Montenegrin Journal of Economics

Vol. 13, No. 2 (2017), 7-24

*About One Approach for Comparing Regions of Different Countries According to the Technical Efficiency of Innovation Space**

SERGEI AIVAZIAN[1], MIKHAIL AFANASIEV[2], and ALEXANDER KUDROV[3]

[1] Professor, Central Economics and Mathematics Institute of the Russian Academy of Sciences, Russia, Moscow, aivazian@cemi.rssi.ru
[2] Professor, Central Economics and Mathematics Institute of the Russian Academy of Sciences, Russia, Moscow, miafan@cemi.rssi.ru
[3] Professor, Central Economics and Mathematics Institute of the Russian Academy of Sciences, Russia, Moscow, kovlal@inbox.ru.

ARTICLE INFO

Received December 11, 2016
Revised from February 21, 2016
Accepted May, 21 2017
Available online June 15, 2017

JEL classification:

C12, C51, R15.

DOI: 10.14254/1800-5845/2017.13-2.1

Keywords:

regional economy,
econometric modeling,
stochastic frontier,
efficiency estimation.

ABSTRACT

In the work (Aivazyan, etc., 2017) it is presented a parametric description of regional innovation systems of several countries using estimates of innovative space technical efficiency obtained by the "national" models . These estimates are comparable for regions of one country, but they are not comparable for regions of different countries. We propose an approach that allows to rank the regions of different countries according to the adjusted estimates of technical efficiency, and it maintain the ratings of regions formed on the basis of "national" models. The described approach can be used in a wide class of the evaluation problems of technical efficiency and building ratings of economic entities which are operating in different institutional conditions.

INTRODUCTION

In the paper (Ayvazyan et al., 2017), quantitative characteristics of the influence of science and business on the results of innovative activity of the subjects of the Russian Federation were obtained. In accordance such results, patents, international patent applications and developed new production technologies are considered. As a result of testing a number of hypotheses, it was established that there is a correlation between the result of innovation activity in the region and

* The work was supported by the Russian Science Foundation (project 17-18-01080)

the number of potential connections between organizations creating new knowledge and innovative active enterprises. The totality of such ties is characterized as the innovative space of the region. It is shown that the dependence of the result of innovation activity on the size of the innovation space is described by the model

$$\ln Q_i = c + \delta \ln V_i + v_i - u_i \ . \quad (1)$$

Here Q_i - The result of innovation activity in the region i (Options were considered: $Q_i = teh_i$ - Number of developed new production technologies in the region i; $Q_i = pat_i$ - Number of issued patents; $Q_i = ipat_i$ Number of international patent applications); $V_i = S_i * B_i$, where S_i - Number of organizations creating new knowledge (options were considered: $S_i = vuz_i$ - Number of higher education institutions, $S_i = ror_i$ - к Number of organizations performing scientific research); $B_i = buz_i$ - Number of enterprises in the region, c, δ - options. Value $V_i = S_i * B_i$ - The number of potential twinning relationships between organizations that create new knowledge and enterprises, which characterizes the size of the region's innovation space. The random component $v_i - u_i$ Reflects the results of the impact on the innovation process of the region of uncertainty factors and efficiency factors.

To simulate the effects of uncertainty factors, a normally distributed random variable v_i *is used* with zero mathematical expectation $v_i \in N(0, \sigma_v^2)$. To simulate the effects of efficiency factors, it is used independent of v_i nonnegative random variable u_i, having a truncated at zero normal distribution with zero mathematical expectation $u_i \in N^+(0, \sigma_u^2)$.

Models of the form (1) are constructed according to the data presented in Table 1 for the subjects of the Russian Federation, the US states (2001, 2006, 2009, 2012) and the prefectures of Japan (2001, 2006).

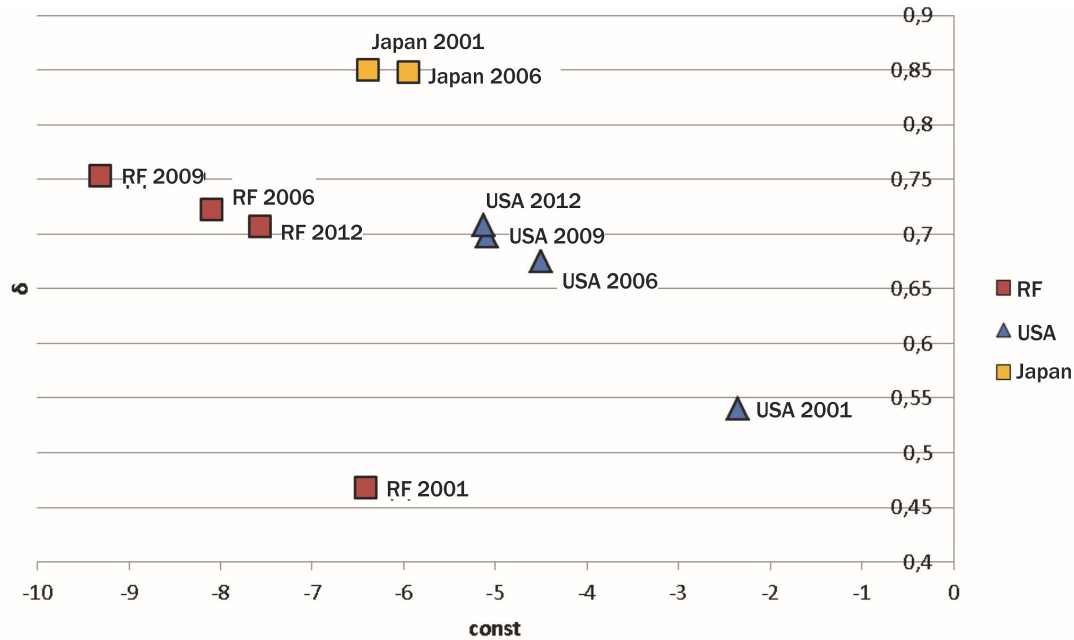
Table 1. Initial data on subjects RF, US states, and Prefectures of Japan

Designation	*Designation Indicators*	*Country*	*Source, years*
pat_i	Number of international patent applications	RF	(PCT patent applications, 2014) 2001, 2006, 2009, 2012
ror_i	Number of organizations performing scientific research	RF	(Organizations performing scientific research, 2013) 2001, 2006, 2009, 2012
vuz_i	Number of higher education institutions	RF	(Higher educational institutions, 2013) 2001, 2006, 2009, 2012
buz_i	Number of enterprises	RF	(Number of enterprises…, 2013) 2001, 2006, 2009, 2012
pat_i	Number of international patent applications	USA	(PCT patent applications, 2014) 2001, 2006, 2009, 2012
vuz_i	Number of higher education institutions	USA	(Number of institutions, 2010) 2001, 2006, 2009, 2012
buz_i	Number of enterprises	USA	(All business establishments, 2014) 2001, 2006, 2009, 2012

pat_i	Number of international patent applications	Japan	(PCT patent applications, 2014) 2001, 2006
vuz_i	Number of higher education institutions	Japan	(Number of universities, 2012) 2001, 2006
buz_i	Number of enterprises	Japan	(Number of establishments, 2014) 2001, 2006

It was concluded that the set of parameters (δ, c, t), where δ and c - The parameters of the model (1), a is the time, can be used for a parametric description of the national innovation system of the Russian Federation when it creates regions of a certain result of innovation activity. Similarly, using a model of the form (1), a parametric description of other national innovation systems can be obtained. Moreover, it is possible to compare their parametric descriptions.

Figure 1. Parametric description of the innovation systems of the Russian Federation, the United States and Japan on international patent applications for the period 2001-2012, the abscissa is the constant estimate, the y-axis is the elasticity estimate, the figure is the year.



In fig. 1 is a parametric description (δ, c, t) innovation systems of the Russian Federation, the United States and Japan on international patent applications for a number of years of the period 2001-2012. The size of the innovation space of the subjects of the Russian Federation is estimated by the number of organizations performing scientific research and enterprises. The size of the innovative space of US states and prefectures in Japan is estimated by the number of higher education institutions and companies. The abscissa indicates the constant c, on the y-axis - the elasticity estimate δ, obtained from a model of the form (1). For each point is the year. Growth in time as a constant c, and elasticity δ, testifies to the development of the national innovation system. It is easy to see that in Fig. 1, the points characterizing the innovation systems of Japan and the USA possess the property of Pareto optimality. The points characterizing the parametric description of the innovation system of the Russian Federation are not pareto-optimal. At the same time, it should be noted that the number of international patent applications filed has increased significantly in terms of the size of the innovation space for both the constituent entities of the Russian Federation and the US states.

Table 2. Estimates of the parameters of the model (1) for the subjects of the Russian Federation, the US states, the prefectures of Japan and the general model according to 2006 data.

	Model M_1: Subjects of the RF	*Model M_2: US states*	*Model M_3: Prefectures of Japan*	*Model M_0: general model*
	(1)	(2)	(3)	(4)
V	0.722*** (0.000)	0,676*** (0.000)	0,848*** (0.000)	1.126*** (0.000)
const	−8.102*** (0.000)	-4,504*** (0.004)	-5,949*** (0.003)	-12.242*** (0.000)
Log likely	−112.531	-65,566	-75,151	-357.390
sigma_v	0.255	0,875	0,903	1.801
sigma_u	1.759	0,010	1,322	.0706

Note. In this table and below, the symbols "*", "**", "***" denote estimates at 10-, 5-, and 1% significance levels, respectively.

Table 2 presents estimates of the parameters of a model of the form (1) constructed from the data of 2006. For 80 subjects of the Russian Federation (column 1), 51 states of the USA (column 2), 47 prefectures of Japan (column 3) and a general model for 178 regions (column 4). The size of the innovative space of the subjects of the Russian Federation is estimated by the number of higher educational institutions and enterprises. The size of the innovative space of US states and prefectures in Japan is estimated by the number of higher education institutions and companies.

1. PROBLEMS OF COMPARISON OF INNOVATIVE ACTIVITY OF REGIONS DIFFERENT COUNTRIES

With the estimated parameters σ_v^2, σ_u^2 Models (1) can be calculated (Battese, Coelli, 1988) mathematical expectation $TE_i = E(e^{-u_i} \mid v_i - u_i) = \dfrac{\Phi(\tilde{\mu}_i / \sigma_* - \sigma_*)}{\Phi(\tilde{\mu}_i / \sigma_*)} \exp\{\frac{1}{2}\sigma_*^2 - \tilde{\mu}_i\}$,

где $\tilde{\mu}_{it} = -(v_i - u_i)\sigma_u^2 / \sigma^2$, $\sigma_*^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

In accordance with the concept of the stochastic boundary (Kumbhakar, Lovell, 2004), the value characterizes the expected value of the technical efficiency of the innovation space of the region as a ratio of the actual result of innovation activity in the region $\exp\{c + \delta \ln V_i + v_i - u_i\}$ to the potential $\exp\{c + \delta \ln V_i + v_i\}$. That is, $TE_i = E(e^{-u_i} \mid v_i - u_i)$. Set of four parameters (δ, c, t, TE_i) Can be used to describe a regional innovation system. The latter parameter is of particular interest, since the evaluation of technical efficiency can be considered as a characteristic of the quality of management of a regional innovation system. At the same time, a direct comparison of different regional innovation systems functioning within the framework of a common national innovation system for a fixed time is allowed, since in this case the technical efficiency estimates obtained on the basis of one model are comparable.

For a parametric description of regional innovation systems of different countries, it is appropriate to use different models of the form (1). Each such model allows to obtain estimates of the parameters of the national innovation system and comparable estimated of the technical efficiency of innovation space in different regions of the same country. These economic entities have the property of homogeneity in the sense that they create innovative products in the general institutional environment formed by the state. Estimates of technical efficiency of regions of different countries, obtained using different models of the form (1), are not comparable, since they are relative. Therefore, comparing the estimates obtained for different models of the form (1), each of which characterizes the set of regions of a particular national innovation system, is generally not permissible.

In column 6 of Table A1 of the appendix, it is presented the technical efficiency estimates obtained for the model of form (1) independently for regions of the Russian Federation, US states and prefectures of Japan according to the data concerning international patent applications of 2006 year. The first 80 values of the technical efficiency estimates in the column 6 are obtained using the model M_1 estimated only for the regions of the Russian Federation, the following 51 – using the model M_2 estimated only for the US states, the following 47 – using the model M_3 estimated only for the prefectures of Japan. Each value of the technical efficiency estimates in column 6 corresponds to the region whose name is indicated in column 2 of this table. Column 1 shows the region's ordinal number in the list of regions of the country. In column 7, the rank of the technical efficiency rating in the sequence of estimates for the regions of the given country (the value of the rank increases with the decrease of technical efficiency). For example, the estimate of the technical efficiency of the innovative space for Bryansk region (the regional serial number in the total 80 regions of the Russian Federation is 2) when creating international patent applications, obtained from the model M_1 estimated for the Russian Federation regions using the data for 2006 year, is 0.41713. The rank of this estimate in the ranking for 80 regions of the Russian Federation is 36. The evaluation of the technical efficiency of the innovation space for the US state Alabama (the serial number of the region in the total 51 US states is 1) when creating international patent applications, obtained by the model M_2 estimated for US states using the data for 2006 year, is 0.99171. The rank of this estimate in the US state ranking is 18.

Figure. 2. Technical efficiency estimates obtained independently for the RF regions (left), US states (in the middle), and prefectures of Japan (right). The regions of each country are ordered in ascending order of their sequence numbers (the abscissa axis). On the ordinate axis - the values of technical efficiency estimates.

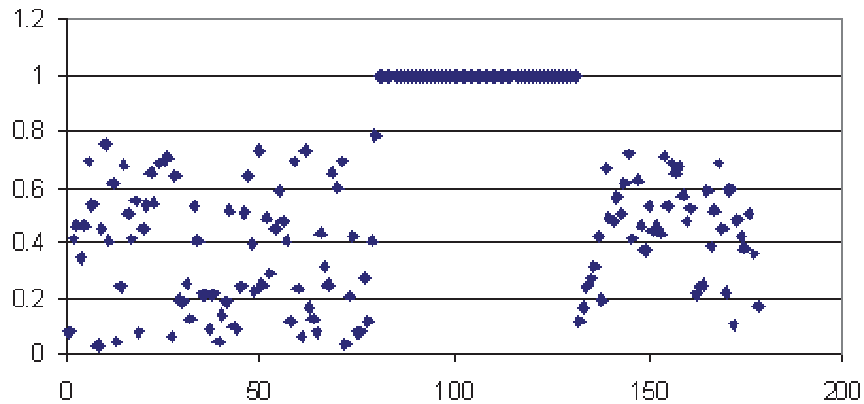
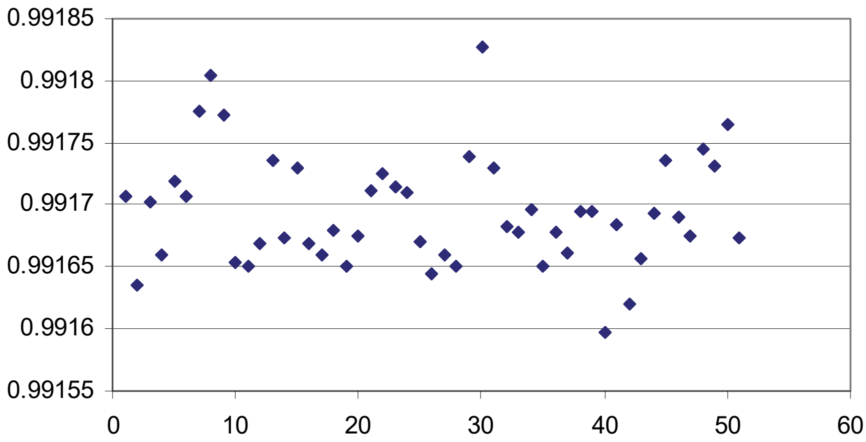


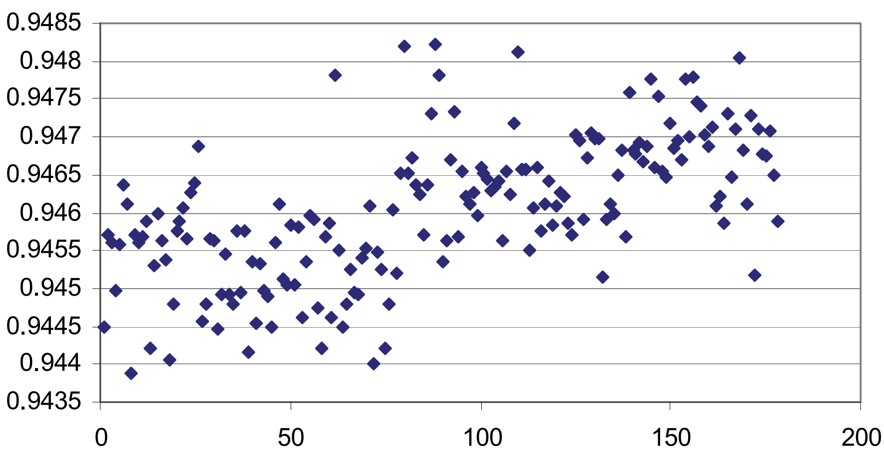
Figure 3. Assessing the technical efficiency of the innovation space of US states. The states are ordered in ascending order of their ordinal numbers (the abscissa axis).



In total, column 6 of Table P1 contains 178 (80 + 51 + 47) technical efficiency ratings. They are taught in three different models of the form (1) and their direct comparison is not correlated. Looking at Fig. 2 we can assume that the technical efficiency of the innovation space of any US state is higher than that of any prefecture in Japan and any region of the Russian Federation, but this is not true, since estimates obtained by different models are not comparable.

Another mistake may be the assumption that all US states are equally effective. However, an analysis of estimates with a higher level of accuracy of their values, as shown in Fig. 3, allows you to rank the regions in terms of efficiency level. In the works of the authors (Aivazyan et al., 2016, Aivazyan, Afanasyev, 2015, 2016) it was shown that the specification of model (1) and residual distribution functions can have a significant effect on the values of technical efficiency estimates. In this case, the ranks of these estimates have the property of resistance to the specification of the mode. It is quite natural to be able to compare the regions of different countries on the basis of technical efficiency estimates obtained from a common model for the whole region of the model M_0 of the form (1). The technical efficiency estimates obtained in this way are shown in Fig. 4.

Figure 4. Technical efficiency assessments obtained from the general model for the regions of the Russian Federation (left), the US states (in the middle), and the prefectures of Japan (right). Regions of each country are ordered by increasing their serial numbers (the same as in Figure 2).



Such assessments of technical efficiency are comparable and can be used to compare regions. But the general model M_0 does not have a satisfactory economic interpretation, because it unites economic entities that actually operate under different institutional conditions. At the same time, the grades of the region's estimates of any country, obtained in two ways: by the general model and the "national" model, can differ substantially. In column 3 of Table P1, technical efficiency estimates are presented for all 178 regions of the three countries, obtained from the general model M_0. In column 4, the ranks of these ratings are in the ranking of the entire aggregate of 178 regions. In column 5, the ranks of these estimates are in the ranking of the regions of each country. For example, an assessment of the technical efficiency of the innovation space of the Bryansk region in the general model M_0, Estimated for 178 regions of the three countries according to 2006, is equal to 0.94571. The rank in the rating of 178 regions of the Russian Federation, the United States and Japan is equal to 114. The rank of this rating in the rating of 80 regions of the Russian Federation is 25. Evaluation of the technical efficiency of the innovation space of the US state Ala-bama by the general model M_0 is equal to 0.94651. The rank in the rating of 178 regions of the Russian Federation, the United States and Japan is 58. The rank of this rating in the rating of the US states is equal to 22. The technical efficiency estimates obtained by the general model differ from the estimates of technical efficiency. Obtained by "national" models. The grades of these grades differ, moreover, the difference in ranks can be significant.

Table 3. Spearman's rank enumeration coefficients

	Subjects of the RF	*US states*	*Prefectures of Japan*
Number of regions	80	51	47
Coefficient of Spearman's rank Correlation	0.7206	0.5846	0.9528

In Table 3, for each country, Spearman's rank correlation coefficients of the regional technical efficiency estimates are presented for the general and "national" model. For Japan prefectures, grades of assessments vary slightly, for US states, changes in grades are significant. It can be concluded that the transition from "national" models of the form (1) to the general model M_0 allows to ensure comparability of estimates, but leads to a distortion of their ranks. The task is to ensure comparability of technical efficiency estimates for regions of different countries in such a way that the ranks of these estimates are equal to the ranks of the estimates obtained from the "national" models. To solve this problem, the method of adjusting the technical efficiency estimates obtained from the general model described in the next section can be used.

2. METHOD OF ADJUSTING THE TECHNICAL EFFICIENCY ESTIMATES TO COMPARABLE FORM.

In this section, it is presented a description of the method which is capable to bring the estimates of the technical efficiency of the innovative space of regions from several countries to a comparable type. We proceed from the premise that a "national" model can be built for each country separately, which makes it possible to obtain estimates of the technical efficiency of the innovation space of the regions from given country. However, the efficiency estimates obtained by the "national" models are not comparable. We get the comparable efficiency estimates from the model, which is common to the whole set of considered regions from different countries. The method described below makes it possible to adjust these comparable estimates so that the inferred ratings of regions from each country coincides with the rating of regions constructed according to the "national" model.

The proposed approach provides with the adjusted estimates of technical efficiency using the solution of the optimization problem. We compare the regions from the n countries. For each country $s, s = 1,...,n$ ($n \geq 2$) it is available the information on the results of innovation activity, the characteristics of science and business for the assessing the size of the innovation space in each region $i_s, i = 1,...,m_s$, from the country s. The comparable estimates of technical efficiency $x^s_{i_s}, i_s = 1,...,m_s, s = 1,...,n$ could be obtained as a result of solving the optimization problem on maximizing the Spearman rank correlation coefficient of the sought corrected technical efficiency estimates $x^s_{i_s}, i_s = 1,...,m_s, s = 1,...,n$ and the technical efficiency estimates $\left\{(TE^s_{i_s})_{M_0}\right\}^{m_s,n}_{i_s=1,s=1}$, obtained from the general model M_0 under the conditions that for each country s, $s = 1,...,$ n Spearman's rank correlation coefficient of the sought technical efficiency estimates $x^s_{i_s}, i_s = 1,...,m_s$ and technical efficiency estimates $\left\{(TE^s_{i_s})_{M_s}\right\}^{m_s}_{i_s=1}$, obtained from the "national" model M_s, equals to 1. The corresponding optimization problem is formalized as follows:

$$spcor(\{x^s_{i_s}\}^s_{i_s}, \{(TE^s_{i_s})_{M_0}\}^s_{i_s}) \rightarrow \max \qquad (2)$$

$$spcor(\{x^s_{i_s}\}_{i_s}, \{(TE^s_{i_s})_{M_s}\}_{i_s}) = 1, \; s = 1,...,n, \qquad (3)$$

where $spcor(\psi, \zeta)$ - the Spearman rank correlation coefficient for the series ψ and ζ (comparable quantitative indicators).

The conditions in the above optimization problem ensure that the grades of the sought corrected technical efficiency estimates coincide with the ranks of the technical efficiency estimates obtained from the "national" models M_s. The objective function makes it possible to bring the ranks of the scaled-up estimations to the maximum correspondence with the ranks of the technical efficiency estimates obtained by the general model M_0. Despite the simple form and compactness (the number of restrictions is equal to the number of countries) of the optimization problem (2-3), the use of unknown quantities as arguments of the Spearman rank correlation coefficient lead to computational difficulties. In the following it is presented an approach, which allows to transform the problem (2-3) to the optimization model of a quadratic objective function with linear constraints.

3. DESCRIPTION OF THE APPROACH

1. For each country s it is estimated the model M_s which has the form (1) and determines the dependence structure of the result of innovation activity on the size of the innovation space for

all m_s regions of the considered country s. We get the parameters of the model M_s.

2. For each region $i_s, i = 1,...,m_s$, from the country s it is estimated the innovative space efficiency $(TE^s_{i_s})_{M_s}$.
3. The estimates $(TE^s_{i_s})_{M_s}$ are sorted in descending order in the set $\left\{(TE^s_{i_s})_{M_s}\right\}_{i_s=1}^{m_s}$. We get the rank $(R^s_{i_s})_{M_s}$ of the technical efficiency $(TE^s_{i_s})_{M_s}, 1 \le (R^s_{i_s})_{M_s} \le m_s$. In the following we will denote each rank $r_s, 1 \le r_s \le m_s$, together with its correspondent region number as follows: $i_s(r_s)$, which means that the region i_s has rank r_s in the sequence $(TE^s_{i_s})_{M_s}$.
4. A common model M_0 of the form (1) for the regions from all countries is estimated, which determines the dependence of the result of innovation activity on the size of the innovation space for all $m, m = \sum_{s=1}^{n} m_s$ regions. We get the parameters of the model M_0.
5. For each region $i_s, i_s = 1,...,m_s, s = 1,...,n$, from the model M_0 it is inferred the technical efficiency of the innovative space for each region $(TE^s_{i_s})_{M_0}$.
6. The estimations $(TE^s_{i_s})_{M_0}$ are sorted in descending order in the set $\left\{(TE^s_{i_s})_{M_0}\right\}_{i_s=1,s=1}^{m_s,n}$. We get the rank $(R^{0s}_{i_s})_{M_0}$ of the technical efficiency $(TE^s_{i_s})_{M_0}, 1 \le (R^{0s}_{i_s})_{M_0} \le m$.
7. For each $s, s = 1,..., n$ the estimations $(TE^s_{i_s})_{M_0}$ are sorted in descending order in the set $\left\{(TE^s_{i_s})_{M_0}\right\}_{i_s=1}^{m_s}$. We get the rank $(R^s_{i_s})_{M_0}$ of the technical efficiency $(TE^s_{i_s})_{M_0}$, $1 \le (R^s_{i_s})_{M_0} \le m_s$.
8. The required comparable and corrected technical efficiency estimates $(x^s_{i_s})_{M_x}, i_s = 1,...,m_s, s = 1,...,n$ can be obtained from the following optimization problem M_x:

Problem M_x [1]:

target function

$$\sum_{s=1}^{n}\sum_{i_s=1}^{m_s}(x^s_{i_s} - (TE^s_{i_s})_{M_0})^2 \to \min,$$

constraints

[1] M_x is a minimization problem with a strictly convex objective function and linear constraints. The model has m parameters (m - the total number of regions) and $m-n$ constraints (n - the number of countries). The set of admissible solutions is not empty, there is a unique optimum.

$$x^s_{i_s(r_s)} \geq x^s_{i_s(r_s+1)} + eps,\ r = 1,...,m_s - 1, s = 1,...,n.$$

9. We get the solution $\left\{(\hat{x}^s_{i_s})_{M_x}\right\}^{m_s,n}_{i_s=1,s=1}$ of the problem M_x.

10. The estimates $(\hat{x}^s_{i_s})_{M_x}$ are sorted in descending order in the set $\left\{(\hat{x}^s_{i_s})_{M_x}\right\}^{m_s,n}_{i_s=1,s=1}$. For each region $i_s, i_s = 1,...,m_s, s = 1,...,n$, we get the rank $(R^{0s}_{i_s})_{M_x}, 1 \leq (R^{0s}_{i_s})_{M_x} \leq m$ of the $(\hat{x}^s_{i_s})_{M_x}$.

The ranks $(R^{0s}_{i_s})_{M_x}, 1 \leq (R^{0s}_{i_s})_{M_x} \leq m$ are used for comparison of the regions from different countries in terms of the technical efficiency of the innovation space.

4. THE PROPERTY OF THE ADJUSTED TECHNICAL EFFICIENCY ESTIMATES.

For each country s we order the estimates $(\hat{x}^s_{i_s})_{M_x}$ in descending order in the set $\left\{(\hat{x}^s_{i_s})_{M_x}\right\}^{m_s}_{i_s=1}$. For each region $i_s, i_s = 1,...,m_s$, we find a rank $(R^s_{i_s})_{M_x}, 1 \leq (R^s_{i_s})_{M_x} \leq m_s$ in the sequence $\left\{(\hat{x}^s_{i_s})_{M_x}\right\}^{m_s}_{i_s=1}$. For any positive eps from the condition $x^s_{i_s(r_s)} \geq x^s_{i_s(r_s+1)} + eps$, $r_s = 1,...,m_s$ it follows: $(R^s_{i_s})_{M_x} = (R^s_{i_s})_{M_s}$. That is, the rank $(R^s_{i_s})_{M_x}$ of the estimate $(\hat{x}^s_{i_s})_{M_x}$ equals to the rank $(R^s_{i_s})_{M_s}$ of the estimate $(TE^s_{i_s})_{M_s}$. The estimates $(\hat{x}^s_{i_s})_{M_x}$ have the same order in the set of the estimates for only one country as the estimates $(TE^s_{i_s})_{M_s}$, obtained from the model M_s. So that, for $eps > 0$ from the condition $x^s_{i_s(r_s)} \geq x^s_{i_s(r_s+1)} + eps$, $r_s = 1,...,m_s$ it follows $spcor(\{(\hat{x}^s_{i_s})_{M_x}\}_{i_s}, \{(TE^s_{i_s})_{M_s}\}_{i_s}) = 1$.

If $eps = 0$, some estimates $(\hat{x}^s_{i_s})_{M_x}$ may coincide. In this case when all constraints of the problem M_x are fulfilled, it isn't necessarily that the following equality $spcor(\{(\hat{x}^s_{i_s})_{M_x}\}_{i_s}, \{(TE^s_{i_s})_{M_s}\}_{i_s}) = 1$ fulfills. That's why in the problem M_x we require that $eps > 0$.

However, with the growth of eps the value of the target function (2) $spcor(\{(\hat{x}^s_{i_s})_{M_x}\}_{i_s}, \{(TE^{0s}_{i_s})_{M_s}\}^s_{i_s})$ doesn't increase.

Table 4. Spearman's correlation matrix for the ranks of technical efficiency estimates.

	$(R_{i_s}^s)_{M_x}, eps=0$	$(R_{i_s}^s)_{M_x}, eps=10^{-6}$	$(R_{i_s}^s)_{M_x}, eps=10^{-5}$	$(R_{i_s}^s)_{M_x}, eps=10^{-4}$	$(R_{i_s}^s)_{M_x}, eps=10^{-3}$	$(R_{i_s}^{0s})_{M_0}$
$(R_{i_s}^s)_{M_x}, eps=0$	1	0.9984148	0.998191	0.784786	0.602593	0.908225
$(R_{i_s}^s)_{M_x}, eps=10^{-6}$	0.998414	1	0.99993	0.788331	0.605083	0.905693
$(R_{i_s}^s)_{M_x}, eps=10^{-5}$	0.998191	0.999929	1	0.789761	0.606683	0.904778
$(R_{i_s}^s)_{M_x}, eps=10^{-4}$	0.784785	0.788330	0.789761	1	0.959239	0.677618
$(R_{i_s}^s)_{M_x}, eps=10^{-3}$	0.602593	0.605082	0.606683	0.959239	1	0.505578
$(R_{i_s}^{0s})_{M_0}$	0.908224	0.905692	0.904778	0.677618	0.505578	1

As it is shown in the last line of Table 4, the Spearman coefficient for the ranks of estimates obtained from the model M_0 and estimates obtained from the problem M_x decreases from the value 0.905692 with $eps = 10^{-6}$ to the value 0.505578 with $eps = 10^{-3}$. The ranks of the estimates, obtained with $eps = 10^{-6}$, are reported in the column 10 Table A1 (see Appendix). For the values eps from the interval $(0, 10^{-5})$ the Spearman's coefficient differs from its maximal value 0.908224 by less than one percent. Therefore, taking eps as sufficiently small value, we get the ranks of the estimates, obtained from the model M_x, for which the Spearman's correlation with the estimates from the model M_0, as closely as necessary to the maximum value.

CONCLUSION

In this paper it is presented a method for obtaining comparable estimates of the technical efficiency of the innovation space in the regions from several countries. These estimates are obtained as a result of adjusting the technical efficiency estimates obtained on the basis of a model common to the whole set of regions, which determines the dependence of the innovation activity result of the region on the size of its innovation space. The construction of a general model for obtaining comparable estimates of technical efficiency is entirely natural. However, the ranks of the estimates of the regions of a particular country obtained by it do not necessarily correspond to the ranks of the estimates obtained from the "national" model used to compare the regions of that country separately. In addition, the general model, as a rule, does not have a satisfactory economic interpretation, since the innovative activity of the regions of different countries is conditioned by different institutional conditions. These drawbacks of the estimates obtained by the general model require their correction.

The proposed method of adjusting allows, solving the problem M_x and taking any positive values for the parameter eps, to obtain comparable estimates $(\hat{x}_{i_s}^s)_{M_x}$, the ranks of which $(R_{i_s}^s)_{M_x}$ correspond to the ranks $(R_{i_s}^s)_{M_s}$ of estimates obtained by "national" models M_s. With a sufficiently small positive value of the parameter eps, the ranks $(R_{i_s}^s)_{M_x}$ correspond at the maximal extent to the ranks $(R_{i_s}^{0s})_{M_0}$ of the technical efficiency estimates obtained from a common model M_0 estimated from the data for the whole set of regions . The ranks $(R_{i_s}^s)_{M_x}$ of the estimates, corrected with the use of the above mentioned optimization problem M_x , allow comparing regions of different countries according to the technical efficiency of innovation space.

This approach can be used in a wide variety of problems of assessing technical efficiency and constructing ratings of economic entities operating under different institutional conditions. On its basis it is possible to rank objects belonging to different groups of generality in the case when theoretically justified comparison of them can be performed only within each group. To rank the entire set of objects, we need estimates obtained from a common model for all objects. These estimates, like the general model, do not need to have a rigorous theoretical justification. However, they must conform to the general principle of comparison used for objects within groups. When ranking the entire set of objects using the proposed optimization problem with a quadratic objective function and linear constraints, corrections are made to estimates obtained by the general model to ensure that their ranks correspond to the ranking results of objects obtained from group models.

REFERENCES

Aivazyan, S., Afanasyev, M., (2015), Assessment of Innovative Activity of Regions in the Russian Federation, *Montenegrin Journal of Economics*, Vol. 11, No. 1, 7-21. показатели, 2013г. URL: http://www.gks.ru/bgd/regl/b14_14p/IssWWW.exe/Stg/ d02/12-01.htm (дата обращения: июнь 2015).

Ayvazyan, S. A., Afanas'yev, M. Yu., Lysenkova M. A. (2016), “Otsenka rezul'tatov innovatsi-onnoy aktivnosti regiona s uchetom razmera prostranstva innovatsiy. Analiz i mode-lirovaniye ekonomicheskikh i sotsial'nykh protsessov”, *Matematika. Komp'yuter. Obra-zovaniye*: *Sb. nauchn. Trudov,* vypusk 23, No. 4, M., Izhevsk: NITS «Regulyarnaya i khaoti-cheskaya dinamika», s. 94-115.

Aivazyan, S., Afanasyev, M. (2016), “The Size of Innovation Space as a Factor of Innovation Activity in Regions”, *Montenegrin Journal of Economics*, Vol. 12, No. 2, pp. 7-27. DOI:10.14254/1800-5845.2016/12-2/11

Ayvazyan, S. A., Afanas'yev, M. Yu., Kudrov A. V., Lysenkova M. A. (2017), “To the question about parameterization of national innovation system”, Applied Econometrics, Vol. 45, pp. 29-49.

All business establishments: Census Bureau, the Business Information Tracking Series (2014): *Science and Engineering Indicators 2014.* Table 8-53. High-technology establishments as a percentage of all business establishments, by state: 2003-2010 URL: http://www.nsf.gov/statistics/seind14/index.cfm/state-data/download.htm (дата обращения: январь 2016).

Battese, Coelli (1988): Prediction of Firm-level Technical Efficiencies with a Generalized Frontier Production Function and Panel Data// Journal of Econometrics. Vol. 38. P. 387-399.

Chislo predpriyatiy regiona (2013), *Regiony Rossii. Cotsial'no- ekonomicheskiye pokazateli, 2013g.* URL: http://www.gks.ru/bgd/regl/b14_14p/IssWWW.exe/Stg/d02/12-01.htm (data obrashcheniya: iyun' 2016).

Organizatsii, vypolnyayushchiye nauchnyye issledovaniya (2013), *Regiony Rossii. Cotsi-al'no-ekonomicheskiye pokazateli - 2013g*, URL: http://www.gks.ru/bgd/regl/ b12_14p/IssWWW.exe/Stg/d03/22-15.htm (data obrashcheniya: iyun' 2015).

Number of establishments. Japan Statistical Yearbook (2014): Statistical Bureau Japan/ URL: http://www.stat.go.jp/english/data/nenkan/back63/index.htm

Number of institutions (2010): U.S. National Center for Education Statistics, Digest of Education Statistics, annual. URL: http://www.nces.ed.gov/programs/digest (дата обращения: январь 2016).

Number of universities. Statistical abstract (2012): MEXT Japan. URL: http://www.mext. go.jp/english/statistics/index.htm

PCT patent applications – count. Dataset (2014): Innovation Indicators, OECD.

Vysshiye uchebnyye zavedeniya regiona (2013), *Regiony Rossii. Cotsial'no- ekonomi-cheskiye*

pokazateli, URL: http://aeer.cctpu.edu.ru (data obrashcheniya iyul' 2016).
4. Itskovits G. (2010): Troynaya spiral'. Universitety–predpriyatiya–gosudarstvo, Innovatsii v deystvii. URL: http://courier-edu.ru/cour1112/0007.htm (data obrashcheniya: yanvar' 2016).

Table A1. Estimates of technical efficiency and their ranks for the regions of Russia, the US states and prefectures of Japan

1	2	3	4	5	6	7	8
i_1	Name of the region of the Russian Federa-tion	$(TE^{1}_{i_1})_{M_0}$	$(R^{01}_{i_1})_{M_0}$	$(R^{1}_{i_1})_{M_0}$	$(TE^{1}_{i_1})_{M_1}$	$(R^{1}_{i_1})_{M_1}$	$(R^{01}_{i_1})_{M_x}$
1	Belgorodskaya oblast'	0.9445	170	72	0.0782	74	172
2	Bryanskaya oblast'	0.9457	114	25	0.4171	36	132
3	Vladimirskaya oblast'	0.9456	126	32	0.4617	30	126
4	Voronezhskya oblast'	0.9450	151	53	0.3481	43	139
5	Ivanovskaya oblast'	0.9456	129	35	0.4630	29	125
6	Kaluzhskaya oblast'	0.9464	68	6	0.6938	6	55
7	Kostromskaya oblast'	0.9461	83	8	0.5343	22	118
8	Kurskaya oblast'	0.9439	178	80	0.0342	80	178
9	Lipetskaya oblast'	0.9457	112	24	0.4489	32	128
10	Moskovskaya oblast'	0.9456	127	33	0.7517	2	42
11	Orlovskaya oblast'	0.9457	118	27	0.4064	40	136
12	Ryazanskaya oblast'	0.9459	99	16	0.6116	16	112
13	Smolenskaya oblast'	0.9442	173	75	0.0465	77	175
14	Tambovskaya oblast'	0.9453	141	45	0.2404	51	147
15	Tverskaya oblast'	0.9460	93	13	0.6780	11	104
16	Tul'skaya oblast'	0.9456	123	30	0.5011	26	122
17	Yaroslavskaya oblast'	0.9454	136	41	0.4168	37	133
18	g, Moskva	0.9441	176	78	0.5511	19	115
19	Respublika Kareliya	0.9448	159	61	0.0834	70	168
20	Respublika Komi	0.9458	108	21	0.4518	31	127
21	Arkhangel'skaya oblast'	0.9459	101	17	0.5354	21	117
22	Vologodskaya oblast'	0.9461	89	11	0.6512	13	109
23	Kaliningradskaya oblast'	0.9457	120	28	0.5450	20	116
24	Leningradskaya oblast'	0.9463	73	7	0.6827	10	86
25	Murmanskaya oblast'	0.9464	66	5	0.6874	9	85
26	Novgorodskaya oblast'	0.9469	34	3	0.7042	5	54
27	Pskovskaya oblast'	0.9446	166	68	0.0667	76	174

28	g, Sankt-Peterburg	0.9448	160	62	0.6380	14	110
29	Respublika Adygeya	0.9457	121	29	0.1920	58	156
30	Respublika Kalmykiya	0.9456	125	31	0.1869	60	158
31	Krasnodarskiy kray	0.9445	171	73	0.2576	47	143
32	Astrakhanskaya oblast'	0.9449	154	56	0.1304	63	161
33	Volgogradskaya oblast'	0.9455	134	39	0.5301	23	119
34	Rostovskaya oblast'	0.9449	155	57	0.4061	41	137
35	Respublika Dagestan	0.9448	158	60	0.2136	54	152
36	Respublika Ingushetiya	0.9458	110	23	0.2117	56	154
37	Kabardino-Balkarskaya Respublika	0.9450	152	54	0.0965	68	166
38	Karachayevo-Cherkesskaya Respublika	0.9458	109	22	0.2127	55	153
39	Respublika Severnaya Oseti-ya - Alaniya	0.9442	175	77	0.0449	78	176
40	Chechenskaya Respublika	0.9454	137	42	0.1427	62	160
41	Stavropol'skiy kray	0.9445	167	69	0.1874	59	157
42	Respublika Bashkortostan	0.9453	140	44	0.5172	24	120
43	Respublika Mariy El	0.9450	150	52	0.0983	67	165
44	Respublika Mordoviya	0.9449	157	59	0.0922	69	167
45	Respublika Tatarstan	0.9445	169	71	0.2409	50	146
46	Udmurtskaya Respublika	0.9456	128	34	0.5091	25	121
47	Chuvashskaya Respublika	0.9461	85	9	0.6349	15	111
48	Permskiy kray	0.9451	147	49	0.3929	42	138
49	Kirovskaya oblast'	0.9451	148	50	0.2276	53	151
50	Nizhegorodskaya oblast'	0.9459	105	19	0.7279	4	53
51	Orenburgskaya oblast'	0.9450	149	51	0.2510	48	144
52	Penzenskaya oblast'	0.9458	107	20	0.4862	27	123
53	Samarskaya oblast'	0.9446	165	67	0.2896	45	141
54	Saratovskaya oblast'	0.9453	139	43	0.4479	33	129
55	Ul'yanovskaya oblast'	0.9460	94	14	0.5809	18	114
56	Kurganskaya oblast'	0.9459	96	15	0.4781	28	124
57	Sverdlovskaya oblast'	0.9448	163	65	0.4094	39	135
58	Tyumenskaya oblast'	0.9442	172	74	0.1213	66	164
59	Chelyabinskaya oblast'	0.9457	117	26	0.6922	7	83
60	Respublika Altay	0.9459	103	18	0.2343	52	149
61	Respublika Buryatiya	0.9446	164	66	0.0701	75	173

62	Respublika Tyva	0.9478	5	2	0.7315	3	43
63	Respublika Khakasiya	0.9455	131	37	0.1670	61	159
64	Altayskiy kray	0.9445	168	70	0.1255	64	162
65	Zabaykal'skiy kray	0.9448	162	64	0.0816	73	171
66	Krasnoyarskiy kray	0.9453	142	46	0.4368	34	130
67	Irkutskaya oblast'	0.9450	153	55	0.3136	44	140
68	Kemerovskaya oblast'	0.9449	156	58	0.2458	49	145
69	Novosibirskaya oblast'	0.9454	135	40	0.6533	12	108
70	Omskaya oblast'	0.9455	130	36	0.5936	17	113
71	Tomskaya oblast'	0.9461	87	10	0.6901	8	84
72	Respublika Sakha (Yakutiya)	0.9440	177	79	0.0384	79	177
73	Kamchatskiy kray	0.9455	133	38	0.2076	57	155
74	Primorskiy kray	0.9452	143	47	0.4253	35	131
75	Khabarovskiy kray	0.9442	174	76	0.0828	71	169
76	Amurskaya oblast'	0.9448	161	63	0.0819	72	170
77	Magadanskaya oblast'	0.9460	91	12	0.2761	46	142
78	Sakhalinskaya oblast'	0.9452	144	48	0.1239	65	163
79	Yevreyskaya avtonomnaya oblast'	0.9465	57	4	0.4115	38	134
80	Chukotskiy avtonomnyy okrug	0.9482	2	1	0.7813	1	1
i_2	US State	$(TE^2_{i_2})_{M_0}$	$(R^{02}_{i_2})_{M_0}$	$(R^2_{i_2})_{M_0}$	$(TE^2_{i_2})_{M_2}$	$(R^2_{i_2})_{M_2}$	$(R^{02}_{i_2})_{M_x}$
1	Alabama	0.9465	58	22	0.9917	18	60
2	Alaska	0.9467	44	13	0.9916	49	101
3	Arizona	0.9464	69	27	0.9917	20	62
4	Arkansas	0.9462	75	32	0.9917	39	81
5	California	0.9457	115	46	0.9917	14	56
6	Colorado	0.9464	67	26	0.9917	19	61
7	Connecticut	0.9473	15	5	0.9918	3	8
8	Delaware	0.9482	1	1	0.9918	2	3
9	District of Columbia	0.9478	6	3	0.9918	4	9
10	Florida	0.9453	138	51	0.9917	43	95
11	Georgia	0.9456	124	49	0.9917	45	97
12	Hawaii	0.9467	46	14	0.9917	36	78
13	Idaho	0.9473	14	4	0.9917	9	25
14	Illinois	0.9457	116	47	0.9917	33	75
15	Indiana	0.9466	53	19	0.9917	11	47
16	Iowa	0.9462	79	35	0.9917	37	79

17	Kansas	0.9461	81	37	0.9917	41	87
18	Kentucky	0.9463	74	31	0.9917	28	70
19	Louisiana	0.9460	95	40	0.9917	44	96
20	Maine	0.9466	50	16	0.9917	32	74
21	Maryland	0.9465	56	21	0.9917	16	58
22	Massachusetts	0.9465	63	23	0.9917	13	51
23	Michigan	0.9463	71	29	0.9917	15	57
24	Minnesota	0.9464	70	28	0.9917	17	59
25	Mississippi	0.9464	65	25	0.9917	35	77
26	Missouri	0.9456	122	48	0.9916	48	100
27	Montana (US)	0.9465	55	20	0.9917	40	82
28	Nebraska	0.9462	76	33	0.9917	46	98
29	Nevada	0.9472	18	6	0.9917	7	21
30	New Hampshire	0.9481	3	2	0.9918	1	2
31	New Jersey	0.9466	52	18	0.9917	12	48
32	New Mexico	0.9466	51	17	0.9917	27	69
33	New York	0.9455	132	50	0.9917	30	72
34	North Carolina	0.9461	90	39	0.9917	21	63
35	North Dakota	0.9466	48	15	0.9917	47	99
36	Ohio	0.9458	111	44	0.9917	29	71
37	Oklahoma	0.9461	80	36	0.9917	38	80
38	Oregon	0.9464	64	24	0.9917	23	65
39	Pennsylvania	0.9458	106	43	0.9917	22	64
40	Rhode Island	0.9461	86	38	0.9916	51	103
41	South Carolina	0.9463	72	30	0.9917	26	68
42	South Dakota	0.9462	78	34	0.9916	50	102
43	Tennessee	0.9459	104	42	0.9917	42	94
44	Texas	0.9457	113	45	0.9917	24	66
45	Utah	0.9470	26	8	0.9917	8	23
46	Vermont	0.9470	30	11	0.9917	25	67
47	Virginia	0.9459	97	41	0.9917	31	73
48	Washington	0.9467	43	12	0.9918	6	19
49	West Virginia	0.9471	24	7	0.9917	10	28
50	Wisconsin	0.9470	29	10	0.9918	5	17
51	Wyoming	0.9470	28	9	0.9917	34	76

i_3	Name of the prefecture of Japan	$(TE^3_{i_3})_{M_0}$	$(R^{03}_{i_3})_{M_0}$	$(R^3_{i_3})_{M_0}$	$(TE^3_{i_3})_{M_3}$	$(R^3_{i_3})_{M_3}$	$(R^{03}_{i_3})_{M_x}$
1	Hokkaido	0.9452	146	47	0.1224	46	148
2	Aomori	0.9459	98	42	0.1686	45	107
3	Iwate	0.9461	82	38	0.2404	39	90

4	Miyagi	0.9460	92	41	0.2649	37	88
5	Akita	0.9465	59	33	0.3154	36	52
6	Yamagata	0.9468	37	23	0.4245	29	40
7	Fukushima	0.9457	119	45	0.1912	43	105
8	Ibaraki	0.9476	10	5	0.6649	6	11
9	Tochigi	0.9468	38	24	0.4892	20	31
10	Gumma	0.9468	41	27	0.4790	22	33
11	Saitama	0.9469	32	19	0.5638	13	20
12	Chiba	0.9467	47	30	0.5038	18	29
13	Tokyo	0.9469	33	20	0.6132	9	14
14	Kanagawa	0.9478	8	3	0.7173	1	4
15	Yamanashi	0.9466	49	31	0.4172	31	44
16	Nagano	0.9475	11	6	0.6264	8	13
17	Shizuoka	0.9466	54	32	0.4628	25	36
18	Niigata	0.9465	61	35	0.3745	34	49
19	Toyama	0.9472	19	11	0.5311	14	22
20	Ishikawa	0.9469	36	22	0.4429	27	38
21	Fukui	0.9469	31	18	0.4632	24	35
22	Gifu	0.9467	45	29	0.4356	28	39
23	Aichi	0.9478	9	4	0.7098	2	5
24	Mie	0.9470	27	17	0.5269	15	24
25	Shiga	0.9478	7	2	0.6827	4	7
26	Kyoto	0.9475	12	7	0.6513	7	12
27	Osaka	0.9474	13	8	0.6692	5	10
28	Hyogo	0.9470	25	16	0.5727	12	18
29	Nara	0.9469	35	21	0.4771	23	34
30	Wakayama	0.9471	20	12	0.5251	16	26
31	Tottori	0.9461	88	40	0.2157	42	93
32	Shimane	0.9462	77	37	0.2401	40	91
33	Okayama	0.9459	102	44	0.2483	38	89
34	Hiroshima	0.9473	16	9	0.5847	11	16
35	Yamaguchi	0.9465	62	36	0.3896	32	45
36	Tokushima	0.9471	22	14	0.5165	17	27
37	Kagawa	0.9480	4	1	0.6840	3	6
38	Ehime	0.9468	39	25	0.4519	26	37
39	Kochi	0.9461	84	39	0.2200	41	92
40	Fukuoka	0.9473	17	10	0.5918	10	15
41	Saga	0.9452	145	46	0.1055	47	150
42	Nagasaki	0.9471	21	13	0.4835	21	32
43	Kumamoto	0.9468	40	26	0.4232	30	41
44	Oita	0.9468	42	28	0.3840	33	46
45	Miyazaki	0.9471	23	15	0.5016	19	30

46	Kagoshima	0.9465	60	34	0.3618	35	50
47	Okinawa	0.9459	100	43	0.1723	44	106