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Convergence across Russian Regions:

A Spatial Econometrics Approach

Tullio Buccellato†

† PhD student in International Economics at the University of Rome Tor Vergata

and visiting researcher at SOAS, London.

Email: t.buccellato@soas.ac.uk

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Centre for the Study of Economic and Social Change in Europe
UCL School of Slavonic and East European Studies
Gower Street, London, WC1E 6BT
Tel: +44 (0)20 7679 8519
Fax: +44 (0)20 7679 8777
Email: csesce@ssees.ucl.ac.uk

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Tullio Buccellato
Ph.D. student in International Economics at the University of Rome Tor Vergata and Visiting Research at DeFiMS(Department for Financial & Management Studies)-SOAS. Email: t.buccellato@soas.ac.uk

Abstract:
This paper analyses the process of convergence across the regions of Russia using spatial econometrics tools in addition to the traditional β-convergence techniques as derived from the neoclassical theoretical setting. The spatial component appears to be non-negligible and, consequently, conventional convergence estimates suffer a bias due to spatial dependence across observations. Furthermore, variables such as hydrocarbon supply, openness to trade and FDI per capita are found to have an unambiguous, positive and statistically significant impact on growth (Results are also confirmed by the panel counterpart of the model. Estimates for this last are presented in the Appendix E).

Key Words: Convergence, Spatial Econometrics, Russian Federation

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1. Introduction

The use of a regional dataset implies consideration of the possibility that observations are not independent as a result of the inter-connections between neighbouring regions (Anselin 1988). Many convergence studies that use the neoclassical framework (Solow 1956 and Swan 1956) rely on the assumption of closed economies. If this assumption can appropriately be applied to the datasets of countries, it instead appears very strong for regions within a single country. Accordingly, many regional studies can suffer from serious bias and inefficiency when it comes to making convergence coefficient estimates and to accounting for possible variables affecting growth rates.

Economic studies on the Russian Federation usually assign scarce importance to possible spatial interaction between regions. Geography becomes a factor in the model only through the introduction of control variables such as distance from the capital or, at best, by employing dummies to control for landlocked regions and other geographic characteristics.

One of the first ground breaking regional studies on the Russian Federation was that done by D. Berkowitz and D. N. Dejong in 2003 who, departing from the noteworthy differences in growth rates across Russian regions, explored the hypothesis that a heterogeneous implementation of reform policies can lead to differences in growth patterns: they found that price-liberalization reforms have a positive direct effect on growth while large-scale regional privatisation makes an indirect impact through the channel of new-enterprise formation. The geographic factor is included through the natural log of the distance from Moscow. Furthermore, the inclusion of initial income level as a control variable confirms the hypothesis of divergence across Russian regions.

Using a panel of 77 Russian regions from 1990-1998, R. Ahrend (2002) conducts a complete analysis of possible determinants affecting Russian regional economic growth. He finds that factors such as capital endowment, human capital and natural resources as well as urbanization can be positively correlated with growth. Factors such as political orientation do not, on the other hand, seem to be correlated with growth in any significant way. Interesting for our purposes is the use of geographic variables to account the effects resulting from sharing borders with China, Mongolia, Georgia or Azerbaijan, Ukraine or Byelorussia, the EU or the Baltic States. Other geographic variables employed in the survey include: permanent sea access, a major port dummy, a European part dummy, a St. Petersburg dummy, regional capital longitude, and a "Red Belt" dummy. Relevant to our purposes is that regions finding themselves in an advantageous geographic position have experienced greater economic growth.

Another recent contribution is the study of convergence across Russian regions implemented by L.Solanko (2003), which applies the neoclassical models of unconditional and conditional convergence. These findings lean toward the Baumol hypothesis of convergence clubs; i.e. regions converge to two separate steady states depending on initial conditions regarding education and share of total industrial production assigned to agriculture and extraction. In this case, the geographic factor is present only through the introduction of the variable "distance from the capital Moscow " in one of the conditional convergence regressions. This variable results as completely insignificant.

In a recent paper on interregional mobility determinants in Russia, Y. Andrienko and S. Guriev (2003) conclude that one third of all Russian regions are unable to emerge from poverty because of their poor inhabitants' lack of liquidity, which prevents their migration towards more prosperous areas of the Federation. The role of migration in enhancing convergence in levels of per capita income seems to be crucial in Russia, which has inherited a geographically concentrated industrial structure and where barriers to geographical mobility are, in some cases, insurmountable. Reciprocal distance across regions is the variable that exhibits the highest impact on migration patterns. Hence, distance appears to be a non-negligible factor and it is supposed that regions sharing common borders experience a higher convergence rate in terms of GDP per capita due to increased mobility, knowledge spill-over and trade relationships.

Noteworthy is the preponderant role of hydrocarbons in post recession recovery: since the August 1998 financial crisis Russia has been experiencing a steady growth rate mainly driven by continuously rising oil prices. Natural resources are not uniformly distributed across the Federation and this affects each region heterogeneously. What makes the difference across these regions is not only their supply of hydrocarbons but also their possible contiguity with endowed regions, which makes the geographic factor even more important.

The present paper examines the elements that enhance divergence in levels of per capita income across 76 regions of the Russian Federation, applying cross-sectional spatial econometric methods (lag and error models) to assess the impact of hydrocarbon supply and other variables pertinent to regional economic growth. As will be examined in detail, oil and gas production constitute the main driving force behind divergence across regional growth patterns.

Section 2 begins to introduce the spatial econometric models to be used in addition to the traditional neoclassical convergence analysis tools; section 3 is devoted to the description of the dataset used for the empirical part of the study; section 4 illustrates results obtained by implementing an absolute convergence study and compares the results with its spatial counterparts. After providing evidence of divergence in levels of GDP per capita, Section 5 proceeds toward a conditional convergence approach, which, once again, is compared to the results obtained using spatial econometrics tools. Conclusions follow.

2. The Model

Relaxing the assumption that the observations are represented by regions with arbitrarily drawn boundaries, we are compelled to confront a possible bias and inefficiency in OLS estimates and, consequently, to implement a model that at least allows for dependence across locations sharing a border. For cross sectional spatial data samples Anselin (1988) proposes a class of models, which can easily be derived as particular cases of the following benchmark:

$$y = \rho W_1 y + X\beta + u$$

$$u = \lambda W_2 u + \varepsilon \qquad (1)$$

$$\varepsilon \sim N(0,\sigma^2 I_n)$$

Where y is the nx1 vector containing the observations, which refer to the dependent variable, X is the usual representation of the nxk matrix containing the regressors. W_1 and W_2 are binary contiguity matrices expressing neighbouring regions by 0-1 values. The value 1 is assigned in the case that two regions have a common border of non-zero length, i.e. they are considered first order contiguous; ρ and λ represent spatial autoregressive coefficients for the dependent variable and the error respectively, and ε is a vector of error terms considered i.i.d.

The simplest specification that can be obtained from (1) is the so-called first order spatial auto-regression (FAR) or spatial lag model, which explains variation in y just as a linear combination of contiguous or neighbouring units. The FAR is achieved directly by imposing restrictions on the matrix of explanatory variables X and on the contiguity matrix W_2, setting both equal to zero

$$y = \rho W_1 y + \varepsilon$$

$$(2)$$

$$\varepsilon \sim N(0,\sigma^2 I_n)$$

Another possible model that can be derived from benchmark (1) is what is known as the mixed regressive-spatial autoregressive, which includes explanatory variables in addition to the spatially lagged dependent variable. It is simply obtained by setting $W_2 = 0$

$$y = \rho W_1 y + X\beta + \varepsilon$$

$$(3)$$

$$\varepsilon \sim N(0,\sigma^2 I_n)$$

It must be remarked that even when the disturbances ε are treated as i.i.d., the spatial lag term shows up as an endogenous variable through the so-called spatial multiplier $(I-\rho W_1)$. As a consequence, OLS estimates will be biased and inconsistent due to a simultaneity bias . Finally, setting $W_1=0$ we obtain the spatial error model, which exhibits spatial autocorrelation in the disturbances:

$$y = X\beta + u$$

$$u = \lambda W_2 u + \varepsilon \qquad (4)$$

$$\varepsilon \sim N(0,\sigma^2 I_n)$$

The error model specification can be assimilated to a regression with non-spherical disturbances and hence OLS remains unbiased. However, OLS estimates will still suffer a lack of efficiency and consequently standard errors will be biased[1].
The spatial econometrics approach is being used increasingly in the study of cross-sectional convergence. The neoclassical approach to β-convergence (Barro and Sala-i-Martin 1991,1997, 2003) relies on the decreasing marginal productivity of capital assumption, implying that richer countries endowed with more capital tend to grow slower than poorer ones (absolute convergence). However, the pace of growth depends also on distance from the country-specific steady state, i.e. the further a country finds itself from its own steady state, the faster its growth rate will be. Assuming a kind of reversed gravity law, specific factors must be considered that could potentially affect the convergence process (conditional convergence). Accordingly, the following two models have been implemented for convergence studies:

$$1/T*\ln(y_{i,T}/y_{i,0}) = \alpha + \beta y_{i,0} + \varepsilon_i \qquad (5a)$$

$$1/T*\ln(y_{i,T}/y_{i,0}) = \alpha + \beta y_{i,0} + \gamma X'_i + \varepsilon_i \qquad (5b)$$

$$\varepsilon \sim i.i.d(0,\sigma^2 I_n)$$

Where $y_{i,t}$ is the GDP per capita of country or region i as of date t, T is the length of the period, α is a constant and β is the convergence coefficient. Specification 5b also includes matrix X containing additional explanatory steady-state variables (physical or human capital, shares of production sectors to GDP, degree of political instability, ratio of public expenditures to GDP and other environmental variables) and the respective vector of associated coefficients γ. As coefficient β is negative and statistically significant, the cross section of countries or regions exhibits β-convergence.

However, both specifications 5a and 5b rely implicitly on the assumption that the observations are geographically independent. If this assumption can adapt well to cross-sections of countries, it becomes very strong for regional studies, for which it appears more plausible to assume spatial interactions among observations. In cases where spatial correlation is detected, OLS estimates turn out to be biased and thus more suitable spatial econometric tools are required (Rey and Montoury 2000; Le Gallo, Ertur and Baoumont 2003; G. Arbia, R. Basile and G. Piras 2005).

Since the main purpose of this paper is to examine not only the convergence process in levels of GDP per capita but also to assess the impact of some environmental variables on economic growth, we will use the spatial counterparts of both absolute and conditional convergence models. For each specification we compare estimates obtained using spatial lag and spatial error models, which yielded four different benchmark models:

$$1/T*\ln(y_{i,T}/y_{i,0}) = \alpha + \beta y_{i,0} + \rho W[1/T*\ln(y_{i,T}/y_{i,0})] + \varepsilon_i \qquad (6a)$$

$$1/T*\ln(y_{i,T}/y_{i,0}) = \alpha + \beta y_{i,0} + \gamma X'_i + \rho W[1/T*\ln(y_{i,T}/y_{i,0})] + \varepsilon_i \qquad (6b)$$

$$\varepsilon \sim i.i.d(0,\sigma^2 I_n)$$

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[1] For a complete explanation about estimation techniques of spatial autoregressive models through the implementation of Maximum Likelihood using MATLAB packages see Le Sage 1998. Alternatively, spatial estimation packages for cross sectional analysis are also provided by STATA.

$$1/T*\ln(y_{i,T}/y_{i,0}) = \alpha + \beta y_{i,0} + u_i \quad (7a)$$

$$1/T*\ln(y_{i,T}/y_{i,0}) = \alpha + \beta y_{i,0} + \gamma X'_i + u_i \quad (7b)$$

$$u_i = \lambda W u_i + \varepsilon_i \qquad \text{with } \varepsilon_i \sim \text{i.i.d}(0,\sigma^2 I_n)$$

3. Data Description

The Russian Federation is characterized by a very complex administrative organization. The first major administrative division has seven federal districts (Central Federal District, North West Federal District, South Federal District, Volga Federal District, Ural Federal District, Siberian Federal District, Far Eastern Federal District). Each federal district is sub-divided into a series of entities that can take one of three different forms: oblast (region, province), kraj (territory) and republic. Some regions are further sub-divided into entities classified as autonomous regions (Avtonomnje Okrugi).

The only reliable dataset for the Russian Federation is the one collected by Goskomstat providing data for 89 regions, but it suffers from several limitations. Data are either completely missing or sporadically available for ten of the regions, which are, therefore, to be excluded from this analysis indeed, data on the Chechen Republic are entirely missing for all the variables included in the analysis[2]. Data are also incomplete for nine autonomous regions-Nenetsia, Parma, Yugra, Yamal, Taymyr, Evenkia, Ust-Ord Buriatia, Aghin Buriatia and Koryakia-yet it must be pointed out that the majority of these are treated as parts of other Russian regions and, as a result, are included in the analysis, albeit at a more general level of aggregation.

The only autonomous okrug with a fully available dataset is the Chukotka region, which, nevertheless, represents an outlier for the majority of estimates performed and thus was eliminated as well. The last variable excluded from the analysis was the region of Kaliningrad, for reasons deriving directly from the spatial econometrics tools implemented, which require observations to have at least one border in common with another region. The Kaliningrad region is an enclave, which, by definition, is surrounded by other countries, representing an outpost of Russian territorial jurisdiction. In total, we end up with a dataset of 77 regions that also includes the cities of St. Petersburg and Moscow.

Remaining to be defined is the period over which the analysis can be implemented. In the case of Russia we would be tempted to use all the available data from the beginning of the transition period, but the GDP had slumped dramatically in the period leading up to the 1998 financial crisis, which was a turning point, and recovery only began in 1999. The non-monotonic growth path makes theoretically critical the use of the complete series, reducing the available period after the structural break following the financial crisis of 1998.

As suggested by L. Solanko (2003), it would be more appropriate to break the series into two parts and implement separate convergence analyses for the two sub-periods. Nonetheless, data are not available for many variables over the period 1992 to1998 and the use of initial values in order to avoid possible problems of endogeneity among variables is crucial to the conditional convergence analysis.

It must also be remarked that the first period of transition is characterized by strong instability in all the principal economic indicators and, for this reason, it is far from being assumed as the basis for any kind of economic analysis. For all these reasons, the analysis covers the years from 1999 to 2004.

[2] The reason in this case is straightforward, as this region has been land of war since 1994.

4. Absolute convergence analysis

4.a. Neoclassical estimates of absolute β-convergence

Our empirical analysis starts with a neoclassical regression of absolute convergence across 77 Russian regions in the period 1999-2004. Hence, we consider equation 5a and we perform cross-sectional OLS estimates of unconditional β-convergence. If convergence holds, we would expect a negative and significant coefficient for the variable referring to the initial condition, considering as dependent variable the average growth rate over the period considered[3].

Table 1: Absolute β-convergence of per-capita income in 77 Russian regions (1999-2004)-OLS Estimates (number into brackets refer to p-values)	
Constant	.2905712
	(0.001)
Initial conditions	-.0047008
	(0.565)
Goodness of Fit	
R^2	0.0044
Observations	77
Log Likelihood	145.2157
Regression Diagnostic	
Breush-Pagan heteroschedasticity test	0.93
	(0.3352)
White heteroschedasticity test	22.19456
	0.000015
Moran's I spatial autocorrelation test	3.246
	(0.001)
LM test (error)	8.438
	(0.004)
LM test (lag)	8.424
	(0.004)
Jarque-Bera normality test	16.00371
	(0.000335)

[3] The complete specification of unconditional convergence model is: $1/5*\ln(y_{i,2004}/y_{i,1999})=\alpha+\beta*\ln(y_{i,1999}))+\varepsilon_i$ where $i=1,2,\ldots,77$

Illustrated in Table 1 are the results of an OLS-based absolute β-convergence regression. The coefficient associated with the initial level of per capita income is negative but completely non-significant. It can thus be concluded that Russian regions experienced divergence during the recovery period that began in 1999. This is in contradiction with L. Solanko's detection (2003) of a significant annual convergence rate of approximately 3%. However, the number of observations used was 76 and the period considered was from 1992 to 2001, which confirms the problem of considering the entire series as starting from 1992.

Table 1 also displays diagnostic statistics detecting possible misspecifications of the convergence regression. Two interesting considerations can be made: first, we cannot reject the null hypothesis of homoskedasticity in a Breush Pagan test on the residuals, while the White test exhibits opposite results; second, the Moran I test[4] significantly detects spatial autocorrelation, which is also confirmed by the two Lagrange Multiplier tests. Particular caution must, however, be used in interpreting these results because the Jarque Bera test indicates that residuals are non-normally distributed.

At this stage we must address the problem of heteroskedasticity, considering spatial dependence as its only possible source (Anselin and Griffith 1988). We shall then proceed with our analysis by attempting to assess which of the two forms of spatial interaction is present, given that the two Lagrange Multipliers tests presented in Table 1 do not provide a clear answer to this question.

4.b. Spatial econometric analysis: Spatial Lag vs. Spatial Error Model

OLS results indeed appear to suffer from a misspecification induced by omitted spatial dependence terms. As already discussed, the assumption of spatial independence can often prove overly restrictive for cross-sectional studies conducted at a regional level. In this section we allow for spatial interdependence across observations, estimating models 6a and 7a for the spatial lag and spatial error models, respectively. Estimates are made through a maximum likelihood estimator in order to avoid the aforementioned problems of endogeneity and inefficiency in OLS estimates[5], which include a spatially lagged regressor among the explanatory variables.

Table 2 displays the results implemented by considering possible interactions between observations across space. Both the coefficients of the spatial lag term and the spatial error term appear strong in magnitude and very significant. The coefficients associated with the initial per capita income level remain not significant and decreased in absolute value. Though results are weakened by the low level of significance, the decreased convergence coefficient seems to confirm the presence of the positive effect induced by factor mobility, which becomes stronger among neighbouring regions.

Nonetheless, it still appears difficult to discriminate between the spatial lag and spatial error models. The only difference comes from the goodness of fit (variance ratio, squared correlation and Log likelihood, this latter component being negligible), which seems to work in favour of the spatial lag specification. To have a more accurate idea of which model fits the dataset, it is necessary to investigate for other possible factors that enhance divergence across regions in order to better disentangle the effects of regions-specific characteristics and geographic interactions - in other words, it is necessary to move towards a conditional convergence analysis.

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[4] Moran's I test null hypothesis is: no spatial autocorrelation.

[5] Estimates are performed using the spatial regression STATA package, elaborated by Maurizio Pisati of the Department of Sociology and Social Research at the University of Milano Bicocca .

Table 1: Absolute β-convergence of per-capita income in 77 Russian regions (1999-2004)-Spatial Lag and Spatial Error Model -Maximum Likelihood Estimates (number into brackets refer to p-values)		
	SPATIAL LAG MODEL	SPATIAL ERROR MODEL
Constant	.1764252	.2768313
	(.0.032)	(0.001)
Initial Conditions	-.0034271	-.0034848
	(0.645)	(0.687)
Rho/Lambda	.4122768	.4106439
	(0.002)	(0.002)
	Goodness of Fit	
Variance ratio	0.063	0.002
Squared corr.	0.172	0.004
Log likelihood	149.37195	149.34709
Observations	77	77
	Diagnostic for the Spatial Coefficients	
Wald test of rho/lambda=0:	chi2(1) = 9.785 (0.002)	chi2(1) = 9.685 (0.002)
Likelihood ratio test of rho/lambda=0:	chi2(1) = 8.312 (0.004)	chi2(1) = 8.263 (0.004)
Lagrange multiplier test of rho/lambda=0:	chi2(1) = 8.424 (0.004)	chi2(1) = 8.438 (0.004)

5. Conditional convergence analysis

5.a. Possible determinants of divergence

Russian economic recovery in the period from 1999 to 2004 was mainly dependent on its hydrocarbon supplies. The price of crude oil and natural gas has risen sharply since 1999 and there is substantial evidence of a positive relationship between GDP growth in Russia and oil prices. Natural resources represent a prominent share of industrial production, 80% of which is accounted for by mining products, along with metals and precious stones. In 2003 oil and gas accounted for 49% of exports and constituted 17.1% of GDP (Gurvich 2004).

Growth driven by oil production is a phenomenon that not only characterizes Russian post-transitional recovery, but one which has historically been a primary source of economic prosperity for the Soviet Union since the 1917 revolution (J.I.Considine, W.A.Kerr and E.Elgar 2002). Oil production was already at a level of approximately 25 million barrels by 1920, and in the year 1987/88 it peaked at 4.5 billion barrels, making Russia the largest oil producer in the world. The early 1990s were characterized by a marked inefficiency in oil reserve management and Russia dropped back to third place among oil producers, behind Saudi Arabia and United States.

Natural resources represent a major portion of Russia's wealth and are very unevenly distributed across the Federation. As of 1999 nearly 58% of oil and gas production was concentrated in

Tyumen region, which, however, includes the two autonomous okrugs of Yugra and Yamal. The substantial heterogeneity in hydrocarbon supply is probably the first factor that enhances divergence among regions. In this context, geographic position takes on a very important strategic function: sharing borders with regions rich in natural resources can be considered a key asset in growth enhancement. It is not surprising then that the Tyumen region had the highest GDP per capita throughout the period in question, nor that the regions surrounding it were among those enjoying the highest growth rates.

Other variables included in the growth regression of the conditional convergence analysis are the three most significant selected from a group of six. Accordingly, we consider the impact of variables such as international openness to trade (ratio of exports plus imports to GDP), R&D (share of the population employed in research and development) and FDI per capita. The three remaining variables, which appear only marginally related to growth, are: health services (numbers of doctors per capita), crime (natural log of registered crimes out of 100,000 inhabitants) and fixed per capita investment[6].

Furthermore, a dummy is included for the Republic of Ingushetia. Ingushetia was the Russian region with the lowest growth rate in the period from 1999 to 2004, even though its initial conditions were very low, which is completely at odds with the neoclassical theory of convergence. This region was part of Chechnya until 1992 and is probably the one that suffered the most from the instability caused by the ongoing civil war. However, it would be improper to include Ingushetia in a war dummy, since at the moment it is separate from Chechnya. Ingushetia's economy is highly dependent on imports mainly coming out of CIS and has, by far, the highest share of imports to GDP of all the regions. The inclusion of a dummy for Ingushetia is thus important also for the sake of avoiding a series of disturbing and misleading effects on the international openness variable.

5.b. Neoclassical conditional convergence analysis

The conditional convergence analysis is conducted using the specification 5b in section 2. This model is in line with the tradition of growth literature, which regresses as dependent variable the average annual growth in per capita income on the initial level of per capita income and other explanatory variables assumed to be proxies of different steady states.

Table 3 summarizes the results of the conditional convergence implemented by using a simple OLS regression. As we consider explanatory variables as possible growth determinants, the coefficient attributed to the initial income conditions becomes very significant, its absolute size increases denoting a conditional β-convergence rate of about 3.6%. As expected, the most significant variable in conditioning growth is the share of oil and gas extraction to GDP per capita. However, the high impact emerging from the regression is mainly due to the contribution of Tyumensk[7]. Openness to trade played also an important role in enhancing growth in the five years considered in the analysis. The coefficient is positive and significant as long as we include the dummy for Ingushetia Republic in the regression. The share of employees in R&D has a positive but only marginally significant coefficient while regions able to attract more foreign capital are displayed to perform better on average than the others. Openness to trade also played an important role in enhancing growth in the five years considered in the analysis. The coefficient is positive and significant as long as we include the Ingushetia Republic dummy in the regression. The share of R&D employees has a positive but only marginally significant coefficient while regions able to attract more foreign capital displayed better performance on average than the others.

The goodness of fit undergoes a substantial increase, denoting that approximate 34% in the variance of growth rates is fully explained by the variables included in the survey. Nonetheless, the regression diagnostic continues to detect the presence of heteroskedasticity and spatial

[6] All the figures concerning the above mentioned variables are taken from Goskomstat's Regiony Rossii 2004.

[7] The coefficient for the variable of oil and gas remains strong and significant also in a regression robust to the presence of outliers.

autocorrelation across the observations. The Jarque Bera statistics improve, but not sufficiently enough to state that residuals are distributed normally. Hence, test outcomes are still to be considered with caution.

The Lagrange Multiplier spatial error and spatial lag term tests show a difference that is more marked than in the case of the absolute convergence regression. Both spatial error and spatial lag appear to be present, but the LM-test for residual spatial lag dependence is clearly more significant. This leads to a closer consideration of the possibility that our observations have violated the independence assumption and that, therefore, the OLS estimates are biased and inefficient. However, we cannot entirely exclude the possibility of correlated error terms across space, which would produce inefficiency.

Table 2: Conditional β-convergence of per-capita income in 77 Russian regions (1999-2004)-OLS Estimates
(number into brackets refer to p-values)

Constant	.5871611
	(0.000)
Initial conditions	-.0365959
	(0.000)
Oil and Gas	.0695902
	(0.000)
Openness to trade	.514478
	(0.013)
R&D	.0012978
	(0.098)
FDI per capita	.0000393
	(0.033)
D_Ingushetia	-.2612279
	(0.000)
Goodness of Fit	
R^2	0.3431
Observations	77
Log Likelihood	164.3892
Regression Diagnostic	
Breush-Pagan heteroschedasticity test	1.19
	(0.2760)
White heteroschedasticity test	44.41333
	(0.002066)
Moran's I spatial autocorrelation test	2.872
	(0.004)
LM test (error)	5.525
	(0.019)
LM test (lag)	7.400
	(0.007)
Jarque-Bera normality test	13.99277
	(0.000315)

5.c. Spatial Lag vs. spatial Error model for the conditional convergence analysis

In this section we analyse and compare the results obtained with the spatial counterparts of the conditional convergence model. In other words we refer to specifications 6b and 7b of section 2.

Consideration must be given, first of all, to which of the two model specifications seems preferable. The addition of explanatory variables to the convergence regression has substantially improved the parameter necessary to discriminate between the two models. The goodness of fit of the lag model is admittedly better than the one performed by the error model, both in terms of variance ratio and log likelihood. All the diagnostic tests on the spatial coefficients indicate a higher robustness and significance of the lag coefficients. Furthermore, results obtained with the error model are much more in line with the OLS regression results.

All these results confirm that the spatial lag model is more suitable to explaining the convergence process across Russian regions over the period considered. Noteworthy is the fact that this specification displays a lower convergence rate than the neoclassical conditional convergence model. The spatially lagged dependent variable captures positive geographic spill-over effects across regions sharing the same borders, which normal growth regressions tend to attribute to the initial conditions in per capita income. In other words, the neoclassical specification of conditional convergence tends to overestimate the β coefficient.

Interesting considerations can also be made for the coefficients attributed to the other explanatory variables included in the regression. The two variables relating to hydrocarbons and openness to trade remain both significant and positive in their impact on average growth. However, their contribution is somehow rescaled with the introduction of the spatial components. The share of R&D employees in the population becomes completely not significant, though its level of significance was already low in the neoclassical specification of convergence. The ability to attract foreign investments is the only variable that undergoes an increase both in significance and in absolute value of the coefficient. The dummy for Ingushetia remains highly significant but with a lower coefficient in both the spatial specifications.

A further comment is required, i.e. that at this stage we are not considering other possible sources of heteroskedasticity related to causes different from spatial autocorrelation, since residual heteroskedasticity analysis is beyond the scope of this paper. Nevertheless, reported in the Appendix C are the results of estimates with robust standard errors for all the models treated and these results do not appear substantially different in their essence.

Table 3: Conditional β-convergence of per-capita income in 77 Russian regions (1999-2004)-Spatial Lag and Spatial Error Model -Maximum Likelihood Estimates (number into brackets refer to p-values)		
	SPATIAL LAG MODEL	**SPATIAL ERROR MODEL**
Constant	.4626981	.5852261
	(0.000)	(0.000)
Initial Conditions	-.0327028	-.036175
	(0.000)	(0.000)
Oil and Gas	.0637439	.0646275
	(0.000)	(0.000)
Openness to trade	.4491642	.4074767
	(0.013)	(0.022)
R&D	.0008427	.0009499
	(0.232)	(0.236)
FDI per capita	.0000423	.0000459
	(0.009)	(0.003)
D_Ingushetia	-.2393965	-.225246
	(0.000)	(0.000)
Rho/Lambda	.3606414	.3970674
	(0.003)	(0.005)
	Goodness of Fit	
Variance ratio	0.434	0.340
Squared corr.	0.473	0.389
Log likelihood	168.33404	167.66079
Observations	77	77
	Diagnostic for the Spatial Coefficients	
Wald test of rho/lambda=0:	chi2(1) = 8.936 (0.003)	chi2(1) = 7.883 (0.005)
Likelihood ratio test of rho/lambda=0:	chi2(1) = 7.890 (0.005)	chi2(1) = 6.543 (0.011)
Lagrange multiplier test of rho/lambda=0:	chi2(1) = 7.400 (0.007)	chi2(1) = 5.525 (0.019)

6. Conclusions

The main purpose of this paper has been to highlight the pattern of convergence/divergence in GDP per capita levels in the Russian Federation during the period from1999 to 2004. Results obtained are made robust to possible spatial dependence or correlation across observations through the use of spatial econometric tools. After having detected the presence of spatial effects in both the neoclassical models of absolute and conditional β-convergence, we proposed alternative estimates using the two different specifications of cross sectional spatial econometric models represented by the spatial lag and the spatial error models. Both the rho and lambda coefficients for the spatial lag and spatial error models respectively are found significant in all specifications. However, the spatial lag model seems to perform better, detecting a stronger presence of spatial dependence rather than spatial correlation across observations.

Absolute convergence is absent, confirming the results obtained in previous studies on the Russian Federation. The β convergence coefficient begins to be significant only after the introduction of other explanatory variables in addition to the initial level of per capita income. The neoclassical conditional convergence model is found to overestimate the absolute value of β with respect to its spatial lag model counterpart, strengthening the hypothesis of a bias due to spatial dependence in the data.

Hydrocarbon production appears, among others, to be the leading factor in enhancing divergence across regions. Natural resources, along with other variables such as openness to trade and FDI per capita, are found to play an important role. The R&D variable shows a low level of significance in neoclassical convergence regressions and is completely insignificant as we take into account the interaction of spatial effects across observations.

This paper's intent has been to illustrate the importance of geographic components in studies on the Russian Federation. The spatial dimension appears to be non-negligible and plays a crucial role in the convergence process through the channels of factor mobility, trade relationships and knowledge spill-over, the impact of which is much more evident in neighbouring regions. The logical next step in this study would be the more explicit introduction of both the temporal and spatial dimensions through the use of spatial panel data models (At this stage of the work, we present the results concerning spatial panel estimates implemented with Matlab 7 in the Appendix E. These preliminary results seem to confirm those obtained in the cross-section analysis presented and discussed in the paper).

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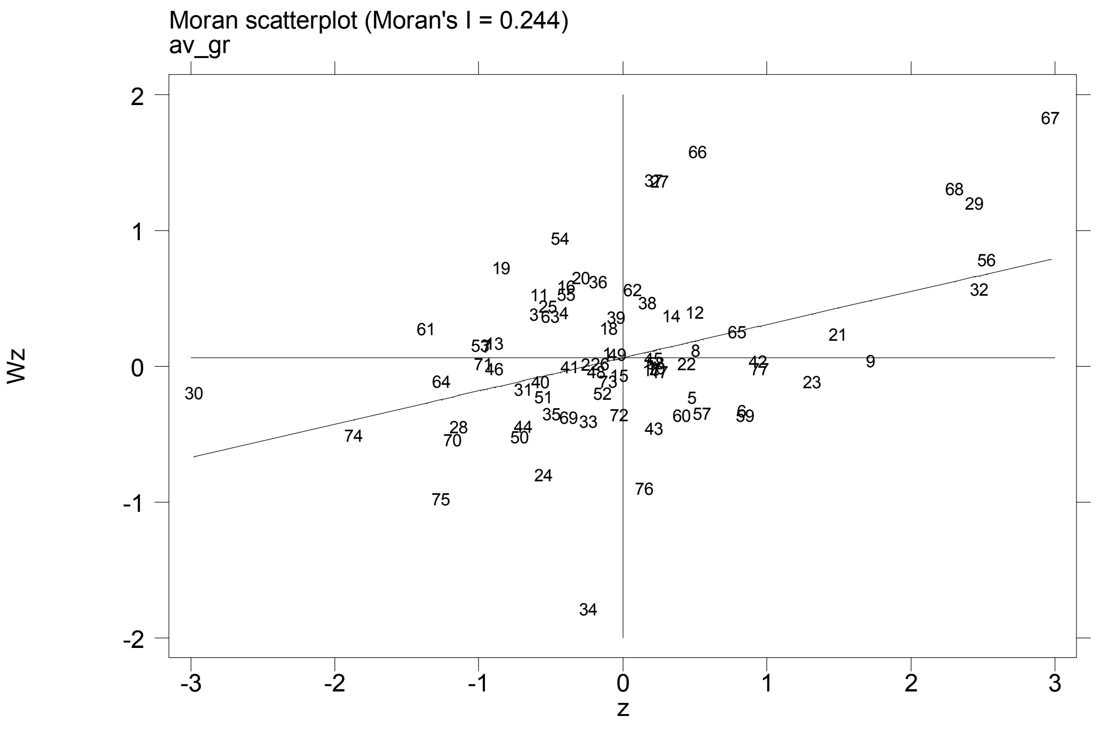
APPENDIX A: Measures of local spatial autocorrelation

Moran's Ii (Average Growth)

	region	Ii	E(Ii)	sd(Ii)	z	p-value*
1	Belgorod Region	-0.005	-0.013	0.685	0.012	0.495
2	Bryansk Region	0.009	-0.013	0.478	0.046	0.481
3	Vladimir Region	-0.208	-0.013	0.425	-0.459	0.323
4	Voronezh Region	-0.145	-0.013	0.354	-0.372	0.355
5	Ivanovo Region	-0.135	-0.013	0.478	-0.255	0.399
6	Kaluga Region	-0.315	-0.013	0.425	-0.711	0.238
7	Kostroma Region	-0.094	-0.013	0.425	-0.19	0.425
8	Kursk Region	0.037	-0.013	0.425	0.118	0.453
9	Lipetsk Region	-0.011	-0.013	0.385	0.005	0.498
10	Moscow Region	-0.015	-0.013	0.329	-0.005	0.498
11	Orel Region	-0.281	-0.013	0.425	-0.631	0.264
12	Ryazan Region	0.179	-0.013	0.354	0.542	0.294
13	Smolensk Region	-0.111	-0.013	0.425	-0.229	0.409
14	Tambov Region	0.112	-0.013	0.425	0.294	0.384
15	Tver Region	0.003	-0.013	0.385	0.042	0.483
16	Tula Region	-0.215	-0.013	0.425	-0.474	0.318
17	Yaroslavl Region	-0.015	-0.013	0.385	-0.004	0.498
18	Moscow City	-0.023	-0.013	0.976	-0.01	0.496
19	Karelia	-0.58	-0.013	0.478	-1.185	0.118
20	Komia	-0.178	-0.013	0.478	-0.344	0.365
21	Arkhangelsk Region	0.286	-0.013	0.425	0.704	0.241
22	Vologda Region	-0.013	-0.013	0.329	0.002	0.499
23	Leningrad Region	-0.219	-0.013	0.425	-0.484	0.314
24	Murmansk Region	0.47	-0.013	0.976	0.495	0.31
25	Novgorod Region	-0.208	-0.013	0.478	-0.408	0.342
26	Pskov Region	0.005	-0.013	0.478	0.038	0.485
27	Saint Petersburg City	0.342	-0.013	0.976	0.364	0.358
28	Adygeya	0.569	-0.013	0.976	0.596	0.276
29	Daghestan	2.844	-0.013	0.685	4.169	0
30	Ingushia	0.72	-0.013	0.976	0.752	0.226
31	Kabard-Balkaria	0.152	-0.013	0.556	0.297	0.383
32	Kalmykia	1.307	-0.013	0.425	3.105	0.001
33	Karachay-Cherkessia	0.11	-0.013	0.556	0.221	0.412
34	North Ossetia	0.444	-0.013	0.685	0.667	0.252
35	Krasnodar Territory	0.199	-0.013	0.478	0.444	0.329
36	Stavropol Territory	-0.1	-0.013	0.385	-0.224	0.411
37	Astrakhan Region	0.286	-0.013	0.685	0.436	0.331
38	Volgograd Region	0.073	-0.013	0.425	0.203	0.42
39	Rostov Region	-0.015	-0.013	0.425	-0.004	0.499
40	Bashkiria	0.095	-0.013	0.425	0.254	0.4
41	Mariy-El	0.019	-0.013	0.478	0.067	0.473
42	Mordovia	-0.012	-0.013	0.425	0.004	0.499
43	Tataria (or Tartary)	-0.112	-0.013	0.329	-0.301	0.382
44	Udmurtia	0.342	-0.013	0.478	0.743	0.229
45	Chuvashia	0.002	-0.013	0.425	0.036	0.485
46	Kirov Region	0.06	-0.013	0.308	0.237	0.406
47	Nizhniy Novgorod Region	-0.022	-0.013	0.329	-0.027	0.489
48	Orenburg Region	0.016	-0.013	0.478	0.061	0.476
49	Penza Region	-0.001	-0.013	0.478	0.025	0.49
50	Perm Region	0.41	-0.013	0.425	0.996	0.16

51	Samara Region	0.152	-0.013	0.478	0.345	0.365
52	Saratov Region	0.035	-0.013	0.385	0.124	0.451
53	Ulyanovsk Region	-0.108	-0.013	0.385	-0.247	0.402
54	Kurgan Region	-0.394	-0.013	0.556	-0.686	0.246
55	Sverdlovsk Region	-0.191	-0.013	0.478	-0.372	0.355
56	Tyumen Region	1.881	-0.013	0.354	5.344	0
57	Chelyabinsk Region	-0.22	-0.013	0.478	-0.433	0.332
58	Altay Republic	-0.005	-0.013	0.478	0.016	0.494
59	Buriatia	-0.351	-0.013	0.556	-0.608	0.272
60	Tuva	-0.17	-0.013	0.425	-0.369	0.356
61	Khakassia	-0.32	-0.013	0.478	-0.642	0.261
62	Altay Territory	0.035	-0.013	0.556	0.087	0.465
63	Krasnoyarsk Territory	-0.163	-0.013	0.354	-0.422	0.336
64	Irkutsk Region	0.204	-0.013	0.425	0.511	0.305
65	Kemerovo Region	0.168	-0.013	0.385	0.469	0.32
66	Novosibirsk Region	0.808	-0.013	0.478	1.716	0.043
67	Omsk Region	5.366	-0.013	0.556	9.674	0
68	Tomsk Region	2.943	-0.013	0.425	6.955	0
69	Chita Region	0.161	-0.013	0.478	0.363	0.358
70	Yakutia	0.703	-0.013	0.385	1.858	0.032
71	Maritime Territory	0.027	-0.013	0.976	0.041	0.484
72	Khabarovsk Territory	0.011	-0.013	0.385	0.063	0.475
73	Amur Region	0.016	-0.013	0.478	0.061	0.476
74	Kamchatka Region	1.054	-0.013	0.685	1.557	0.06
75	Magadan Region	1.311	-0.013	0.556	2.382	0.009
76	Sakhalin Region	-0.143	-0.013	0.685	-0.189	0.425
77	Jewish Autonomous Region	-0.061	-0.013	0.685	-0.07	0.472



APPENDIX B: Definition of Variables and Descriptive Statistics

Variables	Definition of variables	Mean	St.Dev.
Average Growth (1999-2004)	The average growth rate is calculated as the difference in natural logs between the final and the initial value of per capita income of the sample period. The difference is divided by the number of periods, which number five in our analysis.	.2439012	.0370273
Initial Conditions	Initial conditions are represented by the natural log of per capita income in 1999 expressed in roubles.	9.928166	.5245283
Oil and Gas	This variable is represented by the ratio of extracted oil and gas expressed in thousands of tons to per capita income, both referring to year 1999.	.0733565	.2491162
Openness to trade	Openness to trade is summarized by the sum of total export and total import both within and outside of the CIS, all weighted by the regional GDP.	.0224945	.0311809
R&D	As a surrogate for R&D we use the share of employees in research and development in the total population.	3.394136	4.839115
FDI per capita	This variable is simply obtained by dividing the amount of incoming FDI (expressed in US dollars) by the population.	60.63902	203.4259
Health Services	Represented by the number of doctors out of 1000 inhabitants obtained as the ratio of general medical practitioners to the population.	4.434739	.9822847
Crime	Obtained as the natural log of number of crimes perpetrated out of 100000 inhabitants.	7.581	.3674174
Fixed per capita Investment	This variable is simply obtained by calculating the natural log of fixed per capita investment as provided by *Goskomstat*.	8.033061	.6429101

APPENDIX C: Estimates with robust standard errors.

	GLS	SPATIAL LAG	SPATIAL ERROR
Constant	.5871611	.4626981	.5852261
	(0.000)	(0.000)	(0.000)
Initial Conditions	-.0365959	-.0327028	-.036175
	(0.000)	(0.000)	(0.000)
Oil and Gas	.0695902	.0637439	.0646275
	(0.000)	(0.000)	(0.000)
Openness to trade	.514478	.4491642	.4074767
	(0.000)	(0.001)	(0.004)
R&D	.0012978	.0008427	.0009499
	(0.019)	(0.096)	(0.127)
FDI per capita	.0000393	.0000423	.0000459
	(0.079)	(0.017)	(0.032)
D_Ingushetia	-.2612279	-.2393965	-.225246
	(0.000)	(0.000)	(0.000)
Rho/Lambda	-	.3606414	.3970674
	-	(0.015)	(0.034)
Goodness of Fit			
R2 / Variance ratio	0.3950	0.434	0.340
Squared corr.	-	0.473	0.389
Log likelihood	-	168.33404	167.66079
Observations	77	77	77
Diagnostic for the Spatial Coefficients			
Wald test of rho/lambda=0:	-	chi2(1) = 5.963 (0.015)	chi2(1) = 4.481 (0.034)
Lagrange multiplier test of rho/lambda=0:	-	chi2(1) = 7.400 (0.007)	chi2(1) = 5.525 (0.019)

APPENDIX D: Estimates with robust standard errors obtained adding all the explanatory variables.

	GLS	SPATIAL LAG	SPATIAL ERROR
Constant	.5448928	.442487	.6018475
	(0.000)	(0.000)	(0.000)
Initial Conditions	-.0354156	-.0290916	-.0347382
	(0.027)	(0.039)	(0.019)
Oil and Gas	.0721856	.0664372	.0650719
	(0.000)	(0.000)	(0.000)
Openness to trade	.5149044	.4542725	4106888
	(0.001)	(0.001)	(0.002)
R&D	.0012162	.0006935	.000663
	(0.087)	(0.332)	(0.443)
FDI per capita	.0000419	.0000464	.0000479
	(0.117)	(0.026)	(0.057)
D_Ingushetia	-.2453186	-.2299396	-.2237862
	(0.000)	(0.000)	(0.000)
Health Services	.0029145	.0026673	.0018967
	(0.481)	(0.460)	(0.565)
Crime	.0064835	.0022729	-.0034133
	(0.657)	(0.853)	(0.817)
Fixed per capita Investment	-.003961	-.0055671	-.0015911
	(0.776)	(0.648)	(0.896)
Rho/Lambda	-	.3599804	.4028359
	-	(0.013)	(0.039)
Goodness of Fit			
R2 / Variance ratio	0.4025	0.440	0.339
Squared corr.	-	0.478	0.387
Log likelihood	-	168.75578	167.84786
Observations	77	77	77
Diagnostic for the Spatial Coefficients			
Wald test of rho/lambda=0:	-	chi2(1) = 6.162 (0.013)	chi2(1) = 4.257 (0.039)
Lagrange multiplier test of rho/lambda=0:	-	chi2(1) = 7.178 (0.007)	chi2(1) = 4.239 (0.040)

APPENDIX E: Panel Estimates.

1) Panel Estimates without Spatial Effects

	RE	**FE**	**RE**
	Absolute	Absolute	Conditional
Constant	.4130138***	1.195535***	.7875133 ***
	(.1139862)	(.2292122)	(.1405936)
Initial Conditions	-.0157698	-.0887402***	-.0533379***
	(.0106127)	(.0213652)	(.013468)
Oil and Gas	-		.0909608**
			(.0287484)
Openness to trade	-		.7408402**
			(.3736254)
R&D	-		.0019138
			(.0013936)
FDI per capita	-		.0000493
			(.0000324)
D_Ingushetia	-		-.3422949**
			(.1058602) 0.001
Goodness of Fit			
R2 / Variance ratio	within=0.0532 between=0.0232 overall = 0.0057	within = 0.0532 between = 0.0232 overall = 0.0057	within = 0.0532 between = 0.2529 overall = 0.0595
Squared corr.			
Log likelihood			
Observations	385	385	385
corr(u_i, X)	0 (assumed)	-0.6976	0 (assumed)
Hausman Test[8]			
chi2(1)	15.49		4.56
Prob>chi2	0.0001		0.0328

[8] The Hausman test compares results obtained with the random effects models to those using fixed effects. Under the null hypothesis random effects models are consistent. The null is rejected in both cases.

2) Panel Estimates with Spatial Effects

a) Spatial Autoregressive Model (Absolute Convergence)

	Without Fixed Effects	Spatial Fixed Effects	Time Fixed Effects	Time & Spatial Fixed Effects
Constant	0.712340***	-	-	-
	(6.647323)			
Initial Conditions	-0.047963***	-0.172156 ***	-0.059069***	-0.145621***
	(-4.900920)	(-9.353158)	(-6.608237)	(-12.119014)
Rho	0.138971**	-	-	-
	(2.122982)			
W*dep.var.	-	0.041956	0.206981***	0.104958*
		(0.624545)	(3.336897)	(1.817873)
Goodness of Fit				
R2 / Variance ratio	0.1265	0.3506	0.0661	0.2762
Squared corr.	0.1220	0.1850	0.0513	0.0797
Sigma^2	0.0136	0.0101	0.0146	0.0113
Log likelihood	279.45757	337.31912	251.65607	312.30967
Observations	385	385	385	385
# of iterations	16	20	15	17

b) Spatial Error Model Estimates (Absolute Convergence)

	Without Fixed Effects	Spatial Fixed Effects	Time Fixed Effects	Time & Spatial Fixed Effects
Constant	0.699204***	-	-	-
	(6.051091)			
Initial Conditions	-0.043599***	-0.193004***	-0.071882***	-0.162691***
	(-3.958196)	(-10.982990)	(-7.217613)	(-13.588134)
Lambda	0.284991***	-	-	-
	(4.850389)			
spat.aut	-	0.206997***	0.267943***	0.159973**
		(3.380146)	(4.515331)	(2.559358)
Goodness of Fit				
R2 / Variance ratio	0.1537	0.3719	0.0098	0.2699
Rbar-squared	0.1515	0.2143	-0.0033	0.0747
Sigma^2	0.0132	0.0098	0.0155	0.0114
Log likelihood	281.46963	341.81358	252.78433	313.66814
Observations	385	385	385	385
# of iterations	16	13	17	13

c) Spatial Autoregressive Model Estimates (Conditional Convergence)

	Without Fixed Effects	Spatial Fixed Effects	Time Fixed Effects	Time & Spatial Fixed Effects
Constant	1.201921***	-	-	-
	(9.263442)			
Initial Conditions	-0.097632***	-	-0.100332***	-
	(-8.093817)		(-9.895848)	
Oil and Gas	0.131944***	-	0.134219***	-
	(5.140403)		(5.249171)	
Openness to trade	0.907180***	-	0.910013***	-
	(2.707063)		(2.636476)	
R&D	0.003298***	-	0.003335***	
	(2.619282)		(2.609223)	
FDI per capita	0.000078***	-	0.000081***	-
	(2.710688)		(2.734183)	
D_Ingushetia	-0.422766***	-	-0.425895***	-
	(-4.487187)		(-4.422241)	
Rho	0.099982	-		-
	(1.562783)			
W*dep.var.	-	-	0.158982***	-
			(2.662690)	
Goodness of Fit				
R2 / Variance ratio	0.2261		0.1706	
Rbar-squared	0.2118		0.1461	
Sigma^2	0.0121		0.0130	
Log likelihood	303.19527		280.54627	
Observations	385		385	
# of iterations	13		14	

d) Spatial Error Model Estimates (Conditional Convergence)

	Without Fixed Effects	Spatial Fixed Effects	Time Fixed Effects	Time & Spatial Fixed Effects
Constant	1.261047***	-	-	-
	(9.499091)			
Initial Conditions	-0.101020***	-	-0.116532***	-
	(-7.758889)		(-10.847792)	
Oil and Gas	0.131935 ***	-	0.147271***	-
	(5.060265)		(5.571877)	
Openness to trade	0.886219 ***	-	0.968385***	-
	(2.681962)		(2.771871)	
R&D	0.003463***		0.004018***	
	(2.598017)		(2.917335)	
FDI per capita	0.000076***	-	0.000084***	-
	(2.686012)		(2.824840)	
D_Ingushetia	-0.405067***	-	-0.440097***	-
	(-4.355091)		(-4.518135)	
Lambda	0.233996***	-	-	-
	(3.871886)			
spat.aut	-	-	0.215989***	-
			(3.542106)	
Goodness of Fit				
R2 / Variance ratio	0.2418		0.1412	
Rbar-squared	0.2298		0.1182	
sigma^2	0.0118		0.0134	
Log likelihood	305.02366		281.41964	
Observations	385		385	
# of iterations	14		16	

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