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Transport Costs and the Size of Cities: the Case of Russia

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Abstract:

Real costs of freight transportation have strong increased in Russia particularly during the period of price liberalization 1992–93. This paper investigates possible connections between rising transport costs and the evolution of the size structure of the system of cities in the Russian Federation and its federal subjects. Empirical findings suggest that under conditions of a closed system agglomeration processes according to the predictions of the model of Tabuchi et al. (2005) would have taken place especially in the periphere regions of the North and Far East.

1. Introduction

The end of the socialist planned economy, the dissolution of the Soviet Union, and the implementation of market oriented reforms have brought about changes of relative prices and structure of produced goods and services and input factors that have effects on the size distribution of cities of the Russian Federation, too. The evolution of population size of a city is determined by natural growth (as the difference of births and deaths) and net migration (as the difference of in and out migration), whereas migration flows can be distinguished as external (*i.e.* from other countries, *e.g.* the successors of the Soviet Union) and internal (from and to other federation subjects or within one federation subject itself: intraregional) migration movements. Every of these magnitudes can be attributed to different causes of economic, social or ethnic nature (amongst others), whose particular influence can hardly be quantified. The present paper investigates the indirect effects of (real) increasing costs of freight traffic after price liberalisation on the size of cities in the Russian Federation. The theoretical background starts with the analytically solvable New Economic Geography model for two regions by Ottaviano et al. (2002) (OTT) that has been expanded to n cities by Tabuchi et al. (2005) (TTZ). This model allows to study the causal relationship between transport costs, regional real wages and migration movements initiated by utility differentials that can have effects on the size of cities.

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The TTZ model was intended originally to explain the effects of the long term decrease of transport costs during centuries on a national or regional system of cities with different sizes regardless of its positions in an urban hierarchy. Contrary to this generally observable trend is the increase of costs of transport of goods in Russia as a consequence of price liberalisation in 1992 that significantly exceeds the overall price level. The economic impact of increasing transport costs on the size of cities has been rarely investigated so far.[1] Nevertheless, this is an important question for Russia that has particular importance with regard to the frequently expressed challenge to the Russian government to raise its domestic energy prices. However, other countries – particularly the industrial nations with developed transport systems whose potential of extension is increasingly questionable – can face a trend reversal of transport costs in the foreseeable future.

Furthermore the present paper is based on the research of economic geographers on the evolution of the Soviet and Russian city system, particularly of the peripheral regions of the Far North and the Far East. They investigate *(inter alia)* the change of migration patterns and the course of deindustrialisation during the transformation period, or classify the Russian city system by comparison with other ones.[2] Our paper is based on the thesis presented there, that the polarisation reversal to suburbanisation has started in Soviet Russia already in the 80th of the 20th century. The main differences of this contribution to geographical approaches is the focus on the spatial distribution of utility following from economic activity and its relation to transport costs as one cause of migration movements.

In the next section we'll sum up the basic assumptions and implications of the applied economic models. Section 3 presents some empirical findings that provide evidence for the model's findings to the evolution of the size distribution of cities and urban-type settlements in Russia. The last section gives some conclusions.

2. Theoretical approach

Transport costs, increasing returns, as well as preferences for variety and product differentiation have effects on the spatial distribution of economic activity. The interplay of these factors can create a spatial structure even in a geographically featureless space. One objective of New Economic Geography is to explain these processes of forming spatial structures. Its first approach of modelling was an ingenious composition of a particularly utility function of Dixit-Stiglitz type, fixed costs of production, monopolistic competition and iceberg transport costs, distributed among two regions.[3] The resulting non-linear equation system for quantities and prices of goods, nominal wages

[1] Tabuchi/Thisse (2006) in their analysis of the influence of decreasing transport costs on self organising hierarchical systems of cities address also the issue of effects of rising transport costs.

[2] See *e.g.* Lappo/Hönsch (2000), Brade (2002) and Göler (2005) among the first mentioned group. On the classification of the Russian urbanisation pattern into a general scheme see *e.g.* Nefedova/Treivish (2003).

[3] Krugman (1991).

and real wages was only solvable by numeric simulation. The so-called *core-periphery*-model indicates a tendency to agglomeration of economic activity in one region (while the other region becomes empty) if transport costs are undercutting a certain level. Extensions of the model allow to demonstrate the emergence of new cities and the formation of urban hierarchies in the course of population growth.[4]

However, the impossibility to solve these models analytically has impeded their applicability to specific problems. Therefore economists looked for analytically solvable models. One of them is the two-region model by OTT. It is based on the following assumptions:

- Production factors are either mobile (L) or immobile workers (A);
- The production of every variety of the heterogeneous L-good generates only fixed costs of ϕ units of the L-factor;
- The homogeneous A-commodity is produced under constant returns to scale; it is treated as *numéraire*;
- The N varieties of the L-good are produced under increasing returns to scale and supplied under the conditions of monopolistic competition;
- All L-workers are employed; the shares of Regions H and F are λ and $1-\lambda$;
- Preferences of consumers are described by the quasi-linear quadratic utility function[5]

$$U(q_0; q(i), i \in [0, N]) = \alpha \int_0^N q(i)di - \frac{\beta - \gamma}{2} \int_0^N [q(i)]^2 di - \frac{\gamma}{2} \Big[\int_0^N q(i)di \Big]^2 + q_0 \tag{1}$$

  with parameters α, β and γ that stand for the intensity of preferences for the L-good, the love for variety (since $\beta > \gamma$) and the substitutability of a single variety of the L-good by other varieties;
- Transport costs τ are linear in distance and measured in units of the *numéraire*.

The utility function implicates linear demand functions for quantities q_i of the varieties of the heterogeneous good as well as the indirect utility function

$$V(y; p(i), i \in [0, N]) = \frac{a^2 N}{2b} - a \int_0^N p(i)di + \frac{b + cN}{2} \int_0^N [p(i)]^2 di - \frac{c}{2} \Big[\int_0^N p(i)di \Big]^2 + y + \bar{q}_0. \tag{2}$$

The interplay of transport costs, consumer preferences, economies of scale, the quest of firms for spatial proximity to consumers and suppliers as well as the competition for scarce production factors generates centrifugal and centripetal forces that stimulate

[4] *E.g.* FUJITA et al. (II) (1999) and FUJITA et al. (I) (1999).
[5] Based on VIVES (1990).

the mobile workers (and the firms, too) to stay in or to leave the region. It is assumed that workers migrate to that region where they'll find the highest real wage or utility, respectively. It can be shown that indirect utility of each region depends on transport costs. This finding is presented by the central equation of the model (from the H-region's view)

$$\Delta V = C\tau(\tau^* - \tau)(\lambda - \frac{1}{2}), \quad C = \text{const.} \tag{3}$$

that determines the utility differential between the regions that induces migration and, hence, determines the share of L-workers λ that will reside in region H as a function of τ: Since $\Delta V = 0$ no worker finds reason to leave the region. Particularly this spatial equilibrium holds always for $\lambda = \frac{1}{2}$, *i.e.* for the case of spatially uniformly distributed L-workers. If transport costs exceed the threshold of τ^* (determined by the model), any accidental immigration to H will decrease the utility of this region. That causes backward migration from H to F – the spatial equilibrium is stable. However, in case of τ undercuts τ^* any immigration to H increases the utility of all L-workers living in this region. The immigration proves self enforcing; at the end of the agglomeration process all L-workers will reside in H.

The introduction of urban costs into the model allows to investigate the influence of these costs on growth (or shrinking, resp.) processes of urban agglomerations. OTT meet the following assumptions:

- Modelling of an one-dimensional space containing two urban centres (central business districts, CBD) H and F, distant from each other;
- Introduction of housing as the third commodity of this economy;
- L-worker reside around the CBD; every L-worker consumes one unit of distance;
- Land rents are equally redistributed among the L-workers;
- Urban costs amount to Θ units of the *numéraire* per unit of distance from the CBD.

The outcome of this modification is a two-city-model where agglomeration occurs (*i.e.* one city is growing while the other is shrinking) if transport costs are within a symmetric interval around $\frac{\tau^*}{2}$. Larger transport costs entail the drop of utility in the growing city. Are transport costs very low, commuting costs do restrict further immigration (see also fig. 1 p. 5).

In the course of history transport costs have been steadily decreased in the long run. In our model the undercutting of the threshold value τ_2^u (see fig. 1) causes an increase of utility level in city H attracting immigrants from city F. This explains the formation of big agglomerations (change from "Dispersion II" to "Agglomeration" in fig. 1). However, the growth of the agglomeration H also leads to the increase of urban costs in this city that impedes further growth. When transport costs are falling below t_1^u some residents of H move to F (Dispersion I in fig. 1). A model with more

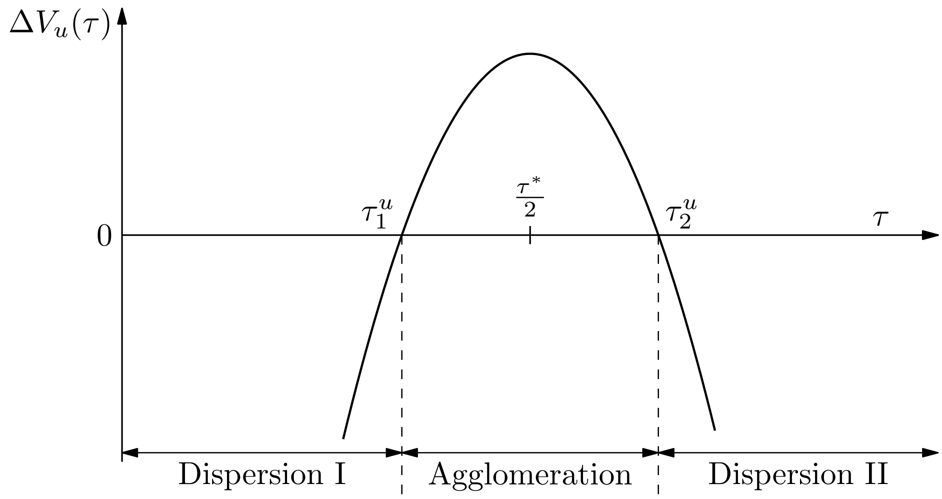

Fig. 1: Regional utility differential in the OTT model with urban costs

then two regions (resp. cities) should show that residents of the agglomeration H will relocate to smaller cities ("urban sprawl"), while the H-city is shrinking.

TTZ apply the assumptions of the OTT model to a spatial configuration of n regions or cities, respectively. This allows to investigate the shifting of weights of the size distributions of whole systems of cities. Assumptions regarding utility, costs, types of markets and urban costs come from the OTT model. Let λ_i be the share of city i in total city population (that is assumed to be constant over time) and $\boldsymbol{\lambda}$ the size distribution of cities $1 \dots n$. The cities grow or shrink due to migration flows within the system. These processes are described by the dynamic system

$$\frac{\mathrm{d}\lambda_i}{\mathrm{d}t} = \sum_{j=1}^{n} \frac{\mathrm{d}\lambda_{ji}}{\mathrm{d}t} = n\Big(V_i(\boldsymbol{\lambda}) - \frac{1}{n}\sum_{j=1}^{n} V_j(\boldsymbol{\lambda})\Big) \quad \forall\, i = 1 \dots n. \tag{4}$$

The basic idea is that L-workers meet their migration decision after comparing the indirect utilities of all pairs of cities. For existing two cities i, j this means

$$\frac{\mathrm{d}\lambda_{ji}}{\mathrm{d}t} = V_i(\boldsymbol{\lambda}) - V_j(\boldsymbol{\lambda}), \tag{5}$$

i.e. every single equation contains the whole distribution $\boldsymbol{\lambda}$. To get the model tractable, TTZ assume identical transport costs between all cities: all cities are located on a circumference, and any pairs of them are connected by transport ways of identical length through the centre (see fig. 2).

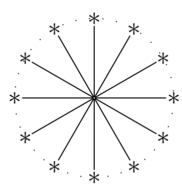

Fig. 2: Arrangement of cities in the TTZ model

This simplifies eq. (4) to

$$\frac{\mathrm{d}\lambda_i}{\mathrm{d}t} = n\Big(S_i(\lambda_i) - \frac{1}{n}\sum_{j=1}^{n} S_j(\lambda_j)\Big) \quad \forall\, i = 1 \ldots n, \tag{6}$$

wherein

$$S_i(\lambda_i) = (C_1\tau - C_2\tau^2)\lambda_i - C_3\tau^2\lambda_i^2 - \Theta_i(\lambda_i) \tag{7}$$

with

$$C_1 = \frac{aN(b+cN)(3b+2cN)}{8(2b+cN)^2},$$
$$C_2 = \frac{N(b+cN)}{8(2b+cN)^2}\Big[4(2b+cN)\frac{cNA}{nL} + 12b^2 + 4bcn - 3c^2N^2\Big],$$
$$C_3 = \frac{cN^2(b+cN)(8b+5cN)}{8(2b+cN)^2}.$$

$S_i(\lambda_i)$ doesn't depend on the total distribution $\boldsymbol{\lambda}$ but only on city i's share. It can be seen as deviation from the average indirect utility (in sense of a statistically normalised variable with zero mean) and is called the *surplus* of city i. As one element of heterogeneity remains the vector of urban costs $\boldsymbol{\Theta}(\boldsymbol{\lambda})$, wherein $\Theta_i(\lambda_i)$ is assumed as increasing function of λ_i with $\Theta_i'(\lambda_i) > \Theta_j'(\lambda_j)\ \forall\ \lambda_i < \lambda_j$.[6] These costs are *e.g.* congestion costs, but also costs for energy, heating and water supply, unfavourable climatic conditions, and so on.[7]

If transport costs change, the interplay of agglomerating forces (returns to scale, love for variety) and of deglomeration factors (immobile A-workers and urban costs) generates effects on the local composition of supplied varieties of the heterogeneous good, on real wages, and hence on the distribution of $\boldsymbol{S}(\boldsymbol{\lambda})$. This provokes migration that reduces utility differentials and leads to a new equilibrium distribution $\boldsymbol{\lambda}$. Fig. 3 shows this effects using the example of a simulated system of six cities.[8]

Before we use fig. 3 to investigate the effects of increasing transport costs we should have a look at the functioning of the model applied to its originally purpose – the long term decrease of transport costs. Starting point is a system of medium-sized cities (on the right edge of fig. 3). Since transport costs fall (move to the left in our figure) the spatial equilibrium becomes disturbed. The indirect utility rises in large cities and falls in smaller ones; this stimulates L-workers to migrate from small to large cities and causes an agglomeration process that finishes in an interval of middle transport costs where the maximum spread of city size distribution is reached. Further decreasing of transport costs reduced the indirect utility in large cities relative to smaller ones

6 The latter assumption is met additionally by the author. Ottaviano et al. (2002) assume $\Theta_i(\lambda_i)$ as convex and tree times differentiable in λ.

7 See Tabuchi et al. (2005) p. 427.

8 The parameter values in this simulation were $n = 6$, $a = 9$, $b = 1$, $c = 1$, $\phi = 1$, $L = 100$, $A = 1200$, $\Theta_1(\lambda_1) = 100\lambda_1$, $\Theta_2(\lambda_2) = 104\lambda_2$, $\Theta_3(\lambda_3) = 108\lambda_3$, $\Theta_4(\lambda_4) = 112\lambda_4$, $\Theta_5(\lambda_5) = 116\lambda_5$ and $\Theta_6(\lambda_6) = 120\lambda_6$.

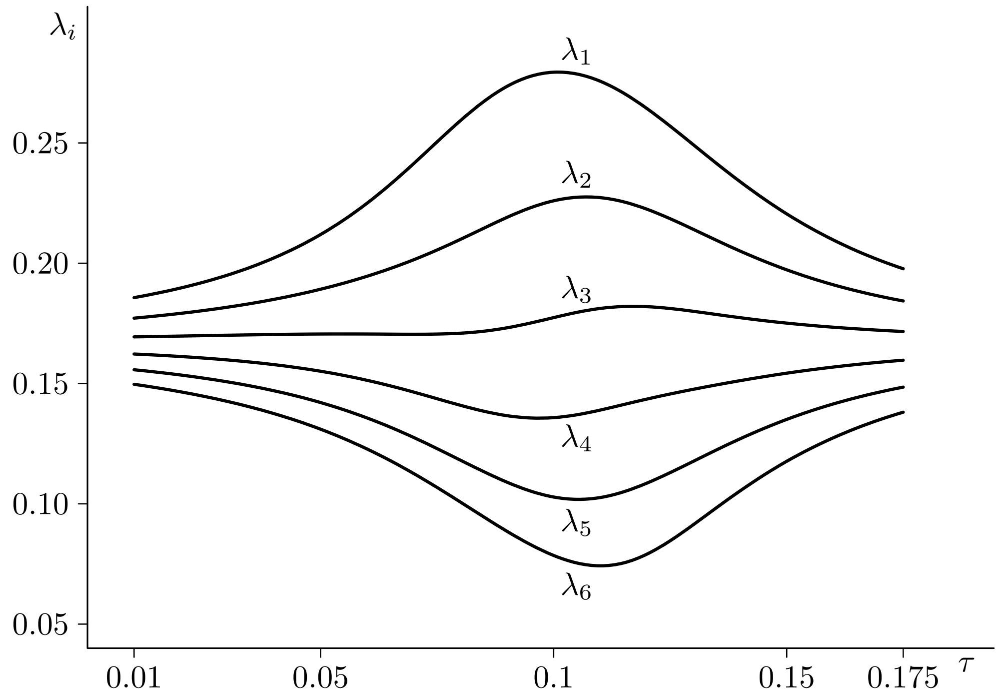

Fig. 3: Transport costs and city size distribution (adapted from Tabuchi *et al. (2005) p. 436)*

because the effects of urban costs. This leads to the polarisation reversal of migration, that opens a period of suburbanisation. This way the model reproduces changes of urbanisation and suburbanisation addressed by the theory of *differential urbanisation*.[9] At the end of the Soviet era Russian urbanisation lagged about 20 years behind the US.[10] Particularly in peripheral regions the establishment of settlements near facilities of extraction or production served as a substitute of dispersion after agglomeration. With regard to the low (but highly subsidised) transport costs this seemed to be rationally.

In order to predict the effects of increasing transport costs it would be sufficient to change the direction of the process displayed in fig. 3, if the phenomena were of long term nature and all other things were equal. However, this assumptions are not adequate to our matter of investigation, neither to the increase of transport costs nor to the processes of transformation started with the liberalisation of prices in Russia in 1992. Transport costs jumped in 1992, and the assumptions of the model particularly regarding the formation of market prices are completely out of touch with the reality of Soviet planned economy. Therefore, let the starting point be the size distribution of cities and urban-type settlements at the beginning of transformation. The question whether this distribution has to be located on the "left" (agglomeration) or "right" side (dispersion) of the family of possible growth paths should stay open initially. In the next section we'll find reason to locate the starting point on the left side of fig. 3 where

[9] Geyer/Kontuly (1993) and Geyer (1996).
[10] Nefedova/Treivish (2003) and Medvedkov/Medvedkov (1999).

transport costs are low and the spread of distribution increases with transport costs – provided that the model is appropriate to explain something of what has happened.

Furthermore we may ask what happens, if the assumption of a constant number of n cities is given up. For the case of falling transport costs TZZ show that both decreasing (at relatively high level of transport costs) and increasing (at relatively low level of τ) numbers of (particularly small) cities are possible equilibria. In case of increasing transport costs in left third of fig. 3 (low level of transport costs) we should expect the abandonment of the smallest settlements. Indeed, this happens primarily in the periphere regions of the North and Far East of Russia. However, we want to restrict our empirical analysis on those cities that are existing during the whole time period of investigation.

3. Empirical findings

Many factors determine the processes of growth and shrinking of cities, settlements and villages of different size in Russia: demography, ethnic conflicts, the conversion of the military-industrial complex or the fear to fall into a trap elsewhere in the Far East, captured by huge costs of passenger traffic. All these influencing variables can explain specific aspects of migration. However, we are only interested in migration that is caused by different real wages at different locations and that happens within the considered region at a specific level (internal migration). There happens neither migration from or to rural units nor from or to other countries (external migration). If we investigate migration at the level of federal subjects we abstract from migration between the considered subject and other ones. To lead empirical analysis conform to our theoretical model, we have to correct the "raw" data of city population for effects of natural growth and external (or interregional, resp.) migration.

City population data stem from "Chislennost' naseleniya rossiiskoi federatsii po gorodam, poselkam gorodskogo tipa i raionam" published annually by Goskomstat Rossii since 1991. Since 1993 city size is defined as number of permanent residing persons. Our analysis is focused on electronic edited data sets for 1993 and 2004. Also considered are the data of 38 cities with "closed" status in 1993; we took the first available data of these cities in our data set (mostly of 1994 or 1995). This way data for 1103 cities and 2063 urban-type settlements in 1993 and for 1097 cities and 1781 urban-type settlements in 2004 are available. The differences are due to administrative reforms (change of the legal state of local authorities, *e.g.* cities to urban-type settlements or villages, or urban-type settlements to villages, or, seldom, reversed); they tend to bias our findings but are rather small for the time period of observation. From this set of urban units we have to drop the cities and settlements located in the Republics of Checheniya and Ingushetiya because data are not reliable for these federal subjects due to the Chechen wars.

The empirical analysis concentrates on the dependence of the city size growth 1993–2004 and its size in 1993 as well on effects of costs of freight traffic and of urban costs or of variables that could approximate these costs. These are the distance between the city and its provincial capital,[11] and other variables that are available at the regional level of federal subjects: the distance of the provincial capital to the federal capital Moscow, the geographical co-ordinates of the provincial capital, the index of transport costs in the federation subject to what the city belongs, the growth rates of transportation quantities of road and rail networks, and the length of transportation networks. Analysis was conducted firstly at the level of federal subjects (that are the republics, krais, oblasts and the Ewish Autonomous Oblast') for that are published regional data sets.[12] Here the city population size in 1993 λ_0 and the distance between the city and its provincial capital δ_{ir} are the only explanatory variables. Secondly we tested the dependence of the size growth of cities and urban-type settlements from their size in 1993 and from other predictors at federal level. Here we could include explanatory variables that are available only at federal subject level. Before starting the analysis we have to correct the population figures of cities and settlements to get conformity of data to the theoretical approach at the level of both the federation and the federal subjects.

Federal level: correction for natural growth and external migration. The purpose of this correction is a data set of population of cities and urban-type settlements that suppresses changes caused by natural growth and migration from and to other countries, according to the model assumption of a closed system of cities with constant population size. Let be

$\mu^{\mathrm{e}}_{\mathrm{in}_{rt}}$	External immigration to federal subject r in period t
$\mu^{\mathrm{e}}_{\mathrm{out}_{rt}}$	External emigration from federal subject r in period t
ν^{u}_{rt}	Natural growth of city population of federal subject r in period t
Λ_{rt}	Whole population of federal subject r in period t
$\Lambda^{\mathrm{u}}_{rt}$	Whole city population of federal subject r in period t.

The correction is based on the assumptions

- External net migration reported for federal subject r $\mu^{\mathrm{e}}_{rt} = \mu^{\mathrm{e}}_{\mathrm{in}_{rt}} - \mu^{\mathrm{e}}_{\mathrm{out}_{rt}} = \mu^{\mathrm{eu}}_{rt} + \mu^{\mathrm{er}}_{rt}$ is distributed on rural (r) and urban (u) population proportional to their share at population,

$$\mu^{\mathrm{eu}}_{rt} = \mu^{\mathrm{e}}_{rt} \frac{\Lambda^{\mathrm{u}}_{rt}}{\Lambda_{rt}};$$

- External migration and natural growth are distributed on cities and urban-type settlements of a federal subject proportional to its shares at the whole city population of this federal subject,

$$\mu^{\mathrm{eu}}_{it} = \lambda_{it}\mu^{\mathrm{eu}}_{rt}, \quad \nu^{\mathrm{u}}_{it} = \lambda_{it}\nu^{\mathrm{u}}_{rt};$$

[11] Each federal subject has one administrative centre, called the provincial capital.

[12] The available data of autonomous okrugs were not sufficient to include them into analysis as statistical units. In some cases that would be desirable, particularly for the western Siberian okrugs Khanty-Mansiisk and Yamalo-Nenetsk.

- Migration between urban and rural settlement areas is neglected.

The change of city population size caused by internal migration is incidental to

$$\Delta\lambda_{iT} = \lambda_{iT} - \lambda_{i0} - \sum_{t=0}^{T-1} \Big[(\mu^{\mathrm{e}}_{\mathrm{in}_{rt}} - \mu^{\mathrm{e}}_{\mathrm{out}_{rt}}) \frac{\Lambda^{\mathrm{u}}_{rt}}{\Lambda_{rt}} + \nu^{\mathrm{u}}_{rt}\Big] \frac{\lambda_{it}}{\Lambda^{\mathrm{u}}_{rt}}, \tag{8}$$

where the periods 0 and T correspond to the years 1993 and 2004.

Federal subject level: correction for natural growth and external and interregional migration. The simulation of a closed system of cities at federal subject level additionally requires the exclusion of interregional migration between the considered region and all other federal subjects. The intraregional migration within a federal subject has no influence on its population size. Therefore, we can carry out the correction for external and internal migration by use of net migration coefficients for urban population of federal subjects μ^{u}_{rt} that are recalculated for the Demographic Yearbook 2006 by inclusion of the recent outcomes of the 2002 census. Here we assume that external and interregional migration to and from cities (and urban-type settlements) of a federal subject and natural growth of its city population are distributed proportional to the share of each city at the whole city population of the federal subject. Again, migration between urban and rural settlement areas is neglected. With $\bar{\Lambda}^{\mathrm{u}}_{rt} = \frac{1}{2}(\Lambda^{\mathrm{u}}_{rt} + \Lambda^{\mathrm{u}}_{r,t+1})$ as annual mean of size of the federal subject's city population the change of city population size caused by intraregional migration amounts to

$$\Delta\lambda_{iT} = \lambda_{iT} - \lambda_{i0} - \sum_{t=0}^{T-1} \big[\mu^{\mathrm{u}}_{rt}\bar{\Lambda}^{\mathrm{u}}_{rt} + \nu^{\mathrm{u}}_{rt}\big] \frac{\lambda_{it}}{\Lambda^{\mathrm{u}}_{rt}}. \tag{9}$$

Indices of transport costs: The index of costs of freight traffic by all means of transport for the Russian Federation made a great leap upward in the period of price liberalisation. The time series is strong correlated to the index of energy prices. Both indices displayed in fig. 4 are price-adjusted by use of the GDP deflator. This deflator is chosen due to its large weight of domestic production in its commodity basket. The time series show two strong movements: Firstly the jump of transport and energy prices in 1991–93 following the price liberalisation, secondly the decrease of these prices in consequence of the financial crisis 1998–99. However, this decrease could not compensate the leaps 1991–93, on the contrary transport costs are increasing slightly since 1999.

Annual change of transport costs in the federal subjects of the RF are published (in nominal terms) in *Regiony Rossii* by Goskomstat. However, the creation of a price adjusted index for the whole period of analysis fails due to lacking of an appropriate regional deflator. The construction of a regional deflator using indices of gross regional product and of production volume was possible only for 1996–2004, but its goodness is weak due to some deficits of construction (*e.g.* chain-linking).

Fig. 5 displays the change of transport costs 1991–93 for 75 federal subjects. To show the increasing linear relationship between transport costs and distance from the federal centre the x-co-ordinate is ordered by distance of the administrative centres of

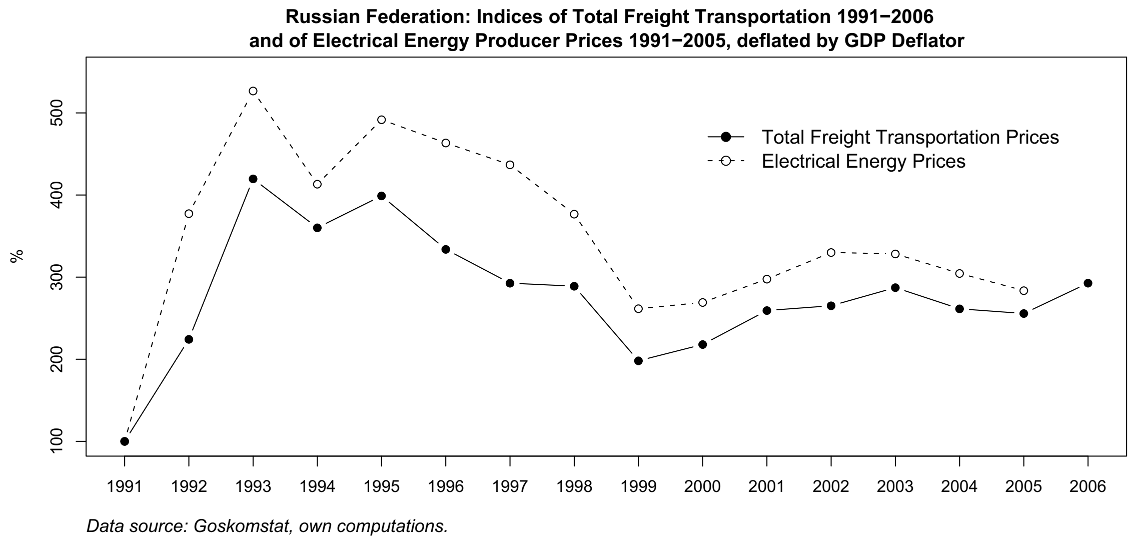

Fig. 4: Russian Federation: indices of transport and energy costs in real terms, 1991–2006

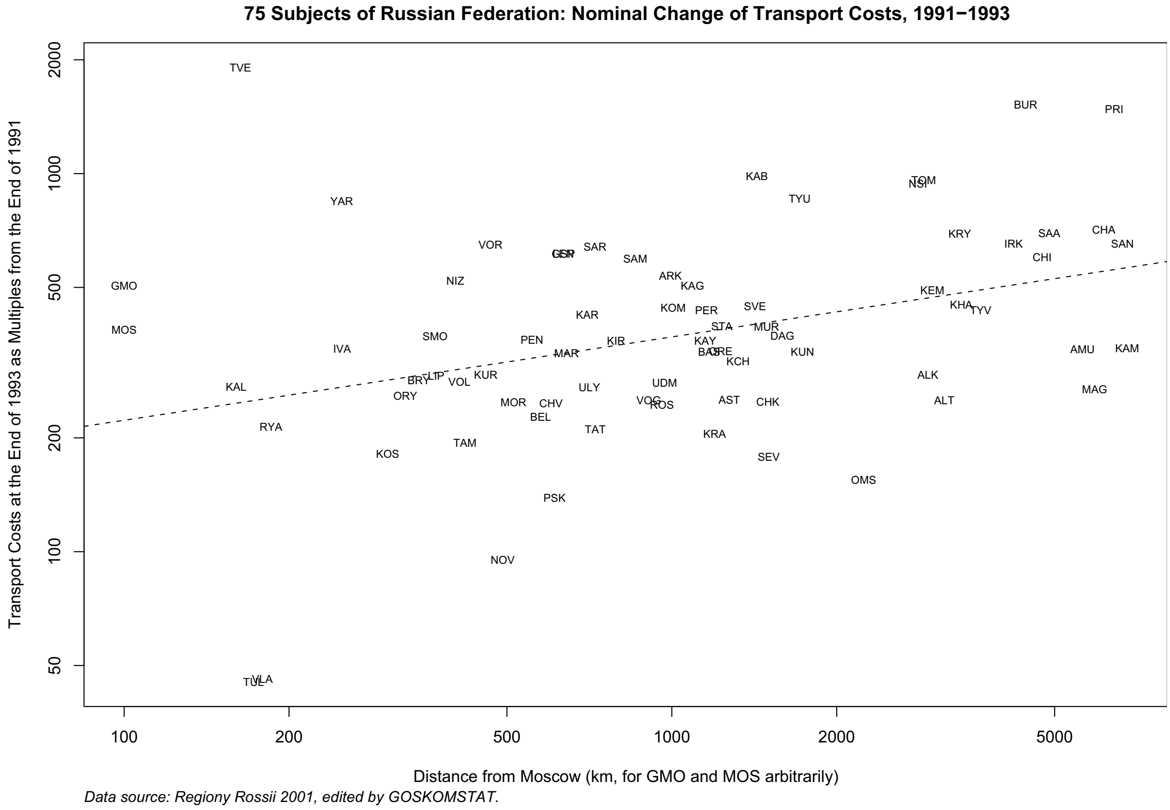

Fig. 5: 75 federal subjects of RF: change of transport costs 1991–93

federal subjects from Moscow.[13] Fig. 6 displays the change of transport costs 1996–2004 for 75 federal subjects, price-adjusted by the regional GDP deflator described above. For this time period the data show no significant relationship between the change of transport costs in real terms in a region and its distance from the centre.

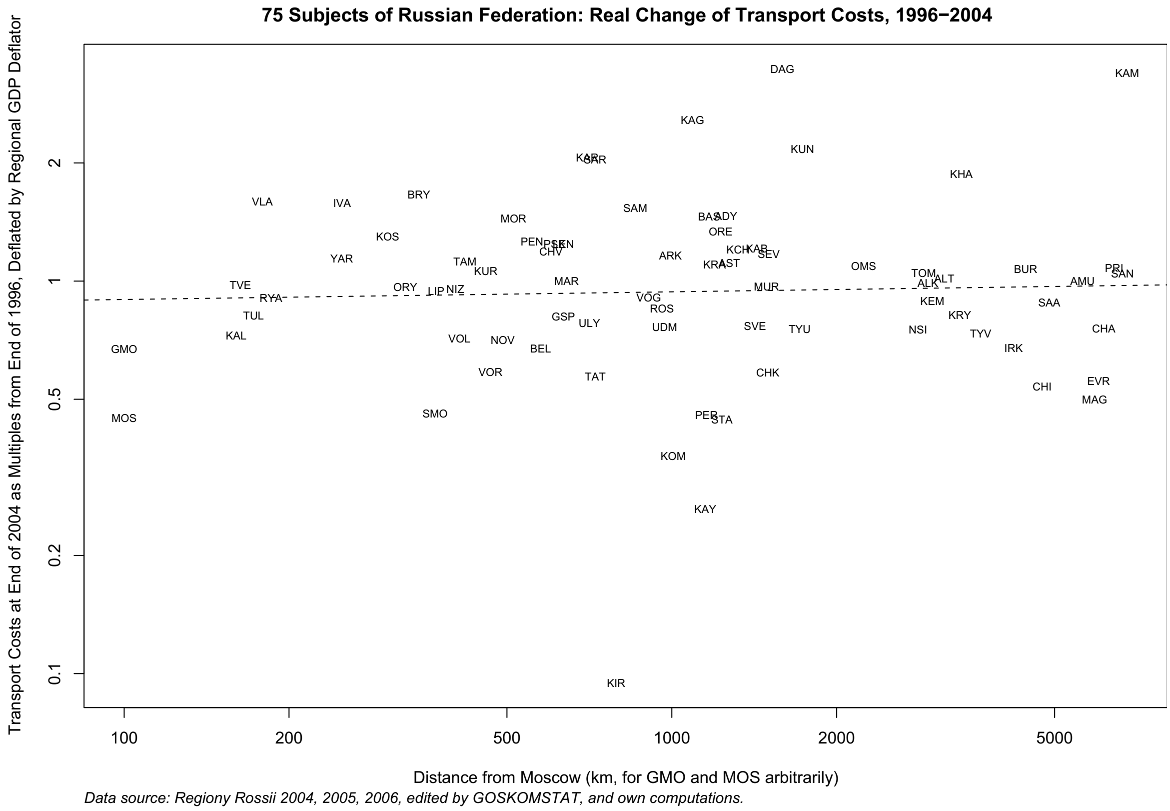

Fig. 6: 75 federal subjects of RF: change of transport costs in real terms, 1997–2004

Regression analysis at federal subject level: Is there any linear relationship between the dependent variable "growth rate of population size of a city 1993–2004" ($\dot{\lambda}_{0T} = \frac{\Delta\lambda_{0T}}{\lambda_0}$) and the explanatory variables "city population 1993" (λ_0, in logarithms) as well as "distance of the city from its provincial capital" (δ_{ir})? To find answer to this question we tested by OLS estimation the single equation model

$$\dot{\lambda}_{OT} = \beta_0 + \beta_1 \ln \lambda_0 + \beta_2 \delta_{ir} + u \tag{10}$$

for cities and urban-type settlements with more then 1000 inhabitants 1993 for 75 federal subjects.[14] Population size figures have been corrected for external and inter-regional migration effects and natural growth according to eq. (9). At a significance

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[13] The names of the federal subjects of the RF and their abbreviations are listed in appendix 1 p. 19.
[14] Regressions could not be executed for the autonomous okrugs; their cities are treated as belonging to their superordinate oblasts. Regressions were not feasible for the republics of Altai, Chechenya, Ingushetiya, and Kalmykiya, too. For regression results see Appendix 2 p. 20.

level of 90 % the coefficient of λ_0 for 16 federal subjects proved significantly positive; not one was significantly negative. This supports the assumption that the increase of transport costs tends to result in concentration of population in large cities at the expense of smaller ones in large parts of the Russian Federation. Hence, the vector $\boldsymbol{\lambda}_0$ has to be located in the "left half" of fig. 3 where transport costs are low.

The coefficient of δ_{ir} proved significantly negative for 24 federal subjects. Only for Arkhangel'sk and Bryansk oblast' the coefficient of δ_{ir} is significantly positive. Intuitionally we should presume that larger distances (what means larger transport costs) tend to account for shrinking of small cities if they are more distant to the provincial capital. Moreover, in the huge federal subjects of the Far East the remoteness of a location from its provincial capital also stands for local disadvantages like extremely coldness or bad supply of goods that raise urban costs. We'll get back to this issue when we present the findings of regressions at federal level.

Figures 7 and 8 display the regional distribution of signs of the significant coefficients of regressions to the federal subjects.[15] It is striking that a significant effect of both predictors emerges primarily in federal subjects that belong to the northern and to the far eastern periphery of Russia. Few federal subjects with significant impact are located rather central, not one in the south. This regional pattern matches roughly a segmentation that was developed in MACKINDERs "heartland theory"[16] that identifies the central and the north western regions, the Volga region, the Urals as well as parts of western Siberia as the "heartland of Eurasia". Eastern Siberia and the Far East are quite different regarding their colonisation and urbanisation as well as their climatic, geographic and economic conditions than the heartland. This also applies to the peripheral regions of the south, whose recent history showed a revival of old ethnic conflicts.

Regression analysis at federal level: At federal level we can introduce characteristics of regions (*e.g.* of federal subjects) as explanatory variables into regression analysis. Amongst others the following cross section data were available:

δ_r	Distance of the provincial capital to Moscow
g_{car}	Growth of transportation quantity (tonne-kilometres) of transports of goods by road per year, 1993–2004
roads	Length of road networks 1990
rail	Length of rail networks 1990
$\tau^n_{91-92}, \tau^n_{92-93}$	Index of transport costs (nominal), 1991–1992 and 1992–1993
τ^r_{96-04}	Index of transport costs (real) 1996–2004

Because the lack of a real index of transportation costs for the whole period of analysis we tested the dependence of growth of cities on nominal growth of transportation costs for single periods, and on "real" growth of transportation costs for 1996–2004. From the results of the influence of annual change of transport costs here we provide only the coefficients for 1991–92 and 1992–93 that are significantly negative.

15 For the enumeration of federal subjects see appendix 1 p. 19.

16 MACKINDER (1904) HOOSON (1964); see also BRADSHAW/PRENDERGRAST (2005) and TREIVISH (2005).

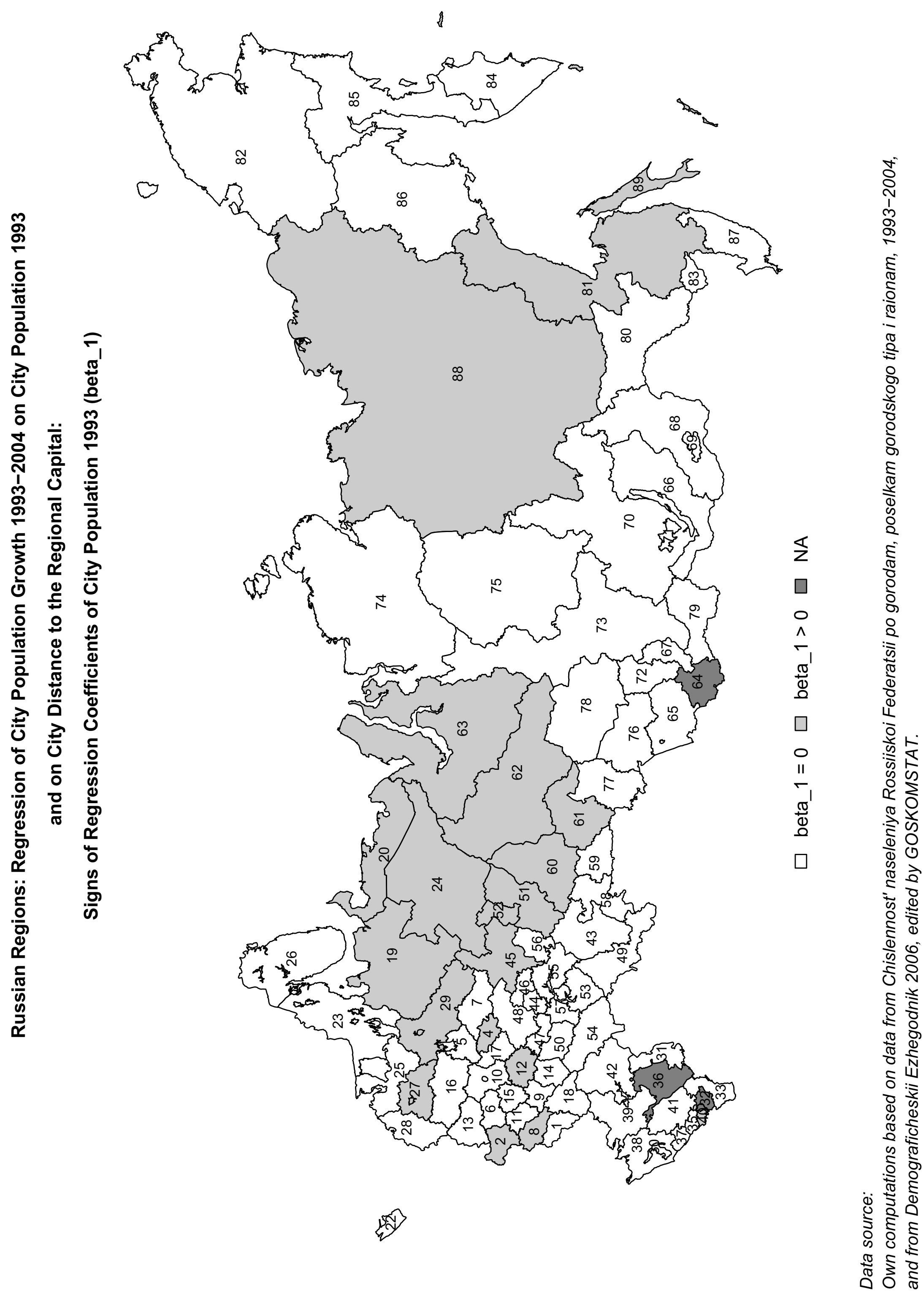

Fig. 7: Regional distribution of the regression coefficients of $\ln \lambda_0$ *in eq. (10)*

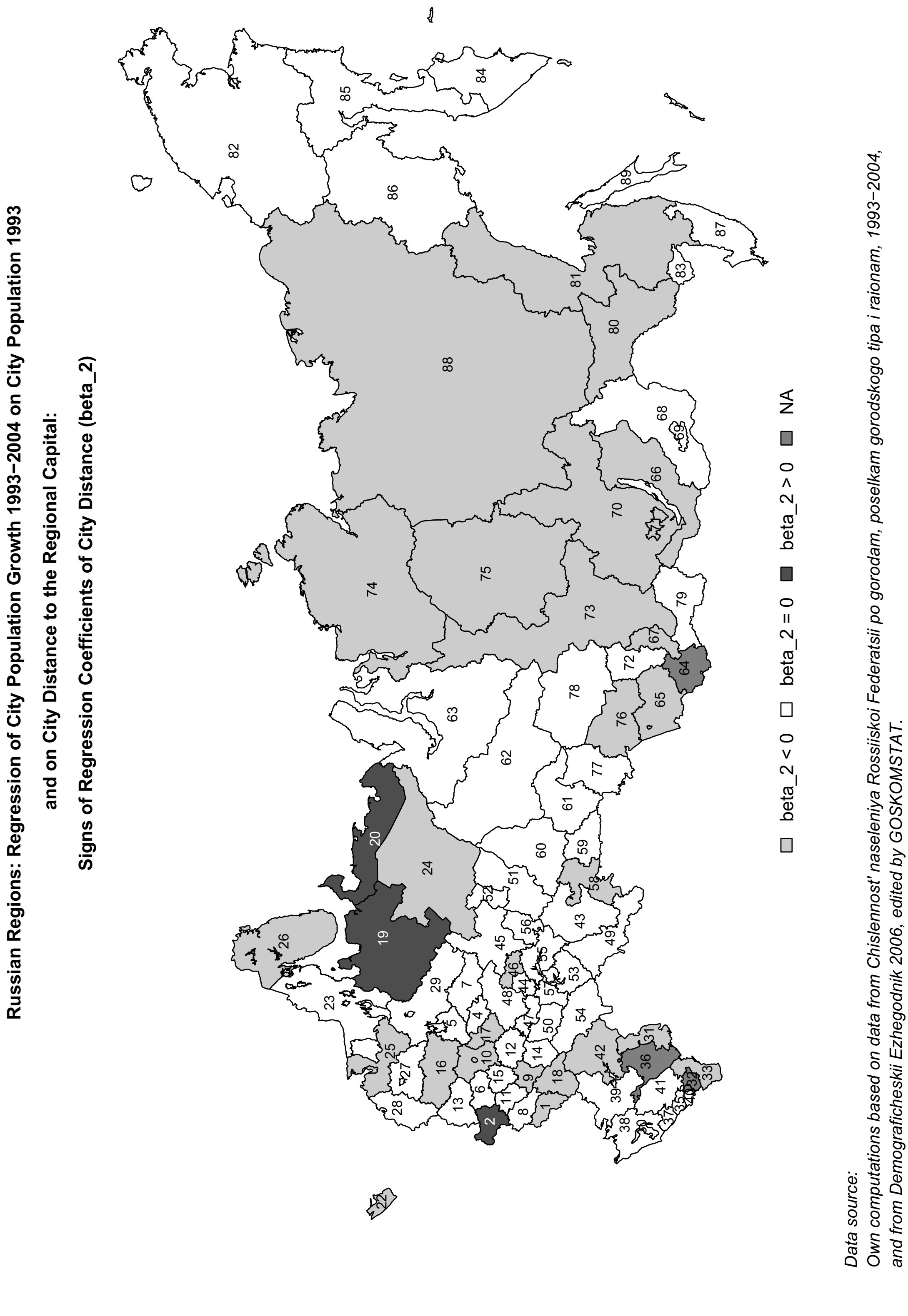

Fig. 8: Regional distribution of the regression coefficients of δ_{ir} in eq. (10)

$$\dot{\lambda}_{0T} = \underset{(-3.7)}{-5.4} \;\; \underset{(10.4)}{+\, 3.1 \ln \lambda_0} \;\; \underset{(-5.5)}{-\, 0.15\, \tau^n_{91-92}} \;\; \underset{(-3.2)}{-\, 0.11\, \tau^n_{92-93}}. \qquad R^2 = 0.05$$

For other periods coefficients change signs following roughly the sign of annual change of the index for the whole federation (see fig. 4). However, the coefficient of determination of these regressions is very small and depends strongly from the existence of outliers. This also holds for the influence of the real change of transport costs 1997–2004:

$$\dot{\lambda}_{0T} = \underset{(-15.5)}{-16.6} \;\; \underset{(10.5)}{+\, 3.1 \ln \lambda_0} \;\; \underset{(6.0)}{+\, 4.5\, \tau^r_{96-04}}, \qquad R^2 = 0.05.$$

Rather than transport costs the distance of the provincial capitals to the federal centre Moscow possesses substantial explanatory power:

$$\dot{\lambda}_{0T} = \underset{(-1.6)}{-1.3} \;\; \underset{(8.3)}{+\, 2.3 \ln \lambda_0} \;\; \underset{(-14.9)}{-\, 0.03\, \delta_{ir}} \;\; \underset{(-12.5)}{-\, 0.0026\, \delta_r}, \qquad R^2 = 0.22.$$

Here the strong decline of population in the northern and far eastern Russian regions displays powerful effects. The distance to Moscow not only approximates parts of the transport costs but also stands indirectly for a part of urban costs Θ_i generated by the severe cold in the northern and far eastern periphery of Russia (average air temperature is dropping by increasing distance from Moscow in a northward and eastward direction).[17] This relationship could also explain partially the strong influence of the distance variable δ_{ir} specially in the huge federal subjects of eastern Siberia and the Far East where the climate is extremely hard and the supply of all kind of goods and services declined dramatically, particularly in the settlements far from the centre.

The impact of geography becomes even more distinct if we replace the distance variable δ_r by geographical co-ordinates of the provincial capitals lon_r and lat_r:

$$\dot{\lambda}_{0T} = \underset{(11.2)}{48} \;\; \underset{(7.4)}{+\, 2.0 \ln \lambda_0} \;\; \underset{(-11.6)}{-\, 0.024\, \delta_{ir}} \;\; \underset{(-16.3)}{-\, 0.19\, lon_r}, \;\; \underset{(-10.6)}{-\, 0.79\, lat_r}, \qquad R^2 = 0.26.$$

This is not amazing because the likewise considerable distances of the southern federal subjects (with favourable climate) to the federal capital dilute the approximation of urban costs by distance of *all* provincial capitals to Moscow (not only that of the North and Far East).

Also the growth of transport quantity by roads and the length of the roads networks of the federal subjects have significant impact:

$$\dot{\lambda}_{0T} = \underset{(-6.3)}{-6.8} \;\; \underset{(7.4)}{+\, 2.0 \ln \lambda_0} \;\; \underset{(-16.3)}{-0.033\, \delta_{ir}} \;\; \underset{(-10.8)}{-0.0022\, \delta_r} \;\; \underset{(7.2)}{+3.7\, g_{\text{car}}} \;\; \underset{(10.1)}{+6.6\, roads}, \quad R^2 = 0.26,$$

or

[17] See Hill/Gaddy (2003) u. Mikhailova (2004). Modelling of climatic conditions as part of urban costs may be more appropriate to our question than the introduction of a temperature-per-capita variable.

$$\dot{\lambda}_{0T} = \underset{(7.6)}{3.4} + \underset{(6.7)}{1.8 \ln \lambda_0} - \underset{(-13.2)}{0.027\, \delta_{ir}} - \underset{(-14.0)}{0.16\, lon_r} - \underset{(-8.5)}{0.63\, lat_r} + \underset{(5.1)}{2.7\, g_{\text{car}}} + \underset{(8.9)}{5.8\, roads}, \quad R^2 = 0.28,$$

respectively. Likewise significant influence showed the variable *rail* but with less explanatory power than *roads*. Longer road and rail networks may reduce transport costs. High transport quantity improves the quality of life (or real wages, resp.). If cities are not equidistant (like in our model) the cities near by the centre do more profit from transportation services. These are often the larger cities. So the positive sign is according to our expectations.

Finally, we proved the relevance of regional patterns that emerged by testing our hypotheses at federal subject level. For this we generate the three dummy variables *core*, *south* and *north* that indicate the belonging of a city to one of the three major regions adopted from Mackinder and Hooson:

Major region	Federal districts
Core	Centre, North West, Volga, Urals
South	South
North	Siberia, Far East

The results support the intuitive findings from fig. 7 and 8 above:

$$\dot{\lambda}_{0T} = \underset{(-5.1)}{-4.3} + \underset{(8.6)}{2.4 \ln \lambda_0} - \underset{(-21.1)}{0.041\, \delta_{ir}}, \quad R^2 = 0.17,$$

$$\dot{\lambda}_{0T} = \underset{(-6.0)}{-6.3} + \underset{(8.7)}{2.4 \ln \lambda_0} - \underset{(-19.3)}{0.039\, \delta_{ir}} + \underset{(3.1)}{2.5\, core}, \quad R^2 = 0.18,$$

$$\dot{\lambda}_{0T} = \underset{(-5.7)}{-4.8} + \underset{(7.8)}{2.2 \ln \lambda_0} - \underset{(-19.6)}{0.04\, \delta_{ir}} + \underset{(7.1)}{9.0\, south}, \quad R^2 = 0.19,$$

$$\dot{\lambda}_{0T} = \underset{(-2.2)}{-1.8} + \underset{(7.7)}{2.1 \ln \lambda_0} - \underset{(-14.6)}{0.03\, \delta_{ir}} - \underset{(-12.3)}{0.0025\, \delta_r} + \underset{(6.8)}{8.3\, south}, \quad R^2 = 0.23,$$

$$\dot{\lambda}_{0T} = \underset{(-4.0)}{-3.4} + \underset{(8.5)}{2.3 \ln \lambda_0} - \underset{(-16.5)}{0.034\, \delta_{ir}} - \underset{(-8.7)}{7.6\, north}, \quad R^2 = 0.195.$$

The *north*-variable has a strong negative influence, it is heavily correlated to the distance variable δ_r (that is therefore omitted). Its impact should be interpreted according to the coefficients of δ_r or to the geographical co-ordinate variables. The *south*-variable has a strong positive effect and is not correlated with distance. This points to other determinants of city growth in the south than explained by our model. The *core*-variable has only weak impact on regression results, it is also strongly correlated with δ_r.

4. Conclusions

The regression results of the last section provide evidence that the predictions of the TTZ model extended by urban costs reproduce the evolution of size distribution of

Russian cities and urban-type settlements during the transformation period at least for big parts of the Russian Federation fairly well. Particularly they are important for the peripheral regions of the Far North and Far East with regard to possibly upcoming increases of energy prices. In the sense of our model, the metaphor of urban centres in the Far East that hold one's ground like islands in an "ocean of land"[18] should be completed as follows: if the archipelago is surrounded by an ocean of land, the sea level rises with costs of freight traffic; the smallest islands will be submerged first and foremost.

The growth of larger cities at the expense of the smaller ones is the outcome of different economic forces. Increasing transport costs reduce competition between regions but also diminish the spectrum of consumer's choice. On the other hand there are urban costs that are determined in the peripheral regions of the Russian North and Far East by the conditions of harsh climate. These costs increase with the distance of a city or settlement from its provincial capital. This also holds for the marginal costs of urbanisation, *i.e.* the costs of exploration, development and colonisation as well as of enhancement of local utilities that are exceedingly expensive in remote small settlements located in permafrost areas. Therefore, economic policy is faced by a trade-off between reduction of transport costs on the one hand and activities to maintain (and improve) the viability of cities on the other hand.

On the one hand it should be an political objective to minimise economic distances. This could be realised by means of

- To keep down the factor costs in the transportation sector;
- Improvement in efficiency of the transportation sector;
- Close gaps in transportation networks to reduce distances.

The postulation of cost minimisation particularly requires low domestic prices for energy. This practice could to turn out to be impossible after the WTO accession of Russia. Improvement of efficiency in the transportation sector should be the main focus to avert the danger of unlinking the periphere regions.

On the other hand the urban costs have to be reduced to a rational extent. This is primarily a task of regional policy. On the one hand the economic rationality of maintenance of every remote settlement should be checked and, in case of doubt, alternatives should be balanced. That could be *e.g.* seasonal production, but also institutional arrangements, *e.g.* the acceptance of responsibility settlements by firms. On the other hand it is important to "strengthen the islands"[19], *i.e.* to improve the quality of life in and the reachability of the conurbations. This also concerns the situation of suburbs and of second cities. This kind of regional policy would diminish the sum of urban costs in the peripheral regions *and* reduce transport costs. This could help to stabilise the population in the regions of Far North and Far East at a small, but necessarily magnitude.

However, the present analysis is restricted on the "outer parenthesis" of the relations modelled by TTZ: increasing costs of freight transportation and high urban

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[18] Treivish (2005) p. 151 f.
[19] *Ibid.*

costs particularly in remote settlements and cities in periphere regions are causing emigration from (or diminish immigration to) this areas. An empirical investigation of the mechanism inside the model (*e.g.* the connection between migration and regional prices and wages) should be done in the future.

Appendix 1: Federal subjects of the Russian Federation

Belgorodskaya oblast'	BEL	1
Bryanskaya oblast'	BRY	2
g. Moskva	GMO	3
Ivanovskaya oblast'	IVA	4
Yaroslavskaya oblast'	YAR	5
Kaluzhskaya oblast'	KAL	6
Kostromskaya oblast'	KOS	7
Kurskaya oblast'	KUR	8
Lipetskaya oblast'	LIP	9
Moskovskaya oblast'	MOS	10
Orlovskaya oblast'	ORY	11
Ryazanskaya oblast'	RYA	12
Smolenskaya oblast'	SMO	13
Tambovskaya oblast'	TAM	14
Tul'skaya oblast'	TUL	15
Tverskaya oblast'	TVE	16
Vladimirskaya oblast'	VLA	17
Voronezhskaya oblast'	VOR	18
Arkhangel'skaya oblast'	ARK	19
Therein:		
Nenenzkiy A. Okr.	NEN	20
g. Sankt-Peterburg	GSP	21
Kaliningradskaya oblast'	KAG	22
Resp. Kareliya	KAR	23
Resp. Komi	KOM	24
Leningradskaya oblast'	LEN	25
Murmanskaya oblast'	MUR	26
Novgorodskaya oblast'	NOV	27
Pskovskaya oblast'	PSK	28
Vologodskaya oblast'	VOL	29
Resp. Adygeya	ADY	30
Astrakhanskaya oblast'	AST	31
Chechenskaya Resp.	CHE	32
Resp. Dagestan	DAG	33
Resp. Ingushetiya	ING	34
Kabardino-Balkarskaya Resp.	KAB	35
Resp. Kalmykiya	KAY	36
Karachaevo-Cherkesskaya Resp.	KCH	37
Krasnodarskii Krai	KRA	38
Rostovskaya oblast'	ROS	39
Resp. Severnaya Osetiya-Alaniya	SEV	40
Stavropol'skii Krai	STA	41
Volgogradskaya oblast'	VOG	42
Resp. Bashkortostan	BAS	43
Chuvashskaya Resp.	CHV	44
Kirovskaya oblast'	KIR	45
Resp. Marii El	MAR	46
Resp. Mordoviya	MOR	47
Nizhegorodskaya oblast'	NIZ	48
Orenburgskaya oblast'	ORE	49
Penzenskaya oblast'	PEN	50
Permskaya oblast'	PER	51
Therein:		
Komi-Permyatskiy A. Okr.	KOP	52
Samarskaya oblast'	SAM	53
Saratovskaya oblast'	SAR	54
Resp. Tatarstan	TAT	55
Udmurtskaya Resp.	UDM	56
Ulyanovskaya oblast'	ULY	57
Chelyabinskaya oblast'	CHK	58
Kurganskaya oblast'	KUN	59
Sverdlovskaya oblast'	SVE	60
Tyumenskaya oblast'	TYU	61
Therein:		
Khanty-Mansiiskii (Yugra) A. Okr.	KHM	62
Yamalo-Nenetskii A. Okr.	YAN	63
Resp. Altai	ALT	64
Altaiskij Krai	ALK	65
Resp. Buryatiya	BUR	66
Resp. Khakasiya	KHA	67
Chitinskaya oblast'	CHI	68
Therein:		
Aginskii Buryatskii A. Okr.	ABU	69
Irkutskaya oblast'	IRK	70
Therein:		
Ust'-Ordynskii Buryatskii A. Okr.	UOR	71
Kemerovskaya oblast'	KEM	72
Krasnoyarskii Krai	KRY	73
Therein:		
Taimyrskii (Dolgano-Nenetskii) A. Okr.	TAI	74
Ewenkiiskii A. Okr.	EWE	75
Novosibirskaya oblast'	NSI	76
Omskaya oblast'	OMS	77
Tomskaya oblast'	TOM	78
Resp. Tyva	TYV	79
Amurskaya oblast'	AMU	80
Khabarovskii Krai	CHA	81
Chukotskii Avtonomnyi Okrug	CHU	82
Evreiskaya avtonomnaya oblast'	EVR	83
Kamchatskaya oblast'	KAM	84
Therein:		
Koryakskii A. Okr.	KOR	85
Magadanskaya oblast'	MAG	86
Primorskii Krai	PRI	87
Resp. Sakha (Yakutiya)	SAA	88
Sakhalinskaya oblast'	SAN	89

Appendix 2: Regression results at federal subject level

	β_0	β_1	β_2		β_0	β_1	β_2
BEL	13.4	-1	-0.147	BRY	-10.3	2.1	0.053
p-val.:	0.123	0.709	0.029	p-val.:	0.004	0.06	0.007
	R^2:	0.174			R^2:	0.21	
MOS	15.6	-1.4	-0.157	IVA	-10.2	3.5	-0.065
p-val.:	0.012	0.351	0.004	p-val.:	0.062	0.017	0.296
	R^2:	0.05			R^2:	0.187	
YAR	-5.7	1.3	0.002	KAL	-1.1	1.3	-0.047
p-val.:	0.076	0.118	0.967	p-val.:	0.898	0.595	0.512
	R^2:	0.113			R^2:	0.032	
KOS	-10.3	2.2	-0.001	KUR	-11.7	2.6	0.01
p-val.:	0.04	0.146	0.964	p-val.:	0.02	0.049	0.794
	R^2:	0.132			R^2:	0.129	
LIP	2.1	1	-0.112	ORY	-4.6	0.4	0.053
p-val.:	0.758	0.435	0.093	p-val.:	0.435	0.795	0.305
	R^2:	0.639			R^2:	0.062	
RYA	-11.5	2.6	0.012	SMO	-6.3	1.6	0.009
p-val.:	0.046	0.087	0.75	p-val.:	0.164	0.207	0.768
	R^2:	0.085			R^2:	0.059	
TAM	2.6	0.3	-0.068	TUL	7.3	-0.7	-0.073
p-val.:	0.771	0.904	0.33	p-val.:	0.186	0.639	0.282
	R^2:	0.07			R^2:	0.019	
TVE	-0.1	0.7	-0.032	VLA	1.7	1.2	-0.086
p-val.:	0.986	0.488	0.037	p-val.:	0.654	0.247	0.03
	R^2:	0.108			R^2:	0.11	
VOR	1.9	0.8	-0.038	ARK	-27	4.6	0.03
p-val.:	0.717	0.624	0.098	p-val.:	0	0	0.002
	R^2:	0.093			R^2:	0.334	
KAG	11.8	-0.9	-0.138	KAR	-1.4	-0.5	-0.005
p-val.:	0.04	0.574	0.012	p-val.:	0.834	0.788	0.739
	R^2:	0.257			R^2:	0.007	
KOM	5.1	4.5	-0.063	LEN	13.9	-0.6	-0.118
p-val.:	0.506	0.059	0	p-val.:	0.018	0.717	0
	R^2:	0.599			R^2:	0.196	
MUR	1.4	-0.4	-0.055	NOV	-12.5	3.2	0.025
p-val.:	0.837	0.829	0.09	p-val.:	0.004	0.015	0.387
	R^2:	0.1			R^2:	0.227	

	β_0	β_1	β_2		β_0	β_1	β_2
PSK	-1	1.6	-0.045	VOL	-13.4	4.1	-0.007
p-val.:	0.89	0.471	0.204	p-val.:	0.044	0.047	0.751
	R^2:	0.099			R^2:	0.162	
ADY	10.1	-3.7	0.051	AST	-5.7	0.8	-0.027
p-val.:	0.609	0.475	0.708	p-val.:	0.116	0.475	0.059
	R^2:	0.236			R^2:	0.284	
DAG	36.7	-5	-0.303	KAB	41.5	-6.2	-0.423
p-val.:	0.011	0.265	0.01	p-val.:	0.382	0.567	0.535
	R^2:	0.287			R^2:	0.076	
KCH	-4.8	3.7	-0.308	KRA	1	0	0.008
p-val.:	0.819	0.496	0.222	p-val.:	0.813	0.979	0.76
	R^2:	0.427			R^2:	0.002	
ROS	0.4	0.5	-0.035	SEV	-36.1	11.7	-0.135
p-val.:	0.934	0.654	0.196	p-val.:	0.172	0.062	0.71
	R^2:	0.057			R^2:	0.512	
STA	1.1	-0.8	0.028	VOG	7.2	0.4	-0.067
p-val.:	0.857	0.587	0.222	p-val.:	0.039	0.712	0
	R^2:	0.097			R^2:	0.403	
BAS	-0.4	1.6	-0.027	CHV	2.4	0.7	-0.139
p-val.:	0.922	0.155	0.197	p-val.:	0.813	0.79	0.103
	R^2:	0.064			R^2:	0.2	
KIR	-10.6	2.3	-0.009	MAR	-4.5	2	-0.096
p-val.:	0.004	0.05	0.573	p-val.:	0.364	0.166	0.049
	R^2:	0.071			R^2:	0.327	
MOR	6.7	-1.6	-0.025	NIZ	-3.8	1.5	-0.004
p-val.:	0.383	0.496	0.557	p-val.:	0.316	0.188	0.841
	R^2:	0.029			R^2:	0.022	
ORE	-5.5	1.9	-0.03	PEN	-11.5	1	0.048
p-val.:	0.645	0.445	0.447	p-val.:	0.016	0.356	0.156
	R^2:	0.095			R^2:	0.097	
PER	-23.1	4.8	0.011	SAM	-3.2	0.2	0.041
p-val.:	0.002	0.013	0.783	p-val.:	0.722	0.924	0.691
	R^2:	0.098			R^2:	0.006	
SAR	8.1	-1.8	-0.025	TAT	7.6	-1.3	0.001
p-val.:	0.273	0.352	0.508	p-val.:	0.162	0.329	0.98
	R^2:	0.027			R^2:	0.026	
UDM	11.9	-1.3	-0.093	ULY	-8.3	2.2	-0.007
p-val.:	0.306	0.521	0.195	p-val.:	0.14	0.208	0.848
	R^2:	0.125			R^2:	0.058	

	β_0	β_1	β_2		β_0	β_1	β_2
CHK	4.2	-0.2	-0.062	KUN	2.2	-0.2	-0.016
p-val.:	0.284	0.821	0.002	p-val.:	0.608	0.861	0.455
	R^2:	0.159			R^2:	0.048	
SVE	-9.3	2	-0.012	TYU	-16	5.1	0.001
p-val.:	0	0.007	0.192	p-val.:	0.057	0.027	0.973
	R^2:	0.066			R^2:	0.073	
ALK	17.5	-0.6	-0.075	BUR	-6.5	2	-0.028
p-val.:	0.105	0.776	0.004	p-val.:	0.282	0.371	0.025
	R^2:	0.482			R^2:	0.219	
KHA	43.9	-9.1	-0.284	CHI	-20	4.2	-0.007
p-val.:	0.07	0.115	0.053	p-val.:	0.054	0.189	0.761
	R^2:	0.257			R^2:	0.046	
IRK	-4.4	2.6	-0.03	KEM	-2.1	1	-0.014
p-val.:	0.501	0.141	0.001	p-val.:	0.757	0.557	0.637
	R^2:	0.211			R^2:	0.01	
KRY	-6.9	2.3	-0.018	NSI	1.1	0.1	-0.028
p-val.:	0.131	0.149	0	p-val.:	0.791	0.953	0.012
	R^2:	0.218			R^2:	0.198	
OMS	1.3	0.4	-0.022	TOM	15.1	-5.1	0.003
p-val.:	0.672	0.652	0.156	p-val.:	0.555	0.351	0.939
	R^2:	0.086			R^2:	0.283	
TYV	-6.2	3.7	-0.079	AMU	-1.8	0.8	-0.037
p-val.:	0.775	0.621	0.32	p-val.:	0.847	0.733	0.055
	R^2:	0.321			R^2:	0.184	
CHA	-7.1	2.8	-0.027	CHU	-8	11.7	-0.022
p-val.:	0.215	0.096	0.003	p-val.:	0.733	0.329	0.512
	R^2:	0.377			R^2:	0.16	
EVR	-3.7	0.4	0.007	KAM	-9.7	-0.2	-0.005
p-val.:	0.816	0.922	0.945	p-val.:	0.503	0.961	0.823
	R^2:	0.001			R^2:	0.007	
MAG	-16.8	6	-0.035	PRI	-8.7	1.7	-0.008
p-val.:	0.089	0.112	0.109	p-val.:	0.149	0.347	0.598
	R^2:	0.248			R^2:	0.028	
SAA	-26.8	15.6	-0.029	SAN	-23.4	7.9	-0.016
p-val.:	0.001	0	0.001	p-val.:	0	0.001	0.124
	R^2:	0.429			R^2:	0.286	

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