RESEARCH PAPER

SUSTAINABLE URBAN DEVELOPMENT AND ECOLOGICAL EXTERNALITIES: RUSSIAN CASE

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ABSTRACT. Inclusive, safe, resilient and sustainable cities are included in Sustainable development Goals. The choice between environmental and social well-being is a very acute issue. It is necessary to take into account the interaction of three city dimensions: economic, ecological and social. The aim of the paper is to evaluate externalities in terms of population for 114 Russian cities all over the country considering all three dimensions.

The methods are the analysis of statistical data by econometric methods and their processing including geographical visualization. The data was taken from the Federal State Statistics Service database. The main results are the followings. The methodology for evaluation of externalities and estimation a hypothetical «efficient city size» in terms of population for Russian cities has been elaborated. The access to high-paying jobs and the availability of social benefits is often associated with living or moving to cities or regions with an unfavorable environment. Some cities feature an extremely high growth rate, dense population and often a low level of management and economic development.

Then there was demonstrated how to achieve a hypothetical «efficient city size» by means of environmental management and changes in city area. This should be helpful in achieving the Sustainable Development Goals (especially the Goal 11) and some targets mentioned in the «New Urban Agenda». It is essential to pay attention to the function of a city and its spatial organization. Some other measures to rise efficiency were proposed as well.

KEY WORDS: Sustainable development, urban planning, ecological externalities, efficient city size, environmental management

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INTRODUCTION

The modern human economic system, despite all societal efforts, still remains imperfect. Indeed, the global environmental and economic crisis is caused by the presence of external effects (externalities). The internalization of such externalities gives rise to debates among researchers from Pigou (Pigou 1946) to Coase (Coase 1960). The existence of externalities in fact makes it impossible to measure social costs and social well-being by market means. This is a well-known phenomenon called «market short-sightedness»: the market «can see» over a period of no more than ten years. There are numerous crucial aspects beyond the market we must consider before making decisions. This task is rather difficult for modern science. There exists the opinion that the internalization of externalities can hinder the market. However, they offer a solution for market problems by means of the market itself. One example of externalities is climate change and its consequences; people do too little to reduce greenhouse gas emissions, and climate change is becoming increasingly acute. Here we can observe temporal externalities (between generations), as well as conflicts of interest between individuals (local externalities). Alternative energy sources have the potential to become one of many solutions to this problem.

If we want our natural resources to not be exhausted too quickly, and the degradation of the environment to not become irreversible, we must do our best. One should use, for example, the concept of the total economic value of the environment, which is well-known in environmental economics and includes use value, non-use value, optional value and existence value. This concept is quite useful for the estimation of urban forests' non-use value for urban development decision makers (Alekseeva, Kudryavtseva, Menshikh 2016).

According to the 2030 Agenda for Sustainable development the Goal 11 is «Make cities and human settlements inclusive, safe, resilient and sustainable»[1].

Externalities disrupt efficiency in urban economy and make it difficult to reach prompt decisions. According to UN experts, in 2050 more than 66% of the world's population will live in urban areas. It is also projected that the global urban population will grow by 2.5 billion between 2014 and 2050. About 90% of this growth will be concentrated in Asia and Africa. The most rapid urban growth over the last decades has been recorded in countries where income per person is above average: Brazil, Iran, Mexico and China. In the coming years, rapid growth is instead expected in countries with below average and low incomes, increasing the urban population from 39% and 30% to 57% and 48% by 2050, respectively[2].

By 2030, six out of every ten people will be living in cities. At the same time, cities in developed countries and cities experiencing rapid growth in developing counties over the last decades, along with those only starting to grow (generally in Africa, Latin America and in the Caribbean Islands) demand profound investigations of urban processes and the development of urban planning. Some cities feature an extremely high growth rate, dense population and often a low level of management and economic development. These problems became more acute during the COVID19 pandemic.

Small and medium-sized cities often face the problem of depopulation or urban shrinkage (Haase et al 2018). The solution of many urban social, economic and environmental problems demands an integrated approach.

Background

There are multiple studies devoted to ranking world cities. One should notice the recent study based on the geographic size index for megacities taking into account territory, population and gross domestic product (Sluka, Tikunov, Chereshnia 2019).

Some research pointed out that despite of new emerging factors and indicators significant for modern cities such as creativity and intelligence, the urban sustainability remains the most important of them (Rodrigues, Franco 2019).

In recent years, in Russia one can observe increasing volume of scientific papers on indicators of sustainable development: some of them devoted to indicators of implementation of sustainable development environmental goals in Russia (Bobylev et al. 2018); some of them devoted to indicators of sustainability for cities (Bobylev, Kudryavtseva, Solovyova 2014; Porfiryev, Bobylev 2018). Sustainable regional development should also be provided in terms of social (Zubarevich 2019) as well as environmental dimensions (Bobylev, Kudryavtseva, Yakovleva 2015). Institutional modernization and regional policy should be taken into account (Zubarevich 2015; Zubarevich 2017); principles of sustainable development should be implemented in this country by means of new priorities (Pakhomova, Richter, Malyshkov 2013).

One should avoid old mistakes in urban development. Within traditional neo-classical theories, scientists attempted to define the «optimal» city size, instead of what is «effective.» When a city grows, the economy of scale is at play. But this is true only before the city reaches a certain size. Nevertheless, if there are some structural transformations, for example, the development of innovative sectors or strengthening communications with other cities, the efficient size increases (Capello, Camagni 2000; Camagni, Capello, Caragliu 2013). The so-called «optimal» size proposed for modern European cities is from 55,500 to 360,000 residents without the structural transformations mentioned above, and from 1,000,000 to 2,100,000 inhabitants with them.

Numerous studies have focused on the issue of «urban sprawl» and its negative impact on the environment (Kahn 2000), society (Downs 1999), and health (Zhao, Kaestner 2010).

In the framework of the traditional theory of urban economics, there is an inverted U-shaped relationship between the size of a city and income per employed resident. The optimal size of the city is at the point of providing maximum income (quality of life not considered). Benefits from «economy of scale» have been investigated through the urban systems approach (Henderson 1974, 1977, 1988), and another approach was provided by a new economic geography (transportation costs taken into account) (Krugman 1991, 1995).

Some Asian countries like Japan and South Korea have introduced policies that limit population growth in large cities. The Japanese government began to limit the growth of Tokyo and neighboring areas in the 1950s. Similarly, in 1984 in South Korea there was a plan for rebuilding the capital city region to help combat urban sprawl. Many other countries are now facing a choice of various urbanization methods. For example, scientists from China often consider employment and wages, but quality of life is not mentioned (Hong Gao, Ming Lu, Hiroshi Sato 2015). Their estimates show that it is more likely for individuals to get a job in large cities, and the least-qualified employees have the most to gain from city scale.

The choice between environmental and social well-being is a very acute issue for many people in Russia (Kudryavtseva, Malikova 2019). The access to high-paying jobs and the availability of social benefits is associated with living or moving to cities or regions with an unfavorable environment. The most profitable economic sectors and highest incomes are found in the energy and raw materials industries, which simultaneously cause severe damage to the environment. Currently, 15% of Russia's urban population lives in cities with 'high' and 'very high' degrees of air pollution (44 cities, 16.4 million people). A classic example is Moscow which is a city with a vibrant cultural environment but poor ecological circumstances. A rather ambiguous air pollution situation can be observed in this city. Indeed, there has been a reduction in emissions of some pollutants, but due to rapid automobilization, the total pollutant load in Moscow oblast has increased. In Moscow, 93.5% of total emissions come from vehicles. Despite of this, many people in Russia buy flats in big cities in order to save money or hoping to move there later so the price for realty in such cities becomes higher than it might be (Kuricheva E.K., Popov A.A. 2016). The issue of urbanization and negative externalities has been considered in many Russian studies (Zemskova O.V. 2015, Malikova O. 2017). The «efficient city size» taking into account the environment and economy is up to 5-6 million residents for Moscow respectively[3].

[1] https://sustainabledevelopment.un.org/post2015/transformingourworld

[2] United Nations, Department of Economic and Social Affairs, Population Division (2014). World Urbanization Prospects: The 2014 Revision, Highlights (ST / ESA / SER.A / 352)

[3] Zemskova O.V. (2015). Socio-economic causes and environmental consequences of overpopulation (the example of Moscow and the Moscow region). Author's abstract of the dissertation. M., MSU named after MV Lomonosov

Small and medium-sized cities might be more comfortable to live in, but today the industries typical for small and medium-sized cities (food, textiles, a part of the engineering industry) are in stagnation. Thus, two connected issues must be addressed: (i) the development of small towns and (ii) the development of manufacturing industries oriented towards the consumer sector and local markets.

The problems of the differences in the development of large, small and medium-sized cities in Russia are also related to the peculiarities of the management and taxation system. Most of the taxes are not collected at the place of the actual production activity of the company but at the place of registration of the company. For example, a company may carry out actual production activities in the Kostroma region (this may be wood harvesting or collecting wild plants), but Moscow may be the place of registration. The head office, accounting, structures involved in logistics are in Moscow. Accordingly, taxes will be paid at the place of registration, and not at the place of receipt of resources and production. In this case the region loses twice, because the region (i) does not receive taxes from the economic activity in its own region and (ii) transfers resources for the development of another territory. Obviously, such system contributes to the development of large cities and the degradation of smaller settlements. That is why parallel tracking of flows of resources and financial flows is extremely important.

Technical progress and new technologies often provide additional boost to harmonizing the urban and rural environment. This fact must be considered when making management decisions. Here, renewable energy can be provided as a classic of technological breakthroughs in the construction of energy-passive and energy-active buildings. Unfortunately, construction technologies and «technology» of making management decisions are inertial (very slow). Future changes and the factor of technical progress are not considered (due to the focus of the businesses to achieve immediate results and present income generation). Today it is advantageous to use solar and wind energy in some Russian regions (for example, in Arctic region (Potravnyi, Yashalova, Boroukhin, Tolstoukhova 2020) in the Far East and some small cities (Grechukhina, Kudryavtseva, Yakovleva 2016). Electricity and heat in small towns can be less expensive than in megacities because of outdated solutions. «An example is the proliferation of multi-storey buildings along the perimeter of megacities. It entails the growth of environmental, transport and social problems in the future. Obviously, it is important to focus on the concept of assessing the full life cycle of buildings when making urban planning decisions, and not just the costs associated with their construction».[1]

Urbanization leads to changes in demographic processes. There is a noticeable decline in the birth rate in large cities coupled with the birth of children from parents of older age groups. A similar trend is typical for Russia. The demographic situation in Russia is characterized by a negative natural population growth. The population loss is partially compensated by positive migration inflows. The most difficult demographic situation in terms of natural population growth in Russia is taking shape in megacities – Moscow and St. Petersburg. These cities are characterized by low natural population growth but a high birth rate for women after 35 years old. The number of births of the first children after 35 years is large in comparison with other regions (Smulyanskaya 2017).

The birth of the first child in the older age groups entails certain medical risks. The risks associated with the possible deterioration of the health of such children in the future increase in conjunction with the residence of late-born children in the conditions of the less prosperous environmental situation inherent in almost all megacities. Today these problems are under-studied and require further research. However, it is obvious that in this case the action of the externalities also manifests itself. The rational desire of parents in megalopolises to postpone the birth of their first child to a later date leads to additional costs for society in the future. These costs cannot be taken into account by parents who make decisions. It is important to note that an environment unfavorable from the viewpoint of ecology exacerbates the problem markedly. The poor environmental conditions in large cities require not only measures to minimize industrial impact, but also innovative approaches to city development («eco-cities») and territorial planning.

In terms of all the external effects, small and medium-sized cities could be more competitive than megacities. However recent research highlighted the growing depopulation of small and medium-sized cities (Haase et al 2018). This problem is especially acute for mono-specialized Russian settlements (Parfenova, Gurova 2020).

MATERIALS AND METHODS

The methods of study are the analysis of statistical data by econometric methods as well as their processing including geographical visualization. Our research includes 114 most populated and significant Russian cities all over the country. Data for the calculations were taken from the Federal State Statistics Service (Rosstat) database in 2018. We define the efficient city size structure for Russian cities the way it was done by Camagni, Capello, and Caragliu (2013). However, their basic model was changed in order to specify some significant for Russia factors. It is very important to include ecological externalities in our analysis.

It is supposed that each city has benefits and costs which depend on some variables. Moreover, city size is included in both benefits and costs. As usual, Cobb-Douglas specification is used in both benefits and costs functions (Camagni et al. 2013).

$$C = size^{a_0} c_1^{a_1} \dots c_k^{a_k} \qquad B = size^{\delta_0} \delta_1^{\delta_1} \dots \delta_m^{\delta_m}$$

Here, $C_1 \dots C_k$ and $b_1 \dots b_m$ are the variables that respectively influence the net benefits of the city *B-C*; $a_1 \dots a_k$ and $\delta_1 \dots \delta_m$ are the corresponding elasticities of costs and benefits. It is proposed that δ_0 is in the interval (0,1) while a_0 is greater than one. This derives from the proposition that the growth rate of costs is increasing as the city size gets bigger.

Obviously, net benefits are to be maximized with respect to the city size. It is required that marginal costs are equal to marginal benefits of the city (with respect to the city size). So, we can derive the efficient city size. Let us do it by transforming the equation of marginal costs and benefits:

$$MCsize = a_0 size^{a0-1} c_1^{a_1} \dots c_k^{a_k} = \delta_0 size^{\delta 0-1} b_1^{\delta_1} \dots b_m^{\delta_m} = MB_{size}$$

$$size^{a_0-\delta_0} = \frac{\delta_0}{a_0} \cdot \frac{b_1^{\delta_1} \dots b_m^{\delta_m}}{c_1^{a_1} \dots c_k^{a_k}}$$

$$lnsize^* = \frac{lnb_0 - lna_0}{a_0 - \delta_0} + \sum_{i=1}^{m} \frac{\delta_i}{a_0 - \delta_0} lnb_i - \sum_{j=1}^{k} \frac{a_i}{a_0 - \delta_0} lnc_i = \mu + \sum_{i=1}^{m} \gamma_i lnb_i + \sum_{j=1}^{k} \omega_j lnc_j$$

[1] Schukin A. (2019). High-rise buildings are a toxic asset with a short lifespan Expert, 25, 28-32

Here γ_i is the quotient of two variables: elasticity of net benefit and the city size elasticity. In the same way, ω_j is the quotient of the cost elasticity and the city size elasticity. It is worthwhile noting that the coefficient γ_i is positive, while ω_j is negative. There are some conclusions that can be drawn from the derived equation. For instance, if the amount of certain benefit b_i (cost c_j) increases by 1%, then the «efficient city size» will increase by γ_i% (decreases by ω_j%).

Let us find the necessary path towards efficiency of the city without changing its size. Suppose one has the efficient value of the city size (we denote it by *size**) and the current value of the city size (we denote it by *size**). It is obvious that the «efficient city size» should change by (*size´/size*-1*)x100%. Let us respectively denote R^{bi}_{growth} and R^{ci}_{growth} as the growth rates of benefit b_i and cost c_j. So, in order to achieve the efficiency, the following equation should be fulfilled:

$$\sum_{i=1}^{m}\gamma_i R_{growth}^{c_j}+\sum_{j=1}^{k}\omega_j R_{growth}^{c_j}=\frac{size'-size^*}{size^*}$$

Suppose it is possible to exogenously change the elasticities of net benefits of the city. Then, if we still need to reach efficiency without changing the actual city size, then the following condition must be met:

$$\Delta lnsize^*=\sum_{i=1}^{m}\frac{\Delta\delta_i}{a_0-\delta_0}lnb_i-\sum_{j=1}^{k}\frac{\Delta a_j}{a_0-\delta_0}\ln c_j=\frac{size'-size^*}{size^*}$$

However, if we can change a_0 and δ_0 coefficients, then the equation will be as following:

$$\Delta lnsize^*=\frac{ln\left(1+\frac{\Delta\delta_0}{\delta_0}\right)-\ln\left(1+\frac{\Delta a_0}{a_0}\right)-\left(\Delta a_0-\Delta\delta_0\right)lnsize^*}{a_0-\delta_0+\Delta a_0-\Delta\delta_0}=\frac{size'-size^*}{size^*}$$

RESULTS

There are some things to discuss here. When a city is overpopulated, it is possible that a part of the population of that city may leave it to go somewhere else in order to increase their utility. Thus, the city size can decrease towards the efficient value.

However, when it comes to underpopulated cities the question becomes more complicated. There is still an incentive to leave the city due to the insufficient utility, but nevertheless the size of an underpopulated city can increase due to natural growth of population and possible migration towards this city from other cities, where it is relatively worse to live in.

And this is where the problem of city management arises. In order not to let the underpopulated city slowly die as its population moves to other cities, it is necessary to change the living conditions in it. According to the model, another way is to decrease the efficient city size by increasing the cost values and decreasing the benefits values for the city. By doing this the actual city size becomes efficient.

On the other side, when it comes to managing overpopulated cities, the efficient city size must be increased. This can be done by increasing benefits and decreasing costs for the city. Once again, the actual city size will become efficient.

The ecological situation is very important for city efficiency. It is a well-known fact that environmental pollution in Russia is one of the biggest problems and yet is being neglected in many Russian cities. Ecological externalities surely affect the quality of life in a city and thus there should be a lot of attention paid to them.

Given the numerical data which includes current values of city size for each city and the variables which affect benefits and costs, we are creating a model that will give us the theoretically efficient desirable values of city size for each city under consideration and the coefficients which correspond to benefits and costs for each of them. The theoretical values of the city size (which will be denoted as $\hat{size}$) should be considered as the «efficient city size». Then, by comparing the theoretical and empirical, or actual (from official statistics) values of city size for each city the necessary city size growth (decrease) rates to reach efficiency will be calculated in order to estimate which cities are «underpopulated» or «overpopulated».

Nowadays in Russia there is a huge migration towards the largest cities, starting with regional centers and ending with cities like Moscow and Saint Petersburg. This makes bigger cities even more overpopulated and smaller cities more underpopulated. The economic structure of Russian cities does vary a lot too. Some cities are focused on primary and secondary sectors of economy like extraction and production of raw materials, manufacturing, production and construction, others are more focused on tertiary and quaternary sectors like service industry, research, banking, education, etc.

The key variables of our model are the «rent/wage ratio» and «emissions per square kilometer». These emissions are the total emissions from all polluting sources: CO, SO_2, CH_4, NOx, volatile organic substances, solid particles reflected in the federal statistics (further: emissions). There are many other ecological factors that were not included in our model (for example the availability of fresh water) but the clean air is the most important ecological factor for city dwellers in this country and it is possible to include some other factors in the model in the future. We have decided to include in this model also the variable «emissions per capita» (it is disputable if we should do it) in order not to miss some possible significant results. Such variables as the «crime rate», «average living space per capita», «amount of investment in city» and others were used as control variables (they reflect essential macro parameters of cities). It can be discussible if we should use such variables as medical support rate and crime rate but we have decided to do it here in order to demonstrate how our model runs taken into account the available data. All the variables were taken in logarithmic scale:

$$lnsize^*=\beta_0+\beta_1 lnRW+\beta_2 lnEmis\_A+\beta_3 lnEmis\_C+V\beta+\varepsilon$$

Here, *RW* is the rent/wage ratio, *Emis_A* is the amount of emissions per square kilometer, *Emis_C* is the amount of emissions per capita and *V* stands for other control variables. β_0, β_1, β_2, β_3 and β stand for the coefficients of the variables, ε is the random error.

Below there are some results of model estimations. In total, nine models were made to represent the whole process of modelling.

The results of modelling showed that the «rent/wage ratio» has a positive impact on the hypothetical «efficient city size». The following explanations for this fact may be provided. Higher rents in the city often mean that the city's infrastructure is more developed, which increases the quality of life in the city and hence the «efficient city size».

DISCUSSION

External effects

The following modern social dilemma is well known: when a city grows, negative ecological externalities occur, causing some

Table 1. Results of model estimations

Dependent variable: Efficient city size in terms of population	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rent/Wage ratio	1.78*** (0.36)	1.47*** (0.39)	1.47*** (0.35)	1.49*** (0.35)	1.60*** (0.35)	1.59*** (0.35)	1.58*** (0.36)	1.54*** (0.39)	1.18*** (0.41)
Emissions per square kilometer	-	-0.11 (0.08)	-0.41*** (0.12)	-0.41*** (0.12)	-0.43*** (0.11)	-0.43*** (0.11)	-0.43*** (0.12)	-0.43*** (0.11)	-0.45*** (0.12)
Emissions per capita	-	-	0.49*** (0.12)	0.52*** (0.11)	0.55*** (0.12)	0.55*** (0.12)	0.55*** (0.12)	0.56*** (0.12)	0.56*** (0.13)
Living space per capita	-	-	-	0.99** (0.44)	1.07** (0.46)	1.04** (0.49)	1.02* (0.52)	1.00* (0.54)	0.99* (0.53)
Investment in the city per capita	-	-	-	-	0.15 (0.14)	0.15 (0.14)	0.14 (0.14)	0.14 (0.14)	0.08 (0.13)
Medical support rate	-	-	-	-	-	0.04 (0.21)	0.05 (0.22)	-0.03 (0.30)	0.02 (0.29)
Crime rate	-	-	-	-	-	-	-0.06 (0.20)	-0.07 (0.21)	-0.04 (0.20)
Regional center	-	-	-	-	-	-	-	0.10 (0.31)	0.12 (0.30)
Federal city	-	-	-	-	-	-	-	-	1.02 (0.68)
Constant	5.37*** (0.12)	5.97*** (0.40)	4.90*** (0.41)	1.60 (1.51)	0.66 (1.86)	0.56 (1.89)	0.76 (2.02)	1.08 (2.17)	1.27 (2.10)
Observations	114	114	114	114	114	114	114	114	114
R^2	0.34	0.36	0.42	0.44	0.46	0.46	0.46	0.46	0.48
Adjusted R^2	0.34	0.35	0.41	0.42	0.43	0.43	0.42	0.42	0.44
Residual Std. Error	0.76	0.75	0.72	0.71	0.71	0.71	0.71	0.71	0.70
F Statistic	58.30***	31.60***	26.78***	21.77***	18.33***	15.15***	12.89***	11.20***	10.68***
Note:	Standard errors in parentheses. ***, **, * imply significance at 1, 5 and 10% respectively								

inhabitants to seek to leave the city. Yet at the same time, though individual welfare might increase, in general the pollution and congestion also increase (the profit of the «scale economy» decreases), and therefore social well-being decreases. Traditional economic theory fails to consider the positive and negative externalities arising from the interaction of three city spheres: economic, ecological and social. Externalities arise at interaction of economic and ecological, economic and social, and ecological and social components. Positive effects can be seen in the availability of social services (including education, health/medicine), and the increase in the probability of finding well-paid work. The economy of scale diminishes the negative impact on the environment, as energy and water use can decrease. The positive influence of the environmental sphere on the social is expressed in improvements in human health. Public welfare increases after a certain volume of vegetation is planted. For an investigation of the influence of external effects and a search for ways to internalize them, various indicators can be used. For example, many researchers have outlined a positive link between the existence of a park within walking distance, and urban real estate value (McCord et al. 2014; Kim et al. 2019). The authors' research for Moscow confirms this fact (Alekseeva et al. 2016).

Negative effects are expressed through emissions growth, congestion, and social tension. These factors can exert a negative impact on the economy by promoting conflicts, fluctuations in the labor market, bankruptcies, the withdrawal of companies from the city, and the outflow of investments. They can also breed interpersonal and intergenerational conflicts of interest.

Some researchers conclude that sometimes urban sprawl is even necessary to prevent overpopulation. Three factors cause inefficiency in terms of externalities: production, consumption and real income. With a decreasing city size (in terms of population), salaries increase with a shift in the labor supply. Companies must pay higher wages, as all local firms face higher salaries. Such an increase in costs is to some extent, albeit not entirely, offset by decreased land rent and rent for capital due to lower demand. Consumption changes according to the same logic, as local prices for goods and services increase with a decrease in the size of the city, due to the net effect of the processes described above. However, households pay less in rent for where they live. Both these externalities of distribution interact and affect the real income of households. Local households receive income from wages and rent from local land and capital. With a decrease in the size of the city, an increase in wages causes an increase in real income per household, yet lower rent for land and capital reduces real income. The latter phenomenon has a relatively greater impact on households with a larger share of local real estate and capital ownership. Generally speaking, this is understandable, since high-income households simultaneously own local businesses and require large buildings with large plots of land in comparison with families with lower incomes. Hence the real income of high-income households is reduced more than the income of lower-income households with a smaller share of local land and capital. Thus, with a decrease in the size of a city, high-income households migrate. Low-income households then find their income increasing with the continued decline in the size of the city, as increasing salaries begin to exceed their land and capital costs, which is the reason for their inflow into the city. This leads to a change in the structure of households within the city. With a decrease in the size of a city and the achievement of its «optimal» size, low-income households make up the greater part of this distribution.

Another way of interpreting these results is that the distribution of households is inefficiently shifted towards high-income households in overcrowded cities. The results show that there is a link between the optimal size of the city and the distribution of households: the first can be estimated using the second. It can be concluded that urban sprawl and the development of transport infrastructure can reduce the inefficiency from «overpopulation» in the city. Some retail activities (for example, shopping centers) can be «exported» out of the city. According to the results, cities with a relatively large share of retail and services have a larger «optimal» size than others. However, when production becomes R&D-oriented, the degree of «overpopulation» is reduced with the increase in the «optimal» size of a city. In general, production in large cities is more R&D-oriented than in small and medium-sized cities (Burnett 2016).

Problem of efficiency

We should notice here that results of our model are discussible and should give rise to more research. We have also discussed above some significant reasons for it.

According to the estimations of the model, «emissions per square kilometer» have a negative impact on the efficient city size, which is intuitively clear. The more polluted the air in the city is, the worse is to live in it. However, the created model states that «emissions per capita» have a positive impact on the «efficient city size». The way this can be explained is that the more emissions are made in the city, the more productive in terms of gross city product per capita the city is. The gross city product does not take into account ecological externalities and pollutions.

After that, the growth rate which is necessary to reach hypothetical efficiency was calculated for each city. This growth rate should provide efficiency for the city. The result for underpopulated cities can be seen on the Fig. 1. Naryan-Mar in the Russian Far North for example should be 8 times more populated in order to obtain the «hypothetical efficient size».

One can see that there is a significant gap between hypothetical efficient and actual city size for some Russian cities. It might be explained by very uneven size and economy structure of Russian cities. In other words, we should notice that cities of the Russian Far North such as Anadyr, Naryan-Mar and Salekhard are extremely underpopulated at present. This can also be explained by unfavorable climatic conditions in areas of northern and remote eastern regions in combination with high cost of living there (Zubarevich 2019). These conditions were not taken into account in this model and should be subject for future research. There is a problem with fresh water in Sevastopol but this fact was also not under consideration in our model.

Murom and Gorno-Altaysk are extremely underestimated with regard to benefits from living in them so new dwellers should be attracted in them by means of governmental programs of «area development». The support of historical heritage and favorable environmental situation should become drivers for economic development including tourism industry. There is a plenty of underpopulated cities all over the country and many of them are in its Western part where climate conditions are rather favorable (Fig. 2).

Russia has done little to support the development of its small and medium-sized cities. The resolutions «On Approval of the Federal Integrated Program for the Development of Small and Medium Cities of the Russian Federation under the Conditions of Economic Reform», June 28, 1996 № 762 and «Federal Integrated Program for the Development of Small and Medium Cities of the Russian Federation under the Conditions of Economic Reform» were adopted in 1996 but in 2002 this decree became invalid.

The Union of Small Cities of Russia developed a draft «Federal Target Program for Social and Economic Development of Small and Medium Cities of the Russian Federation for 2009–2012 and until 2017». Unfortunately, this document was not supported by the federal government.

Measures to support the development of small and medium-sized cities of the Russian Federation can be quite diverse. The principles of 'Priority Social and Economic Development Areas' (hereafter PSEDA) are defined by the Federal Law «On Creating Territories of Advancement of Socio-Economic Development» in 2014. They are justified with the support of single-industry towns (they include urban-type settlements with a population of more than 3,000 inhabitants, of which at least 20% work at enterprises of the same company. As a rule, this company provides 50% or more of the gross output of a city).

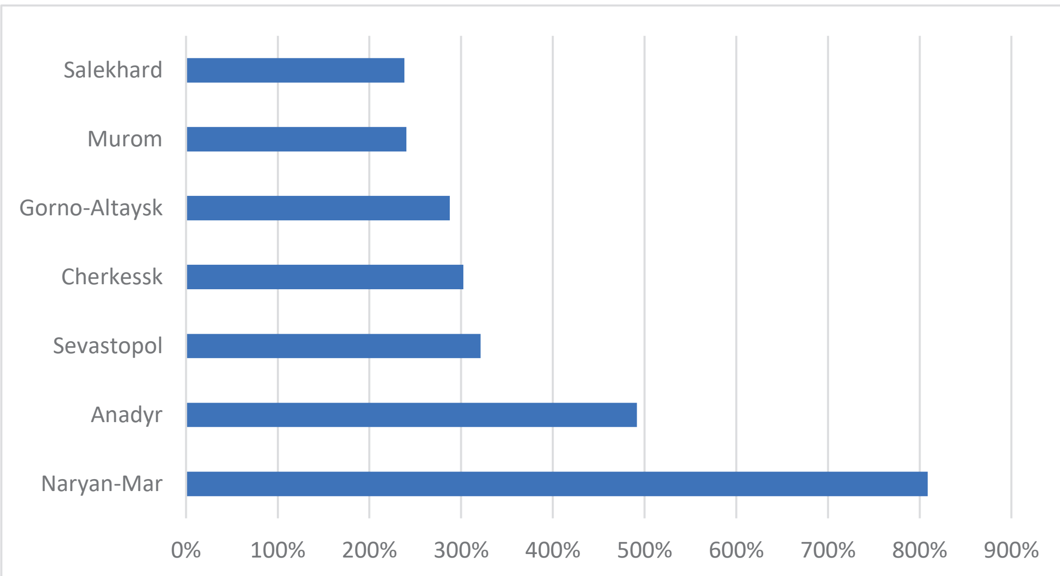

Fig. 1.City size growth rate (in%) to reach efficiency
Source: calculated by the authors using the data provided by Rosstat

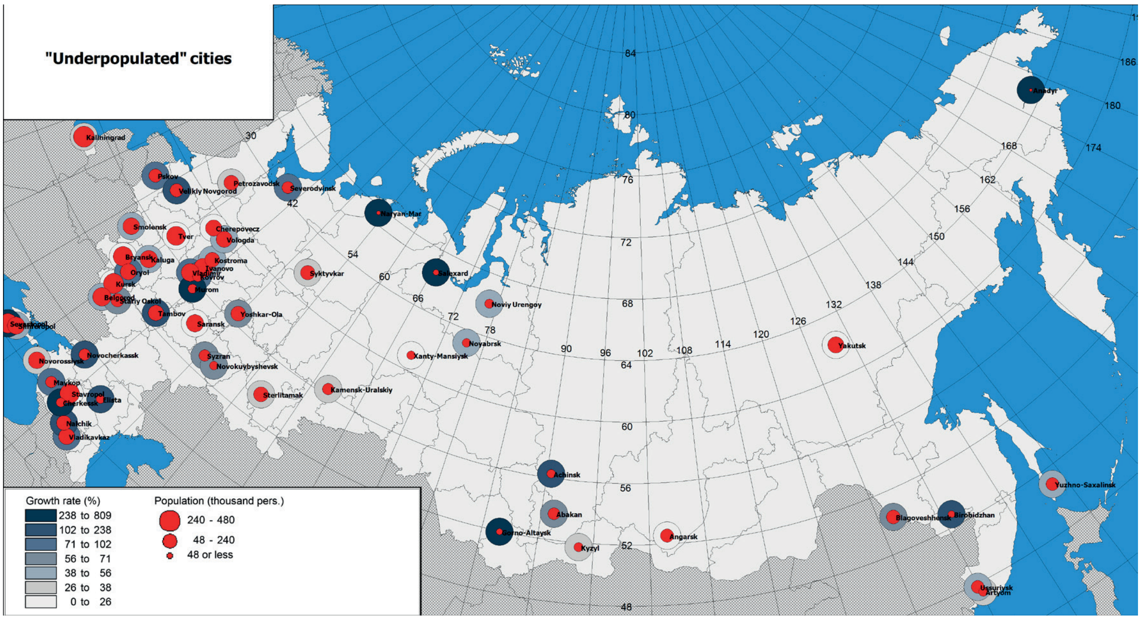

Fig. 2. Underpopulated Russian cities

Source: estimated by the authors using the data provided by Rosstat

Some monotowns (single industry towns, factory towns) of the Russian Federation have already received the status of PSEDA. Support to food and light industry, engineering is a very important measure for the development of small and medium-sized cities. Modernization of the municipal sector of small towns can play a big role. Energy efficiency programs in such cities are implemented. Stabilization of utility payments may be another effective measure (Pershina 2015).

The Resolution of the Government of the Russian Federation «On the All-Russian Competition for the Selection of the Best Projects in the Sphere of Creating a Comfortable Environment in Small Cities and Historical Settlements» prepared by the Ministry of Construction of Russia, was important. The competition was held in 2018 and in 2019. In 2019, 330 applications from 77 Russian regions were submitted to the competition. 80 winning projects were selected. These projects received financial support in the amount of 40 to 85 million rubles from the Federal Budget. The winners of the contest were announced on May 31, 2019. This decision was very important to support the development of small cities but this is not enough for a noticeable change in the situation.

There is also one additional significant and underestimated asset of small and medium-sized cities: historical real estate and the historical environment ensuring the uniqueness of the area. Unfortunately, this asset in many cities is rapidly deteriorating. One measure that can support the preservation of the historical environment and historical real estate could be the decrease of property tax for historical buildings, provided they retain their original appearance and satisfactory technical condition. All kinds of environmentally safe and economical feasible tourism should be developed attracting investments and providing new jobs. This could also help reaching SDG 11.4 «Protect the World's Cultural and Natural Heritage». This is also in accordance with the «New Urban Agenda» that was adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito, Ecuador, on 20 October 2016: «We will support the leveraging of cultural heritage for sustainable urban development and recognize its role in stimulating participation and responsibility. We will promote innovative and sustainable use of architectural monuments and sites, with the intention of value creation, through respectful restoration and adaptation»[1].

On the contrary, Industrial centers of Russia, such as Norilsk, Chelyabinsk, Ekaterinburg, Perm, and Omsk are overpopulated in terms of hypothetical efficiency (Fig. 3). The ecological situation in most of them is very uncomfortable for living, i.e., they have very poor quality of life.

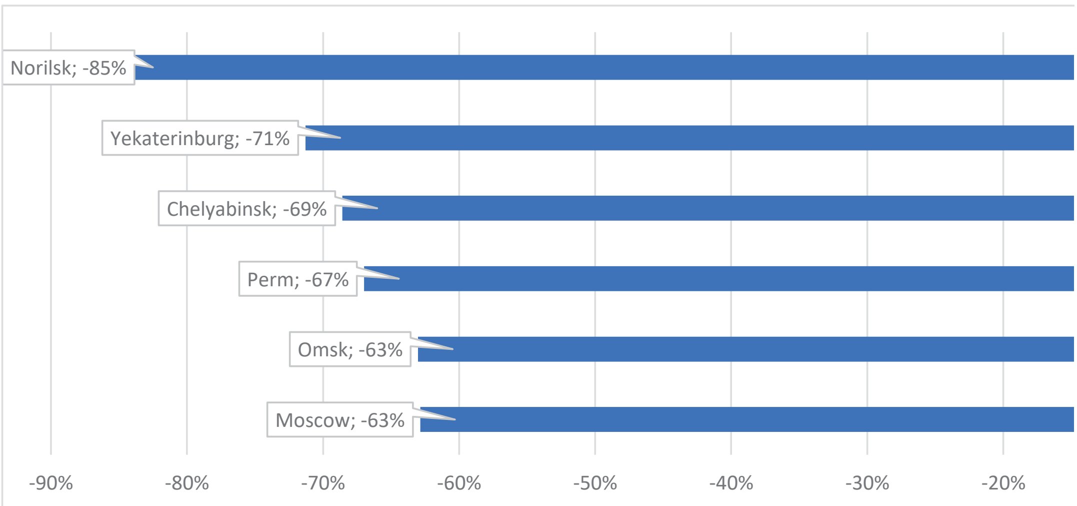

Fig. 3. City size decrease rate (in%) to reach efficiency

Source: calculated by the authors using the data provided by Rosstat

[1] https://uploads.habitat3.org/hb3/NUA-English

Some ways to reach efficiency

How the problem of inefficiency should be resolved? It is possible to achieve efficiency without changing the actual size of a city simply by changing the values of variables that affect the efficient city size. Two variables will be used to reach efficiency: «emissions per capita» and «emissions per square kilometer». There should be an ecological regulation. Given the gap between the actual and «efficient» city size and respective estimated elasticities of these two variables, the efficiency can be reached using a single equation.

$$\hat{\beta}_2 * R_{growth}^{Emis\_A} + \hat{\beta}_3 * R_{growth}^{Emis\_C} = \frac{size - \hat{size}}{\hat{size}} = x$$

Here, $R_{growth}^{Emis\_A}$ and $R_{growth}^{Emis\_A}$ are, respectively, growth rates of emissions per square kilometer and emissions per capita. This equation is linear with respect to growth rates of these variables. However, since the city size is assumed to be unchangeable, growth rates can be transformed into growth rates of gross emissions and city area.

$$\hat{\beta}_2 * \frac{R_{growth}^{Emissions} - R_{growth}^{Area}}{R_{growth}^{Area} + 1} + \hat{\beta}_3 * R_{growth}^{Emissions} = x$$

The set of feasible growth rates of emissions and area that allow the city to reach efficiency is a continuum. However, environmental constraints should be effective in terms of costs of its implementation. Thus, it is possible to specify a task where costs of reaching efficiency of the city are to be minimized under certain constraints. Obviously, there should be a constraint that allows to reach efficiency. Also, there should be upper and lower bounds of emissions and area growth rates.

$$\begin{cases} f_i\left(R_{growth}^{Emissions}, R_{growth}^{Area}\right) \rightarrow \min \\ \hat{\beta}_2 * \frac{R_{growth}^{Emissions} - R_{growth}^{Area}}{R_{growth}^{Area} + 1} + \hat{\beta}_3 * R_{growth}^{Emissions} = x \\ R_{growth}^{Emissions} \in \left[\varphi_{\min}^i, \varphi_{\max}^i\right] \\ R_{growth}^{Area} \in \left[\theta_{\min}^i, \theta_{\max}^i\right] \end{cases}$$

Here, f_i is the cost function of changing emissions and city area i. R^E_{growth} and R^A_{growth} are, respectively, growth rates of gross emissions and city area. $[\varphi^i_{min}, \varphi^i_{max}]$ and $[\theta^i_{min}, \theta^i_{max}]$ are the bound for emissions and are growth rates.

These findings should provide reaching SDG 11.3 «Inclusive and Sustainable Urbanization» taking into account the indicator «ratio of land consumption rate to population growth rate» as well as SDG 11.6

«Reduce the Environmental Impact of Cities and Urban air pollution»

However, it is essential to pay attention to the function of a city and its spatial organization. Environmental constraints are suitable for industrial centers such as Norilsk, Chelyabinsk, Ekaterinburg, Perm, and Omsk which according to results of our model are overpopulated in terms of hypothetical efficiency because of environmental degradation. The implementation of Best Available Techniques (BAT) and principles of circular economy should be helpful.

These findings are also in accordance with the «New Urban Agenda» mentioned above: «We encourage spatial development strategies that take into account, as appropriate, the need to guide urban extension, prioritizing urban renewal by planning for the provision of accessible and well-connected infrastructure and services, sustainable population densities and compact design and integration of new neighborhoods into the urban fabric, preventing urban sprawl and marginalization»[1]. One should also mention the «World Cities Report' (UN-Habitat 2020) according to which local governments should raise revenue simultaneously limiting urban sprawl and relieving overcrowded housing[2].

For underpopulated cities of the Russian Far North one should use other methods such as developing «Priority Social and Economic Development Areas» or PSEDA (Parfenova, Gurova 2020). Renewable energy sources should make living in smaller cities more economically viable. For Murom and Gorno-Altaysk, one should use programs of area development. The environmental situation, environmental and historical heritage make it possible, for example, to develop all kinds of tourism providing new jobs, attracting investments and strengthening local labor market.

CONCLUSIONS

The conclusion can be drawn that when attempting to find solutions for acute modern social problems such as urban development issues, it is necessary to carefully consider many externalities, both negative and positive. The existence of externalities makes impossible to measure social costs and social well-being by market means. Urban economy is crucial domain where externalities disrupt efficiency. Traditional economic theory fails to consider the externalities arising from the interaction of three city dimensions: economic, ecological and social. The results of the research give following recommendations for urban and regional policy for approach the achieving SDG 11 as well as some targets from the «New Urban Agenda» and the «World Cities Report» (UN-Habitat 2020). It is essential to pay attention to the function of a city and its spatial organization. There are different strategies to achieve hypothetical «efficiency» for different city types. Some of them were justified above. Despite of all discussible points of the model presented above, we have shown that under certain assumptions the environmental management may lead to the «efficiency» of the city without changing the city size.

It is important to consider possible external effects within the framework of urban planning; assessment of the flow of resources, income and pollution. The cost of restoring the health of residents of environmentally disadvantaged cities can be comparable to the economic benefits of living in such cities. The concentration of the population in large cities leads to a fatal decrease in fertility. The birth rate is the lowest among residents with a high level of education, living in an urban environment for several generations. It is necessary to develop other «points of growth» as an alternative of large cities.

New technologies and environmental factors will have an increasing impact on the quality of life of urban dwellers. Renewable energy makes living in smaller cities more economically viable. It is important to develop new technologies and adopt modern legislation for the development of renewable energy in order to achieve progress in this direction. It is necessary to adopt a law on microgeneration of electricity (small-scale generation with focus on renewables).

[1] https://uploads.habitat3.org/hb3/NUA-English
[2] https://unhabitat.org/World%20Cities%20Report%202020

It is desirable to adjust the urban and regional policy towards the harmonization of territorial development, smoothing disproportions in the development of cities and towns, and supporting the development of small and medium cities in Russia. In recent years, several legislative initiatives have been taken in this country to support the development of small cities. However, these actions are still not enough. More decisions need to be made to harmonize territorial and cities' development in accordance to Sustainable Development Goals, «New Urban Agenda» and «World Cities Report» (UN-Habitat 2020).

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