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EXPLAINING THE PRODUCTIVITY ADVANTAGES OF MANUFACTURING FIRMS IN RUSSIAN URBAN AGGLOMERATIONS

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This paper empirically analyzes the agglomeration-related productivity premium at the enterprise level of the manufacturing industry in Russia. A settlement is counted as part of an urban agglomeration in two cases: that of a large, central city and that of a town located within 50 kilometers of the central city. Data obtained from a 2009 manufacturing enterprise survey are used, along with linked data on hosting regions and cities. We employ a multilevel model, which allows us to consider firm, urban and regional heterogeneity and test two possible explanations of the productivity advantages of firms in urban agglomerations – own-sector and all economic activity concentration in the city and the surrounding region. The results suggest that Russian plants in urban agglomerations enjoy 17-21% higher labor productivity. This gain arises as a result of urbanization and external scale economy – the agglomeration of firms belonging to different industries at both the urban and the regional levels of analysis. We also found that productivity gained from urban agglomeration is the highest in towns with populations of 100,000 to 250,000 people. Localization and clustering – the own-sector concentration of plants in the city – is not associated with higher labor productivity. The structure and size of the surrounding economy always matter: in contrast to urban clusters, regional own-industry clustering satisfactorily explains the productivity premium, suggesting that efficient clustering requires a scale economy larger than only a city. The region's trade openness almost doubles the productivity premium of a firm in an urban agglomeration. All of our results are robust to changes in estimation technique, sample structure and choice of spatial objects.

JEL classification: R10, R12, D24

Key words: productivity, city, urban, agglomeration

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1. Introduction

Geography may not be a decisive development factor in Russia, but ignoring it in the vast emerging economy would produce misleading results. The existing literature primarily discusses spatial barriers to economic development in Russia. Apart from the traditional issues of spatial heterogeneity, geographers point to weak regional integrity, a cold climate and an exceedingly low density of economic activity. Russia has few large cities with respect to its overall size, and these cities are scattered too far away from one another. Thus, even closely related intermediaries in the supply chain are much more spread out than enterprises in similar chains in smaller countries. As a result, enterprises are burdened by higher energy, transportation and weak infrastructure costs in remote regions, where, in addition, there are no developed market players to place orders for components or outsource non-core functions in a bid to streamline production.

Another important feature of modern industrial geography in Russia is the inefficient allocation of production factors that, for decades, has been driven by reasons other than economic ones [World Bank, 2011]. In other words, as enterprises are often located in the wrong places, producing the wrong products, they fail to obtain efficiency gains from favorable geographic location. Moreover, the advent of market incentives did not render the Russian geography more efficient than it was in Soviet times: beyond the large urban agglomerations, at times, the Russian space is degrading into a void characterized by economic and population reductions.

When examining a map of Russia, favorable geographic positions can be primarily found near the large cities where, as [Nefedova, 2008] aptly stated, even cows provide more milk than they do in the provinces, where the grass may be better but the cows feel worse. As. [Zubarevich, 2010], demonstrated, the growth occurring before the crisis (the global financial crisis of 2008) had an explicit geographic structure, characterized by concentration in the federal cities and their agglomerations and in in mega cities (with populations exceeding one million) and other regional centers, as well as in export-oriented company towns.

This study aims to measure and explain agglomeration effects for manufacturing firms in Russia using microdata. We draw upon an extensive theoretical and empirical literature, establishing a special productivity premium for firms within agglomerations. In this study, we aim to answer two primary questions: (1) does the Russian economy exhibit any signs of urban agglomeration effects on medium-sized and large manufacturing enterprises, given the previous non-economic incentives underlying their location decisions? (2) if such agglomeration effects exist, what characteristics of cities and regions explain them?

2. Russia’s general spatial structure and manufacturing geography: some stylized facts

The empirical literature suggests that agglomeration effects in Eastern Europe and Central Asia are stronger than they are in OECD economies [Békés G., Harasztosi P., 2010]. As [Lappo, 2008], argues, in Russia, long distances and vast spaces predetermine a special role for urban agglomerations as institutional boosters of the economy in surrounding territories. Other authors warn that the agglomerations’ capacity to serve and develop the country’s vast territory may be highly exaggerated. Moreover, the literature demonstrates that the development of urban agglomerations may increase regional inequalities [Gardiner et al, 2011].

In this paper, we assume that Russia may serve as an interesting empirical setting for agglomeration studies. However, urban agglomerations’ capacity to stimulate firm productivity and growth should be addressed with caution. Moreover, it is most likely that urban agglomerations’ benefits are conditioned by the efficiency of the key factor and commodity markets and generate their own momentum, thus swinging the pendulum of location benefits and losses.

Arguments supporting agglomeration effects in Russia would first register that historically, Russian cities grew as agglomerations, which increases the likelihood that agglomeration forces affect modern enterprises. It should be noted that Russia is highly urbanized, with two thirds of the population residing in urban communities and over one fifth living in mega cities. Moreover, this share is growing, as these communities remain destinations for migrants, particularly in the Western part of the country. An expanding automotive fleet and the gradual development of the road network in the post-Soviet period have contributed to the intensity of labor commuting. Another argument supporting the existence of agglomeration economies is that manufacturing industries can be found in all regions of Russia except the Chukot Peninsula. Although globally, it is not typical for manufacturing to be sited within urban agglomerations, Russia presents a different picture. Indeed, Moscow and the Moscow Region enhanced their importance as manufacturing centers during the economic boom of the 2000s, when these regions came to contribute to almost a fourth of the total employment in electronics, over a fifth of employment in the food industry, 16% of employment in chemicals and 13% of employment in mechanical engineering [Rosstat, 2002, 2009]. In other words, no signs have been observed of changes in the structural specialization of manufacturing sites within larger cities or of a change from production functions to management functions.

Conversely, agglomeration skeptics also offer important opposing arguments. Thus, although the urbanization rate is admittedly high, with respect to its vast territory, there are still too few cities in Russia and even fewer neighboring cities. Half of Russia’s population lives in rural and smaller towns – apparently, this is more than large cities can help to develop. The existing cities, even the largest ones, are not quite developed in terms of the basic urban functions of concentration and diversity. Some of them lack resources, and some have followed the growth of the local primary enterprise rather than growing in a natural way [Lappo and Polyan, 2007]. In fact, such towns have remained excessively large counties surrounding exceedingly large and often inefficient enterprises. Some regional capital cities are even too industrially specialized, lacking diversification. There are a few mature agglomerations, and they are largely located in European Russia, the Urals, along the Volga and along the Trans-Siberian Railway. According to [Trevish, 2009], at the same time, the remainder of the territory is a sprawling space experiencing a crisis of size (i.e., an imbalance between the demand and supply of the territory as a production factor).

Expectations of agglomeration economies remain indefinite because of the so-called death of distance effects [Cairncross, 1997]. These effects tend to speedily erode concentration advantages because of the restructuring of the economy and the spread of information and communication technologies. Moreover, [Neffke et al.,2011] disputes the existence of external economies of scale for mature manufacturing industries. The latter are highly heterogeneous: indeed, enterprises in the low-end value chain with high transportation costs will gravitate to resource sources and are likely to concentrate, whereas assembly enterprises and high-tech companies tend to opt for nearby product markets. [Black and Henderson, 2002], demonstrated that old manufacturing industries such as the textiles, food, metals, car-making and woodworking industries tend to be disproportionately located in small, specialized metropolitan areas. With regard to clustering with firms from other sectors, there is little evidence of these effects. Thus, using US manufacturing sector evidence, [Ellison et al, 2010] demonstrated that textile and apparel industries tend to cluster near one another, whereas enterprises producing railroad equipment and missiles/space vehicles do not.

Furthermore, agglomeration effects in Russia are not obvious because of the previously mentioned non-market location determinants present during the Soviet era. At that time, priority was given to defense and security considerations and to the national goals of economic space organization and frontier region development. Such cost-inefficient firm spatial allocation weakens the probability of agglomeration economies and depletes scarce investment, which continues to be wasted on economically hopeless communities. An enterprise located in a large permafrost city will hardly notice concentration, co-location and specialization advantages if its costs are predetermined by excessive transportation, energy and labor costs in the subsidized region.

A relatively low labor mobility in the country is still another important argument against the existence of strong agglomeration effects. In the post-Soviet period, people have developed a higher propensity to commute from the suburbs of large cities, but generally, numerous factors inhibiting labor mobility persist: registration requirements, a lack of affordable housing, a thin rental housing market, in-kind and regional entitlements tied to places of permanent residence, and the conflict between poverty and the high costs of relocation.

However, it should be noted that agglomeration forces affecting enterprises in provincial small towns demonstrate some dynamics, which suggests that agglomerations experience various life-cycle stages. For example, World Bank, 2007, demonstrated that proximity to Moscow and Saint Petersburg in the 1990s was as much of a disadvantage as an advantage for the surrounding provinces because the centers of these agglomerations exhausted the skill and investment resources of the neighboring towns. However, more recent trends in agglomeration forces worked in the opposite direction, with smaller provincial towns surrounding the two cities also being included in the economic boom of the metropolis. Overall, this study demonstrated that urban agglomeration (measured as the size of the largest city) emerged as the most significant predictor of regional economic growth.

3. Literature overview

Although early agglomeration studies appeared almost two hundred years ago, it was relatively recently that a theoretical framework for measuring the contributions of geographic concentration to economic growth was developed in the endogenous growth literature. These works predict increasing returns for factor accumulation, including increasing returns for the external scale economy, which originates from the spatial concentration of production [Romer, 1986]. Another evolutionary branch of agglomeration theories refers to the so-called “new economic geography” [Fujita, Krugman and Venables, 1999], which predicts that the geographic concentration of industry is a result of internal economies of scale, in combination with low transportation costs.

The empirical literature on agglomeration premium for the firms basically seeks to answer two questions: that asking whether agglomeration effects exist and that asking where they originate if they exist. Regarding the first question, authors note one effect observed in almost every country: higher productivity among firms in urban agglomerations than among their comparators in less dense economic environments. However, the authors would immediately raise doubts regarding the role of agglomeration in this effect for two reasons. First, enterprises may be more productive simply because they locate in places endowed with a favorable combination of production factors, which provides them with a cost advantage – the so-called factor endowment phenomenon. [Ellison and Glaeser, 1999] find that at least half of the concentration in an industry is driven by natural advantages of the location rather than induced effects of concentration or specialization.

Second, it may be likely that agglomerations are targeted by more efficient producers for whom entry costs into markets characterized by higher salaries and high competition are lower than the benefits obtained from clustering and interaction with dense market agents; i.e., more productive enterprises self-select into agglomerations. Thus, [Venables, 2011], demonstrated that cities tend to be more productive, as the urban environment acts as a self-selection mechanism for high-skilled and high-paid worker selection of expensive cities, which in turn, improves labor demand and supply matches. As demonstrated by [Melitz and Ottaviano, 2008], another self-selection mechanism may be related to involvement in international trade. Larger markets will attract more firms, competition will become tougher, and weaker firms will be driven out. As a result, the average productivity of survivors will increase.

The recent empirical literature largely focuses on two key sources of agglomeration effects. The first source originates from localization effects, related to the geographical concentration of own-industry enterprises (specialization), therefore creating conditions for the formation of the above-mentioned “thick” factor market and specialized labor market. This mechanism is referred to as Marshall-Arrow-Romer (MAR) externalities in the literature, referring to a combination of Alfred Marshall’s [Marshall, 1920] ideas and the more recent endogenous growth theory [Arrow 1962, Romer 1986]. This mechanism was described in great detail in a paper by [Glaeser et al.,1992], who demonstrated how industry concentration in a region creates conditions for knowledge spillovers between firms in an industry, be it codified or informal knowledge of new products, technologies and business models. In turn, specialization effects are a function of industry size, which should be sufficiently large to have a positive impact on firm performance.

Second, positive spillovers from agglomerations may result from a concentration of all economic activities — the co-location of enterprises belonging to different industries, known as urbanization or the diversification Jacobs externalities [Jacobs,1969]. She argued that the higher the volume and diversity of the division of labor, the higher the regional economy’s capacity to generate new types of goods, services and businesses is.

Furthermore, agglomeration effects are difficult to trace because of their dynamic nature when advantages and disadvantages change as the territory and local businesses develop. Normally, agglomerations begin in a favorable factor market. First, the concentration of more or less related producers sharing resources will increase specialization and enhance returns on scale. In turn, increasing returns on factors will increase the diversity of firms attracted to the agglomeration and the concentration of labor. As they migrate into the agglomeration, the latter will contribute not only their capacity to produce their own goods and services but also a capacity to generate demand for the goods and services produced by others. Therefore, new markets emerge near the enterprises, which initially targeted only specific local factors. Thus, the site develops its advantages using higher scale economies in terms of both production and consumption supported by a higher division of labor [Mills, 1967; Dixit, 1973].

As new entrants seek to utilize the new and the old advantages of the location, they are guided not so much by input costs as by demand and transportation cost savings [Glaeser, 1998; Krugman, 1991]. In this context, a special role is given to thick labor markets in which both hiring and firing of specialized labor is possible and a better balance between supply and demand, i.e., better matching of employers and employees, is possible. Moreover, if workers enhance their skills, the firms that expect to employ these workers would want to invest more in new equipment [Acemoglu, 1996]. Workers with a higher number of potential employers would be in a stronger bargaining position and would be more willing to develop their human capital [Rotemberg and Saloner, 1991]. Moreover, large urban areas are better suited to endurance in the face of industry restructuring, as redundant workers will find it easier to obtain jobs in other sectors currently at a different life-cycle stage.

Firms in urban agglomerations will be more likely to outsource their non-core functions, thus increasing their efficiency and vertical disintegration [Scott 1988; Storper 1989]. A diverse urban environment is conducive to creativity, education and knowledge generation because of the enhanced intensity of interaction between people in such an environment [Audretsch & Feldman, 1996, Saxenian, 1994].

With regard to labor markets in agglomerations, it is also important to note that as they look for a place to live and work, highly skilled workers would consider not only wages but also incremental benefits, including public goods, which are more numerous and better in urban agglomerations – schools, high quality goods and services, retraining and human capital development facilities, etc. These benefits are incremental values offered in urban environments, with their special diversity of supply.

[Duranton and Puga,2004] summarize the above sources of agglomeration economies in terms of the following three groups of mechanisms: (1) the sharing of production factors and risks, including advantages arising as a result of a wider diversity of suppliers of raw materials and components, supported by a higher number of end producers; (2) higher quality and probability with regard to matching between factor demand and supply ; (3) the intensification of learning in a highly interactive environment of knowledge exchange.

The latest reviews of the empirical literature on our subject are quite unanimous in summarizing quantitative estimates of MAR and Jacobs spillovers. Thus, [Rosental and Strange, 2004], report that productivity may increase by 3-8 percent as a result of larger city or sector sizes. Using a meta analysis of empirical works on agglomeration, [De Groot et al, 2008], demonstrate that irrespective of estimation methods and data, there is convincing evidence of the positive effects of diversification and the less apparent effects of specialization and controversial findings regarding competition effects. [Beaudry, C. and Schiffauerova, A., 2009], calculated that 70 percent of the 67 papers on the subject contain evidence supporting specialization effects and that 75 percent contain evidence in support of diversification effects, with results varying in accordance with the analyzed industry, the time of observation, the country and the dependent variable. The same authors demonstrate that negative spillovers from agglomerations in empirical works are more frequently related to specialization and practically never related to diversification.

We are particularly interested in the recent analysis of agglomeration effects using firm-level microdata across countries. It is noteworthy that any straightforward comparisons between quantitative estimations of agglomeration returns with regard to productivity in different countries would not be quite accurate because authors utilize different definitions of agglomerations, employ different analytical methods and objects of analysis, may or may not control for sectoral and time effects in addition to spatial effects, and utilize different measures of productivity.

One notable paper in this line of research is a study by [Rigby and Essletzbichler, 2002], in which the authors explain firm-level differences in labor productivity in US metropolitan areas using aggregated 4-digit and 2-digit microdata. They find that economic density, labor market structure and technological exchange intensity have positive effects on value-added productivity.

Using data from the enterprise register covering three US machine-building industries and four high technology sectors, Henderson, 2003, discovered that industry specialization has a strong positive effect on factor productivity in high-tech sectors (but not in machine and equipment sectors). He has also demonstrated that one-enterprise firms are more sensitive to external scale economies than conglomerates. No signs of urban diversification influence on productivity have been discovered.

A similar approach was applied in a more recent work by [Martin et al, 2011], although it was extended to all manufacturing industries in France. The authors confirmed the specialization effect: a 10% increase in employment in co-located own-industry enterprises increases their factor productivity by 0.55%. This study has also not discovered any urban diversification effects.

Using panel data from the register of Swedish manufacturing firms, [Andersson, Lööf, 2011,] revealed higher firm productivity observable in larger regions and uncovered learning effects of agglomerations, as enterprises in agglomerations increase their productivity.

Some papers estimate agglomeration effects on not productivity but firm survival likelihood or firm growth rates. Thus, [Renski, 2011], showed that industrial specialization and diversity have a positive influence on the survival chances of new entrants in the USA and that urban agglomerations have a limited role. [Audretsch and Dohse, 2007], revealed that firm location has a positive effect on firm growth rates within innovative clusters in Germany, in contrast to firm location in less knowledge-intensive regions. [Neffke et al, 2012], analyzed Swedish manufacturing in agglomerations using microdata. They demonstrated that firm demand for agglomeration externalities depends on the firm's maturity and degree of integration with other market agents and that it changes over time. For non-affiliated firms, they proved that Jacobs externalities have a significant effect on firm survival probability.

There are only few published empirical papers estimating agglomeration effects on productivity through the use of microdata on Russia. Thus, [Gonchar, 2008] demonstrated on 2005 survey data that enterprises in urban agglomerations are more productive than firms in isolated settlements. Related empirical papers use urban agglomerations to explain variance in regional economic growth [Lugovoi et al, 2007] or treat them as a mechanism for the transmission of growth from rich to less wealthy neighboring regions, which is particularly observable in Moscow, St. Petersburg and Rostov agglomerations [World Bank, 2008].

4. Hypothesis and data

The quantitative analysis was performed using data from the 2009 manufacturing enterprise survey obtained during face-to-face interviews conducted by Levada Center. The survey was undertaken by the National University – Higher School of Economics.

The sample included enterprises employing 100 – 10,000 people in eight two-digit manufacturing industries. A stratified random sample was formed at two stratification levels: industry level and size group level. Overall, 1,006 enterprises were surveyed, and 957 observations were included in the data base. The sampled enterprises employ approximately 8 percent of the total general population in the manufacturing sectors included in the survey and produce 6 percent of the total output. The distribution of the surveyed enterprises by industry and by size groups is provided in Figure 1. It should be noted that these data were obtained during a second round of the survey, with approximately half of the sample consisting of an overlapping panel. As some panel enterprises downsized below the threshold of 100 employees, they were included in the lowest employment group in the sample.

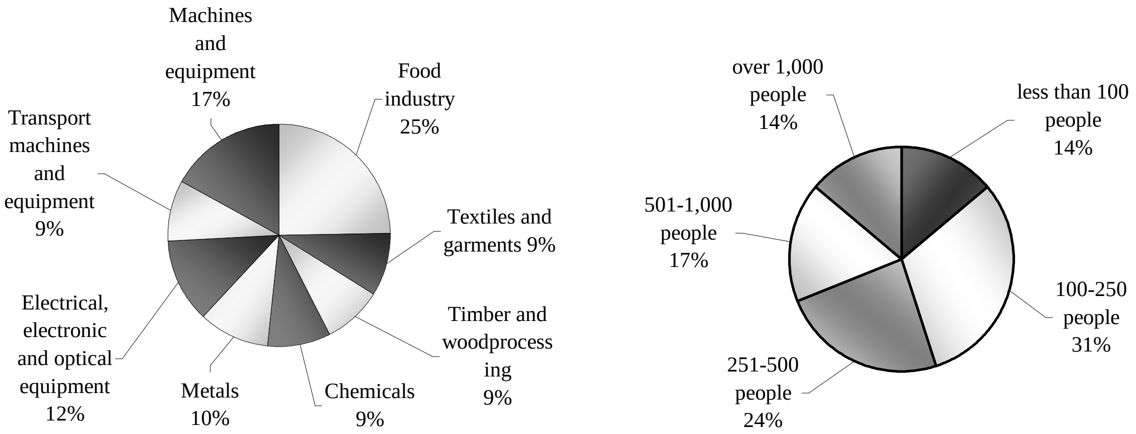


Figure 1. Sample structure by industry and enterprise size - % of total surveyed enterprises

As we knew the actual addresses of the enterprises, we could expand our enterprise data base using indicators characterizing actual firm location, both city-wise and region-wise. *Inter alia*, we construct the agglomeration indicator – a binary variable given a value of one if the enterprise is located within a large city listed as an official agglomeration center by the Ministry of Regional Development or in a settlement no farther than 50 kilometers from this large city. In any other case, the variable will be assigned a value of zero. The distance of 50 kilometers was chosen on the basis of a rough estimate of labor commuting distance in Russia. This estimate is consistent with the findings of [Rosenthal and Strange,2001], [Duranton and Overman 2002], and [Henderson,2003], demonstrating that location effects, including agglomeration forces, decrease within a distance of 50 kilometers. Thus, over one third of the enterprises in our sample are in urban agglomerations delineated by this criterion.

We test the following hypotheses:

H1. Russian manufacturing enterprises in urban agglomerations are more productive than their peers in other geographic environments, despite the prevailing non-economic motives behind their initial location decisions.

H2. Urban industry specialization and economic diversification explain how agglomeration effects work.

H3. The power of urban agglomeration effects depends on the economy size and structure in the surrounding region.

5. Econometric model

The difficulties of agglomeration effects estimation are caused by the problem of unobserved features of heterogeneous cities, industries, enterprises and even employees, related to both the dependent variable (enterprise-level labor productivity) and the specific characteristics of agglomerations. These difficulties may result in biased estimates, particularly if the observations do not have full coverage. The selection of an enterprise for the analysis of agglomeration effect may result in identification errors, given that an enterprise located in an urban community in a densely populated, well-developed Western region of Russia will be observationally equivalent to an enterprise in the Siberian rarefied space in terms of its external scale economy if their sizes, specialization, political status and other urban characteristics correspond.

A study of agglomeration-related productivity gains will also be constrained by the endogeneity problem arising from the potential self-selection of more productive firms into urban agglomerations and from other unobservable factors that may have driven the decision to locate the enterprise in the city in which it is positioned. This issue is indicated in particular by [Henderson, 2003], [Rosental and Strange, 2003], and [Combes et al, 2012]. Empirical researchers, who analyze agglomeration effects on enterprise-level microdata, attempt to address this constraint by introducing lagged historical variables and instruments, as well as by running fixed time effects models. Our data are not suited to this approach. However, given that most surveyed enterprises originated during Soviet times, when their initial owner – the state - was not guided by market incentives during location decision-making, we can assume that at least at the decision-making stage, self-selection among more productive firms can be disregarded.

However, another form of self-selection, the exit of less productive firms driven out by intense competition in urban agglomerations, can hardly be disregarded. Therefore, at the regional level of our analysis, we include a measure of the region's involvement in international trade (exports plus imports as a percentage share of the Gross Regional Product (GRP) in our regression and then analyze to what extent the power of urban agglomeration effects depend on the location within the region opened to trade and competition.

Thus, we consider that our subject of analysis is nested in several external environments, i.e., that the enterprise is located within a city, that the city is located within a region, and that it is likely that these environments, similar by nature, would work differently, modified in turn by the nature of the enterprise. The literature demonstrates that multi-level modeling is being used increasingly frequently to analyze the correlation of productivity and other firm performance indicators with the external environment, including agglomerations [Beugelsdijk, 2007], [van Oort et al, 2012]. This approach proves useful in addressing some of the above problems. The novelty of our approach is that we estimate a multi-level model on firm-level survey data and analyze interactions with the macro environment at both levels of the hierarchy, i.e., not only the hosting region level but also the hosting city level.

Another important advantage of multi-level modeling is that it produces valid estimates even with unbalanced data in which there are excessively large gaps between groups in terms of the number of level-1 observations. This issue is relevant to our case because the number of enterprises varies widely across regions and cities, with dozens of enterprises found in Moscow and only one in a smaller town. Last but not least, multilevel models naturally allow for estimation of the interaction between the effects of level-1 and level-2 variables.

Let us now consider key equations for the multi-level models applicable to our task. We proceed with the level-1 or micro level regression equation:

$$Y_{ij} = \beta_0 + \beta_1 x_{1ij} + X'_{2ij}\beta_2 + \varepsilon_{ij},, \quad (1)$$

where the *i* and *j* indices stand for the number of the first-level unit (firm) and the number of the group (region or city), *Y* denotes the logarithm of labor productivity (output per employee), X_2 captures firm characteristics, and x_1 is an agglomeration dummy.

In this hypothetical model, all of the variables may be assigned different values for each observation, which is denoted by the two indices associated with them. However, the coefficients (influence of the variables) are assumed to be fixed. The coefficients are supposed to reflect the average impact of each variable. This regression is a conventional one-level classical regression. Errors, ε_{ij} in this model, are interpreted as noise, which is inexplicable in this framework.

A multi-level approach differs. Despite its regressing nature, such an approach explicitly aims to model the variance of the ε_{ij} term, assuming that the model's coefficients may vary across various groups.

In its most simple form, known as the random intercept model, the model may be written as follows:

$$Y_{ij} = \beta_{0j} + \beta_1 x_{1ij} + X'_{2ij}\beta_2 + \varepsilon_{ij} \quad (2),$$

where index *j* on β_{0j} denotes that this parameter may vary across groups (regions or cities) around a fixed value, β_0, whereas group differences are captured as a specific group effect, μ_{0j} :

$$\beta_{0j} = \beta_0 + \mu_{0j}$$

If, apart from the constant term, variance is also assumed for the x_{1ij} regressor effect, the model will take the following form:

$$Y_{ij} = \beta_{0j} + \beta_{1j} x_{1ij} + X'_{2ij}\beta_2 + \varepsilon_{ij} \quad (3),$$

where

$$\beta_{1j} = \beta_1 + \mu_{1j}$$

It is assumed that both β_{0j} and β_{1j} are normally distributed random variables with expected means of β_0 and $\beta_{1,}$ respectively and with standard deviations equaling the square root of the variance of specific random group effects μ_{0j} and μ_{1j}.

After including all of the assumptions in one equation, we arrive at the following model:

$$Y_{ij} = \beta_0 + \mu_{0j} + (\beta_1 + \mu_{1j})\, x_{1ij} + X'_{2ij}\beta_2 + \varepsilon_{ij}, \tag{4}$$

which is often rewritten to place fixed terms first and random terms second for convenience:

$$Y_{ij} = \beta_0 + \beta_1 x_{1ij} + X'_{2ij}\beta_2 + \mu_{0j} + \mu_{1j}\, x_{1ij} + \varepsilon_{ij} \tag{5}$$

The random component in this equation, $\mu_{0j} + \mu_{1j}\, x_{1ij} + \varepsilon_{ij},$ represents two levels simultaneously and, given its dependence on $x_{1ij},$ proves heteroscedastic:

$$\text{Level-2 var } (Y_{ij} \mid x_{1ij}) = \text{var}(\mu_{0j}) + 2\text{cov}(\mu_{0j}, \mu_1)\, x_{1ij} + \text{var}(\mu_1)\, x_{1ij}^2 \tag{6}$$

$$\text{Level-1 var } (Y_{ij} \mid x_{1ij}) = \text{var}(\varepsilon_{ij}). \tag{7}$$

However, if the random ε_{ij} component was heteroscedastic with regard to x_{1ij},

$$\text{Level-1 var } (Y_{ij} \mid x_{1ij}) = \text{var}(\varepsilon_{0ij}) + 2\text{cov}(\varepsilon_{0ij}, \varepsilon_{1ij})\, x_{1ij} + \text{var}(\varepsilon_{1ij})\, x_{1ij}^2 \tag{8}$$

However, as noted above, one of the most important advantages of multilevel models is their capacity to not only simulate variability in the effects induced by the variables but also attempt to account for it by adding additional level-2 variables. This approach would be appropriate in a case of significant heterogeneity in variables' influence across groups (in our case, the agglomeration effect among regions or cities). Formally, the model would indicate that the coefficients (both the constant and the slope on x_1) emerge as functions of level-2 variables (W_{1j}):

$$\beta_{0j} = \beta_0 + \alpha_1 W_{1j} + \mu_{0j}$$

$$\beta_{1j} = \beta_1 + \alpha_2 W_{1j} + \mu_{1j} \tag{9}$$

After inserting the above into the model, we arrive at the following result:

$$Y_{ij} = \beta_0 + \alpha_1 W_{1j} + \mu_{0j} + (\beta_1 + \alpha_2 W_{1j} + \mu_{1j})\, x_{1ij} + X'_{2ij}\beta_2 + \varepsilon_{ij} \tag{10}$$

After the occurrence of differentiation on the fixed and the random components, the equation takes the following form:

$$Y_{ij} = \beta_0 + \alpha_1 W_{1j} + \beta_1 x_{1i} + \alpha_2 W_{1j} x_{1i} + X'_{2ij}\beta_2 + \mu_{0j} + \mu_{1j} x_{1ij} + \varepsilon_{ij} \tag{11}$$

Apparently, the random part appears unchanged, whereas the fixed part receives important additions of level-2 variables and cross terms of level-1 and level-2 variables. This specification is a multi-level model featuring cross-level interaction.

This interaction can be introduced and tested to explain the significant random slope of a level-1 variable (in our case, the significant effect of firm presence in an urban agglomeration) using a level-2 variable (in our case, regional- and city-specific characteristics). However, even if the random slope is insignificant, it would be a useful exercise in the case of a substantial suspicion that this type of interaction exists [Snijders and Bosker, 1999].

6. Estimation strategy and descriptive statistics

Our strategy during the first stage of the estimation is to explain firm productivity using predictors that are directly related to endogenous firm characteristics that may affect productivity while controlling for firm size and sector. We simultaneously introduce an indicator for enterprise presence in an urban agglomeration. In fact, this indicator is our key interest here. Regrettably, our dataset does not allow for the construction of a full-scale production function, as we have no value-added data or any reliable fixed capital estimates. Moreover, other quantitative indicators are available for only a small portion of observations, and their estimation diminishes the sample. However, given that first, we control for the industry and, second, the post-regression analysis confirms the absence of specification errors as a result of missing important variables, we have good reason to believe that our choice of method for explaining simple labor productivity is justified in this context.

During the second stage, we identify city determinants of agglomeration effects on productivity, assuming that the coefficient of the agglomeration variable derived during the first stage depends on the characteristics of the hosting city. We extend the regression equation using city characteristics and city characteristics x agglomeration variable (D) cross terms.

During the third stage of analysis, we look for regional determinants of urban agglomeration effects, recognizing that agglomeration effect mechanisms (external scale economy) depend on the characteristics of territories larger than the city and its provinces. The strategy in this case would be comparable to the previous stage of estimation, as we introduce regional characteristics and cross terms of these characteristics and the urban agglomeration variable.

Throughout the three stages, we use logged output per employee as the dependent variable, as the analysis of descriptive statistics has indicated lognormal distribution of the dependent variable.

The first model (2) includes several predictors for controls that may potentially impact firm performance and can be measured using our data. We argue that in addition to firm size and industry characteristics, firm productivity is strongly determined by technological level. The importance of this determinant stems from the extreme heterogeneity of Russian manufacturing firms in this respect, with some enterprises lagging far behind and thus no longer qualifying as potential profit maximizers approaching technology frontiers. Such firms are more focused on completing the life span and exiting the market. These firms still exist because of barriers to exit.

These firms coexist – even within the same industry – with upgraded state-of-the-art firms. We measure the technological stand of the firm via a dummy constructed using responses to a self-assessment of the firm's technological level in comparison with domestic and foreign competitors. Descriptive statistics demonstrate that productivity within the group of worst performers (whose technological level is below the average for domestic performers) is less than half of that of the best performing group (whose technological level is in line with that of international best performers). Tab. 1 shows that agglomerations include a significantly higher share of enterprises reporting a relatively high technological level for their core product.

Tab. 1. Descriptive statistics of enterprises located within and outside urban agglomerations

	Group of enterprises in urban agglomerations	Group of enterprises outside urban agglomerations	Sample mean
Labor productivity, thousand rubles per employee per year Food and garments	1270.09 (1257.81)	1148.85 (1139.83)	1181.87 (1171.35)
Textiles	942.97*** (1035.12)	377.82*** (560.93)	513.74 (737.80)
Timber and woodworking	953.48 (701.26)	720.29 (706.14)	766.93 (706.36)
Chemicals	1381.72 (1049.53)	1315.83 (1161.27)	1352.79 (1093.50)
Metals	1301.11 (1277.46)	1396.40 (1438.73)	1353.47 (1361.81)
Electrical, electronic and optical equipment	789.51 (702.29)	680.76 (978.56)	723.45 (878.51)
Transport vehicles and equipment	1009.77* (886.87)	742.10* (623.14)	844.54 (741.57)
Machines and equipment	1022.07*** (1267.71)	598.24*** (381.61)	732.08 (799.14)
Number of employees, persons	600.93 (965.43)	603.40 (949.62)	602.55 (954.54)
Share of skilled labor, % of the total number of jobs	50.31*** (20.21)	45.72*** (19.89)	47.28 (20.11)
Job creation and destruction coefficient	-.0506 (.1948)	-.0481 (.2223)	-.0481 (0.2131)
ISO certification (% of total responses)	50.8	48.3	49.4
Self-assessment of technological level, % of total responses			
In line with the best international performers	8.38	10.89	10.03
In line with average for international performers	21.73***	12.52***	15.68
In line with the best domestic performers	30.74	28.29	29.13
In line with the average for domestic performers	35.40***	43.57***	40.76
Below average for domestic performance	3.72	4.72	4.37

Note: variance between values within and outside agglomerations is statistically significant: *- at 5%, **- at 1%, and *** - at 0.1%
Source: sample data

Simultaneously, we control the regression for ISO-type international certification. The literature on transition economies explains the potential correlation of this factor with productivity in the following manner: ISO-type certification indicates that the enterprise has mastered a set of management technologies, allowing it to meet technical standards and manage product quality, which in turn, has a significant impact on productivity [OECD, 2009]. Descriptive statistics demonstrate that approximately half of enterprises in the sample reported the possession of ISO certificate, whereas the average productivity of internationally certified enterprises was 22% higher than of their non-certified peers.

Another predictor is a coefficient reflecting job creation and destruction. We argue that in the context of the Russian labor market, with its relatively low job turnover and incomplete enterprise restructuring, in many ways, labor productivity is a function of job creation and destruction rates. Enterprises can enhance their productivity by eliminating excessive and ineffective jobs. Moreover, this process is likely to be significantly different for enterprises located within thick markets and those in thin labor markets, and urban agglomerations should be associated with thicker labor markets. Tab. 1 demonstrates that all of the enterprises in the sample have destroyed more jobs than they have created (negative coefficient). However, a simple comparison of averages does not reveal any statistically significant difference between enterprises within and those outside urban agglomerations.

Another indicator of human capital captures the share of skilled employees, which we define as the share of on the payroll employees who have received higher and secondary specialized technical education. Tab. 1 demonstrates that this indicator is significantly higher in agglomerations than it is in other enterprises.

An analysis of descriptive statistics indicates that we should not expect agglomeration to have effects on productivity in all of the manufacturing industries. Figures 3 and 4 indicate that the share of weakly performing enterprises in agglomerations in the sample is considerably lower than the share of those in isolated settlements. This distribution may suggest the existence of agglomeration effects and, perhaps, a more intensive exit of weaker enterprises because of stronger competition. The same distribution is observable for the textiles, machines, electrical, electronic and optical equipment industries. The food industry does not exhibit any noticeable differences, whereas the chemicals industry appears to exhibit agglomeration effects occurring in the opposite direction, with weak performers concentrated within agglomerations.

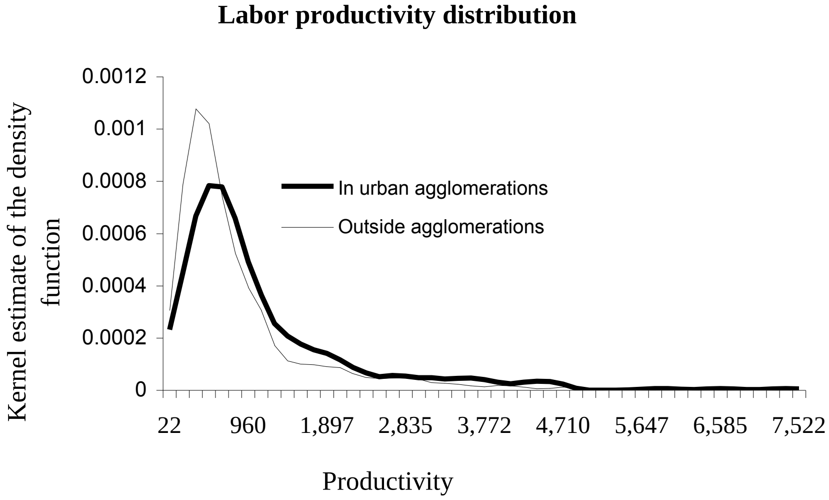
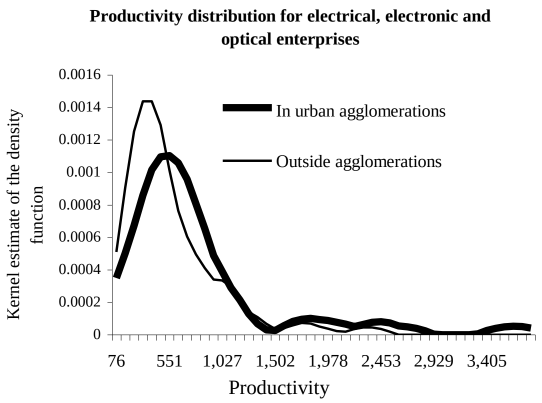
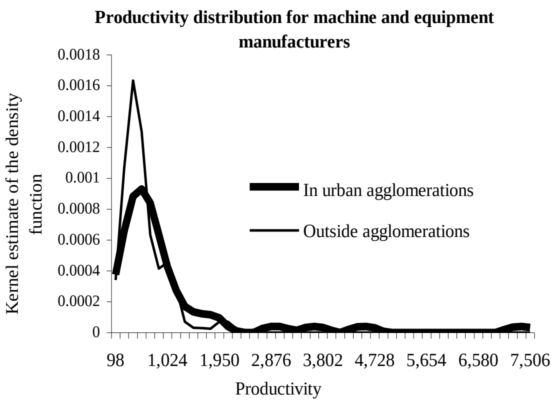


Figure 2. **Labor productivity distribution for groups of enterprises within and outside urban agglomerations**

Note: the vertical axis shows a standardized share of enterprises falling within a certain productivity range, whereas the horizontal axis indicates labor productivity in thousands of rubles per employee per year.

A comparison of industry averages (Tab. 1) reveals that textile enterprises in agglomerations exhibit productivity that is approximately 2.5 times higher than that of their industry peers outside urban agglomerations, transport vehicle producers within agglomerations are 1.5 times more productive, and machine-builders double their output per worker when in agglomerations.





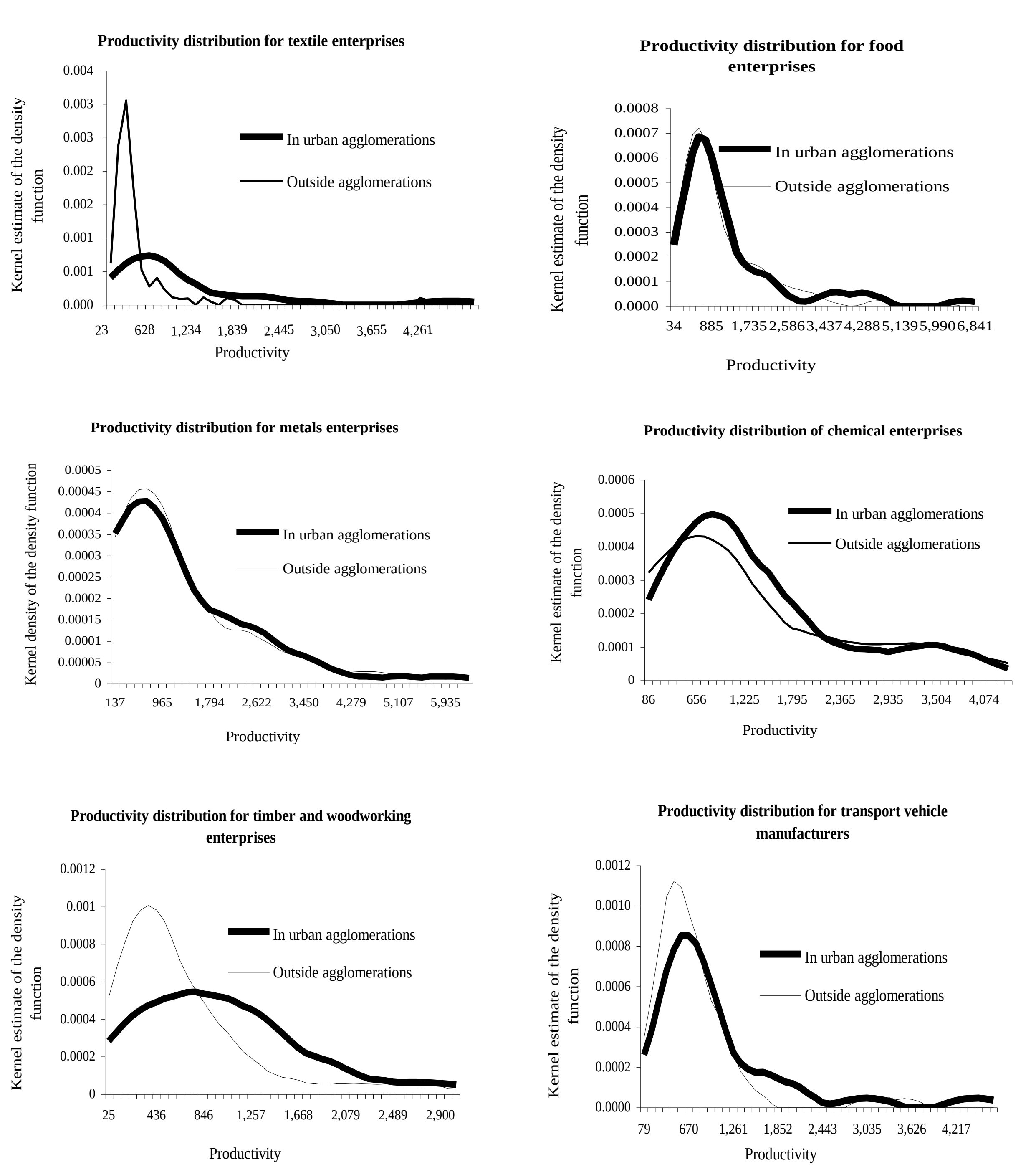


Figure 3. Productivity distribution for enterprises within and outside urban agglomerations, by sector

Note: the vertical axis shows a standardized share of enterprises falling within a certain productivity range, whereas the horizontal axis indicates labor productivity in thousands of rubles per employee per year

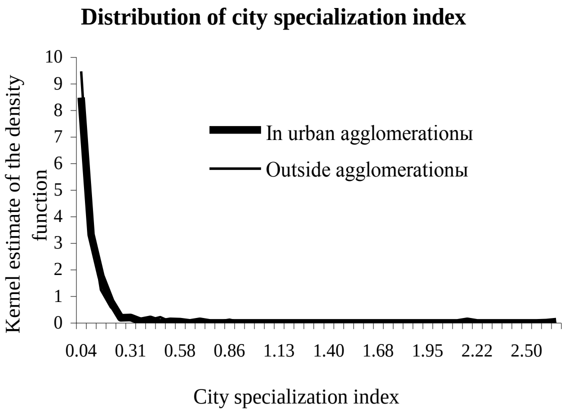
Tab. 2 reflects differences in hosting city characteristics between agglomerations and other types of settlements. This table presents predictors of the second model (3) that we use to explain agglomeration effects through the use of hosting city characteristics. These characteristics are standard indicators and include city size, city administrative status and distance of the city from the regional center and Moscow. We expect that the larger the city is and the closer it is to Moscow or to its regional center, the stronger agglomeration forces are. We expect the hosting city's administrative status to be significant not only because of returns on proximity to political centers but also because recently, migrants have persistently targeted regional capital cities, increasing the probability that agglomeration forces will exist in these locations.

Tab. 2. Descriptive statistics of predictors at the city level

	For enterprises within urban agglomerations	For enterprises outside urban agglomerations	Sample mean
Distribution of enterprises by administrative type of settlement, % of total responses			
1=Moscow	18.34	0	18.34
2=republican /regional center	56.26	39.68	45.35
3=provincial town	22.93	50.00	40.75
4=small county	2.44	10.31	7.62
Enterprises in company towns, % of total responses	9.17	20.00	16.30
Distribution of enterprises by city size, % of total responses			
1 million people and more	68.19	9.52	29.57
500,000 – 999,999	5.81	15.23	12.01
250,000 – 499,999	2.75	17.30	12.33
100,000 – 249, 999	9.48	14.92	13.06
50,000- 99,999	8.86	15.39	13.16
Under 50,000	4.89	27.61	19.85
City size – population headcount of the hosting city (thousand people)	3376.748 (3764.443)	313.1053 (337.8842)	1395.593 (2686.568)
Share of enterprises located in cities hosting mega businesses, % of total responses	3.66	10.79	8.35
Economic density – per capita number of all economic entities registered in the city	71.33 (30.53)	28.08 (20.96)	43.37 (32.26)
City specialization index (per capita number of own industry enterprises in the city)	0.0869 (0.2057)	0.1024 (0.1945)	0.0969 (0.1985)
Distance from the hosting city to the regional center, km	11.30 (27.01)	90.51 (118.39)	63.06 (104.07)
Distance from the hosting city to Moscow, km	980.88 (1229.56)	1052.13 (904.82)	1027.37 (1029.28)

Source: sample data

Furthermore, we add city specialization and city economy diversification (economic density). We measure the former as a per capita number of enterprises in the city within an industry and the latter as a per capita number of all active enterprises registered in the city. These predictors test the hypothesis regarding the significance of MAR and Jacobs externalities at the city level of analysis. Descriptive statistics (Tab. 2) indicate that cities in agglomerations are almost 10 times larger, although we included small towns within 50 kilometers of the center. In addition, cities in agglomerations are much less specialized than isolated settlements, and economic density in such settlements is almost three times higher. Figure 4 provides the distributions of specialization indices and of city economy diversification for enterprises within agglomerations and outside agglomerations.



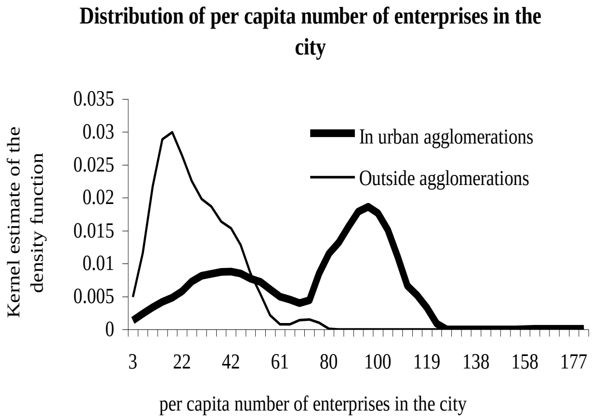


Figure 4. Distributions of city specialization indices (per capita number of own-industry enterprises in the city) and diversification (per capita number of enterprises registered in the city)

In terms of Russia-specific urban indicators, our regression includes the company town dummy. In fact, this dummy represents extreme specialization, which may have a two-fold effect. On the one hand, we can expect cluster specialization effects that boost the productivity of an enterprise surrounded by own-industry firms. On the other hand, company towns in Russia are basically discussed with reference to the risks of excessive specialization, which increases the settlement's dependence on performance and prices in the core industry, especially during cyclical downturns. Tab. 2 indicates that 16% of the sampled enterprises are located in company towns, but they are twice as common in isolated settlements agglomerations as they are in agglomerations.

Another specific indicator denotes that the host city belongs to settlements hosting mega businesses (to review, mega enterprises themselves were not surveyed for confidentiality reasons). We assume that the presence of mega enterprises in a city may enhance the likelihood that neighboring companies would interact because they can initiate connections via supply chains, business associations, training facilities, etc.

Descriptive statistics of predictors in the third model for the regional level of analysis (10) are presented in Tab. 3. They include the Herfindahl-Hirschman regional index, which reflects the degree of regional economy diversification. The index is calculated by squaring the employment shares in industry K in region J across the full range of enterprises of the regional economy and summing the resulting numbers.

$$herf_j = \sum_{k=1}^{K} \left(\frac{\mathrm{emp}_{jk}}{\sum_{l=1}^{K} \mathrm{emp}_{jl}} \right)^2 \tag{12}$$

Therefore, the higher the regional economy diversification, the lower the value of the Herfindahl-Hirschman index will be. Tab. 3 demonstrates that the regions with urban agglomerations that are included in our model are significantly more diversified than the regions hosting isolated settlements. Furthermore, the analysis is complemented by the regional specialization indicator, calculated as the region's share of employment in industry K (coincides with the respondent's specialization industry) throughout Russia. Arguably, this indicator reflects the region's competitive advantages in terms of industry-specific factor endowment while, to a certain degree, also capturing factor advantages of the location.

Table 3. Descriptive statistics of predictors at the regional level

	Regions with urban agglomerations	Regions without urban agglomerations	Sample mean
Herfindahl-Hirschman index	6.21*** (0.78)	7.38*** (1.85)	6.98 (1.66)
Regional specialization index (own industry employment as % of total employment in this industry across Russia), %	4.46*** (3.47)	2.51*** (2.59)	3.18 (3.06)
Accumulated FDI stock as a % of the GRP in 2004-2008	2.0878 (1.5038)	1.9165 (2.0888)	1.9750 (1.9101)
Wages in the region as a % of the national average	133.89 (57.11)	84.00 (21.03)	101.05 (44.31)
GRP per capita, thousand rubles per person	219.58 (56.99)	174.39 (39.24)	189.83 (50.80)
Globalization index (regional exports and imports as % of GRP)	44.7293*** (20.3127)	24.7485*** (15.7792)	31.5758 (19.8599)
Road density (th.km. of road per 1 sq.km. of land area)	509.77 (410.78)	168.65 (105.10)	285.21 (301.68)
Migrant stock (sum of migration balances in 2004-2009 per 10 thousand people as % of 2004).	219.81 (180.40)	88.19 (153.02)	133.16 (174.37)
Share of enterprises located in European Russia, % of responses	91.74	90.47	90.90

Source: Sample data

We also control our regional level regression for indicators capturing the degree of regional economy openness, as we assume that the region's participation in trade (globalization index calculated as the share of exports and imports in the GRP) and international business (accumulated FDI stock within 5 years as a % of the GRP) tends to intensify urban agglomeration effects. Arguably, the openness advantage may materialize via the self-selection mechanism, which essentially induces weak firms to exit from the market because of more intense competition. A more open regional economy is more likely to register the market-based principles of firm location, heightened competition, an increased number of economic agents and their interaction.

7. Results

Tab. 4 presents estimates derived during the first stage of our analysis using OLS, GLS (a hierarchical model with an intercept random effect of region or city) and ML (a two-level nested model) techniques. The two-level regression is estimated using two variations: simultaneous, with an intercept random effect of region (or city) and the use of the random intercept and slope effects of region (the slope is on the dummy capturing agglomeration location effects). If the estimates derived using different instrumental techniques prove consistent, we can be sure that our estimates are robust.

Tab. 4 demonstrates that the agglomeration effect is statistically significant and positive in all of the estimated regressions. Depending on the estimation method, productivity gains for enterprises in urban agglomerations would equal 17-21%, in contrast to productivity of enterprises in isolated settlements. Residuals are homoscedastic, normal at 1% significance and provide no reason to suspect missing variables of importance.

However, it would be reasonable to suppose that the result may be strongly determined by the location of our enterprises in Moscow, with its highly favorable conditions for agglomeration effects on productivity because of its scale, diversity, history, ultimate concentration of investment and human resources, and special political role. It is a known fact that during the period of 2006-2008, up to 60 percent of the net migration increase was acquired by the Moscow agglomeration [Zubarevich, 2010]. It may well be that the rest of Russia will not possess a premium for presence with in insufficiently mature agglomerations. Therefore, we ran the same models from Tab. 4 on a subsample excluding Moscow-based enterprises (to review, over 18 percent of the total surveyed enterprises). The calculations reveal (Tab. 5) that the exclusion does not change the result, as all of the key regularities hold. Although the productivity gain is slightly smaller than that for the complete sample – 15-18% - the coefficients' signs and significance are identical for both variations of the sample.

Table 4. Estimation results. Productivity as a function of the firm presence in an urban agglomeration

Regression type	OLS	Intercept RE of region	Intercept RE of city	Intercept MIX effect of region	Intercept, slope MIX effect of region	Intercept MIX effect of city
Agglomeration dummy	0.1920**	0.1920**	0.1920**	0.1635*	0.1635*	0.1770*
Industry dummies						
Textiles	-0.9321***	-0.9321***	-0.9321***	-0.9372***	-0.9413***	-0.9342***
Timber	-0.4983***	-0.4983***	-0.4983***	-0.4993***	-0.5046***	-0.4994***
Chemicals	-0.0689	-0.0689	-0.0689	-0.0752	-0.0717	-0.0730
Metals	-0.0771	-0.0771	-0.0771	-0.0652	-0.0683	-0.0798
Electronic	-0.5859***	-0.5859***	-0.5859***	-0.6049***	-0.6072***	-0.5895***
Transport vehicles	-0.3099**	-0.3099**	-0.3099**	-0.3311**	-0.3325**	-0.3160**
Machines and equipment	-0.4818***	-0.4818***	-0.4818***	-0.4947***	-0.4941***	-0.4868***
Job creation and destruction coefficient	0.6429***	0.6429***	0.6429***	0.6280***	0.6287***	0.6358***

Log employment	-0.0214	-0.0214	-0.0214	-0.0120	-0.0120	-0.0192
Share of skilled labor	0.0008	0.0008	0.0008	0.0012	0.0012	0.0008
ISO certification	0.1806**	0.1806**	0.1806**	0.1736**	0.1726**	0.1810**
Technological level						
In line with the best international performers	0.3931*	0.3931*	0.3931*	0.3447*	0.3503*	0.3845*
In line with the average international performers	0.5821***	0.5821***	0.5821***	0.5419***	0.5488***	0.5706***
In line with the best domestic performers	0.2954*	0.2954*	0.2954*	0.2770	0.2822	0.2938*
In line with the average domestic performers	0.0512	0.0512	0.0512	0.0266	0.0330	0.0493
constant	6.5143***	6.5143***	6.5143***	6.4829***	6.4756***	6.5043***
R-squared	0.2314	-	-	-	-	-
Regression significance	F = 15.23***	chi2(16)= 243.61***	chi2(16) = 243.61***	chi2(16) = 235.58***	chi2(16) = 234.50***	chi2(16) = 235.63***
LM or LR test vs. linear regression	-	chi2(1)= 25.15***	chi2(1)= 0.38	chibar2(01) =11.19***	chi2(2) = 11.62***	chibar2(01) = 0.55
Number of observations	826	826	826	826	826	826
Breusch-Pagan homoscedasticity test: chi2(1) = 2.52 Prob > chi2 = 0.1122						
Asymmetry and excess test for normality: chi2(2) = 8.44* Prob > chi2 = 0.0147						
Ramsey test for the absence of missing variables: F(3, 806) = 1.00 Prob > F = 0.3912						

Notes: *-significant at 5%, **- at 1%, *** - at 0.1%Reference group for industry dummies – food industry
For symbols see Tab. 5.

Tab. 5. Estimation of agglomeration effects on logged labor productivity for the subsample excluding Moscow-based enterprises

Regression type	OLS	Intercept RE of region	Intercept RE of city	Intercept MIX effect of region	Intercept, slope MIX effect of region	Intercept MIX effect of city
Agglomeration dummy	0.1722**	0.1722**	0.1722**	0.1429	0.1429	0.1522*
Industry dummies Textiles Timber, woodworking Chemicals Metals Electrical, Transport vehicles Machines and equipment	-1.0067*** -0.5254*** -0.0219 -0.0607 -0.5490*** -0.2851** -0.4727***	-1.0067*** -0.5254*** -0.0219 -0.0607 -0.5490*** -0.2851** -0.4727***	-1.0067*** -0.5254*** -0.0219 -0.0607 -0.5490*** -0.2851** -0.4727***	-1.0122*** -0.5279*** -0.0288 -0.0482 -0.5686*** -0.3071** -0.4861***	-1.0122*** -0.5279*** -0.0288 -0.0482 -0.5686*** -0.3071** -0.4861***	-1.0108*** -0.5273*** -0.0275 -0.647 -0.5531*** -0.2929** -0.4796***
Job creation and destruction coefficient	0.5273***	0.5273***	0.5273***	0.5105***	0.5105***	0.5166***
Log employment	-0.0415	-0.0415	-0.0415	-0.0323	-0.0323	-0.0390
Share of skilled labor	0.0007	0.0007	0.0007	0.0012	0.0012	0.0008
ISO certification	0.1984**	0.1984**	0.1984**	0.1919**	0.1919**	0.1991**
Technological level. In line with the best international performers In line with the average international performers In line with the best domestic performers In line with the average domestic performers	 0.3865* 0.6263*** 0.3045* 0.0582	 0.3865* 0.6263*** 0.3045* 0.0582	 0.3865* 0.6263*** 0.3045* 0.0582	 0.3356* 0.5854*** 0.2850 0.0324	 0.3356* 0.5854*** 0.2850 0.0324	 0.3749* 0.6109*** 0.3029* 0.0560
Constant	6.6083***	6.6083***	6.6083***	6.5781***	6.5681***	6.5965***
R-squared	0.2350	-	-	-	-	-
Regression significance	F = 14.46***	chi2(16)= 231.37***	chi2(16) = 231.37***	chi2(16) = 226.61***	chi2(16) = 225.87***	chi2(16) = 223.32***
LM or LR test vs. linear regression	-	chi2(1)= 31.51***	chi2(1)= 1.59	chibar2(01) = 12.25***	chi2(2) = 13.15 ***	chibar2(01) = 1.13
Number of observations	770	770	770	770	770	770
Breusch-Pagan / Cook-Weisberg test for homoscedasticity: chi2(1) = 6.99 Prob > chi2 = 0.0082						

Asymmetry and excess test for normality: chi2(2) = 7.82* Prob > chi2 = 0.0201
Ramsey test for the absence of missing variables: F(3, 750) = 0.76 Prob > F = 0.5150
*-significant at 5%, **-at 1%, *** - at 0.1%

Symbols:
OLS - ordinary least square method;
ML - maximum likelihood method;
Intercept RE of region – ordinary GLS model, with intercept random effect of region; intercept RE of city – ordinary GLS model, with intercept random effect of city;
Intercept MIX effect of region – ML, with intercept random effect of region;
Intercept, slope MIX effect of region – ML, with intercept random effect of region and slope random effect of region for agglomeration dummy variable;
Intercept MIX effect of city – ML, with intercept random effect of city.

Our focus was on the second and third stages of estimation, as we looked for explanations for the productivity premium of enterprises in urban agglomerations. The model specification for these stages was selected in accordance with model (10) (see above for a detailed mathematical description).

It should be noted that model (10) allows for only a somewhat truncated estimation because of its quasi-multi-collinearity. First, all of the city characteristics represented by W variables in equation (10) are inserted sequentially rather than simultaneously. Second, to control for result robustness, estimation is performed using three methods: OLS, ML for two-level specification, with the intercept random effect of region, and ML for two-level specification, with the intercept random effect of city[4]. Third, the terms $\alpha_1 W_{1j}$, $\beta_1 x_{1i}$, and $\alpha_2 W_{1j} x_{1i}$ cannot be simultaneously present in the equation because of their multi-collinearity; therefore, the term $\beta_1 x_{1i}$ (reflecting the agglomeration effect) is not used at all, whereas $\alpha_1 W_{1j}$ (city characteristic) and $\alpha_2 W_{1j} x_{1i}$ (correlation between the agglomeration effect and the above characteristic) are inserted sequentially.

The estimation results are summarized in Tab. 6.

It should be clarified that each line of this table is a result of either regression

$$Y_{ij} = \beta_0 + \mu_{0j} + \alpha_1 W_{1j} + X'_{2ij} \beta_2 + \varepsilon_{ij} \quad , \qquad (13)$$

or regression

$$Y_{ij} = \beta_0 + \mu_{0j} + \alpha_2 W_{1j}\ x_{1ij} + X'_{2ij} \beta_2 + \varepsilon_{ij} \quad , \qquad (14)$$

each of which is a somewhat reduced model (10). In each of the regressions, the influence of one of the level-2 variables - (W) or ($W_1 * x_1$) – is estimated against the group of level-1 variables (X_2). X_2 stands for indicators characterizing the enterprises and is listed in Table 4, whereas x_1 is a dummy reflecting presence within an agglomeration.

[4] The numerical method does not converge for a two-level specification involving the slope random effect of region or city for the agglomeration dummy.

Tab. 6. Estimation results. Influence of the city characteristics on agglomeration productivity premium at the second level of the two-level model (10)

Regression type	OLS	Intercept MIX effect of region	Intercept MIX effect of city
Administrative status of the city (1-Moscow, 4-county)	-0.0895*	-0.0949*	-0.0787
Company town dummy	-0.1181	-0.0714	-0.0986
Per capita number of entities in the city	0.0044***	0.0045***	0.0045***
City size (group)	0.0398**	0.0379*	0.0338*
City size (population, thousand people)	0.0276***	0.0314	0.0288*
Small town (under 100,000 residents), dummy	-0.1393*	-0.1300*	-0.0996
Medium-sized city (100,000 – 249,999 thousand residents), dummy	0.0664	0.0440	0.0903
Megacity (1 million residents and more), dummy	0.1672**	0.1444	0.1441*
City specialization	0.0213	0.0429	0.0318
Big business city	0.0117	0.0523	0.0345
Distance to regional center	-0.0002	-0.0001	-0.0001
Distance to Moscow	0.0000	0.0000	0.0000
Below we list interactions of the above variables with the (D)urban agglomeration dummy			
D*Administrative status of the city	0.0717**	0.0528	0.0627*
D*Company town	-0.3067	-0.2453	-0.2823
D*Per capita number of entities in the city	0.0028***	0.0028***	0.0028***
D*City size (group)	0.0326	0.0108	0.0298
D*City size (thousand people)	0.0277***	0.0320*	0.0292*
D*Small town	-0.0925	-0.1703	-0.0587
D*Medium-sized city	0.4199*	0.2886	0.4381**
D*Megacity	0.2091**	0.2220**	0.1978**
D*City specialization	0.2985	0.1947	0.2236
D*Big business city	-0.2698	-0.1831	-0.2503
D*Distance to regional center	-0.0000	-0.0005	0.0003
D*Distance to Moscow	-0.0000	-0.0000	-0.0000

The concentration of own-industry enterprises in the city has not revealed an influence on the dependent variable. This result rejects our hypothesis that city-level agglomeration effects are associated with urban industry clusters. In fact, this result could have been predicted during the analysis of descriptive statistics stage. Several explanations can be offered: (1) the city and the urban agglomeration fail to generate a scale economy adequate for the presence of specialization positive effects; a specialized manufacturing cluster most likely requires a larger territory than an urban agglomeration; (2) industry specialization suppresses the development of complementary businesses that could have facilitated more efficient organization and management of core production; (3) industry specialization often reflects the influence of one or two large old enterprises in the city; this condition would create risky dependence on the situation in the core industry rather than generate an environment of one-type interacting and competing firms. Indeed, the latter is the type of environment that we expect to generate positive effects of specialization.

An extreme case of specialization - when enterprises are located in a company town (identified by referring to the official list of the Ministry for Regional Development) – also has not exhibited an impact on productivity. However, we do not rule out the possibility that the absence of such effects may be accounted for by the higher diversity of company towns and by the overly extensive list of such settlements. Some of the entities may have been included for political rather than economic reasons – the expectation of federal subsidies.

Urbanization, measured as the per capita number of all entities in a city, has a statistically significant and consistently positive effect on productivity. If, ceteris paribus, business density in the city increases by 10 entities per capita, the productivity of manufacturing enterprises located in this city would increase by 4.4%. However, if the enterprise is situated within an agglomeration, the impact of this indicator on productivity will increase to 7.2% (4.4%+2.8%=7.2%). All three of the models yielded such results.

Hence, the hypothesis predicting the importance of diversification as “a transmission mechanism” for urban agglomeration effects is fully confirmed at the city level. Indeed, if the city has managed to host various businesses and develop its urban functions far beyond narrow specialization, this diversification will significantly and positively impact the productivity of its local enterprises. Moreover, the urban diversification effect is observable in all types of settlements, both agglomerated and isolated. Additionally, this confirmation stands to reason because any mature city with diverse functions is in fact an agglomeration, providing its residents with the benefits of neighborhood and interaction even if its area is limited. However, it should be noted that this diversification effect is stronger for enterprises within large urban agglomerations than for their peers located in stand-alone settlements. This result can be reasonably interpreted as evidence that it is city economy diversification that facilitates agglomeration effects.

Our analysis also demonstrates that the strength of agglomeration economies is a non-linear function of city size. If we measure the size of a city using a quantitative variable for population size, two of the three model specifications will indicate that city size significantly and positively influences the productivity of local enterprises. The city size effect is twice as strong in agglomerations as the sample average. City size will be more strongly associated with enhanced productivity if the city belongs to an agglomeration than if it is located in an isolated settlement.

Conversely, if we measure the settlement size using an ordinal variable, which includes six values, from 1 (minimum value, representing a town of less than 50 thousand people) to 6 (a mega city with more than a million inhabitants), the size will affect productivity in the following fashion: shifting into a larger size group will increase productivity by approximately 4 percent. However, this method of measuring the city size indicator does not allow for differentiation between its impact within and its impact outside agglomerations.

To tackle this issue, we undertook a more thorough analysis, using dummies for each of the six city size groups. This analysis facilitates the observance of the non-linear nature of city size's impact on productivity. OLS regressions and regressions that consider regional heterogeneity (with 5% significance) demonstrate that productivity is approximately 13-14% lower in small towns than it is in big cities. The situation is no better even if the small town is located within an agglomeration. However, if we examine towns with 100 thousand to 250 thousand residents, we find the highest agglomeration effect. If this town is located within an agglomeration, firm productivity increases by 52% ((exp(0.4199)-1)*100% in an OLS regression) and 55% (in regressions controlling for city heterogeneity). Apparently, for one-size cities, the productivity of their local enterprises will depend largely on their presense in an agglomeration.

The political status of a city also reveals an impact that is interesting with regard to interpretation. On average, firm productivity increases with the rise in the settlement's political status (significant negative coefficient on the variable). However, if the settlement is located within an agglomeration, this effect will diminish (significant positive coefficient). As a result, firm productivity in small settlements within agglomerations may be quite comparable to firm productivity in a large city located outside an agglomeration. However, it will still remain somewhat lower on average - 1.9 percent lower, if we rely on OLS estimates – and this difference is statistically significant.

The second model, which controls for regional heterogeneity, reveals a correlation between productivity growth and administrative status growth, exhibiting 5% significance. However, the model does not allow for the detection of the mitigation of the administrative status effect on productivity in agglomerations. At the same time, the third model, which controls for city heterogeneity and exhibits 5% significance, allows for the conclusion that within agglomerations, the lower the administrative status of the settlement, the higher productivity is. However, this paradoxical result may be a product of multi-collinearity that may arise in the third model because of its double capture of city characteristics – random city effect and the "city type" variable. Overall, it is valid to state that agglomerations do not demonstrate a strong correlation between firm productivity and settlement political status, which constitutes proof of the influence that federal and regional cities extend over neighboring communities. Geographical proximity allows enterprises in small agglomerated towns to benefit from excesses in administrative and other resources of capital cities.

Tab. 7 presents the model (10) estimation results, which reveal the contribution of the hosting region's characteristics to the urban agglomeration effect. All of the regional indicators serve as W variables in equation (10), and the aggregates reflecting interaction between regional indicators and agglomeration effects are inserted sequentially rather than simultaneously to avoid multi-collinearity (as previously with city characteristics).

Tab. 7 indicates that practically all of the analyzed indicators are significant, with estimates of their influence produced by the three model modifications being very consistent. A somewhat lower significance of estimates produced by the modification controlling for random effects of region may be a result of multi-collinearity produced by the double capturing of regional characteristics. The significance of the product of all of the variables obtained using the agglomeration dummy should be interpreted as the increased effect of these variables within agglomerations.

The third stage estimation results demonstrate that the economic structure of the region surrounding an urban agglomeration has a significant effect on the power of urban agglomeration effects. Thus, the more developed the region, the higher firm productivity in an urban agglomeration is. Specifically, a 1-percent increase in the GRP will increase productivity by 0.58% ((exp(0.463)-1)%) for firms outside agglomerations while generating a 0.63% ((exp(0.463+0.0364)-1)%) increase in productivity for firms within agglomerations.

Tab. 7 Estimation of the impact of regional characteristics on agglomeration effects at the second level of the two-level model

Variables	OLS	Intercept MIX effect of region	Intercept MIX effect of city
Herfindahl-Hirschman index	-0.0461**	-0.0427	-0.0426*
Regional specialization index	0.0307*	0.0257*	0.0279**
FDI	0.0376**	0.0212	0.0381*
Wages in the region as % of the national average	0.0022***	0.0024*	0.0027**
Log of GRP per capita	0.4630***	0.4663**	0.4933***
Region's globalization index	0.0055***	0.0052**	0.0054***
Road density	0.0004***	0.0004***	the algorithm does not converge
Migration stock	0.0008***	0.0007***	0.0008***
West-East dummy	0.0764	0.0591	0.0556
Below we list products of the above variables by the (D) dummy representing location in agglomeration (interaction effects)			
D* Herfindahl-Hirschman index,	0.0289**	0.0252*	0.0264*
D* Regional specialization index	0.0269**	0.0201	0.0232*
D* FDI	0.0989***	0.0908***	0.1029***
D* Wages in the region as % of the national average	0.0013***	0.0013***	0.0014***
D* Log GRP per capita	0.0364***	0.0312***	0.0339***
D* Region globalization index	0.0043***	0.0042**	0.0043***
D* Road density	0.0004***	0.0004***	the algorithm does not converge
D* Migration stock	0.0009***	0.0008***	the algorithm does not converge
D* West-East dummy	0.2073***	0.1827*	0.1961**

The agglomeration effect intensifies even more with the rise in the region's openness to trade. In isolated settlements, a 10 percent increase in the globalization index will produce a 5.5% increase in firm productivity, whereas in agglomerations, this effect will almost double, as productivity will increase by 9.8%. Agglomerations enjoy a double positive effect resulting from regional migration stock and road density. Accumulated foreign direct investment, which is roughly comparable according to descriptive statistics for enterprises within and outside agglomerations, produce a statistically significant positive effect on productivity in both types of locations. However, in agglomerations, this effect increases four-fold according to OLS regression. These results are robust to controls for regional and urban heterogeneity.

Within the sample, on average, a region's specialization in the respondent's industry has a positive effect on productivity. At the same time, in urban agglomerations, this effect nearly doubles. A 1% increase in the share of own-industry enterprises leads to a 3.1-percent productivity increase outside agglomerations and a 5.8-percent productivity increase within agglomerations (3.01%+2.7%=5.8%), according to OLS regression). Hence, although even within agglomerations, the city does not generate scale economies sufficient for manifestation of the positive effects of industry specialization, in contrast, the region does provide a scale sufficiently large for the materialization of these effects.

Regional economy diversification measured by the Herfindahl-Hirschman index enhances urban agglomeration effects. The higher the index value (i.e., the lower the diversification), the lower firm productivity is across the entire sample. However, in agglomerations, this outcome is weaker by approximately 50 percent.

Our results also suggest the existence of self-selection into agglomerations among more productive firms, although not at the location selection stage. We interpret self-selection in accordance with [Combes et al, 2012]: self-selection indicates a weak firm's inability to survive in a more competitive environment in larger and open markets. Even descriptive statistics (see Figures 3 and 4) demonstrate that agglomerations contain noticeably fewer weak enterprises exhibiting low productivity. That a region's openness to trade doubles urban agglomeration effects suggests that poor performers may be more aggressively driven from more competitive open markets.

8.Conclusions

The study registers significant positive effects of urban agglomerations on productivity and the correlation of their strength with characteristics of surrounding areas. This result is obtained despite the prevalence in the sample of old manufacturing enterprises established by command rather than driven by market-based incentives. We demonstrate that enterprises within urban agglomerations are 17-21% more productive than those in isolated settlements, with these effects being most powerful in cities with 100 – 250 thousand inhabitants.

Empirical testing of the nature of agglomeration effects using Russian data supports the validity of both MAR and Jacobs externalities: both specialization and diversification explain the firm productivity premium, although they do so differently at different levels of spatial hierarchy. At the city level, firms largely leverage complementary advantages of co-location with various businesses in a diversified urban environment, when the influence of clustering with own-industry firms (specialization) is absent. Similar results are reported in the literature, including the literature surveyed in this paper. However, the novelty of our results is apparent in our extension of agglomerations using small towns neighboring large cities and our use of survey microdata, which clarifies details regarding how the externalities work. Furthermore, if we include regional characteristics, i.e., if we define neighbors as similar firms within a region rather than within a city, the regional specialization would be sufficiently significant for the presence of urban agglomeration effects. These results are robust to both the sample composition (we exclude enterprises in the Moscow agglomeration) and the model employed. From the policy perspective, the absence of cluster effects arising from co-location with similar enterprises in a city may constitute a warning against establishing industry clusters, which are currently much emphasized in government discussions. To influence firm effectiveness, specialization requires scale economies much larger than the city.

Another important result relates to the dependence of the power of agglomeration effects on the features of the surrounding area. If the region is open to trade, has a good road network, attracts migrant workers from other regions and has a mature market with relatively high living standards, urban agglomeration effects will be much stronger.

However, our results do not imply that the maximization of agglomeration numbers can resolve the issue of low productivity in manufacturing. Rather, we have demonstrated that agglomeration mechanisms rely on urban diversity, scale and openness in the economy. Indeed, these dimensions deserve stimulation through the use of regional policy measures.

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