, Ural Federal district, Siberian Federal district and Far Eastern Federal district. Every region has its own macroeconomic indicators. For the analysis of cargo flows between districts, the following characteristics were selected: mining (million rubles), manufacturing

industries(million rubles), provision of electric energy(gas) (million rubles), water supply, sanitation, pollution elimination (million rubles), the carriage of goods by road transport organizations of all activities (million tons), freight turnover of road transport organizations of all activities (million ton - km), the turnover of wholesale (retail) trade organizations of wholesale (retail) trade (million tons),retail trade turnover (million tons), export and import (million USD), foreign trade turnover (million USD).

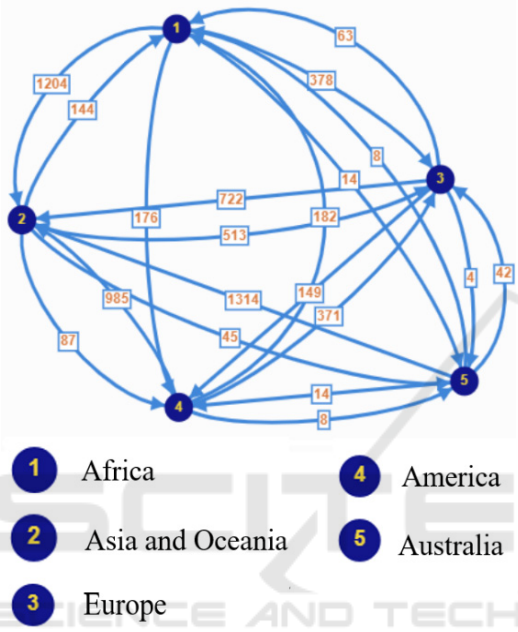

Figure 5: Freight traffic between world regions (million tons).

In order to determine which of these economic indicators have the greatest impact on cargo flows between districts, we construct symmetric correlation matrix (Table 1). As you know, correlation is equivalent to an approximate relationship between any values. The linear coefficient of pair correlation between characteristics is calculated using the "CORREL" function program in Microsoft Excel.

All elements of the main diagonal are equal to one – the correlation of each macroeconomic indicator with itself. The rest of the cells are filled with numbers from the limit [-1; 1], which make it possible to assess the strength of the relationship between quantities. Based on the scale of the statistician Chaddock, it can be argued that values close to -1 reflect a strong negative relationship (strong feedback), to 1 - a strong positive relationship (direct relationship), close to 0 - no relationship. If the correlation coefficient is close to 0.5 or -0.5, then the selected indicators are in moderate dependence.

Table 1: Correlation square matrix.

	Mining	Manufacturing industries	Provision of electric energy (gas)	Water supply, sanitation, pollution elimination	Freight turnover of road transport
Mining	1,0000	0,1425	0,1931	0,2295	0,1449
Manufacturing industries	0,1425	1,0000	0,9843	0,9864	0,9868
Provision of electic energy (gas)	0,1931	0,9843	1,0000	0,9867	0,9579
Water supply, sanitation, pollution elimination	0,2295	0,9864	0,9867	1,0000	0,9733
Freight turnover of road transport	0,1449	0,9868	0,9579	0,9733	1,0000

Therefore, it is necessary: to find such indicators that are most dependent on the characteristics associated with cargo transportation (the correlation coefficient in modulus is close to 1) and to justify the identified dependencies.

Freight turnover of road transport is highly correlated with manufacturing industries. Since the corresponding coefficient is close to 1, then for this pair of macroeconomic indicators, a direct relationship can be identified and explained.

Cargo transportation depends on the volume of output of the chemical, timber, light, food and other industries, which are key in the manufacturing industry of the country. Indeed, when the demand for goods decreases, the number of products produced is also adjusted. As a result, the volume of cargo transportation also decreases. On the contrary, with an increase in the number of products created, it is necessary to deliver proportionally more goods, which entails an increase in the volume of cargo transportation.

The correlation coefficient between freight turnover of road transport and the provision of electric energy is also very close to 1. Therefore, a directly proportional relationship is also noticeable between these indicators: with increased demand for electricity, steam or gas, the need for cargo transportation will also increase. Since provision refers not only to direct transmission, but also to the installation and maintenance of devices, the last two services account for the greatest load associated with cargo flows. You can show the relationship as follows: if you need electricity, you need to bring and install a system of lines, meters, and poles that transmits energy from point A to point B. In case of breakdowns or when the warranty period expires, it is necessary to replace the equipment, that is, to deliver new equipment. However, if the demand for

electricity increases, the volume of cargo flows will increase, which will be proof of a direct proportional relationship.

Water supply, sanitation, and pollution elimination are strongly correlated with road transport freight turnover, which highlights the relationship between them. It is obvious that water distribution for drinking, industrial and other needs is carried out mainly by road. Road transport also provides services for the restoration of various areas that have been affected by pollution. The relationship is obvious here.

Thus, we were able to find three macroeconomic indicators that have the greatest impact on cargo turnover and cargo flows between districts in the Russian Federation. Based on the stable relationship between these characteristics, you can make forecasts that will reflect changes in the volume of cargo flows when one of the three indicators decrease or increase. For example, if there is a reduced demand for water supply due to the rise in the price of provider services, the volume of cargo flows will significantly decrease in this area. However, it is not necessary that a similar situation will occur in the entire district – the lack of demand for these services is compensated by increased demand for others.

5 FORECASTING THE EXPORT VOLUME OF COAL AND PETROLEUM PRODUCTS FROM RUSSIAN FEDERATION

We have found that manufacturing industries strongly affects the volume of cargo flows in the Russian Federation. Based on this material, we will make a forecast for the volume of exports of petroleum products and coal from the country in 2020. There are many different methods used to predict the volume of cargo flows. Here are some of them: a method based on calculating the coefficient of transportability of a certain group of cargo, a method for predicting cargo transportation based on specific standards, methods for predicting the average distance of transportation, and forecasting the transport and economic balance We chose correlation-regression analysis. It uses very clear mathematical tools and a clear algorithm that works perfectly when predicting characteristics that primarily have quantitative indicators, considering the dependence of the effective value on many factors. Moreover, the method is suitable for working with time series, which will be discussed later. It is obvious that the method includes a correlation that has already been used to establish patterns between the volume of automobile cargo flows and three types of macroeconomic indicators, and a regression that allows reflecting the dependence of the effective indicator on the factor indicator. The purpose of this study is to apply the method of correlation- regression analysis in predicting the volume of cargo flows of coal and petroleum in the short term (for 2020 year). I would like to note that a relatively small-time interval is taken, because this will increase the accuracy of the forecast made.

So, as a productive factor, we will choose the volume of petroleum products exported from Russia. To conduct an analysis for this group, we must provide data for the retrospective period for the considered influencing factors (Table 2).

Table 2: Indicators required for correlation-regression analysis by the export volume of petroleum products.

Indicators	2014 year	2015 year	2016 year	2017 year	2018 year	2019 year
Export volume of petroleum products - productive indicator, million tons	165,00	171,00	156,00	148,60	152,10	142
The volume of petroleum products production in the Russian Federation, million tons	206,61	196,60	176,90	171,50	170,60	169,5
The volume of oil production in the Russian Federation, million tons	526,70	533,60	547,30	546,70	555,80	560,2
World oil production, million tons	4223	4355	4368	4380	4474	4450
The volume of world petroleum products consumption , million tons	92,99	94,84	96,49	98,19	100,00	100,6

After selecting the necessary statistical data, we will start calculating linear pair correlation coefficients using the "CORREL" function in Microsoft Excel (Table 3).

Table 3: Calculating Pairwise Correlation Coefficient.

	A	B	C	D	E	F	G	H
1	Indicators	2014	2015	2016	2017	2018	2019	Correlation coefficient with the productive indicator
2	Export volume of petroleum products - productive indicator, million tons	165,00	171,00	156,00	148,60	152,10	142	
3	The volume of petroleum products production in the Russian Federation, million tons	206,61	196,60	176,90	171,50	=CORREL($B$2:$G$2;B3:G3)		
4	The volume of oil production in the Russian Federation, million tons	526,70	533,60	547,30	546,70	555,80	560,2	-0,88
5	World oil production, million tons	4223	4355	4368	4380	4474	4450	-0,67
6	The volume of world petroleum products consumption , million tons	92,99	94,84	96,49	98,19	100,00	100,6	-0,88

The table 4 shows data on the calculated correlation coefficients of the expert identified influencing factors with the indicator volume of petroleum products exports from the Russian Federation (million tons).

Table 4: Correlation coefficients of influencing factors.

Indicators	Correlation coefficient with the productive indicator
Export volume of petroleum products - productive indicator, million tons	
The volume of petroleum products production in the Russian Federation, million tons	0,87556439
The volume of oil production in the Russian Federation, million tons	-0,880529626
World oil production, million tons	-0,665192776
The volume of world petroleum products consumption , million tons	-0,875638429

It's clear that the most closely related factor to the performance indicator is the volume of oil production is the volume of oil mining in the Russian Federation (modulus of the correlation coefficient 0.88 – on the Cheddock scale, the degree of correlation is defined as high, while the relationship is negative). At this stage, the correlation component is over.

Let's move on to finding the regression equation that will help you find the predicted value of the effective factor .To do this, we will plot the correlation between export volume of petrol products and the volume of oil mining (Fig. 6).

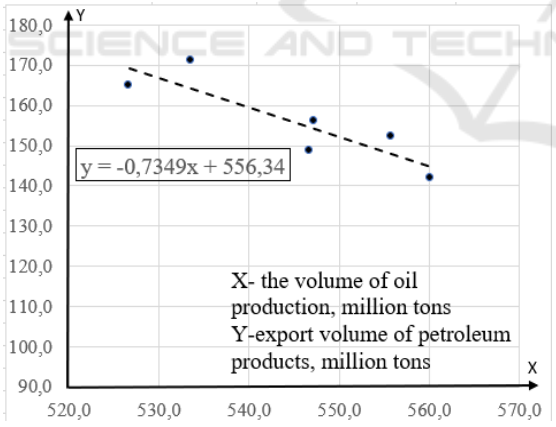

Figure 6: The field of the correlation dependence.

After plotting the correlation dependence, the program outputs the regression equation. At the same time, the coefficient at X (-0.7349) shows the degree of influence of export volume of petroleum products on the volume of oil mining, and the free term 556.34 shows what value the resulting value will take if the factor indicator is not taken into account in the regression equation (meaning the dependence of traffic volume on other factors not described in the model). And the free term 556.34 shows what quantity the effective value will take if the factor indicator is not taken into account in the regression equation (meaning the dependence of the volume of traffic on other factors not described in the model).

Next, to calculate the forecast traffic volume, we substitute the prospective value of the influencing factor (the volume of oil mining) for 2020 into the resulting regression equation. In the energy strategy of Russia until 2035 года, compiled by the former Minister of energy of the Russian Federation A.V. Novak, the desired value is 525 million tons. Substituting this value instead of the variable x, we get 170.5 million tons-the forecast export volume of petroleum products from the Russian Federation in 2020.

As the next productive indicator, let's take the Export volume of coal from the Russian Federation and make a table with data for the period 2014-2019 (Table 5).

Table 5: Indicators required for correlation-regression analysis by the export volume of coal for 2014-2019 years.

Indicators	2014	2015	2016	2017	2018	2019
Export volume of coal - productive indicator, million tons	151,90	151,40	164,70	184,70	189,00	190
The volume of coal mining in Russian Federation, million tons	357,20	371,70	383,80	407,90	432,70	437
World coal mining, million tons	8195,70	7954,20	7492,00	7727,30	7544,00	7323
The volume of world coal consumption , million tons	3862	3765	3706	3732	3700	3721

The next step is to calculate the corresponding correlation coefficients using the program Microsoft Excel (Table 6).

Table 6: Correlation coefficients of influencing factors.

Indicators	Correlation coefficient with the productive indicator
Export volume of coal - productive indicator, million tons	
The volume of coal mining in Russian Federation, million tons	0,9659712
World coal mining, million tons	-0,775559197
The volume of world coal consumption , million tons	-0,697620353

The table shows that the most dependent factor with the effective indicator is the volume of coal mining in the Russian Federation (the value of the correlation coefficient is 0.97-on the Cheddock scale,

the degree of correlation is defined as a strong positive.

Tow let's plot the correlation dependence of 1 and 3 indicators (Fig. 7).

We got the regression equation y = 0,57*x-54,351. To calculate the forecast volume of coal exported from Russia, substitute the prospective value of the volume of coal mining for 2020 instead of the variable x. In the forecast of socio-economic development of the Russian Federation for the period up to 2036, compiled by the Ministry of Economic development of the Russian Federation, the required value is 420 million tons. Then the Export volume of coal from the Russian Federation in 2020 will be 185 million tons.

So, formalized methods of predictive extrapolation are used when predicting certain processes that can be characterized quantitatively.

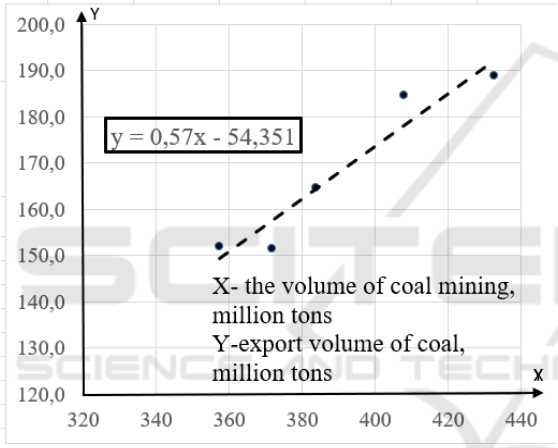

Figure 7: The field of the correlation dependence.

When considering the retrospective period, the trends of the past are considered, analyzed, and the necessary mathematical methods are applied. This results in accurate forecast data for a specific phenomenon. In our research, we used a correlation-regression algorithm that made it possible to make a forecast for the selected indicators in the previously analyzed area. The obtained values - the volume of coal exports from the Russian Federation in 2020 will be 185 million tons, exports of petroleum products from the Russian Federation in 2020-170.5 million tons.

6 CONCLUSIONS

So, the article considered various aspects of the impact of macroeconomic indicators on the volume of cargo flows.

Firstly, such macroeconomic indicators as the average nominal gross domestic product (GDP) and average gross national income (GNI) in each of the 15 selected regions of the world were considered and analyzed. Next, we examined the volume of cargo transportation between these zones, correlated it with the import and export of goods of all types in monetary terms. As a result, it was concluded that cargo turnover between regions of the world depends on many factors. These include the level of economic development of States, the Federal budget of the buyer country, the geographical distance of partners, the type of cargo and its market value.

Secondly, in the Russian Federation, we also analyzed macroeconomic indicators that could theoretically be related to the volume of cargo transportation between districts. In order to identify dependencies, we have compiled a square correlation matrix, which was used to identify indicators that affect the turnover of road transport: output of products by processing industries, provision of electric energy, water supply(sanitation) and elimination of pollution.

Thus, based on these economic characteristics, we considered situations in which the volume of cargo turnover between regions of the country may increase or fall, which marks a success in the field of interregional forecasting.

Thirdly, we applied the correlation-regression model and predicted the volume of exports of petroleum products and coal from the Russian Federation in 2020. We have deliberately made a short-term forecast, as this will increase the accuracy of the forecast. Of course, we must not forget about the availability of other methods that are actively used in forecasting. However, our method is particularly valuable – it allows you to predict the required value based on quantitative characteristics. The algorithm also provides the ability to reflect the relationship between the effective value and influencing factors.

In total, forecasting traffic flows is a very significant element of the economy. A well-functioning freight transport system is one of the most important elements of any successful economy. This process allows you to: predict the prospects for the development of the entire system as a whole when distributing goods in the future; rationally use and distribute available resources; improve the quality of transport services, increasing the competitiveness of the organization; minimize the risk of bankruptcy; make innovations in the enterprise; improve control over the processes of transporting goods.

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