Diffusion of ICT-products and "five Russias"

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Diffusion of innovation and "five Russias"

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Abstract. *The authors explored the potential of new information and communications technologies (ICT) absorption in Russian regions primarily on an example of mobile communication. ICT-sector is rapidly growing, especially in consumer market, and it is an ideal object for diffusion research because it is fast spreading, and it can be obtained by almost all parts of a social system. The purpose was to classify regions by the rate of innovativeness, including the speed of diffusion and the share of innovators in the structure of regional communities. The level of saturation for mobile phone usage (active SIM cards per 100 people) was used as a proper indicator on the first stage of the research. All regions were classified according to rates of diffusion from 1999 to 2011, and five clusters were identified, corresponding to stages of diffusion by E. Rogers: innovators, early adopters, early majority, late majority and laggards. There are four stages of mobile communication diffusion, according to the spatial diffusion theory of T. Hagerstrand, which are determined by several factors. The most influential factors are income, price of services and competition. Mobile phone usage in most Russian regions reached 100% saturation (one active SIM card per capita) in 2006-2007. Later development of cellular communication was determined not by demand for phone connection, but by the demand for internet connection, which is easily provided by mobile systems in smartphones, tablets, and other devices in comparison with other internet sources, which are less developed in most of Russian regions. To assess the innovativeness of regional communities, or their ability to absorb new products, cluster analysis, based on the threshold values of Bass model parameters, was performed. The results were similar to those obtained earlier, but for several regions the early appearance of innovators in communities did not increase the total number of users. Both previous methods of classification can be biased regarding special features of mobile communication diffusion. That is why, in the last stage an integral index of innovativeness was introduced, including rate of diffusion for several ICT-products on the early period of their introduction. The analysis proved that hierarchical model of diffusion from the main centres to secondary prevails in Russia. Factor of geographical location also play an important role. The research showed the significant difference in the rate of diffusion between Russian regions. Five stable clusters were identified, which is corresponding with idea of "five Russias" existence. Moscow and Saint Petersburg's rate of diffusion is higher than in most countries, but there is a widespread periphery.*

Keywords: geography of innovation, diffusion of innovation, Russian regions, mobile communication, logistic curve, Bass model, regions-innovators, index of innovativeness.

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Introduction

According to E. Rogers "Diffusion of innovation is a process, by which innovation is transmitted over communication channels between members of a social system" (Rogers, 2002). Innovations may be ideas, objects, technologies, products, which are new to the community. In our work regions are considered as social systems, and mobile phones are considered as innovative products.

Diffusion of innovations has significantly increased in 90[th] with development of new information and communications technologies (ICT): mobile communication, the internet, social media, wireless devices, etc. (Wareham, Levy, Cousins, 2002; Comin, Hobijn, Rovito, 2006). Nowadays, there are a lot of research papers dedicated to diffusion of mobile communication in different countries, especially in developing countries (Gruber, Verboven, 2001; Gruber, 2001; Kshetri, Cheung, 2002; Massini, 2004; Jang, Dai, Sung, 2005; Lee, Cho, 2007; Singh, 2008; Wu, Wen-Lin, 2010). However, works, devoted to modelling of mobile telecommunications services diffusion in Russia, are rare (Rachinskiy, 2012; Baburin, Zemtsov, 2013). The level of saturation for mobile communication in Russia is over 120%. All Russian regions reach 100%, but the maximum level and rate of diffusion were very different during the period of diffusion (1999-2012).

There is a considerable amount of works, exploring the potential of Russian regions for new technology creation, most of which is based on index approach (Bortnyk et al., 2012; Gochberg, 2012; Baburin, Zemtsov, 2013). But works with an analysis of new technology diffusion are less common (Baburin, Zemtsov, 2013). In Russia, there are practically no works on the analysis of innovation diffusion based on the application of highly recognized model of logistic curve (Bass, 1969; Mahajan, Peterson, 1985; Meade, Islam, 2006).

It was assumed that every regional community in Russia has its particular qualities as a system because of its high difference in history and modern social-economic development (Fan, Overland, Spagat, 1999; Fedorov, 2002; Kholodilin, Oshchepkov, Siliverstov, 2009; Carluer, 2005). Most of the Russian regions were on the same territorial-administrative borders for a long period, which can create a unique regional social system in each case (Lapidus, 1999). That is why it is possible to consider diffusion on regional level rather than settlements level. Diffusion models have not previously been used for classification of Russian regions.

Russia is a unique object for diffusion research because of its large scale, highly differentiated social structure and different level of regional development; and it is possible to find all stages of diffusion between regions.

The technology of mobile communication was firstly introduced in Russia in 1993 in Saint Petersburg, but the diffusion starts only in 1998, when GSM standard was implemented and several private companies started to develop the infrastructure in the regions simultaneously with a decrease in the price for services.

Russian regions differ significantly on the potential of new technologies absorption; inequality in diffusion is much higher than it is for income distribution (Comin, Hobijn, Rovito, 2006). And it is important to understand the main features of diffusion for forecasting and elimination of possible barriers by determining the main factors on regional level. Regions, rather than municipalities, are the main actors in Russian budget system (Diamond, 2002; Reforming the Russian Budget System, 2005). It is essential to identify the regions, where an introduction of new technologies would be done on the highest rate; it could help to understand the government regional priorities in implementation of new technologies, new products or new institutions and it will allow ICT innovative companies to properly evaluate sales dynamics and maximum market size in each region.

The purpose of the work was to classify Russian regions by the type of innovation diffusion, their ability to introduce new technologies and the share of innovators in the structure of the regional community.

Mobile phones usage or subscriptions (active SIM cards[1] per 100 people) was used as a proper indicator for the first stage of the research. There is an open and full data, and it is hard to fabricate or mislead, because it is question of fiscal administration, which is one of the most effective government institutions (Stepanyan, 2003; Gorodnichenko, Martinez-Vazquez, Peter, 2008).

The authors have put forward some basic hypotheses.

Hypothesis 1. Rate of diffusion and proportion of innovators in Russian regions is lower than in OECD countries because of lower incomes, low population density and less intensive contacts.

Hypothesis 2. Hierarchical model of diffusion from the main centres to secondary prevails in Russia regardless to the technology. In this case the centres are the largest agglomerations and regions having links with other countries.

Hypothesis 3. There are several clusters of regions ("several Russias")[2] in accordance with diffusion process, which are significantly different.

To prove these hypotheses several methods, based on a theoretical background, were introduced.

Firstly, all regions were classified by cluster analysis according to rates of diffusion from 1999 to 2012. The first cluster is represented by the 'capital' regions (Moscow, Saint-Petersburg and their suburbs) and the last cluster is mostly represented by agrarian territories of Northern Caucasus and Far East. The classification helps to determine the main features of diffusion but there are a lot of regions, which changed diffusion rate during the period, and the method does not help to identify the proportion of innovators in communities, which can be a transparent indicator for further diffusions. Also it was important to identify the stages of diffusion and factors, which could determine the speed of diffusion on each stage. For this purposes the modified Gompertz model was used.

Diffusion can be described by logistic curves, and Bass model was used for further analysis. According to the model, regional community can be divided into innovators (coefficient p) and imitators (q) by their propensity to diffuse. To assess the innovativeness of regional communities cluster analysis, based on the threshold values of p and q, was performed. The results were similar to those obtained earlier, but for several regions the early appearance of innovators in communities did not increase the total number of users.

Both previous methods of classifications can be biased regarding special features of mobile communication diffusion. And on the last stage an integral index of innovativeness was introduced, including rate of diffusion for several informational and communication technologies on the early period of their introduction: a proportion of users of mobile phones in 1999, a proportion of Internet users in 2009, a proportion of mobile Internet users in 2012.

I. Theoretical framework and methods

According to E. Rogers (Rogers, 2002) most of the charts, demonstrating innovation absorption by members of society, are similar to the standard bell-curve (or normal distribution). The curve shows the speed and innovation diffusion stages in the community. E. Rogers gave the name of each segment based on the arithmetic mean and standard deviation: innovators - 2.5%, early adopters - 13.5%, early majority - 34%, late majority - 34%, and laggards - 16%.

The driving force of the diffusion process is the interpersonal communication between the representatives of these groups. Each new user becomes a source of product information for the next potential customer. After the midpoint the process will be replaced by the opposite trend

[1] A subscriber identity module or subscriber identification module (SIM) is an integrated circuit that securely stores the international mobile subscriber identity (IMSI) and the related key used to identify and authenticate subscribers on mobile telephony devices (such as mobile phones and computers) (URL: http://en.wikipedia.org/wiki/Subscriber_identity_module)

[2] The idea of "four Russias" was firstly introduced by Russian scientist Natalia Zubarevich (Zubarevich, 2013) on an example of social protests in December 2011. From our point of view it is a good analogy, because social demonstrations are also a kind of innovations

with a decrease of the amount of remaining uninformed consumers. The homogeneity of the community, as well as segregation may affect the rate of diffusion, in both cases creating barriers to the transfer of information about a new product[3].

E. Rogers revealed characteristic features of each group (Rogers, 2002): innovators are risky, with high education, and technically savvy; early adopters are presented as social leaders, often they are well known in the community (Iyengar et al., 2011),, rich, highly educated, and tend to use new technologies; early majority has lots of contacts, pragmatic, often associated with middle class; late majority is conservative, has low social status, and they are very sensitive to price; and lagging community members are strongly traditional, isolated, they are often from marginalized communities. In our work we tried to identify these groups between the Russian regions.

All factors, which determine the diffusion process on regional level, can be divided into several groups, according to the previous works (Ahn, Lee, 1999; Burki et al., 2000; Gruber, 2001; Gruber, Verboten, 2001; Liikanen et al., 2001; Kiiski, Pohjola, 2002; Rogers, 2002; Kshetri, Cheung, 2002; Baliamoune-Lutz, 2003; Madden, Coble-Neal, 2004; Massini, 2004; Jang et al., 2005; Koski, Kretschmer, 2005; Rouvinen, 2006; Lee, Cho, 2007; Bagchi et al., 2008; Singh, 2008; Chu et al., 2009; Gupta, Jain, 201; Kiesling et al., 2012): social characteristics, which determine a proportion of innovators, regional special characteristics, which may increase the diffusion according to the position and territorial structure of the regions, and particular qualities of a technology.

The main social characteristics are income, income structure, education, dependence ratio, age and social mobility. The heterogeneity of income, which has a lognormal distribution, can be an explanation for the shape of the curve because of price barriers, when the product appears (Russel, 1980).

For Russia a factor of "demonstrative behaviour" should be also noted (Vigneron, Johnson, 1999; Peshkova, 2013), when absorption of innovation (new product) is not based on your needs, but depending on the desire to demonstrate your "prestige" among other members of community, even if an adopter cannot allow by his level of income. From one point of view, it could lead to acceleration processes for diffusion. But demonstrative behavior could lead to envy, which is the reason of low level of knowledge diffusion[4] about new purchases in social system[5].

It is important to understand the spatial aspects of diffusion (Hagerstrand, 1967; Brown, 1968; Morrill, 1968; Morrill, 1970), especially for distance-determined economy of Russia. The speed and direction of diffusion depend on a distance from the centre of innovation origin and internal characteristics of regions. The rate of diffusion depends on channels of diffusion: infrastructure and institutions. The main regional characteristics are: proximity to innovation centres, population and settlement density, urbanization, economic structure.

The rate of diffusion of innovations is determined by concentration of innovators, which is higher in large metropolitan areas. There are two main types of diffusion: hierarchical diffusion (according to urban hierarchy) and neighbourhood (according to contagion effect) (Hagerstrand, 1967).

There are four stages in a spatial diffusion model (Hagerstrand, 1967). The first stage (the appearance of diffusion) is characterized by the beginning of the diffusion process and the sharp contrast between centre and periphery: the number of acceptors in the centre reaches 70%, on a semi-periphery - 20% and about 10% - in a periphery. The second stage is the process of rapid expansion, which leads to formation of new and rapidly developing centres. On the third stage

[3] Russian regions have both of these features: a high inequality and disconnection between "oligarchs" and industrial workers on the one side, and inherited soviet system of social justice, when despite their efforts many workers have an equal income, especially in the budget sector (education, public health, etc.)
[4] Knowledge dissemination is one of the first stages of diffusion according to E. Rogers (Rogers, 2002)
[5] The first process can be common for cities and the second is more common for agrarian territories.

(accumulation) occurs the same extension in the whole space. On the last stage (saturation) occurs general but slow, asymptotic rise to the maximum possible rate.

Innovativeness of communities, or their ability to absorb innovation, can be evaluated directly through a study of the rate and direction of new technology diffusion, but an application of the method is limited by the influence of "endogenous" factors of the technology. In other words, different technologies have different patterns for diffusion.

E. Rogers notes that there is a certain "critical mass" of users (consumers), which must be achieved before the start of exponential growth. Usually this critical mass associated with innovators and early adopters. Technologies could be divided to "interactive" (cellular and mobile telephones, Internet, etc.), when the technology is based on the process of interaction between people, and "noninteractive" (household appliances, computers, etc.) (Mahler, Rogers, 1999). For the first type critical mass of users is especially important; mobile phone can be used only if the other members of the community also have means of communication, including fixed phone lines. Therefore, during the development of interactive technologies slow growth in users can be observed for a long time.

Several special characteristics of mobile phones' diffusion can be revealed: service price for communication and phone price. The communication price depends on infrastructure, competition between providers, private companies expenditures and investment. Also factors for fixed line development are important, such as penetration rate and service price.

All used variables are in the Appendixy 1.

There are several popular diffusion models: the Griliches, Bass, Gompertz, Logistic, and time-series autoregressive moving average models (Griliches, 1957; Bass, 1969; Geroski, 2000; Stoneman, 2002; Wu, Wen-Lin, 2010).

F. Bass suggested that the likelihood of buying a new product is a linear function of the number of previous buyers (Bass, 1969). "Imitators" are all consumers who are not innovators by E. Rogers. The greater the proportion of people using innovation, it is the harder for a person to avoid interaction with it. Probability of consumption described by dependence:

$$P(t) = p + q / F(t)$$

where *p* is the coefficient of innovation, expresses the "advertising effect", *q* is the coefficient of imitation, which expresses the effect of "word of mouth", or the ability of the consumer to learn about innovation from other people, *F(t)* is the proportion of consumers at time t. The probability function is close to normal distribution. Calculating the derivatives, we obtain the probability density function, which is the probability of a new customer appearance:

$$f(t) = dF(t))/dt = [p + \frac{q}{\overline{F}} \times F(t)] \times [\overline{F} - F(t)]$$

where *f(t)* is the number of new customers at the time t, *F(t)* is the number of acquired innovation at the time t, $\overline{F}$ is the potential maximum number of consumers.

Coefficients *p* and *q* actually show the ratio of innovators and imitators in the community. The parameter (*p* + *q*) affects the scale of the curve, *q p* influence the shape of the curve. Analysis of the parameters on the example of many countries shows that the ratio *q/p* (ratio of imitators to innovators) negatively associated with individualism, but positively associated with hierarchical structure of community (Van den Bulte, 2004) and the Gini coefficient.

Nowadays there are several types of diffusion models, including multi-stage and multi-technological diffusions (Mahajan, 1985; Meade, Islam, 2002).

For the purposes of this paper original Bass model will be converted into a non-differential form (Mahajan, 1985):

$$F(t+1) - F(t) = p\overline{F} + (\frac{q}{\overline{F}}\overline{F} - p) \times F(t) - \frac{q}{\overline{F}} F(t)^2 = A_1 + A_2 \times F(t) + A_3 \times F(t)^2 + \varepsilon(t)$$

where *F(t +1) - F(t)* is an increase in the number of residents who absorbed innovation in the year, *ε(e)* is a residue. The equation was used to find the model parameters (*p, b, q*) as the coefficients of the quadratic equation: $p=A_1/\overline{F}$, $b=\frac{q}{\overline{F}}$ $=-A_3$, $\overline{F}=(-A_2 \pm \sqrt{A_2^2-4A_1A_2})/2A_3$. Regions with low approximation values (R2 <0.8) can be eliminated from consideration, because they cannot be described by this method.

According to the Gompetz model

$$\ln \Delta F = \ln Ft - \ln F(t-1) = \beta_0 + \beta_1 \ln(\overline{F}_t(f_{n,t})) - \delta \ln F(t-1) + \varepsilon$$

where F_t is a number of adopters in the region in a year t; β_0 is an initial level of diffusion in a region; $\overline{F}$ is a maximum potential number of adopters; f_n is a number of factors, which determine $\overline{F}$; ε is an error.

The base model is

$$f_n = Income + Service\_price\_mob + Subscribers\_fix +$$
$$+ Service\_price\_fix + Mob\_phone\_price + Mob\_start +$$
$$+ \sum Social\_characteristics + \sum \text{Re}\,gional\_factors +$$

where *Income* is an average income in a region; *Service_price_mob* is a price of mobile communication services in a region; *Subscribers_fix* is a number of fixed line subscribers per capita; *Service_price_fix* – is a price of fixed lines services; *Mob_phone_price* is a price of an average mobile phone; Mob_start is a year of mobile communication diffusion.

Empirical results indicate that the Gompertz model outperforms the other models in factors determining (Kiiski, Pohjola, 2002; Wu, Wen-Lin, 2010), especially for the stages before point of inflection. In our work we will use the Gompertz model for factors revealing and Bass model for classification purposes. But for the purposes of our work it is much more important to understand the factors, which determine the saturation level (SIM-cards per capita) rather than its difference.

An ability to absorb and disseminate new technologies can be described by the rate of diffusion in long time series. The most useful indicator is mobile phones usage, or subscriptions (active SIM cards per 100 people). It is open and full data and it is hard to fabricate or mislead, because companies are interested in accurate information. All the regions are covered and Russia is one of the leading countries in this sphere (Castells, 2007; Comer, Wikle, 2008). Most of Russian regions have achieved high levels of saturation; indicator can be used for modelling using logistic curve. Theoretically, we can talk about 100% saturation on the level of 100 subscriber terminals per 100 people in the region, but in reality there is a division into "working" and '"home" phones, smartphones and communicators , etc. that leads to a further increase of the indicator.

II. Discussion of results

II.1. Major factors and classification of Russian regions on the diffusion rate

Cluster analysis of the cellular communication dynamics in Russian regions from 1999 to 2010 (Fig. 1) revealed a high degree of differentiation between the leading and the lagging regions, and also showed the presence of a large and poorly differentiated median zone. When the middle-staged regions achieved 100 % level of saturation (one phone per person) in 2006, the diffusion could be ended, but the new 'wave' of smartphones, communicators, and netbooks came, following the development of the mobile Internet, which can be an illustration for the first hypothesis.

The period from 1999-2000 is an initial phase of the diffusion process. St. Petersburg, Moscow and its suburbs are the leaders. It is the largest agglomerations. In 2003, according to the theory T. Hagerstrand diffusion process involved a larger number of regions, but concentrated primarily in the major metropolitan areas (Moscow, Samara, Novosibirsk) and coastal regions (Leningrad, Kaliningrad and Murmansk regions, Krasnodar and Primorsky Kray). In 2006, the diffusion swept rich regions of Siberia (Khanty-Mansi and Yamal-Nenets autonomous districts) and Volga (Tatarstan, Nizhny Novgorod region); most regions have reached 100 % saturation. By 2009, only in a few peripheral regions of the North Caucasus, Southern Siberia and the Far East saturation level was less than 120%. The highest value - 221 mobile phones per 100 inhabitants was typical for Moscow, St. Petersburg and Murmansk region. High saturation is common for northern regions due to the low population density and the need for regular contacts, mobile phones networks are widely used as an access to the Internet. Several Northern regions comprise the forth cluster, which were separated from the third cluster in the second half of 2000^{th}.

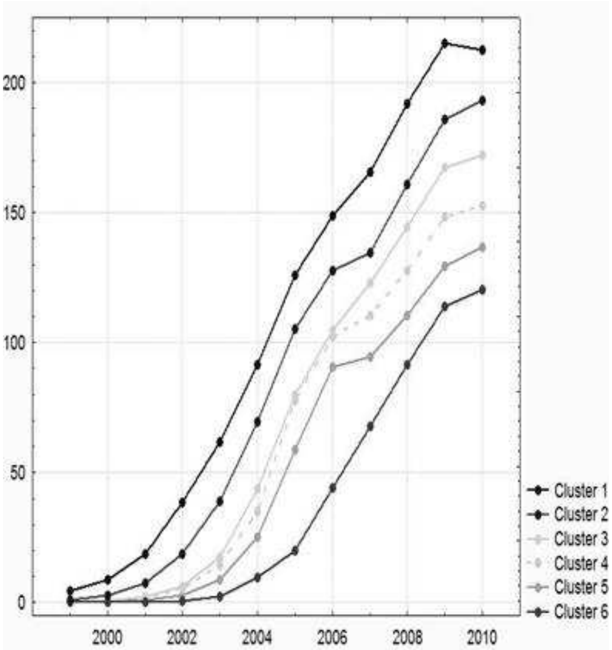

Fig. 1. Clusters of Russian regions by diffusion rate in 1999-2010.

Appendix 2 and Fig. 2 show the important factors influencing the diffusion process of cellular communication in the 2000s.

There are several indicators with the highest positive correlation, during 1998-2012: service prices for fix communication, infrastructure development, credit depts., income and education (Pearson correlation coefficient is higher than 0.5). The saturation rate of fixed communication, competition, income distribution and students' share are also important. Foreign employment, foreign investment, urbanization and share of people living in the largest agglomerations are less important factors, but can be important in several years. Many indicators are not important (Pearson correlation coefficient is less than 0.1): EGP, import per gross domestic product (GRP), population and settlement density, mobile phone price, mobile service expenditures of private companies per capita, mobile communication investment, small cities' citizens, distance to Moscow and agglomerations. The share of agriculture employees, dependence ratio and mobile service prices are highly negatively correlated with saturation of mobile communication.

According to the Fig. 1 and 2, it is possible to define the stages of spatial diffusion (by T. Hagerstrand): early adoption (1999-2000), rapid growth (2001-2005), asymptotic growth (2006-2009) and stabilization (2010-2012)[6]. Every stage has its main factors of diffusion (Appendix 2).

Most of the variables were log-transformed (except competition, EGP and Gini coefficient). Most of the regions were included, except Moscow and Leningrad region (the same indicators of diffusion as for Moscow and Saint Petersburg), Nenets, Khanty-Mansiysk, Chukotka, Yamal-Nenets autonomous regions (because of very low population density and lack of data), and the Chechen republic because of lack of data.

[6] It is a stable period for mobile phones diffusion but the diffusion of other communication devises, which can use SIM-cards and mobile networks was starting to grow. That is why it is not obvious according to Fig. 4.

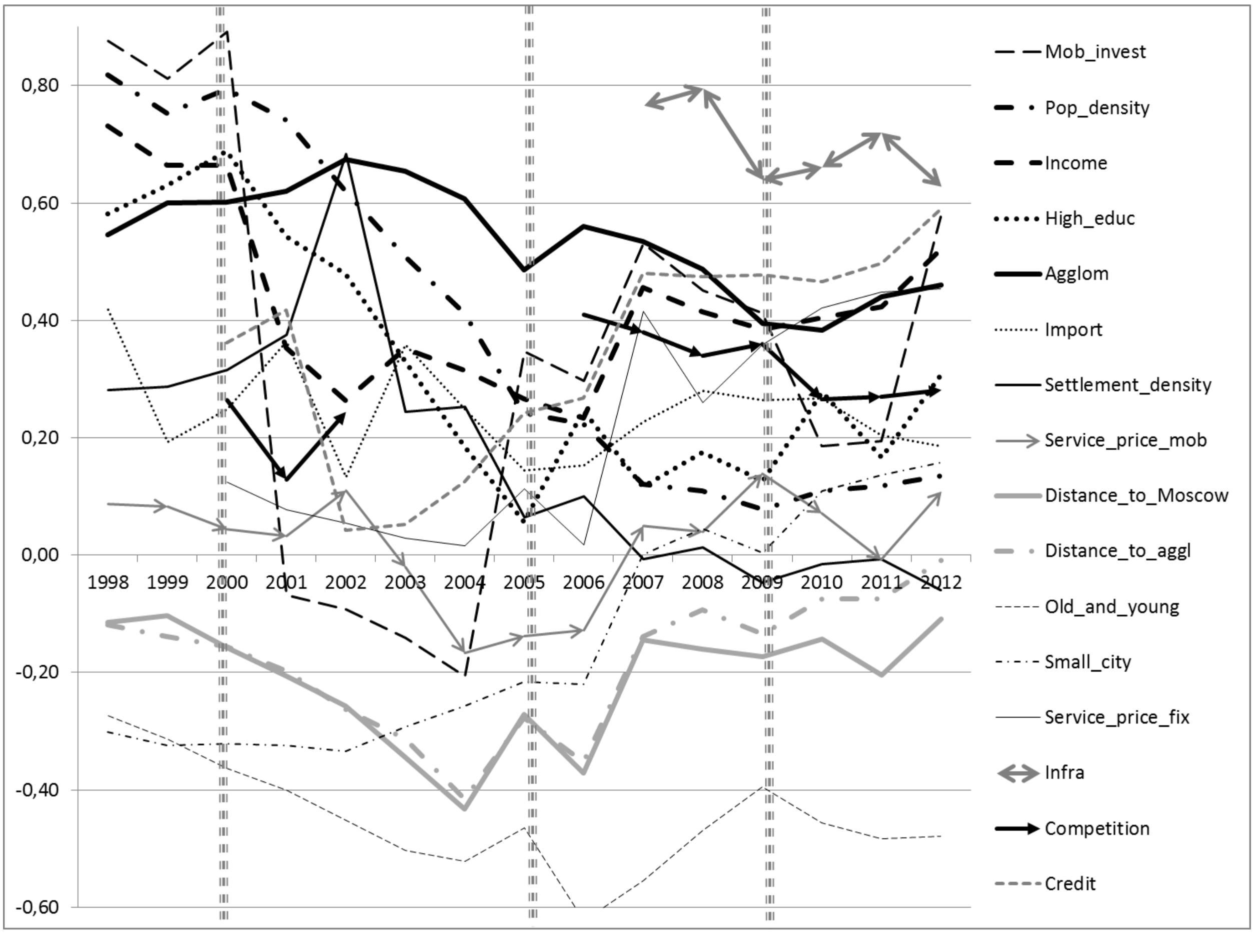

Fig. 2. Correlation between the number of subscribers per 100 inhabitants of the region in the year and several indicators

The regressions were estimated in the GRETLE program. Results of the regression analysis are in Appendixes 3-9. In the Appendixes 3 and 4 there is an estimation of Pearson correlation coefficients between mobile per capita and other variables.

The mobile saturation is a cumulative process, and in many models previous rate of the saturation is positively correlated.

On the first stage in 2000, according to OLS model, the share of fixed phones subscribers is a positive significant variable and mobile phone prices is a negative significant variable. On the initial stage in Russia, the share of foreign employees was an important factor for mobile communication diffusion; the communication was not available for the small cities' citizens. According to panel regression, income is positive significant variable, and mobile service price is negatively correlated.

On the second stage income variable prevails. It can be explained by coincide of rapid diffusion and growth of income due to the rise of oil and gas prices, which is proved in the last model, where time dummies were included, and income variable became negatively correlated. Mobile service price is also an important but negatively correlated variable. The share of fixed line subscribers is positively correlated.

On the third stage the share of fixed line subscribers is negatively correlated. Income is much less important. Proportion of employees with high education is significant positive factor.

And on the last stage the second wave of diffusion is described by negative influence of the share of fixed lines subscribers and fixed phones service prices. It is obvious that the saturation level is near maximum in most of the region, and if we include time dummies only previous saturation level will be a significant factor.

Objective of the study was to identify innovative regions of the first wave of innovation, so the resulting selection of clusters based on data up to 2006, when the new diffusion began (Fig. 6).

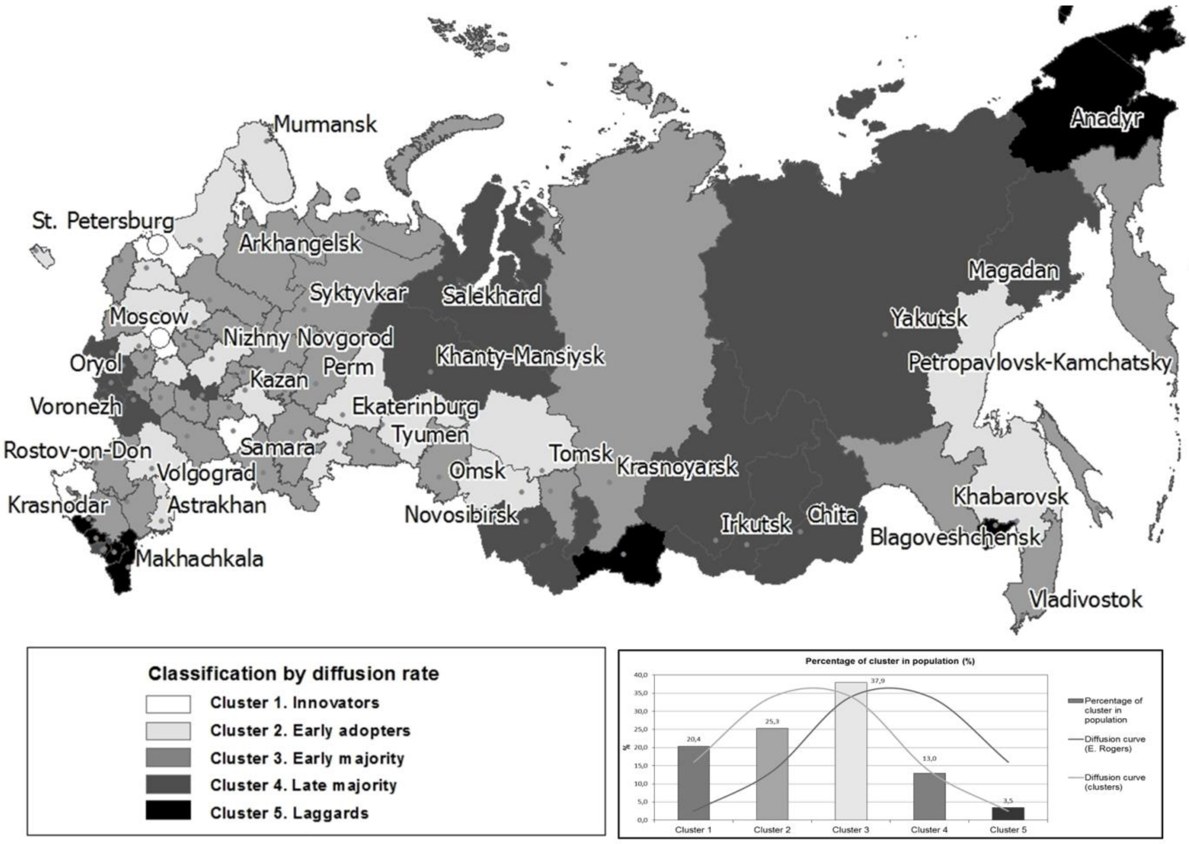

Fig. 3. Diffusion of innovation (mobile phone usage) in clusters from 1999 to 2005.

In the 1st cluster are the ‘capital’ regions. The 2nd cluster is filled by high income regions and regions with exceptional geographical position (with an agglomeration or on a border). The 3rd and 4th clusters are divided in 2006; it is quite homogeneous group of ‘middle’ regions with average values. There are some regions with low population density in the 3rd cluster; people start to use phones more actively to connect because of lack of real meetings. In both clusters there are some agglomerations. The 5th cluster is mostly represented by agrarian territories. Regions of Northern Caucasus and Far Eastern district are in the last cluster.

Five clusters correspond to stages of diffusion by E. Rogers, but with increased proportion of innovators. Russia is characterized by a high concentration of innovation capacity in several major regions. The early adopters are better educated, more literate, have higher social status and greater degree of upward social mobility, and are richer than later adopters. The same factors are common for regions with more than 1 million people agglomerations and regions on the border with European countries in comparison with others.

The approach has a drawback: the program[7] made the calculations itself, and it is difficult to control calculations and to interpret the results. Classification by the rate of absorption is important to understand regional capacity to adopt new technologies, but it does not show innovativeness of regional society as an ability to be the first in adoption. Moreover every region itself consists of Roger’s social groups.

The main critic of the method is related with underestimation of the inner properties of the process. Different factors work on different stages of diffusion, but the method can average it.

[7] For cluster analysis purposes Statistica 6.0 was used

In accordance with the stages of T. Hagerstrand diffusion model in early 2000s innovating regions' share was more than 80% (Fig. 4). Then, the number of subscribers in other regions grew faster. The share of innovating regions decreased to 29% in the 2008, the second wave of diffusion led to a slight re-growth of the first cluster share. The monotonically decreasing diffusion curve from central regions to the periphery can be constructed only for selected regions.

Proportion of regions-innovators in Russia is higher than it can be assumed according to Roger's distribution (inset in Fig. 3). The high concentration of innovators in several regions of Russia can be explained as a heritage of Soviet era, when all the spheres (including science and education) were highly centralized. After Soviet Union destruction only largest agglomerations were able to maintain high level of income, research and industrial development due to their diversity and agglomeration effects. A lot of high-qualified migrants from small cities and villages headed to the largest cities in the late 90's and in the first part of 2000[th]. Many of them were potential innovators.

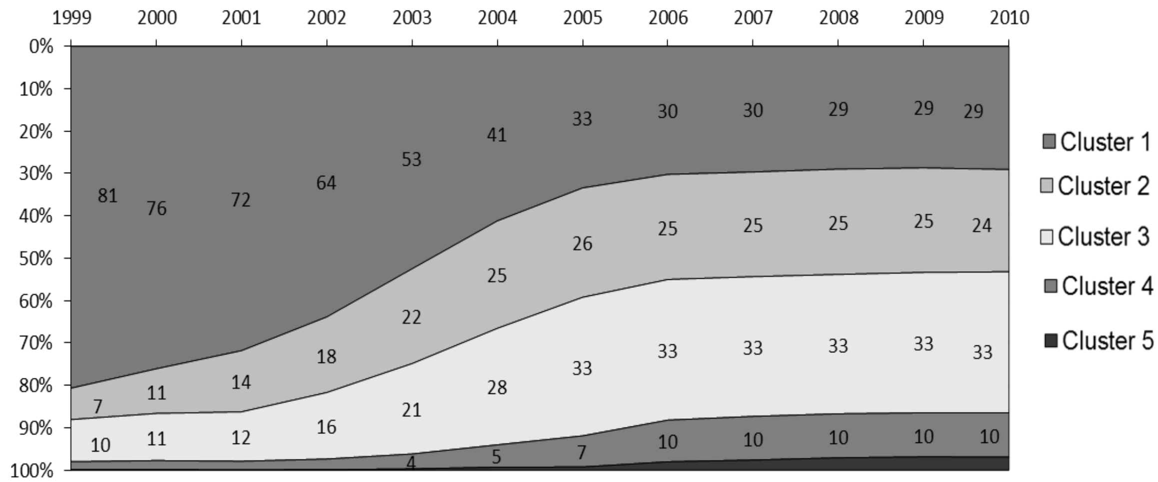

Fig. 4. Distribution of diffusion rate clusters in population

The research shows the second wave of diffusion in Russia in accordance with the first hypothesis.

II.2. Evaluation of innovators' proportion on the basis of the logistic curve

To prove the second hypothesis regions were classified based on 'innovation' and 'imitation' parameters for a diffusion function (Bass Model) on the same example of mobile diffusion.

As it was described in the methodological part of the work, diffusion process can be described by parabolic equation (Fig. 5), when the diffusion is similar to logistic curve. But in reality it is quite a rare situation.

The presented approach showed the result of linear approximation (second-degree polynomial) above 0.66. For better results, the regions with the lowest value of the approximation (R2 <0.8) were excluded from consideration. These are regions in which the diffusion of innovations realized relatively early, but then very slow for the long period of time, but after that it can reach average Russian indicators in one or two years. To explain this paradox it can be hypothesized that the diffusion between different social groups was impossible for some time, or service cost was too high. After removal of these regions overall assessment of the approximation was about 0.84.

The model can be very helpful in diagnostic and distinguish of latent factors (such as next wave of diffusion) and forecasting (determination of $\overline{F}$).

Proportions of 'innovators' (value of ***p***) and 'imitators' (value of ***q***) in total growth rate ('total adds') were established for each region to verify the model. Comparison of model and real values of total growth has led to the conclusion that our model overstates the value of the parameter *p*. The real growth in 1999 should be used for estimation of innovativeness in further calculations[8].

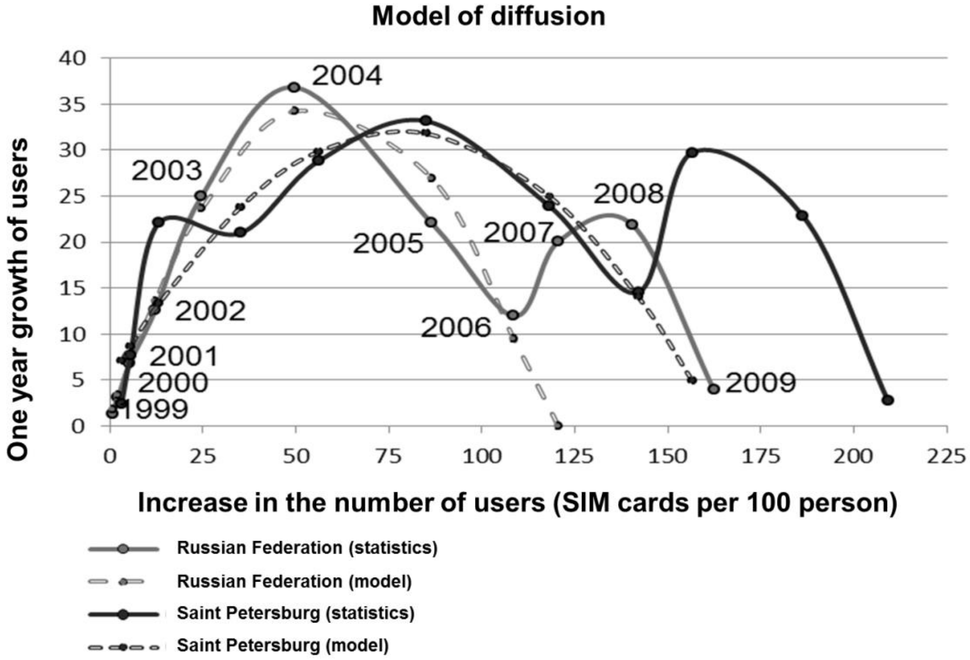

Fig. 5. Diffusion model

Cluster analysis by parameters *p* and *q* (Appendix 10) was made (Fig.6).

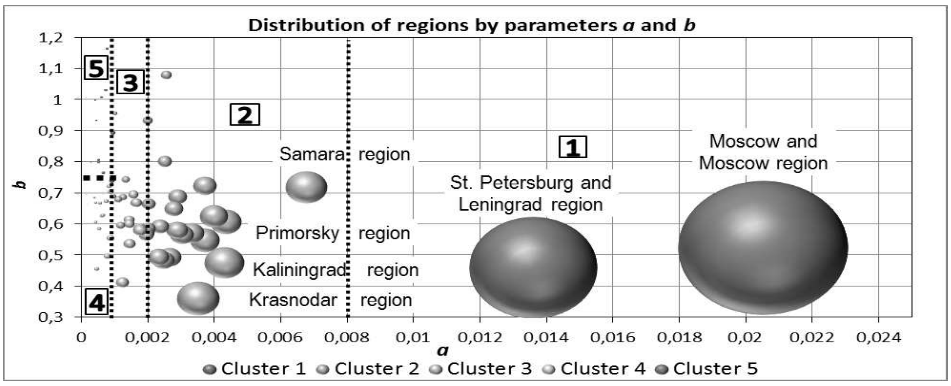

Fig. 6. Clusters of Russian regions by the degree of innovativeness of regional communities

The cluster 1 was separated by the parameter *p* (or *a*) with the value more than 0.008. It is an average value for mobile phones diffusion (Meade, Islam, 2005). The cluster consists of two Russian capitals and its suburbs. The cluster 2 was separated by an average *p* for Russian regions (0.002) and comprises regions with agglomerations and coastal regions. The cluster 3 consist of regions with the value of a more than 0.001, the clusters 4 and 5 were divided by an average for Russian regions *q* – 0.7[9]. The 5th cluster consists of agrarian and forest industry regions. Regions

[8] The author used several modifications and specifications of the Bass model for comparison. The results, which are shown on the paper have the best approximation.

[9] *q* is negatively correlated with $\bar{F}$, which is an important parameter for diffusion rate in the region. That is why region with higher *q* comprise the fourth cluster instead of third.

with p equal to zero or which cannot be approximated by the model equation are in cluster 6. It is northern and Caucasus regions.

The results are quite similar with the previous one, which can be an indicator of the proper approach (Fig. 7).

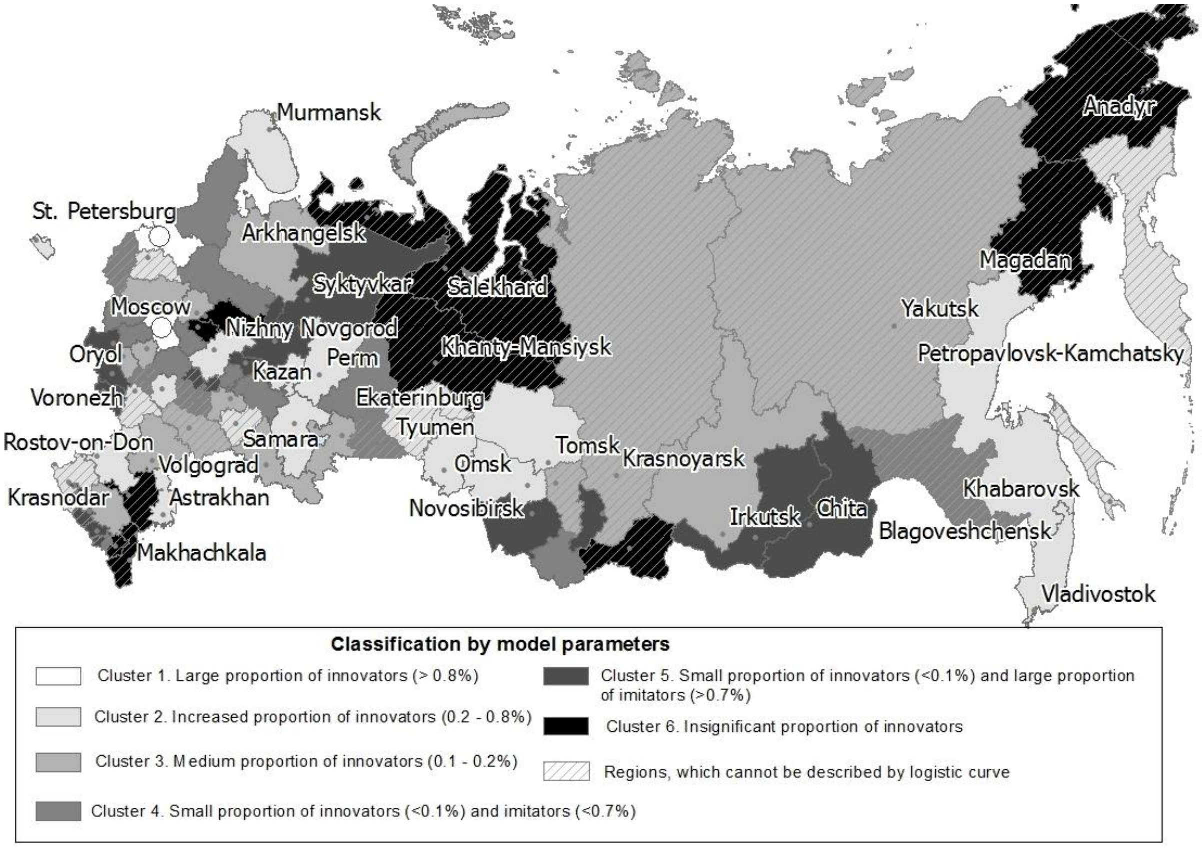

Fig. 7. Clusters of Russian regions by the degree of innovativeness of regional communities

According to the second hypothesis, most of Russian regions have lower rate of diffusion and lower proportion of innovators. Moreover, there is a great Northern and Southern periphery, where diffusion has a very strange dynamics. It is slow on the first and second stage, but can be very fast in one year. Diffusion in 40% of Russian regions (Fig. 7) cannot be described by logistic curve. Among this regions are northern regions, where the expanses for infrastructure creation are quite large, that is the one of the main explanation for their lag.

But Moscow and Saint Petersburg have higher rate of diffusion and can be considered as a global cities because they are incorporated in world innovation diffusion process as a centres of retranslation in post-Soviet countries.

III. Integral assessment of innovativeness of Russian regions

Propensity to absorb innovation can be measured by the example of the individual technologies (internet, mobile communications), but inner factors can affect the results. Hierarchical diffusion may prevail in Russia only in mobile diffusion.

For "stable" estimates of innovativeness an integral index of innovativeness was introduced, including several technologies for different years:

$$I_{INOV} = I_{M1999}^{0,25} + I_{I2009}^{0,25} + I_{MIt2012}^{0,1}$$

where I_{M1999} is the proportion of users of mobile phones in 1999, I_{I2009} is the proportion of Internet users in 2009, I_{MI2012} is the proportion of mobile Internet users in 2012[10].

[10] Data of trends.openstat.ru was used

Every indicator is a proportion of innovators by each technology. In other words, three indicators as a complex show the stable structure of early stage of diffusion in Russia in 2000th. Fig. 8 shows the distribution of regional innovativeness index. Analysis results similar to those obtained previously. But there are numbers for every region, which are average values for cluster number by three methods of the research.

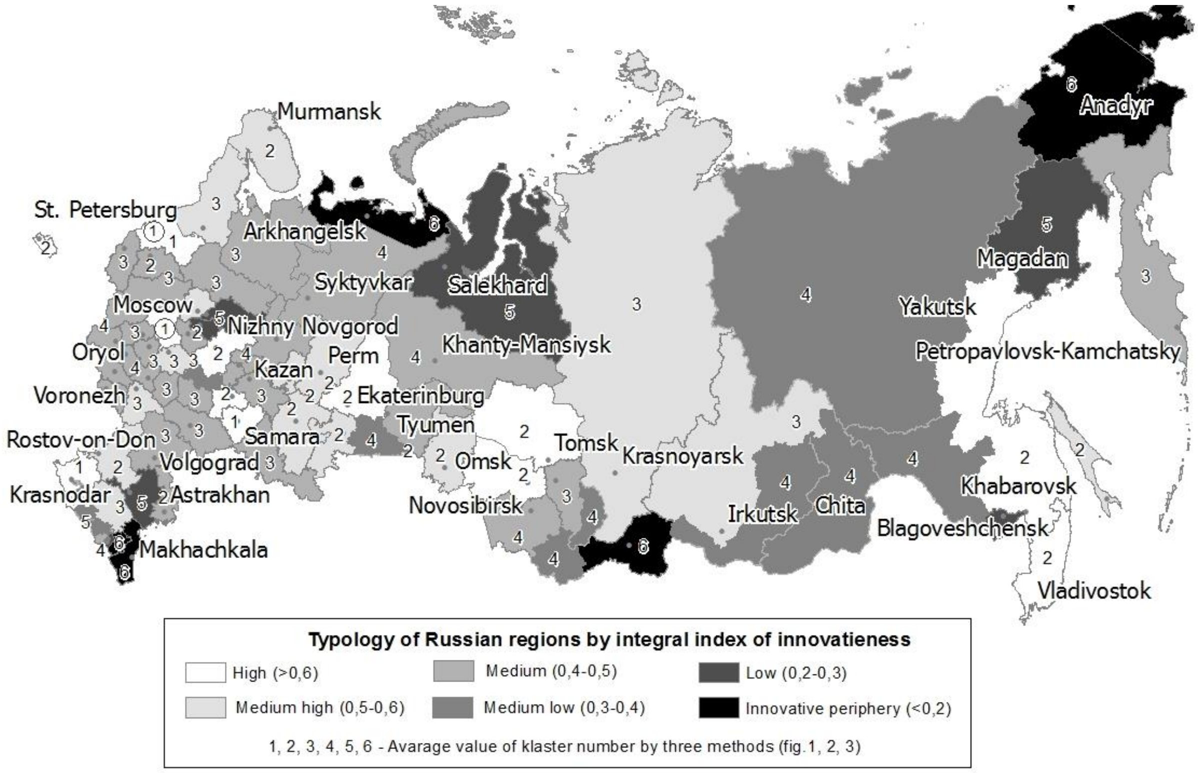

Fig. 8. Typology of Russian regions by integral index of innovativeness

According to final classification, the first cluster (number one on the scheme: Moscow, Saint Petersburg, Samara and Krasnodar regions) includes the capital city and its suburbs with high-tech sectors (IT, biotechnology) and university and scientific centres, one of the largest agglomeration (Samara) with high-tech industry (avia-, auto-industry) and coastal touristic centre (Krasnodar region)[11]. The regions have well-educated employees, high proportion of students and migrants.

The second cluster includes the regions with the largest agglomerations (Ekaterinburg, Nizhniy Novgorod, Novosibirsk, Omsk, Ufa, Chelyabinsk, and Perm), high-tech industries (Ulyanovsk, Khabarovsk (aviation), Ekaterinburg (engineering), Novosibirsk (biotechnology)), with the high proportion of students and scientific workers (Tomsk, Novosibirsk) and favorable location (Vladivostok, Rostov-on-Don). All agglomerations are centres of high populated regions.

The third cluster is the most numerous and contains very different regions with “average” diffusion indicators. There are big (Kazan, Voronezh, Volgograd) and small (Tambov, Kaluga, Pskov) cities, medium educated employees with average income from basic industries (metallurgy, electricity, chemical, etc.).

Cluster 4 consists of regions (Bryansk, Khanty-Mansiysk, Chita, Blagoveshchensk, etc.) with basic but low-technological sectors (agriculture, mining and forest industry). People have high (in oil regions) and low-average value of life.

People in cluster 5 are very conservative and traditional because of specialization of their economy on agriculture (Caucasus republics, Altay) and isolation of settlements because of

[11] Olympic Sochy is one of its coastal cities

mountains or northern distances (Chukotka, Nenetskiy okrug). Institutional factors, such as absence of urban culture, can be also used as an explanation, but it require further research.

We can speak about existence of five Russias,

Conclusion

The paper confirmed that Russian regions differ significantly on rate of diffusion, proportion of innovators and innovativeness.

The hypotheses have been proven. Rate of diffusion in most Russian regions are lower than in OECD countries. Hierarchical model of diffusion from the main centres to secondary prevails in Russia. There are several quite stable clusters of regions according E. Roger's and T. Hagerstrand's models. Centro-peripheral model can describe most of the processes in Russia.

At the initial stage, many regions have similar level of saturation (parameter ***p***), but further absorption stops in the northern regions due to the low population density, and in the southern regions because of agricultural specialization and high institutional barriers.

Russian regions are very different by their propensity to absorb new products and technologies. In the same time there are Moscow and Saint Petersburg, where ICT diffusion rate was even higher than average rate in the world, and Chukotka and Northern Caucasus, where diffusion started in the middle of 2000^{th} and the rate was significantly lower. But many regions despite the later start of diffusion could achieve relatively high level of saturation.

Diffusion of innovations should promote the equalization of regional socio-economic development (Gruber, 2001; Abraham, 2006; Bhavnani et al, 2008; Labonne, Chase, 2009; Rashid, Elder , 2009; Aker, Mbiti, 2010; Gruber, Koutroumpis, 2011), when a new technology spreading bring new jobs and improve productivity. But this situation is observed if diffusion spreads across regions with high and uniform rate. In Russia, the structure of the diffusion of innovation repeats inherited structure of the socio-economic system. Russia is so varied, that there are four or five Russias, and this space pattern is reproduced in the framework of the diffusion processes.

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Appendix

Appendix 1. Results of regressions for four stages of diffusion.

Indicator	Meaning	Time period
Dependant variable.		
Mobile_per_capita	Number of subscribers per 100 inhabitants of region in the year	1998-2012
Independent variables		
Technology characteristics		
Mob_1998	Number of mobile communication subscribers per 100 inhabitants of region in the year (F(t))	1998-2012
Mob_start	The year, when the number of adopters reach 1% saturation rate	1998-2012
Mob_previous	Number of mobile communication subscribers per 100 inhabitants in previous year (F(t-1))	1999-2012
Service_price_mob	Price of mobile communication services in a region;	1998-2012
Service_price_fix	Price of fixed lines services	2000-2012
Subscribers_fix	Number of fixed line subscribers per capita	1998-2012
Mob_phone_price	Price of an average mobile phone	1998-2012
Infra	Number of base stations per square km	1998-2012
Infra_density	Number of base stations	2007-2012
Competition	Number of providers	2000-2002; 2006-2012
Mob_expenditure	Private spending on communication services in companies, rubles. All values in constant 1999 prices	2002-2011
Mob_invest	Investment in communication sector per capita	1998-2012
Social and innovators characteristics		
Income	Income per capita, rubbles per capita. All values in constant 1999 prices.	1998-2012
Gini	Gini coefficient of income.	2001-2011
High_educ	Percentage of employed with high education, %.	1998-2012
Educ_years	Number of education years	2000-2012
Student	Number of students per 10000 citizens	1998-2012
Old_and_young	The percentage of elder (over 65) and young (less than 18) people	1998-2012
Foreign_empl	Percentage of foreign employees, %	2000; 2005-2012
Credit	Credit debt per capita	2000-2012
Agriculture	Percentage of employed in agriculture, %.	1998-2012
Regional characteristics		
EGP	Economic-geographical position (coastal and border regions)	1998-2012
Pop_density	Population density, people per km2.	1998-2012
Settlement_density	Settlement density, cities per km2.	1998-2012

Urban	Percentages of cities population, %.	1998-2012
Small_city	Percentages of small cities population (residents of cities with less than 100 thousand people), %.	1998-2012
Agglom	Percentages of large cities population (residents of cities with more than 250 thousand people), %.	1998-2012
Distance_to_aggl	Distance from regional capital to the nearest large agglomeration (more than 1 million people), km.	1998-2012
Distance_to_Moscow	Distance from regional capital to Moscow by automobile road, km.	1998-2012
Foreign_invest	Percentage of foreign investment in GRP, %	1998-2012
Import	Percentage of import in GRP, %	1998-2012

Appendix 2. Key factors affecting the diffusion of mobile communication, according its influence during 1998-2012

	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**1998-2012**
Service_price_fix			0,13	0,08	0,05	0,03	0,02	0,11	0,02	0,41	0,26	0,36	0,42	0,45	0,45	0,88
Infra										0,77	0,80	0,64	0,66	0,72	0,63	0,78
Credit			0,36	0,42	0,04	0,05	0,12	0,24	0,27	0,48	0,47	0,48	0,47	0,50	0,59	0,75
Income	0,73	0,66	0,66	0,35	0,26	0,35	0,31	0,27	0,23	0,46	0,42	0,38	0,40	0,42	0,52	0,56
Educ_years			0,60	0,56	0,44	0,45	0,36	0,24	0,47	0,36	0,37	0,30	0,49	0,42	0,49	0,54
High_educ	0,58	0,63	0,69	0,54	0,48	0,33	0,18	0,06	0,25	0,12	0,18	0,13	0,28	0,17	0,31	0,50
Subscribers_fix	0,55	0,52	0,50	0,46	0,46	0,52	0,44	0,41	0,51	0,47	0,44	0,38	0,45	0,52	0,54	0,49
Mob_previous		0,92	0,93	0,84	0,74	0,68	0,58	0,50	0,43	0,45	0,42	0,39	0,40	0,41	0,44	0,48
Competition			0,26	0,13	0,24				0,41	0,38	0,34	0,36	0,27	0,27	0,28	0,44
Gini					0,43	0,42	0,36	0,34	0,27	0,46	0,39	0,34	0,34	0,28		0,43
Student	0,74	0,74	0,67	0,70	0,66	0,56	0,45	0,39	0,52	0,44	0,34	0,27	0,26	0,28	0,30	0,42
Infra_density										0,28	0,26	0,21	0,23	0,22	0,26	0,29
Foreign_empl			0,31					-0,17	-0,26	0,05	0,16	0,16	0,26			0,17
Urban	0,40	0,45	0,44	0,43	0,46	0,51	0,51	0,45	0,55	0,74	0,71	0,62	0,66	0,71	0,54	0,15
Foreign_invest	0,48	0,29	0,04	0,28	0,12	0,01	-0,08	0,02	0,03	0,07	0,10	0,11	0,07	0,04	0,12	0,12

Appendix 3. Correlation matrix for indicators in 1999-2012

	Mob_per_capita	*Mob_previous*	*Credit*	*Service_price_fix*	*Infra*	*Income*	*Competition*	*Student*	*Mob_invest*	*Subscribers_fix*	*Foreign_empl*	*Educ_years*	*High_educ*	*Mob_expenditure*	*Foreign_invest*	*Gini*
Mob_per_capita	1,00	0,94	0,86	0,85	0,82	0,71	0,66	0,65	0,64	0,55	0,55	0,50	0,49	0,45	0,43	0,39
Agglom	0,55	0,60	0,60	0,62	0,67	0,65	0,61	0,49	0,56	0,53	0,49	0,39	0,38	0,44	0,46	0,11
Mob_1998	1,00	0,98	0,97	0,90	0,79	0,67	0,51	0,36	0,34	0,39	0,38	0,35	0,38	0,39	0,45	0,10
EGP	0,22	0,33	0,25	0,35	0,44	0,46	0,37	0,33	0,25	0,33	0,41	0,40	0,45	0,41	0,40	0,09
Import	0,42	0,19	0,25	0,36	0,13	0,36	0,25	0,14	0,15	0,23	0,28	0,26	0,27	0,20	0,19	0,07
Pop_density	0,82	0,75	0,79	0,74	0,62	0,51	0,41	0,24	0,22	0,12	0,11	0,08	0,11	0,12	0,14	0,05
Mob_phone_price	0,11	0,08	0,07	0,02	0,01	0,07	0,01	0,16	0,18	0,01	0,06	0,18	0,26	0,21	0,29	0,04
Mob_expenditure					-0,01	-0,14	-0,17	-0,23	-0,39	-0,24	-0,21	-0,20	-0,16	-0,14		0,03
Small_city	-0,30	-0,32	-0,32	-0,32	-0,33	-0,29	-0,26	-0,22	-0,22	0,00	0,05	0,00	0,11	0,14	0,16	-0,01
Settlement_density	0,28	0,29	0,32	0,38	0,68	0,24	0,25	0,06	0,10	-0,01	0,01	-0,05	-0,02	-0,01	-0,06	-0,01
Mob_invest	0,88	0,81	0,89	-0,07	-0,09	-0,14	-0,21	0,35	0,30	0,53	0,45	0,41	0,19	0,19	0,58	-0,02
Distance_to_aggl	-0,12	-0,14	-0,16	-0,20	-0,26	-0,31	-0,42	-0,28	-0,35	-0,14	-0,09	-0,14	-0,07	-0,07	-0,01	-0,03
Distance_to_Moscow	-0,11	-0,10	-0,16	-0,21	-0,26	-0,34	-0,43	-0,27	-0,37	-0,15	-0,16	-0,17	-0,14	-0,20	-0,11	-0,05
Mob_start	-0,22	-0,30	-0,31	-0,37	-0,43	-0,54	-0,58	-0,56	-0,62	-0,53	-0,46	-0,39	-0,40	-0,40	-0,42	-0,10
Agriculture	-0,35	-0,40	-0,34	-0,32	-0,33	-0,41	-0,38	-0,33	-0,24	-0,59	-0,57	-0,49	-0,47	-0,57	-0,60	-0,25
Old_and_young	-0,27	-0,31	-0,36	-0,40	-0,45	-0,50	-0,52	-0,47	-0,62	-0,55	-0,47	-0,39	-0,46	-0,48	-0,48	-0,38
Service_price_mob	0,09	0,08	0,04	0,03	0,11	-0,02	-0,17	-0,14	-0,13	0,05	0,04	0,14	0,07	-0,01	0,11	-0,69

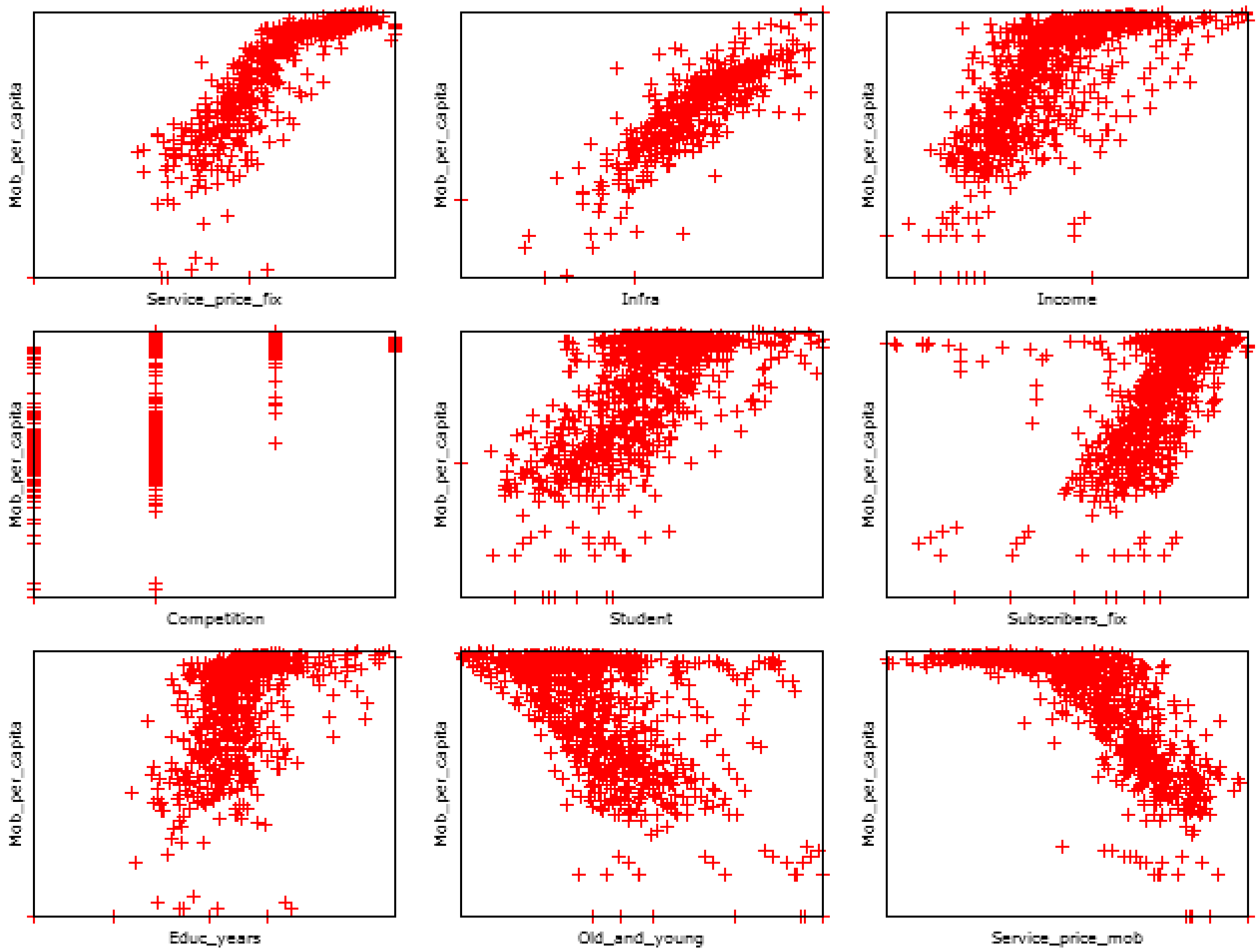
Mob_previous	0,94	1,00	0,82	0,81	0,25	0,74	0,68	0,64	0,54	0,50	0,56	0,52	0,49	0,37	0,44	0,53
Credit	0,86	0,82	1,00	0,95	0,60	0,79	0,68	0,48	0,55	0,47	0,73	0,52	0,42	0,45	0,44	0,52
Service_price_fix	0,85	0,81	0,95	1,00	0,58	0,77	0,68	0,45	0,53	0,44	0,70	0,53	0,43	0,49	0,44	0,46
Infra	0,82	0,25	0,60	0,58	1,00	0,27	0,30	0,01	0,41	0,20	0,23	0,31	0,20	0,24	0,19	0,15
Income	0,71	0,74	0,79	0,77	0,27	1,00	0,46	0,58	0,55	0,48	0,73	0,60	0,50	0,34	0,54	0,77
Competition	0,66	0,68	0,68	0,68	0,30	0,46	1,00	0,40	0,48	0,39	0,35	0,36	0,32	0,23	0,27	0,31
Student	0,65	0,64	0,48	0,45	0,01	0,58	0,40	1,00	0,48	0,54	0,42	0,53	0,56	0,18	0,26	0,53
Mob_invest	0,64	0,54	0,55	0,53	0,41	0,55	0,48	0,48	1,00	0,45	0,63	0,45	0,45	0,14	0,38	0,24
Subscribers_fix	0,55	0,50	0,47	0,44	0,20	0,48	0,39	0,54	0,45	1,00	0,45	0,29	0,19	0,15	0,41	0,29
Foreign_empl	0,55	0,56	0,73	0,70	0,23	0,73	0,35	0,42	0,63	0,45	1,00	0,43	0,25	0,16	0,50	0,48
Educ_years	0,50	0,52	0,52	0,53	0,31	0,60	0,36	0,53	0,45	0,29	0,43	1,00	0,87	0,30	0,38	0,47
High_educ	0,49	0,49	0,42	0,43	0,20	0,50	0,32	0,56	0,45	0,19	0,25	0,87	1,00	0,26	0,34	0,40
Mob_expenditure	0,45	0,37	0,45	0,49	0,24	0,34	0,23	0,18	0,14	0,15	0,16	0,30	0,26	1,00	0,30	0,17
Foreign_invest	0,43	0,44	0,44	0,44	0,19	0,54	0,27	0,26	0,38	0,41	0,50	0,38	0,34	0,30	1,00	0,32
Gini	0,39	0,53	0,52	0,46	0,15	0,77	0,31	0,53	0,24	0,29	0,48	0,47	0,40	0,17	0,32	1,00
Infra_density	0,23	0,46	-0,24	-0,08	0,30	-0,10	0,30	0,13	-0,19	0,00	-0,27	0,30	0,26	0,06	0,00	0,07
Mob_1998	0,18	0,32	0,11	0,09	0,16	0,27	0,07	0,23	0,11	0,30	0,18	0,24	0,15	0,06	0,19	0,32
Urban	0,15	0,25	0,19	0,16	0,33	0,37	0,08	0,26	0,16	0,46	0,33	0,23	0,03	0,18	0,27	0,31
Agglom	0,09	0,14	0,08	0,02	0,30	0,18	0,09	0,38	0,19	0,30	0,14	0,42	0,26	0,10	0,09	0,26
EGP	0,08	0,10	0,06	0,07	0,30	0,17	0,04	0,04	0,09	0,17	0,17	0,21	0,12	0,01	0,21	0,03

Competition	*Income*	*Infra*	*Service_price_fix*	*Credit*	*Mob_previous*	*Mob_per_capita*		*Service_price_mob*	*Old_and_young*	*Agriculture*	*Mob_start*	*Mob_phone_price*	*Distance_to_aggl*	*Distance_to_Moscow*	*Import*	*Small_city*	*Pop_density*	*Settlement_density*
0,31	0,77	0,15	0,46	0,52	0,53	0,39	*Gini*	-0,76	-0,56	-0,19	-0,18	-0,14	-0,09	-0,06	-0,05	0,00	0,02	0,03
0,30	-0,10	0,30	-0,08	-0,24	0,46	0,23	*Infra_density*	-0,70	-0,57	-0,20	-0,35	0,02	-0,23	-0,14	0,11	-0,04	0,16	0,12
0,07	0,27	0,16	0,09	0,11	0,32	0,18	*Mob_1998*	-0,70	-0,39	-0,31	-0,13	0,33	0,01	0,10	0,16	0,10	-0,19	-0,19
0,08	0,37	0,33	0,16	0,19	0,25	0,15	*Urban*	-0,73	-0,37	-0,27	-0,11	0,32	0,04	0,08	0,15	0,12	-0,15	-0,14
0,09	0,18	0,30	0,02	0,08	0,14	0,09	*Agglom*	-0,44	-0,24	-0,28	-0,12	0,20	-0,02	-0,12	0,29	0,17	-0,02	0,05
0,04	0,17	0,30	0,07	0,06	0,10	0,08	*EGP*	-0,52	-0,37	-0,49	-0,27	0,21	0,03	0,14	0,06	0,19	-0,21	-0,24
0,11	-0,24	0,05	-0,14	-0,19	0,12	0,03	*Settlement_density*	-0,67	-0,42	-0,16	-0,19	0,07	-0,26	-0,11	0,12	-0,10	0,13	0,11
0,13	-0,21	-0,02	-0,15	-0,19	0,16	0,02	*Pop_density*	-0,47	-0,53	-0,09	-0,26	-0,10	-0,25	-0,02	-0,04	-0,16	0,11	-0,01
-0,10	0,19	0,17	0,12	0,10	-0,04	0,00	*Small_city*	-0,56	-0,44	-0,21	-0,08	-0,02	-0,05	-0,02	0,04	0,09	-0,03	-0,03
0,12	0,06	0,29	0,15	0,16	0,11	-0,05	*Import*	-0,37	-0,77	-0,26	-0,38	-0,10	-0,21	-0,21	0,12	0,16	-0,04	-0,01
-0,11	0,14	-0,12	0,08	0,10	-0,14	-0,06	*Distance_to_Moscow*	-0,29	-0,35	-0,40	-0,22	0,37	0,05	0,17	0,32	0,27	-0,29	-0,27
-0,26	0,03	-0,02	0,04	0,01	-0,23	-0,09	*Distance_to_aggl*	-0,36	-0,27	-0,27	-0,17	0,30	-0,07	-0,06	0,22	-0,05	0,08	0,03
0,07	0,21	0,20	0,32	0,33	0,02	-0,14	*Mob_phone_price*	-0,45	-0,22	-0,04	-0,04	0,14	-0,06	-0,03	0,08	-0,12	0,16	0,10
-0,19	-0,27	-0,12	-0,11	-0,13	-0,35	-0,18	*Mob_start*	-0,25	-0,19	-0,15	-0,06	0,22	0,04	-0,09	0,19	0,07	-0,01	0,06
-0,16	-0,49	-0,28	-0,27	-0,31	-0,20	-0,19	*Agriculture*	-0,32	-0,32	-0,29	-0,17	0,09	-0,06	-0,05	0,24	0,10	0,02	0,07
-0,42	-0,37	-0,24	-0,37	-0,39	-0,57	-0,56	*Old_and_young*	-0,16	-0,18	-0,28	-0,32	0,36	-0,19	0,05	0,16	0,02	0,01	-0,14

Distance_to_aggl	*Distance_to_Moscow*	*Import*	*Small_city*	*Pop_density*	*Settlement_density*	*EGP*	*Agglom*	*Urban*	*Mob_1998*	*Infra_density*	*Gini*	*Foreign_invest*	*Mob_expenditure*	*High_educ*	*Educ_years*	*Foreign_empl*	*Subscribers_fix*	*Mob_invest*	*Student*
-0,19	0,05	0,16	0,02	0,01	-0,14	0,03	0,26	0,31	0,32	0,07	1,00	0,32	0,17	0,40	0,47	0,48	0,29	0,24	0,53
-0,51	-0,65	0,33	-0,25	0,95	0,90	0,10	0,23	0,07	0,26	1,00	0,07	0,00	0,06	0,26	0,30	-0,27	0,00	-0,19	0,13
-0,30	-0,06	0,17	-0,06	0,23	0,14	0,28	0,35	0,32	1,00	0,26	0,32	0,19	0,06	0,15	0,24	0,18	0,30	0,11	0,23
-0,14	-0,14	0,17	0,38	-0,01	0,06	0,27	0,53	1,00	0,32	0,07	0,31	0,27	0,18	0,03	0,23	0,33	0,46	0,16	0,26
-0,28	-0,09	0,21	-0,43	0,16	0,06	0,18	1,00	0,53	0,35	0,23	0,26	0,09	0,10	0,26	0,42	0,14	0,30	0,19	0,38
0,11	0,09	0,35	0,22	0,01	0,13	1,00	0,18	0,27	0,28	0,10	0,03	0,21	0,01	0,12	0,21	0,17	0,17	0,09	0,04
-0,40	-0,68	0,22	-0,10	0,93	1,00	0,13	0,06	0,06	0,14	0,90	-0,14	0,07	0,06	0,10	0,03	-0,27	-0,01	-0,03	-0,01
-0,53	-0,65	0,16	-0,31	1,00	0,93	0,01	0,16	-0,01	0,23	0,95	0,01	0,02	-0,01	0,16	0,08	-0,29	-0,04	-0,03	0,11
0,27	0,03	0,15	1,00	-0,31	-0,10	0,22	-0,43	0,38	-0,06	-0,25	0,02	0,10	0,07	-0,12	-0,05	0,27	0,16	0,09	-0,16
-0,09	-0,15	1,00	0,15	0,16	0,22	0,35	0,21	0,17	0,17	0,33	0,16	0,24	0,19	0,08	0,22	0,32	0,12	0,04	-0,04
0,39	1,00	-0,15	0,03	-0,65	-0,68	0,09	-0,09	-0,14	-0,06	-0,65	0,05	-0,05	-0,09	-0,03	-0,06	0,17	-0,21	-0,02	-0,02
1,00	0,39	-0,09	0,27	-0,53	-0,40	0,11	-0,28	-0,14	-0,30	-0,51	-0,19	-0,06	0,04	-0,06	-0,07	0,05	-0,21	-0,05	-0,25
0,33	0,26	0,11	0,19	-0,29	-0,25	0,13	-0,01	0,11	-0,03	-0,33	0,36	0,09	0,22	0,14	0,30	0,37	-0,10	-0,02	-0,10
0,36	0,11	-0,07	0,09	-0,12	-0,03	-0,21	-0,24	-0,46	-0,68	-0,15	-0,32	-0,17	-0,06	-0,04	-0,17	-0,22	-0,38	-0,08	-0,26
-0,15	-0,15	-0,09	-0,42	0,34	0,22	-0,33	-0,19	-0,66	-0,12	0,16	-0,28	-0,29	-0,15	-0,04	-0,27	-0,40	-0,26	-0,21	-0,09
0,40	0,49	-0,23	-0,18	-0,29	-0,33	-0,16	-0,35	-0,57	-0,34	-0,39	-0,18	-0,32	-0,19	-0,22	-0,27	-0,35	-0,77	-0,44	-0,53

Mob_phone_price	0,36	-0,33	-0,03	0,11	-0,01	0,13	-0,25	-0,29	0,19	0,11	0,26	0,33	1,00	0,12	-0,21	0,22
Mob_start	-0,32	-0,15	-0,68	-0,46	-0,24	-0,21	-0,03	-0,12	0,09	-0,07	0,11	0,36	0,12	1,00	0,23	0,42
Agriculture	-0,28	0,16	-0,12	-0,66	-0,19	-0,33	0,22	0,34	-0,42	-0,09	-0,15	-0,15	-0,21	0,23	1,00	0,20
Old_and_young	-0,18	-0,39	-0,34	-0,57	-0,35	-0,16	-0,33	-0,29	-0,18	-0,23	0,49	0,40	0,22	0,42	0,20	1,00
Service_price_mob	-0,16	-0,42	-0,02	0,04	0,00	0,02	-0,15	-0,15	0,10	0,08	0,13	0,11	0,13	0,03	0,03	0,41

Appendix 4. Connections between mobile per capita and several important variables during 1998-2012



Appendix 5. Results for OLS. Dependent variable: Mob_per_capita. 2000.

	Model 1		Model 2		Model 3	
	Coefficient	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
const	-7,64	9,91	3,40	10,02	10,85	12,96
Mob_previous	**0,49*** **	**0,13**	**0,53*** **	**0,13**	**0,37** **	**0,15**
Income	0,05	0,41	-0,26	0,43	-0,42	0,43
Subscribers_fix	**1,75*** **	**0,48**	**1,38** **	**0,55**	0,84	0,57
Mob_phone_price	**-0,39** **	**0,19**	**-0,38** **	**0,19**	**-0,31* **	**0,17**
Competition	0,01	0,21	0,00	0,21	0,22	0,19
EGP	0,05	0,44	0,10	0,36	0,54	0,55

Educ_years	1,50	3,66	-1,74	3,58	-4,33	4,41
Foreign_empl			**0,18****	**0,08**	**0,18***	**0,09**
Foreign_invest					0,06	0,07
Urban					0,60	0,89
Small_city					**-0,59****	**0,27**
Distance_to_aggl					0,12	0,14
R-squared	0,71		0,70		0,58	
Adjusted R-squared	0,68		0,66		0,48	

Significance: *** - 0.005; ** - 0.05; * - 0.1

Appendix 6. Fixed-effects. Dependent variable: Mob_per_capita. 1998-2000.Robust (HAC) standard errors

	Model 1		Model 2		Model 3	
	Coefficient	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
const	**-14,93****	**7,02**	0,1	11,05	4,69	16,47
Income	**3,27*****	**0,74**	**3,18*****	**0,68**	**3,63*****	**1,13**
Service_price_mob	**-3,49*****	**0,52**	**-2,68*****	**0,72**	**-2,55*****	**0,87**
Subscribers_fix	0,9	1,40	0,29	1,51	0,29	1,40
High_educ	-0,18	0,27	-0,15	0,28	0	0,25
Mob_phone_price			-0,77	0,67	-1,06	0,71
Pop_density			**-4,63***	**2,54**	-7,22	5,03
Foreign_invest					**0,06****	**0,03**
Student					-0,8	2,04
R-squared	0,9		0,9		0,9	
Adjusted R-squared	0,84		0,84		0,84	

Significance: *** - 0.005; ** - 0.05; * - 0.1

Appendix 7. Fixed-effects. Dependent variable: Mob_per_capita. 2001-2005. Robust (HAC) standard errors

	Model 1		Model 2		Model 3		Model 4	
	Coeff.	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**
const	**- 39,19*****	**4,18**	**- 37,82*****	**6,22**	**36,9****	**14,24**	**30,68*****	**11,02**
Income	**3,5*****	**1,23**	**1,77****	**0,75**	0,09	0,69	**-2,35*****	**0,52**
Service_price_mob	**-1,25*****	**0,26**	**-0,35***	**0,18**	-0,03	0,14	0,08	0,15
Subscribers_fix	**7,15*****	**1,67**	**5,97*****	**1,49**	**3,56*****	**1,16**	**2,71****	**1,18**
Mob_phone_price	-0,44	0,33	**-0,47***	**0,24**	-0,25	0,16	-0,22	0,18
Student			**1,95*****	**0,64**	0,12	0,45	-0,51	0,51
Mob_expenditure			**0,08****	**0,04**	**0,05***	**0,03**	0,02	0,02
Foreign_invest			0,03	0,03	0,01	0,02	0,02	0,02
Educ_years			3,73	2,32	**3,11***	**1,76**	1,7	1,68
Import			**0,12*****	**0,03**	0,02	0,02	0,02	0,03
Old_and_young					**-18,2*****	**2,83**	**-7,06***	**3,66**
dt_2							**-2,23*****	**0,54**
dt_3							**-1,37*****	**0,32**
dt_4							**-0,7*****	**0,15**
R-squared	0,84		0,92		0,95		0,96	
Adjusted R-squared	0,79		0,88		0,92		0,94	

Significance: *** - 0.005; ** - 0.05; * - 0.1

Appendix 8. Fixed-effects. Dependent variable: Mob_per_capita. 2006-2009. Robust (HAC) standard errors

	Model 1		Model 2		Model 3		Model 4	
	Coeff.	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**
const	1,03	1,13	**2,12****	**0,88**	-0,11	2,08	**4,97****	**2,44**

Income	**1,04*** **	0,11	**0,33*** **	**0,09**	**0,23*** **	**0,08**	**0,16***	**0,09**
Service_price_mob	**-0,17*** **	0,06	**-0,1** **	**0,05**	**-0,11*** **	**0,03**	-0,04	0,03
Subscribers_fix	**-0,57** **	0,27	-0,09	0,22	-0,16	0,32	-0,22	0,24
Mob_phone_price	**0,24** **	0,10	**0,23*** **	**0,09**	**0,08***	**0,05**	-0,01	0,04
Mob_previous			**0,36*** **	**0,06**	**0,32*** **	**0,08**	**0,12***	**0,06**
Infra					0,65	1,64	0,71	1,21
Foreign_invest					0,01	0,00	0	0,00
Competition					0,02	0,02	-0,02	0,01
Educ_years					**1,22** **	**0,58**	0,43	0,53
Import					0,02	0,02	**0,03***	**0,02**
Mob_expenditure					0,02	0,02	0,02	0,02
Infra_density					-0,4	1,68	-0,66	1,22
dt_2							**-0,22*** **	**0,03**
dt_3							**-0,12*** **	**0,02**
R-squared	0,8		0,88		0,96		0,97	
Adjusted R-squared	0,73		0,83		0,93		0,95	

Significance: *** - 0.005; ** - 0.05; * - 0.1

Appendix 9. Fixed-effects. Dependent variable: Mob_per_capita. 2010-2012. Robust (HAC) standard errors

	Model 1		Model 2		Model 3		Model 4	
	Coeff.	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**
const	**9,04*** **	**0,89**	**7,47*** **	**1,17**	**8,74*** **	**0,87**	**9,54*** **	**0,89**
Income	-0,04	0,09	-0,12	0,10	0,03	0,11	-0,11	0,16
Service_price_mob	**-0,09*** **	**0,03**	**-0,07***	**0,04**	0	0,02	0,01	0,02
Subscribers_fix	**-0,39*** **	**0,11**	**-0,3*** **	**0,11**	**-0,21** **	**0,11**	-0,09	0,14
Mob_phone_price	-0,04	0,05	-0,03	0,05	-0,01	0,05	-0,03	0,05
Mob_previous			0,03	0,06	**-0,14** **	**0,06**	**-0,14** **	**0,06**
Service_price_fix			**0,27***	**0,15**	**0,05***	**0,03**	0,02	0,03
Infra_1					0	0,03	-0,01	0,02
Competition					-0,01	0,01	0	0,02
dt_2							-0,02	0,02
R-squared	0,92		0,93		0,98		0,98	
Adjusted R-squared	0,87		0,88		0,96		0,96	

Significance: *** - 0.005; ** - 0.05; * - 0.1

Appendix 10. Model parameters of the logistic curve

Region	*p*	*q*	*F*	*p/q*	*p+q*	R^2	Cluster
1. St. Petersburg and the Leningrad region	0.030	0.004	163.4	0.145	0.035	0.85	1
2. Moscow and Moscow region	0.022	0.004	183.9	0.171	0.025	0.95	1
3. Primorsky Kray	0.024	0.006	144.1	0.273	0.030	0.81	1
Northwest	***0.020***	***0.006***	***143.4***	***0.312***	***0.026***	***0.94***	***1***
Central	***0.008***	***0.006***	***143.9***	***0.748***	***0.014***	***0.99***	***1***
4. Kaliningrad region	0.021	0.007	131.2	0.352	0.028	0.91	1
5. Ryazan region	0.031	0.008	119.2	0.265	0.040	0.80	1
6. Tver region	0.031	0.008	124.5	0.249	0.039	0.82	1
7. Murmansk region	0.030	0.008	130.9	0.264	0.038	0.85	1
8. Vologda region	0.029	0.008	126.1	0.281	0.037	0.87	1
9. Smolensk region	0.017	0.008	131.3	0.457	0.025	0.81	1
10. Novosibirsk region	0.014	0.008	128.2	0.539	0.022	0.97	1
11. Kaluga region	0.029	0.009	116.2	0.301	0.038	0.87	1
12. Arkhangelsk region	0.028	0.009	124.9	0.318	0.036	0.87	1
13. Kostroma region	0.034	0.010	114.4	0.294	0.044	0.80	2
14. The Republic of Karelia	0.032	0.010	116.2	0.298	0.042	0.82	2

Region	*p*	*q*	*F*	*p/q*	*p+q*	R^2	Cluster
15. Nizhny Novgorod region	0.024	0.010	120.5	0.410	0.034	0.91	2
16. Yaroslavl region	0.022	0.010	117.8	0.452	0.032	0.94	2
17. Tomsk Oblast	0.020	0.010	119.6	0.489	0.030	0.95	2
18. Komi Republic	0.017	0.010	127.6	0.606	0.028	0.91	2
19. Irkutsk region	0.011	0.010	130.9	0.903	0.020	0.90	2
20. Chelyabinsk region	0.033	0.011	122.8	0.322	0.043	0.82	2
21. Ivanovo region	0.028	0.011	114.7	0.376	0.039	0.91	2
22. The Republic of Tatarstan	0.007	0.011	113.6	1.692	0.018	0.92	2
Ural	***0.027***	***0.012***	***115.3***	***0.439***	***0.039***	***0.87***	***2***
23. Kursk region	0.017	0.014	113.7	0.824	0.032	0.93	2
24. Tula region	0.031	0.010	105.5	0.308	0.041	0.84	3
25. Vladimir region	0.029	0.010	111.6	0.352	0.040	0.88	3
26. The Republic of Buryatia	0.021	0.010	111.8	0.505	0.031	0.79	3
Siberian	***0.018***	***0.011***	***107.5***	***0.624***	***0.030***	***0.88***	***3***
27. Sverdlovsk region	0.022	0.012	109.8	0.539	0.034	0.94	3
28. The Republic of Bashkortostan	0.018	0.012	107.7	0.658	0.030	0.89	3
29. Khabarovsk Kray	0.013	0.012	112.7	0.881	0.025	0.91	3
30. Perm Kray	0.017	0.013	104.9	0.751	0.030	0.86	3
31. Ulyanovsk region	0.025	0.013	106.9	0.533	0.038	0.91	4
32. Udmurtia	0.016	0.013	104.8	0.804	0.030	0.87	4
Volga	***0.008***	***0.013***	***111.3***	***1.673***	***0.021***	***0.98***	***4***
Far East Federal District	***0.013***	***0.014***	***103.5***	***1.061***	***0.028***	***0.79***	***4***
33. Astrakhan region	0.010	0.014	112.1	1.370	0.024	0.90	4
34. Orenburg region	0.008	0.014	102.0	1.710	0.022	0.97	4
35. Orel region	0.012	0.015	107.9	1.295	0.027	0.87	4
36. Belgorod region	0.006	0.015	111.5	2.404	0.021	0.90	4
37. Kirov region	0.027	0.016	101.8	0.594	0.042	0.89	4
38. Omsk region	0.006	0.016	101.0	2.793	0.022	0.84	4
39. The Chuvash Republic	0.015	0.017	111.5	1.086	0.032	0.95	4
40. The Republic of Khakassia	0.024	0.018	104.5	0.779	0.042	0.95	4
41. Mari El Republic	0.014	0.018	112.9	1.298	0.031	0.93	4
42. Volgograd region	0.024	0.015	94.2	0.647	0.039	0.96	5
43. Tambov region	0.012	0.015	92.1	1.231	0.027	0.83	5
44. Stavropol region	0.005	0.015	96.5	2.833	0.021	0.97	5
45. Altay Kray	0.025	0.016	87.3	0.653	0.041	0.90	5
46. Rostov region	0.018	0.017	86.2	0.910	0.035	0.95	5
47. The Kabardino-Balkar Republic	0.004	0.017	75.9	4.831	0.021	0.79	5
48. Transbaikalia territory	0.024	0.018	85.4	0.716	0.042	0.90	5
49. Altai Republic	0.022	0.018	72.2	0.844	0.040	0.95	5
Southern	***0.001***	***0.018***	***90.3***	***23.083***	***0.019***	***0.98***	***5***
50. Bryansk region	0.003	0.019	98.3	7.521	0.022	0.95	5
51. Republic of Adygea	0.014	0.022	97.6	1.558	0.036	0.85	5
The Russian Federation	***0.006***	***0.010***	***117.2***	***1.610***	***0.016***	***0.96***	
Average	***0.019***	***0.012***	***113.4***	***0.994***	***0.031***	***0.89***	

Federal districts (administrative group of regions) are marked in bold italics