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01.16

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Impressum:

Working Papers on Innovation and Space
Philipps-Universität Marburg

Herausgeber:

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Erschienen: 2016

More bucks, more growth, more justice? The effects of regional structural funds on regional economic growth and convergence in Germany

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Abstract:

This paper analyzes the impact of the German structure program "Joint Task for the Improvement of Regional Economic Structures" (GRW) on regional economic growth. The paper extends the existing literature by several aspects. First of all, using the popular augmented Solow model by *Mankiw et al. (1992)* as starting point, we develop an enhanced growth model by including employment as well as technological spatial spillovers to the model. Secondly, the program has not been analyzed within a dynamic spatial panel framework on the level of the 402 German small scale regions before. We use a detailed dataset on this regional level and address the problem of endogeneity by using a System Generalized Method of Moments (GMM) estimator. Finally, we investigate the impact of regional conditions on the effects of the GRW program.

The results illustrate that the impact of public subsidies is overestimated in the current literature. In fact, the infrastructure program even emanates a negative direct impact on regional economic growth, especially in sparely populated regions as well as in non-innovative regions.

Keywords: Regional economic growth, ß-convergence, Structural funds, Spatial panel econometrics, Generalized Methods of Moments (GMM) Estimation

JEL Classifications: C23, R11, R48, O47

1. Introduction

The German constitutional law postulates equivalent living conditions and equal opportunities in German regions as well as a uniform spatial development within the country. It is argued that a balanced development between structurally weak and strong regions fosters social balance, economic prosperity and improvement (cf. Deutscher Bundestag 2014).

One crucial instrument of the German regional policy is the 1969 introduced "Joint Task for the Improvement of Regional Economic Structures" (GRW).[1] The aim of this policy is to foster investments in economic lagging regions in order to generate long-term employment and economic growth as well as convergence between German regions. One part of the GRW focuses on direct financial support for enterprises with a high share of export activity, while another part subsidizes investments in the regional economically oriented infrastructure (cf. Eckey and Kosfeld 2005, Deutscher Bundestag 2014).

In times of decreasing public funds, studying the economic effects of the GRW are of major interest. Especially interesting are the impacts of the GRW on regional growth and convergence. Additional questions are: Does the success of the GRW program depend on regional circumstances? Are there specific types of regions that benefit more from subsidizing investments like the GRW?

These are still unanswered questions, although a large number of empirical studies examined the impact of the GRW policy on the macro-level (cf. Schalk and Untiedt 2000, Blien et al. 2003, Eckey and Kosfeld 2005, Alecke and Untiedt 2007, Eggert et al. 2007, Röhl and von Speicher 2009, Alecke et al. 2011). So far, the existing studies provide contradictory results. They are based on different theoretical frameworks and follow heterogeneous research designs (cross-sectional or panel data analysis), largely ignoring spatial interactions. None of the existing studies use a dynamic spatial panel framework on a small scale level, such as 402 German regions, and only *Röhl and von Speicher (2009)* consider regional conditions influencing the effects of GRW grants.

The aim of this paper is to close these research gaps. Based on the approach of *Mankiw et al. (1992)* as starting point, we enhance and complement the existing neoclassical growth models by including technological variables, the share of population employed as well as spatial interactions to our growth model. On this basis and by taking advantage of a large set of panel data on economic conditions on the small scale level of 402 German administrative districts,

[1] Original title in German: Gemeinschaftsaufgabe „Verbesserung der regionalen Wirtschaftsstruktur“ (GRW)

we estimate a dynamic spatial panel model employing a Generalized Method of Moments (GMM) estimator to obtain consistent and efficient estimates. Such an approach has become common in (spatial) growth econometrics in recent years (cf. Hoeffler 2002, Beugelsdijk and Eijffinger 2005, Ederveen et al. 2006, Esposti and Bussoletti 2008, Bouayad-Agha and Védrine 2010, Darku 2011, Kubis and Schneider 2012).

The reminder of the paper proceeds as follows. In the first part of Section 2 the theoretical framework of growth and convergence as well as the GRW is introduced. Furthermore, section two provides an overview of recent empirical studies in the context of the GRW program. Section 3 presents the methodical approach and data base, including a short introduction to specific spatial econometric issues. In section 4, the economic effects on growth and convergence of the GRW are estimated. In addition, special robustness checks and results on further hypotheses are presented. Section 5 summarizes.

2. Theoretical considerations and recent empirical studies

2.1. The theoretical framework

The augmented Solow Growth Model

While the literature provides a number of theoretical approaches, such as the new economic geography (cf. Krugman 1991) or the endogenous growth theory (cf. Romer 1986, Lucas 1988), most of the recent empirical literature (cf. Eggert et al. 2007, Alecke and Untiedt 2007, Dall'erba and Le Gallo 2008, Mohl and Hagen 2010, Alecke et al. 2011, Darku 2011) is based on neoclassical growth models and the pioneering work by *Mankiw et al. (1992)*. We also use this approach as basic starting point for two reasons: First, the identification of convergence processes is important for our research question, and the Mankiw-Romer-Weil approach allows to differentiate between *conditional* and *unconditional convergence*.[2] Second, our data provides good information about the output and little information about the input of the various endogenous processes, so that it is not meaningful to explicitly model endogenous growth processes. However, we deviate – like it is common in panel models – from the approach by *Mankiw et al. (1992)* and assume that the values determining the steady state change over consecutive time intervals and are not constant for the entire period (cf. Islam 1995, Durlauf et al. 2005).

Hence, we start from the well-known production function from *Mankiw et al. (1992)*

[2] For a detailed definition and description of unconditional and conditional convergence see *Islam (2003)*.

(1) $$Y(t) = K(t)^{\alpha} H(t)^{\beta} (A(t) L(t))^{1-\alpha-\beta},$$

with the assumption of decreasing returns to all capital $\alpha + \beta < 1$.[3] One grave shortcoming of this model is the assumption that labour growths simultaneously with the population, respectively with the working-age population. Especially, modelling regional growth in German, this is an unrealistic assumption. *Bräuninger and Pannenberg (2002)* develop an extension of the Solow model that is based on a similar idea, although it is mathematically slightly different due to their focus on the effects of unemployment. Therefore, besides (cf. Mankiw et al. 1992)

(2) $$A(t) = A(0)e^{gt},$$

we define

(3) $$L(t) = \lambda(t) \cdot P(t)$$

$$L(t) = \lambda(t) \cdot P(0)e^{nt},$$

where P(t) is the population and λ(t) represents the share of population employed, which might fluctuate over time.

Straightforward, output per effective unit of labour can be reformulated from the adapted equation (1)

(4) $$Y(t) = K(t)^{\alpha} H(t)^{\beta} (A(t) \lambda(t) P(t))^{1-\alpha-\beta}$$

as

$$\frac{Y(t)}{A(t)\lambda(t)P(t)} = \frac{K(t)^{\alpha}}{(A(t)\lambda(t)P(t))^{\alpha}} \cdot \frac{H(t)^{\beta}}{(A(t)\lambda(t)P(t))^{\beta}}$$

and

$$y = (k)^{\alpha} \cdot (h)^{\beta}.$$

To calculate the steady state of k and h their change has to equal the growth necessary for the growth in P(t) and A(t). However, λ(t) might also change in time. We denote the dynamics of λ(t) at time t by $l(t)=(d\lambda(t)/dt)/\lambda(t)$.[4] Hence, the effective labour grows at rate n+g+l(t), and the steady state of k and h are expressed very similar to the *Mankiw et al. (1992)* approach as

(5) $$k^{*} = \left(\frac{s_k^{1-\beta} s_h^{\beta}}{n+g+l(t)+\delta}\right)^{1/(1-\alpha-\beta)}$$

$$h^{*} = \left(\frac{s_k^{\alpha} s_h^{1-\alpha}}{n+g+l(t)+\delta}\right)^{1/(1-\alpha-\beta)},$$

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[3] The notation is standard: Y is output, K physical capital, H human capital, A the level of technology and L labour.

[4] Of course, in the long-term steady-state values of k*, h* and y* the l(t)-term is assumed to be zero. The l(t)-term is relevant in the empirical estimation of short and medium-term developments.

where s_k and s_h are the fractions of income that are saved and invested in physical and human capital, and δ is the constant rate of depreciation.

While *Mankiw et al. (1992)* calculate output per effective unit of labour, the usual approach in the empirical growth literature is to use output per capita (cf. Islam 1995). Inserting equation (5) into the production function (4) and taking the logs, we obtain the per capita steady state output level

$$\ln\frac{Y(t)}{P(t)} = \ln A(0) + gt + \ln\lambda(t) + \frac{\alpha}{1-\alpha-\beta}\ln(s_k) + \frac{\beta}{1-\alpha-\beta}\ln(s_h) - \frac{\alpha+\beta}{(1-\alpha-\beta)}\ln(n+g+l(t)+\delta). \quad (6)$$

Finally, if the change rate l(t) is assumed to be, at least, constant from time 0 to time t, the evolution of an economy towards its steady state is given by

$$\ln\frac{Y(t)}{P(t)} - \ln\frac{Y(0)}{P(0)} = \left(1-e^{-\psi t}\right)\ln A(0) + gt + \left(1-e^{-\psi t}\right)\ln\lambda(0) + l(t)t + \left(1-e^{-\psi t}\right)\frac{\alpha}{1-\alpha-\beta}\ln(s_k)$$
$$+ (1-e^{-\psi t})\frac{\beta}{1-\alpha-\beta}\ln(s_h) - (1-e^{-\psi t})\frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+l(t)+\delta) - (1-e^{-\psi t})\ln\frac{Y(0)}{P(0)}, \quad (7)$$

where ψ is the convergence rate towards steady state.[5] We will use a panel approach, which is able to explicitly account for unobservable regional fixed-effects contained in A(0), while a cross-sectional approach does not provide this feature (cf. Islam 1995 & 2003, Hoeffler 2002). In addition, we include additional control variables Z_i to account for the *observable* heterogeneity in the technological growth rate gt (cf. Durlauf et al. 2005). Therefore, following the usual panel data notation, our basic growth model can be represented as

$$\ln y_{it} - \ln y_{i,t-1} = \Delta\ln y_{it} = \beta_0 + \beta_1\ln y_{i,t-1} + \beta_2\ln X_{it} + \beta_3\lambda_{it} + \beta_4 Z_{it} + \eta_t + \mu_i + \epsilon_{it}. \quad (8)$$[6]

A spatial dynamic panel growth model

One major shortcoming of the basic neoclassical model is the assumption that economies are supposed to be independent (cf. Yu and Lee 2012). Ignoring spatial effects in the case of spatial autocorrelation leads to biased estimates (cf. Carrington 2003, Yu and Lee 2012).

Carrington (2003) assumes that spillovers originate from physical and human capital accumulation in neighboring areas, while the degree of the spatial spillovers depends on the R&D activity. *López-Bazo et al. (2004)* introduce spatial spillovers in the technology parameter into the basic Solow model by *Mankiw et al. (1992)*. They assume that the technology in a region

[5] For a detailed derivation of the evolution of an economy see for instance *Islam (2003)*.

[6] $\ln y_{i,t-1}$ is the per capita income from the previous year, X_{it} contains the share of investments in physical $\ln(s_k)$ and human capital $\ln(s_h)$ as well as the "depreciation-term" $\ln(n+g+l(t)+\delta)$. Furthermore, λ_{it} describes the initial share of population employed $\ln\lambda(0)$ as well as its fluctuating growth rate l(t)t. Z_{it} accounts for the observed heterogeneity of the growth rate gt of the initial technological level lnA(0), which is unobserved. Therefore, μ_i denotes the unobservable regional fixed-effects (includes $\ln A(0)_i$) that also include resource endowment, climate or institutions (cf. Mankiw et al. 1992). Finally, η_t captures the unobserved part of the technological growth rate gt as well as unobservable time effects (time fixed-effects) and ϵ_{it} describes the usual error term.

depends on a global technological level and on the technological levels of surrounding regions, which depend on the stock of physical and human capital (cf. López-Bazo et al. 2004). *Fischer (2011)* models the generation of technological advancement explicitly within a region and adds spillovers from the technological advancement in neighboring regions. *Yu and Lee (2012)* follow the panel Solow model by *Islam (1995)* and also include spatial interactions among regions in form of technological spillovers. They hypothesize that the level of technology is not only fixed by the initial level A(0) and its growth rate g, but also by the level of technology of the neighboring regions (cf. Yu and Lee 2012). They solve this spatially interactive technological development first, which results in a common technology growth rate g for all regions. Hence, their model does not allow to explicitly consider fluctuations in the technological development in regions and their spatial impact. Therefore we modify their approach.

In line with the above literature, we restrict spatial interactions to the technological parameter. Instead of equation (2)

$$A(t) = A(0)e^{gt}$$

we write the development of technology as

(9) $$A(t) = A(0)e^{\hat{g}t}, \qquad \text{with } \hat{g} = g + \Phi\, w_{ij}g,$$

where Φ measures the strength of spatial technological spillovers and w_{ij} denotes the spillover relationship between region i and region j within the spatial weighting matrix W. Hence, the technological advancement $\hat{g}$ in a region i depends on the technological growth rate that is generated within this region (g_i) as well as on the technological growth rate generated in neighboring economies ($\Phi \sum_j w_{ij} g_j$). Spillovers are only explicitly modelled for technological development here, although there are also spillovers in labour or capital in reality. The reason for this lies in the way the various variables are measured. Technological development is measured here by patents and Research and Development (R&D) employees, meaning that it is measured in the region in which it is generated. In contrast, capital investments and labour inputs are measured in the region in which they become effective. Hence, if the economic situation in one region has impacts on capital and labour in a neighboring region, this will already show up in the variables there and has not to be explicitly included into the estimation model. To consider technological spillovers between regions, g is just replaced by $\hat{g}$ in the above equations. As a consequence, Equation (8) is expanded to

(10) $$\Delta \ln y_{it} = \beta_0 + \beta_1 \ln y_{i,t-1} + \beta_2 \ln X_{it} + \beta_3 \lambda_{it} + \beta_4 Z_{it} + \beta_5 (WZ_{it}) + \eta_t + \mu_i + \epsilon_{it}.$$

The GRW policy and its potential contribution to the neoclassical growth model

The aim of the 1969 introduced GRW program is to foster investment projects in economic lagging regions with locational disadvantages in order to create long-term employment and economic growth in as well as convergence between German regions (cf. Deutscher Bundestag 2014). Establishing equivalent living conditions is even fixed in the German constitution law (Article 72, clause 2, cf. Grundgesetz für die Bundesrepublik Deutschland 2014). The main policy tools are direct investment grants to enterprises, which are willing to invest in economic lagging regions (foundation, expansion and modernization of commercial units) as well as the promotion of investments into the regional economically oriented infrastructure (cf. Eckey and Kosfeld 2005, Deutscher Bundestag 2014). The GRW especially targets enterprises with a high share of export activity. In the period 2002 through 2011, nearly 6.02 billion € were granted to foster the economically oriented infrastructure (66.05 % to the New Bundesländer without Berlin) and around 13.49 billion € to foster industrial investments (82.31 % to the New Bundesländer without Berlin) (own calculation based on data from Federal Office for Economic Affairs and Export Control).

The description of the GRW policy clearly shows that the program generates additional investments, so that an increased regional investment rate can be expected. Therefore, the GRW policy should accelerate the growth rate due to a higher investment rate (cf. Ederveen et al. 2003 & 2006, Alecke et al. 2011). Nevertheless, there are several arguments why raising the investments rate through structural funds may fail:

A1. Windfall gains may occur (cf. Eggert et al. 2007, Bade 2012). This addresses public infrastructure as well as industry subsidies.

A2. *Bade (2012)* hypothesizes, that if an investment is only made because of the public grant, this could lead to a misallocation of capital and negative effects.[7] Again, this may be the case for infrastructure and industry investments.

A3. Furthermore, the GRW investments may emanate negative incentives to the poorer regions. With high subsidies, there are less incentives for structural reforms. Moreover, regions with increasing growth rates are at risk to lose subsidies in the next period (cf. Eggert et al. 2007). Thus, allocation mechanics might hinder the efforts of economic lagging regions and do not provide strategies for higher growth (cf. Dall'erba and Le Gallo 2008). This may occur especially in the context of infrastructure investments.

[7] *Bade (2012)* neither observe windfall gains nor a misallocation of capital in his empirical analysis.

A4. *Baldwin and Okubo (2006)* argue that public investment grants mainly attract non-productive enterprises to relocate to the periphery while efficient firms remain in agglomerations. This argument also affects infrastructure as well as industry investments.

A5. Overall, public (industry and infrastructure) investments may be too scarce to balance the agglomeration process to richer regions (cf. Dall'erba and Le Gallo 2008).

A6. Based on the ideas of *Krugman (1991)*, infrastructure investments may influence the regional competition. If the money is invested mainly in an improved interregional infrastructure, the increased reachability of poorer regions could rather help the already well-developed regions. It may stimulate even more entrepreneurs to move in regions with a specialized labor-market, knowledge externalities and further agglomeration advantages, because the improved national-wide infrastructure increases the size of the market for firms in agglomerations and minimizes competition there. In addition, it increases the profits of firms in other regions, as they can export their goods easier and cheaper to this regions, what, in turn, increase the competition in the poorer regions. This argument holds especially for infrastructure investments in economically lagging and sparsely populated regions.

A7. In addition to the arguments from the existing literature, we hypothesize that mostly labor-intensive firms may be attracted by low wages in economically lagging regions. Especially, larger firms may source out their labor-intensive units to these regions. These firms do not reinvest their profits at their site in the subsidized region, instead the capital will be removed from poorer to richer regions. This argument applies especially to industry investments in economically lagging and less innovative regions.

2.2 State of the Art – Recent empirical Studies

Overall, investigating the macro-economic impact of the GRW has provided heterogeneous and contradictory results so far (the main findings are summarized in table 1).[8]

Table 1: Overview empirical literature GRW

Paper by	Econometric approach and time period	Regional Units	Key Results impact of GRW on economic growth
Schalk and Untiedt (2000)	Panel Regression (1978-1989), Error-correction model, Cross-regional effects included in the output function, Non-Linear Least Squares Estimator	327 Western German administrative districts	Positive effects with respect to the investment as well as to the employment target. It remains unanswered, whether the GRW increase the per capita income in the fostered regions.

[8] In contrast to all other studies focusing on growth, *Blien et al. (2003)* determine the impact of the GRW subsidies on employment. While not discussing this study in detail, their results are listed in table 1.

Blien et al. (2003)	Panel Regression (1993-1999), Shift-share-analysis, No spatial model, Estimator is unknown	Administrative districts East Germany	Statistically significant positive impact of the GRW policy on the employment trend in the New Bundesländer in Germany.
Eckey and Kosfeld (2005)	Cross-Sectional Regression (2000-2002), Spatial autoregressively distributed lag model (SADL), Maximum Likelihood Estimator (MLE)	180 German labour market regions	The net effect of the GRW intervention is low (just 4 %). Neither the direct nor the indirect impact of the GRW subsidies are statistically significant.
Alecke and Untiedt (2007)	1. Cross-Sectional Regression (1994-2003), No spatial model, Estimator is unknown 2. Panel Regression (1996-2003), No spatial model, Arellano-Bond-Estimator (First-Differenced GMM-Estimator)	225 German labour market regions	Statistically significant positive impact of the GRW on the growth of income and a boost of the convergence process.
Eggert et al. (2007)	Panel Regression (Two time periods: 1994-1999, 2000-2004), No spatial model, Pooled Ordinary Least Square Estimator (Pooled OLS)	16 German Bundesländer	The GRW grants have no statistically significant impact on the growth of the per capita income.
Röhl and von Speicher (2009)	Panel Regression (1996-2006), No spatial model, Fixed-Effects Estimator	113 Administrative districts East Germany	Statistically significant positive effects of the GRW on the gross value added in the manufacturing sector. The impact is highest in centers of agglomeration. Also positive impact of the GRW on employment in different sectors.
Alecke et al. (2011)	Cross-Sectional Regression (1994-2006) 1. No spatial model, OLS Estimator 2. Spatial Lag Model, Spatial Error Model, Spatial Durbin Model, Spatial Durbin Error Model, MLE	225 German labour market regions	The GRW has a statistically significant positive impact on the growth and enhances the convergence speed of aided labour market regions.

One key explanation for the ambiguous results are the different theoretical approaches, the empirical models are built on. *Schalk and Untiedt (2000)* use a partial analytical approach for the manufacturing sector, they found their model on two factor demand functions and one output function.[9] The empirical model of *Eckey and Kosfeld (2005)* refers to the theory of regional development and endogenous growth theory, where regional evolution and competitiveness is determined by key factors like infrastructure, human capital, institutions, physical and sectorial structure. In contrast, *Röhl and von Speicher (2009)* develop their empirical model without an explicit deduction from one theory. *Alecke and Untiedt (2007)*, *Eggert et al. (2007)* and *Alecke et al. (2011)* base their empirical model on the neoclassical growth theory, which is also well established in the international growth literature (cf. Ederveen et al. 2003 & 2006, Dall'erba and Le Gallo 2008, Mohl and Hagen 2010, Darku 2011). However, as discussed above (see section 2.1) this neoclassical growth approach has some shortcomings that might well influence the empirical results.

Some international studies relate the payoff of public funding to national characteristics like the degree of corruption (cf. Beugelsdijk and Eijffinger 2005) or institutional quality (cf. Ederveen et al. 2006). Only *Röhl and von Speicher (2009)* investigate the impact of the GRW

[9] The factor demand functions are based on the (neoclassical) theory of a firm that accounts for simultaneity and mutual interdependence of firm decisions in regard to investment, employment as well as to output. The output equation is based on several demand- and supply-side aspects (cf. Schalk and Untiedt 2000).

in relation to four types of agglomeration in Eastern Germany. The paper on hand expand the state of the art by relating several regional circumstances to the success of the GRW subsidies.

Another explanation for the divergent results are the different research designs. Some studies use a cross-sectional analysis, others apply a panel approach. Panel data generally feature more information as well as more variation over time (cf. Hoeffler 2002, Mohl and Hagen 2010). In addition, the studies vary by considering spatial interactions. In the case of spatial spillovers, ignoring them could represent an omitted variable bias (cf. Carrington 2003, Yu and Lee 2012). Unfortunately, all panel approaches in the GRW context (cf. Schalk and Untiedt 2000, Blien et al. 2003, Alecke and Untiedt 2007, Eggert et al. 2007, Röhl and von Speicher 2009) mainly ignore potential spatial interactions. The two spatial studies (cf. Eckey and Kosfeld 2005, Alecke et al. 2011) are based on a cross-sectional analysis, which, in turn, could lead to inconsistent and biased estimates due to treating the initial level of technology A(0) as part of the error term.

This gap is obvious even from an international perspective.[10] A range of international studies analyzes the impact of EU structural funds (with the exception of *Darku (2011)*), but ignore potential spatial interactions (cf. Cappelen et al. 2003, Ederveen et al. 2003 & 2006, Rodríguez-Pose and Fratesi 2004, Beugelsdijk and Eijffinger 2005, Esposti and Bussoletti 2008, Darku 2011). A few studies include spatial dependence, but use a cross-sectional approach (cf. Dall'erba 2005, Dall'erba and Le Gallo 2008, Ramajo et al. 2008).[11] Only *Mohl and Hagen (2010)* use a dynamic spatial panel framework, which seems, to the author's opinion, the most efficient method applied so far. Therefore, we also apply a dynamic spatial panel model with a GMM estimator, which has become common in (spatial) growth econometrics (cf. Hoeffler 2002, Beugelsdijk and Eijffinger 2005, Ederveen et al. 2006, Esposti and Bussoletti 2008, Bouayad-Agha and Védrine 2010, Darku 2011, Kubis and Schneider 2012).

[10] We complement the overview from *Mohl and Hagen (2010)* of the international policy studies, who analyze the impact of structural funds, in Appendix A.

[11] In contrary to the German spatial studies of *Eckey and Kosfeld (2005)* and *Alecke et al. (2011)*, *Dall'erba (2005)* applies an exploratory spatial data analysis, *Dall'erba and Le Gallo (2008)* use a Two Stage Least Squares (2SLS) approach to control for endogenous variables besides the spatial lag term, while *Ramajo et al. (2008)* estimate their spatial model also by MLE.

3. Econometric method and data

3.1 Estimation formula and econometric method

Based on the theoretical derivation of our growth model (equation 10), we include the GRW investments for each administrative district as fraction of the GDP (cf. Ederveen et al. 2006) as

(11) $\Delta lny_{it} = \beta_0 + \beta_1 lny_{i,t-1} + \beta_2 lnX_{it} + \beta_3\lambda_{it} + \beta_4 Z_{it} + \beta_5(WZ_{it}) + \beta_6 ln(SF_{it}) + \eta_t + \mu_i + \epsilon_{it}$.[12]

Equation 11 represents a spatial lag of X model. In contrast to the frequently used spatial lag or spatial error models, this approach does not represent specific econometric problems like simultaneity (cf. Elhorst 2014).

In dynamic panel models, there are well-known econometrical drawbacks. Equation (11) is a dynamic panel model with the presence of an unobserved time-invariant regional effect μ_i. The μ_i term is necessarily correlated with the $y_{i,t-1}$ term (cf. Roodman 2009). Moreover, more explanatory variables in our model may be correlated with μ_i or ϵ_{it}, which would yield biased and inconsistent estimates (endogeneity problem).

Furthermore, it has to be considered that the composite error u_{it} is necessarily serially correlated because it contains fixed-effects μ_i (cf. Roodman 2009, Wooldridge 2009).[13] In addition, μ_i and/or ϵ_{it} and thus u_{it} may be heteroscedastic, which also causes efficiency problems and problems with statistical inference. In sum, the presented aspects will cause usual estimation methods like OLS to be biased, inconsistent and inefficient (cf. Baum et al. 2003, Roodman 2009).

Based on the seminal papers by *Arellano and Bover (1995)* and *Blundell and Bond (1998)*, the System GMM estimator became popular in order to face endogenous variables in empirical growth models. This method incorporates on the one hand the method to transform the data in order to remove fixed-effects (First-differenced GMM, cf. Arellano and Bond 1991), and on the other hand to instrument endogenous variables (like $y_{i,t-1}$) with (internal) instruments uncorrelated with the fixed-effects (cf. Arellano and Bover 1995, Blundell and Bond 1998). Besides, the System GMM estimator does not rely on the assumption of a normally distributed

[12] $ln(SF_{it})$ are the GRW investments as fraction of the GDP. Moreover, the other variables are similar to them in equation (8) and (10). Although we observe a part of the technological advancement (patents and R&D-employment ratio) in a region as well as in the neighboring regions, we do not observe the initial level of technology lnA(0). Therefore, the technological growth rate is not calculable. Moreover, a part of the technological advancement is unobservable (η_t), this is why we do not replace $\hat{g}$ through $\hat{g}_i$ in the $ln(n+g+l(t)+\delta)$-term. Instead we assume $g+\delta$ to be in average 0.05 (cf. Mankiw et al. 1992). Before taking the natural logarithm (ln), we replace zero values through a very small value (cf. Alecke et al. 2011). Negative values in the $ln(n+g+l(t)+\delta)$-term are also replaced by very small values, but they are the exception.

[13] The composite error contains the time-invariant region effect η_i and the idiosyncratic error ϵ_{it}: $u_{it} = \eta_i + \epsilon_{it}$ (cf. Wooldridge 2009).

error term, it can also deal with complex error structures, including heteroscedasticity and serial correlation (cf. Roodman 2009). Hence, in the presence of heteroscedasticity and/or serial correlation, the two-step GMM estimator is more efficient than the 2SLS estimator (respectively the one-step GMM estimator, cf. Baum et al. 2003). Following recent empirical studies estimating dynamic (spatial) panel growth models, we also apply the system GMM estimator (cf. Hoeffler 2002, Ederveen et al. 2006, Esposti and Bussoletti 2008, Darku 2011, Kubis and Schneider 2012). In order to minimize the number of instruments as well as to utilize an optimal weighting matrix for the efficient two-step estimation, we use a collapsed instrument matrix for estimation (cf. Roodman 2009).

3.2 Data and spatial weights matrix

The panel includes information about the 402 German administrative districts for the period 2002 through 2011. The utilized variables and the data sources are described in table 2 below. Growth takes place continuously at every day, but GDP is measured for a complete year. Hence, the change of GDP from a year t to the next year is the weighted sum of all growth from the first day of year t until the last day of the next year (with the highest weight for the middle). Hence, all influencing variables that are measured also as a change between the two years are used as such. For all variables that are measured in the middle of years, we use the average between the two considered years.

Table 2: Definition of the variables and data sources

Variable	Description	Data source
Δ ln GDP per capita ($y_{it} - y_{it-1}$)	ln Nominal GDP per capita (Nominal GDP in €/population) in t minus ln nominal GDP per capita in t-1 (variable in ln).	Statistical offices of the Federal and the Länder
ln GDP per capita previous year ($y_{i,t-1}$)	Nominal per capita income from the previous year (variable in ln).	
ln Investment Ratio (included in X_{it})	Industry investments in the Manufacturing, the Mining and Quarrying Sector as share of the nominal GDP (Industry Investments in € / GDP in €) (variable in ln).	Regionalatlas Germany and Statistical offices of the Federal and the Länder
ln Foundation Ratio (included in X_{it})	Foundations as share of the nominal GDP (foundations / GDP in Mio. €) (variable in ln).	Mannheimer Enterprise Panel (MUP) (cf. Bersch et al. 2014) from the Center for European Economic Research Mannheim (ZEW) See Δ ln GDP per capita (Nominal GDP)
ln Higher Education Ratio (included in X_{it})	Higher education ratio (employees with university degree / employees total) (variable in ln).	Institute for Employment Research Nürnberg (IAB)
ln (n+g+l(t)+δ) (included in X_{it})	Population growth from t-1 to t plus growth rate of the gross employment rate (employees total / population) from t-1 to t plus g+δ, which is assumed to be constant at 0.05 (cf. Mankiw et al 1992) (variable in ln).	See Δ ln GDP per capita and ln Higher Education Ratio
ln Gross Employment Rate (included in λ_{it})	Gross employment rate (employees total/ population) (variable in ln).	See ln(n+g+l(t)+δ)
Δ Gross Employment Rate (included in λ_{it})	Growth rate of the gross employment rate from t-1 to t.	See ln(n+g+l(t)+δ)

Patent Ratio and **Patent Ratio neighboring areas** (included in Z_{it})	Patents as share of the nominal GDP (Patents / GDP in Mio. €) within a region and as spatial lag. This variables are interpreted as proxy for the technological growth rate gt (A(0) is unobserved).	Own calculation from the Patstat database (Version October 2014, European Patent Office)
R&D-Employment Ratio and **R&D-Employment Ratio neighboring regions** (included in Z_{it})	R&D quota (R&D employees / employees with university degree) within a region and as spatial lag. This variables are interpreted as proxy for the technological growth rate gt (A(0) is unobserved).	Institute for Employment Research Nürnberg (IAB)
ln GRW Ratio, Industry and **Infrastructure Investments** (included in SF_{it})	GRW investments (industry investments and infrastructure) as share of nominal GDP (GRW investments in € / GDP in €) (variables in ln).	Federal Office for Economic Affairs and Export Control (BAFA)

To construct our weighting matrix we follow *Eckey and Kosfeld (2005)* by using a neighboring matrix. The construction of the weighting matrix W proceeds as follows

(7) $W^*_{ij} = 0$ if i = j and if i and j ≠ same border

$W^*_{ij} = 1$ if i and j = same border

$W_{ij} = W^*_{ij} / \sum_i W^*_{ij}$.

W^*_{ij} is an element of an unstandardized weighting matrix and W_{ij} is an element of a normalized weighting matrix. We normalize the weighting matrix by dividing each element of W^*_{ij} by the column sum of the matrix. In contrary to the row normalization approach, we assume that the degree of the spatial spillover depends on the number of neighbors the radiating region has, meaning that a region distributes its given impact similarly to all its neighboring regions.

4. Empirical Results

The results of the regressions are reported in Tables 3-5. We focus on the coefficients of the GRW-investment variables.

4.1 The direct influence of the GRW on regional growth – All regions

Table 3 presents the regression results of the full model with all German regions included. The Hansen J-Test shows that the used collapsed instruments are not appropriate. Therefore, we also present the results for an analysis without collapsing the instruments in table 3.[14]

[14] In order to limit instrument count, we restrict the instrument lag limit to four.

Table 3: Two-step System GMM estimation, 2002-2011 (Full Model Regression)

Dependent Variable: Δ ln GDP per capita	Collapsed Instrumentmatrix	No Collapsed Instrumentmatrix*
ln GDP per capita previous year	-0.0986*	-0.0975***
	(0.0413)	(0.0217)
ln Investment Ratio	-0.00104	-0.00323
	(0.00534)	(0.00394)
ln Foundation Ratio	0.00836	-0.00728
	(0.0110)	(0.00724)
ln Higher Education Ratio	-0.000313	0.00229
	(0.0116)	(0.00523)
ln (n+g+l(t)+δ)	-0.000774	-0.000406
	(0.00137)	(0.000809)
Patent Ratio	-0.0497	-0.577
	(0.779)	(0.373)
Patent Ratio neighboring regions	1.269	0.0366
	(1.113)	(0.385)
R&D-Employment Ratio	0.123	0.117*
	(0.170)	(0.0476)
R&D-Employment Ratio neighboring regions	-0.0434	0.00853
	(0.0691)	(0.0248)
ln Gross Employment Rate	0.101*	0.0773***
	(0.0410)	(0.0177)
Δ Gross Employment Rate	0.457*	0.187
	(0.182)	(0.114)
ln GRW Ratio, Industry Investments	-0.000266	-0.0000753
	(0.000634)	(0.000291)
ln GRW Ratio, Infrastructure Investments	-0.000748	-0.000927**
	(0.000454)	(0.000336)
Hansen J-test (p-value)	0.001	0.328
Shortest/ longest lag	2/9	2/4
Number of Instruments	126	386
AR(1)	0.000	0.000
AR(2)	0.236	0.257
AR(3)	0.391	0.425
Observations	3420	3420
Number of regions	396	396

Notes: Significane levels * p <0.05, ** p <0.01, *** p <0.001. Standard errors in parentheses. They are consistent in the presence of serial correlation and heteroskedasticity, incorporating the *Windmeijer (2005)* correction for the two-step covariance matrix as well. Time dummies and constant are not explicitly shown. With the exception of the time dummies, all variables are treated as endogenous, therefore only second and deeper lags are used as instruments. The regression was run by the STATA command xtabond2 by *Roodman (2009)*.

* Two-step estimated covariance matrix of moments is singular. A generalized inverse to calculate the optimal weighting matrix is used for two-step estimation.

The coefficient of the dependent lag variable has the expected sign and is significant. Therefore, we confirm the finding of conditional convergence (cf. Alecke and Untiedt 2007, Alecke et al. 2011). That implies, if German regions have similar steady state levels, they are converging (cf. Mankiw et al. 1992). The ß-coefficient is smaller than the one in the cross-sectional studies of *Alecke and Untiedt 2007* and *Alecke et al. 2011*, which implies a higher convergence speed of German regions.[15] In addition, the results indicate a significant positive impact of the gross employment rate as well as of its growth rate (only in the regression with collapsed instruments). This illustrates the importance of employment on regional economic growth and clarifies the omitted variable bias problem in traditional neoclassical models ignoring the employment rate.[16] In addition, the R&D-Employment ratio has a significant positive effect in the regression without collapsed instruments.

[15] The panel regression in the study of *Alecke and Untiedt (2007)* rejects convergence, the ß-coefficient is positive.

[16] Overall, no German or international growth study include employment in the way that we derive from the basic augmented Solow model (see section 2.1). In matters of the German studies, which are based on a neoclassical growth approach, *Eggert et al. (2007)* ignore the role of employment. *Alecke and Untiedt (2007)* as well as *Alecke et al. (2011)* normalize their explan-

Both GRW coefficients indicate a negative impact of the public subsidies on economic growth. However, only the negative impact of the GRW infrastructure subsidies on the growth performance of German regions is significant in the regression without collapsed instruments. The results contradict especially the findings of *Alecke and Untiedt (2007)*, *Röhl and von Speicher (2009)* and from *Alecke et al. (2011)*, who conclude significant positive effects. In turn, a significant negative impact of the GRW investments was never measured before, but, for instance, *Ederveen et al. (2006)* find a significant negative impact of the European Structural Funds as well.

In the context of the infrastructure investments, the presented arguments A1 and A5 in section 2.1 would only explain non-significant effects. In contrast the arguments A2, A3, A4, A6 and A7 explain potential negative effects. These negative effects seem to be stronger for infrastructure investments than for industry investments. This contradicts argument A7 and is well in line with argument A3, that subsidies may hinder regions to undertake additional growth efforts in fear of losing the public grants in the future, as well as argument A6, that regional competition may decrease in the agglomerations while it increases in the subsidized regions.

However, to investigate this in more detail we study whether the effects depend on this regional conditions.

4.2 Regional conditions and their impact on the effects of the GRW program

To this end, we divide the German regions into three subgroups[17] according to three criteria:

1. GDP per capita,
2. R&D-employment ratio and
3. Population.

Apart from the GRW investments, the results of the regressions confirm the findings of the full model (table 4). Conditional convergence is again observed. The results also emphasize a positive impact of the gross employment rate and its growth rate on the regional growth performance. In one case a positive impact of the R&D-employment ratio is significantly found.

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atory variables by employees. Consequently, in the study of *Alecke et al. (2011)* the n-term in the depreciation-term (n+g+δ) represents the employment growth. The former study uses the percentage of employees in sectors with a high Ellison-Glaeser-Index (> 0.005) as well as the degree of specialization in employment (cf. Alecke and Untiedt 2007) and the latter study additionally use the share of employees in technology-intensive sectors as well as in the manufacturing industry as proxy for technological differences between regions (cf. Alecke et al. 2011). *Eckey and Kosfeld (2005)* also include employees in their model, but their model is not based on neoclassical growth theory (see section 2.2). In the international studies, based on neoclassical theory, *Esposti and Bussoletti (2008)* normalize the variables by employees as well. *Dall'erba and Le Gallo (2008)* and *Ramajo et al. (2008)* include the employment in agriculture as well as the (un-)employment rate to their model. Finally, *Cappelen et al. 2003* and *Rodríguez-Pose and Fratesi 2004* include different employment variables (e.g. employment in the agriculture sector) to their models (not based on the traditional neoclassical growth theory).

[17] We calculate the average GDP per capita, the average R&D employment ratio and the average population for the period 2001 and 2011 for each region and divide the regions into three groups with each containing 33 percent of the cases.

Surprisingly, we find a negative impact of the patent ratio in the high GDP and agglomerated regions. These regions are usually already strong in innovation activity. We see three possible explanations: First, further innovativeness might not be helpful. Second, innovations have a negative impact in the short run but pay off in the long run, which is not measured here. Third, those wealthy regions that have a stronger focus on the service sector, which creates less patents, did better in recent years.

Table 4: Two-step System GMM estimation for subgroups, 2002-2011

	Subdivisions GDP per capita			**Subdivisions R&D-Employment Ratio**			**Subdivisions Population**		
Dependent Variable: Δ ln GDP per capita	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
ln GDP per capita previous year	-0.198**	-0.333**	-0.298***	-0.0751*	-0.165**	-0.272***	-0.141	-0.130*	-0.188**
	(0.0617)	(0.118)	(0.0806)	(0.0334)	(0.0530)	(0.0661)	(0.0751)	(0.0618)	(0.0615)
ln Investment Ratio	0.00150	-0.00213	-0.0137	-0.00251	-0.00257	-0.000982	0.00882	-0.0127	-0.00590
	(0.00728)	(0.0116)	(0.0117)	(0.00515)	(0.00820)	(0.0106)	(0.00797)	(0.0123)	(0.00805)
ln Foundation Ratio	0.00678	0.00805	0.00661	0.00774	-0.00650	-0.00674	0.0232	0.00138	-0.0147
	(0.0156)	(0.0237)	(0.0169)	(0.0144)	(0.0193)	(0.0181)	(0.0165)	(0.0194)	(0.0168)
ln Higher Education Ratio	-0.0236	0.0000183	0.0348	-0.0286	0.00611	0.0414	0.0174	-0.0176	-0.00955
	(0.0269)	(0.0256)	(0.0219)	(0.0167)	(0.0146)	(0.0271)	(0.0282)	(0.0300)	(0.0280)
ln (n+g+l(t)+δ)	-0.000717	0.00166	0.00128	-0.000835	-0.000714	0.00388	0.00108	-0.00309	-0.00238
	(0.00118)	(0.00220)	(0.00234)	(0.00145)	(0.00191)	(0.00265)	(0.00158)	(0.00218)	(0.00220)
Patent Ratio	0.948	0.496	-3.786*	1.649	-0.0865	1.315	0.246	2.060	-3.725**
	(0.876)	(1.363)	(1.552)	(1.320)	(1.422)	(1.113)	(1.204)	(1.454)	(1.373)
Patent Ratio neighboring regions	-1.303	-0.691	2.225	-1.994	0.0448	1.341	0.224	-1.437	1.657
	(1.451)	(1.883)	(1.897)	(1.699)	(1.595)	(2.394)	(1.808)	(1.548)	(1.623)
R&D-Employment Ratio	0.322	0.258	0.221	0.0344	-0.270	0.403*	0.393	0.247	0.228
	(0.234)	(0.303)	(0.166)	(0.290)	(0.227)	(0.199)	(0.298)	(0.282)	(0.148)
R&D-Employment Ratio neighboring regions	-0.0909	-0.0255	0.0795	-0.0348	0.0219	-0.0923	-0.0703	-0.104	0.0381
	(0.0803)	(0.114)	(0.112)	(0.106)	(0.0595)	(0.185)	(0.152)	(0.169)	(0.0988)
ln Gross Employment Rate	0.0218	-0.00787	0.324***	0.0606	0.118*	0.171*	0.126	0.0884	0.266**
	(0.0577)	(0.0925)	(0.0904)	(0.0445)	(0.0508)	(0.0761)	(0.0671)	(0.0632)	(0.102)
Δ Gross Employment Rate	0.416*	0.391	0.545*	0.485**	0.312	0.186	0.532*	0.286	0.557**
	(0.188)	(0.258)	(0.243)	(0.173)	(0.244)	(0.244)	(0.242)	(0.190)	(0.203)
ln GRW Ratio, Industry Investments	-0.000220	0.00207*	-0.00129	-0.000536	0.000677	0.000431	-0.000301	-0.000155	-0.00119
	(0.000659)	(0.000803)	(0.000981)	(0.000727)	(0.000683)	(0.00109)	(0.000712)	(0.00127)	(0.00114)
ln GRW Ratio, Infrastructure Investments	-0.0000552	-0.000678	-0.00167	-0.000281	-0.00121*	0.000666	-0.00183*	-0.000337	-0.00110
	(0.000396)	(0.000700)	(0.00139)	(0.000369)	(0.000556)	(0.00101)	(0.000717)	(0.000773)	(0.000925)
Hansen J-test (p-value)	0.213	0.362	0.238	0.301	0.247	0.291	0.305	0.170	0.242
Shortest/ longest lag	2/ 9	2/ 9	2/ 9	2/ 9	2/ 9	2/ 9	2/ 9	2/ 9	2/ 9
Number of Instruments	126	126	126	126	126	126	126	126	126
AR(1)	0.000	0.007	0.000	0.000	0.000	0.001	0.000	0.002	0.000
AR(2)	0.356	0.285	0.934	0.860	0.616	0.261	0.965	0.217	0.304
AR(3)	0.612	0.384	0.980	0.591	0.296	0.107	0.332	0.233	0.243
Observations	1141	1157	1122	1128	1153	1139	1066	1163	1191
Number of regions	132	133	131	133	133	130	129	133	134

Notes: Significane levels * p <0.05, ** p <0.01, *** p <0.001. Standard errors in parentheses. They are consistent in the presence of serial correlation and heteroskedasticity, incorporating the *Windmeijer (2005)* correction for the two-step covariance matrix as well. Time dummies and constant are not explicitly shown. With the exception of the time dummies, all variables are treated as endogenous, therefore only second and deeper lags are used as instruments. The regression was run by the STATA command xtabond2 by *Roodman (2009)*.

To stress the impact of regional conditions on the effect of the GRW-investments, we first consider the GDP per inhabitant as a crucial regional condition. The results of the three regressions show that the public infrastructure subsidies have a continuously non-significant negative impact on regional economic growth. In turn, industry investments have non-significant (negative) effects in low and high per capita income regions, while industry investments into regions with a medium income indicate a significant positive effect. Hence, we can conclude that in regions that are rather average in GDP per inhabitant industry investments fall on good grounds and increase growth. This is not the case in regions with low GDP per capita, probably because of the above mentioned arguments. Regions with high GDP per capita receive little or no GRW-investments (see argument A5 above), so that non-significant results are no surprise.

Furthermore, the GRW investments depends on the innovativeness of a region. Although we do not find a significant impact of the GRW industry investments, the coefficient changes from negative to positive for an increasing R&D-employment ratio. A similar dependence is also found for the impact of the GRW infrastructure investments, although we find a significantly negative impact here for regions with an average R&D-employment ratio. Hence, the results provide some indication that above arguments hold especially for regions with a low (and average) innovativeness, while innovative regions might benefit from GRW investments. This finding supports especially argument A4 and A7 above.

The partitioning of the sample of regions according to population size encourages the presented arguments for sparsely populated regions (arguments A4 and A6). The GRW coefficients are continuously negative, but only the public infrastructure investments grants show statistically significant negative impacts in regions with a low average population, which strongly supports argument A6.

Overall, our analysis indicates that German politicians should foster industry investments only in regions with an average GDP and high innovativeness, while they should avoid infrastructure investments especially in sparsely populated and non-innovative regions. The more significant negative impacts of the GRW infrastructure investments in sparsely populated and less innovative regions support especially the above argument A6 that an improved interregional infrastructure might bring more competition to regions that are not competitive. However, also the above arguments A3, A4, A5 and partly A7 find some support by our results.

4.3 The influence of the GRW on absolute convergence – All regions

We conclude, on average, rather negative impacts of the GRW on the regional growth performance: The higher the GRW subsidies, the lower the regional growth rates. But this fact does not finally answer the question whether the GRW program foster convergence between regions. The public subsidies could foster other factors like the employment rate that, in turn, foster the economic growth in Germany indirectly.

To verify the impact on the convergence between regions, we run a classic absolute convergence regression as well as an additional regression with the GRW variables additionally added. On the one hand we get the absolute convergence coefficient with the impact of the GRW included (pure model) and at the other hand we observe the absolute ß-convergence coefficient without the impact of the GRW (extended model).

The Hansen J-test rejects the null hypothesis of proper instruments for the collapsed instrument matrix in this regression, so that we run the regression without collapsing the instrument matrix. The ß-coefficient (table 5) with the GRW subsidies implied is smaller (-0.00684) than the coefficient in the model with the isolated impact of the GRW investments (-0.00451). This illustrates that without the GRW investments, the convergence rate between German regions is smaller than with GRW investments. Hence, we find that the GRW investments increase convergence between German regions.

Table 5: Two-step System GMM estimation, Absolute convergence, 2002-2011

Dependent Variable: Δ ln GDP per capita	Collapsed Instrumentmatrix		No Collapsed Instrumentmatrix*	
	With GRW	Without GRW	With GRW	Without GRW
ln GDP per capita previous year	-0.00373	-0.00380	-0.00684*	-0.00451
	(0.00821)	(0.00977)	(0.00320)	(0.00428)
ln GRW Ratio, Industry Investments		0.000628		0.000491**
		(0.000360)		(0.000176)
ln GRW Ratio, Infrastructure Investments		-0.000442		-0.000496*
		(0.000384)		(0.000205)
Hansen J-test (p-value)	0.000	0.000	0.283	0.280
Shortest/ longest lag	2/9	2/9	2/4	2/4
Number of Instruments	126	126	385	385
AR (1)	0.000	0.000	0.000	0.000
AR(2)	0.638	0.646	0.639	0.639
AR(3)	0.784	0.791	0.783	0.782
Observations	3618	3618	3618	3618
Number of regions	402	402	402	402

Notes: Significane levels * p <0.05, ** p <0.01, *** p <0.001. Standard errors in parentheses. They are consistent in the presence of serial correlation and heteroskedasticity, incorporating the *Windmeijer (2005)* correction for the two-step covariance matrix as well. Time dummies and constant are not explicitly shown. With the exception of the time dummies, all variables are treated as endogenous, therefore only second and deeper lags are used as instruments (Note: time lags of the explanatory variables from the previous regressions are also used as instruments). The regression was run by the STATA command xtabond2 by *Roodman (2009)*.

* Two-step estimated covariance matrix of moments is singular. A generalized inverse to calculate the optimal weighting matrix is used for two-step estimation.

This is probably caused by the fact that, besides the rather negative direct effect on economic growth, GRW investments may foster the growth of other factors. In this context, especially the impact of the GRW program on the employment or the innovativeness should be considered in further research. For instance, the study by *Blien et al. (2003)* already constitute a positive impact of the GRW subsidies on the employment in the Eastern German regions.

5. Conclusion

In this paper we first enhanced the existing neoclassical growth model by including the employment rate and spatial interactions to the basic augmented Solow model.

Then, we applied the resulting model to analyze the impact of the GRW investments on the economic growth performance of German regions within a dynamic spatial panel framework by using a System GMM estimator. Our results strongly support the hypothesis that GRW investments do not foster economic growth in German regions, on average. In fact, the investments in the infrastructure even influence growth of regions negatively. On the one hand, this sort of investments may reduce the growth efforts of poorer regions, fearing the loss of the public subsidies. On the other hand, an improved infrastructure shifts the competition from regional to national level. While it reduces the competition in the centers, which additionally benefit from their agglomeration externalities, it increases the competition in rural areas, which are better accessible. Moreover, the labor-intensive units could be sourced out to the economic lagging regions, profiting from low wages and an improved reachability, while the profits are retransferred to the centers.

Deeper insights on this are gained by investigating whether the effect of the GRW program depends on regional circumstances. The results indicate that especially sparsely populated and non-innovative regions suffer from the outcome of high infrastructure subsidies. In turn, in regions with an average GDP per capita, the industry investments show significant positive effects. Nevertheless, the GRW program is proved to increase convergence among regions in our study.

The results of the analysis also highlight the need of further research. At first, it is necessary to investigate the impact of the GRW subsidies on additional factors like employment and innovativeness. Furthermore, it is necessary to prove the impact of other regional policies with different aims and targets on economic growth. Finally, the role of infrastructure investments must be examined more sophisticated in terms of disparities between intra- and interregional or between communication and construction infrastructure investments.

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Appendix A

Mohl and Hagen (2010) already present a detailed overview. Table 6 summarize the key results of international growth studies in the context of public structural funds that are not listed in Table 1 of their study.

Table 6: Overview of the impact of structural funds in international growth studies

Paper by	Policy	Econometric approach and time period	Regional Units	Key Results impact of policies on economic growth
Cappelen et al. (2003)	EU structural funds (Objective 1, 2 and 5b)	Panel Regression (Two time periods: 1980-1988, 1989-1997), No spatial model, Estimator is unknown	EU NUTS-1 and -2 regions	The EU structural funds have a significant positive effect on growth and enhance a greater equality in productivity and income. This effects are stronger in more developed countries.
Beugelsdijk and Eijffinger (2005)	EU structural funds	Panel Regression (1995-2001), No spatial model, First-Differenced GMM Estimator	15 EU countries	EU structural funds have a positive impact, poorer countries catch up. The degree of corruption does not affect the effects of the EU structural funds.
Ederveen et al. 2006	EU structural funds (European Regional Development Fund (ERDF))	Panel Regression (7 five-year periods 1960-1995), No spatial model, Pooled OLS Estimator (Additional estimators for robustness checks are used, e.g. First-Differenced and System GMM Estimator)	13 EU countries	Generally, the structural funds do not improve the growth performance of countries, but it enhances growth in countries with proper institutions. Therefore, EU structural funds are only conditional effective.
Becker et al. 2010	EU structural funds (Objective 1)	Panel Regression (Three time periods: 1989-1993, 1994-1999, 2000-2006), Regression-Discontinuity Design (RDD), No spatial model (Robustness check spatial spillovers), MLE for first-stage regression (Probit), Pooled OLS and Fixed-Effects Estimator for second-stage regression	285 EU NUTS-2 and 1213 NUTS-3 regions	The EU structural funds increase the GDP per capita growth about 1.6 %. Statistically significant employment effects are not observed.
Mohl and Hagen 2010	EU structural funds (Objective 1, 2 and 3)	Panel Regression (2000-2006) 1. No spatial model, First estimator is unknown (standard errors are corrected for heteroscedasticity, serial and spatial correlation), System GMM Estimator 2. Dynamic Spatial Lag Panel Model, MLE	126 EU NUTS-1 and -2 regions	The impact of the structural EU funds depends on the particular objective. Total EU aid has no impact, while objective 1 has a positive impact on regional growth.
Darku 2011	Fiscal Transfer Program, Canada-United States Free Trade Agreement (CUSFTA), North American Free Trade Agreement (NAFTA)	Panel Regression (1981-2006), No spatial model, OLS, Within Group (WG) Estimator, First-Differenced and System GMM Estimator	10 Canadian provinces	Regional integration (CUSTFA and NAFTA) reduce the convergence speed of Canadian provinces, while the federal fiscal transfers foster regional convergence in Canada.
Becker et al. 2013	EU structural funds (Objective 1)	Panel Regression (Three time periods: 1989-1993, 1994-1999, 2000-2006), Regression-Discontinuity Design (RDD), No spatial model, MLE for first-stage regression (Probit), Pooled OLS and Fixed-Effects Estimator for second-stage regression	186 through 251 EU NUTS-2 regions	The absorptive capacity of regions (human capital and quality of government) positively influence the regional growth process.

Acknowledgements

We gratefully acknowledge the VolkswagenStiftung for funding our project (grant number 89 472).