Methods for Estimating the Gross Regional Product Leading Indicator¹

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This paper discusses two methods for estimating the quarterly values of the gross regional product (GRP) leading indicator. The first method is based on Rosstat methodology using the growth rates of indicators that reflect the output for main economic activities in the region. The second method uses temporal disaggregation (disaggregation in time). A distinctive feature of the second method is the possibility of obtaining high-frequency series using not only the indicators specified in Rosstat methodology but also other variables reflecting the dynamics of business activity in regions. The research suggests that temporal disaggregation methods provide more accurate estimates of quarterly values of the physical GRP volume index as compared to methods based on Rosstat methodology. The particular temporal disaggregation model used to forecast GRP for seven federal districts (i.e., all except the North Caucasian District) is chosen based on the performance in forecasting the gross domestic product (GDP) volume, which is close in economic terms to the overall GRP for Russia.

Keywords: *leading indicator, gross regional product, temporal disaggregation, Chow-Lin, Litterman, Fernandez*

JEL Codes: *C15, C43, C53, C65, E23, E37*

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1. Introduction

Gross regional product (GRP) is the gross value added (GVA) of goods and services created by region's residents and is defined as the difference between output and intermediate consumption. GRP is calculated in both current base prices (nominal GRP) and comparable prices (real GRP). To assess the real GRP dynamics, the physical GRP volume index is used; this is a relative indicator that characterises the changes in the GRP volume (excluding changes caused by price dynamics) in the current period as compared to the base period.

Rosstat publishes annual GRP values in its statistical publications on an ongoing basis; however, the data is published with a certain lag (see Table 1).

Table 1. GRP data publishing timelines

Annual GRP estimates	Publishing timeline	Base information used for estimation
Rosstat's 1st estimate	August of the year following the reporting year	Annual statistical reports of companies, report on budget performance, report on the use of extra-budgetary funds and other information
Rosstat's 2nd estimate	December of the year following the reporting year	Formed after the estimates are verified at the federal level and GRP and GDP data are matched
Rosstat's 3rd estimate	April of the second year following the reporting year	Formed based on the 3rd GDP estimate

Source: State Statistical Committee of the Russian Federation (Goskomstat of Russia) (1999)

At the same time, the Methodological Regulations on Statistics (Goskomstat of Russia, 1998, the 'Rosstat methodology') provides for estimation of GRP at annual, quarterly, and monthly intervals. Monthly GRP estimates differ from annual and quarterly estimates: according to the Rosstat methodology, monthly GRP estimates are subject to a large number of expert estimates and indirect calculations, which is due to the lack of detailed information for most economy sectors that would make it possible to determine the value added in current prices. Quarterly and monthly GRP estimates are not published.

Thus, for prompt assessment of the current economic situation in the Russian regions, it is useful to obtain higher-frequency data on the GRP dynamics compared to those published by the official sources.

The purpose of this paper is to obtain high-frequency estimates of GRP, which is an aggregate indicator of production of goods and services for their end use in the constituent entities of the Russian Federation.

In this paper, the authors address two approaches to estimating the GRP leading indicator. The first approach involves estimating the GRP leading indicator based on the data on the output dynamics for the main types of economic activities (taking into account the relative contribution of these activities to the aggregate regional output). The second approach is to disaggregate the annual data on the GRP physical volume index to quarterly data using temporal disaggregation methods.

2. Estimation of the GRP leading indicator based on the Rosstat methodology

According to the Rosstat methodology (Goskomstat of Russia, 1998) for monthly GRP estimates, if there is no current information on the production of goods and services for a certain sector of the economy, the general scheme for estimating the output and intermediate consumption is as follows. The sector's gross output in the previous period of the respective year in the period's current prices is multiplied by the index of the sector's physical output (as a percentage of the previous period).

Based on the Rosstat methodology, in the first approach the GRP leading indicators of the federal districts and constituent entities of Russia are built as weighted average growth rates of various indicators reflecting the output in these federal districts and constituent entities by the main types of economic activities (TEA). The shares of the respective main TEA in the sectoral structure of the GVA are used as weights. To estimate the GRP leading indicator, the following statistical data were collected for Russia as a whole and broken down by federal districts and constituent entities of Russia² (see Table 1 of the Appendix for a description of statistical data with references):

1. Annual data (2009–2017):
 - GRP, million rubles;
 - GRP structure broken down by main TEA.
2. Quarterly data (2009Q1–2019Q2, as a percentage of the respective quarter of the previous year):
 - agricultural output index.
3. Monthly data (January 2009 – December 2009, as a percentage of the previous month; January 2010 – June 2019, as a percentage of the respective month of the previous year):
 - industrial output index;
 - index of the physical volume of construction, including performed in-house;
 - index of the physical volume of retail trade turnover;
 - index of the physical volume of paid services provided to households.

The dynamics of these indicators (taking into account their economic nature) are close to the dynamics of value added and reflect the changes in the aggregate newly created value in comparable periods. Their use is generally in line with international practice (Goskomstat of Russia, 1998; Mitchell et al., 2005).

Using monthly data, the output indices for sectors are calculated with a quarterly frequency (2008Q1 = 100%) based on the indicators reflecting the output for the main TEA by regions, except for the agricultural production index, as there are no chained intra-annual indices. The quarterly indices are calculated using the following method:

² The GRP indicator is not estimated for the Yamalo-Nenets, Khanty-Mansiysk and Nenets Autonomous Districts.

1. For 2009, monthly basic indices are calculated using monthly chain indices of the physical output of the sectors for the respective month:

$$i_{Q_t}^n = i_{Q_{t-1}}^n * i_t^n, \quad (1)$$

where $i_{Q_t}^n$, $i_{Q_{t-1}}^n$ are the indices of physical output of the sector n in the period t to be assessed and in the previous period $t - 1$, respectively; i_t^n is the monthly index of the physical output of the sector n for the period to be assessed in 2009.

2. Since 2010, monthly indices of the physical output of sectors are calculated using the chain method by multiplying the indices for a month (as a percentage of the respective month of the previous year) by the value of the index for the respective period of the previous year:

$$i_{Q_T}^n = q_{T_{yy}}^n * i_{Q_{T-12}}^n, \quad (2)$$

where $q_{T_{yy}}^n$ is the index of the sector n physical output for the assessed month against the respective month of the previous year; $i_{Q_{T-12}}^n$ is the value of the index of the sector n physical output for the respective month of the previous year; and $i_{Q_T}^n$ is the index of the sector n physical output for the month to be assessed.

3. The quarterly indices are calculated as an arithmetic mean of the monthly indices of physical output for the respective quarter:

$$I_{Q_T}^n = \frac{\sum_{t=1}^3 i_{Q_t}^n}{3}, \quad (3)$$

where $I_{Q_T}^n$ is the accumulated quarterly index of the sector n output in the quarter to be assessed T ; and $i_{Q_t}^n$ is the monthly index of the sector n output.

At the next stage, we estimate the GVA sectoral structure in the regions for 2018 and the first two quarters of 2019, as currently there are no officially published Rosstat data for later dates:

1. On the basis of the GVA in the current prices for 2017, broken down by the constituent entities of Russia and its sectoral structure, we calculate the GVA of individual sections of the Russian National Classifier of Economic Activities (OKVED) of the regions.
2. The GVA values obtained in the current prices of the individual sections of OKVED of the regions for 2017 are multiplied by the annual growth rates of the indicators reflecting the output for main TEAs for each quarter of 2018. Similarly, we estimate the GVA for main TEA for the first two quarters of 2019: the GVA for individual sections of OKVED of the regions are multiplied by the value of changes in main TEA for the first two quarters of 2019.

3. Based on the estimated GVA for 2018 and for the first two quarters of 2019, we obtain the sectoral GVA structure of the constituent entities of Russia for the respective periods.

After calculating the quarterly indices for the indicators reflecting the output for main TEA and estimating the weights of main TEA for 2018 and for the first two quarters of 2019, we calculate the GRP leading indicator broken down by the constituent entities of Russia and the federal districts using the following formula:

$$I_Y^T = \sum_{i=1}^N I_{Q_T}^i * D_T^i, \quad (4)$$

where I_Y^T is the index of the GRP leading indicator; $I_{Q_T}^i$ is the index of the sector i physical output in the assessed period; and D_T^i is the share of sector i in the GRP structure in the assessed period.

3. Estimation of the GRP leading indicator using temporal disaggregation methods

An alternative method for estimating the GRP leading indicator is temporal disaggregation, a procedure that enables the transformation of a series with a low frequency into a series with a higher frequency based on high-frequency (e.g., quarterly or monthly) data on the dynamics of related indicators. For example, an annual or quarterly series can, thus, be transformed into a series with a quarterly or monthly frequency, respectively. To solve the problem of the absence of higher frequency data economists use various methods of temporal disaggregation.

3.1. Literature overview

Various statistic methods of temporal disaggregation are used in the literature to build a leading indicator of economic activity. Each of those methods uses a pool of auxiliary series of higher frequency than the indicator concerned. One of the first research papers applying such methods was Chow and Lin (1971). The point of their temporal disaggregation is to estimate a dependent low frequency series (for example, annual) using explanatory higher frequency series (quarterly or monthly) based on a generalised least squares (GLS) regression:

$$\begin{aligned} y^{(q)} &= X\beta + u, \\ y^{(y)} &= Cy^{(q)}, \\ u_t &= \rho u_{t-1} + \varepsilon_t, \\ \beta^{GLS} &\rightarrow \hat{y}^{(q)} = X\hat{\beta}^{GLS}, \end{aligned} \quad (5)$$

where $y^{(v)}$ is the time series with annual frequency of dimension n ; $y^{(q)}$ is the time series of dimension $4n \times 1$ disaggregated to quarterly frequency; X is the explanatory time series matrix of dimension $4n \times m$ with a quarterly frequency; m is the number of explanatory time series; C is the $n \times 4n$ conversion matrix; β is the regression coefficient vector of dimension $m \times 1$; u is the random error vector with zero mean and error covariance matrix Σ .

To convert $4n$ quarterly observations into n annual observations within the framework of temporal disaggregation by Chow-Lin method, various conversion matrices can be used (Chow and Lin, 1971).

The possibility of applying various specifications of conversion matrices (in terms of stock and flow) when performing temporal disaggregation in the Chow-Lin method makes it possible to obtain the best linear unbiased estimates of regression coefficients (5) and the required high-frequency estimates of the time series $y^{(q)}$ using GLS.

An important aspect of the Chow-Lin method is the assumption that random errors are stationary, which is possible only in the case of the stationarity or co-integration of the series in equation (5), but in reality this assumption is not always satisfied.

Fernandez (1981) was one of the first to point out this fault of the Chow-Lin method. As a solution, the author proposes using quarterly residuals in the form of random walk (RW): $u_t = u_{t-1} + \varepsilon_t$.³

Table 2. Temporal disaggregation model

Model	Conditions	Disaggregation principle	Specifics
Chow-Lin	High-frequency (quarterly) series must be stationary or co-integrated	The dynamics of the disaggregated series are based on the regression relationship between the high-frequency data	Quarterly residuals correspond to the first-order autoregressive process (AR(1)): $u_t = \rho u_{t-1} + \varepsilon_t$, where ε_t corresponds to white noise (WN) and $ \rho < 1$
Fernandez	The series must not be co-integrated. Quarterly residuals correspond to a non-stationary process		Quarterly residuals correspond to the RW: $u_t = u_{t-1} + v_t$, where $v_t = \varepsilon_t$
Litterman			Quarterly residuals correspond to the following process: $u_t = u_{t-1} + v_t$, where $v_t \sim \text{AR}(1)$ ($v_t = \rho v_{t-1} + \varepsilon_t$), $\varepsilon_t \sim \text{WN}$

The Chow-Lin model was further developed by Litterman (1983). He noticed that in individual cases the quarterly residuals in the form of RW according to Fernandez (1981) do not eliminate autocorrelation. Litterman (1983) softened Fernandez (1981) assumption of the specification of quarterly residuals, suggesting that they can be presented in the following form: $u_t = u_{t-1} + v_t$,

³ This specification of quarterly balances is in essence a modified form of quarterly balances of the Chow-Lin model, where $\rho = 1$.

where v_t , in turn, is the first-order autoregressive process (AR(1)): $v_t = \rho v_{t-1} + \varepsilon_t$, and ε_t is white noise $WN(0, \sigma_\varepsilon^2)$.

Thus, at the moment, the main models using temporal disaggregation are the models by Chow–Lin, Fernandez and Litterman (see Table 2). For temporal disaggregation according to the Chow-Lin method, the series to be disaggregated and the auxiliary series must be either stationary or co-integrated, whereas the Litterman and Fernandez methods are used for non-stationary series which are not co-integrated. Proceeding from these conditions, the main difference between the methods suggested is in the structure of residuals.

Table 3. Examples of using temporal disaggregation methods

No.	Authors	Methods	Result
1	Abeysinghe and Rajaguru (2004)	Chow-Lin	To build quarterly GDP values for China and ASEAN countries, the authors compare the Chow-Lin method with one-factor methods. Quarterly indicators of industrial production, agriculture and paid services are used as explanatory variables. The authors conclude that, among the methods reviewed, the Chow-Lin method has the best predictive potential
2	Sorić and Buljan (2014)	Chow-Lin, Litterman и Fernandez	The authors estimate monthly GDP values for Croatia. For temporal disaggregation, indices of physical volume of industrial production and retail turnover are used as explanatory variables. According to the results of the conducted correlation analysis of the monthly forecast and the quarterly observed GDP, the Fernandez method demonstrates the best forecast effectiveness
3	Negash and Daalmans (2014)	Chow-Lin	The authors estimate monthly GDP values for the Netherlands using the industrial production index, the unemployment rate, the inflation rate, and the consumer lending volume as explanatory variables. Based on the conducted regression analysis, the authors conclude that the inflation rate is statistically insignificant

The literature features various examples of using the above methods for building high-frequency data of a country's GDP (see Table 3).

There are also a number of papers in which the authors perform temporal GDP disaggregation using a modified form of the Chow-Lin method. For example, to forecast the GRP of Spain's regions, Polasek et al. (2010) use the Chow-Lin spatial model together with Bayesian distribution. Bruno et al. (2005) estimate the GDP for G7 countries using the dynamic model of the Chow-Lin method.

In Russian practice, temporal disaggregation is used to construct leading indicators of the socio-economic development of the Eurasian Economic Union member states. With the Chow-Lin method, quarterly GDP data and monthly indicators characterising the dynamics of the main types of economic activities are used to build a Consolidated Coincident Indicator (CCI). The latter serves as the baseline (predictive) variable for estimating the Consolidated Leading Indicator of economic activities in the member states of the Customs Union and the Common Economic Space (Eurasian Economic Commission, 2014).

Motorin (2016) suggests a temporal disaggregation method based on movement preservation principle and a Proportional First Differences (PFD) benchmarking method from Denton (1971) incorporating a known initial conditions from Cholette and Dagum (1994) into the analytical solution. The method allowed the author to calculate a temporal disaggregation for the Russian quarterly GDP in 2011–2015 using monthly data on output index for the main sectors of the economy. Denton method makes a temporal disaggregation while using only one high-frequency indicator. Hence, the high quality disaggregation is only possible if there is a relatively high correlation between a high-frequency indicator and a low-frequency series.

Except for the above-mentioned papers, Russian literature features no examples of temporal disaggregation of leading indicators of GDP, much less GRP, which makes this research even more important.

It should be noted that the literature also mentions other approaches (models) of building leading indicators of economic activities using higher frequency data. These papers are mainly dedicated to the nowcasting and forecasting of quarterly GDP values using monthly data of various macroeconomic indicators. Thus, Porshakov et al. (2016) and Styrin and Potapova (2009) use the dynamic factor model (DFM) in order to extract several non-observable factors from a large information set of monthly macroeconomic series which explain a significant portion of the dispersion in the original variables. This model is also used to extrapolate the values of extracted factors for the subsequent months of the current or future quarters, for which a current estimate or forecast is made. After that, the obtained values of the extracted non-observable factors are averaged to transition to the quarterly frequency in order to estimate various equations for forecasting quarterly GDP values.

Another approach is demonstrated by Mikosh and Solanko (2019). The authors also use a large pool of explanatory variables of daily and monthly frequency to predict quarterly GDP values using various models with mixed data (MIDAS (Mixed Data Sampling), U-MIDAS (Unrestricted Mixed-Frequency Models), and Bridge Equations).

A common point of the models used in the papers mentioned above is that monthly values of various macroeconomic indicators are aggregated with the help of the above-mentioned models to obtain quarterly GDP values. Temporal disaggregation methods based on the current dynamics of economic indicators, on the other hand, make it possible to obtain estimates of both unpublished low-frequency (e.g., annual GDP/GRP) and unpublished higher-frequency indicators (e.g., quarterly).

3.2. Research methodology and results

Choosing a temporal disaggregation model specification is equivalent to choosing a linear regression model specification.

Temporal disaggregation is a kind of forecast of an unobservable time series based on known observable high-frequency data. Thus, it is necessary to take into account the quality of the forecast of the required unobservable high-frequency series. In practice, there are two ways to assess forecast quality obtained by means of temporal disaggregation.

The first method is to use a conversion matrix to convert quarterly series obtained via temporal disaggregation into annual series. First, temporal disaggregation of the required unobservable quarterly series is performed. The obtained quarterly series are then converted into annual series using the conversion matrix. The obtained annual series are compared with the actual annual values of the indicator in question. This method can be used when there are long retrospective series of both annual values of the indicator concerned and quarterly series used for temporal disaggregation, and the type of conversion matrix is known precisely.

The second method uses an alternative series similar in meaning and values to both low- and high-frequency observable data as an explained variable for temporal disaggregation. Thus, the quarterly data obtained as a result of temporal disaggregation are compared with the observable quarterly values.

For Russia, the first method is not feasible because there are no long retrospective series of annual GRP or explanatory variables to be used for temporal disaggregation.

The second method of evaluating the quality of prediction was chosen as the preferable one in this study as there exists a GDP indicator, which is similar to the required non-observable GRP indicator in its economic content, and values and data on which are published by Rosstat on an annual and quarterly basis (see Figure 1).

Figure 1. Index of the physical volume of Russia's GRP and GDP
(as a % of the previous year)

At the same time, despite the similar dynamics and economic meaning of these indicators, there are certain differences between the federal-level GDP and the regional-level GRP. One of the main differences is that GDP is calculated

taking into account net taxes on products and imports, while GRP does not take parts of centrally collected taxes into account (VAT, excise duties, foreign trade taxes, etc.) that cannot be distributed among regions.

Moreover, the GRP calculation does not take into account the added value created as a result of multi-regional activities for non-market collective services (national defence, part of public administration services, financial intermediaries, etc.) provided by public institutions to the society as a whole.

Nevertheless, we chose the annual Russia's GDP in value terms (billion rubles in 2008 prices) as the dependent variable for temporal disaggregation.

Since the authors chose the second method of assessing the quality of forecast (using an alternative variable), the main objective of this research transforms into choosing a model that most accurately predicts the quarterly values of Russia's GDP, when the annual values in value terms are disaggregated. To determine the accuracy of the forecast, the authors compare model quarterly forecasts of Russia's GDP with the actual quarterly values officially published by Rosstat. Then the specification of the model with the most accurate estimates of Russia's GDP quarterly values is used for temporal disaggregation of annual GRP values both for Russia as a whole and for all federal districts.

To find the best specification of the temporal disaggregation model of Russia's GDP leading indicator, several main methods of temporal disaggregation are used. These methods differ mainly in the autoregressive parameter estimates and the specifics of the estimation of the covariance error matrix.

Table 4. Types of temporal disaggregation implemented in the TempDisagg package

Method	GLS regression estimate	Parameter ρ estimate	Specifics of the estimation of the covariance error matrix for GLS
Chow-Lin	Maximum likelihood method	GLS estimate	The correlation error matrix is multiplied by the coefficient $1/(1 - \rho^2)$
Chow-Lin		$\rho = 0.5$	
Litterman		GLS estimate	Optimisation problem solution
Litterman		$\rho = 0.5$	
Fernandez		$\rho = 0$	Optimisation problem solution (Litterman method approach)
Chow-Lin Ecotrim	RSS (Residual Sum of Squares) minimisation	GLS estimate	The correlation error matrix is used
Chow-Lin Quilis			The correlation error matrix is multiplied by the coefficient $1/(1 - \rho^2)$
Litterman			Optimisation problem solution

To perform temporal disaggregation, the TempDisagg statistical package for R Studio (Sax and Steiner, 2013) was chosen, which makes it possible to calculate different specifications of temporal disaggregation (see Table 4).

The real economy indicators based on Rosstat's official data and the Bank of Russia's Monitoring of Companies are used as independent variables for temporal disaggregation of annual Russian GDP. Quarterly data are used in the form of seasonally adjusted indexes (as a % of 2008Q4) for the period from 2009Q1 to 2019Q2 (see Table 2 of the Appendix).

The Bank of Russia's Monitoring of Companies has been carried out by its regional branches on a monthly basis since January 2000. As of 2019, the sample included over 11,600 companies in various sectors of the economy, including industry, agriculture, construction, transportation and storage, wholesale and retail trade, etc. Companies across all Russian regions covering both small- and medium-sized enterprises and large companies are polled in the form of a survey (Bank of Russia, 2018).

The respondents' answers are used to calculate the balances of answers reflecting the prevalence of estimates of an increase/decrease in production volumes, of improvement/deterioration in the economic conditions in the sector in which the company operates, and of good/bad company's financial standing:

$$B_t = P_t^+ - P_t^-, \quad (6)$$

where B_t is the difference between the shares of 'more' type answers (increased/improved/good, P_t^+) and 'less' type answers (decreased/deteriorated/bad, P_t^-) relative to the total number of answers. The change in the balance of answers as compared to the previous month reflects the direction and intensity of the changes going on. For example, an increase/decrease in the positive balance of answers as compared to the previous month evidences an acceleration/slow-down in the growth of production volumes, a significant improvement/deterioration in the economic conditions of the sector concerned, and a significant improvement/deterioration of the financial standing of companies in the sector concerned.

The Bank of Russia's company survey methodology (Bank of Russia, 2018) is in line with international practice, which was established with the active participation of the Institute for Economic Research, Munich (IFO Institute). Besides the Bank of Russia, this methodology is used by the Bank of France, the Bank of Japan, the Bank of Poland, the Bank of Belgium, and the Bank of Canada. The companies surveyed by regulators provide information of various nature, such as business conditions, changes in supply and demand in production and investment sectors, sales volumes, industrial production capacity utilisation, etc. The qualitative data are converted into quantitative ones mainly by calculating the balance of answers (the difference between positive and negative answers).

The indicators of the real economy sector and the indicators of the Bank of Russia's Monitoring of Companies have a common feature that allows them to be used for temporal disaggregation of annual values of Russia's GDP (GRP of Russia's constituent entities): first, the selected indicators characterise the

dynamics of goods and services output in the region, and second, these data are available for all Russian regions.

Before describing the results of the temporal disaggregation conducted, it should be mentioned that the statistical data for the real economy indicators with a quarterly frequency broken down by Russian regions are available only starting from 2009. As the selected model will be used subsequently for disaggregation of the GRP of Russian constituent entities, it was decided to limit the selection of annual GDP data to the range of available regional data, which gives us ten annual GDP data points.

The optimal model and method of temporal disaggregation are selected as follows. At the first stage, initial variables of the real economy sectoral indicators and the indicators from the Monitoring of Companies are taken as candidates for explanatory series. Because of the identification problem and the need for further testing of the model in pseudo-real time, the number of explanatory series k included in the model is limited to seven. For a fixed number of explanatory series, the authors review all possible combinations from 25 series; for each set of k ($k = 1, \dots, 7$) series, temporal disaggregation is performed using all methods available (see Table 4). For each method, the mean absolute percent error (MAPE) is calculated, and for this set of explanatory series the MAPEs of different methods are summed up. Among all possible combinations of the given number of explanatory series, the combination with minimal total MAPE is chosen. The best specification for a fixed number of explanatory series and the corresponding MAPEs are provided in Table 3 of the Appendix.

To choose among the models with a different number of variables, the authors also calculate the Akaike information criterion (AIC) and the Schwarz (or Bayesian) information criterion (BIC). The results of the calculations, provided in Tables 4 and 5 of the Appendix, demonstrate that the minimum total value among the types of temporal disaggregation considered, according to both the Akaike information criterion and the Schwartz information criterion, is observed for the third specification ($k = 3$).

All of the above model quality indicators are intra-sample indicators of the equation 'fit' quality – that is, they are calculated based on the same data as the model is built. To study the stability of the selected models and the possibility of their further use for temporal disaggregation, the authors also analyse the quality of out-of-sample model prediction.

To that end, at the second stage of the study, the best models are tested in pseudo-real time (pseudo out-of-sample forecast). As a test period for models with six or fewer variables, the authors take the period from 2017Q1 to 2019Q2 (nowcasting for ten quarters), and for models with seven or fewer variables, the authors take the period from 2018Q1 to 2019Q2 (nowcasting for six quarters). In the first step, temporal disaggregation is performed on a sample from 2009Q1 to 2017Q4 for the nowcasting for six quarters (and on a sample from 2009Q1

to 2016Q4 for the nowcasting for ten quarters) with an estimation of quarterly GDP for four quarters ahead.

At the next stage, the training sample is expanded by four quarters forward, then GDP is estimated again for four quarters forward and so on. The corresponding MAPEs for the nowcasting for six and ten quarters are provided in Tables 6 and 7 of the Appendix.⁴ To compare the obtained results of temporal disaggregation for the model with seven explanatory variables, MAPEs for six-quarter nowcasting are used. The model with seven variables do not show the minimum total MAPE value among the specifications considered, which include one to seven explanatory variables (see Appendix, Table 6). To choose the best specification among the models with one to six explanatory variables, MAPEs of ten-quarter nowcasting are taken. The third specification is the best in terms of the MAPE criterion (see Appendix, Table 7).

Thus, the best model, according to the AIC, BIC and MAPE criteria estimated for ten-quarter nowcasting, is the third specification using the GDP leading indicator based on the Rosstat methodology and two indicators from the Bank of Russia Monitoring of Companies, the sufficiency of orders the company has and the changes in demand for products (services), as explanatory variables.

To choose the best method of temporal disaggregation, a rank table is built for the third (final) specification using intra-sample MAPE indicators both for six- and ten-quarter nowcasting (see Appendix, Table 8). All temporal disaggregation methods are ranked based on the MAPE indicator. The minimum value is assigned Rank 1, and the maximum value is assigned Rank 7. To select the final specification of the temporal disaggregation performed, the authors calculate a weighted average rank. The minimum weighted average rank is observed for temporal disaggregation using Litterman ML (Litterman model with a maximum likelihood estimation method).

The graphical analysis of actual quarterly values of Russia's GDP published by Rosstat and the obtained estimates of quarterly values of Russia's GDP based on the final specification for Litterman ML is provided in Figure 2.

Table 5 presents the quantitative characteristics of the correspondence between the estimated model series and the actual value of quarterly GDP. As a reference model, a 'naïve disaggregation' is applied, where the annual GDP is divided into four equal parts to obtain quarterly GDP values. From the results obtained we can draw the conclusion that, in general, temporal disaggregation approximates the quarterly values of Russia's GDP better than the leading indicator estimated by the authors in accordance with the Rosstat methodology and 'naïve disaggregation'.

⁴ The MAPE of the nowcasting for ten points is not calculated for the specifications with seven variables because of the limited degrees of freedom for the sample from 2009Q1 to 2016Q4.

Figure 2. Index of the physical volume of Russia's GDP
(as a % of 2009Q1, seasonally adjusted)

Table 5. Comparative characteristics of disaggregation methods
of Russia's quarterly GDP values

Method	RMSE (Root Mean Square Error)	MAPE
GDP leading indicator (Rosstat methodology)	2.086	0.0163
GDP estimates (Litterman ML)	0.967	0.0078
'Naïve' disaggregation	1.176	0.0084

Table 6. Comparative characteristics of Russia's annual GDP forecast quality

Model	MAPE	$MAPE_{Litterman} / MAPE_{Reference}$
Temporal disaggregation (Litterman ML)	0.015	–
ARIMA(1, 1, 0)	0.022	0.68
RW	0.019	0.79

Temporal disaggregation methods can also be used to estimate the dynamics of annual GDP (GRP) based on current statistics. The obtained quarterly GDP (GRP) values can be aggregated to get an estimate of annual GDP (GRP), the official figures of which are published with a long delay. To find out whether this approach has advantages in comparison with simpler prediction methods, the authors compare the forecast of the annual value of Russia's GDP with reference models, such as the RW model and the Autoregressive Integrated Moving Average ARIMA(1, 1, 0). The forecast is made for one period forward using the expanding window method in pseudo-real time for 2017–2019. The comparative characteristics of forecast quality are provided in Table 6.

Based on the comparative characteristics, we can draw a conclusion about the advantages of temporal disaggregation in forecasting annual GDP as compared to reference models.

As the purpose of the research is to obtain quarterly estimates of GRP, at the last stage estimates of quarterly GRP data for Russia as a whole and for seven federal districts⁵ are obtained using the third specification of the model for the GDP data and the Litterman ML method (see Figure 3). The diagrams presented in Figure 3 show that temporal disaggregation is generally much better at approximating GRP for the federal districts than the leading indicator built as per the Rosstat methodology.

4. Conclusion

In conclusion, it should be noted that significant gaps periodically arise between the actual annual GRP data and the model quarterly estimates of the GRP leading indicator as per the Rosstat methodology (Figure 3). One of the reasons for the gaps is that GRP is the gross value added created by the region's residents, calculated as the difference between output and intermediate consumption. In turn, because of the lack of regional information about the volume of intermediate consumption in industrial production, construction, retail trade, and paid services provided to households, the authors did not adjust the obtained indicator for the possible volume of intermediate consumption when estimating the GRP leading indicator according to the Rosstat methodology.

It should be noted that the authors estimated the GRP leading indicator without taking data on agricultural output into account due to the lack of chain indices broken down by regions.

Moreover, when calculating the GRP leading indicator in accordance with the Rosstat methodology, the authors chose the index of the physical volume of retail trade turnover as an indicator of section G – 'Wholesale and retail; repair of motor vehicles and motorcycles', because it is impossible to objectively separate the values of gross value added for retail, wholesale, and repair services for motor vehicles and motorcycles.

Also, paid services to households do not include a number of services (e.g., catering services, financial and insurance services, mandatory health insurance services, etc.), for which no current regional information is officially published (Rosstat, 2017).

To summarise, it should be noted, that in order to improve the accuracy of model estimates, research will be continued within the scope of temporal disaggregation using state space models.

⁵ Temporal disaggregation of North-Caucasus district is not calculated because of lack of retrospective data on most of the indicators.

Figure 3. Index of physical volume of gross regional product
(as a % of the mean value for 2009, seasonally adjusted)

Figure 3 continues on p. 19

Continuation, Figure 3 starts on p. 18

References

- Abeyasinghe, T. and Rajaguru, G.** (2004). Quarterly Real GDP Estimates for China and ASEAN4 with a Forecast Evaluation. *Journal of Forecasting*, 23(6), pp. 431–447. doi: 10.1002/for.922
- Bank of Russia** (2018). *Analiz Tsenovykh Ozhidaniy Predpriyatiy: Metodologicheskii Kommentarii* [Analysis of Price Expectations of Companies: Methodological Commentary]. Moscow: Bank of Russia. [In Russian]. Available at: http://www.cbr.ru/Content/Document/File/104012/analysis_18-12.pdf [accessed on 20 May 2020].
- Bruno, G., Di Fonzo, T., Golinelli, R. and Parigi, G.** (2005). Short-run GDP Forecasting in G7 Countries: Temporal Disaggregation Techniques and Bridge Models. *The OECD–Eurostat Workshop on Frontiers in Benchmarking Techniques and Their Application on Official Statistics*, 7–8 April.
- Cholette, P. and Dagum, E.** (1994). Benchmarking Time Series with Autocorrelated Survey Errors. *International Statistical Review*, 62(3), pp. 365–377.
- Chow, G. C. and Lin, A.** (1971). Best Linear Unbiased Interpolation, Distribution, and Extrapolation of Time Series by Related Series. *The Review of Economics and Statistics*, 53(4), pp. 372–375.
- Denton, F.** (1971). Adjustment of Monthly or Quarterly Series to Annual Totals: An Approach Based on Quadratic Minimization. *Journal of the American Statistical Association*, 66(333), pp. 99–102.
- Eurasian Economic Commission** (2014). *Metodologicheskiye Podkhody k Postroyeniyu Operezhayushchikh Indikatorov Ekonomicheskogo Razvitiya Gosudarstva – Chlenov TS i YEEP* [Methodological Approaches to Building Leading Indicators of Socio-Economic Development of the Customs Union and Common Economic Space Member States]. [In Russian]. Available at: http://www.eurasiancommission.org/ru/act/integr_i_makroec/dep_makroec_pol/investigations/Documents/LEI_meths.pdf [accessed on 20 May 2020].
- Fernandez, R. B.** (1981). A Methodological Note on the Estimation of Time Series. *The Review of Economics and Statistics*, 63(3), pp. 471–476.
- Goskomstat of Russia** (1998). *Metodologicheskiye Polozheniya po Statistike* [Methodological Regulations on Statistics], Vol. 2. Moscow.
- Goskomstat of Russia** (1999). *O Reglamente Razrabotki i Predstavleniya Danykh po Valovomu Regional'nomu Produktu* [On the Regulations on Development and Presentation of Data on Gross Regional Product]. Order N 20, 22 February. [In Russian].
- Litterman, R. B.** (1983). A Random Walk, Markov Model for the Distribution of the Time Series. *Journal of Business and Economic Statistics*, 1(2), pp. 169–173. doi: 10.1080/07350015.1983.10509336
- Mikosch, H. and Solanko, L.** (2019). Forecasting Quarterly Russian GDP Growth with Mixed-Frequency Data. *Russian Journal of Money and Finance*, 78(1), pp. 19–35.

- Mitchell, J., Smith, R. J., Weale, M. R., Wright, S. and Salazar, E. L.** (2005). An Indicator of Monthly GDP and an Early Estimate of Quarterly GDP Growth. *Economic Journal*, 115(501), pp. 108–129. doi:10.1111/j.0013-0133.2005.00974.x
- Motorin, V. I.** (2016). A Method for Temporal Disaggregation of Flow Time-Series Based on High-Frequency Indicator Data and Movement Preservation Principle. *Voprosy Statistiki*, 8, pp. 27–38. [In Russian]. doi: 10.34023/2313-6383-2016-0-8-27-38
- Negash, F. and Daalmans, J.** (2014). Method: Chow-Lin Method for Temporal Disaggregation. In: *Memobust Handbook on Methodology of Modern Business Statistics*. Luxembourg: Eurostat. Available at: <https://ec.europa.eu/eurostat/cros/system/files/Macro-Integration-06-M-Chow-Lin%20v1.0.pdf> [accessed on 20 May 2020].
- Polasek, W., Llano, C. and Sellner, R.** (2010). Bayesian Methods for Completing Data in Spatial Models. *Review of Economic Analysis*, 2(2), pp. 194–214.
- Porshakov, A., Ponomarenko, A. and Sinyakov, A.** (2016). Nowcasting and Short-Term Forecasting of Russian GDP with a Dynamic Factor Model. *Journal of the New Economic Association*, 2(30), pp. 60–76. [In Russian].
- Rosstat** (2017). *Ob Utverzhdenii Ofitsial'noy Statisticheskoy Metodologii ob Ob'yeme Ofitsial'noy Informatsii v Razreze Vidov Uslug* [On the Approval of the Official Statistical Methodology for Generating Official Statistical Information on the Volume of Paid Services to Households by Types of Services]. Rosstat Order N 643, 29 September. [In Russian].
- Sax, C. and Steiner, P.** (2013). Temporal Disaggregation of Time Series. *R Journal*, 5(2), pp. 80–87.
- Sorić, P. and Buljan, V.** (2014). Estimating Monthly GDP in Croatia: a Temporal Disaggregation Approach. In: *2014 M-Sphere Book of Papers*. Zagreb: M-Sphere, pp. 411–416.
- Styrin, K. and Potapova, V.** (2009). *RenCap-NES Leading GDP Indicator Forecasts—Better and Earlier*. Available at: <https://old.nes.ru/dataupload/files/projects/indicator/RenCap-NES%20Leading%20GDP%20Indicator%2010%20Dec.pdf> [accessed on 20 May 2020].

APPENDIX

Table 1. Description of statistical data used to calculate the leading indicator as per the Rosstat methodology

Indicator	Data source	Units of measurement
Annual data (2009–2017)		
GRP	Russian regions. Socio-economic indicators (www.gks.ru)	million rubles
Index of physical GRP volume	Russian regions. Socio-economic indicators (www.gks.ru)	%
Sectoral structure of GVA	Russian regions. Socio-economic indicators (www.gks.ru)	%
Quarterly data (2009Q1–2019Q2, as a percentage of the corresponding quarter of the previous year)		
Agricultural output index	Information for monitoring the socio-economic situation in the constituent entities of the Russian Federation, see at: www.gks.ru/folder/11109/document/13259.	%
Monthly data (January 2009 – December 2009, as a percentage of the previous month; January 2010 – June 2019, as a percentage of the corresponding month of the previous year)		
Industrial output index		%
Index of physical volume of construction, including work performed in-house	Information for monitoring the socio-economic situation in the constituent entities of the Russian Federation, see at: www.gks.ru/folder/11109/document/13259.	%
Index of physical volume of retail trade turnover		%
Index of physical volume of paid services to households		%

Table 2. Description of statistical data used to estimate the GRP leading indicator by means of temporal disaggregation methods

Sample	Indicator	Designation	Format
Real sector indicators			
Official Rosstat data (2009Q1 – 2019Q2)	Industrial output index	pp	As a % of December 2008
	Index of physical volume of construction	str	
	Index of physical volume of wholesale trade turnover	ort	SA (X13/TRAMO SEATS)
	Index of physical volume of retail trade turnover	oot	
	Index of physical volume of paid services to households	opu	
	Agricultural output index	sx	

Table 2 continues on p. 23

Continuation, Table 2 starts on p. 22

Sample	Indicator	Designation	Format
Assessment of the current economic situation and agents' expectations			
Official data of the Bank of Russia Monitoring of Companies (2009Q1–2019Q2)	Changes in economic conditions	id1	Companies, total; balance of answers
	Assessment of the financial standing of companies	id2	
	Changes in production volumes (contract work, transport services, communications services, trade turnover)	id4	As a % of December 2008
	Changes in the volumes of shipped products (commissioned facilities, shipped cargoes, sales)	id5	
	Changes in the stock of finished products (volumes of construction in progress, commodity resources)	id6	SA (X13/TRAMO SEATS)
	Changes in the volumes of orders for products (contract agreements, transportation contracts, contracts for communication services) in the domestic market	id7	
	Changes in the volumes of orders for products (contract agreements, transportation contracts, contracts for communication services) in the foreign market	id8	
	Sufficiency of orders (contract agreements, service agreements, contracts)	id9	
	Changes in industrial production capacity utilisation	id10	
	Changes in production (circulation) costs	id11	
	Changes in demand for industry products (services)	id12	
	Changes in working capital availability	id13	
	Changes in lending terms	id14	
	Changes in the investment activity of companies (investment questionnaire)	id23	
	Expectations: changes in production volumes (contract work, transport services, trade turnover)	id15	
	Expectations: changes in demand for products (services) of companies	id16	
	Expectations: changes in the financial standing of companies in the quarter following the reporting quarter (investment questionnaire)	id22	
Estimated indicators			
Estimations of the Ural Main Branch of the Bank of Russia (2009Q1–2019Q2)	GDP leading indicator based on the Rosstat methodology	oper	As a % of December 2008
Estimates of the Bank of Russia (2009Q1–2019Q2)	Business climate indicator (BCI) based on the data of the Bank of Russia Monitoring of Companies	id3	SA (X13/TRAMO SEATS)

Note: all time series are non-stationary integrated of order one (I(1)).

Table 3. Results of the best specifications of modelling Russia's quarterly GDP using temporal disaggregation methods (2009–2018)

Number of variables (<i>k</i>) included in the specification, where $k = 1, \dots, 7$		1	2	3	4	5	6	7
Number of tested specifications		25	300	2,303	12,650	53,130	177,100	480,700
Real sector indicators	Industrial output index						•	
	Index of physical volume of construction				•	•	•	•
	Index of physical volume of wholesale trade turnover		•				•	
	Agricultural output index							
	Index of physical volume of retail trade turnover	•						
Estimates of the Ural Main Branch of the Bank of Russia	GDP leading indicator based on the Rosstat methodology (estimates of the Ural Main Branch of the Bank of Russia)			•	•	•		•
Indicators of the Bank of Russia Monitoring of Companies	Changes in economic conditions				•		•	
	Changes in the stock of finished products						•	
	Sufficiency of orders		•	•				•
	Changes in demand for products (services)			•		•		•
	Changes in working capital availability					•		•
	Expectations: changes in production output					•	•	•
	Expectations: changes in demand for products				•			
	Changes in the investment activity of companies							•
R Studio	Types of temporal disaggregation							
	Chow-Lin ML	0.00369	0.00370	0.00401	0.00399	0.00385	0.00396	0.003333
	Chow-Lin min RSS Ecotrim	0.00454	0.00369	0.00396	0.00401	0.00378	0.00389	0.003477
	Chow-Lin min RSS Quilis	0.00354	0.00373	0.00403	0.00386	0.00372	0.00372	0.003381
	Chow-Lin fixed rho	MAPE	0.00486	0.00452	0.00392	0.00397	0.00382	0.00393
	Litterman ML		0.00365	0.00389	0.00403	0.00391	0.00368	0.00352
	Litterman min RSS		0.00375	0.00391	0.00405	0.00397	0.00368	0.00353
	Litterman fixed rho		0.00352	0.00376	0.00403	0.00392	0.00371	0.00364
Total MAPE among all types of temporal disaggregation	Fernandez		0.00352	0.00373	0.00403	0.00386	0.00372	0.00372
			0.03107	0.03093	0.03207	0.03150	0.02996	0.02991
Estimates of the Ural Main Branch	MAPE of the GRP leading indicator according to the Rosstat methodology without temporal disaggregation across the entire sample							0.00493

Note: • – inclusion of the variable into the model specification.

Table 4. Akaike information criteria of the best specifications of modelling of Russia's quarterly GDP using temporal disaggregation methods

The best specification for the variables (k) included in the specification, where $k = 1, \dots, 7$		1	2	3	4	5	6	7
Real sector indicators	Industrial output index						•	
	Index of physical volume of construction				•	•	•	•
	Index of physical volume of wholesale trade turnover		•				•	
	Agricultural output index							
	Index of physical volume of retail trade turnover	•						
Estimates of the Ural Main Branch of the Bank of Russia	GDP leading indicator based on the Rosstat methodology (estimates of the Ural Main Branch of the Bank of Russia)			•	•	•		•
Indicators of the Bank of Russia Monitoring of Companies	Changes in economic conditions				•		•	
	Changes in the stock of finished products						•	
	Sufficiency of orders		•	•				•
	Changes in demand for products (services)			•		•		•
	Changes in working capital availability					•		•
	Expectations: changes in production output					•	•	•
	Expectations: changes in demand for products		•					
	Changes in the investment activity of companies							•
R Studio Types of temporal disaggregation	Chow-Lin ML	10.433	8.591	8.178	7.587	8.730	9.350	7.929
	Chow-Lin min RSS Ecotrim	11.473	9.547	6.934	7.409	7.530	8.143	7.145
	Chow-Lin min RSS Quilis	10.293	8.460	6.286	6.863	6.757	7.626	6.788
	Chow-Lin fixed rho	AIC 12.759	11.449	7.271	7.906	7.861	8.448	7.197
	Litterman ML	7.464	5.004	5.028	4.232	3.725	4.665	6.788
	Litterman min RSS	7.334	4.952	4.183	4.187	3.692	4.634	3.418
	Litterman fixed rho	9.030	7.187	5.234	5.795	5.655	6.499	5.807
	Fernandez	10.282	8.450	6.285	6.862	6.754	7.625	6.788
Total AIC value among all types of temporal disaggregation		79.069	63.639	49.401	50.841	50.703	56.990	51.860

Note: • –inclusion of the variable into the model specification.

Table 5. Schwartz information criteria of the best specifications of modelling of Russia's quarterly GDP using temporal disaggregation methods

The best specification for the variables (k) included in the specification, where $k = 1, \dots, 7$		1	2	3	4	5	6	7
Indicators of the real sector	Industrial output index						•	
	Index of physical volume of construction				•	•	•	•
	Index of physical volume of wholesale trade turnover		•				•	
	Agricultural output index							
	Index of physical volume of retail trade turnover	•						
Estimates of the Ural Main Branch of the Bank of Russia	GDP leading indicator based on the Rosstat methodology (estimates of the Ural Main Branch of the Bank of Russia)			•	•	•		•
Indicators of the Monitoring of Companies of the Bank of Russia	Changes in economic conditions				•		•	
	Changes in the stock of finished products						•	
	Sufficiency of orders		•	•				•
	Changes in demand for products (services)			•		•		•
	Changes in working capital availability					•		•
	Expectations: changes in production output					•	•	•
	Expectations: changes in demand for products				•			
	Changes in the investment activity of companies							•
R Studio Types of temporal disaggregation	Chow-Lin ML	10.494	8.682	8.299	7.587	8.911	9.561	7.929
	Chow-Lin min RSS Ecotrim	11.534	9.638	7.055	7.409	7.711	8.354	7.145
	Chow-Lin min RSS Quilis	10.353	8.550	6.407	6.863	6.939	7.837	6.788
	Chow-Lin fixed rho	12.820	11.539	7.392	7.906	8.042	8.660	7.197
	Litterman ML	7.524	5.095	5.149	4.232	3.906	4.877	6.788
	Litterman min RSS	7.394	5.043	4.304	4.187	3.873	4.846	3.418
	Litterman fixed rho	9.091	7.278	5.355	5.795	5.837	6.711	5.807
	Fernandez	10.343	8.540	6.406	6.862	6.935	7.837	6.788
Total BIC value among all types of temporal disaggregation		79.553	64.365	50.369	50.841	52.155	58.684	51.860

Note: • – inclusion of the variable into the model specification.

Table 6. Results of the nowcasting of Russia's quarterly GDP for 2018Q1 – 2019Q2 using the best specifications of temporal disaggregation models

The best specification for the variables (k) included in the specification, where $k = 1, \dots, 7$		1	2	3	4	5	6	7
Indicators of the real sector	Industrial output index						•	
	Index of physical volume of construction				•	•	•	•
	Index of physical volume of wholesale trade turnover		•				•	
	Agricultural output index							
	Index of physical volume of retail trade turnover	•						
Estimates of the Ural Main Branch of the Bank of Russia	GDP leading indicator based on the Rosstat methodology (estimates of the Ural Main Branch of the Bank of Russia)			•	•	•		•
Indicators of the Monitoring of Companies of the Bank of Russia	Changes in economic conditions				•		•	
	Changes in the stock of finished products						•	
	Sufficiency of orders		•	•				•
	Changes in demand for products (services)			•		•		•
	Changes in working capital availability					•		•
	Expectations: changes in production output					•	•	•
	Expectations: changes in demand for products				•			
	Changes in the investment activity of companies							•
R Studio Types of temporal disaggregation	Chow-Lin ML	0.02897	0.01638	0.01188	0.00474	0.01171	0.00425	0.00853
	Chow-Lin min RSS Ecotrim	0.03690	0.02484	0.00872	0.00363	0.01197	0.00369	0.00696
	Chow-Lin min RSS Quilis	0.02447	0.01413	0.00517	0.00952	0.01169	0.00379	0.00337
	Chow-Lin fixed rho	0.04400	0.02938	0.00985	0.00176	0.01184	0.00379	0.00719
	Litterman ML	0.02185	0.00964	0.00512	0.00310	0.00255	0.00365	0.00405
	Litterman min RSS	0.02130	0.00876	0.00271	0.00310	0.00255	0.00365	0.00405
	Litterman fixed rho	0.02217	0.01404	0.00512	0.01199	0.01153	0.00379	0.00283
	Fernandez	0.02416	0.01399	0.00515	0.00946	0.01166	0.00378	0.00336
Total MAPE of the nowcasting (6 prediction points)		0.22383	0.13114	0.05372	0.04731	0.07549	0.03039	0.04033
Estimates of the Ural Main Branch of the Bank of Russia	MAPE of the nowcasting of the GRP leading indicator using the Rosstat methodology (6 points): 0.1302							

Note: • – inclusion of the variable into the model specification.

Table 7. Results of the nowcasting of Russia's quarterly GDP for 2017Q1 – 2019Q2 using the best specifications of temporal disaggregation models

The best specification for the variables (k) included in the specification, where $k = 1, \dots, 6$		1	2	3	4	5	6
Real sector indicators	Industrial output index						•
	Index of physical volume of construction				•	•	•
	Index of physical volume of wholesale trade turnover		•				•
	Agricultural output index						
	Index of physical volume of retail trade turnover	•					
Estimates of the Ural Main Branch of the Bank of Russia	GDP leading indicator based on the Rosstat methodology (estimates of the Ural Main Branch of the Bank of Russia)			•	•	•	
Indicators of the Bank of Russia Monitoring of Companies	Changes in economic conditions				•		•
	Changes in the stock of finished products						•
	Sufficiency of orders		•	•			
	Changes in demand for products (services)			•		•	
	Changes in working capital availability					•	
	Expectations: changes in production output					•	•
	Expectations: changes in demand for products				•		
	Changes in the investment activity of companies						
R StudioTypes of temporal disaggregation	Chow-Lin ML	0.02226	0.01743	0.01783	0.00853	0.01380	0.01869
	Chow-Lin min RSS Ecotrim	0.03205	0.02447	0.01476	0.01368	0.01387	0.01687
	Chow-Lin min RSS Quilis	0.01760	0.01562	0.01159	0.01827	0.01348	0.01454
	Chow-Lin fixed rho	0.03963	0.03215	0.01577	0.01157	0.01384	0.01735
	Litterman ML	0.01546	0.01264	0.01102	0.01001	0.00955	0.01166
	Litterman min RSS	0.01675	0.01231	0.00898	0.00999	0.01195	0.01166
	Litterman fixed rho	0.01431	0.01540	0.01134	0.01996	0.01326	0.01362
	Fernandez	0.01735	0.01552	0.01158	0.01823	0.01340	0.01452
	Total MAPE of the nowcasting (10 prediction points)	0.17541	0.14553	0.10286	0.11024	0.10316	0.11891
Estimates of the Ural Main Branch of the Bank of Russia	MAPE of the nowcasting of the GRP leading indicator using the Rosstat methodology (10 points): 0.1305						

Note: • – inclusion of the variable into the model specification.

Table 8. Selection of the best method of temporal disaggregation for the best specification selected

Type of temporal disaggregation		Chow-Lin ML	Chow-Lin min RSS Ecotrim	Chow-Lin min RSS Quilis	Chow-Lin fixed rho	Litterman ML	Litterman min RSS	Litterman fixed rho	Fernandez
Temporal disaggregation (intra-sample)	MAPE	3	2	5	1	4	8	7	6
type rank (1 – the best type; 7 – the worst type)	MAPE of nowcasting for 6 points (2018Q1–2019Q2)	8	6	5	7	2	1	3	4
	MAPE of nowcasting for 10 points (2017Q1–2019Q2)	8	6	5	7	2	1	3	4
	Weighted average rank (minimum value – the best specification)	6.33	4.67	5	5	2.67	3.33	4.33	4.67

Note: the best specification includes the GDP leading indicator based on the Rosstat methodology (estimates of the Ural Main Branch of the Bank of Russia) and the indicators of the Bank of Russia Monitoring of Companies: sufficiency of orders (contract agreements, service agreements, contracts) and changes in demand for the industry's products (services).