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Economic and Mathematical Models for Assessing and Forecasting the Dynamics of Labour Potential of the Border Regions of Siberia and Far East

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Abstract

The article is dedicated to assessment and forecasting of Gross Regional Product, employment, labour force and unemployment by sectors of the economy in the border regions of Siberia and Far East until 2025. For this purpose, there are developed economic and mathematical models considering the parameters of social and economic development. The social component is based on systematic approach to forecasting employment depending on the anthropogenic burden index, which takes into account duration and standard of living, population literacy, crime rate, environmental status and other indicators of the border regions of Siberia. The economic component uses econometric analysis of the types of economic activity in the border regions of Siberia and Far East, as well as time series analysis to forecast employment both in the medium and short term. In the labour market part, the labour force is projected considering the socio-economic effect of hidden unemployment.

Keywords: Anthropogenic burden, Economic and mathematical models, Value added, Labour force participation rate, Unemployment, Employment

1 Introduction

The Siberian Federal District is the region with one of the highest unemployment rates (4). At the same time, Siberia is the region with the lowest rate of employment growth. Over the past 10 years, employment has increased at a compound annual rate of 1%. Over the same period, the unemployment rate fell from 8.7% to 7.3%. All that is caused by the very slow growth of labour force due to the demographic factors. The level women participation in the labour force is not high enough as well, comparing to the average values of participation in the regions, since its growth is constrained by the negative effect of financial and economic crisis in Russia (8). The recovery process that has begun in recent years (1) does not provide an increase in labour force participation of previously disillusioned people, especially women.

It is important to note the significant innovative potential of Siberian Federal District and the innovative infrastructure created in it. All that leads to significant opportunities for sustainable and long-term development. The need of Siberian Federal District economy for qualified personnel can be fully met at the expense of scientific, educational and technical potential of the regions, included in the district.

The Siberian Federal District can be described as a territory with uneven regional development. Within the district, subsidized regions border on regions with a high potential for innovative development (5). Thus, there are demographic differences within the Siberian region. In particular, the subsidized Republic of Tuva is the border region with the highest unemployment rate of 18.3%. Krasnoyarsk - the inland region, is economically developed; the employment rate and economically active population there grow faster than in the rest of Siberian Federal District.

The birth rate in Siberia is higher than the national average. According to this indicator, the Siberian Federal District is in third place after the North Caucasus and Ural Federal Districts. The Omsk Region demonstrates the highest level of labour force participation (about 69.5%). In 2005, the figure was 64.9%. As a result of job placement (18) the level of labour force participation in the following years increased by almost

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5%, with high sensitivity to economic cycles (17). As a consequence of this change, the unemployment rate continued to fall despite lower employment growth. The border region with the lowest number of unemployed is the Altai Republic. This figure in the Altai Republic is six times less than in the Omsk Region. However, since 2005, the labour force participation rate for the region has hovered at around 67%, and as employment continues to grow, the unemployment rate has fallen from 9.4% to 2.5%.

The border regions today are largely less developed and economically less prosperous than the deep territories, which are similar in terms of development (3, 7, 9, 12). The hypothesis of the study formulated in this article is as follows: the actual conditions in the labour market of Siberia and Far East contribute to the reduction of unemployment in the short and medium term. Thus, this article is devoted to forecasting the Gross Regional Product, employment, labour force and unemployment rates in the border regions of Siberia until 2025. The article is structured as follows: first of all, there are considered some economic and mathematical models, then the results of assessment and forecasts. After all, there follow conclusions.

2 Research Methodology

Economic and mathematical models consist of two basic sub-models that take into account both social and economic factors. The social sub-model follows a cohort-based forecasting method. They investigate the relationships between demographic indicators and the index of anthropogenic load (13, 14, 15, 16), which takes into account life expectancy, standard of living, literacy, health and culture of the population. It also takes into account the level of crime and the state of environment.

Thus, the labour market is explained by socio-demographic factors when modelling the relevant trends. Any attempts to predict the employment level using social factors cause difficulties because the adequate forms of equations are not defined. The accuracy of existing models, based solely on demographic indicators, is low (2, 10, 11), so we propose a systematic approach that links socio-demographic and economic variables.

The economic sub-model uses econometric analysis and time series analysis to predict value added and employment in the short to medium term. In addition, the socio-demographic unit provides forecasts depending on the cyclical factors of the region's economic sectors. Unemployment is then defined as the balance between employment and economically active population. The stimulating and restraining influence of short and medium-term economic fluctuations on employees is taken into account as well: the labour force is explained considering both demographic growth and the sensitivity of labour force participation rates to cyclical fluctuations in labour demand.

The developed models consist of four recursive equations that explain the following groups of variables: population structure of the Siberian regions, value added, employment and labour force. Value added and employment are projected in the medium term using regional econometric models. These models predict value added and employment for the larger regional sectors of the economy, namely agriculture, manufacturing and services. The value added block (1) consists of industry demand equations that explain the corresponding value added using economic indicators at the Federal and regional levels.

$$V_{it} = \alpha_{0i} + \alpha_{1i} NP_{it} + \alpha_{2i} NV_{it} + \alpha_{3i} V_{it-1}, \quad (1)$$

V_{it} is added value of the sector *i* in the region in the period *t*; NP_{it} is the price level of the sector *i* in the Federal District in the period *t*; NV_{it} is added value of the sector *i* in the Federal District in the period *t*; and V_{it-1}- added value of the sector *i* in the region in the period *t-1*. Employment block (2) consists of dynamic sectoral demand equations that relate value added, socio-economic factors and employment in previous periods. Cobb-Douglas production functions are used as well.

$$LnE_{it} = \beta_{0i} + \beta_{1i} LnV_{it} + \beta_{2i} LnNR_{it} + \beta_{3i} LnS_t + \beta_{11i} LnE_{it-1} \quad (2)$$

E_{it} is average annual number of employees in the period *t* by type of economic activity *i*; V_{it} is added value of the sector *i* in the region in the period *t*; NR_{it} is the level of wages by type of economic activity in the region *i* in the period *t*; S_t is index of anthropogenic load in the period *t*; and E_{it-1} is the average annual number of employees in the period *t-1* by type of economic activity *i*. The developed models make it possible to predict the labour force, depending on demographic and socio-economic factors, taking into account fluctuations in demand for labour.

The level of labour force participation (3) depends on two variables representing demographic and socio-economic factors. The demographic variable is those aged 15 to 72 years. The variable representing socio-economic factors is labour demand (gross employment). The latter is measured in natural logarithms to account for the disproportionate effect of exogenous variables. Using the partial adjustment approach, it is possible to formalize the level of labour force participation as the following dynamic equation.

$$PL_t = \gamma_1 PO_t + \gamma_2 LnTE_t + \gamma_3 PL_{t-1} + \varepsilon_t, \quad (3)$$

PL_t is level of labour force participation in the period *t; PO_t* is persons aged 15 to 72 years; $TE_t = \sum_{i=1}^{m} E_{it}$ is gross number of employees in the period *t*; and ε_t is correction factor. As a complement to the medium-term forecasts based on the developed econometric models, we use multidimensional time series models for short-term quarterly employment forecasts and exogenous variables in models (1) and (2). For this purpose, they use autoregressive modelling on the basis of moving averages (6), which allows the use of regional series of indicators as predictive variables of short-term employment in the border regions of Siberia and Far East. Time series models are more efficient for short-term forecasting than cause-and-effect econometric models. They meet or even exceed the accuracy of short-term forecasting with the help of econometric models. When we forecast short-term regional employment using econometric models, hypotheses are

introduced in the process of model specification and selection. This is a source of predictive inaccuracy that is difficult to assess and control. Confidence intervals and various scenarios for short-term forecasting are ineffective as well. Our short - and medium-term employment models provide a forecasting horizon for testing the sensitivity of labour force participation and unemployment forecasts to different data sources and hypotheses.

3 Results and Discussion

3.1 Estimates of Economic and Mathematical Models

The main data sources used to evaluate the models in this article are the reports of the Federal State Statistics Service and the Governmental Analytical Center of the Russian Federation. They need the data from 2004 to 2018 to work with the value added and employment blocks. The labour force unit and the short-term model were estimated from quarterly data. For the short-term model, the sampling period is 2004-2019.2 (2019, the second quarter). Table 1 presents the results of evaluation of econometric models of the added value V_i of the *i* economic sector, where *i* = {1-agriculture; 2-manufactured goods and services}, for seven border regions of Siberia. Table 1 also presents the advising determination coefficient R^2 of econometric models. Table 2 presents the results of evaluation of the dynamic sectoral equations of the employed number in the period *t* by the *i* type of economic activity, where *i* = {1-agriculture; 2-manufactured goods and services}, for seven border regions of Siberia and Far East. Table 2 also presents the advising coefficient of determination.

Table 1: Estimates of Econometric Added Value Models of Border Regions of Siberia.

Equations	R^2
The Republic of Altai	
$V_{1t} = -0,29NP_{1t} + 0,53NV_{1t} + 0,57V_{1t-1} - 0,27V_{2t}$	0,79
$V_{2t} = 0,23NP_{2t} - 0,47NV_{2t} - 0,2V_{1t} + 0,56V_{2t-1}$	0,96
The Republic of Buryatia	
$V_{1t} = 0,23NP_{1t} - 0,05NV_{1t} + 0,82V_{1t-1} - 0,08V_{2t}$	0,95
$V_{2t} = 0,53NP_{2t} - 1,11NV_{2t} + 0,14V_{1t} + 0,15V_{2t-1}$	0,8
The Republic of Tuva	
$V_{1t} = -0,2NP_{1t} + 0,23NV_{1t} + 0,83V_{1t-1} + 0,06V_{2t}$	0,93
$V_{2t} = 0,62NP_{2t} + 0,02NV_{2t} - 0,36V_{1t} + 0,65V_{2t-1}$	0,94
The Altai Territory (Krai)	
$V_{1t} = -0,07NP_{1t} + 0,66NV_{1t} + 0,43V_{1t-1} - 0,73V_{2t}$	0,86
$V_{2t} = 0,07NP_{2t} + 0,73NV_{2t} + 0,32V_{1t} + 0,42V_{2t-1}$	0,97
The Zabaikalye Territory (Krai)	
$V_{1t} = 0,57NP_{1t} + 0,13NV_{1t} + 0,26V_{1t-1} + 0,02V_{2t}$	0,93
$V_{2t} = -0,48NP_{2t} + 0,98NV_{2t} + 0,59V_{1t} - 0,13V_{2t-1}$	0,95
The Novosibirsk Region	
$V_{1t} = 0,27NP_{1t} + 0,35NV_{1t} + 0,73V_{1t-1} - 0,06V_{2t}$	0,96
$V_{2t} = -0,14NP_{2t} + 0,06NV_{2t} + 0,27V_{1t} + 1,06V_{2t-1}$	0,79
The Omsk Region	
$V_{1t} = 0,32NP_{1t} + 0,85NV_{1t} + 0,06V_{1t-1} + 0,17V_{2t}$	0,61
$V_{2t} = -0,26NP_{2t} + 0,43NV_{2t} - 0,03V_{1t} + 1,05V_{2t-1}$	0,9

Table 2: Estimates of Forecasting Models for the Number of Employed in the Border Regions of Siberia and Far East.

Equations	R^2
The Republic of Altai	
$LnE_{1t} = 0,37LnV_{1t} + 1,51LnNR_{1t} - 1,6LnS_t + 0,93LnE_{1t-1}$	0,9
$LnE_{2t} = -0,87LnV_{2t} + 2,27LnNR_{2t} - 1,79LnS_t - 0,11LnE_{2t-1}$	0,92
The Republic of Buryatia	
$LnE_{1t} = -0,78LnV_{1t} - 0,95LnNR_{1t} - 0,25LnS_t + 1,17LnE_{1t-1}$	0,96
$LnE_{2t} = -0,34LnV_{2t} + 0,24LnNR_{2t} - 0,35LnS_t + 0,78LnE_{2t-1}$	0,92
The Republic of Tuva	
$LnE_{1t} = -1,03LnV_{1t} - 1,44LnNR_{1t} + 0,08LnS_t - 0,01LnE_{1t-1}$	0,73
$LnE_{2t} = 0,73LnV_{2t} + 0,41LnNR_{2t} - 0,26LnS_t + 0,25LnE_{2t-1}$	0,66
The Altai Territory (Krai)	
$LnE_{1t} = -0,26LnV_{1t} - 0,69LnNR_{1t} + 0,2LnS_t + 0,32LnE_{1t-1}$	0,95
$LnE_{2t} = 0,79LnV_{2t} - 0,03LnNR_{2t} + 0,25LnS_t + 0,36LnE_{2t-1}$	0,96
The Zabaikalye Territory (Krai)	
$LnE_{1t} = -0,57LnV_{1t} - LnNR_{1t} + 0,15LnS_t + 0,62LnE_{1t-1}$	0,95
$LnE_{2t} = 0,1LnV_{2t} - 0,91LnNR_{2t} + 0,67LnS_t + 0,81LnE_{2t-1}$	0,92
The Novosibirsk Region	
$LnE_{1t} = -0,45LnV_{1t} + 0,15LnNR_{1t} - 0,35LnS_t + 0,75LnE_{1t-1}$	0,98
$LnE_{2t} = 0,04LnV_{2t} + 0,35LnNR_{2t} - 0,15LnS_t + 0,75LnE_{2t-1}$	0,96
The Omsk Region	
$LnE_{1t} = -0,11LnV_{1t} + 0,16LnNR_{1t} + 0,43LnS_t + 0,84LnE_{1t-1}$	0,94
$LnE_{2t} = 0,64LnV_{2t} - 1,02LnNR_{2t} - 0,38LnS_t + 0,41LnE_{2t-1}$	0,97

Table 3: Estimates of Forecasting Models for the Level of Labour Force Participation in the Border Regions of Siberia and Far East.

Equations	R^2
The Republic of Altai	
$PL_t = -0,57PO_t + 0,64LnTE_t + 0,2PL_{t-1}$	0,91
The Republic of Buryatia	
$PL_t = -0,09PO_t + 0,41LnTE_t + 0,59PL_{t-1}$	0,87
The Republic of Tuva	
$PL_t = 0,35PO_t - 0,38LnTE_t + 0,22PL_{t-1}$	0,41
The Altai Territory (Krai)	
$PL_t = 0,3PO_t + 0,01LnTE_t + 0,41PL_{t-1}$	0,55
The Zabaikalye Territory (Krai)	
$PL_t = -0,32PO_t - 0,17LnTE_t + 0,62PL_{t-1}$	0,91
The Novosibirsk Region	
$PL_t = 0,18PO_t + 0,42LnTE_t + 0,65PL_{t-1}$	0,83
The Omsk Region	
$PL_t = -0,35PO_t + 0,32LnTE_t + 0,81PL_{t-1}$	0,95

Table 3 presents the results of assessment and forecasting of the level of participation in the labour force depending on the population from 15 to 72 years and employment in agriculture and the sector of production of manufactured goods

and services. It can be seen from the estimates that the models have high prognostic properties. The accuracy of the constructed models, calculated on the basis of determination coefficient averages 0.87. The labour force participation equations include high-coefficient employment as an explanatory variable (see Table 3). This means that labour force participation in the border regions of Siberia depends significantly on the economic cycle and social factors, but the main effect on the labour force is produced by the demographic factors in the Border Regions of Siberia and Far East.

3.2 Long-Term and Short-term Forecasts

Projections of value added (Gross Regional Product) differ from sector to sector (see Figure 1 and Figure 2). While agriculture is expected to grow up to 5% by 2022, production of manufactured goods and provision of services will not increase. Moderate growth in agriculture will give way to a fall by 2023, while the manufactured goods and services sector will see modest growth.

If we look at employment by sectors of the economy of the border regions of Siberia (see Figure 3 and Figure 4), the forecasts differ from the results on value added. Value added in agriculture is expected to grow until 2022, but employment in this sector of economy will decline. The manufactured goods and services sector is growing in production by 2023, there takes place expected employment growth. Figures 5 and 6 demonstrate the short-term projections of total employment for the next four quarters. Compared to the results presented by the econometric model (see Figure 3 and Figure 4), the most significant discrepancy is observed in the manufactured goods and services sector. Between 2020 and 2021, the econometric model predicts a decline in employment of about 1%, as opposed to the short-term model, which predicts an increase of about 1.2%. As for agriculture, the short-term forecast is higher than the medium-term one. The forecast of total employment in agriculture, presented by the econometric model, is 0.8% lower than the short-term forecast in 2020.

Figures 7 and 8 present, respectively, the medium-term and short-term labour potential forecasts of the border regions of Siberia and Far East. In the period of 2020-2021, the econometric model predicts a 1.25% decrease in labour force participation, as opposed to the short-term model, which predicts an increase of about 1.35%.

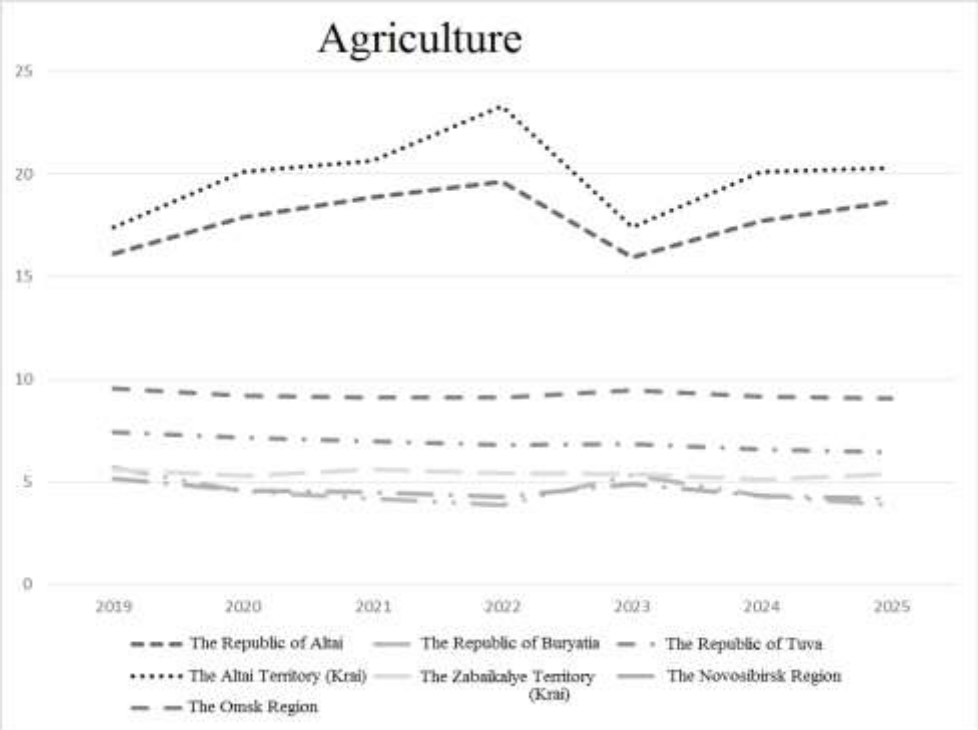

Figure 1: Value Added of Agriculture, in Current Basic Prices; Percentage of the Total

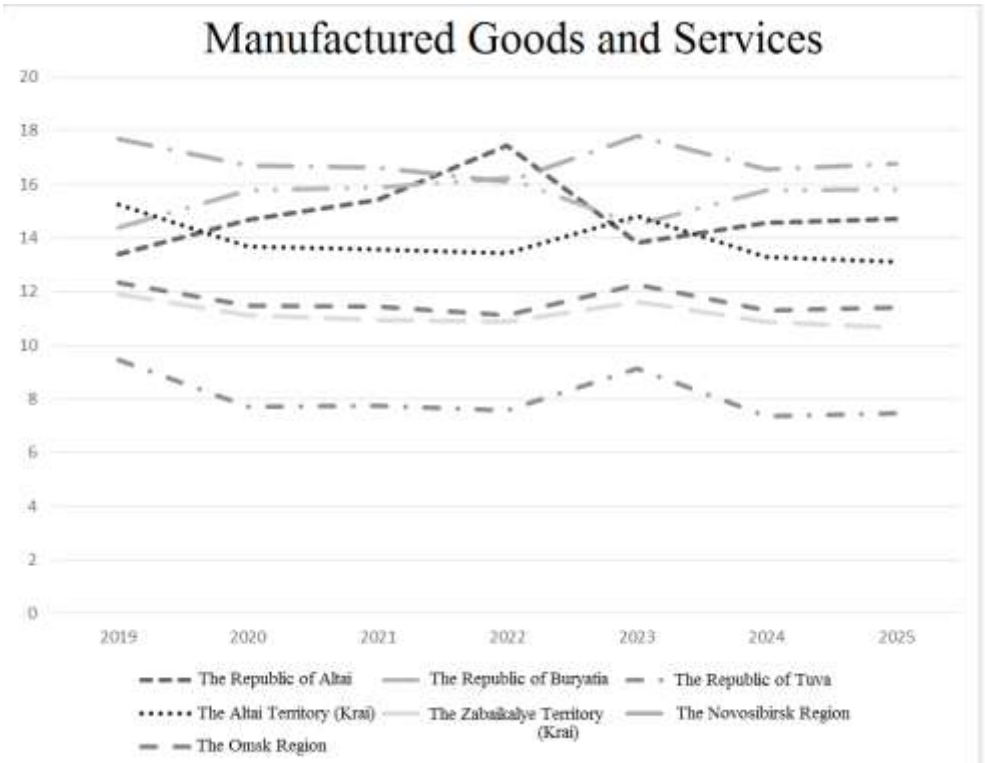

Figure 2: Value Added of the Manufactured Goods and Services Sector, in Current Basic Prices; Percentage of the Total

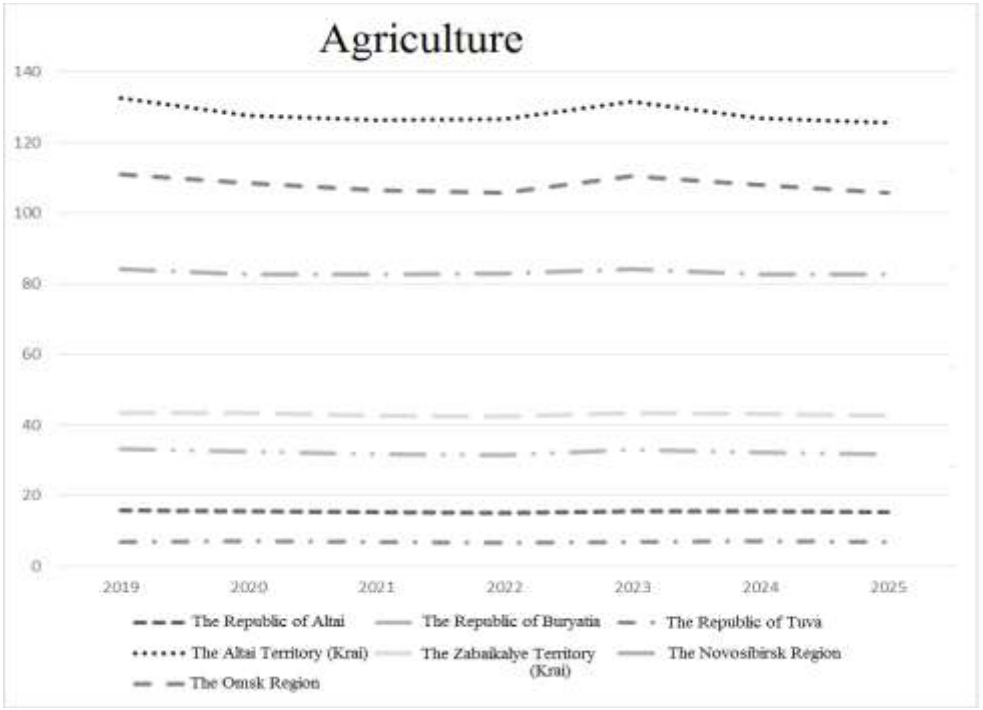

Figure 3: Average Annual Number of People Employed in Agriculture (Thousands of People)

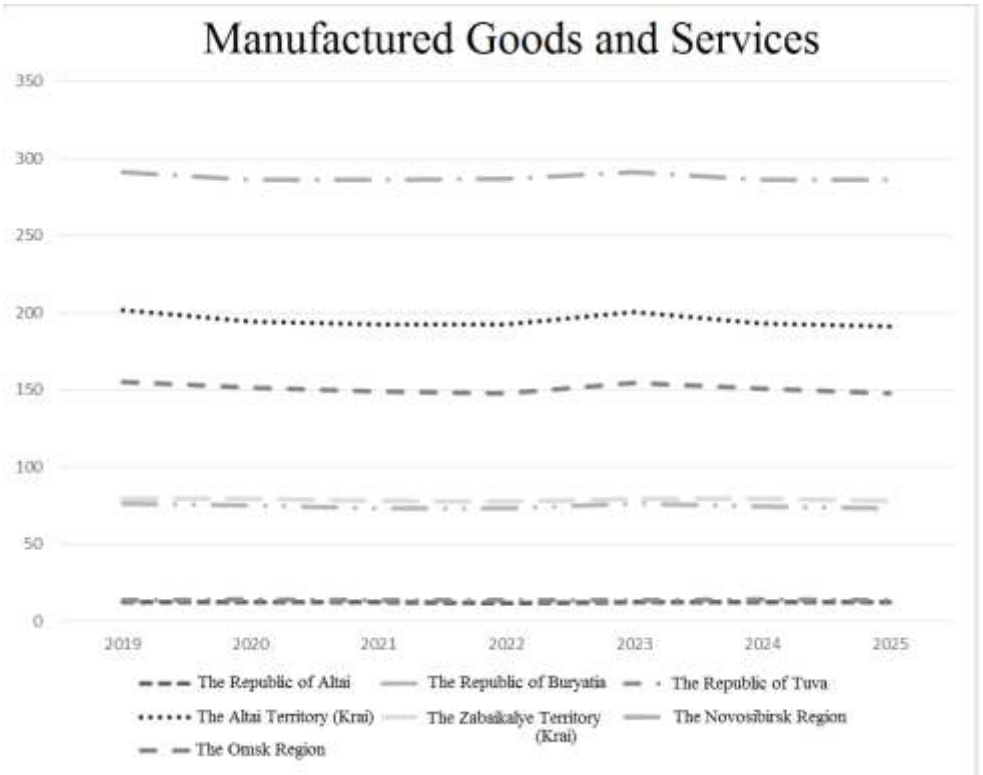

Figure 4: Average Annual Number of Employees in the Sector of Manufactured Goods and Services (Thousands of People)

Figure 5: Quarterly Number of People Employed in Agriculture (Thousands of People)

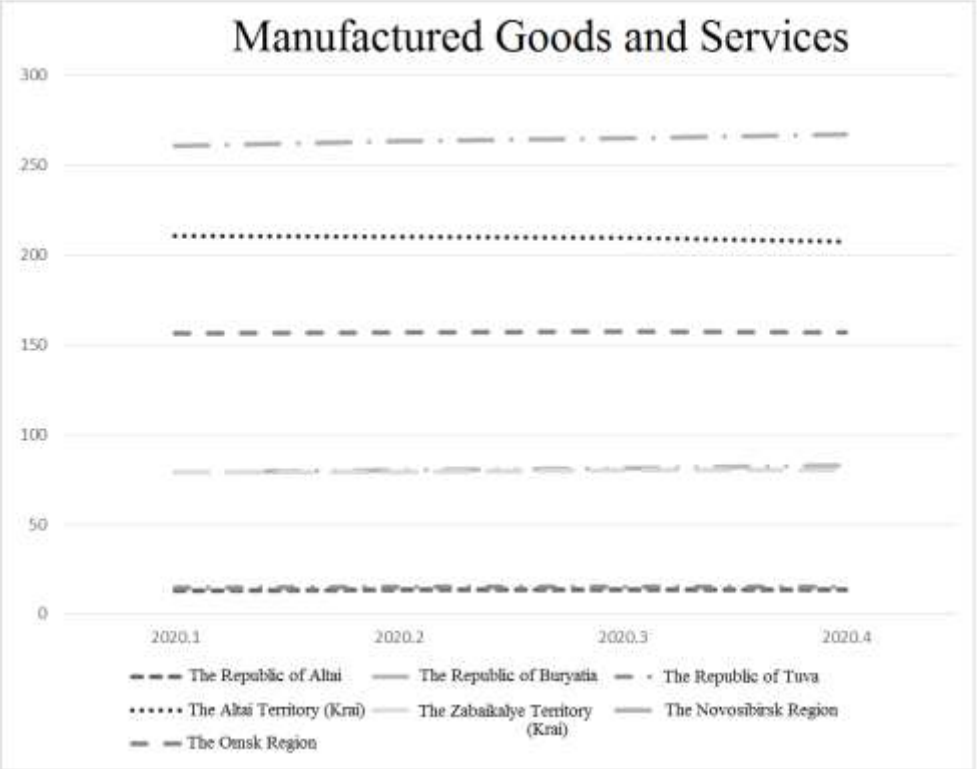

Figure 6: Quarterly Number of Employees in the Sector of Production of Manufactured Goods and Services (Thousands of People)

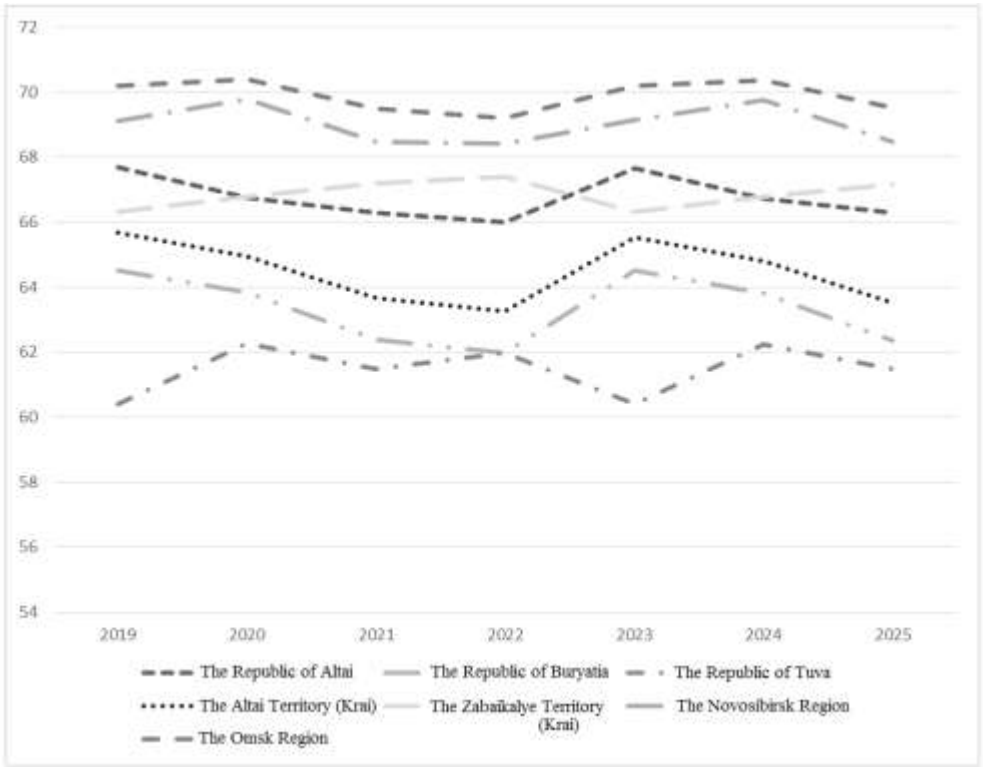

Figure 7: Labour Force Participation Rate, Percentage

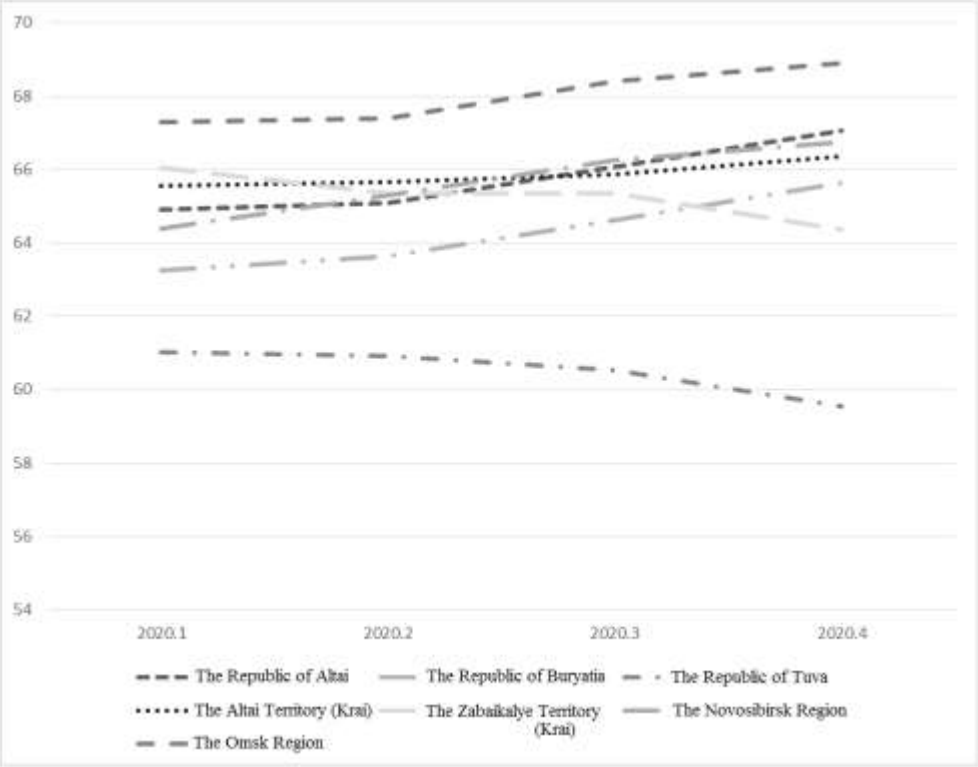

Figure 8: Quarterly Labour Force Participation Forecast, Percentage.

4 Conclusion

In this article, we have developed and applied economic and mathematical models to predict the Gross Regional Product, employment and labour force rates in the border regions of Siberia in the Border Regions of Siberia and Far East. According to the results of the study, there can be drawn two main conclusions.

First, unemployment, defined as the difference between labour and employment, depends on socio-economic factors in two ways. The sensitivity of unemployment to employment forecasts is lower than might be expected. Thus, despite the difference between the two short-term and medium-term employment forecasts, the hypothesis formulated in Introduction can be answered as follows: both the short-term and medium-term models predict an increase in unemployment.

As a result of the expected reduction in labour force, the unemployment rate will remain close to the current level in the short term, despite the projected reduction in 2020 unemployment rate. In the medium term, however, we should expect a slight increase in the unemployment rate in the border regions of Siberia.

Secondly, taking into account the estimates of labour force equations, they can conclude that the labour force is sensitive to employment and socio-economic factors, but is mainly determined by demographic determinants. Unemployment is expected to remain a social problem for Siberia and in the Border Regions of Siberia and Far East in the short term, despite the expected significant increase in labour demand by 2022. The unemployment rate and its level can be reduced by creation of new jobs in accordance with national socio-economic prospects. Thus, there should be emphasized the importance of using some tools to support strategic decision - related to promotion of employment in the region.

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Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

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