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Impact of COVID-19 on outputs of small and medium enterprises in Russia: A spatial view

This paper examines the impact of the COVID-19 pandemic on firm performance in different parts of Russia. We construct regressions explaining the revenue of small and medium-sized Russian firms, taking into account their individual, spatial, and regional characteristics. The strictness of the quarantine during the pandemic did not affect firm performance, while agglomeration effects and the situation in neighbouring regions became less influential on business performance during the COVID-19 pandemic. Fast-growing regions also stimulate the development of surrounding areas, while the impact of agglomeration effects on firms is weaker in Eastern Russia.

Keywords: COVID-19; output; Russian business; Russian regions; agglomeration effects; spatial econometrics; multilevel analysis; geographically weighted regression.

JEL classification: C21; D24; L25; R32.

1. Introduction

The COVID-19 pandemic was a crisis that has affected all spheres of our lives. The same was true for business: no firm escaped the effects of the pandemic and the accompanying restrictions. However, the impact of COVID-19 was not the same for all firms. Exactly how and to what extent the pandemic and quarantine affected a company depends on many characteristics of the firm: age, size, financial situation, location, interaction with other firms, industry affiliation, etc.

How a company survived the crisis is significantly influenced by its location: the peculiarities of the region in which it is located and infrastructure and the number of neighbouring firms and their characteristics.

Quarantine restrictions of varying severity and duration were introduced in different regions of Russia in 2020: from complete absence of restrictions to lockdowns for several months. Even in the same region, firms located in large cities with a high level of business interaction and competition experienced the crisis differently from those located in "an empty field", surrounded by prosperous neighbours or in a depressed area. Therefore, when analysing the impact of COVID-19 on firm performance, it is important to consider not only the region in which it is located, but also its location within the region.

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The revenue distribution of Russian companies in 2019 (before the crisis) and 2020 (during the crisis)[2] shows that companies located further from the regional centre have lower revenues (irrespective of the region), and while in 2019 the difference is almost insignificant (p-value for Kolmogorov–Smirnov test is equal to 0.08), with the onset of the pandemic the differences become significant (p-value < 0.001).

This work is dedicated to the effect of the geographical location characteristics of a company on its performance during the COVID-19 pandemic.

The paper consists of five main parts. Section 2 is devoted to the analysis of the existing scientific literature on the factors affecting the performance of the enterprise and the impact of the COVID-19 pandemic on economy and business in Russia. This section formulates the research hypotheses also. Section 3 describes the selection of variables, data and methodology used for the study. Section 4 presents the specifications of the selected econometric models and their estimation results. And final Section 5 contains summary of the study.

2. Literature review

Economists usually consider three main indicators of firm performance: company output, growth rate and profitability.

However, profit-based indicators (including profitability) may be incorrect due to the company's accounting policy and attempts to reduce profit tax, while the mechanism for calculating revenue is more transparent (Zyuzin et al., 2020). Revenue, unlike profit (and the measures based on it) is not subject to distortions due to large irregular expenses typical of small and medium-sized businesses (Huang et al., 2015). Theoretical and empirical studies show that the growth rate of a company is more dependent on its age (life cycle stage) than on the efficiency of the particular company (Coad et al., 2018).

Output demonstrates the long-term efficiency of the company in a general sense. The most successful companies are those that have been able to organise their production processes in a more effective way than their competitors. These companies are able to survive, develop and have a a significant share of the market. Accordingly, this study examines the output[3] as an indicator of firm performance.

Firm output is usually modelled by the Cobb–Douglas production function and in baseline model it is determined by labour and capital (and also by the level of the production efficiency). It is important to note that in empirical studies (including this one), data on the physical output of each company is not always available. In such cases, data on turnover, i.e. goods *sold*, is used as a substitute. This value is influenced not only by production processes but also by market processes. In a real economy characterised by imperfect market mechanisms, such as government intervention, information asymmetry, transport costs and exogenous shocks[4], a firm's revenue

[2] Compiled by author on the basis of Spark Interfax database (https://spark-interfax.ru/).

[3] It would be more correctly to use value added, but in the absence of complete data on wages and depreciation (as well as on external purchases of materials and components), we use the revenue indicator, following other authors, for example, Baltagi et al. (2016).

[4] Here we establish a parallel with the stochastic frontier model (SFA), in which the ordinal production function is multiplied by a production efficiency parameter TE, ranging from 0 to 1. In the case of $TE = 1$, production is fully efficient; if $TE < 1$, then $1 - TE$ share of the product is lost due to inefficient production. The same can be said about market efficiency: if it is low, the total value of goods sold will be lower, all other investments of labour and capital being equal.

is influenced not only by *technological* efficiency but also by *allocative* efficiency (Stiglitz, 1989). In particular, spatial factors have been demonstrated to exert a significant influence on the revenue of firms. For example, Krugman (1991) shows in his center–periphery model that the demand for goods, the supply of labour and transport costs differ according to the specialisation and location of the firm, and this affects its efficiency (both technical and allocative) and, consequently, output: for example, the model suggests that in large agglomerations, due to lower transport costs, product diversity, labour concentration and technology spillovers, the efficiency of production is higher. Tran et al. (2023) developed a model according to which the output of a firm depends also on the output of neighbouring firms and on environmental factors: the skills of workers, the degree of market power, and the state ownership of the firm.

Recent Russian empirical studies show that output is affected by factors such as firm age — both positively and negatively (Rutskiy et al., 2020; Kolomak, Sherubneva, 2023a); the form of ownership — state-owned organisations have lower output because they do not have the goal of maximising financial performance (Kolomak, Sherubneva, 2023a); the sector of activity — for example, industrial companies have 20% higher output than agricultural ones (Kolomak, Sherubneva, 2023a); the degree of the localisation of the industry, up to a certain level, increases revenues, but then it begins to have a negative impact (Davidson, Mariev, 2015).

An additional crucial element influencing the company's performance is its geographical location, particularly the spatial and agglomeration effects. Russia's unique spatial development characteristics can be broadly classified into three main categories: its vast territory, low population density (9 people per square kilometer, while the European average is 70 people/km^2), and the concentration of business activity. Secondly, the historical legacy of socialism is of significance. During the 70 years when Russia was part of the USSR, decisions on the location of production, and domestic and international cooperation were made centrally by the state. These decisions were not always dictated by economic considerations and market laws (Idrisov, Mikhailova, 2019). Conversely, spatial effects vary across Russia. In the European part of the country, there is a positive spatial correlation of macroeconomic indicators in regions, whereas in the Asian part, spatial correlations are weaker and their direction is ambiguous (Demidova, 2014; Kolomak, Sherubneva, 2023b).

Russia is a heterogeneous country from both natural-resource and socio-cultural points of view, which leads to dramatic inequalities in production (Bufetova, 2023) and income between regions (Gluschenko, 2011). Each of its regions has its own production specifics. In particular, this is reflected in the development of high-tech production, which is contingent upon such regional factors as a lack of specialisation in mining, a developed digital infrastructure, the share of people with secondary education, the number of researchers and workers with secondary education, and the share of spending on technological innovation in GRP (Khalimova, Yusupova, 2020). Accordingly, when modelling a firm's output, it is essential to consider the characteristics of the region in which the firm is located.

The findings of firm-level studies indicate that agglomeration effects are a significant determinant of firm performance: Gordeev et al. (2017) found out that the total factor productivity (TFP) in Russia increases by 8–10% when the population of a settlement doubles, and this indicator is higher than in Europe (~5%). Studies on Siberia show that the further away from the regional centre a company is located and the fewer the number of other companies located around it, the lower its output and profitability (Kolomak, Sherubneva, 2023a; Sherubneva, 2024). The agglomeration effects are the strongest in cities with a population exceeding 1.5 million (Lavrinenko et al., 2019).

This section is devoted to the impact of COVID-19 on the economy and business in Russian regions. While the global impact of the economic crisis precipitated by COVID-19 is widely acknowledged, the Russian pandemic exhibited distinctive characteristics. Similarly with other countries, Russia experienced a severe economic downturn: a 3.1% decline in its GDP in 2020, accompanied by an increase of 1.4% in its unemployment rate. In 2020, the service sector was the most severely affected, with a repercussion analogous to that observed during the global economic crisis of 2008 (Zubarevich, Safronov, 2020). The virus spread more slowly throughout the country due to the low population density, with the majority of cases occurring in large, affluent areas. However, it spread to every region of Russia within two months of the first case being reported, and not all medical systems were adequately prepared (Pilyasov et al., 2021).

Visible and concealed unemployment rates increased; in the first quarter of 2020, the number of unemployed increased by 35%, while the number of people working part-time increased by 70%. The largest increases in unemployment occurred in the areas around big cities (Makarentseva et al., 2020).

The most severely affected areas exhibit considerable variation in geography, specialisation, and degree of affluence. The regression analysis demonstrated that while the extent of urbanisation and the number of small enterprises served to mitigate the adverse impact of the pandemic, a high gross regional product (GRP) served to exacerbate those effects (Kolomak, 2020b). The pandemic also affected the banking sector: regions with a high incidence of the disease faced a decline in the quality of the corporate loan portfolio (Popova, 2024).

The region's economic activity indicators demonstrated an increase in correlation with the share of urban residents and small and medium-sized enterprises (SMEs) within the area (Kolomak, 2020a). Conversely, the region's elevated share of the gross value added contributed to a decline in these indicators. Zemtsov et al. (2022) concluded that the population of the regional capital and a favourable investment climate had a positive impact on the growth of SMEs in Russian regions; conversely, the percentage of businesses in potentially vulnerable industries and the intensity of quarantine restrictions had a negative impact. State tax incentives also have a significant positive impact on the efficiency of SMEs (Razumovskaia et al., 2020).

The efficiency of Russian companies (before and during the crisis) depends on their size, age, credit burden, the socio-economic situation in the region, and spatial and agglomeration effects. During the pandemic, sectoral affiliation and the severity of regional quarantine restrictions also played a role.

Russian empirical studies investigating the impact of COVID-19 on the economy and business in the spatial aspect are usually conducted at the regional level. However, within a region, the effects of the pandemic can also vary: the operation of a business is also affected by whether it is located in the city centre or on the outskirts, what is located nearby, and the characteristics of the municipality and district.

In this paper we investigate the impact of COVID-19 on Russian business at the micro level, i.e. not for regions or industries, but for individual companies. We extend and develop the work of Sherubneva (2024) on the impact of COVID-19 on South Siberian firms by looking at Russia as a whole. While the regions of South Siberia are quite homogeneous from a natural resource and socio-economic point of view, and in the previous paper we focused on micro-level effects, Russia as a whole is characterised by great inter-regional heterogeneity, and here we study both individual and regional effects.

The main objective of this paper is to investigate the influence of spatial factors on the technical and allocative efficiency of small and medium firms. We attempt to empirically disentangle the influence of the "big city" factors described in the book by Fujita et al. (1999) into regional factors — the size and growth rate of the region, the degree of urbanisation, the proximity to other regions and countries, and local factors — because within a region there are both large metropolitan areas and small villages.

At the same time, the COVID-19 pandemic and its associated restrictions have become a natural experiment for studying agglomeration effects, and it would be interesting to track changes during the quarantine period.

In this paper, we make the following hypotheses based on the above literature review.

A large population in a region, on the one hand, provides more opportunities for scientific and technological development due to the economies of scale — more skilled labour, more budgetary resources, the ability to open universities and colleges in different fields in the region. On the other hand, the larger the region, the greater the volume of domestic demand for goods produced. Although entering the markets of other regions within the country does not involve customs duties and logistics within the region can also be very expensive [5], local legislation, local authorities and the institutional environment differ in the Russian regions, and entering the market of a neighbouring region is accompanied by additional costs that affect, among other things, the allocative efficiency of the enterprise (Hall, Jones, 1999). The rate of population growth in a region does not always have a direct and immediate impact on the economy (especially natural increase, which has a long time lag), but to some extent it reflects social trends (people migrate to large cities), moods and expectations (if the present and the future seem stable, people want to have more children than in conditions of uncertainty). These moods and expectations can also influence the actions of entrepreneurs: population growth today is a future potential demand and a reserve for the emergence of new cities (Fujita et al., 1999), which influences decisions on the location of production, business expansion and investment in research and development. Of course, it is worth taking into account the size and population growth of neighbouring regions, as this affects the flow of technology and labour: the presence of a strong neighbouring region can help neighbouring areas by providing development impulses (Friedmann, 1966), but often leads to the relocation of production and labour and the extraction of resources from the weaker region (Myrdal, 1957).

Hypothesis 1. *The scale of a region (in terms of population) and its population growth rate increase the revenues of enterprises in the region and decrease those of neighbouring regions.*

Geographical proximity to friendly countries provides opportunities for international trade with low transport costs and customs duties (Hall, Jones, 1999; Zemtsov et al., 2023), which leads to increased external demand and market competition and, as a result, improves the economic situation of the region.

Hypothesis 2. *The presence of borders with countries with which Russia has good diplomatic relations increases the average revenue in the region.*

Agglomeration effects are associated with greater population density, higher demand, a greater concentration of labour and proximity to other businesses, which can facilitate collaborations and reduce logistics costs (Fujita et al., 1999). It is worth noting that the strength of agglomeration effects can vary greatly within the same region: compare agglomeration effects in the centre of a regional capital (a city of one million people) and "agglomeration effects" in a small village of 100 people 300 km from the nearest city. During the pandemic, many business processes

[5] For example, the distance between Krasnoyarsk and Norilsk is 650 km, there is no railway, and you can only get there by boat in the summer and by plane the rest of the year — and these are two big cities in the same region!

moved online and employees moved to remote working, and it can be assumed that geographical neighbourhood became less important.

Hypothesis 3. *Intra-regional agglomeration effects increase company efficiency, but their effect became weaker during the COVID-19 pandemic*.

Quarantine measures reduce supply and demand: they create obstacles to the operation of enterprises, however, people were restricted in travelling (and, as a result, consumption outside the home) and due to the unstable economic situation were more inclined to save their money. In other words, quarantine restrictions had a negative impact on the company's allocative efficiency: materials and labour were procured inefficiently, and products already produced sold worse than before the pandemic.

Hypothesis 4. *Regional quarantine restrictions reduced the output of enterprises in 2020*.

According to theoretical works (Webster, 1990; Krugman, 1991), mass movement to cities and a high proportion of the urban population entails higher average levels of education, productivity and consumption. However, in 2020, during the COVID-19 pandemic, urbanisation proved to be a double-edged sword — cities experienced higher disease incidence and stricter quarantine restrictions.

Hypothesis 5. A *high level of urbanisation in the region raised firm efficiency in non-crisis times, but lowered it in crisis times*.

These hypotheses test how regional characteristics and location within a region affected business performance in a stable economic situation (before COVID-19) and during the COVID-19 pandemic and compare the impact of individual, spatial and regional factors on business performance before and during the crisis.

3. Data and methodology

The sample includes 214298 small and medium enterprises (SMEs)[6] from 66 regions of Russia. We excluded from the study such industries as medicine, education, and military security, as most enterprises in these industries are state-owned, operate according to a set plan and do not have the goal of maximising revenue (or any other financial indicators typical of a market economy). The study used annual data for two years: 2019 (favourable economic environment) and 2020 (COVID-19 pandemic period).

Classical model, explaining company output, is the Cobb–Douglas production function $Y = AL^{\alpha}K^{\beta}$, where Y is output, L is labour, K is capital, α and β are the elasticities of output for labour and capital respectively. A is a total factor productivity (TFP) — the output not explained by the labour and capital.

Van Beveren (2012) divides TFP in empirical models into the explained part, which is the same for all observations (in the econometric model it is a constant), and the unexplained part (stochastic error). According to the model, the unexplained part of TFP depends on the individual efficiency of the firm — both technological and allocative (especially when output is measured not as the physical volume of products produced but as the monetary value of products sold). Other studies (Khalimova, Yusupova, 2020) usually include investment in R&D as a proxy for technology

[6] According to the legislation, small and medium-sized enterprises in Russia include companies with up to 250 employees and annual revenues of up to 2 billion Russian rubles.

when modelling economic development indicators. However, according to (Fujita et al., 1999), investments in technological development (both at the national and regional levels, as well as at the level of an individual firm) are not the cause, but a consequence of territorial development processes, and it is precisely the study of this (rather than the return on investment) that is the aim of our work. Therefore, in this paper we try to explain the technological and market efficiency of firms primarily from the point of view of agglomeration processes.

The dependent variable (a proxy for a firm output) was used as the firm's annual revenue in real prices[7]. Of course, it would be more correctly to use value added or at least physical volume of production, but there is no available data on wages and capital depreciation (as well as on external purchases of materials and components), we use the revenue indicator. The Spark Interfax database[8] was used as a source of information (in particular, the financial statements) on Russian enterprises.

Testing the hypotheses described in Section 2 involves the use of explanatory variables of two levels — individual (for individual companies) and regional. We also include some control variables in the model, both firm-level and region-level.

The number of employees at the end of the year was used as a labour indicator, while capital is the size of assets in monetary terms.

According to the company life cycle theory (Mueller, 1972), the size of a firm (including TFP part) increases over time up to a certain age (growth phase) and then begins to gradually decrease (aging phase), making the firm size graph form an inverted parabola. However, this is not always empirically confirmed in Russian data: for example, in the paper (Kolomak, Sherubneva, 2023a) it was shown that TFP, on the contrary, falls with age, which can be explained by a decrease in the incentives for development among small enterprises. To check for it, we included the age of the firm and age squared in the model as control variables.

The firm's TFP is also affected by its financial leverage, and the effect is bidirectional. Modigliani and Miller (1958) suggest that the use of borrowed funds helps to reduce the tax burden and redirect funds to the development of the firm, which increases its technological efficiency. Gertler and Gilchrist (1993), on the other hand, argue that debt primarily represents risk, uncertainty and an increased probability of bankruptcy, which limits managers' freedom of action and may force them to make inefficient decisions. In this work we included in our model a financial leverage of a firm (debt-to-equity ratio).

Also, a company's TFP depends on its industry due to the industry specificities. To account for industry effects, dummy variables were incorporated in line with OKVED (Russian Classifier of Economic Activities, the Russian analogue of NAICS in USA) groups[9]: agriculture, mining, manufacturing, etc. The agriculture sector, which was minimally impacted by the pandemic and the associated restrictions, was set as the default group. The sample excluded organisations in the public administration, education, and healthcare sectors as most of the companies within these sectors are state-owned, and the profitability indicators do not serve as a benchmark for them.

Next, we consider explanatory variables of the regional level. Baltagi et al. (2016) show that a firm's TFP depends on both individual, and municipal and regional factors, as well as neighbours. In order to test hypothesis 1, to estimate the scale and growth rate of the region (in terms

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7 Price adjustments are detailed further in this section.

8 Spark Interfax Group — https://spark-interfax.ru/.

9 Classification — http://taxpravo.ru/analitika/statya-419604-kodyi_okved_2019.

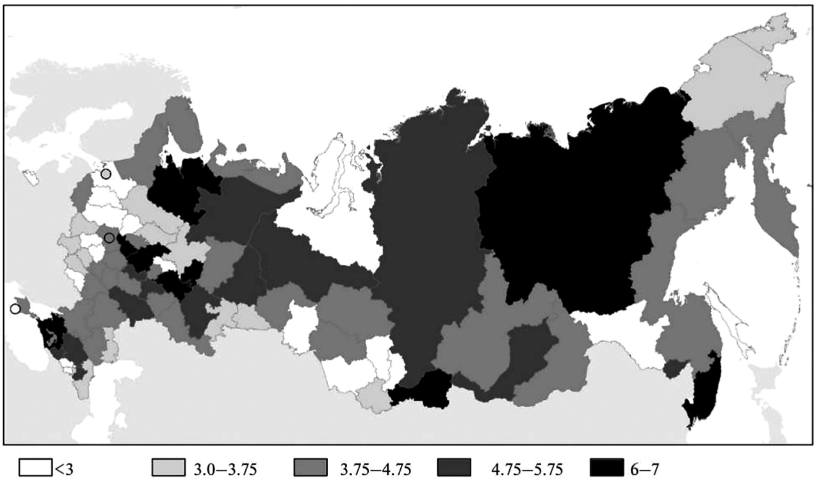

Fig. 1. Severity of quarantine restrictions in Russian regions, 2020

Source: Constructed by (Zemtsov et al., 2022) based on (Mau, 2020).

of population), we used the percentage of the region's population of the Russian population and annual population growth in the region in percentage terms, based on population of each region at the end of year[10]. A regional-level spatial lag was also used to estimate these two indicators for neighbouring regions. The leading regions in terms of population in 2019–2020 were Moscow, Moscow region and St. Petersburg, Krasnodar, Ekaterinburg and Rostov, the Republic of Tatarstan and Tyumen[11]. The population loss across the country increased five-fold during the pandemic (from 0.04 to 0.2%). In 2019, 21 regions showed positive annual population growth and 5 regions showed growth of more than 1%. In 2020, there were only 16 regions with positive growth and 3 regions with growth greater than 1%.

Neighbouring other countries (hypothesis 2) was included in the model in the form of dummy — variables for countries with which Russia has a land border. If a region has a border with the corresponding country, the dummy variable for it is 1, otherwise it is 0. Countries with short common border and overlapping neighbouring regions were combined into groups: for example, the dummy variable Baltics for a region is 1 if this region borders at least one of the three Baltic countries (Lithuania, Latvia or Estonia).

As a policy variable for hypothesis 3 we used the agglomeration effect indicator for each company. In this paper, we use the continuous variable of inverse distance to the regional centre. It takes into account most of the agglomeration effects accurately and does not require making strong assumptions.

To test hypothesis 4 (on the impact of quarantine restrictions on business), a cumulative index of the severity of quarantine restrictions in the region by Mau (2020) was used. It includes expert assessments of the severity of restrictions by such criteria as travel bans (within the region and to other regions), suspension of transport communication, self-isolation and quarantine regime,

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[10] From Russian Statistics Service — https://rosstat.gov.ru/compendium/document/13282.

[11] These regions had populations greater than 2.5% of Russia's population.

electronic pass system, mandatory wearing of masks and gloves and regional fees for violation of quarantine measures. Figure 1 shows the severity of quarantine restrictions in Russian regions (the stricter the quarantine restrictions in a region, the higher the index and the darker the color of region on the map). It can be seen that the severity of quarantine measures does not correlate with population density in the region, the presence of major transport hubs and state borders, i.e. those factors that determine the rate of virus spread. However, the severity of restrictions was determined by the potential rate of infection and, for example, by the capacity of the local health care system, sectoral features of the economy, etc.

To assess the level of urbanisation (hypothesis 5), the percentage of urban population in the region were selected[12].

An important part of the company's allocative efficiency is the demand for its products. In this case, not only the number of potential consumers is important, but also their solvency. Bessonova and Tsvetkova (2020) empirically showed that more efficient firms are located in rich regions. To control for effective demand in the region, we used real median income in the respective region (for the current year, prices are comparable)[13] and the spatial lag[14] of median income. The median income during the COVID-19 crisis included state support at the federal and regional levels.

A favourable institutional environment improves business performance because it reduces risk and uncertainty and minimises costs not directly related to production (Hall, Jones, 1999). An important indicator of a region's institutional environment is the level of corruption, it always was one of the main problems for business. Corruption increases the price of goods and services (as the amount of bribes paid is ultimately passed on to the final consumer), reducing the level of demand and sales of the goods produced, thus disturbing the market equilibrium (Dal Bó, Rossi, 2007). Two variables were used as indicators of the level of corruption in the region — the number of criminal cases initiated in the respective year under art. 290 "Bribe taking" and art. 285 "Abuse of official powers" of the Criminal Code[15]. Both variables were prorated per 100000 people. The number of reported offences related to the abuse of authority remained virtually unchanged during the pandemic compared to the pre-crisis period, while the number of bribes increased from 2.72 to 2.85 cases per 100000 people. This can be explained by the constantly changing legislation and the inefficiency of the law enforcement system.

In the 21st century, the Internet is an important part of sales. Online orders are often faster and more convenient than offline ones: no time is wasted on shopping in different locations, and finding the right product is much more convenient with search algorithms on marketplaces. Widespread use of the Internet makes sales more convenient and cheaper (for both the seller and the buyer), thus increasing the allocative efficiency of the enterprise and raising the demand for its products. The importance of communications infrastructure in Russia is also confirmed empirically, for example, Kolomak (2011) shows that the spread of mobile networks increases output in Russian regions. In our work, the percentage of the households using the internet every day[16] served as a proxy for digitalisation at the regional level.

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[12] https://showdata.rosstat.gov.ru/report/278932/.

[13] https://www.fedstat.ru/indicator/61787.

[14] This is discussed in more detail further in this section.

[15] http://crimestat.ru/offenses_table.

[16] https://www.fedstat.ru/indicator/43570.

Table 1 summarises the descriptive statistics for the listed continuous variables.

Table 1. Descriptive statistics for the model variables (2019 / 2020)

Indicator	Min	Max	Mean	Median	Std. Dev.
Dependent variable					
Y (revenue), million rubles	< 0.01 / < 0.01	1994.35 / 1992.92	45.20 / 44.10	13.00 / 11.68	116.11 / 118.90
Individual non-spatial variables					
K (assets), million rubles	< 0.01 / < 0.01	200330.73 / 219621.87	61.81 / 64.13	8.04 / 8.62	842.33 / 848.30
L (workers), persons	0 / 1	250 / 250	10.25 / 10.12	4 / 4	19.78 / 19.63
debt_ratio (debt / equity)	0 / 0	451772.9 / 290385.7	31.9 / 30.8	0.99 / 0.95	1117.3 / 854.8
age, years	0 / 1	61 / 62	9.89 / 10.89	8 / 9	7.25 / 7.25
Individual spatial variables					
center_dist, km	0.014 / 0.014	2214 / 2214	57.9 / 57.9	9.5 / 9.5	116.7 / 116.7
Regional variables					
Urbanization, %	55.2 / 55.4	100 / 100	80.4 / 80.4	79.1 / 79.2	12.5 / 12.3
Digitalization, %	53.5 / 59.2	86.7 / 89.1	75.2 / 78.5	74.3 / 78.1	7.9 / 7.1
Median_income, thousand rubles	18.726 / 18.615	39.191 / 39.673	28.264 / 28.081	26.023 / 25.804	5.886 / 6.039
Population_growth, %	–1.38 / –1.13	1.69 / 1.20	–0.004 / –0.249	–0.18 / –0.29	0.65 / 0.51
Share_population, %	0.09 / 0.09	8.61 / 8.64	3.02 / 3.03	1.96 / 1.95	2.59 / 2.61
Bribes, number of cases per 100000 population	0.56 / 0.54	11.37 / 20.77	2.15 / 2.33	1.93 / 2.02	1.00 / 1.35
Abuse_power (AP), number of cases per 100000 population	0.00 / 0.07	25.58 / 15.76	1.10 / 0.98	0.93 / 0.69	1.09 / 0.79
Quarantine, expert estimations	— / 1	— / 7	— / 4.3	— / 4.5	— / 1.2

When we analyse financial indicators in Russian regions for different years, the problem of price comparability arises for two reasons: price change over time (inflation) and price differences between Russian regions — the cost of a fixed set of consumer goods and services between the cheapest and the most expensive regions to live in both 2019 and 2020 differed more than twofold (Federal State Statistics Service). In order to make prices comparable, all monetary indicators used (in rubles) were adjusted for the cost of the consumer set in each region. The 2020 indicators were also adjusted for inflation in 2020. Thus, all monetary indicators are presented in average Russian prices in 2019 and are comparable.

In this part, we consider two types of regression models. The first model, multilevel linear model (MLM), is estimated in order to properly assess the impact of both individual and regional level factors on firm output. The second model, geographically weighted regression (GWR), is needed to estimate the variation of the model coefficients across space. Below we consider each of them in more detail.

The set of explanatory variables includes individual firm characteristics and regional characteristics, and therefore one-level models may produce spurious coefficient estimates. In order to correctly account for the influence of different levels of factors, we used a multilevel linear model (MLM) for the whole sample (Raudenbush, Bryk, 2002).

In this paper, the object of observation is the enterprise, and the regions of Russia are the groups with individual characteristics. Since the specification includes explanatory variables at the regional level, the model with a random intercept with constant remaining coefficients was chosen.

The model specification includes not only regional-level explanatory variables, but also spatial lags (i.e., the weighted average of the variable for the nearest facilities) for variables which are directly connected with inter-regional labor force flows. Models of this type are called Spatial Lag X (SLX) models (Elhorst, Halleck Vega, 2017). In this work the weight matrix W represents the inverse squared distances between regions, the influence of distant regions is virtually ignored (unlike the simple inverse distance). When calculating the regional spatial lags of the explanatory variables, not only regions from the sample were taken into account, but also those regions that were removed due to the lack of company data. Thus, the influence of neighbouring regions was fully taken into account.

We constructed two separate regression models for the pre-crisis period and the pandemic period to compare estimates of the impact of various factors on firm performance before and during the crisis. The specification of the multilevel linear model we estimate for pre-crisis 2019 is as follows:

$$\log(Y_{ij}) = \alpha + \beta_1 \log(K_{ij}) + \beta_2 \log(L_{ij}) + \beta_3 \frac{age_{ij}}{10} + \beta_4 \frac{age_{ij}^2}{100} + \beta_5 \frac{debt\_ratio_{ij}}{100} + \tag{1}$$

$$+\beta_6 \frac{center\_dist_{ij}}{100} + \sum_{b=1}^{15} \tau_b d_{bi} + \gamma_1 urbanisation_j + \gamma_2 digitalisation_j + \gamma_3 bribes_j + \gamma_4 AP_j +$$

$$+\gamma_5 median\_income_j + \gamma_6 share\_population_j + \gamma_7 population\_growth_j + \gamma_8 (W \cdot median\_income)_j +$$

$$+\gamma_9 (W \cdot share\_population)_j + \gamma_{10} (W \cdot population\_growth)_j + \sum_{n=1}^{8} \varphi_n d_{nj} + u_j + \varepsilon_{ij},$$

where i is the company identifier; j is the identifier of region where the company is located; Y is the revenue of company; $\log(K)$ is the logarithm of company assets; $\log(L)$ is logarithm of the number of employees; *age* is the age of the firm; *debt_ratio* is the debt to equity ratio; *center_dist* is the distance to the centre of the region; d_{bi} is a dummy variable showing the affiliation of company i to industry group b[17]; *urbanisation* is the share of urban population in the region; *digitalisation* is the percentage of internet-using households in the region; *bribes* is the number of criminal bribe cases in the region per 100000 people; *AP* is the number of criminal cases on abuse of power in the region per 100000 people; *median_income* is the median per capita income in the region; *share_population* is the share of the region's population in the Russian population; *population_growth* is the population growth in the region; W is the spatial weight matrix for spatial lags of explanatory variables; d_{nj} are dummy variables for borders with countries or groups of countries (Baltic[18], Scandinavian countries[19], Eastern Europe[20], Georgia, Kazakhstan, Mongolia,

[17] The industry groups are listed here: http://taxpravo.ru/analitika/statya-419604-kodyi_okved_2019; the default group is agriculture, and separate dummy variables are introduced for each of the others.

Industry affiliation may affect not only TFP but also the elasticity of the output by labour and capital. However, in this paper we cannot include (in addition to the existing variables) 30 more cross terms due to high multicollinearity.

[18] Lithuania, Latvia and Estonia.

[19] Norway and Finland.

[20] Ukraine, Belarus and Poland (models estimated for 2019–2020).

China, North Korea); u_j are random effect for region j; ε_{ij} is the firm random error; $\alpha, \beta, \tau, \gamma$ and φ are model coefficients estimated using the maximal likelihood method.

The model specification for the crisis year 2020 is similar, the only difference is that the variable of severity of quarantine restrictions in the region ($quarantine_j$) is added to the regression equation:

$$\log(Y_{ij}) = \alpha + \beta_1 \log(K_{ij}) + \beta_2 \log(L_{ij}) + \beta_3 \frac{age_{ij}}{10} + \beta_4 \frac{age_{ij}^2}{100} + \beta_5 \frac{debt\_ratio_{ij}}{100} + \tag{2}$$

$$+\beta_6 \frac{center\_dist_{ij}}{100} + \sum_{b=1}^{15} \tau_b d_{bi} + \gamma_1 urbanisation_j + \gamma_2 digitalisation_j + \gamma_3 bribes_j +$$

$$+\gamma_4 AP_j + \gamma_5 median\_income_j + \gamma_6 share\_population_j + \gamma_7 population\_growth_j +$$

$$+\gamma_8 (W \cdot median\_income)_j + \gamma_9 (W \cdot share\_population)_j + \gamma_{10} (W \cdot population\_growth)_j +$$

$$+\sum_{n=1}^{8} \varphi_n d_{nj} + \psi \cdot quarantine_j + u_j + \varepsilon_{ij}.$$

Models (1)–(2) estimate the regional factors affecting the output of an enterprise and take into account intra-regional differences only in the form of the distance to the centre of the regional capital included in the regression equations. Intra-regional differences are discussed in more detail below, in the geographically weighted regression (GWR) model.

Also, we estimated the percentage contribution of factors to the firm output in multilevel models (1)–(2). McClosky and Ziliak (1996) criticised the assessment of the importance of the explanatory factors of the regression *only* by their statistical significance: if the coefficient by some explanatory variable is significant and stable, but the value of this explanatory variable is very small, then with high statistical significance the real contribution of this factor to the dependent variable is insignificant. Following them, Holgersson et al. (2014) proposed an estimate of the economic significance of a factor i as $\left(\beta_i \bar{X}_i / \bar{Y}\right) \times 100\%$, where $\bar{X}_i$ is the mean of the factor X_i, β_i is the estimation of coefficient by the factor X_i, and $\bar{Y}$ is the mean of the dependent variable. This approach allows (in addition to testing the statistical significance of the regression coefficients) to assess the magnitude of the factor's influence from a practical point of view.

Russia is a very heterogeneous country, and economic processes in Russia may differ significantly not only between regions, but also within a single region. This may suggest that the model coefficients are not constant across space. Therefore, we also estimated GWR model (Brunsdon et al., 1996) with individual firm characteristics to compare the model coefficients across space.

In practice, to obtain the GWR coefficients, at each point "local" regression using weighted least squares are separately estimated, where the weights are determined for each point (Brunsdon et al., 1996).

As in MLM, in GWR we constructed separate regressions for 2019 and 2020 explaining firm output by different characteristics. However, while in MLM the model coefficient estimates were general for the whole sample and individual and regional factors were included in the model, in the GWR model local coefficients are estimated for each firm and therefore only individual firm characteristics are used as explanatory variables. Thus, we estimate both inter-regional and intra-regional differences in the model coefficients.

The following GWR model was estimated both for 2019 and 2020:

$$\log(Y_i) = \beta_0(u_i, v_i) + \beta_1(u_i, v_i)\log(K_i) + \beta_2(u_i, v_i)\log(L_i) + \beta_3(u_i, v_i)\frac{age_i}{10} + \tag{3}$$

$$+\beta_4(u_i, v_i)\frac{age_i^2}{100} + \beta_5(u_i, v_i)\frac{debt\_ratio_i}{100} + \beta_6(u_i, v_i)\log(center\_dist_i) + \sum_{b=1}^{15}\tau_b(u_i, v_i)d_{bi} + \varepsilon_i,$$

where i is the identifier of the enterprise; b is the identifier of the industry to which the enterprise belongs; u_i and v_i are the geographical coordinates of company i; β and τ are regression coefficients depending on the geographical coordinates of the company, and ε_i is a firm random error.

The significance of local coefficients was tested using the variance of the coefficient estimates, which helps to provide an approximation of the standard t-statistic (Wheeler, 2021). The GWR model was estimated using a Gauss kernel, with coefficient estimates at each point being calculated using a weighted least squares based on all observations in the sample. Closer observations were given more weight than farther observations. Accordingly, if the pseudo t-statistics for the corresponding coefficient are greater than the critical value, we consider the coefficient to be pseudo-significant.

4. Results

4.1. Multilevel linear model

The models for 2019 and 2020 were estimated as follows. First, the full model with all factors was estimated (equations (1) and (2), respectively). Then, a Wald test was performed on the *joint* significance of all factors whose estimates were not significant at the 10% level. For the set of industry dummy variables, their joint significance was estimated using the Wald test, as this is a categorical variable and it would be incorrect to estimate the significance of these dummy variables separately. If all variables that were not separately significant were also jointly insignificant (also at the 10% level), they were dropped from the specification. If there were still variables that were not significant at the 10% level in the reduced specification, the algorithm was repeated. Also, the joint significance of the set of industry dummy variables was tested at each stage. For both 2019 and 2020, all variables that were not significant separately were also not significant in common, while the industry affiliation dummies were significant at all stages.

Table 2 shows the factor estimates[21] for 2019 and 2020. 'All factors' column shows estimation of the first (initial) model with all variables, and 'Final' column represents the estimation on the last stage, when all factors are significant at least on 10% level.

In 2020, while the elasticity of output for capital decreased slightly (from 0.449 to 0.441%), and for labour it increased significantly (from 0.693 to 0.767%) among Russian enterprises. This may be a consequence of difficulties with the organisation of labour under quarantine conditions. The findings of the study demonstrated a negative correlation between the age of the company and its revenue, with an average decrease of 0.6% in revenue for every year that the company's age increased. This relationship was consistent both before and during the pandemic. Conversely, the square of age, despite its statistical significance, exerts a negligible influence on revenue.

[21] Models were estimated using the statistical package *lme4* in R.

Table 2. Results of MLM estimations for 2019–2020

Factor group	Factor	2019		2020	
		All factors	Final	All factors	Final
	Intercept	7.681# (0.215)	7.720# (0.131)	7.595# (0.236)	7.762# (0.151)
Individual characteristics of a company	log (*K*)	0.449# (0.001)	0.449# (0.001)	0.441# (0.001)	0.441# (0.001)
	log (*L*)	0.693# (0.003)	0.693# (0.003)	0.767# (0.003)	0.767# (0.003)
	age/10	–0.060# (0.001)	–0.060# (0.001)	–0.060# (0.001)	–0.060# (0.001)
	age^2/100	0.0012# (0.0001)	0.0012# (0.0001)	0.0012# (0.0001)	0.0012# (0.0001)
	debt_ratio/100	–0.0007# (0.0002)	–0.0007# (0.0002)	–0.0009# (0.0003)	–0.0009# (0.0003)
	center_dist/100	–0.012# (0.003)	–0.012# (0.003)	–0.009*** (0.003)	–0.009*** (0.003)
Branch group (default is agriculture)	Mining	0.068 (0.181)	0.067 (0.181)	–0.182 (0.199)	–0.181 (0.199)
	Manufacture	0.148 (0.109)	0.148 (0.109)	0.220* (0.120)	0.220* (0.120)
	Electricity supply	–0.025 (0.152)	–0.025 (0.152)	–0.050 (0.167)	–0.050 (0.167)
	Water supply	0.196 (0.147)	0.196 (0.147)	0.145 (0.162)	0.145 (0.162)
	Construction	0.251** (0.104)	0.251** (0.104)	0.256** (0.115)	0.256** (0.115)
	Trade	0.612# (0.104)	0.611# (0.104)	0.677# (0.115)	0.677# (0.115)
	Transport and storage	0.418# (0.105)	0.417# (0.105)	0.384# (0.115)	0.385# (0.115)
	Hotels and catering	0.398# (0.105)	0.398# (0.105)	0.164 (0.115)	0.165 (0.115)
	Information and communication	–0.181 (0.163)	–0.181 (0.163)	–0.079 (0.179)	–0.078 (0.179)
	Finance and insurance	–0.777# (0.175)	–0.777# (0.175)	–0.485** (0.193)	–0.485** (0.193)
	Real estate transactions	–0.094 (0.104)	–0.095 (0.104)	–0.019 (0.115)	–0.019 (0.115)
	Professional. scientific and technical activities	–0.064 (0.105)	–0.065 (0.105)	0.005 (0.115)	0.005 (0.115)
	Administrative services	–0.008 (0.105)	–0.009 (0.105)	–0.833# (0.116)	–0.833# (0.116)
	Culture. sports and entertainment	0.113 (0.452)	0.114 (0.452)	–0.237 (0.497)	–0.236 (0.497)
	Other types of services	0.430 (0.503)	0.428 (0.503)	–0.038 (0.553)	–0.038 (0.553)

End of Table 2

Factor group	Factor	2019		2020	
		All factors	Final	All factors	Final
Regional variables (without state borders)	*urbanisation*	0.0024*	0.0027**	0.0026*	0.0023*
		(0.0013)	(0.0012)	(0.0014)	(0.0013)
	digitalisation	0.0009		–0.0008	
		(0.0016)		(0.0019)	
	median_income	0.0085**	0.0094***	0.0075*	0.0088***
		(0.0043)	(0.0030)	(0.0043)	(0.0031)
	W· median_income	0.00001		0.01034	
		(0.00768)		(0.00776)	
	population_growth	0.0542**	0.0553**	0.0794***	0.0735***
		(0.0250)	(0.0230)	(0.0276)	(0.0257)
	W · population_growth	0.088*		0.090*	0.069*
		(0.046)		(0.048)	(0.042)
	share_population	–0.024**	–0.026***	–0.026**	–0.030$^{\#}$
		(0.0108)	(0.009)	(0.010)	(0.008)
	W · share_population	–0.057		–0.060*	–0.045*
		(0.036)		(0.036)	(0.024)
	bribes	–0.012		0.005	
		(0.008)		(0.006)	
	abuse power (AP)	0.001		–0.008	
		(0.005)		(0.008)	
COVID-19	*quarantine* (2020)	—	—	0.0006	
		—	—	(0.0072)	
State borders (regional variables)	Eastern Europe	0.016		0.006	
		(0.028)		(0.028)	
	Baltics	–0.155***	–0.135***	–0.143***	–0.135***
		(0.056)	(0.050)	(0.055)	(0.049)
	Scandinavia	–0.017		0.009	
		(0.034)		(0.033)	
	Georgia	–0.12*		–0.146**	–0.156**
		(0.070)		(0.073)	(0.065)
	Kazakhstan	–0.001		0.008	
		(0.028)		(0.028)	
	Mongolia	0.135		0.064	
		(0.092)		(0.095)	
	China	0.007		0.011	
		(0.052)		(0.054)	
	North Korea	0.084		0.063	
		(0.085)		(0.083)	
Variance for random regional effect		0.0040	0.0041	0.0037	0.0036
Conditional R^2		0.668	0.668	0.645	0.645
Marginal R^2		0.667	0.667	0.644	0.644
Wald test (p-value)	Model in total	< 0.001	< 0.001	< 0.001	< 0.001
	Dummies for industry groups	< 0.001	< 0.001	< 0.001	< 0.001
	Non-significant variables	0.36		0.24	
Observations		214298			
Groups		66			

Note. Standard errors in parentheses. Levels of significance: * — 10%, ** — 5%, *** — 1%, $^{\#}$ — 0.1%.

The minimum of the quadratic function, observed in both years, occurs at age 250. This suggests that, in reality, where the lifespan of firms is much less than 250, revenue declines over time. This finding is consistent with the conclusions of Kolomak and Sherubneva (2023a).

In both 2019 and 2020, the company's revenue fell while the debt load increased, but during the pandemic, the sensitivity to relative debt increased by 30%. Typically, companies with high debt loads are at financial risk, and during the 2020 crisis, these risks were realised. If we look at the sectoral aspect, we can see that during the pandemic the industries traditionally associated with offline interaction "fell": transport, hotel accommodation and catering, administrative services. The trade sector showed an unexpected result: the TFP of retailers even slightly increased during COVID-19, which can be explained by consumer panic and increased demand for some goods at the beginning of the pandemic.

In 2019, an increase in the distance from a regional centre by 1 km reduced a company's revenue by 0.012% on average, and during the COVID-19 pandemic, it was 0.009% only. The number of offline interactions that go hand-in-hand with agglomeration effects decreased during the pandemic, which may have slightly lowered the dependence of a firm's revenue on its geographic location (while maintaining the importance of factors affecting logistics).

The levels of digitalisation and corruption did not affect the revenue of companies in the respective region. At the same time, the level of urbanisation in the region increased the efficiency of firms: before the pandemic, a 1% increase in the share of urban population increased TFP by 0.27%. During the pandemic, this effect was reduced (to 0.23%) because of the higher incidence in urban areas. An increase in the median income in the region by 1000 rubles in 2019 led to an average revenue (i.e. TFP) growth of 0.94% for companies in the region, and 0.88% in 2020. The median income in neighbouring regions did not affect the revenue of companies.

Population growth in the region both before and during the pandemic increased the revenue of companies, and this effect became stronger during COVID-19 (1% annual growth in population raised 5.5% revenue growth in 2019 and 7.3% in 2020). Moreover, during COVID-19 the growth in population of the one region affected neighbouring ones. This refutes the hypothesis that fast-growing regions pull resources from neighbouring regions in periods of growth, and we can say that the development of one region may create impulses for neighbouring regions. However, before and during the pandemic the size of a region had a negative impact on the revenue of enterprises in it (and in 2020 it negatively affected even neighbouring regions!), and this may be due to the fact that large regions have more competition and it is harder to sell goods and services.

Before and during the pandemic regions neighbouring Baltic countries reduced the output of enterprises in the bordering regions by 13.5%. This result can be explained by Russia's poor diplomatic relations with Baltic countries, which leads to reduced commodity and labour flows. During the pandemic, regions which have a border with Georgia faced 15.6% decrease of output. It can be explained by strict quarantine restrictions in Georgia and reduction of Russia–Georgia trade and labour flows.

The severity of quarantine restrictions during the pandemic did not have a significant impact on the output of enterprises in regions. This indicates a high degree of adaptation of SMEs to quarantine measures: changing the business model of the enterprise with a reorientation to online sales, transferring employees to remote work, ensuring compliance with quarantine measures, etc.

Table 3 shows the *economic* significance of the statistically significant factors in models (1)–(2) via methodology of (Holgersson et al., 2014), with the exception of the intercept and industry. For each variable, its percentage contribution to the dependent variable is shown (if the coefficient on the variable is negative, the contribution is also negative).

Table 3. Economic significance of explanatory variables, 2019–2020

Factor group	Factor	Impact (%)	
		2019	2020
Individual characteristics of a company	log (*assets*)	45.68	44.99
	log (*workers*)	9.519	10.493
	age	–3.374	–3.710
	age^2	0.671	0.775
	debt_ratio	–0.001	–0.002
	center_dist	–0.039	–0.029
Regional variables (without state borders)	*urbanisation*	1.215	1.056
	median_income	1.508	1.400
	population_growth	–0.001	–0.104
	$W \cdot$ *population_growth*		–0.097
	share_population	–0.450	–0.519
	$W \cdot$ *share_population*		–0.774
State borders (regional variables)	Baltics	–0.046	–0.046
	Georgia		–0.027

The economic significance analysis shows that firm output is most affected by asset size (45%), number of employees (9.5–10.5%, the impact increased during COVID-19) and age (3%). Proximity to the centre of the region contributes only 0.03–0.04% and decreased during the pandemic. The median income and the level of urbanisation in the region contribute 1–1.5%, while the size of the region gives ~0.5%. The population growth rate in the region and the neighbourhood with other countries have a very small impact (0.1% or less), although their coefficients are statistically significant.

We believe that in scientific research it is necessary to study and take into account the influence of all statistically significant factors, at least because their influence is stable and consistent, and also because it allows us to develop theoretical models with causal relationships. However, in practical planning and management decisions, the economic significance is more important and it is worthwhile to critically consider the size of the contribution made by one or another factor[22].

4.2. Geographically weighted regression (GWR)

Table 4 shows the results[23] of the GWR estimation for the full sample in 2019 and 2020. For each variable, the global coefficient (OLS estimate for the full sample) and its significance are given in parentheses, the quantiles for the local coefficients, and the number of positive, negative and insignificant local coefficients.

[22] Also, there is a discussion question that in assessing the practical importance of a factor when making a policy decision, it is not so much its absolute (static) value that matters, but how much that factor *can change* in the future and how much a policy maker can affect it (and, consequently, how much the target variable will change as a result). For example, the level of urbanisation across Russian regions on average ($\bar{X}$) is 80%, this is a lot, and because of this its economic importance according to (Holgersson et al., 2014) is high. However, now the urban population is growing slowly compared to the 20th century, and the expected increase in the urban population is small, besides it is mathematically limited to 100%, so the absolute value of the share of urban population does not affect much here.

[23] The calculations were performed via supercomputer cHARISMa NRU HSE (Kostenetskiy et al., 2021), using *mgwr* module in Python.

Table 4. Results for GWR estimations, 2019–2020

Variable	Global coef.	P-value	Min	1st Qu.	Median	3rd Qu.	Max	$t > 1.96$	$t < -1.96$	$\|t\| < 1.96$
					2019					
Intercept	8.12	< 0.001	8.04	8.14	8.26	8.30	8.38	214298	0	0
log (K)	0.45	< 0.001	0.45	0.45	0.45	0.45	0.45	214298	0	0
log (L)	0.69	< 0.001	0.69	0.69	0.69	0.69	0.69	214298	0	0
debt_ratio/100	–0.0007	< 0.001	–0.003	0.00	0.00	0.00	0.003	0	208254	6044
log (*center_dist*)	–0.01	< 0.001	–0.03	–0.02	–0.02	–0.02	–0.01	0	214298	0
age/10	–0.06	< 0.001	–0.09	–0.06	–0.06	–0.05	–0.02	0	214298	0
age^2/100	0.0011	< 0.001	0.00	0.00	0.001	0.001	0.001	214298	0	0
Industry					Yes[24]					
R^2					0.666					
Adjusted R^2					0.666					
Observations					214298					
					2020					
Intercept	7.99	< 0.001	7.95	7.98	7.99	8.00	8.12	214298	0	0
log (K)	0.44	< 0.001	0.44	0.44	0.44	0.44	0.45	214298	0	0
log (L)	0.76	< 0.001	0.76	0.76	0.76	0.76	0.77	214298	0	0
debt_ratio/100	–0.001	< 0.001	–0.003	0.00	–0.01	0.00	0.00	0	193945	20353
log (*center_dist*)	–0.01	< 0.001	–0.02	–0.02	–0.02	–0.01	0.00	0	214298	0
age/10	–0.06	< 0.001	–0.1	–0.06	–0.06	–0.04	–0.01	0	214298	0
age^2/100	0.0012	< 0.001	0.00	0.00	0.001	0.001	0.001	214298	0	0
Industry					Yes					
R^2					0.644					
Adjusted R^2					0.644					
Observations					214298					

On average, the elasticity of output by labour increased in Russia during the crisis (from 0.69 to 0.76%). The elasticity by debt burden was negative in both 2019 and 2020, and increased by 50% during the crisis. The elasticity for the distance to the centre of the regional capital was also negative in both periods: while the distance from the centre increases by 1%, the revenue of the firm falls by 0.1%. In general, the results are similar to the MLM results, adjusted for differences in the model and the set of explanatory variables.

A comparison of the local coefficients by distance elasticity of output for 2019 and 2020 reveals a decline in revenue for enterprises across Russia as they move away from the centre of the regional capital. In other words, there are positive agglomeration effects across the country. However, there is also a clear pattern: the further west a company is located, the stronger its revenue will grow as it gets closer to the regional centre. Thus, agglomeration effects for enterprises are stronger in the European part of Russia than in the Asian part.

5. Conclusion

This paper analysed the impact of regional and spatial factors on the output of Russian small and medium enterprises both in a favourable economic situation and during the pandemic. Below we summarised the main conclusions of the study.

[24] The industry effects were included as control variables, but was not analysed here.

Population growth in the region (and in neighbouring regions) contributes to the growth of enterprises' revenues, and this suggests that fast-growing regions create growth points around themselves rather than "pulling" resources from neighbouring regions. Meanwhile, in large regions enterprises have less revenue, and it may occur due to difficulties of high competition as well as the lack of incentives for development at the regional level. At the same time, the impact of a region's population size and growth on firms in neighbouring regions increased during the pandemic, although the opposite effect was expected. A possible explanation for this unexpected result is that enterprises in Russian regions are characterised by sectoral rather than geographical ties (Idrisov, Mikhailova, 2019), and the choice of business partners from other regions is not usually based on geography; however, during COVID-19, when logistical problems and pandemic constraints appeared in the regions, it became easier to cooperate with neighbouring regions than with distant ones. The level of urbanisation has a significant positive effect on the TFP of enterprises, which is in line with theoretical models and intuition.

Neighbouring with "unfriendly" countries with which economic relationships are not established reduces the revenue of enterprises in the region due to the loss of opportunities for trade and cooperation.

The median personal income in a region had a significant positive impact on the revenue of local businesses (but this did not extend to neighbouring regions). During the period of economic uncertainty associated with COVID-19, the effect of median income slightly declined. This is likely due to a greater propensity to save during economic uncertainty.

The level of digitalisation and corruption in a region had no significant impact on the output of businesses there in either period.

The severity of regional quarantine restrictions in 2020 had no significant impact on the revenue of businesses, although other studies of businesses during the pandemic show that strict quarantine restrictions reduced gross value added (Kolomak, 2020a) and the number of SMEs (Zemtsov et al.,2022). Modern technology and the adaptability of small businesses largely enabled SMEs to operate even under strict quarantine conditions.

Industries involving active live interaction were most affected by the pandemic and associated constraints. This result is consistent with earlier studies (Zubarevich, Safronov, 2020; Kolomak, 2020b; Zemtsov et al., 2022; Sherubneva, 2024).

In general, regional centre agglomeration effects had a positive impact on business performance. During the pandemic period, the impact of agglomeration effects on business operations decreased across the country due to a decrease in offline interactions. Businesses in the European part of Russia are more susceptible to the influence of agglomeration effects. This result is consistent with that of previous Russian studies: a similar pattern is observed at the regional level by Demidova (2014), while Kolomak, Sherubneva (2023b) show the same at the municipal level.

It should be noted that distinguishing the influence of agglomeration effects into components (size of the region, its growth rate, the level of urbanisation and proximity of the enterprise to the regional centre), which are usually considered cumulatively, has led to interesting results showing that the influence of agglomeration effects is multidirectional and has many nuances. It is also worth looking not only at the statistical significance of different factors, but also critically assessing the scale of their influence.

In terms of practical recommendations, there are three main points that should be considered. Firstly, irrespective of the impact of the COVID-19 pandemic, the development of large cities is a worthwhile endeavour, as they act as growth points for the surrounding areas. Secondly, the territories of Asian Russia require the development of transport connections in order to realise their potential and not to lose efficiency due to underutilisation of agglomeration effects. Thirdly, the example of the 2020 crisis demonstrates that SMEs in Russia adapt well to constraints, which indicates their flexibility and the effectiveness of state support, and therefore, when it comes to people's lives and health, the restrictions are justified.

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