Chapter 9
Speed Up or Slow Down? The Effects of Capital Investment Grants on German Regional Growth

9.1 Introduction

In this chapter, we analyze the quantitative impacts of the regional policy scheme 'Joint Task for the Improvement of Regional Economic Structures' (in German, *Gemeinschaftsaufgabe "Verbesserung der regionalen Wirtschaftsstruktur"*, henceforth GRW) on labor productivity growth for a cross-section of 225 German labor markets between 1994 and 2006. The GRW is the key instrument of the German federal government and the states (the so-called 'Bundesländer') to foster investments in lagging regions with weak economic structures. Besides its redistributive effect of balancing out differences in the standards of living among German regions, the scheme is also intended to contribute to allocative efficiency. That is, by fostering economic performance in targeted regions, it shall ultimately contribute to German aggregate economic growth. From a theoretical perspective, the latter assumption holds in a perfectly neoclassical world. Here, due to decreasing marginal returns of capital, poor regions with a higher initial gap towards steady-state income grow faster relative to rich regions which are near their (identical) steady-state levels.

Given this potential 'double payoff' out of GRW spendings in terms of achieving two major social goals with a single instrument, it has attracted considerable interest in the empirical literature since its start in the late 1960s. The allocative motivation of the GRW is especially subject to criticism. Opponents question the predictions of (unconditional) convergence given the existence of increasing returns to scale, e.g. through agglomeration effects. Motivated by recent contributions in the fields of new growth theory and new economic geography, it is argued that from an allocative point of view the support of strong rather than weak regions would be in order.

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Jointly with Björn Alecke and Gerhard Untiedt. Björn Alecke, Gesellschaft für Finanz- und Regionalanalysen (GEFRA), e-mail: Alecke@gefra-muenster.de; Gerhard Untiedt, GEFRA & Technical University Clausthal, e-mail: Untiedt@gefra-muenster.de.

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Given these conflicting theoretical predictions, any economic impact analysis of the GRW needs to shift the focus to the empirical level. However, the picture is also not clear cut here: While some authors find positive economic effects, other scholars report insignificant or even negative correlations between GRW payments and regional growth for funded regions.[1] Moreover, recent research also extended the focus from a sole inspection of the direct effects of the GRW on supported regions to an augmented analysis including the likely role of spillover effects to neighboring regions.

The diversity of results found in the empirical literature can partly be explained by a plethora of different methodological approaches used for evaluation. Only few of them explicitly account for a thorough theoretical foundation, while the bulk of studies rather uses reduced-form models with weak identification strategies to estimate the causal impact of funding. Against this background this analysis attempts to specify an empirical model that explicitly refers to a growth-theoretical foundation. Additionally, we try to carefully account for new insights in the theory of spatial growth (regressions) and try to detect possible spillovers associated with regional policies, for instance, whether financial GRW support positively or negatively affects the growth path of neighbors. Negative spillovers may potentially arise from specific locational advantages of GRW support, which enable regions to poach factor inputs and thus production from their neighbors.

The remainder of the chapter is organized as follows: Sect. 9.2 presents some stylized facts of the institutional framework of the GRW. Additionally, it provides a literature review concerning the reported empirical impacts of the funding scheme on regional growth and convergence. This evidence serves as an empirical benchmark for our own estimation strategy to come in the next sections. Section 9.3 discusses the theoretical foundations of our empirical approach with a focus on neoclassical growth theory. Using this framework, the section then derives an empirical model to test for convergence in labor productivity among the German labor markets. We show how to properly incorporate GRW support as explanatory regressor, derive a testable null hypothesis in concordance with neoclassical growth theory and show how to interpret the estimation results. Section 9.4 presents the empirical results for our cross-section of 225 regions between 1994 and 2006. In Sect. 9.5, we augment the neoclassical but aspatial growth model by an explicit account for spatial dependence among the German regions—both with respect to productivity spillovers as endogenous variable as well as external effects originating from the set of covariates including the GRW. Section 9.6 finally concludes the chapter.

9.2 Institutional Setup and Literature Review

Since its introduction in the late 1960s, the GRW is operating as a coordinated action between the federal government and the states. For a time period of four years, they

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[1] This result also mirrors conflicting empirical evidence for the success of regional policies at the European level (see, e.g., Ederveen et al. 2006; Dall'erba and Le Gallo 2008, for an overview).

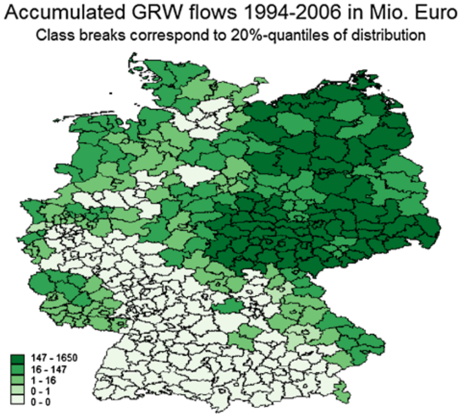

Fig. 9.1 Spatial distribution of GRW support among German labor markets. *Note*: For details about the data see Table 9.1

agree on a common general framework that contains the regulations for assistance—in particular the set of those regions which are eligible for public support. The two main instruments of the GRW are subsidies for investments of the private business sector in economically underdeveloped regions as well as the provision of local public infrastructure, which are closely related to private business activity.

In the course of German reunification the GRW scheme has been adapted on a one-to-one basis to the East German states. Between 1991 and 2009, the overall GRW budget amounted to 60.7bn. Euro with about two-third (39.3bn. Euro) assigned to private sector capital investment subsidies. The spatial distribution of cumulated financial flows to German regions is shown in Fig. 9.1. The figure shows that besides the East German states, which received about 85 percent of all GRW spendings, structural weak regions in North Germany, old-industrial centers in North Rhine-Westphalia, the Saarland and Rhineland-Palatinate received most parts of the GRW support. Besides it status as financially powerful funding scheme, the political importance of the GRW also stems from the fact that it acts as central coordination framework for most policies and programmes in Germany that intend to shape the regional development (such as the European Regional Development Fund (ERDF) and fiscal investment allowances in East Germany).

By now, there is a huge stock of empirical contributions aiming to analyze whether the GRW has achieved its political goals.[2] However, among these contributions there are only few approaches that are designed as a global impact analysis, addressing if and to what extent investment subsidies are causal for economic performance either at the firm or regional level. Instead, most evaluations conducted so far rather focus on the simple accounting principles such as execution and target control. One shortcoming of the latter approaches compared to a global impact is that they do not relate the observed outcome difference for supported regions over time (and/or relative to a comparison unit) to the notion of causality originating

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[2] See, e.g., Bölting (1976), Franz and Schalk (1982, 1995), Klemmer (1986, 1995), Asmacher et al. (1987), Deitmer (1993), Lammers and Niebuhr (2002).

from the funding scheme. The latter approach would require that the strict 'with-without' evaluation principle has to be applied, which relates the observed outcome for a funded region to the counterfactual outcome situation, where everything else is unchanged except that the policy scheme is not implemented.

In general, impact analyses for the GRW could be conducted at the firm level or at the regional and macro-regional level. While the analysis at the firm level may be seen as a necessary condition for any policy effect to be at work, moving up the geographical level and looking at the region's performance, on the one hand, shifts the focus to the analysis of regional net effects for the funding scheme. This is particularly true if one assumes that there is a non-linear relationship between outcomes observed at the firm level and the regional scale. Non-linearities in turn may, for instance, stem from intra-regional spillover effects between funded and non-funded firms, which may augment or diminish the total regional effect. However, since the GRW programme is ultimately designed to foster regional growth, the analysis of regional net effects may still be justified from an evaluator's perspective. Also, an explicit advantage of studies at the regional and macro-regional level is that they are more likely to capture forward–backward linkages, second-round multipliers and feedback effects of the policy stimulus both for the region in focus as well as a system of interconnected regional units. That is, for example, while the funding of manufacturing firms is quite likely to have an impact on local suppliers and service providers, which then also affect the region's average per capita growth rate, such indirect effects are typically missed at any firm level analysis.

Since this analysis conducts a regional rather than firm level analysis, in the following review, we focus on related empirical contributions at the (macro-)regional level of aggregation. The international literature dealing with an empirical assessment of the effectiveness of capital investment support schemes dates back to the late 1980s and early 1990s. Here, at the international level, a variety of very similar studies have been published. Some examples are Luger (1984) for the US, Faini and Schiantarelli (1987) for Italy, Harris (1991) for Northern Ireland and Daly et al. (1993) for Canada, among others. Common to these studies is the simultaneous analysis of output and factor demand in small multiple-equation systems, focusing on the supply side of the economy. The approaches typically center around an output equation based on a production function approach as well as structural equations for factor demand in physical capital and labor, respectively. The advantage of estimating a structural model crucially driven by policy-induced changes in the user costs of capital is that the authors are able to identify both output and substitution effects between production factors, which are related to the investment support scheme.

The empirical results of this modelling approach are quite similar in the sense that they typically find a positive effect of investment promotion policies on output and investment. However, the empirically estimated effect on employment varies significantly among the different contributions. That is, while Daly et al. (1993) report negative employment effects as a result of a high elasticity of substitution between factor inputs, the results in Luger (1984) and Harris (1991) show rather moderate elasticities of substitution. In the analysis of Faini and Schiantarelli (1987), the output effect is even found to outweigh the substitution effect between factor demands for a policy-induced change in relative factor prices. This result is also confirmed by Schalk and Untiedt (2000), who were among the first to adapt the empirical method of analysis to the German case for a sample of 327 West German districts between 1978 and 1989. Subsequently, further empirical evidence was reported. Focusing on the East German economy, Blien et al. (2003) use a model with variable selection motivated by different streams of regional science to estimate the employment effect of GRW support. For the sample period 1993–1999, the authors find that GRW spendings have a significantly positive effect on the regional evolution of employment for East German districts.

An empirical contribution closely related to the design of our empirical analysis is the approach taken by the German Council of Economic Advisors (SVR 2005). Based on a conditional convergence equation, the SVR (2005) uses data for East German labor market regions between 1991 and 2001 and finds a significant positive effect of GRW support on productivity growth. Also, in a prior work to this study, Alecke and Untiedt (2007) find positive effects of GRW support when using a cross-sectional convergence equation for German labor markets between 1994 and 2003. Finally, Röhl and von Speicher (2009) use a rather a-theoretical estimation approach for a panel data set of 113 East German districts between 1996 and 2006. In their paper, different outcome variables are used as dependent variables including aggregate labor productivity and GVA in the manufacturing sector, respectively. They are regressed on a time trend, a set of dummy variables for regional settlement types, and lagged GRW payments. Both for aggregate as well as sectorally disaggregated model specifications the authors find significantly positive policy effects. Röhl and von Speicher (2009) also show that their results likewise hold for employment growth.

Even if some of the recent empirical contributions use a theoretically founded neoclassical convergence approach, one nevertheless has to carefully design the study regarding the inclusion of the policy variable. In this sense, most of the above discussed empirical approaches rest on specifications with an un- or misspecified functional form, which makes it extremely hard to interpret the obtained empirical results in light of economic theory. To take an example, even if the model is based on a neoclassical convergence equation of the 'Barro'-type form such as in SVR (2005), the ad-hoc inclusion of a policy variable like investment grants as right hand side regressor would imply that the null hypothesis being tested is whether the GRW policy has any impact on the regional long-run technology level, which in turn determines regional differences in long-run steady-state income. However, testing for its long-run steady-state implications clearly conflicts with the neoclassical growth model as theoretical basis of analysis, since the latter framework assumes that investment subsidies may only have a transitory impact on regional growth until long-run steady-steady is reached. We come back to this point in more detail when describing the theoretical predictions of the neoclassical growth model in Sect. 9.5.

Recent contributions dealing with the spatial effects of the GRW and similar funding schemes have shown that disregarding these effects may additionally lead to a bias in the overall assessment of the empirical effects. In a first empirical study, which explicitly controls for spatial effects, Eckey and Kosfeld (2005) use a cross-section of German labor markets for the year 2001 in order to identify direct and spatially related indirect effects of the GRW investment subsidies on per capita GDP. To measure the latter effect, the authors use a spatially augmented regression approach that incorporates spatial lags of the endogenous and exogenous variables as right-hand-side regressors. The main message from the analysis is that, although the authors find a positive direct effect for supported regions, they also reveal negative indirect effects, which entirely cancel the positive effect. However, for both effects the authors only get limited statistical support. Negative indirect effects of private sector investment grants are also reported in De Castris and Pellegrini (2005) for Italian regions. Both contributions hint to the likely importance of spatial effects in the analysis of regional policy schemes. We take up this point at latter stages of our empirical modelling strategy.

9.3 Theoretical Foundation and Empirical Specification

9.3.1 The Neoclassical Growth Model and Income Convergence

Besides the structural approach in Schalk and Untiedt (2000), most studies quantifying the empirical effects of the GRW rely on estimating a single equation reduced-form model. Typically they all start from a regression equation, in which the outcome variable of interest (such as growth in per capita GDP, labor productivity, or regional employment) is regressed on one or more policy variables such as GRW volumes in absolute terms or as a share of GDP or in relation to the population size, respectively. In order to be able to isolate the policy effect, a set of covariates is included in the regression which comprises variables that are necessary to control for economic determinants of the outcome variable besides the policy effect so that no omitted variable bias may apply. However, despite its importance, in empirical practice, the set of control variables is typically included in an ad-hoc and incomplete fashion, ignoring a thorough theoretically guided variable selection. A related criticism applies to the specification of the functional form of the empirical model which is seldom well-grounded on a special economic theory but simply assumes a linear relationship among the outcome variable on the one side and the policy and control variables on the other side of the equation.

In an attempt to account for these shortcomings, in this analysis we extend the empirical approach used in Alecke and Untiedt (2007) aiming for a growth theoretical foundation of the chosen empirical specification. Deriving an empirically testable model from growth theory has mainly two advantages. First, it allows us to compare the estimated model coefficients with the theoretically expected structural parameters. Second, it may guide variable selection. Based on theoretical as well as statistical arguments, we also put a special emphasis on controlling for spatial dependencies among the German labor markets. As Eckey and Kosfeld (2005) have shown, the inclusion of indirect spatial effects is an important part in conducting an impact analysis of investment support by the GRW scheme. From a statistical perspective, it additionally may help to avoid misspecifications regarding the models error term, which may result in biased and/or inefficient estimation results of aspatial empirical models.

Our model specification starts from neoclassical growth theory, which is a well-suited vehicle for the analysis of income convergence and the role of investment incentives. The main motivation for using the concept of convergence as a workhorse model is that it allows us to control for different initial income levels in the analysis of growth determinants. Initial income thereby serves as a proxy for the region's initial capital endowment (typically in units of efficient labor) and is expected to be negatively correlated with the growth rate of the regional economy, given decreasing marginal returns to capital. The fundamental ingredient of convergence analysis is then the idea of a transitory income path common to all regions, which exhibits declining growth rates towards the path to the steady-state income. Or in other words, initially 'poor' regions are expected to grow faster the more remote they are with respect to steady-state income. Besides the crucial assumption of the neoclassical growth model that i) the production factors capital and labor each have diminishing marginal products, the model predictions further depend on ii) an exogenous level of technology, and iii) constant returns to scale for the production factors capital and labor in the production function (see, e.g., Tondl 2001, for details).

Since the first assumption implies that the marginal productivity of capital is a negative function with respect to the accumulated capital stock, regions with lower stocks per capita will grow faster.[3] Assumptions i) to iii) together implies that regions will converge to a common steady-state income level, meaning that convergence is 'unconditional'. The only reason why regions show differences in their per capita income growth rate is the initially heterogeneous endowment with capital. In the long run, only a rise in the exogenously determined technology level leads to changes in the steady-state income. Relaxing the strong assumption of homogeneity in the long-run technology level leads to a different prediction known as 'conditional' convergence. Here regions face identical growth rates in steady-state. Nevertheless, their income levels may differ. Differences in the technology level are thereby typically treated as 'catch all' parameter for all kind of potential driving factors of regional long-run income such as the regional knowledge stock, human capital, and public infrastructure. Finally, spatial linkages such as the ability to absorb knowledge from other regions also potentially drive the region's long-run income level. We give an account of the concept of spatial convergence in Sect. 9.5.

Both for 'conditional' as well as 'unconditional' convergence, the implications from changes in the private investment rate, as intermediate goal of investment subsidies, are then easily accessible in the neoclassical framework. The model basically predicts that a permanent increase in the economy's investment rate leads to a temporary increase in the economic growth rates with a permanent shift of the economy's steady-state income level. The basic intuition behind the model's transmission mechanism can be easily shown by means of graphical presentation (for details

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[3] In the literature, this concept of convergence is also known as β-convergence. The latter is a necessary (although not sufficient) condition for the reduction of income disparities, known as σ-convergence.

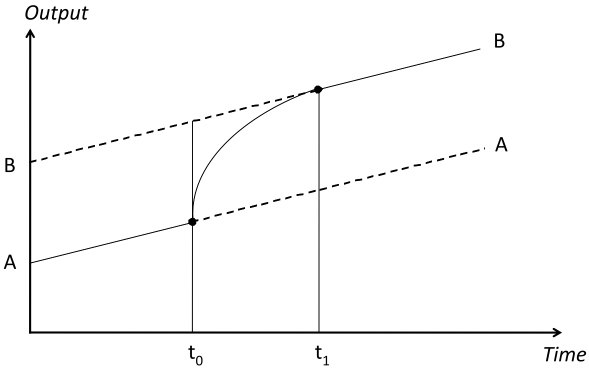

Fig. 9.2 Effect of a permanent increase in the physical investment rate

see, e.g., Tondl 2001; Favero 2001). Figure 9.2 shows a representative economy along its long-run (or steady-state) growth path *AA* as a function of exogenously determined technical progress.

In time period t_0, the investment rate is permanently increased (e.g., via an investment subsidy scheme). As the figure shows, this leads to a temporary increase in the economy's growth rate between time period t_0 and t_1. However, the more the economy converges towards its new path *BB* in t_1, this effect vanishes. Nevertheless, there is a permanent level effect resulting in a higher steady-state growth path *BB* with a higher output (productivity) level as a result of increased investment activity. For economic policy, it is important that this level effect is only permanent if the increase in the investment rate is long lasting. Otherwise, the economy would return to the long run path *AA*. In the next section, we show how to translate this effect into an empirically testable form.

9.3.2 Empirical Specification of the Convergence Equation

In seminal papers, Barro and Sala-i-Martin (1991, 1992) have initiated a bulk of empirically oriented studies, analyzing income convergence among groups of nations as well as regions within a national economy. The starting point for empirical estimation in a cross-sectional context is a convergence model derived from neoclassical growth theory as

$$(1/T)\log[y_{iT}/y_{i0}] = g + \frac{(1-e^{-\beta T})}{T}\log[y_i^*/y_{i0}] + u_{i0,T}, \tag{9.1}$$

where i is the cross-sectional dimension as $i = 1, \ldots, N$, T is the time dimension for which the change in the output variable y is measured, y_{i0} and y_i^* denote initial and steady-state levels of the outcome variable. u is the model's error term with standard normality assumptions, g denotes the constant rate of technology growth and β is the convergence rate, which can be interpreted as the region's annual speed of convergence (measured in percentage terms). Since neither the steady-state income level nor its growth are observable, a convenient way to estimate (9.1) in its unconditional form is to introduce a common intercept a_0 that captures the steady-state income level for the set of regions as

$$a_0 = g + [(1 - e^{-\beta T})/T] \times [\log(y_i^*)], \tag{9.2}$$

so that (9.1) reduces to

$$(1/T)\log[y_{iT}/y_{i0}] = a_0 - b \times \log(y_{i0}) + u_{i0,T}, \tag{9.3}$$

where β can be recovered from the regression coefficient b as $b = (1 - e^{-\beta T})/T$. In analyzing income convergence, special attention is devoted to the interpretation of the coefficient b. If $b < 0$, convergence forces are at work, meaning that initially poorer regions grow faster than richer ones. However, $b < 0$ is not a sufficient condition for unconditional convergence to occur. The latter in fact would require that the empirical regression shows a good fit with respect to the data analyzed; especially the residual term should not capture the effects from any omitted variable. Moreover, the convergence rate β should be in accordance with its theoretically expected value, where β can be derived as $\beta = (1-\alpha)(g+n+\delta)$, and α is the output elasticity of capital, n and δ are population growth and capital depreciation rate respectively (see, e.g., Tondl 2001, for details). In the empirical literature a 'rule-of-thumb' for $\beta \approx 0.02$–0.03 has been established, which holds for different sample settings involving both national and regional data (see, e.g., Barro and Sala-i-Martin 1991, 1992, 2003).

Estimating conditional convergence relaxes the assumption of a common intercept a_0 as proxy for the steady-state income level of regions under study. As argued in the above section, there are different potential driving forces of the region's technology level such as the regional knowledge and human capital stock or the endowment with public capital. One straightforward way to control for region-specific steady-state income levels would imply to include N individual effects a_i as

$$(1/T)\log[y_{iT}/y_{i0}] = a_i - b \times \log(y_{i0}) + u_{i0,T}. \tag{9.4}$$

However, in a cross-section setup, estimating (9.4) is not feasible since it requires estimating N fixed effects for the N regions involved, which implies that the number of regression coefficients ($(N+1) = N$ individual effect plus the convergence parameter b) exceeds the number of observations N. An approach to circumvent this problem for the estimation of conditional convergence equations is to substitute the individual effects by k coefficients from a variable vector X that controls for differences in the steady-state levels as[4]

$$a_i = a + c_1 \log(x_{1,i}) + c_2 \log(x_{2,i}) + \cdots + c_j \log(x_{j,i}) + \cdots + c_k \log(x_{k,i}). \tag{9.5}$$

Substituting (9.5) into (9.4) leads to a conditional convergence equation, which can be estimated as

$$(1/T)\log[y_{iT}/y_{i0}] = a - b \times \log(y_{i0}) + \sum_{l=1}^{k} c_j \log(x_{l,i}) + u_{i0,T}. \tag{9.6}$$

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[4] Using logarithmic values for each variable x, which allows us to directly interpret the obtained regression coefficients as elasticities.

As Tondl (2001) points out, conditional convergence analysis tests for convergence to different steady-state income levels and not a common one as in (9.3). Thus, any estimation including variables $x_1, \ldots, x_k$, even if they are only dummy variables for each regional economy, investigates convergence to different steady-state income levels. As argued above, we should thereby carefully use theoretical considerations in guiding variable selection for $\sum_{i=1}^{N} c_i x_i$. Besides factors directly related to the neoclassical growth concept, further regressors motivated by new growth theory, new economic geography, and/or more traditional strands of regional economics have been suggested in the literature. These typically include:

- the regional knowledge intensity measured in terms of patents and high-tech sectors,
- the degree of international openness and external input–output relations,
- the regional stock of human capital,
- the region's market potential, proxied by the market size in surrounding areas,
- geographical advantages of the regions
- localization and urbanization effects.

Besides these long-run control factors, policy variables can be included in the regression framework. Typically this has been done in the following ad-hoc fashion

$$(1/T)\log[y_{iT}/y_{i0}] = a_0 - b \times \log(y_{i0}) + \sum_{j=1}^{k} c_j x_{j,i} + \gamma s_i + u_{i0,T}, \tag{9.7}$$

where the coefficient γ measures the impact of policy intervention s_i on growth. However, adding s_i as further regressor to $\sum_{i=1}^{N} c_i x_i$ implies that the researcher tests for the null hypothesis of the policy driving differences in the steady-state income level for the sample of regions in focus. However, this is not an appropriate model design for the analysis of investment incentive schemes, which is only expected to affect the transitory growth dynamics in convergence to long-run steady-state income level, but leaving differences in the long-run steady-state income level unaffected. As explained in the following, we thus modify (9.7) to properly account for the predictions of growth theory when designing an empirical test for GRW policy effectiveness.

To measure the policy impact from GRW, two alternative variable definitions are generally possible. First, regions eligible for receiving GRW subsidies can be identified by a binary dummy variable, which takes a value of one if the region has received subsidies for the period of analysis and zero otherwise. Second, total GRW spendings normalized by size or performance indicators of the region (such as population, total employment or regional GDP) can be used, which results in a measure for the funding intensity of the policy scheme. Private and public capital investment subsidies are then expected to influence the speed of convergence of the regional economy towards its steady-state. We operationalize this transmission channel by including an interaction term defined as the policy variable times initial income as $s_i \times y_{i0}$. As Bambor et al. (2005) point out, in order to adequately measure the marginal effect of funding conditional on these two exogenous variables, s_i and y_{i0} have to be included in the regression framework:

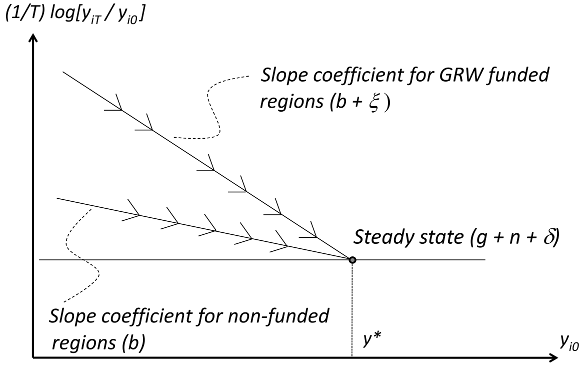
$$(1/T)\log[y_{iT}/y_{i0}] = a - b \times \log(y_{i0}) + \sum_{j=1}^{k} c_j x_{j,i} + \gamma s_i + \xi[\log(y_{i0}) \times s_i] + u_{i0,T}, \tag{9.8}$$

where $s_i = [D_{GRW}, \log(GRWQ)]$ with D_{GRW} as binary dummy for GRW regions and $\log(GRWQ)$ is a proxy for funding intensity. The use of the interaction term in the convergence equation can be motivated as follows. As shown, the convergence rate β is determined by the output elasticity of capital, as well as population growth and capital depreciation rate, respectively. This fixed relationship, however, only holds for a closed economy. For regional analysis, the latter assumption does not seem plausible since we can expect a high mobility of capital among interrelated regional units.

The introduction of (incomplete) capital mobility in the neoclassical growth model framework can then be done conditional on the initial income level, so that the value of the convergence rate β additionally captures the effect of capital mobility. To be more precise, the convergence rate β can now be formulated as $\beta = (1-\alpha)(g+n+\delta+\omega)$, where ω reflects the elasticity of external capital supply. Thus, as long as ω is non-zero, taking capital mobility into account, it obviously increases β. As Schalk and Untiedt (1996) point out, the basic assumption for this transmission channel to work is that the external capital influx is determined by regional differences in the marginal return of capital. However, it is precisely the goal of investment subsidies by the GRW to reduce the user cost of capital and thus to affect regional differences in the marginal return of capital in favor of supported regions. Not accounting for this policy-induced change in the regional rate of return to physical investment in poor regions would result in a biased estimation of β. We expect that the regression coefficient for the interaction term ξ is negative, which implies that the speed of convergence for supported regions is enhanced. The total convergence rate can then be measured as $(b+\xi) = (1-e^{-\beta T})/T$.

The theoretically expected relationship between initial income and the GRW policy effect induced by a permanent increase in the investment rate is shown graphically in Fig. 9.3. The negative coefficient ξ for the interaction term implies that, for each initial income level below the steady-state (y^*), funded regions show a

Fig. 9.3 GRW policy induced change in slope coefficient of convergence equation



higher speed of convergence in the growth/initial income-diagram relative to non-funded regions. The intersection of convergence curves for funded and non-funded regions marks the steady-state income level, where regions uniformly grow by $(g + n + \delta)$, driven by the constant rate of growth of technology (g), population growth (n), and the capital depreciation rate (δ). Equation (9.8) represents a special case of a more general empirical setup, which relaxes the assumption of homogeneous regression parameters between funded and non-funded regions in (9.8). This would lead to a fully interacted switching-regime model specification and would imply testing for significantly different long-run convergence clubs for the set of funded and non-funded regions. The model in (9.8) may thus be seen as a nested specification, which assumes statistical insignificance of interaction terms for $[s_i \times \sum_{i=1}^{N} c_i x_i]$.[5]

9.4 Data and Empirical Results

To estimate cross-section convergence equations as in (9.3) and (9.8) we use data on 225 German labor markets for the period 1994–2006. The year 1994 was chosen as a starting point to account for structural distortions in East Germany directly after reunification. Since geographical boundaries of German labor markets vary over time, we use the definition of labor markets valid just before the start of our sample period—dated back to the year 1993—in order to consistently track the GRW funding areas (see Hierschenauer 1994, for details). The dependent variable used throughout the analysis is growth in real labor productivity Δy_i, where Δ is the difference operator for logarithmic values of y according to $\Delta y = (1/T)(y_{iT} - y_{i0})$, i is the index for German labor markets according to $i = 1, \ldots, 225$ and T is the length of the time period, in our case $T = 13$.[6]

To measure the effect of GRW subsidies, we use both a dummy indicating the status of the region as either being supported over the sample period or not, as well as the intensity of GRW funding defined as total granted financial spendings in relation to the working age population in the region. We sum up both categories of GRW (private sector investment subsidies and business related public infrastructure). To account for differences in the economic structures of the 225 German labor markets, we use different control variables, which are listed in Table 9.1. Summary statistics of the variables are given in Table 9.2.

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[5] We also tested for significance of the remaining interaction terms in the full regime switching model. However, the obtained results did not provide strong empirical support for the latter. Moreover, the stability of the convergence parameter β was unaffected, so that we work with the nested model specification in the following.

[6] As alternative outcome variable, we also used per capita GDP. Since the results turned out to be very similar, the latter results are not reported here but can be obtained from the authors upon request. The main difference between labor productivity and per capita GDP is the consideration of the labor participation or unemployment rate, which is typically not the focus of empirical growth analysis.

Table 9.1 Variable descriptions for the regional productivity growth model

Variable	Definition	Theoretical concept	Mnemonic
Initial level of labor productivity	GDP per total employment in 1994	Capital accumulation per unit of efficient labor	$\log(Y94)$
Physical investment intensity	Physical investments in manufacturing sector per total employment (av. 1994–2006)	Capital accumulation per unit of efficient labor	$\log(S)$
Capital accumulation per unit of efficient labor	Employment growth	Change in total employment 1994–2006 (plus 0.04 for exogenous growth in technical progress and depreciation rate)	$\log(EWT)$
Skill level of labor force	Employment share with at least one level of vocational qualification (av. 1994–2006)	Human capital	$\log(HK)$
Patent intensity	Patents per labor force (av. 1995–2005)	Innovation & Competition	$\log(PAT)$
Employment share of manufacturing sectors	Share of employment in manufacturing sectors in total employment (av. 1998–2006)	Innovation & Competition	$\log(IND)$
Employment share of high-tech sectors	Share of employment in technology intensive sectors according to ISI/NIW classification per total employment (av. 1998–2006)	Innovation & Competition	$\log(TECH)$
International openness	Share of foreign turnover per total turnover for manufacturing sector (av. 1994–2006)	Innovation & Competition	$\log(AUM)$

(*continued on the next page*)

Table 9.1 (Continued)

Variable	Definition	Theoretical concept	Mnemonic
Sectoral specialization	Sum of squared deviations in employment shares for each NACE3 sector between region and national average in 1998	Localization advantages	$\log(SPZG)$
External economies of scale	Employment in sectors with high Ellison–Glaeser index (> 0.005) relative to total employment in the region	Localization advantages	$\log(EGH)$
Market potential	Sum of GDP in own region plus GDP of neighboring regions, weighted by inverted distance between regions	Settlement structure & Locational advantages	$\log(MPOT9)$
Transport accessibility	Average travel time in minutes for road and air traffic to all 41 European agglomeration areas in 1998 (BBSR transport network model)	Settlement structure & Locational advantages	$\log(ERBK)$
Population density	Population per km^2	Settlement structure & Locational advantages	$\log(BV)$
Indicator for GRW supported regions	Binary dummy: If region has received GRW funds $= 1$, otherwise 0	GRW promotion scheme	D_{GRW}
Total GRW volume	Sum of GRW funds per labor force in 1994–2006 (zeros are replaced by small values before log-linearization)	GRW promotion scheme	$\log(GRWQ)$

Source of Data: Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR 2009), Federal Employment Agency (2009), VGR der Länder (VGRdL 2009), own calculations

Table 9.2 Descriptive statistics for variables

Variable	Mean	Max	Min	St. dev.
Labor productivity growth	0.021	0.055	−0.003	0.009
Initial productivity level in 1994	42915	61906	27973	7452
Employment growth	0.002	0.023	−0.028	0.008
Physical investment intensity	0.058	1.233	0.016	0.092
Vocational training	0.802	0.909	0.662	0.058
Employment share in manufacturing	0.268	0.719	0.068	0.110
International openness	0.288	0.617	0.037	0.109
Employment share in high-tech sectors	14.05	58.26	3.75	7.40
Patent intensity	609.8	2754.2	40.6	462.2
Sectoral specialization	0.897	1.556	0.499	0.194
External economics of scale	146.5	2935.7	34.3	259.6
Market potential	275.5	386.3	199.7	31.1
Geographical accessibility	11746	42770	2414	7388
Population density	252.9	3552.5	40.5	349.6
GRW intensity	69.9	1084.9	0.001	139.2

Source: See Table 9.1

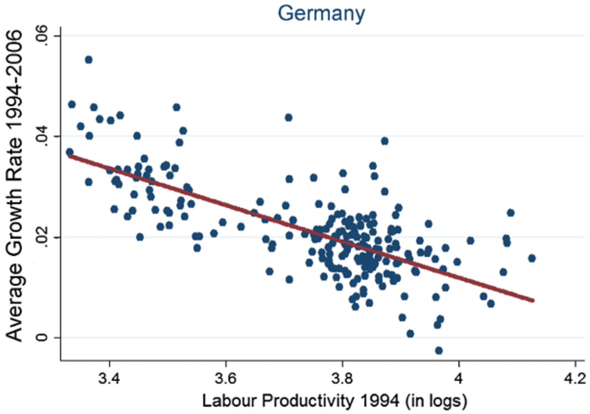


Fig. 9.4 Regression results for unconditional convergence among German labor markets

We start with the regression equation for unconditional convergence among the 225 German labor markets according to (9.3). As Fig. 9.4 shows, the graphical presentation of the regression results for b indeed shows a significantly negative correlation between initial labor productivity in 1994 and productivity growth for the period 1994–2006. The regression line in Fig. 9.4 has a slope coefficient of $b = -0.036$ (t-statistic $= 15.5$). Recovering the convergence rate β from the fitted model, shows an annual speed of convergence of roughly 4.7 percent, which is slightly above the average convergence speed of 1–3 percent reported in the empirical literature for Germany. A convergence speed of $\beta = 4.7$ percent implies a half-life H as time period to close half of the gap towards long-run steady-state productivity level with $e^{-\beta t} = 1/2$ as

$$H = \log(2)/\beta = 0.69/\beta \quad \text{for } \beta = 0.047: H \approx 14.7, \tag{9.9}$$

which means that it takes about 15 years to close half of the gap to the common long-run labor productivity level. However, as Fig. 9.4 demonstrates, the empirical variance around the fitted regression line is rather high. The fit of the regression is $R^2 = 0.52$. Thus, only half of the variation in regional growth rates can be explained by initially different productivity levels.

In order to further investigate the convergence relationship, we move on to test for the validity of its conditional form according to (9.6) and (9.8). Results for different model specifications are shown in Table 9.3. Columns I and II thereby report specifications including the full set of control variables as listed in Table 9.1 including the two different indicators for GRW subsidies. In column I, we add the dummy D_{GRW} plus the interaction term; in column II, we include GRW funding intensity $\log(GRWQ)$ and the interaction term. In both specifications we find a significantly negative coefficient for the interaction term, indicating that the convergence speed increases due to GRW subsidies. For the dummy-variable approach in column I, we also test for the heterogeneity of the coefficient in the interaction terms between West and East German labor markets. The results show that the imposed restriction of slope-coefficient homogeneity between the two macro regions cannot be rejected on the basis of a Wald F-test. In columns III and IV, we exclude insignificant control variables, which lead to more parsimonious model specifications. The null hypothesis of validity of parameter restrictions in the parsimonious model cannot be rejected on the basis of a set of likelihood ratio tests (see Table 9.3).

Turning to the interpretation of the results with regard to the quantitative impact of GRW subsidies on regional labor productivity, columns III and IV in Table 9.3 show that convergence forces are still in order. However, the estimated coefficients for the initial level of labor productivity for non-funded regions are somewhat smaller than the coefficients found in the unconditional convergence equation, that is, in column III, we get a regression coefficient of $b = 0.026$ and in column IV, of $b = 0.032$. These parameter results imply a convergence rate β of 3.1 and 4.1 percent respectively. As Bambor et al. (2005) point out, the coefficient of the interaction term has to be interpreted conditional on the estimated coefficients for y_{i0} and s_i. In order to quantify the additional growth impulse of GRW support, we take the difference in the convergence rate between funded and non-funded regions as $\xi = (1 - e^{-\beta_{net} T})/T$, solve for β_{net} and then use the obtained coefficient to measure the difference in the speed of convergence conditional on the gap to steady-state income as:

$$\Delta_n y_i = \beta_n \times (y^* - y_{it}). \tag{9.10}$$

$\Delta_n y_i$ measures the marginal effect of GRW funding conditional on the region's gap at time period t to the long-run steady-state level y^* (in percentage points). To take an example, the estimated coefficient for the interaction term according to

Table 9.3 Conditional convergence estimation among German labor markets 1994–2006

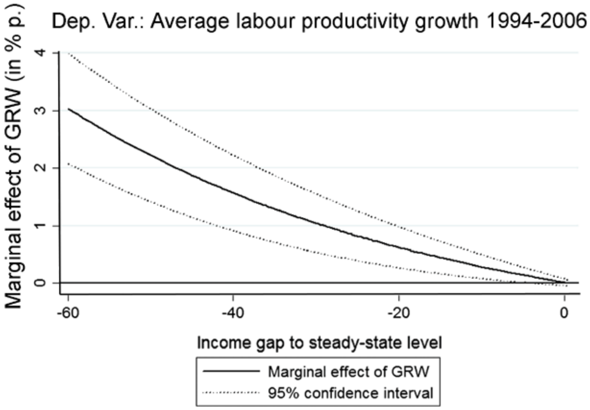
Dep. var.: $(1/T)\log[y_{iT}/y_{i0}]$	I/OLS	II/OLS	III/OLS	IV/OLS
Initial labor productivity	-0.0257^{***}	-0.0324^{***}	-0.0233^{***}	-0.0315^{***}
$\log(Y94)$	(0.00267)	(0.0043)	(0.0066)	(0.0041)
Employment growth plus $(g+\delta)$	-0.0062^{***}	-0.0060^{***}	-0.0060^{***}	-0.0054^{***}
$\log(EWT)$	(0.0020)	(0.0010)	(0.0020)	(0.0019)
Investment intensity	0.0044^{***}	0.0044^{***}	0.0045^{***}	0.0048^{***}
$\log(S)$	(0.0012)	(0.0012)	(0.0011)	(0.0012)
Vocational training	0.0210^{*}	0.0178^{***}	0.0108	0.0115
$\log(HK)$	(0.0108)	(0.0110)	(0.0101)	(0.0105)
Share of manufacturing sector	0.0034^{***}	0.0037^{**}	0.0049^{***}	0.0048^{***}
$\log(IND)$	(0.0017)	(0.0015)	(0.0014)	(0.0014)
International openness	0.0015	0.0013		
$\log(AUM)$	(0.0011)	(0.0015)		
Share of high-tech industries	0.0013	0.0026^{*}	0.0036^{***}	0.0035^{***}
$\log(TECH)$	(0.0011)	(0.0015)	(0.0012)	(0.0012)
Patent intensity	0.0015^{*}	0.0008		
$\log(PAT)$	(0.0009)	(0.0009)		
Ellison–Glaeser index	0.0026	0.0016		
$\log(EGH)$	(0.0021)	(0.0021)		
Sectoral specialization	0.0005	0.0005		
$\log(SPZG)$	(0.0007)	(0.0007)		
Geographical accessibility	-0.0044	-0.0011		
$\log(ERBK)$	(0.0062)	(0.0061)		
Market potential	0.0009	0.0015		
$\log(MPOT)$	(0.0013)	(0.0013)		
Population density	-0.0088	-0.0060^{*}	-0.0100^{*}	-0.0067
$\log(BVD)$	(0.0054)	(0.0052)	(0.0053)	(0.0051)
Squared population density	0.0006	0.0003	0.0008^{*}	0.0005
$\log(BVD^2)$	(0.0004)	(0.0005)	(0.0005)	(0.0004)
Dummy for GRW regions	0.0671^{**}		0.0812^{***}	
D_{GRW}	(0.0308)		(0.0294)	
GRW intensity		0.0093^{***}		0.0099^{***}
$\log(GRWQ)$		(0.0030)		(0.0029)
Interaction term	-0.0181^{**}	-0.0025^{***}	-0.0222^{***}	-0.0027^{***}
$\log(Y94)\times s_i$	(0.0080)	(0.0008)	(0.0077)	(0.0008)
Adj. R^2	0.68	0.70	0.68	0.70
Wald test for interaction	$F=0.03$			
term $GRW_{West}=GRW_{East}$	(0.85)			
LR-test for model			$\chi^2(6)=5.01$	$\chi^2(6)=4.66$
I/II vs. III/IV			(0.54)	(0.58)

Source: Standard errors in brackets. In the specification of the interaction term s_i indicates, that depending upon the unconditionally included regressor as $s_i=[D_{GRW},\log(GRWQ)]$ also the computation of the interaction term varies

*Denote statistical significance at the 10% level **Denote statistical significance at the 5% level

***Denote statistical significance at the 1% level

Fig. 9.5 Marginal effect of GRW subsidies relative to regional income gap



model specification in column III of Table 9.3 is $\xi = 0.022$. This implies that the total effect b increases in absolute terms as $|b| = (0.022 + 0.023) = 0.045$. The latter in turn can be interpreted as convergence rate for founded labor market regions as $\beta = 6.5$ percent. The difference in the speed of convergence between funded and non-funded regions after controlling for further growth determinants amounts to 3.8 percentage points. Using this convergence rate, we now can plot the distribution of the additional growth impulse of public support conditional on the observed empirical variance of labor productivity for funded labor market regions. This effect is shown graphically in Fig. 9.5.

The horizontal axis in Fig. 9.5 shows the income gap for funded labor market regions relative to their steady-state level.[7] The vertical axis plots the marginal effects of the GRW in percentage points. The displayed distribution of the marginal effects relative to the income gap in Fig. 9.5 can be interpreted as follows. Assuming that a funded labor market region has an actual income level of 50 percent of its long-run steady-state level, the specific growth impulse of the GRW investment subsidy increases the convergence rate of about 2.6 percentage points. This in turn translates to roughly a doubling of its speed of convergence taking that the average growth rate for the 10% lowest income percentile of German regions is around 2.5 percent. The 95-percent confidence interval in Fig. 9.5 also shows that the effect remains significant for most numerical values of the income gap. In line with our theoretical expectations, it is declining the closer the region is relative to its long-run steady-state income position.[8] Effectiveness of the funding scheme is thus the higher the further away the subsidized region is from its steady-state productivity level.

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[7] For simplicity, we assume that funded labor markets converge to the same steady-state level. Here, we simulated different scenarios, either taking the 100 or 80 percent income percentile for non-funded West German regions as benchmark level. The latter assumes that even in the in long-run, German regions do not fully converge to a common income level, e.g., due to differences in the technological efficiency of regions (see, e.g., Schalk et al. 1995). We report results for the first scenario in Fig. 9.5, further results can be obtained upon request.

[8] For the computation of confidence intervals in interaction models see Bambor et al. (2005).

Also, for most of the other economic control variables in Table 9.3, we get empirical support in line with their growth-theoretic underpinnings. That is, as expected by the neoclassical framework, employment growth has a negative effect on labor productivity growth, while physical investments per employee translate into positive growth effects. Looking at the impact of the regional knowledge stock, the coefficient for the share of high-tech industries (measured as the relative employment share in total employment) is found to be statistically significant and of positive sign, while the effect of the patent intensity—although of the right sign—only turns out to be significant at the 10 percent level in the specification reported in column I. The share of manufacturing industries in the total composition of the regional economy similarly exhibits a positive correlation with labor productivity growth. The latter gives empirical support for the hypothesis of 'unbalanced growth' between manufacturing and service industries as postulated in Baumol (1967).

A further important variable to control for long-run differences in regions' steady-state productivity levels is the endowment of skilled employees. Here, we use a broad definition of human capital including all employees in total employment with at least one vocational qualification.[9] Also, the regional export share as foreign turnover to total turnover for firms in the manufacturing sector is found to be positively correlated with the region's overall growth performance. While these results are rather clear cut, the estimated influence from variables proxying localization and urbanization advantages turns out to be ambivalent: While population density shows a clearly positive impact on growth, no significant correlation was found for regional sectoral specialization and external economies of scale proxied by the share of total employment in industries with high values for the Ellison–Glaeser index. Insignificant results were also found for the market potential (as sum of the own region's GDP plus neighborhood regions GDP, where the latter decays with distance) as well as the average regional accessibility from European agglomeration areas.

Summing up, the estimated conditional convergence equations are able to explain roughly 70 percent in the variation of productivity growth for German labor market regions. Generally, we observe that convergence forces are at work, indicating that initially poorer regions grow faster. The significance of factors controlling for the long-run technology level also shows that convergence is conditional rather than unconditional. Vocational qualification, regional knowledge stock, the regional economic structure, openness to world trade and population density turn out to be important drivers of the region's overall growth rate. With respect to GRW spendings, we find a significant positive marginal effect conditional on the region's initial income level. As shown in the theoretical section, without controlling for the positive transitory effect of funding, the estimated convergence rate among German labor market regions would be biased downwards. Our results show that the effect is higher for poor regions with a large gap to steady-state income. Here, the speed of convergence almost doubles. Investment subsidies are thus found to meet its (theory consistent) goal of fostering productivity growth in lagging regions and speed up convergence towards the regions 'own' steady-state.

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[9] We also tried alternative specification including only those employees as share of total employment with tertiary education. However, the results did not change much.

9.5 Model Extension to the Analysis of Spatial Effects

Recent contributions in the field of regional science have pointed to the empirical relevance of spatial dependencies in the analysis of income growth and convergence as well as spatial spillovers from regional policy instruments (see, e.g., Moreno and Trehan 1997; Fingleton 2001; Ertur and Koch 2007). This also led to various reformulations of the neoclassical growth model to properly account for spatial effects. Fischer (2010), for instance, augments the neoclassical framework to capture spatial spillovers by endogenizing the constant region-specific technology parameter a_i from (9.5) to account for spatially related technological interdependencies. The model basically assumes that the region i's technology level is a function of the technology level from regions in the direct proximity of region i.

In a similar vein, Egger and Pfaffermayr (2006) argue that the region's speed of convergence depends on its relative location in space and can be decomposed into three parts: One part measuring the region's own speed of convergence net of any spatial spillovers, and two remaining parts, which measure the importance of regional spillovers. The specification of regional spillovers implies that the region's labor productivity (growth) depends on the spatially weighted average of all other regions. In the spatial β-convergence model of Egger and Pfaffermayr (2006), spillovers stem from a remoteness effect (for common initial income gaps) and the effect of different starting positions (initial gaps).

Applications for (West) Germany such as in Niebuhr (2000), Funke and Niebuhr (2005) as well as Eckey et al. (2007) among others have shown that spatial effects driven by technological interdependencies indeed matter for regional growth and convergence processes. Moreover, there is a growing literature that aims at examining the spatial distribution of regional policies. Applied to the case of capital investment grants, De Castris and Pellegrini (2005) find for Italian regions that capital subsidies exhibit negative spillover effects to neighboring regions. A similar negative (though insignificant) result is reported in Eckey and Kosfeld (2005) for Germany.

Using quantitative tools, the analysis of spatial dependencies is typically conducted within the framework of spatial econometrics. Here, the most widely used model specifications are the spatial lag (also labeled spatial autoregressive, SAR) model and/or the spatial-error model (SEM). The main difference between the two approaches is the way in which spatial dependencies are assumed to operate. While the SAR model assumes that dependencies occur due to spillover effects from the endogenous variable, the SEM approach leaves the source of spatial autocorrelation undiscovered and simply accounts for the non-normality of the residuals by including a spatially weighted component in the total error term of the model. Applied to the neoclassical growth model, the SAR framework models growth rates to be inherently connected to each other, either in a positive or negative way depending on the estimated regression parameter for the spillover variable. Formally, the SAR model (in matrix notation) can be specified as follows:

$$y = a + \rho(W \times y) + dX + e, \tag{9.11}$$

where, next to the vector of regressors X, the spatial lag of the endogenous variable y is added. W in turn is a $(N \times N)$ spatial weighting matrix with matrix cells w_{ij}

measuring the pairwise distance for all combinations of cross-sectional units i, j and the coefficient ρ measures the degree of spatial spillovers, which arises from the spatialized endogenous variable defined as $\sum_{j=1}^{N} w_{ij} \times y_j$. The error term of the model is assumed to be well-behaved with zero mean and constant variance σ_e^2.

The SEM instead models spillovers to be of unknown exogenous source and all spatial effects are captured in the spatialized residual term as:

$$y = a + dX + \epsilon \quad \text{with } \epsilon = \lambda(W \times \epsilon) + \nu. \tag{9.12}$$

For empirical modelling the choice of implementing either (9.11) and (9.12) matters. As pointed out by Ward and Gleditsch (2008), the selection cannot be made solely on statistical grounds since both models are non-nested. Rather, good a-priori expectations about the source of spillovers are important. The theoretical literature on the 'spatialization' of the neoclassical growth framework clearly points towards the direction of the SAR specification. However, this may only be one part of the story. Instead, as Eckey and Kosfeld (2005) and De Castris and Pellegrini (2005), for instance, have shown is that models may be inadequate in order to measure the impact of spatial spillovers arising from the policy instrument.

In the recent spatial econometric literature therefore extensions to the SAR and SEM framework have been proposed (see e.g. LeSage and Pace 2009). An extension to the SAR model that also allows for spillovers arising from the vector of explanatory regressors is the so-called Spatial Durbin model (SDM). The SDM takes the following general form:

$$y = a + \rho(W \times y) + dX + \omega(W \times X) + e. \tag{9.13}$$

The main advantage of the latter is to explicitly quantify any effect stemming from the implementation of the GRW in neighboring regions from the perspective of region i as $\omega_s\,(W \times s)$. However, one has to note that the effect of s is not directly accessible through ω_s given the simultaneous presence of ρ. Instead, LeSage and Pace (2009) propose the computation of summary statistics decomposing the total effect from a variable into its direct and indirect effect. While the computation in the SAR is somewhat easier given that it has a global multiplier, for the SDM case all spatial lags from X have to be incorporated. In the latter case interpretation becomes much more easy, if we are able to zero-out spillovers from the endogenous variables (that is $\rho = 0$) after all spillovers from the set of exogenous regressors have been included. In the SDM model spillovers from the endogenous variable have the characteristics of a 'catch-all' term, that arise from factors outside the modelling framework.

Thus, an alternative to the SDM is the Spatial Durbin Error model (SDEM), which may be seen as an extension to the SEM framework that allows obtaining a theoretically meaningful interpretation to spillovers arising from the set of regressors and catches all remaining spatial autocorrelation in the residual term

$$y = a + dX + \omega(W \times X) + \epsilon \quad \text{with } \epsilon = \lambda(W \times \epsilon) + \nu. \tag{9.14}$$

One of the main advantages of the SDEM framework is that the coefficients d and ω can be interpreted as direct and indirect effect arising from any variable x with no further transformation being necessary.

Summing up the above discussion, in terms of our empirical growth model the most general specification arises from (see e.g. Moreno and Trehan 1997; Tondl 2001)

$$\begin{aligned}\Delta y_i &= a - b \times \log(y_{i0}) + \sum_{j=1}^{k} c_j x_{j,i} + \gamma s_i + \xi[\log(y_{i0}) \times s_i] \\ &\quad + \rho\left(\sum_{j \neq i}^{N} w_{ij} \times \Delta y\right) + \kappa\left[\sum_{j \neq i}^{N} w_{ij} \times \log(y_{i0})\right] \\ &\quad + \sum_{l=1}^{k} \phi_l \left(\sum_{j \neq i}^{N} w_{ij} \times x_{l,i}\right) + \psi\left(\sum_{j \neq i}^{N} w_{ij} \times s_i\right) \\ &\quad + \omega\left(\sum_{j \neq i}^{N} w_{ij} \times [\log(y_{i0}) \times s_i]\right) + e_{i0,T} \\ \text{with} \quad e_{i0,T} &= \lambda\left(\sum_{j \neq i}^{N} w_{ij} \times e_{i0,T}\right) + \nu_{i0,T}, \end{aligned} \tag{9.15}$$

which embeds the following restricted specifications:

- SAR: $\kappa = \phi_j = \psi = \omega = \lambda = 0$,
- SEM: $\kappa = \rho = \phi_j = \psi = \omega = 0$,
- SDM: $\lambda = 0$,
- SDEM: $\rho = 0$.

In order to estimate models according to (9.11)–(9.14), the choice of an empirical operationalization for the spatial weighting matrix W is needed. Here, the spatial econometrics literature has proposed different ways to handle spatial dependence giving weight to distance decay. The simplest form is to assume a binary neighborhood matrix that takes the value of 1 if a certain criterion for spatial proximity is fulfilled and zero otherwise. One standard way is to choose common geographical borders as geographical discrimination criteria, but the choice is not limited in this dimension. Also, common cultural, institutional and other factors may determine direct neighborhood.[10] However, one potential shortcoming of binary weighting matrices is their strict classification of either being in or out. Alternative measures for spatial neighborhood may therefore be constructed using the metric distance (for instance in kilometers) among cross-sectional entities.

Distance decay may then either enter in a linear or exponentially growing way. To give an example, matrix entries for a linear distance decay typically take the form of $w_{ij} = (D^{-1})_{ij}$, while a non-linear relationship to distance can be proxied as $w_{ij} = \exp(-D \times k)_{ij}$, where D is the geographical distance between to

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[10] Moreover, though typically restricted first-order neighborhood, higher ranks are also possible, implying that cross-sections are seen as neighbors of order N if they share a common border with other cross-sections of rank order N.

cross-sections i and j, k is the distance decay parameter. The latter can take values as $k \in [1, \dots, \infty]$. Since distance based matrices may become quite complex, mixed distance-neighborhood concepts have also been proposed, which uses distance based thresholds to specify binary specifications of W (see, e.g., Badinger and Url 2002). Threshold based computations of W typically work in a sequential manner as:

$$w_{ij} = \begin{cases} 0 & \text{if } i = j, \\ 1 & \text{if } c_{ij} = 1, \\ 0 & \text{otherwise,} \end{cases} \tag{9.16}$$

where c_{ij} is the element of a $(N \times N)$ link matrix with

$$c_{ij} = \begin{cases} 1 & \text{if } i \text{ and } j \text{ are spatially linked to each other,} \\ 0 & \text{otherwise.} \end{cases} \tag{9.17}$$

The function c_{ij} thus marks the critical threshold for the maximal distance (in kilometers) between i and j for which both entities are still considered as neighbors. Threshold values can either be set according to theoretical guidelines or algorithm-based. In the following we apply an algorithm proposed by Badinger and Url (2002), which uses spatial statistics in order to find those points in space, for which spatial autocorrelation inherent to a variable is maximized (in our case, labor productivity growth). The algorithm builds on the G_i-statistic proposed by Getis and Ord (1992). Figure 9.6 shows the results of the algorithm-based search for maximizing the standardized test Z_{G_i}-statistics for G_i using the distance between German labor markets on an interval [25 km, 280 km]. Spatial correlation for labor productivity growth among labor markets shows a global maximum at 130 kilometers. This point is chosen as cutoff distance to discriminate between spatial neighbors and non-neighbors in binary type weighting schemes for W.

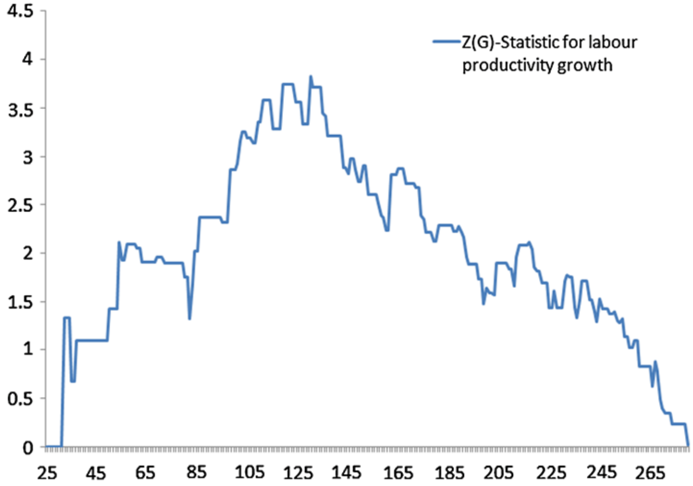

Fig. 9.6 Evolution of Getis–Ord G-statistic for alternative threshold distances

Table 9.4 Tests for spatial autocorrelation in the OLS residuals

Model Spatial weighting matrix W	*Residuals from OLS* Linear metric	*Residuals from OLS* Optimal binary
Moran's I (Z_I-statistic)	2.48***	2.20**
Getis–Ord G (Z_G-statistic)		−2.24**

*Denote statistical significance at the 1% level **Denote statistical significance at the 5% level
***Denote statistical significance at the 10% level

Next to distance based weighting schemes using a linear and quadratic distance decay, we also use the optimal-binary weighting scheme according to the above described algorithm with threshold value 130 kilometers. All matrices are used in their row-standardized form according to

$$w^*_{ij} = w_{ij} / \sum_j w_{ij}. \tag{9.18}$$

Before moving to the computationally more complex spatial econometric models, we first check whether the standard aspatial regression approach shows any sign of misspecification in the error term of the model. Here we use the commonly known Moran's I test for spatial autocorrelation in the residuals (see, e.g., LeSage and Pace 2009). We take Specification III from Table 9.3 and apply both the linear metric as well as optimal binary concept for W. As the results in Table 9.4 show, we detect significant spatial autocorrelation in the OLS residuals. The results thus point to explicitly account for spatial dependencies in order to properly estimate the convergence equation for German labor markets and quantify the global effect of GRW support.

The results for the spatially augmented specifications are reported in Table 9.5. All equations are estimated using maximum-likelihood techniques. As with the aspatial model we start with the full set of control variables and additionally allow for different spatial lagged transformations in line with (9.11)–(9.14). Subsequently we restrict our attention to the set of control variables which turned out significant in the aspatial model plus those variables which in addition proved significant in the spatially augmented models. Table 9.5 only reports regression results for model specifications for GRW funding based on the binary dummy D_{GRW}. The results for GRW intensity turned out to be quite similar and are skipped for brevity.[11] Table 9.5 starts with the commonly applied SAR and SEM approach and allows for further channels for spatial interdependencies by estimating SDM and SDEM specifications.

In general, for all spatially augmented models, we see that the estimated coefficient for the set of regressors remains rather stable. This also accounts for the empirically estimated direct effect of GRW subsidies. The only notable difference

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[11] Detailed regression tables for the latter can be obtained from the authors upon request.

Table 9.5 Spatial regression results for conditional convergence among German labor markets

Dep. var.: $(1/T)\log[y_{iT}/y_{i0}]$	V/ ML-SAR	VI/ ML-SEM	VII/ ML-SDM	VIII/ ML-SDEM
Initial labor productivity	-0.024^{***}	-0.024^{***}	-0.028^{***}	-0.029^{***}
$\log(Y94)$	(0.006)	(0.006)	(0.006)	(0.006)
Employment growth plus $(g+\delta)$	-0.006^{***}	-0.006^{***}	-0.007^{***}	-0.007^{***}
$\log(EWT)$	(0.002)	(0.002)	(0.002)	(0.002)
Investment intensity	0.006^{***}	0.005^{***}	0.005^{***}	0.005^{***}
$\log(S)$	(0.001)	(0.001)	(0.001)	(0.001)
Vocational training	0.012	0.015	0.029^{***}	0.030^{***}
$\log(HK)$	(0.010)	(0.010)	(0.011)	(0.010)
Share of manufacturing sector	0.004^{***}	0.005^{***}	0.007^{***}	0.007^{***}
$\log(IND)$	(0.001)	(0.001)	(0.001)	(0.001)
Share of high-tech industries	0.004^{**}	0.004^{**}	0.002^{*}	0.002^{*}
$\log(TECH)$	(0.001)	(0.001)	(0.001)	(0.001)
Market potential	0.002^{*}	0.002^{*}	0.003^{***}	0.003^{***}
$\log(MPOT)$	(0.001)	(0.001)	(0.001)	(0.001)
Population density	−0.007	−0.006	−0.005	−0.005
$\log(BVD)$	(0.005)	(0.005)	(0.005)	(0.005)
Squared population density	0.001	0.001	0.001	0.001
$\log(BVD^2)$	(0.001)	(0.001)	(0.001)	(0.001)
Dummy for GRW regions	0.071^{***}	0.081^{***}	0.085^{***}	0.081^{***}
D_{GRW}	(0.028)	(0.028)	(0.028)	(0.028)
Interaction term	-0.019^{***}	-0.021^{***}	-0.022^{***}	-0.021^{***}
$\log(Y94) \times D_{GRW}$	(0.007)	(0.007)	(0.007)	(0.007)
$W \times D_{GRW}$			-0.323^{**}	-0.276^{***}
			(0.005)	(0.103)
$W \times [\log(Y94) \times D_{GRW}]$			0.085^{**}	0.072^{**}
			(0.040)	(0.028)
$W \times \log(BVD)$			-0.020^{***}	-0.022^{***}
			(0.005)	(0.004)
ρ	0.073		0.240	
	(0.098)		(0.461)	
λ		0.561^{***}		−0.634
		(0.164)		(0.862)
log likelihood	863.55	866.32	873.88	874.06
Wald test of $\rho, \lambda = 0$	0.56	11.69^{***}	0.27	0.54
(p-value)	(0.45)	(0.00)	(0.60)	(0.46)
Moran's I	2.490^{***}	6.452^{***}	0.706	−0.147
(p-value)	(0.00)	(0.00)	(0.24)	(0.44)

Source: Standard errors in brackets

*Denote statistical significance at the 1% level **Denote statistical significance at the 5% level

***Denote statistical significance at the 10% level stems from population density, which turns out to be insignificant for most specifications, as well as the skill level of regional employment which only shows a significant effect in the SDM and SDEM equations. On the contrary, market potential, which was estimated insignificantly in the OLS regressions, is found to be significant in the spatially augmented models. With respect to the spatial parameters ρ and λ in the SAR and SEM, respectively, Table 9.5 shows only statistical support for the SEM alternative. Further including spatial spillover effects from the vector of regressors X in the SDM and SDEM approach supports this result. Here, starting from a general approach and only keeping significant variables, besides the spatial lag of population density, also the spatial GRW dummy and—more important—the spatial lag of the interaction term $W \times (D_{GRW} \times y_{i0})$ turn out to be significantly different from zero. The interaction term thereby measures how far a policy-induced change in the convergence rate of neighboring regions translates to the region's own growth path. As Egger and Pfaffermayr (2006) have shown, we can thus augment (9.10) to measure the growth in labor productivity conditional on the relative gap to the steady-state level under the presence of spatial spillovers. The total spatially augmented net effect is then composed out of its aspatial and spatial element as

$$\Delta_{sn} y_i = \beta_{sn} \times (y^* - y_{it}). \tag{9.19}$$

The coefficient β_{sn} in turn can be obtained from the following relationship as $(\xi + \omega) = (1 - e^{-\beta_{sn} T})/T$ based on the gap between actual and steady-state income y^*. Given the positive regression coefficient ω, the results in Table 9.5 indicate that the spatially associated spillover effects from the GRW funding scheme is negative. These results are qualitatively in line with earlier results reported in Eckey and Kosfeld (2005). The graphical distribution of the spatial effect in line with the graphical inspection in the aspatial model is shown in Fig. 9.7. As the figure shows, the indirect spatial effect partly offsets the positive direct effect of funding, the downward shift is about one third of the original direct effect for regions far below their steady-state level. Here, the total effect from GRW funding is nevertheless still significantly positive. The more the region approaches its steady-state income level, the more dominates the negative indirect effect of the support scheme. However,

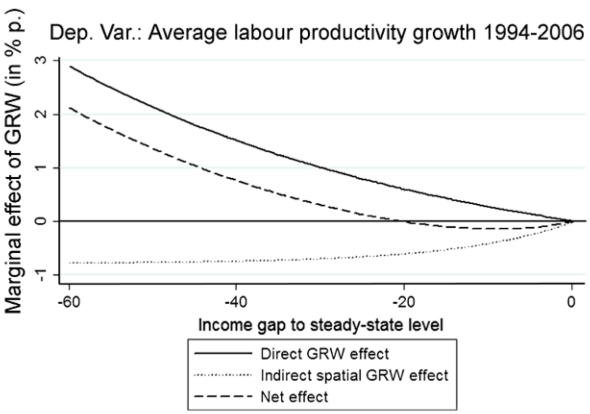

Fig. 9.7 Marginal effect of GRW subsidies relative to regional income gap

this only applies for income regions in which both effects of GRW funding also reduces in absolute terms, so that the negative overall distortionary effect of the GRW is rather small.

Finally, the plausibility of a negative indirect effect of the policy instrument has to be discussed. As Eckey and Kosfeld (2005) argue, one likely explanation is the role of spatial replacement effects due to changes in the relative capital investment prices among regions. In this line of argumentation, regions which receive funding become *ceteris paribus* more attractive compared to non-funded regions and are thus able to poach production factors from their neighbors. Our analysis shows that solely focusing on the direct effect of GRW funding overestimates its total effect since it ignores the poaching of factor inputs. Nevertheless, from an overall perspective, the net GRW impact is found to be positive arguing in favor of policy effectiveness, which aims to foster labor productivity growth in lagging regions. The inspection of the models' residuals finally shows that in the spatially augmented SDM and SDEM no misspecification from uncaptured spatial autocorrelation remains. Regarding the role of spatial spillovers from the endogenous and exogenous regressors, empirical support is given to the SDEM specification. We could not find statistical support for a further direct link through the spatial lag of labor productivity as 'catch-all' parameter, hence, the extension to a more subtle SDM is not required.

9.6 Conclusion

In this chapter, we have analyzed the role of physical investment subsidies and business related public infrastructure projects under the 'Joint Task for the Improvement of Regional Economic Structures' (GRW) for labor productivity growth among German labor markets between 1994 and 2006. We used an empirical specification guided by neoclassical growth theory, which allows for a temporary increase in the region's speed of convergence towards its long-run steady-state level to occur in the course of being supported. Next to the direct policy effect, we also accounted for the likely role of indirect spatial spillovers in a system of interconnected supported and not-supported regions.

Our empirical results show that the neoclassical growth model is an adequate vehicle for modelling growth and convergence processes among German labor markets. All estimated specifications indicate that spatial convergence forces are in order. Controlling for potential long-run driving forces of the regions technology level and in turn steady-state productivity level allows us to identify the GRW policy effect. Because enhancement of capital supply in lagging regions is the primary goal of the GRW scheme, in our empirical model we carefully design the null hypothesis of being tested as the policy induced change in the convergence rate towards long-run income. To do so, we construct an interaction term linking the convergence rate to the policy stimulus, which allows us to measure the change in the speed of convergence for funded over non-funded labor markets. This approach can be seen as an advantage over models, in which simply a measure for the policy input is added to the set of control variables for the long-run technology level. Instead, our specification is perfectly in line with the 'spirit' of neoclassical growth theory in which even a permanent increase in the physical investment rate may only exhibit a temporary effect on productivity growth, leaving the long-run growth rate unaffected.

Our results show that, on average, the GRW leads to an increase in the convergence rate, which is found to be the higher for those regions, whose income gap relative to steady-state productivity level is large. Accounting for spatial dependencies, we also apply different spatial econometric extensions to the neoclassical convergence model, which are capable of modelling spillover effects originating from the endogenous and exogenous variables in the regression setup. We find that negative indirect spillover effects of the GRW are in order. The obtained negative spillovers can be motivated by changes in relative prices for physical investment among regions and result in poaching of production factors from their neighborhood. However, the total effect of the GRW support scheme remains positive. This in turn indicates that the funding scheme is able to foster the growth dynamics of funded regions towards its long-run steady-state growth path.

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