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Estimating and interpreting internal migration flows in Russia by accounting for network effects

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ABSTRACT

The present article follows two objectives. First, to apply a recently developed spatial interaction model and discuss its power in explaining social developments. Second, to obtain information on internal migration's determinants in Russia by taking into account that its eastern and western regions differ in many respects. Two alternative panel specifications are considered, labelled "spatial interaction specification with exogenous spatial lags" and "gravity-type specification with network effects". While both specifications are designed to capture the impacts of neighbouring regions in migration dynamics, they differ with respect to the implementation of fixed effects. It is argued that neighbourhood impacts manifest themselves either as spillover effects, which amplify a variable's impact, or competition effects, which attenuate them. The results show that variables indeed differ from each other in these respects, demonstrating how migration patterns are subject to events beyond the directly involved regions, and that these are furthermore influenced by the distances between regions. In addition, the results provide further evidence that migration determinants differ for Eastern and Western Russia.

1. Introduction

Discussions on migration-related topics seem ubiquitous in the media, politics and many countries in the world. Over the passage of time migration's consequences for sending and receiving regions can be quite dramatic. Concerning Russia, some regions, in particular those in the sparsely populated eastern (Asian) part, are confronted with permanent population loss since the Soviet Union's dissolution, facing the challenge how to retain or attract people. This matters all the more as out-migration's impacts are frequently amplified by the migrants' attributes (possibly younger and better educated than those they leave behind) and low fertility rates. In order to influence migration patterns a deeper understanding of migration's causes and relationships is indispensable.

Studies on migration are often hindered by a lack of sufficient data. One thing the existing empirical literature does show is that migration's determinants are by no means universally valid. One issue, for instance, relates to the question whether the acquisition of a higher-wage job is the result of, or a cause of, migration behaviour [1]. A related open question concerns the importance of income levels as such, as this is one variable which should most obviously motivate migration, with some studies displaying the expected positive impacts [2,3] while others do not [4,5]. This, however, does not mean that results on income are inconclusive but rather that migration drivers differ across countries and even within countries as illustrated by the differing impacts of regional wage-levels for various countries in Crozet [6].

Regarding methodological development, Poot et al. [7] declare that the gravity-model of migration is currently enjoying "the successful comeback of an ageing superstar". Beine et al. [8] point out that the use of dyadic data is, on the one hand, a blessing as it allows to analyse many previously unaddressed questions, but also a curse, as "methodological challenges that are implied by the use of this type of data are numerous" (ibid, pp. 509). In its most basic form the gravity-model explains migration as a function of the sizes of the sending and receiving economies and the distances between them. The reason why it is so attractive can be assigned to its intuitive consistency not only with migration theory [7] but also with our everyday experience regarding the migrants we meet, or the migration decision we may think about taking or not taking for ourselves. The typical obstacle is not theorising but rather accessing sufficient data and a CPU that can cope with it. Hence it comes as no surprise that considerable progress has been made over the past ten years.

Spatial econometric models combined with the gravity approach were first developed by LeSage and Pace [9] and are referred to as

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"spatial interaction models". They demand flow-data for each pair of n spatial units which means that they amount to n^2 observations. If the model is considered to be dynamic, i.e. corresponding to a spatial panel econometric specification, then the number of observations increases to n^2T, with T representing the number of periods. "Spatial" means that a spatial weights matrix is involved, which has to be extended to the dimension of $n^2T \times n^2T$.

Whereas modern computers can handle such challenges a larger hurdle to applying spatial interaction models regards the lack of sufficient data. It may seem surprising how little is known about migration, given the important role it has come to play in politics and policy-making in most developed societies. For instance, free migration within its territory is one of the European Union's four freedoms and also largely regarded as the main motivation for the British electorate to vote "leave" in the 2016 referendum on whether to remain an EU member state. Yet, the EU does not keep track of migration within its territory which leads not only to democratic issues (e.g. people having several EU citizenships and hence being able to vote as many times in EU parliamentary elections) but making it impossible to draw safe conclusions.

The lack of sufficient data is certainly one reason why methodological progress has been made but so far no study on internal migration within a large economic area applying spatial interaction models exists. The present paper fills this gap by applying appropriate methods with a rich panel data-set covering migration-flows between and within 77 regions of the Russian Federation for the observation period 1997–2010. Hence, the contribution of this paper is threefold: First, it provides information on the determinants of migration within a large economic area which is not only interesting to Russian policy-makers but may also provide useful information for other countries and economic areas. Second, the results are discussed in connection with the model's setup and against alternative specifications, adding to the so far underdeveloped discussion on model interpretation. Third, it provides further evidence on how the determinants for choosing to migrate differ for Eastern and Western Russia.

The paper is set up as follows. The next Section provides a literature review on the method as well as migration within Russia, Sections 3 presents the data. In Sections 4 and 5 the spatial interaction specification with exogenous spatial lags and alternative specifications, respectively, are presented. After that, the respective results are discussed and interpreted in Sections 6 and 7. The eighth and final Section concludes.

2. Literature review

Results from previous studies on migration in Russia after the Soviet Union's dissolution may be briefly summarised as follows.[1] The 1990s were characterised by (i) large flows from eastern (Asian) to western (European) regions,[2] at least partly in response to the state-subsidised migration from western to eastern regions during the Soviet era [10], and (ii) many potential migrants facing severe constraints to their migration-plans as recession-induced poverty meant they couldn't afford them [11]. The latter problem alleviated during the booming 2000s, while intercontinental migration patterns continued to display a net minus for Eastern Russia. In this context, Sardadvar and Vakulenko [12] show by application of spatial panel regressions that internal migration's determinants differ substantially for Eastern and Western Russia, with economic growth being the driving force for people leaving or staying in eastern regions, while income levels dominates in-migration of western regions. Sardadvar and Vakulenko [13] show theoretically and empirically that the growing importance of the mining sector for the Russian economy plays a crucial role in explaining migration patterns.

Note that Sardadvar and Vakulenko [12] apply spatial panel econometric techniques with total regional migration numbers as dependent variables, while Sardadvar and Vakulenko [13] use panel econometric data with distance measures and flows between dyads of regions but no spatial weights matrices. The present paper adds to these results as the applied specifications correspond to spatial panel econometrics with flows between dyads of regions as the dependent variable. The paper follows LeSage and Fischer [14] who present the exogenous spatial interaction specification in detail and discuss how to interpret it by application of teacher migration data within the US-state Florida for the observation period 1995–2004. In the present paper the exogenous spatial interaction specification is compared to some possible alternatives, namely restricted versions of the exogenous spatial interaction specification and a gravity-type specification with network effects.

Of particular interest are "competition effects" which arise if neighbouring districts exert a negative influence regarding the explanatory variable of interest. For instance, in LeSage and Fischer [14] districts neighbouring the origin district display a positive coefficient for the variable salary, meaning that outflows from the latter are increased if salaries in its neighbourhood increase. A competition effect is found for salaries in districts neighbouring the destination which display a negative coefficient, therefore suggesting that districts with higher salaries that neighbour the destination decrease inflows to the latter.

The *exogenous* spatial interaction specification takes into account direct effects from neighbouring spatial units, but considers no feedback effects. The latter would also consider the impact of regions which are not part of the origin-destination dyad, taken into account in *endogenous* spatial interaction specifications. Such specifications typically use spatially weighted values of the dependent variable as additional explanatory variables. In contrast, in exogenous specifications only spatially weighted explanatory variables show up on the right hand side, i.e. the dependent variable is not spatially weighted. As expressed by LeSage and Thomas-Agnan [15] spatial spillovers in endogenous specifications can take the form of network spillovers that impact regions not directly involved as origin or destination regions in the dyadic flow-relationships that characterise dependent variable observations. The present paper does not discuss which variant is more realistic, as so far either is lacking a theoretical model of migration which would be directly transferred to an econometric specification. Instead, in what follows only exogenous spatial interaction specifications are considered, concentrating on the set-up and implications as well as related alternatives. That being said, it should be pointed out that spillover effects amplifying certain trends are not neglected in exogenous models as discussed in the remainder of this Section.

Spillover and competition effects in theoretical spatial models as well as spatial regressions have attracted considerable interest in growth theory and empirics, although spillover effects have gained more attention, being based on the idea that, e.g., technology spreads in space and benefits neighbours of a knowledge-creating source. An example of spillover effects is provided by Ertur and Koch [16] who assume that the state of technology of an economy is a function of its neighbours' average state of technology. It follows that an economy benefits if economies which are spatially close increase their knowledge, thus inducing knowledge spillovers. An example of competition effects is given by Sardadvar [17] who shows that investment inflows reduce if an economy's neighbours increase their stocks in human capital.

Within the relatively young field of spatial interaction models the taxonomy so far remains unspecific how effects should be interpreted.

[1] For a review also covering migration during the Soviet era see Ref. [13].

[2] In English language countries Russia is typically understood as consisting of a European and an Asian part, while in Russia these regions are considered as "West" and "East", respectively. In what follows the expressions "European regions" and "western regions" as well as "Asian regions" and "eastern regions", including expressions which replace "region" by "Russia", refer to identical areas, respectively.

In the present paper spatial autocorrelation statistics are used as an additional source of information. The interpretation distinguishes between effects that amplify particular relationships and effects that attenuate them. Consider income, a variable which is typically expected to have a positive impact on in-migration and a negative impact on out-migration. If the dependent variable measures flows from origin to destination, a positive coefficient for the destination region and a negative coefficient for the origin region reflects what would be expected. In spatial interaction as well as gravity-type specifications with network effects, the spatially weighted values of income may show the following effects:

- A positive coefficient for the regions neighbouring the destination. This means that an increase in income in the destination's neighbourhood increases flows from the origin to the destination, possibly reflecting a general trend regarding larger areas. The sign is the same as for the destination region and may be referred to as a *destination spillover* effect.
- A negative coefficient for the regions neighbouring the destination. This means that an increase in income in the destination's neighbourhood decreases flows from the origin to the destination, possibly reflecting that the region becomes less attractive for people willing to migrate over similar distances. The sign is contrary to the destination region and may be referred to as a *destination competition* effect.
- A negative coefficient for the regions neighbouring the origin. This means that an increase in income in the origin's neighbourhood decreases flows from the origin to the destination, possibly because of a general trend for a broader set of neighbouring regions, or because migrants take the opportunity to travel shorter distances. The sign is the same as for the origin region and may be referred to as an *origin spillover* effect.
- A positive coefficient for the regions neighbouring the origin. This means that an increase in income in the origin's neighbourhood increases flows from the origin to the destination, perhaps because the destination region is perceived as becoming less attractive in comparison to the origin's neighbours, again possibly due to the shorter distances. The sign is contrary to the origin region and may be referred to as an *origin competition* effect.

Spillover and competition effects may be summarised as *network destination* and *network origin* effects as they reflect some kind of relationship between regions not directly affected by the migration-flows under consideration but nevertheless exerting an impact.

3. Data

The dependent variable corresponds to yearly realised annual migration-flows between and within 77 regions of the Russian Federation for the observation period 1997–2010 in absolute numbers.[3] Data on interregional migration is defined as region-to-region residence changes, while intraregional migration refers to residence changes that occur within a region. In other words, interregional migration is defined as a residence change between two of the 77 regions, while intraregional migration is defined as a residence change between two administrative divisions (cities, municipalities, etc.) within one of the 77 regions, which means that a residence change within the same city or municipality is not defined as migration. Any occurrence of migration as defined is considered as either interregional or intraregional.

The first set of explanatory variables capture those which in the literature are found as key variables determining migration decisions, these are total population, average personal income (at constant 2010 prices),[4] real gross regional product (GRP) growth per capita,[5] and the unemployment rate. The population sizes in origin and destination regions are expected to affect migration-flows positively, in line with the gravity-model of migration [18]. In addition, larger populations offer more economic opportunities and services and therefore may attract migrants. Income per capita controls for the overall level of well-being and labour market conditions, while GRP growth indicates future trends. It is expected that both income and GRP growth are positively correlated with in-migration, although it also potentially increases the number of people who are able to afford migrating in the first place [11], therefore the impact on the origin reason is ambiguous. The unemployment rate is associated with the probability of being employed [19] as well as with expected incomes [1], hence likely to be negatively correlated with in-migration and positively with out-migration.

The second set of explanatory variables refers to Russia being fairly diverse in terms of development, especially when comparing the relatively densely populated areas of Western Russia with Eastern Russia. Variables which have been identified to influence migration in Russia [20] refer to development as indicated by the infant mortality rate, housing availability defined as the average area of housing in square meters per capita as well as the number of students per capita.

Potential migrants are presumed reacting to labour market signals, but needing some time to react to changes in the origin and destination environments. For this reason, explanatory variables are typically taken for the preceding years [21–23], which also helps to avoid endogeneity issues. In what follows the variables unemployment, income and the number of students per capita are taken for the respective preceding years (i.e., 1996–2009), the others for the current year. The source for all data is the official Russian Statistical Service (Rosstat).

Distance is captured by an $n \times n$ spatial weights matrix $\mathbf{W}$, where each element in row i and column j captures geographical proximity between any pair of the n respective regions i and j. These distance-based elements are defined as $w_{ij} = f(d_{ij})$, where d_{ij} denotes the distance by railway kilometres between the regions' capital cities.[6] The distances between cities are calculated by application of the Atlas of Railways in Russia.[7] As argued by Mkrtchyan and Karachurina [24] railway distances are best suited for migration in Russia for a number of reasons. First, railways are relatively ubiquitous in Russian regions. Second, the movement of people to a permanent place of residence is in most cases accompanied by a large volume of transportation of baggage and personal property, more easily and cheaper carried out by rail. Considering air travel most cities are connected via Moscow, making flight inappropriate for most connections. Car density is much lower in Russia than in West European or North American countries, making it impossible for most people to migrate by car. The matrix $\mathbf{W}$'s elements correspond to a pre-defined number of regions considered as neighbours ("nearest neighbours"):

[3] Of the Russian Federation's 89 regions the Republic of Chechnya as well as the Republic of Ingushetia and Chukotka autonomous districts are excluded due to unavailability of data. Nine autonomous districts (Nenets, Komi-Perm, Khanty-Mansijsk, Yamalo-Nenets, Taimyr/Dolgano-Nenets, Evenk, Ust-Ordyn Buryat, Aginsk Buryat and Koryak) are included as administrative parts of other regions, which accounts to a total of 77 regions considered in this study. For a complete list please refer to the Appendix.

[4] This variable includes any source of monetary income, including self-employment, wages, transfer payments (e.g. pensions), and income from property (e.g. dividends).

[5] Gross regional product is conceptually identical to gross domestic product. Note that it includes only income that is produced within a region, while the "income" variable includes income received from other regions or countries, e.g. interest or transfer payments.

[6] If there is no railway between cities alternative ways of estimating distances are applied, in particular by road, by sea or by air.

[7] Available from http://atlas-rzd.ru/, accessed 31-July-2018.

$$\begin{cases} w_{ij} = 0 \text{ if } i = j \\ w_{ij} = 1/\nu \text{ if } d_{ij} \le d_i^*(\nu) \\ w_{ij} = 0 \text{ if } d_{ij} > d_i^*(\nu) \end{cases}$$

where $d_i^*(\nu)$ is a defined critical cut-off distance for each region so that d^* is the νth order smallest distance between two regions i and j resulting in each region having exactly ν neighbours. This results in a matrix where every row has the same number of nonzero elements whose sums equal one, corresponding to a row-standardised spatial weights matrix [25]. Furthermore, note that although the distances are considered as symmetric, i.e. $d_{ij} = d_{ji}$, the weight matrix is not as the ν nearest neighbours of i are typically not the same as j's and hence frequently $w_{ij} \neq w_{ji}$.

4. Spatial interaction specification with exogenous spatial lags

The present paper's basic specification corresponds to the exogenous spatial interaction specification in LeSage and Fischer [14]; taking the following form for panel data

$$\mathbf{M} = \boldsymbol{\alpha}_\mathbf{0} \otimes \boldsymbol{\iota}_\mathbf{T} + \boldsymbol{\alpha}_\mathbf{t} \otimes \boldsymbol{\iota}_{\mathbf{n}^2} + \tilde{\mathbf{X}}_\mathbf{O}\boldsymbol{\beta}_\mathbf{O} + \tilde{\mathbf{X}}_\mathbf{D}\boldsymbol{\beta}_\mathbf{D} + \mathbf{X}_\mathbf{I}\boldsymbol{\beta}_\mathbf{I} + \mathbf{W}_\mathbf{O}\tilde{\mathbf{X}}_\mathbf{O}\boldsymbol{\theta}_\mathbf{O} + \mathbf{W}_\mathbf{D}\tilde{\mathbf{X}}_\mathbf{D}\boldsymbol{\theta}_\mathbf{D} + \boldsymbol{\varepsilon} \quad (1)$$

and representing a regression that includes spatial lags of the explanatory variables [25]. The dependent variable as well as all explanatory variables are taken as logs, and the vector containing the values for the dependent variable is constructed by stacking columns of the observed $n \times n$ matrices of flows in each year t, assuming destination-centric organisation as defined by LeSage and Pace [9]. Put differently, $\mathbf{M}$ is an $n^2T \times 1$ vector consisting of the stacked annual flows from origin region j to destination region i.[8] In 1.77% of observations no migration is documented, in which cases the value of 0.5 is taken to avoid undefined log values.[9] GRP growth numbers are taken as factors, e.g. if growth equals four per cent, the variable equals 1.04.

The $n^2 \times 1$ vector $\boldsymbol{\alpha}_\mathbf{0}$ symbolises the pairwise fixed effects to control for institutions, climate, culture etc., with $\boldsymbol{\iota}_\mathbf{T}$ symbolising a $T \times 1$ identity vector. The $T \times 1$ vector $\boldsymbol{\alpha}_\mathbf{t}$ represents time effects for the year dummies, with $\boldsymbol{\iota}_{\mathbf{n}^2}$ symbolising an $n^2 \times 1$ identity vector.

Let $\mathbf{X}$ be an $nT \times k$ matrix with k explanatory variables for each region and year. From this the $n^2T \times k$ matrices $\mathbf{X}_\mathbf{O} = \boldsymbol{\iota}_\mathbf{n} \otimes \mathbf{X}$ and $\mathbf{X}_\mathbf{D} = \mathbf{X} \otimes \boldsymbol{\iota}_\mathbf{n}$ are constructed, now ordered by the origin and destination attributes with respect to the order of $\mathbf{M}$, with $\boldsymbol{\iota}_\mathbf{n}$ being an $n \times 1$ identity vector. To distinguish interregional from intraregional effects it is necessary to isolate the values of the explanatory variables where the origin region is identical to the destination region (i.e. intraregional migration) by defining $\mathbf{X}_\mathbf{I}$ as an $n^2T \times k$ matrix which contains non-zero values only in those lines which correspond to intraregional migration. Mathematically, any element of $\mathbf{X}_\mathbf{I}$ is a non-zero element according to the sequence $\{a_m\}_{m \in n} = (m-1)n + m$, i.e. the elements have the values

$$x_{I,ij} = \begin{cases} x_{ij} \text{ if } i(x_{I,ij}) = (i(x_{ij}) - 1)n + i(x_{ij}) \\ 0 \text{ if } i(x_{I,ij}) \neq (i(x_{ij}) - 1)n + i(x_{ij}) \end{cases} \quad (2)$$

where $x_{I,ij}$ and x_{ij} refer to the elements in the ith row, jth column of $\mathbf{X}_\mathbf{I}$ and $\mathbf{X}$, respectively. From these the $n^2T \times k$ matrices $\tilde{\mathbf{X}}_\mathbf{O}$ and $\tilde{\mathbf{X}}_\mathbf{D}$ can be calculated as $\tilde{\mathbf{X}}_\mathbf{O} = \mathbf{X}_\mathbf{O} - \mathbf{X}_\mathbf{I}$ and $\tilde{\mathbf{X}}_\mathbf{D} = \mathbf{X}_\mathbf{D} - \mathbf{X}_\mathbf{I}$, and the $k \times 1$ vectors $\boldsymbol{\beta}_\mathbf{O}$, $\boldsymbol{\beta}_\mathbf{D}$ and $\boldsymbol{\beta}_\mathbf{I}$ contain the coefficients regarding origin, destination and intraregional effects, respectively.

The spatial weights matrix as defined in the previous Section is expanded according to the pairs of dependent and explanatory variables so that $\mathbf{W}_\mathbf{O} = \mathbf{I}_\mathbf{nT} \otimes \mathbf{W}$ and $\mathbf{W}_\mathbf{D} = \mathbf{W} \otimes \mathbf{I}_\mathbf{nT}$, with $\mathbf{I}_\mathbf{nT}$ being an $nT \times nT$ identity matrix. The $k \times 1$ vectors $\boldsymbol{\theta}_\mathbf{O}$ and $\boldsymbol{\theta}_\mathbf{D}$ contain the coefficients regarding network origin and network destination effects, respectively.

The following estimations correspond to panel specifications with fixed effects, i.e. after the fixed effects (within) transformation, OLS is used. In order to interpret coefficients for the spatial model with intraregional effects the corrected coefficients in accordance with LeSage and Fischer [14] are calculated. The correction for origin and destination effects as well as for network origin and destination effects, i.e. the coefficients β_O, β_D, θ_O and θ_D, corresponds to the multiplier $(n-1)/n$, where n is the number of regions – in the present case $76/77 = 0.987$. The correction for intraregional effect, β_I, is the multiplier $1/n$ or approximately 0.013. Therefore, if n tends to infinity, corrections of the coefficients β_O, β_D, θ_O and θ_D are not necessary as intraregional effects tend to zero. With $n = 77$, however, corrections are necessary as they may make a decisive difference. Standard errors for t-statistics calculations are estimated via bootstrap procedures as in LeSage and Pace [25]; by using a sample of 1000 simulated parameters. Note that all variables are taken as logs, therefore the obtained coefficients can be interpreted as elasticities. Total effects are calculated as in LeSage and Fischer [14]; representing the cumulated coefficient values of a variable. Standard errors and corresponding statistical significance levels are estimated by bootstrap procedures, too.

5. Alternative specifications

The basic specifications as defined in eq. (1) represents only one in a range of possible alternatives to include spatial effects in an interaction model. Many of these are restricted versions of eq. (1) which can be compared by likelihood-ratio tests. This is done for instance by LeSage and Pace [9] who test their basic specification (in this case: an endogenous spatial interaction specification without spatially lagged explanatory variables) against various restricted alternatives. The present paper's basic specification is tested against the following restrictions:

- The restriction $\boldsymbol{\beta}_\mathbf{I} = 0$ produces a spatial interaction specification with exogenous spatial lags, but without considering intraregional effects.
- The restriction $\boldsymbol{\beta}_\mathbf{D} = -\boldsymbol{\theta}_\mathbf{D}$ reveals whether effects internal to the destination and network destination effects outweigh each other.
- The restriction $\boldsymbol{\beta}_\mathbf{O} = -\boldsymbol{\theta}_\mathbf{O}$ reveals whether effects internal to the origin and network origin effects outweigh each other.

As in LeSage and Pace [9] restrictions may be also combined.

An alternative specification corresponds to a gravity-type specification with distance and neighbouring-regions effects included, i.e. spatially lagged explanatory variables. The advantage of this method is that – in contrast to a pairwise fixed effects specification as in eq. (1) – it

[8] The original 1078×77matrix of flows is ordered so that the first row consists of all flows *to* $i = 1$ *from* each $j = 1,2,...,77$ at $t = 1$, the second row consists of all flows to $i = 2$ from each $j = 1,2,...,77$ at $t = 1$, and so on. The first column, therefore, consists of all flows *from* $j = 1$ *to* each $j = 1,2, ...,77$ at $t = 1$, and so on. From the 78th to the 156th row the elements capture flows from each j to each i by the same principle and order for $t = 2$. After that, the same set of flows is repeated for $t = 3$, and so on until $t = 14$. With 77 regions and 14 yearly observations, $\mathbf{M}$ is hence an $83{,}006 \times 1$ vector. "Destination-centric" means that vector $\mathbf{M}$ is ordered so that the first n rows correspond to the first row of the flow matrix of year 1, the rows from $n + 1$ to $2n$ to the second row, and so on. After that, the process is repeated for each year t, as specified above. In the case of 77 regions and 14 periods, the 100th row of vector $\mathbf{M}$ contains the flow from region 2 to region 33 in year 1, the 1000th row contains the flow from region 76 to region 12 in year 1, the 10,000th row contains the flow from region 67 to region 52 in year 2, and so on to the 83,006th row, which contains intraregional flows of $i = 77$ at $t = 14$.

[9] An alternative way of dealing with zero migration cases is to leave them out. Arguably, assuming 0.5 migration flows is closer to the truth as there will always be migration flows which remain unregistered or return migration taking place within the same year. As will be discussed in Section 7, simply leaving out observations with zero migration has only very minor effects on the estimations.

allows for the inclusion of variables which are constant over time for pairs of regions, including geographical ones such as the distance between regions and whether they share a common physical border. When considering an observation period consisting of several periods the specification corresponds to a panel regression with exogenous spatial lags and origin and destination specific dummies:

$$\mathbf{M} = \boldsymbol{\alpha}_{\mathbf{O}} \otimes \boldsymbol{\iota}_{\mathbf{nT}} + \boldsymbol{\alpha}_{\mathbf{D}} \otimes \boldsymbol{\iota}_{\mathbf{nT}} + \boldsymbol{\alpha}_{\mathbf{t}} \otimes \boldsymbol{\iota}_{\mathbf{n}^2} + \tilde{\mathbf{X}}_{\mathbf{O}}\boldsymbol{\beta}_{\mathbf{O}} + \tilde{\mathbf{X}}_{\mathbf{D}}\boldsymbol{\beta}_{\mathbf{D}} + \mathbf{X}_{\mathbf{I}}\boldsymbol{\beta} + \mathbf{W}_{\mathbf{O}}\tilde{\mathbf{X}}_{\mathbf{O}}\boldsymbol{\theta}_{\mathbf{O}} + \mathbf{W}_{\mathbf{D}}\tilde{\mathbf{X}}_{\mathbf{D}}\boldsymbol{\theta}_{\mathbf{D}} + \lambda\mathbf{d} \otimes \boldsymbol{\iota}_{\mathbf{T}} + \gamma\mathbf{b} \otimes \boldsymbol{\iota}_{\mathbf{T}} + \boldsymbol{\varepsilon} \quad (3)$$

Four terms enter eq. (3) in comparison to eq. (1). The $n \times 1$ vector $\boldsymbol{\alpha}_{\mathbf{O}}$ captures the fixed effects for origin regions, with $\boldsymbol{\iota}_{\mathbf{nT}}$ symbolising an $nT \times 1$ identity vector. In similar vein, $\boldsymbol{\alpha}_{\mathbf{D}}$ is an $n \times 1$ vector capturing the fixed effects for destination regions. In other words, the specification as in eq. (3) considers different types of fixed effects as dummy variables for origin and destination regions which capture variables which are constant over time in the origin and destination region, i.e. not just pairs of regions as in eq. (1). These specific dummies capture, for example, infrastructure effects: There may be much more migration between two distant regions that are well connected by airlines than between two close regions having inferior rail or road connections.

The other two additional variables correspond to $\mathbf{d}$, which is an $n^2 \times 1$ vector consisting of the logarithms of distances between each pair of regions as defined in the third Section, while $\mathbf{b}$ is an $n^2 \times 1$ vector whose elements equal one if a pair of regions does not share a common physical border, zero else, with the scalars λ and γ representing the respective coefficients. Note that $d_{ii} = 0$, hence the logarithm of d_{ii} is not defined. To avoid undefined values 0.5 is added, i.e. it is assumed that $d_{ii} = 0.5$. All other variables are as defined as above, including the stacking orders.

Finally, the regression may also be estimated as year-by-year cross sectional regressions. Such regressions may be useful to detect and interpret year-by-year changes. The specification of eq. (3) simplifies to

$$\mathbf{M}^{\mathbf{t}} = \alpha \otimes \boldsymbol{\iota}_{\mathbf{n}^2} + \tilde{\mathbf{X}}_{\mathbf{O}}^{\mathbf{t}}\boldsymbol{\beta}_{\mathbf{O}}^{\mathbf{t}} + \tilde{\mathbf{X}}_{\mathbf{D}}^{\mathbf{t}}\boldsymbol{\beta}_{\mathbf{D}}^{\mathbf{t}} + \mathbf{X}_{\mathbf{I}}\boldsymbol{\beta} + \mathbf{W}\tilde{\mathbf{X}}_{\mathbf{O}}^{\mathbf{t}}\boldsymbol{\theta}_{\mathbf{O}}^{\mathbf{t}} + \mathbf{W}\tilde{\mathbf{X}}_{\mathbf{D}}^{\mathbf{t}}\boldsymbol{\theta}_{\mathbf{D}}^{\mathbf{t}} + \lambda\mathbf{d} + \gamma\mathbf{b} + \boldsymbol{\varepsilon}^{\mathbf{t}} \quad (4)$$

where a superscript $\mathbf{t}$ indicates that only the rows corresponding to the respective year t are considered, i.e. $\mathbf{M}^{\mathbf{t}}$ is an $n^2 \times 1$ vector consisting of the migration flows in a particular year, and so on for the other variables. The main purpose is to compare the year-by-year results with the panel regression estimations as specified above.

6. Results and interpretation of the spatial interaction specification

The results for ten nearest neighbours (i.e. $\nu = 10$) as they correspond to eq. (1) are displayed in Table 1. Results for five nearest neighbours ($\nu = 5$) can be found in Table A1 in the Appendix. Although some differences exist, the results are remarkably similar; the explanatory power is slightly better for ten nearest neighbours.

Three specifications are estimated to account for the fact that eastern and western regions may differ from each other. The first estimation, referred to as "all regions", considers each pair of the 77 regions for 14 periods, hence resulting in $77^2 \cdot 14 = 83{,}006$ observations. The coefficients show how flows respond to changes in each of the explanatory variables in the origin region ("origin effects"), destination region ("destination effects"), own region ("intraregional effects"), neighbours of the origin region ("network origin effects") and neighbours of the destination regions ("network destination effects"). The second set of results, labelled "east-west migration" in Table 1, considers only migration from eastern to western regions. Note that the same set of coefficients shows up, but the spatially weighted variables may include regions in the respective other part of Russia to account for the fact that there are no formal barriers, hence networks effects across continents also matter even though only intercontinental migration is considered. The same holds for the third set of results, labelled "west-east migration", considering only migration from western to eastern regions. Furthermore, note that intraregional effects are considered for the complete sets of pairs only because origin and destination regions are not identical with intercontinental migration. For the same reason, corrections for origin and destination effects as well as for network origin and destination effects are not necessary as discussed above. In this case, the usual coefficients from OLS regressions for within-transformed variables are taken.

The interpretation starts with the first column where all pairs of regions are considered. The population numbers display positive impacts for both destination and origin regions. This result represents the gravity effect according to which magnitudes of flows are positively correlated with the sizes of origin and destination. However, it is interesting to note that both coefficients are considerably larger than one, suggesting that migration-flows are more than proportionally related to sizes. As discussed below, alternative regressions reveal that this effect is most likely due to the inclusion of pairwise fixed effects, which are not reported in Table 1.

Other than perhaps expected population's network origin and destination effects are positive and negative, respectively. This suggests, first, a competition effect regarding destination regions: If neighbouring regions are larger, less people migrate to i as more people choose to migrate to i's neighbours. Second, a spillover effect regarding origin regions means that a population-increase in j's neighbourhood increases flows to i, perhaps as a consequence of congestion. The intraregional effect is positive as would be expected: The more populous a region, the higher the absolute number of people changing residencies within that region.

Unemployment displays the expected effects for origin and destination regions, too, but the signs for the network effects are the same as the corresponding origin and destination effects, indicating spillover effects. Considering that regions struggling with unemployment are often geographically close to each other, this result suggests that unemployment-induced migration follows a general pattern, from struggling to thriving larger areas. Indeed, the unemployment rate's Moran's *I* spatial autocorrelation coefficients are positive, equalling on average 0.375 for ten nearest neighbours (see Table A2 in the Appendix for detailed results). Furthermore, it should be noted that an intraregional effect is virtually non-existing, which further suggests the impression that people migrate to thriving areas rather than receiving job offers within their origin region struggling with unemployment.

Perhaps the most interesting result refers to income, which is positive though non-significant for origin regions but positive and significant for destination regions. One candidate explanation why the origin region's coefficient is not negative refers to the observation that economies with high unemployment rates are not necessarily poor regions. This is especially true for Russia where eastern regions' income levels *and* unemployment rates are, on average, both in fact higher than in western regions (see Table A4 in the Appendix for details). Naturally, unemployed people are less interested in the average wage other people receive but rather in the expected wage they can achieve for themselves, therefore a lower unemployment rate corresponds to higher expected wages for currently unemployed people. However, network effects are negative and statistically significant for origin regions, suggesting a competition effect: If income in j's neighbourhood increases, migration from j to i reduces, probably because the latter becomes less attractive. The destination region's network effects are positive, suggesting a spillover effect though statistically not significant.

GRP growth is positive as expected for destination regions but, rather unexpectedly, positive for origin regions, too. A potential explanation refers to national economic development, as in times of higher economic growth the prospects of becoming employed increase, and those wanting to migrate anyway may perceive increased employment opportunities. Indeed, the result makes more sense if

Table 1
Results for ten nearest neighbours, spatial interaction specification.

	All regions		East-west		West-east	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
Origin effects						
Population	1.946***	0.097	2.236***	0.262	1.700***	0.234
Unemployment rate	0.036***	0.009	0.045	0.029	0.014	0.019
Income	0.029	0.021	−0.048	0.050	0.188***	0.056
GRP growth	0.095***	0.019	0.116***	0.040	0.108**	0.050
Housing	0.438***	0.083	−0.048	0.313	0.342**	0.166
Infant mortality rate	0.043***	0.015	0.064	0.043	0.138***	0.034
Students per capita	−0.071***	0.012	−0.073	0.051	−0.051***	0.020
Destination effects						
Population	2.371***	0.097	2.572***	0.214	2.033***	0.265
Unemployment rate	−0.084***	0.009	−0.131***	0.020	0.056*	0.028
Income	0.096***	0.022	0.130**	0.054	0.151***	0.051
GRP growth	0.047**	0.018	0.061	0.047	0.026	0.043
Housing	0.408***	0.075	0.270	0.165	0.230	0.256
Infant mortality rate	−0.024	0.016	−0.025	0.035	−0.128***	0.044
Students per capita	0.090***	0.014	0.115***	0.029	0.018	0.048
Intraregional effects						
Population	0.022***	0.005				
Unemployment rate	0.000	0.000				
Income	0.000	0.000				
GRP growth	0.001***	0.000				
Housing	0.009***	0.003				
Infant mortality rate	−0.001	0.001				
Students per capita	0.001	0.001				
Network origin effects						
Population	1.517***	0.253	4.272***	0.791	0.582	0.640
Unemployment rate	0.050***	0.019	0.260***	0.097	0.053	0.048
Income	−0.237***	0.064	−0.213	0.163	−0.145	0.223
GRP growth	0.289***	0.050	0.225*	0.129	0.350**	0.147
Housing	0.658***	0.210	0.788	0.565	−0.896	0.733
Infant mortality rate	−0.323***	0.049	0.171	0.170	0.163	0.125
Students per capita	−0.114***	0.042	0.050	0.151	−0.099	0.094
Network destination effects						
Population	−0.716***	0.266	0.506	0.623	0.205	0.704
Unemployment rate	−0.180***	0.020	−0.301***	0.046	−0.175	0.107
Income	0.048	0.058	0.102	0.224	−0.451***	0.170
GRP growth	−0.114**	0.051	0.004	0.146	0.040	0.133
Housing	−0.392*	0.223	0.796	0.732	1.726***	0.566
Infant mortality rate	0.270***	0.052	0.330**	0.130	0.164	0.193
Students per capita	−0.053	0.043	0.005	0.114	−0.002	0.137
Total effects						
Population	5.140***	0.356	9.549***	1.003	4.552***	0.998
Unemployment rate	−0.178***	0.028	−0.129	0.110	−0.057	0.129
Income	−0.063	0.084	−0.032	0.314	−0.260	0.312
GRP growth	0.319***	0.068	0.398*	0.213	0.523***	0.194
Housing	1.120***	0.312	1.744*	1.014	1.462	1.005
Infant mortality rate	−0.035	0.069	0.540**	0.244	0.337	0.239
Students	0.147**	0.059	0.097	0.191	−0.134	0.172
Year dummies						
1998	0.120***	0.032	0.152	0.104	0.194*	0.103
1999	−0.086*	0.046	−0.119	0.147	−0.244*	0.147
2000	−0.185***	0.043	−0.279**	0.137	−0.283**	0.135
2001	−0.245***	0.039	−0.296**	0.126	−0.268**	0.119
2002	−0.290***	0.042	−0.296**	0.137	−0.243*	0.127
2003	−0.281***	0.047	−0.304*	0.160	−0.148	0.149
2004	−0.351***	0.052	−0.350*	0.182	−0.195	0.172
2005	−0.372***	0.056	−0.341*	0.199	−0.175	0.188
2006	−0.369***	0.063	−0.324	0.225	−0.116	0.217
2007	−0.326***	0.071	−0.241	0.253	0.019	0.244
2008	−0.373***	0.077	−0.242	0.280	0.065	0.271
2009	−0.426***	0.080	−0.366	0.290	0.078	0.281
2010	−0.329***	0.084	−0.107	0.305	0.037	0.296
Model characteristics						
Observations	83,006		17,808		17,808	
R-squared	0.261		0.296		0.211	
AIC	72,515		19,887		20,848	
BIC	72,963		20,206		21,167	

Note: Standard errors were obtained using the bootstrapping procedure, the number of iterations is 1000. The estimated effects are corrected for the coefficients in the "all regions" column (except for time dummies) but not in the other columns for the reasons discussed in the text. Total effects in the "east-west" and "west-east" columns were estimated by bootstrapping with a number of iterations of 1000. The constant and the fixed effects are not reported. Stars indicate statistical significance levels, with "***" referring to 1%, "**" to 5% and "*" to 10%.

considered jointly with network effects, which correspond to spillover effects for origin and competition effects for destination regions. The impression that GRP growth is related to employment opportunities and increases migration is further underlined by the positive intraregional coefficient.[10] Furthermore, it is worth mentioning that while income is positively spatially autocorrelated in each year, GRP growth in most years is not, i.e. spatial dependence is – perhaps surprisingly – much weaker for growth than for income.

Housing availability has a considerably positive effect on migration, as would be expected, being positive for both origin and destination regions. While the latter effect is as one would expect, the former is difficult to interpret but perhaps due to preceding population losses. Similarly to unemployment there exists a spillover effect regarding origin regions. In contrast, the destination regions display a competition effect, i.e. if housing availability in its neighbouring regions increases, i loses attractiveness. Interestingly, this variable reacts sensitively to different weight matrices (see Table A1 in the Appendix). Furthermore, note that housing is the only variable besides population size and GRP growth which displays intraregional effects, which are positive as would be expected.

Infant mortality rate is positive for origin regions, which means that underdevelopment increases outflows. It could perhaps be expected that the variable behaves similarly as unemployment, as they are strikingly similar: both are expected to reduce attractiveness, both display on average higher values in eastern regions, and both have positive and highly significant Moran's I values. However, in contrast to unemployment, infant mortality displays competition effects for both origin and destination regions.

More students within a region means less out-migration and more in-migration, which is in line with the expectation that students are particularly mobile, and the presence of universities (proxied by the number of students per capita) making a region more attractive to them. The network effect of the origin regions is of the spillover type, while for the destination region it is a competition effect though statistically not significant at the ten per cent level. Note that students per capita is simultaneously the only variable which shows no spatial autocorrelation but with statistically significant effects regarding origins and destinations, while intraregional effects do not seem to matter.

Regarding total effects, population numbers, GRP growth, housing and students show the expected positive effects, i.e. an increase in one of these variables increases the total magnitude of migration within Russia. Interestingly, unemployment has a negative impact, which indicates that migration is positively correlated with employment opportunities rather than negatively with unemployment, i.e. people do not leave regions because they are unemployed there but rather enter regions in which they become employed. This impression is underlined by the strong total effect of GRP growth and the non-significant total effect of income. Total effects of income and infant mortality display no statistically significant effects.

Finally, the year dummies suggest a tendency of decreasing over time,[11] which means that either total migration is decreasing, or the explanatory power of the regressors increases over time, or both. As can be seen in Fig. A1 in the Appendix, internal migration numbers indeed decrease over time. Whereas in 1997 2.725 million people changed residencies that number reduced to 1.911 million people in 2010, with all types of migration showing negative trends.[12] However, the corresponding migration *growth rate* is not negative for each year, although the year dummies are.

Considering intercontinental migration, in general those coefficients which in the second and third column are statistically significant typically have the same sign as in the first column. The only exceptions are unemployment and housing availability which deviate in the case of west-east migration, being positive for unemployment destination effects and housing availability network origin effects. Remarkable differences, however, exist when considering the coefficients' values. For instance, the population variable behaves similarly for origin and destination regions, although it is larger for east-west migration, and smaller for west-east migration. The network origin effect for east-west migration may be considered as extreme with a coefficient of 4.272, which suggests very strong spillover effects. In contrast, the coefficient for west-east migration is statistically not different from zero. The total effect for east-west migration reaches an astonishing value as large as 9.549 (it should be kept in mind that pairwise fixed effects' have an impact on the values). Also interestingly, GRP growth displays no significant effect regarding destination regions or destination network effects, while origin and origin network effects are positive for both east-west and west-east migration. In contrast, unemployment seems to matter more for destination region and destination network effects, underlining the impression that employment opportunities matter more than income.

A notable effect regards infant mortality rates, which has a strong positive total impact with respect to east-west migration, but not in the case of the other two types, which underlines that underdevelopment is a motivation for people leaving eastern regions. As for students, it is non-significant concerning intercontinental migration although the signs differ, being positive for east-west and negative for west-east migration. Finally, the time dummies lose their statistical significances for most years regarding east-west and west-east migration and seem to matter more for the earlier part of the observation period.

7. Alternative results and interpretation

The first set of alternatives corresponds to restricted versions of the general model of eq. (1). In what follows the discussion relates to the full set of regions only, with the purpose to get a feel for alternative specifications. Various combinations of restrictions as presented in the fourth Section are tested against the general model. Table 2 shows the log-likelihood values, the χ^2-values of the likelihood-ratio tests, degrees of freedom and the p-values for rejecting the restricted regressions.

From a methodical point of view the most relevant test corresponds to $\boldsymbol{\beta}_{\mathbf{I}} = 0$ as intraregional flows are often structurally different from interregional flows. Region-specific attributes obviously play a different role. This can also be seen from Table 1 in which the estimated intraregional effects are either minor or statistically not different from zero. However, the likelihood-ratio test rejects excluding intraregional variables, i.e. explanation power is higher if they are also considered.[13] Concerning the remaining variables the results are almost identical with respect to coefficients' values and p-values. For the purpose of the present study the most important result is that none of the network effects changes sign or probability value whether intraregional effects are considered or not.[14]

As for other restricted versions none comes close regarding explanation power as can be seen from the log-likelihood values as

[10] An interesting detail relates to year dummies which indeed react sensitively to the inclusion of GRP growth by becoming smaller (results are available upon request). Although this relationship is not necessarily causal it suits the impression that the impact of national economic growth is more important than regional growth.

[11] An OLS line drawn through a scatter plot of the time dummies has a slope of -0.031, $R^2 = 0.665$.

[12] OLS lines drawn through the scatter plots have slopes of -0.063, $R^2 = 0.808$ for total internal migration, -0.029, $R^2 = 0.736$ for interregional

(*footnote continued*)
migration and -0.034, $R^2 = 0.852$ for intraregional migration.

[13] To test the hypothesis whether the results improve by not considering intraregional effects it is necessary to estimate eq. (1) without the corrections as described in the last paragraph of Section 4.

[14] The results of the restricted regressions are not presented in this paper but available from the authors upon request.

Table 2
Results and comparisons of alternative specifications, ten nearest neighbours.

Restriction	Log likelihood	χ^2-value	Degrees of freedom	p-value
none	−36,209.51	–	–	–
$\beta_I = 0$	−36,227.69	36.37	7	0.0000
$\beta_I = 0$, $\beta_D = -\theta_D$	−36,816.12	1213.22	14	0.0000
$\beta_I = 0$, $\beta_O = -\theta_O$	−36,478.39	537.76	14	0.0000
$\beta_I = 0$, $\beta_D = -\theta_D$, $\beta_O = -\theta_O$	−37,060.78	1702.53	21	0.0000

reported in Table 2. In this context it is perhaps worth mentioning that the difference between whether including intraregional effects or not is not very large and may turn out not to be rejected in future migration studies. Hence, although in the present paper keeping intraregional variables is clearly preferred this may not always be the case.

While Table 2 considers various spatial interaction specifications with exogenous spatial lags which are nested in the specification as expressed in eq. (1), a gravity-type specification with network effects as expressed in eq. (3) represents an alternative which cannot be directly compared. The purpose here is to check for robust results by studying the behaviour of the various variables. The results corresponding to eq. (3) are presented in Table 3 in similar vein for ten nearest neighbours as in Table 1 (for five nearest neighbours see Table A3 in the Appendix). Intraregional variables as well as origin and destination dummies are included to allow for direct comparisons.

The most important difference between the spatial interaction and gravity regressions is that the latter allows for constant variables, represented in Table 3 by the distance between regions and whether they not share a common border. The coefficients are, as would be expected, negative, strong and highly significant. However, a closer look reveals that distance is only critical if all regions are considered, as for both types of intercontinental migration the coefficients are statistically not different from zero.[15] This is not surprising considering that intercontinental migration is almost always associated with travelling very long distances, i.e. marginal cost of additional distance may be close to zero once the decision to travel that far has been made. By comparing all regions' results in Tables 1 and 3 it is striking that origin and destination effects show almost no difference. Intraregional effects remain weak and p-levels vary, but no coefficient which is statistically significant changes its sign.

Things are different for network effects, which vary between Tables 1 and 3. Most notably, population and unemployment behave differently, changing from origin spillover to origin competition effects, i.e. a population-increase or unemployment rate in j's neighbourhood decreases flows to i. In contrast, GRP growth, housing, infant mortality rate, and students keep their signs while income becomes statistically non-significant. Regarding network destination effects it is remarkable how all variables are statistically non-significant except for the unemployment rate, keeping its negative sign. The year dummies are comparable. However, the Akaike and Schwarz criteria suggest a preference for the spatial interaction specification.[16]

As for intercontinental migration the impression is similar: There is almost no change regarding origin and destination effects while network effects differ in some cases although to a lesser degree. Especially population differs with respect to network origin effects in the case of east-west migration and network destination effects in the case of west-east migration. Unemployment, in contrast, remains similar for east-west migration, displaying destination and origin spillover effects, while destination competition effects are found for west-east migration. GRP growth continues to show strong origin spillover effects in all cases which may be hence considered a robust network effect. Also worth mentioning are the network effects regarding housing and infant mortality rate, which continue to differ between types of migration (i.e., between a Tables' columns) while displaying similar effects regarding types of specifications (i.e., between the same columns of different Tables).

The yearly cross-sectional regressions as specified in eq. (4) without regional dummies but including intraregional effects are run to check for the impact of population size.[17] The regressions' coefficients have to be corrected by the factor $76/77 = 0.987$ due to the inclusion of intraregional effects. The population coefficients are in each case close to but smaller than one, both for origin and destination effects. As with total migration numbers and time dummies both display negative trends, although for destination effects the trend is stronger.[18] These results are displayed in Fig. A2 in the Appendix.

Finally, the results are checked how leaving out observations of zero migration instead of assuming 0.5 migrations flows affect the estimations. The effects, if they have a measureable impact at all, change the coefficients only to the third decimal place. This applies both to the spatial interaction specification as well as the gravity-type specification and may be considered a corollary result.

8. Conclusions

The present paper has applied the spatial interaction model with exogenous spatial lags for migration-flows in Russia with the aim to increase our understanding of both the method and the examined subject. The paper builds on a previous approach by LeSage and Fischer [14] with the focus set on the interpretation of the regression estimations yielded from a rich data-set. The results are then compared to a variation of the gravity-type specification with network effects. The main results may be summarised as follows.

First, the present paper argues that effects in regions neighbouring destination and origin regions may be referred to as network effects and be further distinguished as spillover and competition effects. A spillover effect occurs if neighbouring regions display the same effects as the region under consideration. For instance, if unemployment displays a positive impact on flows from region j to i in the origin region j as well as j's neighbours, we may think of unemployment as a spatial phenomenon creating outflows not just from particular regions but rather from a whole area struck by unemployment. In similar vein, negative coefficients of unemployment in the destination region i and i's neighbours may be considered as being created by forces not just present within one region but on a grander scale, in this sense representing spillover effects. This interpretation is underlined by positive spatial autocorrelation coefficients of the respective variable.

If a variable happens to display contrary signs, we may refer to competition effects. For instance, infant mortality rate as an indicator for underdevelopment may show the same signs as unemployment regarding origin and destination regions, i.e. positive and negative, respectively. In contrast, the signs for the origin's and destination's neighbours are negative and positive, respectively. A competition effect is at work in the sense that if the neighbours of i have higher infant mortality rates this increases flows to i from j. Similarly, an increase in

[15] A notable difference exists here whether five or ten neighbours are included, as can be seen from the results in Table A3 in the Appendix: In the case of five nearest neighbours distance has a negative impact for intercontinental migration, too.

[16] The reported R^2 values are not comparable, as in the gravity specification it is the usual coefficient of determination while for the spatial interaction specification it is the within coefficient of determination.

[17] As with the results of the restricted regressions these are not presented in this paper but available from the authors upon request.

[18] An OLS line drawn through the scatter plot of population origin effects has a slope of -0.0023, $R^2 = 0.171$, while for population destination effects the slope equals -0.0078, $R^2 = 0.626$.

Table 3
Results for ten nearest neighbours, gravity specification.

	All regions		East-west		West-east	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
Origin effects						
Population	1.974***	0.107	2.367***	0.257	1.677***	0.236
Unemployment rate	0.027*	0.015	0.035	0.029	0.017	0.02
Income	0.060**	0.023	0.017	0.05	0.199***	0.057
GRP growth	0.116***	0.019	0.146***	0.041	0.107**	0.05
Housing	0.335***	0.089	0.092	0.312	0.325**	0.164
Infant mortality rate	0.061***	0.019	0.062	0.044	0.142***	0.034
Students per capita	−0.089***	0.013	−0.084*	0.051	−0.055***	0.02
Destination effects						
Population	2.325***	0.115	2.537***	0.216	2.026***	0.261
Unemployment rate	−0.101***	0.015	−0.127***	0.02	0.052*	0.028
Income	0.111***	0.023	0.141***	0.054	0.166***	0.05
GRP growth	0.062***	0.019	0.065	0.047	0.035	0.044
Housing	0.300***	0.088	0.231	0.166	0.23	0.258
Infant mortality rate	−0.014	0.019	−0.025	0.036	−0.129***	0.044
Students per capita	0.084***	0.014	0.111***	0.029	0.015	0.049
Intraregional effects						
Population	0.049***	0.004				
Unemployment rate	0.022***	0.008				
Income	−0.011	0.007				
GRP growth	−0.005	0.005				
Housing	0.072***	0.026				
Infant mortality rate	−0.004	0.009				
Students per capita	0.002	0.004				
Network origin effects						
Population	−0.387**	0.175	−0.578***	0.192	0.006	0.229
Unemployment rate	−0.061**	0.026	0.168*	0.101	0.051	0.048
Income	0.129	0.172	0.156	0.18	0.021	0.224
GRP growth	0.346***	0.059	0.363***	0.14	0.330**	0.147
Housing	0.728*	0.413	−0.637	0.569	−1.054*	0.567
Infant mortality rate	−0.394***	0.115	−0.153	0.174	0.233*	0.13
Students per capita	−0.400***	0.080	−0.514***	0.115	−0.157	0.095
Network destination effects						
Population	−0.239	0.180	−0.365	0.231	−0.686***	0.2
Unemployment rate	−0.234***	0.024	−0.303***	0.047	−0.207*	0.109
Income	0.032	0.171	0.248	0.225	−0.328*	0.182
GRP growth	−0.041	0.063	0.041	0.147	0.105	0.139
Housing	0.312	0.435	0.148	0.606	1.489***	0.57
Infant mortality rate	0.062	0.122	0.367***	0.134	0.086	0.19
Students per capita	−0.022	0.080	−0.05	0.112	−0.082	0.11
Total effects						
Population	3.722***	0.374	3.970***	0.465	3.036***	0.468
Unemployment rate	−0.347***	0.036	−0.229**	0.115	−0.085	0.132
Income	0.321	0.283	0.571*	0.314	0.068	0.299
GRP growth	0.477***	0.091	0.608***	0.211	0.576***	0.205
Housing	1.747***	0.603	−0.109	0.906	0.970	0.834
Infant mortality rate	−0.288	0.193	0.248	0.243	0.336	0.243
Students	−0.424***	0.119	−0.536***	0.168	3.036	0.468
Year dummies						
1998	0.188***	−0.038	0.263**	−0.107	0.215**	−0.104
1999	0.126	−0.131	0.251*	−0.143	−0.075	−0.145
2000	−0.044	−0.107	0.074	−0.131	−0.143	−0.13
2001	−0.168**	−0.086	0.023	−0.116	−0.162	−0.111
2002	−0.294***	−0.079	−0.007	−0.127	−0.162	−0.118
2003	−0.360***	−0.074	−0.049	−0.15	−0.098	−0.142
2004	−0.497***	−0.077	−0.158	−0.175	−0.18	−0.168
2005	−0.579***	−0.085	−0.195	−0.194	−0.184	−0.185
2006	−0.667***	−0.102	−0.246	−0.222	−0.162	−0.217
2007	−0.722***	−0.125	−0.232	−0.253	−0.065	−0.248
2008	−0.864***	−0.141	−0.305	−0.28	−0.05	−0.275
2009	−0.925***	−0.156	−0.421	−0.291	−0.055	−0.287
2010	−0.823***	−0.166	−0.226	−0.308	−0.106	−0.304
Distance	−0.591***	−0.023	−0.048	−0.139	−0.118	−0.15
No border	−0.917***	−0.062	−0.832***	−0.217	−0.810***	−0.259
Model characteristics						
Observations	83,006		17,808		17,808	
R-squared	0.853		0.892		0.864	
AIC	166,937		29,722		30,536	
BIC	168,831		30,648		31,462	

Note: Standard errors were obtained using the bootstrapping procedure, the number of iterations is 1000. The estimated effects are corrected for the coefficients in the "all regions" column (except time dummies, distance and no border variables) but not in the other columns for the reasons discussed in the text. Total effects in the "east-west" and "west-east" columns were estimated by bootstrapping with a number of iterations of 1000. The constant and the fixed effects are not reported. Stars indicate statistical significance levels, with "***" refereeing to 1%, "**" to 5% and "*" to 10%.

infant mortality rate in the neighbourhood of *j* reduces the flows from *j* to *i* as more people migrate from *j*'s neighbours to *i*, thus creating competition.

Second, the paper argues that statistical interpretation is improved by studying descriptive and exploratory statistics. For instance, unemployment displays positive spatial autocorrelation, underlining the spillover effects. However, with infant mortality displaying similar spatial autocorrelation but competition effects in the regressions it cannot be concluded that positive spatial autocorrelation always means spillover effects. It is, however, worth mentioning that the spatial autocorrelation coefficients are positive in these cases while other variables which display network effects, in particular student-ratio, are not necessarily spatially autocorrelated. The relevance of interpreting regression estimations together with descriptive statistics is demonstrated by Eastern and Western Russia being very different regarding socio-economic conditions, as, for instance, regions in Eastern Russia are characterised by higher unemployment rates *and* higher income.

Third, the results show that interpretation and hence policy-making may improve if different kinds of effects are considered. For instance, although unemployment has the expected effects in origin and destination regions, no intraregional effect exists in the spatial interaction specification, and its total effect is negative. This shows that increasing unemployment may in fact reduce migration, probably because employment opportunities are reduced. The above mentioned spillover effects support this impression. In other words, in order to reap the efficiency gains typically associated with migration, unemployment must reduce. This impression is underlined by the positive impact of regional economic growth.

Fourth, the results show that migration patterns in Russia can be better understood if it is acknowledged that the western (European) and eastern (Asian) regions are different from each other. Although this finding is at the heart of Sardadvar and Vakulenko [12] the present study provides additional evidence by relying on total numbers as well as network effects. One major result refers to population size, a variable to which migration reacts very differently, in particular regarding east-west migration. Furthermore, although coefficients' signs seldom differ when examining migration-flows separately for all regions, east-west migration and west-east migration, magnitudes and statistical significance differ considerably.

Fifth, likelihood-ratio tests carried out to test the general model against various restricted versions show that the general model has indeed the best explanation power. This is most relevant for deciding whether to include intraregional effects in the regressions as, arguably, intraregional flows may be subject to different determinants. In the present study, the inclusion of intraregional effects is preferred but this does not mean that this represents a general outcome.

Sixth, a comparison of the spatial interaction model with a gravity-type specification reveals sensitivity of some variables to the chosen specification, caused by differing fixed effects: In the spatial interaction specification pairwise effects are considered, while in the gravity-type specification fixed effects are considered separately. While origin and destination effects are almost identical, some of the network effects change. Therefore, it is recommended to compare results in order to get a feel for their robustness. In the present case, for example, regional economic growth displays a significant origin spillover effect regardless of specification and whether all regions or just intercontinental migration is considered. This means that it is a relatively safe conclusion that GRP growth in regions neighbouring the origin region will increase the outflow of the origin region, probably as a reaction to increased employment possibilities. Some network effects, however, are less robust and should hence be interpreted with care.

To conclude, the present paper has shown that spatial interaction regressions are a powerful tool with the capability to improve our understanding of socio-economic phenomena which manifest themselves in geographical space. The method has only recently been developed with the present paper suggesting some ways to interpret results. Future studies may build on the findings and further extend the method, for instance by considering long-term signals to migration decisions or multilateral resistance terms as discussed by Beine et al. [8] or Royuela and Ordonez [26]. In the present paper, comparisons with other specifications including exogenous spatial lags show that while some measured network effects are robust, others react sensitively to changing specifications. The paper further shows that a split between groups of regions which are considerably different from each other enriches results and interpretation. More applications for a wider range of topics, from crime-rates to consumer behaviour, may add to our understanding regarding both the method as well as the subjects of interest as such.

Conflicts of interest

Neither author has a competing interest to declare.

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Appendix

Table A1
Results for spatial interaction specifications with five nearest neighbours

	All regions		East-west		West-east	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
Origin effects						
Population	1.974***	0.097	2.183***	0.247	1.687***	0.232
Unemployment rate	0.039***	0.009	0.053*	0.029	0.017	0.020
Income	0.028	0.022	−0.013	0.050	0.202***	0.057
GRP growth	0.096***	0.019	0.134***	0.040	0.117**	0.051
Housing	0.387***	0.082	−0.301	0.301	0.250	0.165
Infant mortality rate	0.039**	0.015	0.081**	0.041	0.171***	0.034
Students per capita	−0.076***	0.013	−0.062	0.051	−0.059***	0.019
Destination effects						
Population	2.468***	0.099	2.667***	0.209	1.725***	0.260
Unemployment rate	−0.082***	0.009	−0.130***	0.020	0.062**	0.028
Income	0.109***	0.023	0.159***	0.055	0.193***	0.050
GRP growth	0.052***	0.019	0.068	0.047	0.052	0.043
Housing	0.428***	0.077	0.108	0.167	0.106	0.249

(*continued on next page*)

Table A1 (*continued*)

	All regions		East-west		West-east	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
Infant mortality rate	−0.024	0.016	−0.045	0.036	−0.134***	0.043
Students per capita	0.094***	0.014	0.135***	0.030	0.004	0.049
Intraregional effects						
Population	0.024***	0.004				
Unemployment rate	0.000	0.000				
Income	0.001	0.001				
GRP growth	0.001***	0.000				
Housing	0.008***	0.003				
Infant mortality rate	−0.001	0.001				
Students per capita	0.001	0.001				
Network origin effects						
Population	0.223	0.184	1.401**	0.595	−0.493	0.423
Unemployment rate	0.074***	0.014	0.203***	0.066	0.093***	0.033
Income	−0.018	0.042	0.391***	0.135	0.163	0.120
GRP growth	0.126***	0.034	0.284***	0.092	0.029	0.100
Housing	0.130	0.149	0.053	0.390	−0.875*	0.461
Infant mortality rate	−0.091***	0.034	0.100	0.105	0.271***	0.076
Students per capita	−0.106***	0.025	−0.109	0.087	−0.072	0.057
Network destination effects						
Population	−0.787***	0.196	−0.666	0.453	−0.137	0.516
Unemployment rate	−0.082***	0.015	−0.081**	0.033	−0.013	0.067
Income	−0.039	0.045	−0.162	0.129	0.216	0.138
GRP growth	−0.075**	0.034	0.101	0.093	0.064	0.096
Housing	−0.686***	0.166	−1.270***	0.460	0.495	0.393
Infant mortality rate	0.020	0.034	−0.074	0.077	−0.002	0.108
Students per capita	0.120***	0.028	0.261***	0.079	0.335***	0.082
Total effects						
Population	3.902***	0.276	5.611***	0.775	2.780***	0.720
Unemployment rate	−0.052**	0.022	0.044	0.084	0.157*	0.083
Income	0.080	0.069	0.376*	0.210	0.777***	0.218
GRP growth	0.201***	0.050	0.593***	0.147	0.265*	0.149
Housing	0.268	0.251	−1.424**	0.693	−0.057	0.679
Infant mortality rate	−0.058	0.049	0.066	0.154	0.306**	0.143
Students per capita	0.032	0.043	0.231*	0.130	0.208*	0.113
Year dummies						
1998	0.015	0.025	0.161**	0.074	−0.089	0.074
1999	−0.071**	0.034	−0.023	0.098	0.123	0.099
2000	−0.207***	0.031	−0.272***	0.092	−0.086	0.089
2001	−0.291***	0.029	−0.313***	0.086	−0.272***	0.079
2002	−0.354***	0.031	−0.367***	0.099	−0.376***	0.089
2003	−0.367***	0.036	−0.443***	0.120	−0.449***	0.112
2004	−0.465***	0.040	−0.567***	0.142	−0.656***	0.135
2005	−0.499***	0.044	−0.581***	0.157	−0.725***	0.151
2006	−0.504***	0.050	−0.612***	0.180	−0.766***	0.178
2007	−0.481***	0.057	−0.586***	0.204	−0.772***	0.202
2008	−0.519***	0.062	−0.573**	0.223	−0.797***	0.224
2009	−0.609***	0.066	−0.681***	0.234	−0.949***	0.235
2010	−0.529***	0.069	−0.534**	0.249	−0.978***	0.246
Model characteristics						
Observations	83,006		17,808		17,808	
R-squared	0.260		0.294		0.212	
AIC	72,646		19,932		20,805	
BIC	73,093		20,251		21,124	

Note: See Table 1.

Table A2
Moran's *I* values for ten nearest neighbours

Year	Population	Unemployment rate	Income	Housing	Infant mortality rate	Students per capita	GRP growth
1997	0.064**	0.377***	0.097***	0.466***	0.229***	0.040*	0.027
1998	0.066**	0.369***	0.099***	0.496***	0.194***	0.036*	0.099***
1999	0.067**	0.518***	0.091***	0.538***	0.212***	0.025	0.039
2000	0.068**	0.448***	0.121***	0.394***	0.251***	0.018	−0.011
2001	0.067**	0.374***	0.133***	0.341***	0.187***	−0.020	0.000
2002	0.067**	0.380***	0.174***	0.352***	0.274***	−0.009	0.018
2003	0.065**	0.429***	0.163***	0.363***	0.215***	0.013	−0.048
2004	0.064**	0.466***	0.152***	0.377***	0.245***	0.008	0.042
2005	0.064**	0.345***	0.139***	0.391***	0.161***	−0.001	−0.040
2006	0.063**	0.437***	0.130***	0.401***	0.236***	−0.004	0.022

(*continued on next page*)

Table A2 (*continued*)

Year	Population	Unemployment rate	Income	Housing	Infant mortality rate	Students per capita	GRP growth
2007	0.062**	0.414***	0.109***	0.407***	0.288***	−0.009	−0.044
2008	0.061**	0.315***	0.126***	0.409***	0.237***	0.004	0.063**
2009	0.060**	0.192***	0.100***	0.424***	0.236***	0.020	0.221***
2010	0.058*	0.186***	0.125***	0.355***	0.244***	0.030	−0.048

Note: All variables are taken in logarithms, stars indicate statistical significance levels, with "***" refereeing to 1%, "**" to 5% and "*" to 10%. The values for unemployment, income and students per capita are given for the preceding year in each case, as applied in the regressions.

Table A3
Results for gravity specifications with five nearest neighbours

	All regions		East-west		West-east	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
Origin effects						
Population	1.899***	0.123	2.266***	0.241	1.669***	0.232
Unemployment rate	0.020**	0.015	0.049*	0.029	0.013	0.02
Income	0.047*	0.024	0.017	0.049	0.199***	0.057
GRP growth	0.110***	0.020	0.139***	0.04	0.114**	0.05
Housing	0.298***	0.092	−0.135	0.292	0.277*	0.165
Infant mortality rate	0.049***	0.019	0.074*	0.041	0.167***	0.034
Students per capita	−0.080***	0.012	−0.069	0.051	−0.056***	0.019
Destination effects						
Population	2.340***	0.125	2.644***	0.212	1.718***	0.258
Unemployment rate	−0.105***	0.015	−0.138***	0.021	0.062**	0.028
Income	0.119***	0.024	0.150***	0.055	0.198***	0.049
GRP growth	0.063***	0.021	0.063	0.047	0.053	0.043
Housing	0.328***	0.092	0.171	0.168	0.121	0.245
Infant mortality rate	−0.022	0.019	−0.054	0.036	−0.134***	0.043
Students per capita	0.098***	0.014	0.142***	0.03	0.004	0.049
Intraregional effects						
Population	0.049***	0.004				
Unemployment rate	0.021**	0.008				
Income	−0.013*	0.008				
GRP growth	−0.006	0.005				
Housing	0.074***	0.026				
Infant mortality rate	−0.006	0.009				
Students per capita	0.001	0.004				
Network origin effects						
Population	−0.243*	0.144	−0.392***	0.111	−0.068	0.126
Unemployment rate	0.038**	0.019	0.180***	0.067	0.102***	0.033
Income	0.201	0.159	0.418***	0.141	0.155	0.122
GRP growth	0.186***	0.059	0.245***	0.091	0.027	0.101
Housing	0.167	0.284	−0.705**	0.342	−0.551	0.355
Infant mortality rate	−0.105	0.085	0.023	0.105	0.274***	0.076
Students per capita	−0.188***	0.053	−0.301***	0.068	−0.061	0.056
Network destination effects						
Population	−0.094	0.158	0.273**	0.132	−0.399***	0.11
Unemployment rate	−0.093***	0.020	−0.064**	0.032	−0.009	0.067
Income	0.086	0.169	−0.22	0.137	0.246*	0.146
GRP growth	−0.015	0.056	0.094	0.094	0.065	0.097
Housing	−0.040	0.304	−0.54	0.391	0.389	0.354
Infant mortality rate	0.018	0.087	−0.068	0.076	−0.001	0.108
Students per capita	0.134**	0.056	0.287***	0.077	0.308***	0.066
Total effects						
Population	3.951***	0.399	4.797***	0.390	2.906***	0.412
Unemployment rate	−0.118***	0.029	0.028	0.078	0.164*	0.088
Income	0.440	0.285	0.354	0.225	0.801***	0.230
GRP growth	0.337***	0.096	0.541***	0.146	0.252	0.156
Housing	0.826*	0.443	−1.190*	0.648	0.231	0.585
Infant mortality rate	−0.066	0.157	−0.035	0.152	0.301**	0.142
Students per capita	−0.034	0.086	0.064	0.117	0.194**	0.099
Year dummies						
1998	0.063*	−0.034	0.140*	−0.074	−0.098	−0.074
1999	0.084	−0.111	−0.008	−0.102	0.124	−0.098
2000	−0.111	−0.088	−0.236***	−0.089	−0.088	−0.09
2001	−0.247***	−0.071	−0.283***	−0.076	−0.281***	−0.082
2002	−0.364***	−0.064	−0.333***	−0.084	−0.388***	−0.095
2003	−0.440***	−0.056	−0.401***	−0.107	−0.465***	−0.115
2004	−0.593***	−0.059	−0.528***	−0.131	−0.679***	−0.137
2005	−0.667***	−0.069	−0.555***	−0.147	−0.753***	−0.153
2006	−0.737***	−0.089	−0.586***	−0.175	−0.798***	−0.177

(*continued on next page*)

Table A3 (*continued*)

	All regions		East-west		West-east	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
2007	−0.781***	−0.114	−0.568***	−0.201	−0.812***	−0.202
2008	−0.871***	−0.128	−0.578***	−0.222	−0.842***	−0.221
2009	−0.978***	−0.144	−0.690***	−0.234	−1.002***	−0.231
2010	−0.916***	−0.161	−0.564**	−0.245	−1.041***	−0.247
Distance	−0.690***	−0.02	−0.510***	−0.144	−0.596***	−0.134
No border	−0.911***	−0.072	−0.824***	−0.27	−0.797***	−0.216
Model characteristics						
Observations	83,006		17,808		17,808	
R-squared	0.852		0.890		0.862	
AIC	167,953		30,053		30,838	
BIC	169,846		30,980		31,764	

Note: See Table 3.

Table A4
Summary statistics

	Mean			Median		
	all	east	west	all	east	west
Population	14.12	13.92	14.22	14.09	13.90	14.10
Unemployment rate	2.23	2.36	2.17	2.24	2.33	2.17
Income	9.00	9.14	8.94	8.96	9.14	8.88
Housing	3.02	2.95	3.05	2.96	2.96	3.05
Infant mortality rate	2.49	2.63	2.42	2.52	2.64	2.45
Students per capita	−1.19	−1.15	−1.21	−1.11	−1.08	−1.13
GRP growth	0.04	0.04	0.04	0.07	0.07	0.08

Note: All variables are taken in logarithms.

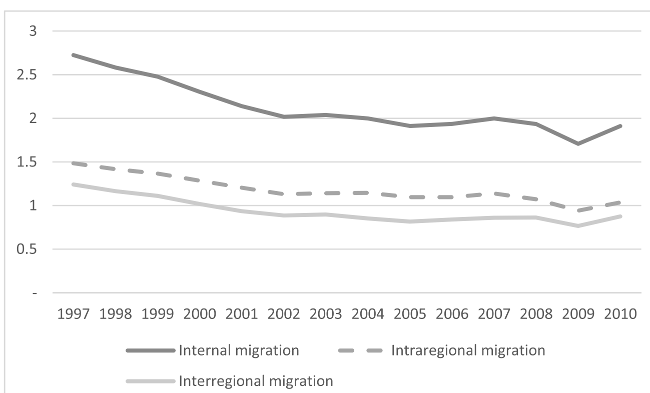

Fig. A1. Yearly migration numbers, in millions.

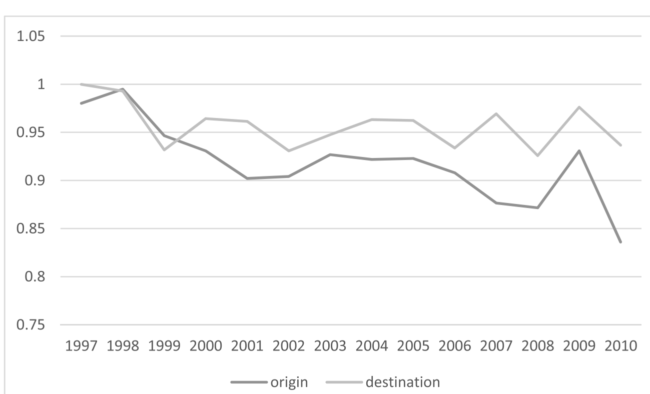

Fig. A2. Coefficients of population variable, yearly regressions.

Lists of regions

Eastern regions: Kurgan oblast, Sverdlovsk oblast, Tyumen oblast (including Khanty-Mansi, Yamalo-Nenets autonomous districts), Chelyabinsk oblast, Altai republic, Buryat republic, Tuva republic, Khakasia republic, Altai krai, Chita oblast (Zabaykalsk krai) (including Agin-Buryat autonomous district), Krasnoyarsk krai (including Taimyr, Evenk autonomous districts), Irkutsk oblast (including Ust-Orda Buryat autonomous district), Kemerovo oblast, Novosibirsk oblast, Omsk oblast, Tomsk oblast, Sakha (Yakutia) republic, Primorskii krai, Khabarovsk krai, Amur oblast, Kamchatka krai (including Koryak autonomous district), Magadan oblast, Sakhalin oblast, Evrei autonomous oblast, Chukotka autonomous okrug

Western regions: Belgorod oblast, Bryansk oblast, Vladimir oblast, Voronezh oblast, Ivanovo oblast, Kaluga oblast, Kostroma oblast, Kursk oblast, Lipetsk oblast, Moskow oblast, Oryol oblast, Ryazan oblast, Smolensk oblast, Tambov oblast, Tver oblast, Tula oblast, Yaroslavl oblast, Moscow city, Karelia republic, Komi republic, Arkhangelsk oblast (including Nenets autonomous district), Vologda oblast, Kaliningrad oblast, Leningrad oblast, Murmansk oblast, Novgorod oblast, Pskov oblast, St. Petersburg city, Adygeya republic, Dagestan republic, Kabardino-Balkar republic, Kalmyk republic, Karachaevo-Cherkess republic, North Osetiya republic, Krasnodar krai, Stavropol krai, Astrakhan oblast, Volgograd oblast, Rostov oblast, Bashkortostan republic, Mari-El republic, Mordovia republic, Tatarstan republic, Udmurtia Republic, Chuvash republic, Kirov oblast, Nizhny Novgorod oblast, Orenburg oblast, Penza oblast, Perm krai (including Komi-Permyak autonomous district), Samara oblast, Saratov oblast, Ulyanovsk oblast.

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