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Modelling of Passenger Air Transportation Prices

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ABSTRACT

The pricing policy of airlines is developed based on a retrospective analysis of the price dynamics of air transportation and forecasting the market situation of supply and demand. The price dynamics of passenger air transportation has a certain structure and patterns, the identification of which helps to develop a competitive price offer for consumers.

The objective of the work is to determine the structure of price dynamics and identify patterns of price fluctuations in passenger air transportation from 2008 to 2022, which is important to consider when developing the pricing policy of airlines and the range of tariffs. Studies of the price dynamics of airline tickets by econometric methods allowed to identify the structure of the time series of prices and develop several models.

The study of the price dynamics structure, first, identified and analysed the seasonal component of the dynamics of airline ticket prices. Its calculation was carried out using additive and multiplicative models. The range of seasonal changes was -8,5% to +12,5%. The autocorrelation function of the dynamics of average monthly prices showed that the time series of airline ticket prices contained a trend. In addition to trend and seasonal components, cyclical fluctuations were identified in the price dynamics, the modelling of which was carried out based on regression analysis. Cyclical changes in the dynamics of air ticket prices, identified from 2008 to the present, are not sustainable.

Analysed dynamics revealed several medium-term cycles with a duration of 4–6 years. The cyclical dynamics of air transportation prices largely coincides with the general economic medium-term cycles, but there are time lags or lagging growth and decline rates.

Thus, the change in prices for civil air transportation has a natural trend-cyclical character shaped under the influence of fundamental macroeconomic factors and new determinants, the effect of which may result in a stronger change but with shorter impact or lag effect. Additive and multiplicative models will help predict average annual prices.

Keywords: civil aviation; price dynamics of passenger air transportation; the structure of price dynamics; regression and correlation analyses; trend patterns; cyclical and seasonal components of the dynamics of airline ticket prices; adaptive, additive and multiplicative models.

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INTRODUCTION

Global political tensions, economic constraints and social challenges are integrating new operating conditions for businesses, industries, societies and countries and concern also Russian civil aviation industry. The totality of factors including the pandemic and post-pandemic recovery, is reflected in passenger traffic and airfare. The singularity of the price dynamics of passenger air transportation, fluctuations and shifts in the equilibrium price lead to an increase in transformation and transaction costs, to a decrease in the efficiency and profitability of airlines [1–4].

Along with other processes, the efficiency of the airline's economic activity is determined by a decrease in the cost of air transportation of passengers, and by an increase in prices for air tickets, which may differ significantly from the equilibrium supply and demand in the passenger air transportation market. The pricing policy and pricing strategies of airlines are aimed at achieving maximum profitability, both under the conditions of stable economic development and under the tense socio-economic and political conditions. The development of the pricing policy of airlines should be built with an understanding of the structure of price dynamics and considering the patterns of price movement regarding passenger air transportation, which will remove uncertainty and provide a competitive price offer for consumers. Consequently, studies of the price dynamics of air transportation remain relevant from the theoretical aspect and are in demand from practical point of view. Another important reason for the need to conduct a study of movement of air transportation prices for many entities of the aviation business, including government authorities, is the state support for domestic airlines.

State support for passenger air transportation and, in particular, domestic air transport is carried out in many countries of the European Union, Australia, the USA, Canada, etc. For example, in Australia, 75 % of local air transportation is subsidised at 50 % of the commercial rate [5; 6]. In the United States, almost $150 million is allocated annually to subsidise air transportation [5–7]. In Russia, state subsidies are allocated for socially significant routes[1]. In the context of growing political and economic tensions in 2022, an important decision was made to expand state subsidies for air transportation to increase the availability of air transportation for Russian residents and realise the maximum opportunities for maintaining and developing the mobility of the population. In 2022, it was accepted to subsidise air transportation in the amount of more than 12 billion rubles (with regard to more than 170 routes), and about 9 billion rubles were allocated for development of regional air transportation on 415 routes[2]. Therefore, the study of the dynamics of prices for air transportation and modelling of the price trajectory will contribute to improvement of methods for forecasting prices/tariffs, the pricing mechanism, which is important and relevant for the aviation business [8; 9]. Analysing charts, developing price models, evaluating the height and length of price fluctuations, determining correlations and the strength of the influence of various factor signs on the effective sign of price change, it is possible to assess the likelihood of an increase or decrease in prices for air tickets on the market in the future, which is very important for forecasting and planning the activities of airlines and other aviation enterprises.

Today, many works of scientific and applied nature refer to the modelling of the processes of transportation of goods and passengers. The models differ as by complexity, possibility of implementation, and the objectivity of interpreting the data obtained. Such complex models as neural networks, models with artificial intelligence, Markov chains and others are certainly of scientific interest for a debatable discussion of the impact of new factor realities, such as global changes, institutional transformations of aviation infrastructure, improvement of the technical and technological platform of the aviation business, but they are of little use for the practical purposes of forecasting the volume of air traffic. Forecasting air transportation processes based on econometric modelling provides reliable results compared to the conclusions obtained using other methods. The novelty of the study of the price dynamics of air transportation and modelling of time series is associated with taking into account in full the information about the correlation between the data of the modelled series. Also, the resulting

[1] Federal Air Transport Agency. Statistical data. [Electronic resource]: https://favt.gov.ru/dejatelnost-ajeroporty-i-ajerodromy-stat-dannye/?ysclid=ld01tld0f218381281/. Last accessed 10.10.2022.

[2] In 2022, 172 billion rubles were allocated to support subsidising civil aviation. AVIA.RU Network – Russian aviation Web portal. [Electronic resource]: https://www.aviastat.ru/analytics/131. Last accessed 15.09.2022.

models allow monitoring and adding new data to the time series to ensure greater reliability of the results.

To develop the experimental base of the study, information resources were used as follow: data of international statistical organisations, the Russian Federal state statistics service, aggregated data of Aviastat, Aviaport and Aviapro and other orgnaisations[3, 4], scientific publications, other statistical and analytical materials [10–12].

The hypothesis of the study on the dynamics of prices for passenger air transportation is based on the following main provisions:

- Change in prices in civil air transportation has a natural character with a trend.
- Variation and specifics of passenger air transportation prices are cyclically and seasonally repeated under the influence of market and non-market factors.
- The dynamics of prices for passenger air transportation reveals the market situation and determines the possible prospects for its development.

The *objective* of the study is to determine the structure of price dynamics and identify patterns of movement of prices for passenger air transportation. The object of the study is the dynamics of prices for air transportation of passengers in Russia.

METHODOLOGY

The main tasks of the current stage of the study of the economic processes in the aviation market included determining the structure of the price dynamics of the cost of passenger air transportation using econometric methods, developing an adaptive model for the seasonal component of average monthly prices, additive and multiplicative models for average annual prices. The initial study of air ticket price dynamics included a qualitative analysis of the phenomenon, search for reliable data, development of databases, and construction of time series of average annual prices from 2008 to 2022, average monthly and average quarterly prices both for entire country and for individual routes. The second stage of the study included the analysis of price time series using statistical methods (grouping, averages, range, etc.) and econometrics (extrapolation/interpolation, modelling, etc.).

Based on a content analysis of time series data using the least squares method, different types of linear and non-linear relationships are calculated. At the next stage, the results were interpreted with determination of those results that could be the most accurate in the retrospective aspect and suitable for practical use of models for constructing air transportation price projections. The study involved software products and software tools for data processing: MS Access, MS Excel, SPSS, Statistica, the Loginom analytical platform software package.

RESULTS

Visualization of data since 2000 and graphical analysis of price dynamics of the 15-year period from 2008 to the present confirmed the wave movement of prices (Pic. 1). The current state of change in average prices for air tickets shows that the cost of an economy class flight began to decline from 2019 and by the end of 2021 amounted to 5482 rubles (calculated per 1 thousand km of travelled route), so the decrease was of 13 %. The absolute maximum of average prices for air tickets in Russia was observed in 2010 at the level of 6804 rubles. In the following year, there was a sharp drop in prices (by about 38 % compared to the previous year). And in 2011, the minimum extremum of the average ticket price was fixed: 4279 rubles (Pic. 1). In 2022, according to government statistics, the increase in airfare prices may exceed the highs since 2000. Thus, the average cost of a domestic air flight increased by 8–9 % in March and by 16 % in April 2022 and approached 6000 rubles[5]. The trend of growing prices for air transportation until the end of 2022 is likely to continue, which is due to many factors and, first, to the growing systemic problems of the national and global aviation industry.

The dynamics of airfare in dollar terms has other features (Pic. 1). The difference in the directions of growth and decline in price dynamics in the national and world currencies was observed in the period 2013–2017. Analysis of the price dynamics of air tickets in dollar terms is just as

[3] SITA: airports urgently need to be digitised to avoid long queues. [Electronic resource]: http://www.ato.ru/content/sita-aeroporty-nuzhno-srochno-cifrovizirovat-chtoby-izbezhat-mnogochasovyh-ocheredey. Last accessed 20.09.2022.

[4] Annual Review 2021. IATA. [Electronic resource]: https://www.iata.org/contentassets/c81222d96c9a4e0bb4ff6ced0126f0bb/iata-annual-review-2021.pdf. Last accessed 20.09.2022.

[5] Air transportation of passengers in Russia – results of 2021. AviaStat – Analytical agency. [Electronic resource]: https://www.aviastat.ru/statistics/123-aviaperevozka-passazhirov-v-rossii-itogi-2021-goda. Last accessed 15.09.2022.

Table 1

Assessment of the seasonal component of average monthly prices in Russia in 2020 with an additive model [developed by the authors]

Assessment	1	2	3	4
1	–	-293,77	-915,10	910,77
2	670,26	-829,50	216,27	769,27
3	121,6	-124,01	–	–
Adjusted value of the seasonal component	278,19	-533,44	-467,06	722,31

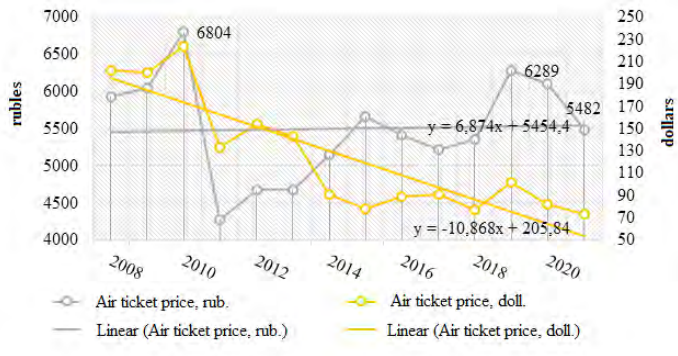
important as in the national currency, since 80 % of aircraft of Russian airlines are foreign leasing planes with monthly payments in foreign currency of at least 1 % of the cost of an aircraft. With an increase in the exchange rate, leasing costs, the cost of aviation kerosene, the current costs for airlines of ground handling of aircraft, if these are international flights, grow accordingly, which will inevitably affect the prices of air tickets. Another reason for the need to analyse the price dynamics of air tickets in world convertible currencies is related to the fact that all airlines upload fares in euros or dollars to a specialised global distribution system designed to search, book, and sell air services. And there is another important point: the situation with the official rates of world currencies today is ambiguous.

The study of the structure of dynamics, first, focused on identification and analysis of the seasonal component of the dynamics of air ticket prices. Decomposition of time series of average annual and average monthly airfare prices made it possible to calculate the seasonal component. The selection of seasonal components was carried out based on the average monthly price dynamics in Russia for 2020 and 2021 (Pic. 2, Table 1). Also, seasonality analysis was carried out on average monthly prices for popular destinations of domestic air routes from Moscow: Kazan, Kaliningrad, Novosibirsk, St. Petersburg, Sochi. For international air routes, directions to Istanbul, Paris, Yerevan were chosen. The initial autocorrelation of average monthly price series with a lag of 4 showed that the series have minor trends and periodic fluctuations (seasonality) with a period equal to 4. The calculation of the seasonal component of price dynamics was also carried out using additive and multiplicative models (Tables 1 and 2, Pic. 4).

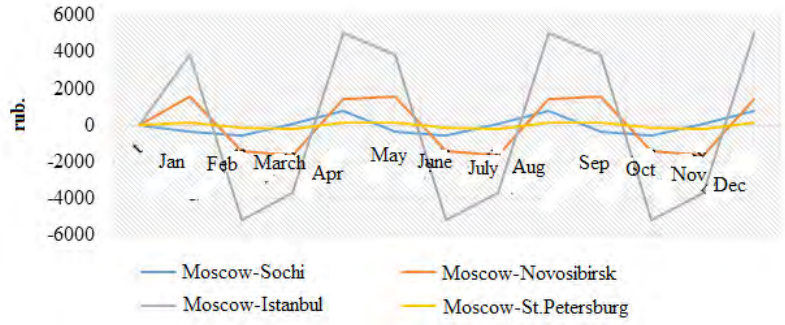
The range of seasonal changes in air ticket prices is between –8,5 % and +12,5 % (Pic. 3).

To predict the seasonal dynamics of air tickets prices, that is, for short-term forecasting, self-tuning adaptive models, which are built on different smoothing options based on a moving average, in which the weights obey the exponential distribution of the levels of a series with discrete shifts (Pic. 4), could be most required and accurate, even under the conditions of rapid changes. For an adaptive model of price forecasting of seasonal price fluctuations, the deviation of the predicted value from the actual value for each month is calculated, which is necessary to adjust the modelled parameter of the time series [12–14].

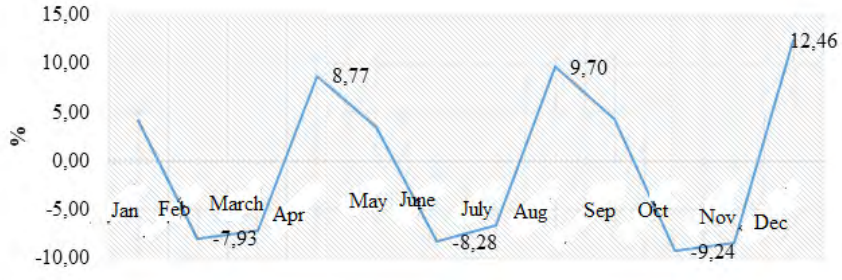
Adaptive models have also been developed for other components of the air ticket price time series. The developed adaptive models of the



Pic. 1. Dynamics of average air ticket prices in Russia. EMISS [developed by the authors based on Rosstat [Federal state statistics service] data]. [Electronic resource]: https:// fedstat.ru. Last accessed 15.09.2022.



Pic. 2. Seasonal component of the additive model of average annual price dynamics of air tickets [developed by the authors].



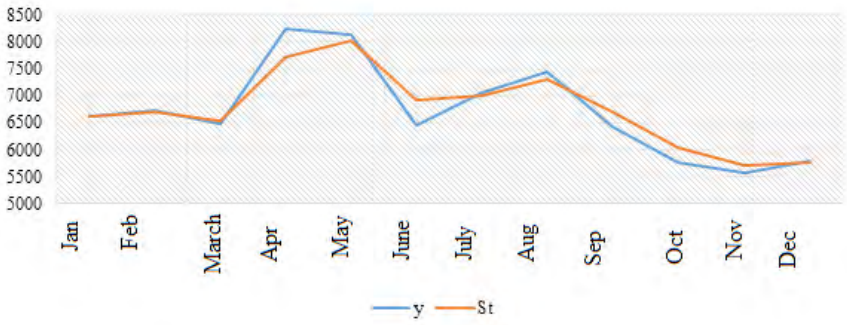
Pic. 3.The amplitude of seasonal fluctuations of price average monthly dynamics [developed by the authors].

average annual price dynamics of air tickets with the Brown method do not have acceptable accuracy and cannot give accurate forecasts (Pic. 5), since trend and cyclical fluctuations are affected by a large number of different factors that weaken or strengthen the influence in different periods [15]. Accordingly, the level, variation, growth rate, variance and other characteristics of price dynamics are not constant, and therefore it is impossible to tune the model to numerous factors.

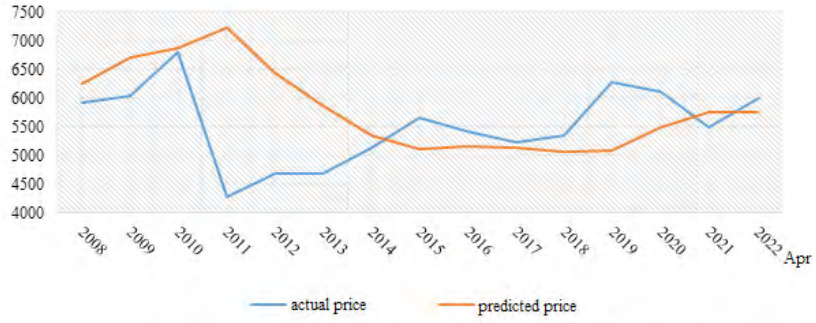
The developed additive models of average monthly prices confirmed the presence of a trend and a seasonal component in price dynamics (Pics. 6, 7 and Table 2), and showed also an acceptable level of accuracy, which is important for price forecasting purposes.

The calculated autocorrelation function of the dynamics of average monthly prices showed that the time series of airfare prices contains a trend in most of the time series close to a linear approximation (Pic. 8). The calculated regression coefficients for the dynamics from 2008 to 2022 have positive (2014–2021) and negative values (2008–2014), which shows multidirectional trends in the time series. To refine the trend component of price dynamics, time series were checked through autocorrelation. With a sufficiently high amplitude of air ticket price fluctuations, it was possible to calculate linear and non-linear regression of the air ticket price dynamics trend in ruble and dollar terms, which showed the difference in the trends of ruble and dollar price fluctuations, as mentioned earlier.

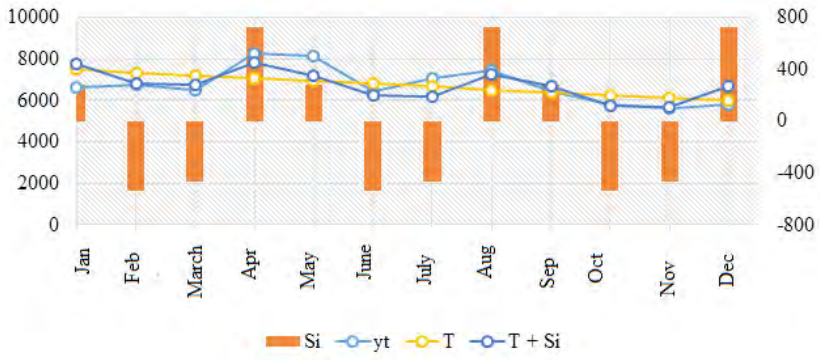
In addition to trend and seasonal components, other cyclical fluctuations are distinguished in price dynamics, their modelling was carried out based on regression analysis. Cyclical changes



Pic. 4. Adaptive model of predicting the seasonal components of price dynamics [developed by the authors].



Pic. 5. Adaptive model of predicting price dynamics with the Brown method [developed by the authors].



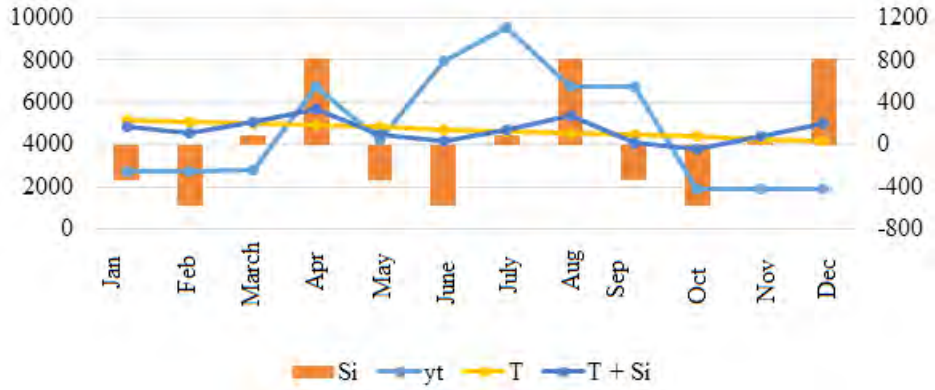
Pic. 6. Additive model of average monthly dynamics of average air ticket price in Russia [developed by the authors].

in the dynamics of prices for air tickets, identified from 2008 to the present, are not sustainable, since for a long period in a planned economy, the price for civil transportation was set without considering macroeconomic and microeconomic patterns, as well as under the influence of global changes in political and economic development. From 2007–2008 several medium-term cycles lasting 4–6 years have been identified (Pic. 9). The first cycle is highlighted incompletely from the analysed data, starting at a low point in 2008 and ending by 2011 with a record price drop since 2000. The second (2011–2017) and third (2017–2021) cycles are complete and have a duration of 4–5 years. Currently, price movement shows the beginning of a new cycle. Analysing the periods of cycles in the dynamics of prices for air transportation, one can establish in many

Table 2

Structure of air ticket price dynamics in Russia for 2020 [developed by the authors]

Period	Actual value, *y*	Seasonal component, Si	Difference between actual value and seasonal component, yt	Trend component, T	Trend and seasonal components T + Si	Random
January	6629	278,2	6350,8	7480,3	7758,5	-1129,5
February	6724	-533,4	7257,4	7343,8	6810,4	-86,4
March	6481	-467,1	6948,1	7207,4	6740,3	-259,3
April	8237	722,3	7514,7	7070,9	7793,2	443,8
May	8142	278,2	7863,8	6934,4	7212,6	929,4
June	6445	-533,4	6978,4	6798,0	6264,5	180,5
July	7063	-467,1	7530,1	6661,5	6194,5	868,5
August	7448	722,3	6725,7	6525,1	7247,4	200,6
September	6431	278,2	6152,8	6388,6	6666,8	-235,8
October	5773	-533,4	6306,4	6252,1	5718,7	54,3
November	5586	-467,1	6053,1	6115,7	5648,6	-62,6
December	5798	722,3	5075,7	5979,2	6701,5	-903,5



Pic. 7. Additive model of average monthly dynamics of air ticket price for the Moscow–Sochi route [developed by the authors].

respects the coincidence with the general economic medium-term cycles, but nevertheless, there are time lags of delay or lag in growth and decline rates.

The periodic fluctuations and trends in the dynamics of prices for air tickets are caused by various factors. Cyclical processes in the aviation industry are influenced by strengthening or weakening of competition. Short-term price movements of a seasonal nature are affected by the balance between the demand of the population and the supply of airlines [9; 11; 13]. An analysis of the dynamics of GDP and prices for air transportation showed a unidirectional change in prices and the presence of trends in the time series of prices for air tickets and in the dynamics of the cost volume of GDP, which are close in parameters. Thus, a long upward trend from 2011 to the present is characteristic of the time series of GDP and airfare prices. Some distinctive features compared to GDP dynamics are noted in changes in airfare prices (Pic. 10). Thus, in the period from 2009 to 2011, there was an increase in GDP, and in the dynamics of airfare prices there was a decrease after the growth in 2008–2010, which distorts the trend dynamics of prices and, accordingly, does not allow calculating linear regression equations for the entire fifteen-year period. The elasticity coefficients of the regression equations for the time series of air ticket prices and the value of GDP, showing the average changes in the resultant attribute with a change in the factor attribute by 1 %, have close values (0,45–0,58).

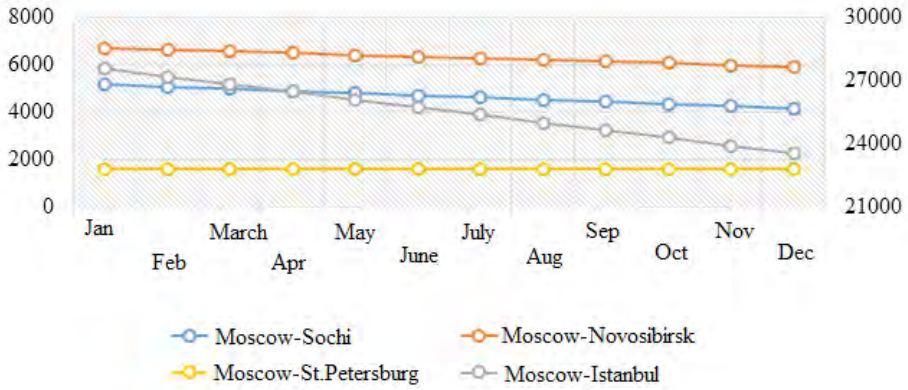
There is also a similarity in direction of trends in the dynamics of airfare, average income, and average salary (Pic. 11).

The correlation analysis carried out with regard to the levels of the time series of the analysed indicators showed sufficient values (Table 3). Checking for the presence of a false correlation of the studied indicators by calculating integration confirmed the validity of the causal relationship between them.

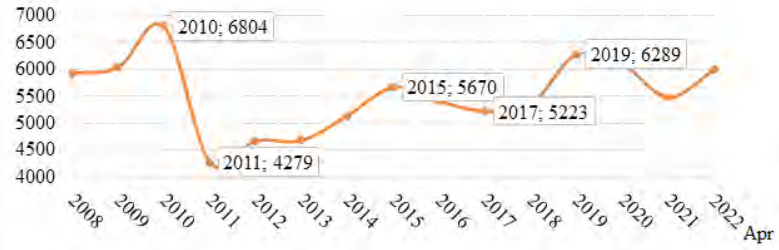
RESULTS

The obtained results of the study of the price dynamics of air transportation over a long period show a complex structure with a trend and periodic components (seasonal and cyclic ones).

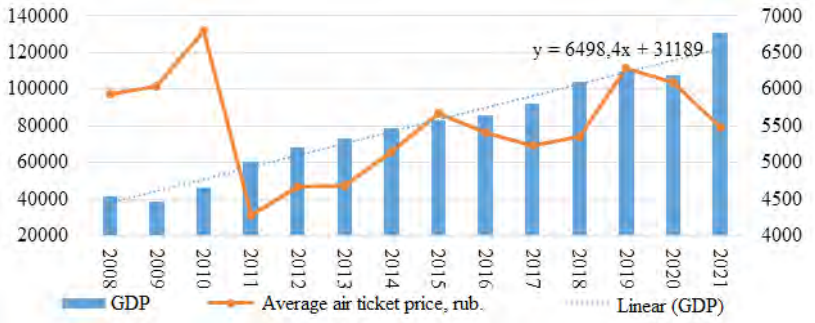
When modelling price dynamics for combined time series, it is required to take into account and



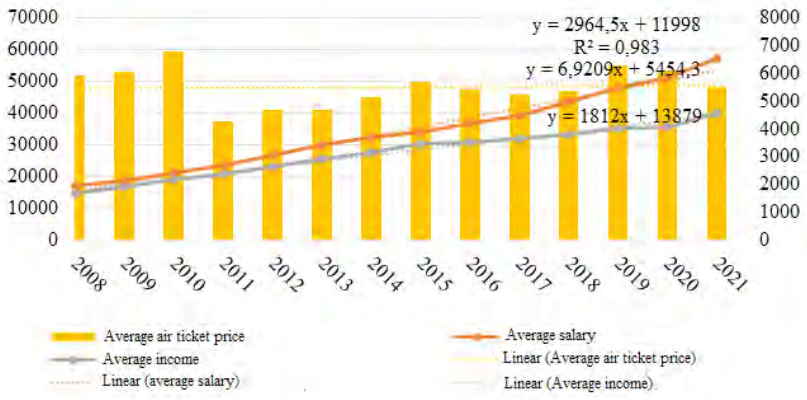
Pic. 8. Trend of the additive model of average annual price dynamics of air tickets in 2022 [developed by the authors].



Pic. 9. Cyclicity in the dynamics of prices for air tickets [developed by the authors].



Pic. 10. Dynamics of GDP and average air ticket prices in Russia [developed by the authors based on Rosstat data]. Report «Social-economic position of Russia». [Electronic resource]: https:// gks.ru. Last accessed 20.09.2022.



Pic. 11. Dynamics of average air ticket prices, average salary, and income of the population in Russia, EMISS [developed by the authors based on Rosstat data]. [Electronic resource]: https:// fedstat.ru. Last accessed 15.09.2022.

Table 3

Correlation matrix of time series [developed by the authors]

Correlation coefficient	Coefficient value	Coefficient assessment (correlation feature)
Correlation coefficient: average air ticket price / average salary	0,734	Straight, strong
Correlation coefficient: average air ticket price/average income	0,525	Straight, moderate
Correlation coefficient: average air ticket price/GDP	0,643	Straight, moderate
Correlation coefficient: passenger flow/average income	0,838	Straight, strong
Correlation coefficient: passenger flow/GDP	0,840	Straight, strong
Correlation coefficient: average air ticket price/passenger flow	-0,529	Reverse, moderate

combine all the components of the time series in the forecast.

Calculated regression coefficients for dynamics from 2008 to 2022 have positive (2014–2021) and negative values (2008–2014), which indicates the presence of multidirectional trends in the levels of the series.

Seasonal fluctuations in air ticket prices change significantly: from minus 8,5 % to plus 12,5 %.

Cyclical changes in the dynamics of prices for air tickets, identified from 2008 to the present, are not sustainable. During a long period of the planned economy, the price of civil transportation was set without taking into account macroeconomic and microeconomic patterns. The cyclical nature of processes in the aviation industry is strongly influenced by the global transformation of political and economic development. From 2007–2008 several medium-term cycles lasting 4–6 years have been identified. The fourth phase (recession) of the new cycle is currently underway.

The adaptive model can become the most reliable for the seasonal component of average monthly prices. Additive and multiplicative models will help predict the average annual price of air transportation.

Further research plans include the development of the ARIMA model using the Foresight analytical platform, the Python programming language and the Statistica software environment.

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