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Regional Convergence in the Russian Federation - Spatial and Temporal Dynamics

Jens K. Perret*

Abstract

Set in the context of the neoclassical growth model this study revisits the discussion of economic convergence in the context of the Russian Federation. Compared to previous similar studies, here a larger more comprehensive data set is implemented (1994-2013) allowing in particular to check for differences in convergence during different time periods. Using a panel approach more reliable results are achieved which point to absolute convergence occurring across the regions of the Russian Federation. The stability of these results is strengthened by estimating Kernel density to test for the presence of potential groups of regions with different steady states, on the one hand, and Markov transition matrices to test for the temporal stability of the regions on the other. Finally, a quantile regression approach is used to assure overall stability of the convergence speed.

All results show that Russia reports absolute convergence up to Vladimir Putin's the second term as president and occurring again during his third term in office and conditional convergence in all time periods. All results remain stable even when including spatial effects or when testing for temporal stability. Quantile regression analysis also reports a more or less stable speed of convergence across the whole time horizon which is significantly higher than comparable results for the US or the regions of the European Union.

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1 Introduction

[1]The neoclassical growth model introduced in 1956 by Solow and Swan[2] proposes a negative relation between initial GDP per capita levels and the growth rate of the GDP per capita. This development is then referred to as β-convergence - in contrast to σ-convergence which is not treated in this study.

A number of studies have tested this hypothesis against real world data and found that it mostly holds only if regional differences between countries or regions are controlled for or if conditional instead of absolute convergence is considered. The first paper to perform an empirical analysis of the convergence process has been the seminal paper by Barro and Sala-I-Martin (1990) on convergence across the US. The only two studies considering convergence across the regions of the Russian Federation are by Solanko (2003) and Buccellato (2007) which, in contrast to their innovative nature, do not employ all available analytical tools and base their analysis on a very limited data set.

The present study does not try to simply replicate these previous studies with a more comprehensive set of data but also aims to offer a number of stability tests and answer a number of questions regarding the convergence process in the Russian Federation. One major question, i.e. the division of the data set into economically or politically motivated sub-sets, has already been mentioned by Buccellato (2007) but has not been pursued due to lack of usable data.

This paper proceeds in three steps. The following second chapter begins with the convergence hypothesis being deduced from the general solution of the neoclassical growth model before specific regression models like the spatial lag and the spatial error model are introduced. This theoretical background is accompanied by a literature review of the most relevant studies and provides an overview of the most important strands of research. In the fourth and final part of chapter two, the implemented data set is discussed and some basic information on the geographical layout of the regions of the Russian Federation is given.

The third chapter contains the central analysis of this paper whereby in a first step the absolute and conditional convergence hypothesis is tested. As a number of tests point to the presence of spatial effects, all tests are repeated while controlling for regional effects in the context of a spatial lag and spatial error model.

[1]The author would like to thank Mr. David Hanrahan for editorial support.

[2]See Solow (1956) and Swan (1956).

The third part of the third chapter presents kernel density estimates to test for the presence of potential convergence clubs. A convergence club is a group of regions with a common steady state for the regions inside the club but with different steady states across clubs. Adding to this analysis the results of Markov transition matrizes the applicability of quantile regression analysis is secured which is performed in the fourth part of the chapter.

The fourth and final chapter summarizes the results and concludes.

2 Background

2.1 Neoclassical Growth Theory

The neoclassical growth model starts with the development dynamics of the capital stock in period t, given as K_t:

$$K_t = K_{t-1} + I_t - \delta K_t \tag{1}$$

with I_t as investments in period t and δ as the depreciation rate. The equilibrium condition $I_t = S_t$ and the definition of the savings function as $S(Y) = sY_t$ implementing a Cobb-Douglas-style production function with the input factors capital and labor in per capita terms[3]. Reformulating the resulting equation in per capita terms leads to the following Bernoulli difference equation:

$$\Delta k_t = s k_t^{\beta} - \delta k_t \tag{2}$$

Solving the equation for the stock of capital per capita results in:

$$k_t = \left(C_0 exp(-\delta(1-\beta)t) + \frac{s}{\delta} \right)^{\frac{1}{1-\beta}} \tag{3}$$

Using the production function to calculate GDP per capita leads to:

$$y_t = \left(C_0 exp(-\delta(1-\beta)t) + \frac{s}{\delta} \right)^{\frac{\beta}{1-\beta}} \tag{4}$$

Solving for the parameter C_0 under the starting condition that $y(0) = y_0$ leads to:

$$C_0 = y_0^{\frac{1-\beta}{\beta}} - \frac{s}{\delta} \tag{5}$$

[3] $y_t = k_t^{\beta}$

Inserting this result in equation (4) and taking the first derivative according to time t gives:

$$\frac{dy}{dt} = -\delta\beta exp(-\delta(1-\beta)t)y_t\left(\left(y_0^{\frac{1-\beta}{\beta}} - \frac{s}{\delta}\right)y_0^{\frac{1-\beta}{\beta}} - \frac{s}{\delta}\right)y_t^{2-\frac{1}{\beta}} \tag{6}$$

It becomes obvious that the growth rate of the GDP per capita is negatively dependent on the initial level of GDP per capita y_0.

If this result is transferred to a testable regression model it reads:

$$\frac{1}{T}(ln(y_{i,T}) - ln(y_{i,0})) = \alpha_0 + \alpha_1 ln(y_{i,0}) + \mu_i \tag{7}$$

whereby T is the length of the underlying timeframe and $y_{i,0}$ and $y_{i,T}$ are the first and the last observations of the GDP per capita for region i respectively. This version is also the one implemented by Barro and Sala-I-Martin (1990) and Buccellato (2007). In the context of this study however, we want to exploit the panel structure of the available data set and therefore use the altered variant of the regression model as implemented for example by Badinger et al. (2004), Arbia (2004), Arbia et al. (2005) or Arbia and Piras (2005) which can be summarized by the following equation:

$$ln\left(\frac{y_{i,t+k}}{y_{i,t}}\right) = \alpha_0 + \alpha_1 ln(y_{i,t}) + \mu_i \tag{8}$$

whereby the term on the right hand side is the yearly growth rate of GDP per capita and $y_{i,t}$ is the level of GDP per capita at the beginning of the respective time period. The error term μ_i can further be divided into regional fixed effects a_i and a random factor ϵ_i so that it reads $\mu_i = a_i + \epsilon_i$. Furthermore, the coefficient α_1 can be broken down in the following way:

$$\alpha_1 = 1 - exp(-\beta) \tag{9}$$

Here, β is the speed of convergence[4].

If the coefficient α_1 is statistically significant absolute convergence exists. For an insignificant coefficient the second step is testing for conditional convergence where specific parameters for the regions are held constant. This is achieved by adding k additional variables X_k to the equation so that it reads:

$$ln(\frac{y_{i,t+k}}{y_{i,t}}) = \alpha_0 + \alpha_1 y_{i,t} + \sum_{k=2}^{K} \alpha_k X_k + \mu_i \tag{10}$$

[4]It can be noted that the difference between α_1 and β is almost negligible up to a value of 0.3-0.4 for α_1 while it becomes significant for values larger than 0.5.

If the coefficient α_1 becomes significant while it has not been significant in the previous case, conditional convergence exists. The condition being the constancy of the variables X_k.

2.2 Spatial Models

With serial autocorrelation, temporal lags of the dependent variable are causal to the development of the dependent variable itself. In contrast, with spatial autocorrelation, the spatial lags of the dependent variable are causal to its development. While in the case of serial autocorrelation the effect is motivated via the presence of path dependency, with spatial autocorrelation motivation usually stems from the idea of clustering or wavelike diffusion patterns.

In contrast to the one-dimensional temporal effects in the context of serial autocorrelation, spatial autocorrelation is an at least two-dimensional problem and thus needs a two-dimensional matrix - referred to in the literature and hereafter as the distance or weight matrix - to describe potential dependencies[5]. This matrix is also one of the biggest weaknesses of the spatial regression approach as it is on the one hand not stable regarding regional scaling and on the other hand it is very dependent on the geometry and geography of the underlying regions.

The two basic approaches to designing spatial weight matrices are firstly the neighborhood approach where the weight matrix contains a 1 at position $(i,\ j)$ only if countries i and j are neighboring countries; all other entries are zero[6]. Secondly, in the distance matrix approach, the actual Euclidean distance between two regions is considered, whereby the distance is calculated as the distance between the capitals of both regions. Perret (2011) proposes an alternative to this procedure by using the economic output of all or at least the major cities in a region and calculating an economic center of gravity, with economic output being their mass, by considering the geographic location of the cities[7].

[5]Note that the approach by Bottazzi and Peri (2003) essentially reduced the spatial problem to a one-dimensional problem. However, a lot of spatial information is lost when referring to this approach and it is based on strict a priori assumptions as regards the spillover reaches.

[6]In an extended version position $(i,\ j)$ is assigned a weight of $\frac{1}{s}$ if $s-1$ countries are lying on the shortest path from country i to country j. Alternatively approaches where a region's impacts exponentially decreases have been considered in the literature.

[7]This approach, however, becomes problematic for highly non-convex regions. Additionally, the collection of output data on a metropolitan level becomes very hard to nigh on impossible making it difficult for this approach to be applied consistently.

In light of this short discussion, in this study the distance approach is implemented. In addition to the basic approach, the standardization procedure given by Tiefelsdorf et al. (1999) and Tiefelsdorf (2002) is applied to assure statistical stability of the weight matrix.

With selection of the spatial weight matrix W, three basic approaches to including spatial effects in the model are possible.

In the spatial lag model, a situation is considered where the output of nearby regions influences the output in the region under consideration. Thus the independent variable is influenced by its spatial lags and the respective regression equation reads as:

$$ln(\frac{y_{i,t+k}}{y_{i,t}}) = \alpha_0 + \alpha_1 y_{i,t} + \sum_{j=1}^{I}(W_{i,j} y_{j,t}) + \mu_i \quad (11)$$

If the dependent variable is not influenced by its own spatial lags, but instead, in the context of conditional convergence, spatial lags of the conditioning variables influence GDP per capita growth, this type of model is referred to as a Durbin model. However, the present study will not specifically consider this type of spatial model.

Instead, the third type of model, the so-called spatial error model, is considered. In the spatial error model, in contrast to the spatial lag model, it is not the dependent variable whose spatial lags influence it but in this model spatial autocorrelation in the error terms is considered and thus the error term μ_i changes to $\mu_i = a_i + \sum_{j=1}^{I} W_{i,j}\epsilon_j + \epsilon_i$[8].

Aside from the three discussed approaches to integrate spatial effect into a convergence analysis, it is also possible to use an approach whereby the Eigenvectors of a modified weight matrix are included in the regression equation. Eckey et al. (2007b) is one example where this approach is used. However, as with the Durbin approach, the Eigenvector approach is not considered in this study.

2.3 Literature Review

To list all publications on the topic of economic convergence could be considered an endeavor worthy of a study of its own, thus in this section we limit ourselves to a description of the main strands of research of economic convergence and where this study fits in.

[8]The spatial error model already accounts for a considerable share of the spatial autocorrelation induced via spatially lagged independent variables and thus using the more common spatial error model renders an inclusion of Durbin-type lags obsolete.

In this context, Eckey et al. (2006b) and Jungmittag (2006) give a suitable first overview of studies executed with regard to the topic of economic convergence.

The division of studies regarding their orientation on specific regions can be seen as a first way to classify them. The study by Barro and Sala-I-Martin (1990) can be seen as the beginning of the research of economic convergence. It is primarily focused on the USA. Another paper focused primarily on the US is Rey and Montouri (1999).

For the European Union some research approaches, such as Martin (2001), focus only on Eurozone countries, while others specifically include all EU countries or in some cases compare the EU 15 countries with the South Eastern member countries. Examples for both foci can be found in Cuadrado-Roura (2001), Herz and Vogel (2003), Carrington (2003), Enflo (2005), Geppert et al. (2005), Bräuninger and Niebuhr (2005), Carrington (2006), Eckey et al. (2006a) or Feldkircher (2006).

A focus on the convergence process across regions of the European Union leads one to also consider the question of which factors influence the convergence process. With convergence the primary goal of European structural policy for over two decades the question arose of whether structural funds had any impact at all on the convergence process. This question is studied for example by Lall and Yilmaz (2000) or Cappelen et al. (2003).

While most of these studies focus on regions as the unit of study, Barro and Sala-I-Martin (1991) is one of those studies that puts countries and the global convergence process into focus.

In contrast to the international perspective, there also exists a number of studies which focus on the convergence of the regions in only one country, e.g. for the EU there are the studies by Buscher et al. (1999), Eckey et al. (2007a) for Germany and the study by De la Fuente (2002) for Spain. For Russia there are the two aforementioned studies by Solanko (2003) and Buccellato (2007). Additionally, as Russia is considered a BRICS country and thus often compared to countries like India or China, the study by Ding et al. (2008) focusing on Chinese regional convergence could also be mentioned.

Aside from this geographical focus, it is also possible to classify convergence studies by the methods they implement. Aside from the purely cross-sectional regression approach without spatial effects there are studies that discuss a number of possibilities to introduce spatial effects. Traditional spatial econometrical approaches - the spatial lag and error model - as discussed in the previous section are implemented for example by Rey and Montouri (1999), Rey and Dev (2006), Fingleton (2003) or Le Gallo and Dall'erba (2006). Related to this question of spatial correlation is also the study of cross-regional knowledge transfers, a line of thought taken up for example by De La Fuente (2000).

A second approach is the use of kernel density estimation techniques to analyze whether the regions under consideration converge to only one steady state or if more than one steady state exists. This line of thought was taken up by Quah (1993) and further developed by Quah (1995), Canova (2001) or Cantner and Graf (2004).

Also, in contrast to the use of cross-sectional approaches over time and with the increasing availability regional data, panel approaches became more common as seen in Tondl (1997), Badinger et al. (2004), Arbia (2004), Arbia et al. (2005) or Arbia and Piras (2005).

Aside from those mainly empirical studies, Galor (1996) developed a version of the neoclassical growth model that allows for a conditional convergence hypothesis to be deduced.

2.4 Data Sources

With the exception of the price level data, all data used in this analysis has been taken from the Russian regional statistical yearbooks Regionii Rossii published by Rosstat, the Russian statistical office. The Rosstat price levels have only been used from 2002 onwards as previous price levels are highly biased as shown by Gluschenko (2006). Instead, regional price levels for 1998 and 1999 are taken from Surinov (1999) and are inter- and extrapolated for the missing years.

In this study, we consider 80 Russian regions whose general structure is more or less comparable to the status of the regional layout as of late 2011. It needs to be noted, however, that a change in 2012 led to a redistribution between the city of Moscow and the Moscow region. Additionally, the Russian occupied regions of Crimea and Sevastopol are not included in this study.

3 Analysis

3.1 Absolute and Conditional Convergence

In the first step of this study, the hypothesis of absolute convergence of GDP per capita across the regions of the Russian Federation is tested. In this context most of the following analyses are divided into seven parts. At first the full time frame from 1994 to 2013 is considered[9]. This time frame is then split into the periods of 1994-1999 and 2000-2013. The first period not only

[9]While data has been available for 1994 to 2014 the last year had to be dropped to calculate growth rates.

	1994-2013	1994-1999	2000-2013	2000-2003	2004-2007	2008-2011	2012-2013
GDPpc	-0.1153***	-0.3582***	-0.0884***	-0.0954***	-0.0446	-0.0117	-0.1598*
	(-7.36)	(-17.01)	(-5.05)	(-2.83)	(-1.37)	(-0.36)	(-1.99)
Const	1.0628***	2.3481***	0.8710***	0.8884***	0.5628**	0.2107	1.5048**
	(9.40)	(20.27)	(6.25)	(3.77)	(2.20)	(0.75)	(2.10)
N	1.600	480	1.120	320	320	320	160
R^2	0.179	0.400	0.248	0.428	0.424	0.460	0.488
F-Stat	54.16***	289.18***	25.49***	8.01***	1.88	0.13	3.94*

Table 1: Regression Results - Absolute Convergence

coincides with the period usually referred to as the Russian transition period, it also coincides with the presidency of Boris Yeltsin. The period 2000-2013 is by itself rather nondescript and thus is split into the sub-periods 2000-2003 and 2004-2007 to represent the first and second terms of President Vladimir Putin, the sub-period 2008-2011 to represent the presidency of Dmitry Medvedev and the last period 2012-2013 to represent the first years of the third presidency of Vladimir Putin. Incidentally, this division also allows to check for effects of the global financial crisis which coincides mainly with the presidency of Medvedev. Due to issues of data availability, the effects of the economic sanctions, levied in the context of the Russian occupation of Crimea and the beginning of the conflicts in Eastern Ukraine, on convergence across Russia cannot yet be studied but remain as an interesting topic for future research.

Table 1 summarizes the results regarding the absolute convergence hypothesis. Absolute convergence takes place in all periods except the years 2004-2011. However, if the coefficients are considered, starting with a coefficient of -0.3582 and thus a speed of convergence of $\beta = 0.4435$, during the transition years[10] the coefficient is steadily decreasing until it reaches a value of -0.0117 and thus a speed of convergence of $\beta = 0.0118$ in the period 2008-2011[11]. Therefore, although the coefficients are no longer significant, this results mainly from a decrease of the speed of convergence below some critical level and not so much from a real stop in absolute convergence. This finding is furthermore strengthened by the fact that the coefficients for the periods 1994-2013 as well as for 2000-2013 are highly significant[12].

Even more noteworthy, however, is that in the last period of 2012 and 2013 the speed of convergence picks up again with a significant coefficient of -0.1598 and thus a speed of convergence of $\beta = 0.1741$. From a certain

[10]This compares to a half-life for closing the gap between richest and poorest region of approximately 1.6 years.

[11]This compares to a half-life of 58.7 years.

[12]Note that in comparison to Solanko (2003) all estimations report at least reasonably high R^2 statistics which could, however, be due to the fact that here a panel estimator has been used.

empirical point of view this makes sense as during the transition years regions became increasingly similar due to a general rapid decrease in income, with a half-life of around 1.5 years the convergence process has been very fast and by the end of the transition phase differences were rather small and kept decreasing due to ongoing convergence thus leading to a natural decrease in the convergence speed.

Although, disregarding the used data-set, an increasing income gap - at least in nominal terms - already existed in Russia in the 1990s, it became even more severe during the last 25 years: Russia in 2016 ranks on a level with the USA or China regarding income equality. Additionally, even though the comments by Gluschenko (2004) and Gluschenko (2006) were taken into account and Russian GDP per capita numbers have been cleared of the biased price levels of Rosstat prior to 2002, the data for the transition years in particular and possibly also for the period of 2000-2003 might be considered at least slightly biased and results should be treated with due caution.

It is noteworthy though, that a decrease in income in nominal terms supposedly is reflected in the above results by a higher speed of convergence and vice versa.

In a second step of testing, the convergence hypothesis dummy variables for the specific time periods were introduced in the full model[13]. The severe increase in the coefficient to 0.4208 and thus a speed of convergence of $\beta = 0.5461$ shows that inherent differences across the sub-periods are the main source for the difference in convergence speeds. In this line it seemed only prudent to also consider the hypothesis of conditional convergence and thus hold constant essential drivers of regional growth.

Table 2 summarizes the respective results[14]. Not only do convergence speeds increase but they also become more similar to each other thereby underlining that the differences between the sub-periods glimpsed from Table 1 are mainly due to the different resource and infrastructure endowments of the regions as well as differences in their integration in the global economy.

[13] Results are summarized in Table 9 in the appendix.

[14] Note that Solanko (2003) argues against the inclusion of both the SME share and an education variable (here the number of students). Arguments for both cases separately can be found in the literature, e.g. Fingleton et al. (2003) for the share of SME and De La Fuente (2000) for human capital and even Solanko (2003) includes each variable separately. Considering the results in Table 2, the results by Solanko (2003) seem to hold here as well and the SME variable might be dropped from the regression.

	1994-2013	1994-1999	2000-2013	2000-2003	2004-2007	2008-2011	2011-2013
GDPpc	-0.4431***	-0.7713***	-0.4455***	-0.6180***	-0.4974***	-0.8442***	-0.7131***
	(-6.96)	(-14.92)	(-6.81)	(-8.20)	(-6.36)	(-16.85)	(-6.48)
Labor	-0.2729	-0.3257**	-0.6651***	-0.9597***	-0.5278	-0.2040	-0.0191
	(-1.46)	(-2.55)	(-2.76)	(-3.44)	(-1.01)	(-0.86)	(-0.03)
Ex	0.0038	0.0948***	-0.0135*	-0.0016	-0.0147**	-0.0229***	0.0062
	(0.28)	(3.00)	(-1.67)	(-0.26)	(-2.14)	(-4.50)	(0.88)
Im	-0.0294	0.0740*	-0.0223**	-0.0422**	-0.0022	-0.0248**	-0.0164
	(-1.44)	(1.91)	(-2.18)	(-2.34)	(-0.14)	(-2.00)	(-0.97)
Open	0.0162	-0.0078	-0.1800	0.0754	0.2622	-1.3006	0.5083
	(0.65)	(-1.07)	(-0.93)	(0.61)	(1.04)	(-0.97)	(0.28)
Res	-0.1380*	0.0292	-0.0468	-0.0505	-0.0121	-0.0045	0.0145
	(-1.92)	(0.28)	(-1.03)	(-1.00)	(-0.29)	(-0.09)	(0.18)
FDI	0.0003	0.0024	-0.0026	-0.0002	-0.0008	-0.0027	0.0001
	(0.12)	(0.64)	(-1.13)	(-0.09)	(-0.41)	(-1.55)	(0.03)
GovPers	0.3080**	-0.5783**	0.4229***	0.5074***	0.5683***	-0.1995	-0.1200
	(2.06)	(-2.11)	(3.47)	(4.16)	(3.46)	(-1.06)	(-0.35)
Stud	0.1815**	0.0994*	0.1757***	0.1748**	-0.0157	-0.0244	-0.0320*
	(2.02)	(1.75)	(3.58)	(2.09)	(-0.16)	(-0.49)	(-1.95)
OilGas	-0.0193	-0.0405**	-0.0149	0.0020	-0.1119**	0.0447	-0.0540
	(-0.93)	(-2.00)	(-0.94)	(0.19)	(-2.12)	(1.11)	(-1.16)
SME	-0.2255	-0.1077	0.0572	0.1621	-0.0670	0.0917	-0.0381
	(-1.26)	(-0.69)	(0.43)	(0.84)	(-0.34)	(0.73)	(-0.33)
Price	0.0054***	0.0203***	0.0040***	0.0079***	0.0074***	0.0079***	0.0049***
	(4.04)	(5.73)	(4.72)	(3.85)	(3.81)	(11.16)	(7.59)
Const	1.8668	9.7357***	3.2700**	5.2435**	1.7735	9.7857***	7.0688
	(1.09)	(3.98)	(2.38)	(2.55)	(0.45)	(5.31)	(1.58)
N	1.600	480	1.120	320	320	320	240
R^2	0.342	0.256	0.190	0.133	0.125	0.122	0.252
F-Stat	13.89***	65.09***	9.89***	14.27***	10.96***	47.48***	12.10***

Table 2: Regression Results - Conditional Convergence

	1994-2013	1994-1999	2000-2013	2000-2003	2004-2007	2008-2011	2011-2013
GDPpc	-0.1163***	-0.3356***	-0.1199***	-0.2541***	-0.1963**	-0.1126	-0.1708
	(-7.03)	(-6.98)	(-4.56)	(-2.87)	(-2.30)	(-1.21)	(-1.10)
ρ	-0.1154	-0.3564	-0.2125	0.4336***	0.4666***	0.4999***	-0.0714
	(-1.51)	(-0.97)	(-1.04)	(2.97)	(2.71)	(3.07)	(-0.14)
Const	1.5888***	2.7708***	1.6901***	2.3860***	2.1854***	1.5659**	2.1054
	(13.47)	(9.59)	(8.34)	(3.98)	(3.37)	(2.06)	(1.57)
N	1.600	480	1.120	320	320	320	240
R^2	0.179	0.400	0.248	0.025	0.424	0.460	0.488
F-Stat	349.17***	318.13***	368.45***	8.24***	233.79***	271.162***	150.591***

Table 3: Regression Results - Spatial Lag Model - Absolute Convergence

	1994-2013	1994-1999	2000-2013	2000-2003	2004-2007	2008-2011	2011-2013
GDPpc	-0.1045***	-0.3365***	-0.1202***	-0.2517***	-0.1867**	-0.1093	-0.1706
	(-6.41)	(-6.98)	(-4.56)	(-2.84)	(-2.17)	(-1.16)	(-1.10)
λ	0.0255	-0.3759	-0.2202	0.4672***	0.4794***	0.5155***	-0.0721
	(0.27)	(-1.01)	(-1.05)	(3.03)	(2.67)	(3.17)	(-0.14)
Const	1.5220***	2.5277***	1.5604***	2.8961***	2.7040***	2.1817***	2.0642
	(9.37)	(27.14)	(7.10)	(5.01)	(4.20)	(2.92)	(1.59)
N	1.600	480	1.120	320	320	320	240
R^2	0.179	0.199	0.248	0.428	0.424	0.460	0.488
F-Stat	349.17***	118.67***	368.45***	237.50***	233.79***	271.162***	150.591***

Table 4: Regression Results - Spatial Error Model - Absolute Convergence

3.2 Spatial Effects

While the preceding approach controlled for a number of important regional characteristics, it did not control for the geographic layout of the Russian Federation and the distribution of the Russian regions across space.

Tables 3 and 4 approach this problem by introducing a spatial lag term and a spatial error term, respectively. To differentiate spatial effects from region specific effects at first only the case of absolute convergence is reported. Here, spatial effects measured via the parameters ρ and λ, respectively, considerably influence the results and increase the speed of convergence. The results for the spatial lag and spatial error design yield more or less comparable results. These results, however, are not surprising as preliminary tests on the presence of spatial effects within the model, as reported in Table 5, clearly indicate the presence of spatial effects and motivate the use of the spatial lag as well as the spatial error model.

If, in a final step, the conditional convergence model is estimated as a spatial lag or a spatial error model, respectively, as reported in Tables 6 and 7, the results mirror those of the absolute convergence case, however with somewhat larger coefficients and thus convergence speeds.

Summarizing these results, starting with a relatively fast speed of convergence during the transition years the convergence speed consistently decreased until the presidency of Medvedev only to slightly increase again during the third term of President Putin. However, referring to the last two

Test	Statistic	Probability
	Spatial Error	
Morans I	0.175	0.000
Gearys C	0.814	0.000
Getis-Ord	-0.175	0.000
Robust LM-Test	1349.193	0.000
	Spatial Lag	
Anselin LM-Test	1129.091	0.000
Robust LM-Test	37.8290.000	

Table 5: Tests for Spatial Auto-correlation

	1994-2013	1994-1999	2000-2013	2000-2003	2004-2007	2008-2011	2011-2013
GDPpc	-0.2338***	-0.6158***	0.0751	-0.4684***	0.1075	0.0941	0.5345
	(-4.54)	(-11.10)	(0.87)	(-2.68)	(0.67)	(0.38)	(1.35)
Labor	0.4898***	0.5758***	0.4128***	0.7824***	0.5055*	1.0134***	0.8782***
	(5.29)	(3.49)	(3.32)	(2.71)	(1.87)	(4.12)	(3.09)
Ex	-0.0077	0.0309*	-0.0281**	-0.0001	-0.0367	-0.0425	-0.0394
	(-0.72)	(1.67)	(-2.06)	(-0.01)	(-1.36)	(-1.58)	(-1.01)
Im	-0.0754***	-0.0898***	-0.0757***	-0.0487*	-0.0306	-0.1118*	-0.1407*
	(-5.97)	(-4.18)	(-4.02)	(-1.76)	(-0.77)	(-1.92)	(-1.65)
Open	-0.0193**	-0.0319***	0.1514	0.1108	-0.4473	9.2584	16.7571
	(-2.34)	(-2.70)	(0.38)	(0.18)	(-0.56)	(1.16)	(0.99)
Res	0.2062***	0.3331***	0.1612***	0.4216***	0.1634**	0.0186	-0.1066
	(5.02)	(3.69)	(3.61)	(5.38)	(2.25)	(0.19)	(-0.67)
FDI	-0.0123***	-0.0037	-0.0203***	0.0043	-0.0286***	-0.0100	-0.0540***
	(-2.75)	(-0.43)	(-3.82)	(0.47)	(-2.90)	(-1.03)	(-3.02)
GovPers	-0.9151***	-1.0687***	-0.8087***	-1.1786***	-0.9998***	-1.0649***	-0.5361*
	(-8.61)	(-5.78)	(-6.53)	(-4.19)	(-3.80)	(-4.55)	(-1.86)
Stud	0.1839***	0.1598***	0.1822***	-0.1240	0.1883	-0.0528	-0.1284
	(6.35)	(5.21)	(2.85)	(-0.98)	(1.32)	(-0.38)	(-0.67)
OilGas	-0.0134**	-0.0180*	-0.0140*	-0.0078	-0.0068	-0.0179	-0.0196
	(-2.14)	(-1.80)	(-1.80)	(-0.60)	(-0.43)	(-1.30)	(-0.93)
SME	-0.5108***	-0.6952***	-0.0534	-0.2303	-0.5286	0.0745	0.1106
	(-3.26)	(-2.64)	(-0.26)	(-0.37)	(-0.82)	(0.20)	(0.26)
Price	0.0056***	0.0245***	-0.0012	0.0177***	0.0008	-0.0033	-0.0021
	(4.80)	(6.54)	(-0.86)	(3.28)	(0.21)	(-1.03)	(-0.63)
ρ	0.1243*	-0.3672	-0.2862	0.3602**	0.3448*	0.4949***	-0.3126
	(1.73)	(-1.06)	(-1.44)	(2.53)	(1.76)	(2.75)	(-0.58)
Const	7.3138***	9.4440***	5.4999***	8.5545***	6.0685***	5.8366***	-0.9829
	(12.99)	(10.23)	(7.46)	(5.68)	(4.04)	(2.79)	(-0.28)
N	1.600	480	1.120	320	320	320	240
R^2	0.270	0.241	0.192	0.130	0.076	0.253	0.018
F-Stat	49.02***	12.33***	21.88***	3.81***	2.11**	8.68***	0.22

Table 6: Regression Results - Spatial Lag Model - Conditional Convergence

	1994-2013	1994-1999	2000-2013	2000-2003	2004-2007	2008-2011	2011-2013
GDPpc	-0.2281***	-0.6196***	0.0702	-0.4568***	0.0983	0.0900	0.5497
	(-4.42)	(-11.18)	(0.81)	(-2.64)	(0.62)	(0.36)	(1.42)
Labor	0.5743***	0.5806***	0.4201***	0.7894***	0.5004*	0.9745***	0.8838***
	(5.74)	(3.50)	(3.34)	(2.79)	(1.84)	(3.89)	(3.10)
Ex	-0.0103	0.0309*	-0.0273**	0.0011	-0.0357	-0.0420	-0.0390
	(-0.97)	(1.67)	(-1.99)	(0.04)	(-1.30)	(-1.56)	(-1.01)
Im	-0.0770***	-0.0898***	-0.0755***	-0.0509*	-0.0290	-0.1134**	-0.1399
	(-6.19)	(-4.15)	(-4.01)	(-1.88)	(-0.68)	(-1.98)	(-1.64)
Open	-0.0206**	-0.0327***	0.1177	0.0979	-0.5607	9.0013	15.4489
	(-2.55)	(-2.75)	(0.29)	(0.16)	(-0.66)	(1.17)	(0.91)
Res	0.1993***	0.3326***	0.1631***	0.4232***	0.1707**	0.0187	-0.1053
	(4.90)	(3.63)	(3.68)	(5.48)	(2.33)	(0.19)	(-0.68)
FDI	-0.0136***	-0.0035	-0.0198***	0.0045	-0.0278***	-0.0082	-0.0551***
	(-3.02)	(-0.42)	(-3.71)	(0.49)	(-2.70)	(-0.79)	(-2.97)
GovPers	-1.0083***	-1.0732***	-0.8186***	-1.1936***	-1.0011***	-1.0263***	-0.5356*
	(-8.93)	(-5.76)	(-6.54)	(-4.27)	(-3.72)	(-4.28)	(-1.86)
Stud	0.1814***	0.1603***	0.1795***	-0.1255	0.1858	-0.0434	-0.1376
	(6.41)	(5.30)	(2.80)	(-1.02)	(1.30)	(-0.31)	(-0.69)
OilGas	-0.0134**	-0.0185*	-0.0142*	-0.0084	-0.0051	-0.0186	-0.0191
	(-2.17)	(-1.88)	(-1.85)	(-0.64)	(-0.31)	(-1.31)	(-0.90)
SME	-0.4563***	-0.6878***	-0.0734	-0.2822	-0.5540	0.1040	0.0922
	(-2.81)	(-2.61)	(-0.36)	(-0.44)	(-0.85)	(0.28)	(0.21)
Price	0.0057***	0.0247***	-0.0011	0.0174***	0.0013	-0.0031	-0.0020
	(4.51)	(6.59)	(-0.76)	(3.31)	(0.32)	(-0.99)	(0.62)
λ	0.2704***	-0.4412	-0.3056	0.3664***	0.3532	0.5147***	-0.4223
	(3.40)	(-1.20)	(-1.45)	(2.70)	(1.55)	(2.66)	(-0.69)
Const	7.9116***	9.2225***	5.4007***	8.9822***	6.4748***	6.2577***	-1.3240
	(13.04)	(10.11)	(7.35)	(5.90)	(3.90)	(2.86)	(-0.38)
N	1.600	480	1.120	320	320	320	240
R^2	0.261	0.429	0.191	0.126	0.066	0.267	0.026
F-Stat	46.62***	29.21***	21.82***	3.68***	1.80**	9.31***	0.33

Table 7: Regression Results - Spatial Error Model - Conditional Convergence

tables, significant convergence actually only takes place during the transition years and during the first term of President Putin. In the other periods the speed of convergence no longer remains significant.

This development is only partially mirrored in reality where during the transition years all regions suffered comparably due to the transition shock and were thus reduced to comparable levels. During the first term of President Putin, a general growth of income occurred that effected the poorer regions relatively more than the already richer regions.

In the years since 2003, tendencies of divergence among the regions became increasingly stronger thus reducing the speed of convergence. At this point it should be stressed that this study implements real GDP per capita numbers and thus real exports, imports and FDI numbers. If nominal numbers were used, the results might be considerably different.

3.3 Kernel Density Estimation

In the previous section, the convergence hypothesis has been tested for the whole of the Russian Federation at once. In contrast, in this section we are analyzing whether there exist groups of regions within the whole of Russia that are each converging to their own steady state, thus, following the notation of other papers on this topic, we test for the presence of convergence clubs.

In this section, a kernel density estimator has been applied to the GDP per capita growth numbers thus approximating the density function of GDP per capita growth[15].

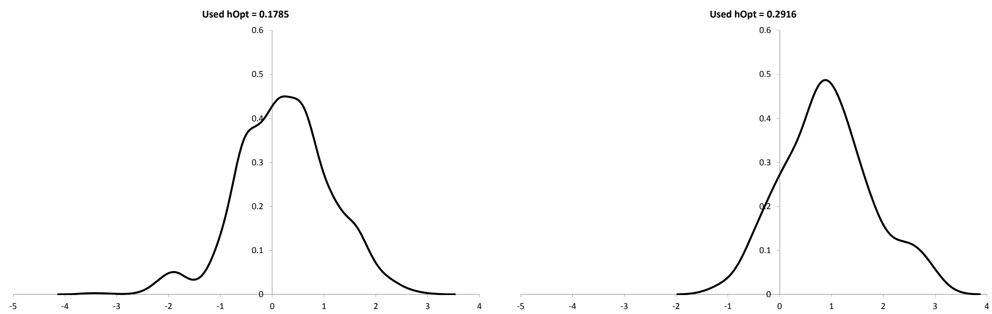

Figure 1: Kernel Density Estimation of the Growth Rate of GDP per Capita - 1994-2013 (left) and 1994 (right)

The left part of Figure 1 shows the results for the full time frame from

[15]The implemented kernel density estimator used a Gaussian kernel and the optimal bandwidth is calculated from the standard deviation and the interquartile distance.

1994-2013. The results give rise to the assumption of the existence of two distinct convergence clubs, however, the second convergence club, around a mean of -2, would be much less important than the main one with a mean of around zero. To test the validity of this assumption, the time frame is split into one year intervals starting with the right part of Figure 1 which reports on the kernel density distribution of 1994, through Figures 2, 3 and 4 and kernel density estimations for the years 1997, 2000, 2003, 2006, 2010 and 2013, respectively. This allows to illustrate any temporal shifts in the distribution and to see if the presence of a second convergence club holds steady.

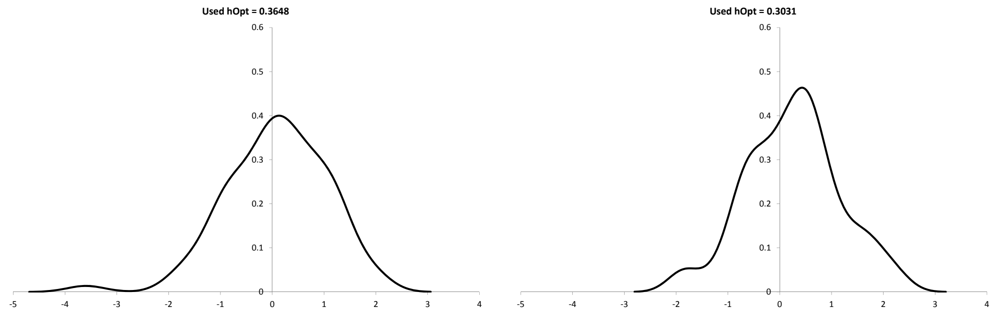

Figure 2: Kernel Density Estimation of the Growth Rate of GDP per Capita - 1997 (left) and 2000 (right)

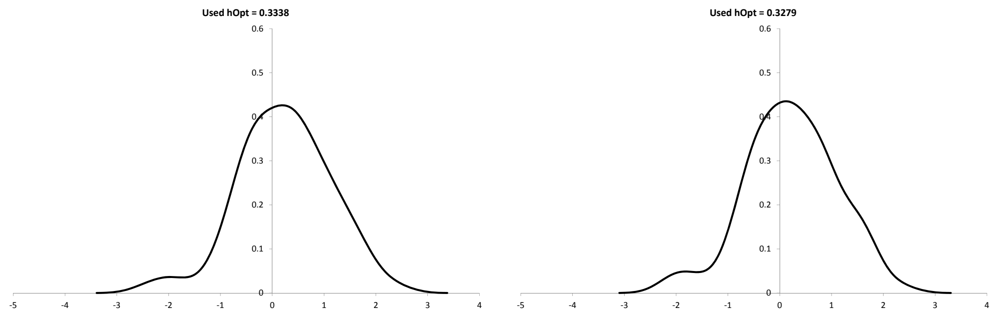

Figure 3: Kernel Density Estimation of the Growth Rate of GDP per Capita - 2003 (left) and 2006 (right)

From the figures it becomes obvious that the presence of a second convergence club as seen in the left part of Figure 1 is most likely a statistical artifact generated by a leftward shift of the general density function and its fat tails in the leftmost part of most of the single year distribution plots in particular the recent ones. However, the results for 2010 and 2013 might hint

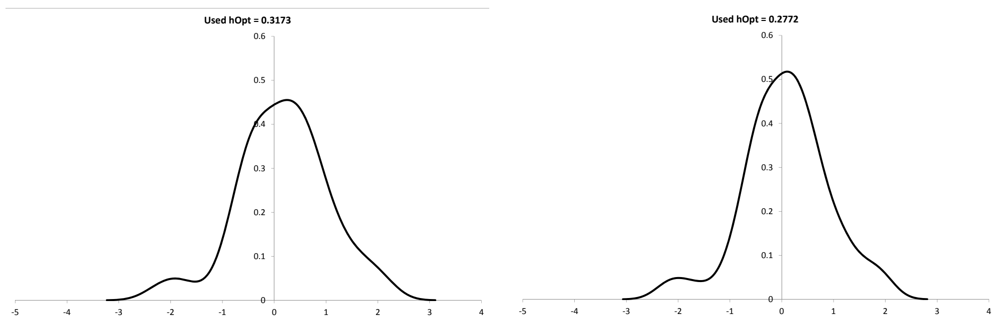

Figure 4: Kernel Density Estimation of the Growth Rate of GDP per Capita - 2010 (left) and 2013 (right)

that around 2010, and thus following the global financial crisis, a second low growth convergence club began to form.

Summarizing the results from these figures, for most of the considered time frame Russia reported only a single convergence club and thus convergence happened uniformly across the regions of the Federation according to the dynamics shown in the previous chapter. It furthermore shows that over the two decades analyzed herein a general leftward shift of the density function has taken place which translates into overall lower growth rates over the years. This also coincides with the results from the previous section where the speed of convergence generally decreased over time. Only the most recent results hint at the rise of a second convergence club and thus a split in overall growth dynamics. This might be a possible explanation for the returned increase in the speed of convergence witnessed for the period of 2012 and 2013. While this development certainly requires a deeper analysis, we judge the time too early, especially regarding the recent economic developments in the Russian Federation, to perform this type of analysis as part of the present study and expect stable results.

3.4 Quantile Regression Analysis

As a final step of this study, a quantile regression approach is selected to account for temporal and spatial dynamics at the same time and assure overall stability of the convergence results.

As a first preceding analysis, a Markov transition matrix is calculated for the change from the years 1994 to 2013. The matrix reports on a quartile basis the changes in the growth rates of the GDP per capita[16].

[16] I.e. cell $(i,\ j)$ represents those regions that in 1994 have been in quartile j while in 2013 they are in quartile i.

	1. Quartile	2. Quartile	3. Quartile	4. Quartile
1. Quartile	16	3	1	0
2. Quartile	4	9	7	0
3. Quartile	0	8	7	5
4. Quartile	0	0	5	15

Table 8: Markov Transition Matrix 1994 to 2013

Table 8 illustrates this type of Markov transition matrix. Roughly two thirds of all the regions remain in their original quartile, proving that some, but no significant, change is taking place among the regions. While these results could be more pronounced, they are still suitable enough and complement the results from the previous section. As the matrix measures the change from 1994 to 2013, it seems reasonable to assume that the rise of a second possible convergence club starting in 2010 might have impacted the results summarized in the matrix. They also validate the use of quantile regression analysis and allow for a sensible interpretation of the results thereof.

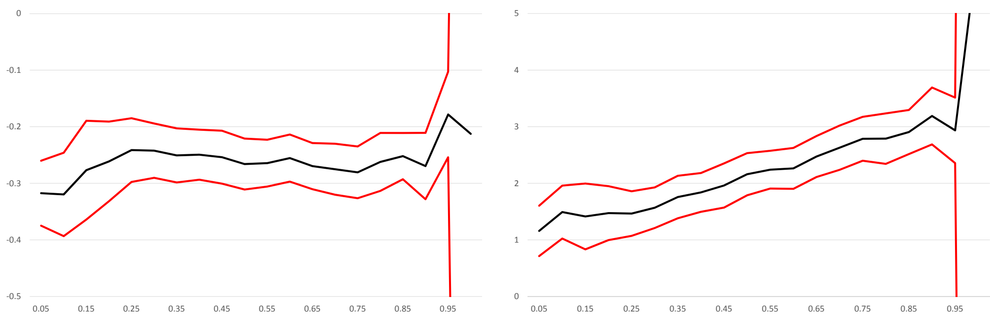

Figure 5: Panel Quantile Regression Results - Slope Parameter (left) and Intercept (right)

Figure 5 illustrates the results of quantile regression analysis. The left part reports the development of the slope parameter and thus the speed of convergence across all quantiles while the right part reports the development of the intercept. Across all quantiles the speed of convergence remains nearly constant. Thus, there is no significant cross-temporal and cross-regional difference in the speed of convergence. The slight linear increase of the slope parameter in the lowest quantiles could be considered a reflection of the second possible low-growth convergence club.

Returning to the data, it therefore seems to be the case that growth and thus convergence dynamics in the worst-off regions, regarding real GDP per capita growth, are slightly different from the rest of Russia.

While this mirrors the results of the previous section, it is somewhat in contrast to the results of the traditional convergence analysis where significant differences between the different time periods exist[17]. Considering that each of the quantiles is basically a set of the observations for three to five regions, due to rather few shifts between quartiles as shown via the Markov matrix, it can be assumed that temporal dynamics do not really influence the results of the quantile regression and these results can be seen as an analog to the kernel density estimations of the previous section and thus a cross-regional counterpart to the traditional cross-temporal analyses of the first part of this chapter.

Finally, it is interesting to note that the average coefficient in this case is rather similar to the one calculated for the full time frame in the spatial conditional convergence model motivating an overall speed of convergence of 25% to 30% across all quantiles and thus all regions.

4 Conclusions

In the present study the focus has been on the development of regional GDP per capita in the Russian Federation in the years 1994 to 2013. In this context, in addition to testing the traditional spatial and non-spatial absolute and conditional convergence hypothesis, it has been tested whether the convergence speeds and the respective steady states remain stable across regions and across time. While until 2011 the speed of absolute convergence has steadily declined as such, the steady state remains the same singular one for all regions of the Federation. Only in recent years, i.e. after the financial crisis, a potential second steady state arose whose importance, however, remains very limited.

Using quantile regression, the results gained from conditional convergence analysis have further been strengthened as the speed of convergence remains nearly constant across all 5% quantiles.

While during the 1990s the development in real terms as analyzed herein has been a positive one insofar as regions converged rather fast, in nominal terms it can be seen that this basically meant that regions shrank to comparably low levels of income. Contrarily, in the years since 2000, especially during the early years 2000-2003, a real upward convergence process has taken place. This development is only achieved again in the years since 2012. However, in

[17]It needs to be noted that applying quantile regression analysis to the different time periods might lead to a loss in predictive quality as in this case for the 4 year periods only eight observation per 5% quantile would be usable leading to too few degrees of freedom for stable results.

light of economic sanctions, the occupation of Crimea and the formation of the Eurasian Union, all events that took place after the analyzed time frame, it is very hard to come up with suitable policy recommendations that would still remain valid in light of more recent developments.

It can just be said that until 2011 Russia followed a path of convergence that only got disrupted by the time of the third presidency of Vladimir Putin when convergence took up again. What exactly triggered this increase in convergence speed remains a question for future research; whether it has been due to a change in the overall steady state - a possible scenario considering the kernel density estimation results for 2000 and 2013 -, or a switch in the direction of convergence - more likely due to a decrease in oil prices since 2011 - or due to as of yet unknown factors remains to be seen.

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	Absolute	Conditional	Conditional + Spatial Lag	Conditional + Spatial Error
GDPpc	-0.4208***	-0.5765***	-0.3039***	-0.3493***
	(-9.94)	(-8.92)	(-5.60)	(-4.74)
1994-1999	-1.1338***	-0.8179***	-0.2060	-0.8567**
	(-7.40)	(-5.35)	(-1.03)	(-1.92)
2000-2003	-0.6623***	-0.4112***	-0.0971	-0.4587*
	(-8.12)	(-3.76)	(-0.61)	(-1.74)
2004-2007	-0.3035***	-0.1513*	0.1292	-0.0827
	(-6.39)	(-1.78)	(1.01)	(-0.44)
2008-2011	-0.1250***	-0.0877**	0.1270	0.0796
	(-6.39)	(-2.06)	(1.57)	(0.61)
Labor		-0.5441***	0.5698***	0.6907***
		(-3.19)	(6.09)	(6.71)
Ex		-0.0002	-0.0015	-0.0037
		(-0.02)	(-0.14)	(-0.36)
Im		-0.0090	-0.0674***	-0.0652***
		(-0.47)	(-5.27)	(-5.11)
Open		0.0001	-0.0275***	-0.0290***
		(0.01)	(-2.90)	(-3.40)
Res		-0.1128*	0.2178***	0.2222***
		(-1.81)	(5.37)	(5.63)
FDI		-0.0006	-0.0126***	-0.0128***
		(-0.29)	(-2.83)	(-2.90)
GovPers		0.2890*	-1.0107***	-1.1331***
		(1.99)	(-9.32)	(-9.81)
Stud		0.0893	0.1540***	-0.1373***
		(1.35)	(5.76)	(5.21)
OilGas		-0.0215	-0.0134**	-0.0143**
		(-1.21)	(-2.15)	(-2.33)
SME		-0.1196	-0.4100**	-0.3599*
		(-0.89)	(-2.37)	(-1.91)
Price		0.0040***	0.0055***	0.0032*
		(3.00)	(3.60)	(1.89)
ρ/λ			0.0941	0.4564***
			(1.26)	(2.75)
Const	3.8261***	5.3200***	8.1481***	9.8492***
	(10.14)	(3.74)	(13.13)	(8.40)
N	1.600	1600	1.600	1.600
R^2	0.420	0.229	0.022	0.373
F-Stat	33.16***	24.11***	2.19***	58.93***

Table 9: Regression Results - Absolute and Conditional Convergence with Time Dummies