E.ON Energy Research Center
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FCN Working Paper No. 5/2013

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Publisher: Prof. Dr. Reinhard Madlener
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Economic Growth and Regional Labor Market Development in German Regions: Okun's Law in a Spatial Context

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March 2013

Abstract

The inverse relationship between economic growth and labor market developments in the form of changes in the unemployment rate is known in economic literature as Okun's law. The objectives of this paper are to estimate a regionalized Okun coefficient and its associated (regional) unemployment thresholds. The suitability and limitations of Okun's law as a rule of thumb for regional economic growth and labor market policy are also discussed. Motivated by "Germany's Jobs Miracle" in face of the economic crisis of 2008 and 2009, the existence of an uncoupling effect between economic and unemployment growth is questioned and whether regional economic growth is a driving force for regional labor market development. A regional dataset for the years 2002 to 2009 is employed for this study. The spatial dimension is pursued in two ways: a non-parametric approach using functionally defined labor markets as study areas and the application of spatial econometric panel data models, in particular the Spatial Durbin Error Model. The rationale is that functionally defined regional study areas are the appropriate spatial reference level for the analysis. It is found that, without accounting for spatial dependence, regionalized Okun coefficients are likely to be overestimated. The empirical results confirm a positive impact of economic growth on labor market performance; however, the estimated effect of regional economic growth is far lower than would have been expected. The paper illustrates the limited transferability of Okun's law as a rule of thumb for growth dynamics on a regional level as well as limitations of regional growth dynamics for regional labor market development.

Keywords: Okun's Law, Spatial Econometrics, Regional Labor Markets, Regional Growth

JEL Classification Codes: C21, C23, E24, E32, R12

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1. Introduction

The very robust response of the German labor market to the sharp economic downturn in 2008 and 2009 due to the global financial crisis, when no corresponding impairments of the unemployment rate had occurred, invokes discussion on the functional connection between economic output and labor market developments, especially in Germany. In labor economics literature the inverse relationship between economic growth and labor market performance is known as Okun's law, named after Arthur Melvin Okun (Okun, 1962). His important "rule of thumb"[i] for economic policy is based on empirical observations in the USA for the years 1947 – 1960, identifying the necessity of a 1% decline in the unemployment rate to achieve a 3% increase in economic output. Nowadays, in most studies the argumentation is inverted by asking how much economic growth is necessary to lower or stabilize the unemployment rate, and the so-called Okun coefficients for different countries, regions or periods are estimated.

The financial and economic crisis seems to challenge the relevance of Okun's law for Germany, with the start of the economic crisis in 2008 and an ensuing economic downturn of 4.7%, only negligible changes in the unemployment rate were observed. In figure 1 the national aggregated time series for values of the unemployment rate (black line), the change in unemployment rate (dotted red line), and the economic growth (blue dashed line) are shown for Germany. Up to 2008 the lines for changes in the unemployment rate and economic growth are more or less concurrent with each other, with a spread of one to two percentage points, but in 2008 this parallel run is interrupted. The question arises as to whether this indicates decoupling effects. Nevertheless, there was a period of economic boom alongside with a vigorous recovery of the labor market before the crisis.

This study examines the exceptional response of the German labor market to an economic downturn in 2008, using a disaggregated regional analysis approach to address the regional heterogeneity of the German labor market. Another question considered is how far regional economic growth matters in comparison to national macroeconomic growth developments. Hence the research question is specified in a regional context, by asking if regional economic growth is related to regional labor market development. The objective of this paper is to see whether Okun's law can be confirmed as a rule of thumb for labor market response to variations in regional economic growth. Identifying whether and to what extent economic growth is a driving force of regional labor market development, is important for economic and regional policy and a crucial factor in labor market analysis (Elhorst, 2003). An estimation strategy is applied, starting with the simplest model and expanding it gradually to more complex ones. The analysis is based on functionally defined regional markets and thereby accounts for systematic spatial dependency with a non-parametric approach, but will also use parametric modeling to take further non-systematic spatial effects and dynamic effects into account, utilizing spatial econometric panel data models.

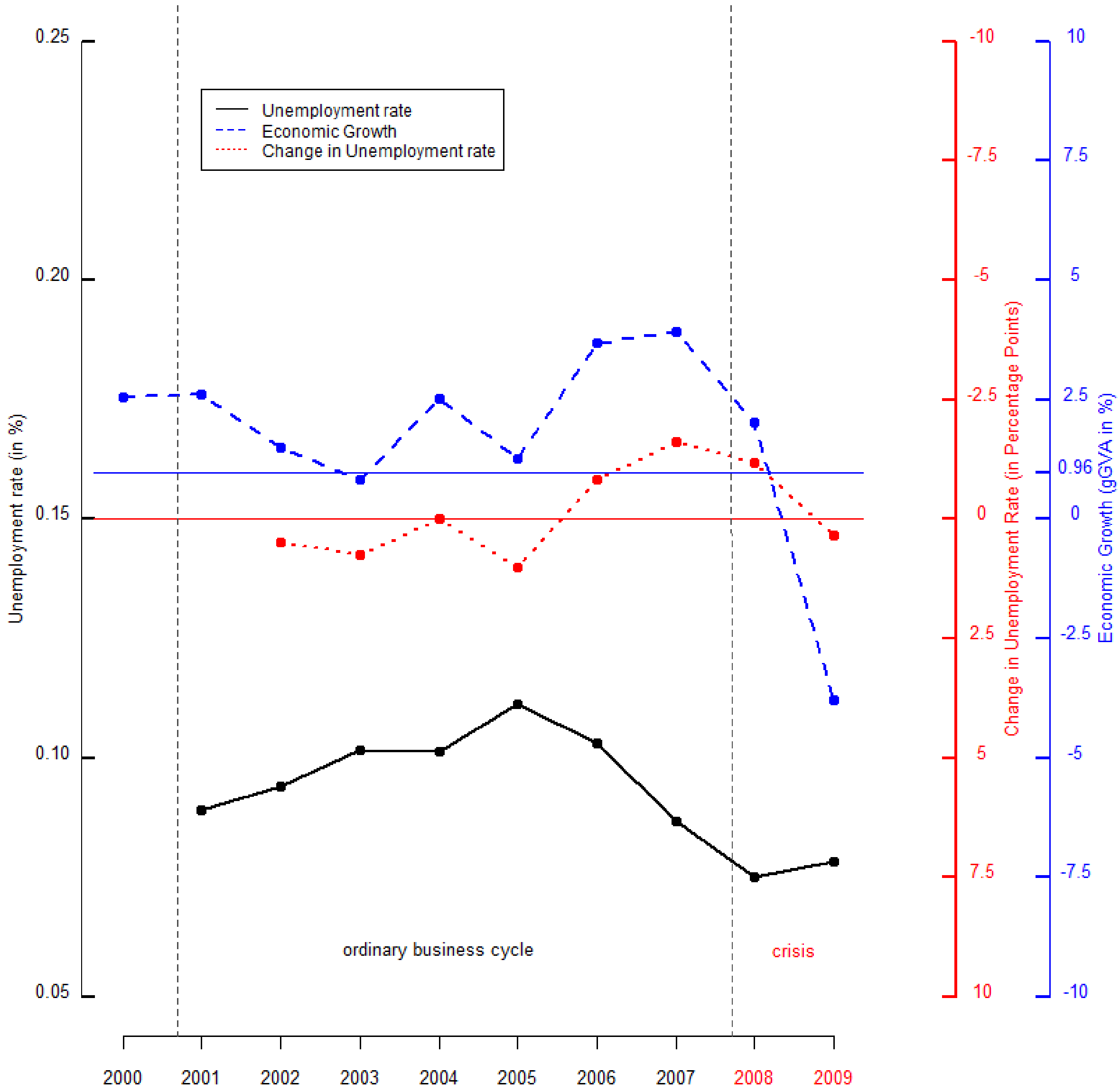


Figure 1: Time series of aggregated values for Germany

The paper is structured as follows. In section 2 the theoretical background is discussed and a literature overview of Okun's law is presented. The spatial reference level of functionally defined regional labor markets is discussed in section 3, and the data set is described in section 4. In section 5 the estimation approach and the composition of the model are discussed, starting with a standard pooled regression model [1] as a benchmark for Okun's law in a regional context (section 5.1). On this basis extensions are explored, in section 5.2 by fixed effects, in section 5.3 by spatial econometric panel data models and, finally, in section 5.4 by a combination of both. Section 6 reports the results together with a brief discussion. Section 7 concludes.

2. Literature review

Many economic studies consider the relationship between economic growth and labor market development and often refer to Okun's law. It seems to be a fair assumption that the impact of economic growth on labor market performance is positive. However, this might occur delayed in time, since employers need time to select and hire new workers. Firing workers and hence giving up or losing (company-specific) human capital is another reason for time lags, as employers might hesitate with dismissals. Employment protection legislation and expectations concerning the duration of up- and downturns in the economic situation also have to be taken into account. As seen in Germany during the financial crisis, firms did not dismiss their workers immediately at the beginning of the crisis. Furthermore, a sound, orderly situation is necessary to hire new workers. Thus hiring and firing workers depends rather on the long-term economic outlook, which could result in delayed adjustment of labor forces to the economic situation. The inclusion of time lags of the explanatory variable, the so-called dynamic version of Okun's law, is a common approach in the literature. For example, Sögner/Stiassny (2002) investigate 15 OECD countries, using annual data for the years 1960-1999, and find a structural break for the years 1982/83. Focusing on Germany, Schalk/Lüschow/Untied (1997) show the delayed impact of economic shocks on the unemployment rate. Further, they add two dummy variables for the years 1982/83 and 1990-92 to control for structural breaks and checked for different periods to show an increasing Okun coefficient over time. They also find a significance effect for the unemployment rate of the previous period, indicating hysteresis effects. Chamberlin (2011) shows similar effects with quarterly data for the UK from 1973 to 2010. He improves the explanatory power of his model by adding four lags (with a quarterly dimension) of GDP growth which are all significant. In a further step, he inserts the change in the unemployment rate of the previous two periods (quarters) showing the path dependency of the unemployment rate on the one hand and models improving explanatory power on the other hand. For the choice of numbers of time lags of economic growth, as well as for the hysteresis effects with previous changes of unemployment rates, it is of course highly relevant if yearly, quarterly or monthly data is regarded (Ball/Leigh/Loungani, 2012). The inclusion of time lags, dummy variables to control for structural breaks (e.g. the crisis period), and the level of regional unemployment to capture hysteresis effects and path dependency, which are considered below, are in line with the literature.

Aside from these studies there is much criticism of Okun's law. Blanchard/Illing (2004), for example, state that economic growth might be met with other resources than labor force and thus unemployment rates do not necessarily change if economic output changes. Malley/Molana (2008) argue that Okun's law is only suitable to highly developed countries since output changes cannot be adjusted by increasing productivity in comparison to developing countries. Several studies, such as Lee (2000) and Knotek (2007), identify instability over time.[ii] Stock/Vogler-Ludwig (2010) emphasize the unsuitability of Okun's law for forecasts, as future entrepreneurial reactions or political behavior can offset the estimated relationship. Comparing the different empirical results, it is clear that there is a high sensitivity regarding the chosen model specification, time periods and variables.[iii] Nevertheless, the negative relationship between the unemployment rate and economic growth occurs in most analyses. Pierdzioch/Rülke/Stadtmann (2012) identify Okun's law as having high relevance for professional economic forecasts, as forecasts of output growth and unemployment rates are consistent with this macroeconomic model. Therefore Okun's law as a rule of thumb is still applicable (Perugini/Signorelli, 2005; Ball/Leigh/Loungani, 2012) and informative for policy-makers (IMF, 2012). Thus it is indispensable to scrutinize this relationship and to identify diverse interdependencies.

Most studies deal with international comparisons of labor market reactions to economic dynamics. Among others, Chamberlin (2011), Sögner/Stiassny (2002), Schäfer (2005), Lee (2000), Moosa (1997), Moazzami/Dadgostar (2009) chose a set of OECD- and G7-group countries to compare the Okun coefficients estimated with different models. In many cases, either the rigidity of national labor market institutions (e.g. Moosa (1997), Sögner/Stiassny (2002) or Hubert (1997)) is discussed or the impact of certain crisis or shocks is illustrated. The current crisis is discussed with the aid of Okun-estimation by OECD (2010) and IMF (2010) as well as by Daly/Hobijn (2010). Cazes/Verick (2011) compare asymmetry and the development and influence of national labor market institutions on the Okun coefficients of the present financial crisis with those of previous recessions. The influence of labor market institutions, such as the Employment Protection Legislation during the crisis, is further discussed by Cazes/Verick/Al Hussami (2011), comparing OECD countries. Owyang/Sekhposyan (2012) identify a changing correlation between unemployment and output fluctuations during the financial crisis. They state that this effect occurred during previous recessions, too, and therefore the coefficient is unstable over time.

Regional aspects have been represented less in the literature on Okun's law. To the authors' knowledge, Freeman (2000) is one of the first to do this, estimating regionalized Okun coefficients in the broadest sense for eight regional economies of the United States. Here, spatial effects are omitted and the investigation is performed on the basis of very large-scale survey regions. For these regions he finds quite stable coefficients, which are in line with most estimated coefficients for the US. Adanu (2005) identifies different coefficients for ten Canadian provinces using a gap version of Okun's law, i.e. with an estimated output gap and the natural unemployment rate,[iv] combined with time-lag structures (not considering a spatial or regional dimension). A positive correlation between the coefficient and regional level of industrialization, population and output is found, though without further research on causality. The coefficients for 17 administrative regions of Spain for the years 1980-2004, estimated by Villaverde/Maza (2009), differ notably and significantly. The authors explain these spreads by disparities in productivity growth. It should be noted that no spatial dependency can be clearly identified for these Spanish regions using Moran's I as a global measure for spatial autocorrelation. Christopoulos (2004) validates an Okun coefficient for six out of thirteen Nuts II regions of Greece using fully modified OLS estimation.[v] Spatial patterns are taken into account by Yazgan/Yilmazkuday (2009), who focus on the convergence of US-states' Okun coefficients. They use a geographically weighted regression for their first-difference approach, weighting regional output by the distance of the location of production, to implement cross-country interactions. Kangasharju/Pehkonen (2001) use a combination of regional, sectoral and time-effects in their first-difference and dynamic approach for the Finnish labor market to identify the employment-output relation between different regions. They find sectoral structure as one possible explanation.[vi]

A combination of institutional and regional influence of the unemployment intensity on economic growth is analyzed by Herwartz/Niebuhr (2011). They control for institutional settings such as the EPL (Employment Protection Legislation) on NUTS 2 regions in the EU-15. They also consider interaction among neighboring labor markets, as well as the sectoral specialization and employment density of regions. They find significant influence of all of these determinants, stressing the persistence of regional disparities which cannot be directly influenced by labor market policies. Kangasharku/Tavéra/Nijkamp (2011) also account for spatial dependencies in their survey as they use a hidden cointegration approach for their estimation of the Okun coefficients. One special feature of this analysis is the usage of functional delineated Finnish labor market regions. Similar to the approach that will be used here, they deal with travel-to-work areas as regional labor markets. This is also done by Kosfeld/Dreger (2005) for Germany. Their estimation approach is a spatial seemingly unrelated regression, and both studies show that unemployment thresholds estimated without regarding spatial effects are notably overestimated. The necessity of taking spatial interaction into account is also shown by Niebuhr (2003) who identifies significant spatial dependencies between regional labor markets in Europe.

In the present paper, we will include the aforementioned necessity of considering dynamic aspects in the form of time lags[vii], as well as spatial effects, by testing, *inter alia*, regional individual fixed effects, spatially lagged explanatory variables and spatial error processes in the disturbances – all in combination with the use of functional delineated economic market areas as study areas. These functional markets will lower spillover effects and strengthen the explanatory power of our estimations. In comparison with the literature, our data set consists of a rather short period covering 2002 to 2009, but a high number of observation units with 110 regional markets.

3. Spatial reference level

While an analysis of the Okun relationship on a national level neglects the high regional heterogeneity within the German labor market, the use of sole administrative regions as the German districts (NUTS 3 level, i.e. the 413 German districts “kreisfreie Städte und Landkreise”) neglects the systematic interdependency between those districts. We argue that both approaches are inadequate study areas for the analysis of regional labor market developments as they will distort our observation of the behavior of the labor force (Casado-Diaz, 2000). Thus our analysis is based on functionally defined regional economic market areas. The 110 Functional Economic Market Areas (FEMA) proposed by Oberst

(2012), defined on the basis of commuting patterns, are used in this study. For robustness checks, alternative regional concepts are used: the 50 labor market regions suggested by Kropp/Schwengler (2011), which are on a larger scale and take a wider perspective on the regional labor markets in Germany; and the 413 administrative districts, which display smaller-scaled labor markets (see sensitivity analysis in section 6.2).[viii] The calculation of relevant indicators, for example, the regional unemployment rates, is performed on the spatial reference level of functionally defined regional economic market areas to avoid systematic overlapping effects and interdependencies between regions. The ability and possibility of participating in the labor market depends significantly on the regional mobility of the work force. The chosen regional markets allow a reduction of the impacts of exogenous shocks on regional effects, as results are not distorted by activities in neighboring regions. Commuting of the labor force would skew the results. As the regional market areas are designed on the basis of commuting data, the commuting intensity within these regional markets is high and is minimized between them. In choosing regional markets based on commuting data, the two options of dealing with commuters presented by Elhorst (2003) are expanded here by a third option. The two alternative options mentioned by Elhorst (2003) are: treating commuters as an explanatory variable for regional unemployment, a relationship which should be positive; or replacing commuters with other explanatory variables, e.g. human capital and level of welfare. The commuting effect is thereby "hidden in the coefficient of these two explanatory variables" (Elhorst, 2003). Note that the delineation approach of the 110 FEMA leads to similar delineation results on the basis of migration data which can be attributed to the fact that commuting and migration patterns on district level in Germany are highly correlated.[ix]

Functionally defined regional study areas as subnational economies are useful laboratories for the examination of macroeconomic theory and policy (Carlino/DeFina 2006). These enable additional data observations within one country, which are comparable with respect to the legal, political and social systems. Furthermore, the socio-economic factors show greater homogeneity, and production factors can be expected to be more mobile as barriers should not exist, in contrast to international studies (McCombie/de Ridder, 1984). Besides this pure data motivation, we argue that the regional perspective corresponds better to real labor market behavior. It should be noted that a regionalized approach cannot be treated as a pure data expansion with common estimation techniques, as will be argued in the following discussion.

The need for the aggregation of administrative regions to functional areas can be illustrated with a spatial variant of Simpson's Paradox (Simpson, 1951) shown in table 1. The regions of Passau and Bamberg are chosen as an example. The results on the spatial level of administrative borders differ from those of the functionally delineated regions. Taking the labor force of the whole functional region into account, the unemployment rate shows a more realistic image of the labor market situation. Administrative borders obviously do not represent the separation of residential choice and place of work, which are connected by commuting. Changes in labor demand within the core city district have effects on the labor force living in the belt (neighboring rural districts) as well. Commuting costs would be a restriction on matching success within the job-search process. These costs are somewhat independent from those administrative borders, but certainly not for the ones between functional delineated regions.

Table 1: Spatial analog to Simpson's Paradox

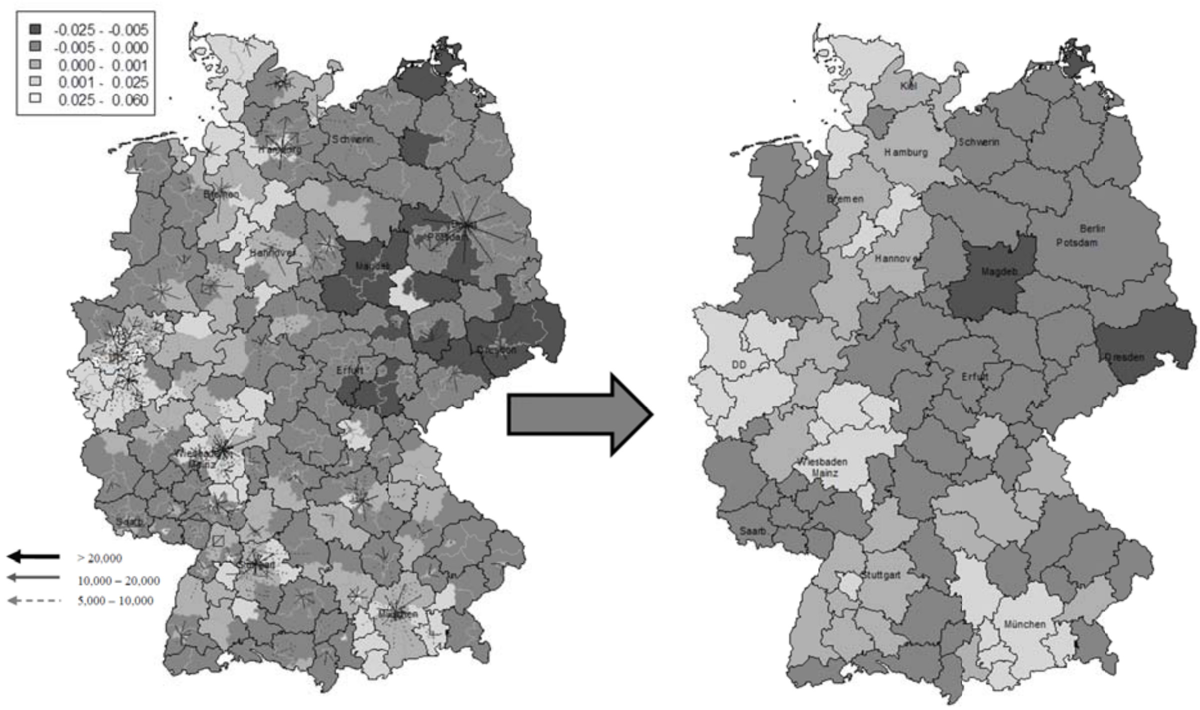
Data for 2001	Region A	Labor force	Unempl.	Unemploy-ment rate		Unemploy-ment rate	Unempl.	Labor force	Region B
Core city district	Passau (city)	44,200	1,710	**3.72%**	<	**3.83%**	2,617	64,900	Bamberg (City district)
Belt districts	Passau (rural district) and Freyung-Grafenau	109,700	9,073	**7.64%**	<	**10.21%**	4,853	42,700	Bamberg (rural district)
Regional labor market	Region Passau	153,900	10,783	**6.55%**	>	**6.49%**	7,470	107,600	Region Bamberg

4. Data set

To investigate the regional labor market response by means of unemployment rates in relation to economic output measured in Gross Value Added (GVA), a panel data set with annual values for the years 2002-2009 is employed. Considering annual changes in economic variables and growth rates, respectively, the time index t for each year ($t = 2002, \dots, 2009$) denominates only the final year of the time period (e.g. 2002 for the period 2001 to 2002). The data are those reported by the Statistical Offices of the Federal and State Governments for 413 districts of Germany ("kreisfreie Städte und Landkreise"), which largely coincide with the NUTS 3 level of the European Union's geocode reference classification. However, the major study areas are the 110 Functional Economic Market Areas (FEMA), defined on the basis of districts and commuting patterns by Oberst (2012). With R = 110 study areas ($r = 1, \dots, 110$) and $T = 8$ time periods ($t = 2002, \dots, 2009$) the data sets results in a balanced panel with $N = 880$ observations. The computation of values for each regional market ($r_{(FEMA)} = 1, \dots, 110$) is performed by aggregation of assigned districts. For example, to calculate the unemployment rate of the regional economic market of Flensburg, each of the unemployment and employment numbers of the relating districts Flensburg, Nordfriesland and Schleswig-Flensburg are aggregated. Figure 2 shows a geographical display of the data aggregation.

The period of investigation is derived by data availability and the consideration of 2001 to 2007, approximating a normal business cycle. 2008 can be seen as the start of the economic crisis (see e.g. OECD, 2011). Accordingly, 2008 and 2009 represent the periods of economic downturn, i.e. the "Crisis", in our analysis.[x]

Average annual change of unemployment rates 2001 to 2007



413 districts 110 districts

Figure 2: Aggregation of 413 districts to 110 study areas

The choice of the dependent variable and the selection of explanatory variables are guided by the framework of Okun's law in the first-difference version, and the requirements of a regionalized analysis.

a) Dependent variable: $d\_uer_{r,t}$ (**y**)

The change of unemployment rates in percentage points in region *r* over the time period *t*. The explanatory variables are differentiated in four groups:

b) Traditional Okun variables: $gGVA_{r,t}$, $gGVA_{r,t-1}$ ($\mathbf{x_1}$, $\mathbf{x_2}$)

Regional economic growth measured in Gross Value Added ($gGVA_{r,t}$, $\mathbf{x}_1$) as well as the time-lagged value for the economic growth in the previous time period ($gGVA_{r,t-1}$, $\mathbf{x}_2$). The latter is called the dynamic version and is a common approach in the literature (Knotek, 2007). Note that the regional economic growth rates represent a factor variable summarizing a variety of economic effects on the labor market.

c) Structural dummy variables: east, crisis, east·crisis ($\mathbf{x_3}$, $\mathbf{x_4}$, $\mathbf{x_5}$):

For historical reasons, the Okun relationship in eastern German regions is expected to differ structurally from the ones in western regions. In addition, as mentioned above, a decoupling of economic trend and labor market performance during the financial crisis is assumed. Both structural breaks will be mirrored with dummy variables for eastern regions *(east*, $\mathbf{x}_3$*)* and for the years 2008 and 2009 (*crisis*, $\mathbf{x}_4$).[xi] The economic crisis predominantly hit export-oriented companies, with a major impact in Germany's Southwest (Möller, 2010). To identify such regional differences of this external shock, the dummy variables c*risis* and *east* are multiplied (*east·crisis*, $\mathbf{x_5}$).

d) Regional characteristics (regional fixed effects $\boldsymbol{\alpha_r}$ or the level of unemployment rate $\mathbf{x_6}$)

Regional individual fixed effects ($\boldsymbol{\alpha_{r=110}}$) represent the unobserved regional individual characteristics, as, for example, regional differences in inflation rates or cultural attitudes, and are included in the model as an individual intercept for each region. They are assumed to be constant over time. A very special issue would be to add regional inflation rates as a reminiscence of the Phillips curve. To our knowledge, these data are not available on a regional scale. However, some approaches for regional price levels, as for example in Kholodilin/Silverstovs (2012), are available on a different spatial scale. Another potential approach is to use instrumental variables for regional differences in the inflation rate, for example regional house prices. The suitability of house prices as a reflection of differences in regional inflation rates would need to be empirically investigated before they can be used.[xii] Instead, a somewhat constant difference in regional inflation rates is assumed, as this depends on fundamental economic structures and should be captured by the regional fixed effects ($\boldsymbol{\alpha_r}$). Nevertheless, this is an important issue for further research. The level of regional unemployment rates ($\mathbf{x_6}$), displayed in the unemployment rate of the base-year (uer_{t-1}), will be used as a factor variable substituting for regional individual fixed effects. The estimator of included unemployment rates can also be interpreted as a hysteresis effect and path dependency. Note, that the unemployment rate is highly correlated with the structural variable *east* ($\mathbf{x_3}$),

Further, combinations of regional fixed effects or the level of unemployment with the *crisis* variable ($\boldsymbol{\alpha_r} \cdot \mathbf{x_4}$) or ($\mathbf{x_6} \cdot \mathbf{x_4}$) are considered in section 4.4, in order to test for a regional heterogeneous response to the crisis.

e) Macroeconomic effects (national economic growth rate $\mathbf{x_7}$ or time fixed effects $\boldsymbol{\alpha_T}$)

The national economic growth rate ($\mathbf{x_7}$) is been used to account for macroeconomic effects. This rate is the most prominent indicator for the economic situation and to some extent represents national expectations. By using the national economic growth rate, it is assumed that economic development in one region out of 110 is negligible for the national economic growth. By a theoretical point of view, the economic growth rate of all other regions should be considered. However, these growth rates of all other regions are very similar to the national economic growth rates, which are therefore used as better interpretable approximation.[xiii] An alternative approach is to account indirectly for macroeconomic effects by using the difference of regional and national economic growth instead of regional economic growth as major explanatory variables. However, this would not answer the research question in how far regional economic growth matters in comparison to national economic growth developments. Furthermore, the national economic growth rate is a dominant value discussed in public media and reflects expectations concerning the macroeconomic situation. It might therefore influence individual decisions within the regions. The national economic growth rate ($\mathbf{x_7}$) is as the regional level of unemployment rates ($\mathbf{x_6}$) included in the set of explanatory variables in **X**. An alternative to control for macroeconomic effects is the implementation of time fixed effects ($\boldsymbol{\alpha}_\mathbf{T}$), representing annual specific effects, which are equal for all regions, and which are estimated as an individual intercept for each year. However, time fixed effects overlay highly with both the national economic growth rate and the dummy variable for the crisis. These are therefore omitted in most of the results presented later, and the focus lays on the directly economically interpretable national economic growth rates. For results on estimations with pure time fixed effects, see Appendix 2.

f) Spatial parameters (**WX**, and/or $\lambda\mathbf{W}\boldsymbol{\varepsilon}$)

Intuitively, spatially lagged explanatory variables (**WX**) can be interpreted as the weighted average values from neighboring regions. To calculate these values, the assumption of the spatial weight matrix (**W**), representing the structure of spatial connectivity between regions, is decisive. The spatial weights included in the matrix are usually interpreted as functions of economic or geographic proximity between spatial units. Since it has to be defined *a priori*, the specific form of **W** is probably the strongest assumption of the spatial analysis. Yet economic theory provides little guidance on specifying these weights. In order to examine the robustness of the results with respect to the form of **W**, three different weight matrices are employed (see section 6.2). The reference matrix, for which results are reported in the following sections, is a standard row-stochastic first-order queen-contiguity matrix.[xiv] $\boldsymbol{\varepsilon}$ is a disturbance term governed by a spatial autoregressive process ($\mathbf{W}\boldsymbol{\varepsilon}$), with $\boldsymbol{\lambda}$ as the associated scalar parameter. See section 5.3 for a more detailed description of spatial parameters.

Some descriptive statistics for average regional unemployment rates, the average annual change in unemployment rates, and the economic growth measured in GVA are documented in table 2. For three different time periods average values for the regional mean, standard deviation (sd), minimum, median and maximum values, the interquartile range (IQR, 0.75-quantile – 0.25-quantile) and the Moran's I statistics (Cliff/Ord, 1981)[xv] as a global measure for spatial autocorrelation are reported.

The average regional unemployment rate during the time of the normal business cycle, at 10.2%, exceeds the value of the crisis period, which is 7.8%. This mirrors the dynamics that took place in the years before 2008 when there was a strong recovery of the German labor market – and the transition from the "sick man of the euro" (The Economist) at the beginning of the century, via Germanys Jobs Miracle (e.g. Krugman, 2009) to Europe's Engine and Model of success (expressions refer to articles in The Economist, June 3, 1999, March 11, 2010, and April 17, 2012, as well as Krugman, November 12, 2009 in The New York Times). The changes in regional variation in unemployment rates are ambiguous: while the standard deviation is lower for the time period 2007-2009, the interquartile range is higher. The improvement in the labor market is shown for the best performer (minimum) as well as for the low-performing, but the discrepancy within the German labor market remains high with a range of regional unemployment rates from 3.8% to 19.4%.

Table 2: Descriptive statistics – values taken from functional labor markets

Average values[1]:	time period	mean	sd	min	median	max	IQR	Moran's I	Moran p-value
Un-employment rate (uer)	2001-2009	0.0969	0.0467	0.0441	0.085	0.2425	0.0494	0.8421	0.0000
	2001-2007	0.1021	0.0495	0.0461	0.0896	0.2563	0.0478	0.8445	0.0000
	2007-2009	0.0783	0.0378	0.0292	0.0706	0.1944	0.0533	0.8210	0.0000
Annual changes in uer	2001-2009	-0.0014	0.0022	-0.0079	-0.0007	0.0024	0.0022	0.7916	0.0000
	2001-2007	-0.0005	0.0018	-0.007	-0.0004	0.0031	0.0020	0.6404	0.0000
	2007-2009	-0.0047	0.0051	-0.0213	-0.0038	0.0056	0.0057	0.7288	0.0000
Growth of GVA	2001-2009	0.0142	0.0065	-0.0071	0.0145	0.0301	0.0071	0.1254	0.0173
	2001-2007	0.0222	0.0087	-0.0082	0.023	0.0431	0.0099	0.1823	0.0020
	2007-2009	-0.0095	0.0167	-0.0573	-0.0102	0.0315	0.0228	0.2474	0.0001

At a first glance, the annual changes in regional unemployment rates show unexpected differences as the annual decreases in the unemployment rate during the crisis (-0.5%) were stronger than during the period of the "normal business cycle" (-0,05%). Note, that these values are aggregated over the relevant years. Positive and negative growth rates from 2002 to 2007 offset each on average. The labor market recovery took place since 2005 and the effects are manifested in the years 2008/2009 (see figure 1). The increase in the standard deviation indicates a heterogeneous impact of the crisis on the regional labor markets, and the regional variation became higher during the crisis period than prior to it. Note that for the unemployment rate (level and annual changes) highly relevant and significant spatial autocorrelation is indicated by the Moran`s I.

The same holds true for the economic growth, with values for Moran's I showing still positive but less relevant spatial dependency. Over the economic crisis the correlation of values for neighboring regional markets is to some extent higher, but still clearly below the results for the unemployment rate. This rising Moran's I during the crisis might exhibit the crisis impact on specific, export-oriented regions. In other words, this exogenous shock was not diffusely spread all over the country (Möller, 2010).

These brief and descriptive results provide initial empirical evidence to control for regional individual characteristics, for spatial interdependencies, as well as for heterogeneous impact of the economic crisis.

[1] For example mean value of average regional values over time (e.g. 2001 to 2007), standard deviation of average regional values over given time period, and so forth.

5. Econometric approach

5.1 Benchmark model and its drawbacks

In what follows, the selection of regional panel data models that will be estimated in the empirical investigation of the inverse relationship between changes in the regional unemployment rate (**y**) and regional economic output growth rates ($\mathbf{x_1}$) will be described and discussed. With respect to notation, symbols refer to vectors and matrices when emboldened and to scalar variables otherwise. The basic model is based on a pooled data set, where every combination of a region *r* at a point of time *t* adds up to one observation *i*. As a benchmark for the empirical analysis a standard multiple linear regression model is estimated on the basis of functional delineated economic regions:

$$\mathbf{y} = \alpha\boldsymbol{\iota} + \mathbf{X}\boldsymbol{\beta} + \mathbf{u} \qquad [1]$$

y is a *N*-dimensional vector of the dependent variable consisting of one observation for every unit in the sample (i = 1, …, *N*). *N* results from the multiplication of the number of investigated regions *R* and observed periods of time *T*. $\alpha\boldsymbol{\iota}$ is the constant term parameter α multiplied by $\boldsymbol{\iota}$ (vector of all ones); **X** is an $N \times K$ matrix including regional observations for the defined explanatory variables. $\boldsymbol{\beta}$ is a *K*-dimensional vector of the associated regression coefficients of **X,** and **u** is an *N*-dimensional vector of stochastic innovation with the usual properties of independently and identically distributed error terms for all *i* with zero mean and variance σ^2.

While this basic model is useful as a benchmark, it has some drawbacks. First, each unit of observation represents a region located in space with its own individual characteristics, which are not displayed in [1] and likely to cause an omitted variable bias. If any omitted factor is correlated with the explanatory variables, its influence is erroneously attributed to the included covariates. Second, although the functional regional markets are delineated on the basis of commuting patterns and thereby are based on systematic linkages between spatial units[xvi], it is likely that unsystematic spatial dependency remains within the data. Besides imperfect specification of the regional markets and aggregation of spatially dispersed data, it must be pointed out that the regional labor market is an aggregation of manifold sub-labor markets (e.g. by industry, profession, age, and other mobility influential factors like homeownership). Despite the use of functional delineated regions, spatial autocorrelation is likely the case within the data set, given that even functional regions virtually never coincide with 'true' regional markets. Those issues arising will lead to spatial measurement errors and spatial autocorrelation between errors; and therefore the use of spatial econometric models is necessary (see e.g. Anselin/Bera, 1998). This is confirmed by the previously mentioned Moran's I values in table 2, which strongly indicate the presence of spatial dependency.

While spatial dependence in the dependent variable causes biased estimates, it leads to asymptotically unbiased but inefficient estimates in the error terms (Anselin, 1988; Anselin et al., 2004).[xvii] The cost of ignoring this problem would thus be high relative to ignoring spatial dependence in the residuals. However, the hypothesis of spatial dependency in the dependent variable by systematic linkages is rejected here due to theoretical considerations, and it is assumed that the present spatial dependency is caused by unsystematic linkages. Note that systematic spatial dependency is already captured by the non-parametric approach of functionally defined regional markets.

The drawbacks of the benchmark model [1] will be addressed as follows. First, in section 5.2, the implementation of fixed effects is discussed to control for different regional characteristics of the regional labor markets as well as to control for macroeconomic effects. Second, in section 5.3, the model is estimated in spatial econometric settings, with the Spatial Durbin Error Model (SDEM) as the preferred approach due to the assumed simultaneous presence of omitted variable bias and spatial dependency caused by unsystematic linkages. Finally, a potential combination of both approaches is considered in section 5.4.

5.2 Regional fixed effects models

As an alternative to the pooled benchmark model [1], the panel data set that is being used allows the implementation of regional individual fixed effects, time fixed effects, and combinations of both.[xviii] The period from 2001 to 2007 covers approximately one economic business cycle for Germany; the exceptional time period of 2008 to 2009 is depicted by the structural dummy variable *crisis* ($\mathbf{x_4}$). Following the argument in section 5.1, and with respect to the sample size N (880) = R (110) × T (8), the integration of both types of fixed effects into the model is excluded in advance, and will only be tested with the economically interpretable substitute variables $\mathbf{x_6}$ and $\mathbf{x_7}$.

The fixed effects regression model is given in [2],

$$\mathbf{y} = \mathbf{I}\boldsymbol{\alpha} + \mathbf{X}\boldsymbol{\beta} + \mathbf{u} \qquad [2]$$

in which $\mathbf{y}$, $\mathbf{X}$, $\boldsymbol{\beta}$ and $\mathbf{u}$ are the same as in equation [1], but $\boldsymbol{\alpha}$ contains in [2] the group of specific constant terms and $\mathbf{I}$ is an $N \times N$ matrix including dummy variables for each region representing the individual fixed effects. Equation [2] can be interpreted as having R intercepts when applying regional individual fixed effects, one for each region, or T intercepts for each time period with time fixed effects (e.g. 110 regional individual or 8 time fixed effects). The regional individual fixed effects represent unobserved regional characteristics that vary over the sample (e.g. state capital, cultural attitudes), but are constant over time. The argument for time fixed effects is analogous.

Taking up the first drawback of the benchmark model discussed above, it is likely that the regional individual characteristics not displayed in [1] cause an omitted variable bias. One approach worth considering to address this problem could be to account for regional individual characteristics with a wide range of explanatory variables. This is hardly practicable due to unknown, unobservable or at least unpublished factors, as for example the difficulties discussed above, with regional inflation rates or regional cultural attitudes.[xix] Thus the differences in regional characteristics are modeled by including regional individual fixed effects ($\boldsymbol{\alpha}_{\mathbf{r=110}}$) or their substitute variable of the regional level of unemployment ($\mathbf{x_6}$). However, the explanation of differences in regional characteristics, as well as finding and constructing suitable explanatory variables, is an important aspect for further research.

5.3 Spatial econometric models[xx]

The simultaneous presence of spatial dependence and omitted variables provides a very strong case for using a spatial econometric model in this regional economic analysis of Okun's law. LeSage/Pace (2010), for example, pointed out that adding spatial lags in the dependent and the explanatory variables allows capturing unobserved regional characteristics indirectly.[xxi] In other words, modeling spatial dependence can act as a substitute for regional fixed effects, which could allow degrees of freedom to be reduced in these estimations. Intuitively, this can be clarified by pointing out that neighboring regions might have unobserved regional characteristics in common, which should thus exhibit spatial dependence of their own. Following the line of argument of spatial dependency caused by unsystematic linkages, the focus lies on spatial models with a spatial autoregressive process for the disturbances (Spatial Error Model), and excludes models with spatial lags of the depended variable (Spatial Lag Model) from the discussion.
In order to address the presence of spatial dependence in the disturbances, a Spatial Error Model is introduced, which is given as:

$$\mathbf{y} = \alpha\boldsymbol{\iota} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \qquad \boldsymbol{\varepsilon} = \lambda\mathbf{W}\boldsymbol{\varepsilon} + \mathbf{u} \qquad [3]$$

In equation [3], $\mathbf{y}$, α, $\boldsymbol{\iota}$, $\mathbf{X}$, $\boldsymbol{\beta}$ and $\mathbf{u}$ are the same as in equation [1], $\mathbf{W}$ denotes a $N \times N$ row-stochastic spatial weight matrix representing the structure of spatial connectivity between the regions; λ is a scalar parameter and $\boldsymbol{\varepsilon}$ is a disturbance term governed by a spatial autoregressive process.

Including spatially lagged explanatory variables might be useful to address unobserved and spatially dependent regional characteristics and growth factors. In this case, the literature advises the use of Spatial Durbin Models (SDMs), a class of models including spatial lags of the explanatory variables together with either a spatial lag in the dependent variable or a spatially autoregressive error term. The use of SDMs for applied practice has been particularly advocated by LeSage/Pace (2010) and Elhorst (2010), arguing that spatial dependence in the explanatory variables can influence the performance of spatial models in relation to OLS models substantially. Building on the rationale favoring a spatially autocorrelated error term, a Spatial Durbin Error Model (SDEM) is estimated as follows:

$$\mathbf{y} = \alpha\boldsymbol{\iota} + \mathbf{X}\boldsymbol{\beta} + \mathbf{W}\mathbf{X}\gamma + \boldsymbol{\varepsilon}, \qquad \boldsymbol{\varepsilon} = \lambda\mathbf{W}\boldsymbol{\varepsilon} + \mathbf{u} \qquad [4]$$

$\mathbf{y}$, α, $\boldsymbol{\iota}$, $\mathbf{X}$, $\boldsymbol{\beta}$, $\mathbf{u}$ and $\mathbf{W}$, $\boldsymbol{\varepsilon}$, λ are the same as in equation [3], while $\boldsymbol{\gamma}$ denotes a K-dimensional vector which indicates the spatial dependency in the explanatory variables. Later, exceptions for regional invariant variables, as for example the dummy variable for the crisis, or the national (macro-) economic growth rates, are made in $\mathbf{WX}$. For the Spatial Durbin Error Model (SDEM), the partial effect of change in an explanatory variable $\mathbf{x_k}$ on $\mathbf{y}$ can be obtained by:

$$\frac{\partial y}{\partial x_k} = I_n \beta_k + W_n \gamma_k \qquad [5]$$

for all k, where $\mathbf{I_n \beta_k}$ measure the direct effect (within the regional market) and $\mathbf{W_n y_k}$ the indirect effect (cumulative neighboring effects). The **β**-coefficient can be interpreted as in common OLS-regression, while $\mathbf{W_n \gamma_k}$ is the product of the spatial weight matrix and the considered spatial lag parameters $\boldsymbol{\gamma_k}$ and includes the SDEM-typical local multiplier. The average row sum corresponds to the average cumulative indirect effect (see Lerbs/Oberst, 2012). The possibility of this intuitive parameter interpretation is another advantage of the SDEM in regard to spatial models, including spatial lags of the dependent variable as the SDM.

5.4 Spatial econometric models with fixed effects

As derived from the previous discussion, it is important to account for regional individual characteristics, macroeconomic effects, as well as spatial dependency. In general, the employed regional panel data set allows for control of all of this. However, the main obstacles are multicollinearity problems and sample size. Three variations of the Spatial Durbin Error Models (SDEM) with regional fixed effects will be considered in the following discussion. The first model [6] controls for regional heterogeneous characteristics and is a combination of the SDEM with regional individual fixed effects, the second model [7] depicts only a regional heterogeneous response towards the economic crisis with an interaction term of the dummy variable for the *crisis* ($\mathbf{x}_4$) and the matrix of and the $N \times N$ matrix **I** (in analogy with the interaction of *east·crisis*, $\mathbf{x}_5$), but consists of an ordinary intercept α [7]. Finally, the third model [8] is a combination of both, displaying both regional heterogeneous characteristics and heterogeneous response to the crisis. A detailed description of formulas is omitted here, since most terms are already described above.

$$\mathbf{y} = \boldsymbol{\alpha\iota} + \mathbf{X\beta} + \mathbf{WX\gamma} + \boldsymbol{\varepsilon}, \qquad \boldsymbol{\varepsilon} = \lambda\mathbf{W}\boldsymbol{\varepsilon} + \mathbf{u} \qquad [6]$$

$$\mathbf{y} = \alpha\boldsymbol{\iota} + \mathbf{X\beta} + \mathbf{WX\gamma} + \boldsymbol{\alpha\iota}\cdot\mathbf{x}_4\tau + \boldsymbol{\varepsilon}, \qquad \boldsymbol{\varepsilon} = \lambda\mathbf{W}\boldsymbol{\varepsilon} + \mathbf{u} \qquad [7]$$

$$\mathbf{y} = \boldsymbol{\alpha\iota} + \mathbf{X\beta} + \mathbf{WX\gamma} + \boldsymbol{\alpha\iota}\cdot\mathbf{x}_4\tau + \boldsymbol{\varepsilon}, \qquad \boldsymbol{\varepsilon} = \lambda\mathbf{W}\boldsymbol{\varepsilon} + \mathbf{u} \qquad [8]$$

While $\boldsymbol{\alpha}$ in [6] and [8] contains the group of R specific constant terms for regional individual fixed effects as described in section 5.2, α in [7] is the scalar parameter and constant term as in the benchmark model [1]. $\boldsymbol{\alpha\iota}\cdot\mathbf{x_4}$ displays the described regional heterogeneous response, with $\boldsymbol{\tau}$ as the vector of associated coefficients.

6. Empirical results

6.1 Empirical results for the reference level of 110 FEMA

All the models presented are estimated with a maximum likelihood procedure[xxii] and employed on the aggregated regional panel data set for 110 functional delineated regional markets in Germany with values for 2002 to 2009. The empirical results are summarized in table 3, where standard errors of estimates are given in parentheses and the level of significance is indicated with *, **, and *** for 10%, 1%, and 0.1%-level. The R^2 and the log likelihood are used for model comparison. While R^2 indicates the goodness of fit between estimated **y** and observed values for **y**, the log likelihood shows the values of the log likelihood function at the optimum. The higher the log likelihood values, the more likely the parameter. Subsequent to the presentation of empirical results, a sensitivity analysis for alternative regional market definitions and spatial neighborhood criteria follows in section 6.2.

The discussion of the empirical results starts with the pooled and non-spatial Benchmark Model specified in [1], the results of which are given in the 1st column of table 3 and serve as a reference point for the analysis.[xxiii] The estimated Okun coefficient $\beta_{1,2}$ (with consideration of timely lagged effects, t, t-1) is -0.24. The resulting estimated regional growth threshold[xxiv] is 2.3%, (for calculation of these thresholds see Appendix 1). All included control variables are shown as significant with negative signs, indicating lower growth thresholds for eastern regions (1.9%); for the time period of the economic crisis (1.5%); and for eastern regions during the economic crisis (0.7%). This pooled model implies the assumption that the same estimated coefficients and thus the Okun relationship is the same for each region in each year (except for the differences controlled for with structural dummies). This assumption of stability is questionable, as can be shown with theoretical arguments and empirical testing (chow test).[xxv]

The standard way of accounting for regional characteristics with panel data is to add individual fixed effects $\boldsymbol{\alpha}_{\mathbf{r}}$ for each regional labor market, as in equation [2] with $\boldsymbol{\alpha}_{\mathbf{r}}$ containing R=110 intercepts. Alternatively, the level of regional unemployment $\mathbf{x}_6$ as a substitute for regional individual fixed effects and as a proxy variable for different regional labor market situations is proposed. The correlation coefficient between regional individual fixed effects and the level of unemployment rates across different estimated models is sufficiently high, at 0.9 in non-spatial pooled models and about 0.74 in spatial models. Note that the level of unemployment rate is just one aspect of regional attributes – albeit most likely the decisive one, and that a simultaneous estimation of both variables for regional characteristics is not feasible due to the occurrence of multicollinearity problems. The same holds true for the temporal dimension, where the national economic growth rate $\mathbf{x}_7$ and time fixed effects $\boldsymbol{\alpha}_{\mathbf{T}}$ are substitute variables. Note that time fixed effects need to be interpreted in a broader sense because they also cover special annual effects (e.g. policy reforms such as Agenda 2010 by the Schröder Government). However, the estimation results for a time fixed effects model [2], with $\boldsymbol{\alpha}_{\mathbf{T}}$ containing T=8 intercepts, and the reference model [1] including the proposed alternative variables to account for regional characteristics and macroeconomic effects are very similar to each other, with model criteria slightly in favor of the latter. The results with the alternative variables in [1] can be interpreted in a more general context (for all regions at once) and serve as a basis for further model extension, due to more remaining degrees of freedom. For reported estimation results of fixed effects models see Appendix 2, and for the combination of regional fixed effects with augmented spatial models see column 4 to 6 in table 3, all of which are discussed later.

Table 3: Estimation results

d_uer ~ y	1 **Benchmark M.**	2 **M.** w. extended X	3 **SDEM** w ext. X, w/o (W*uer*Crisis)	4 **SDEM** w. **αI**	5 **SDEM** w **αI·x₄**	6 **SDEM** w **αI and αI·x₄**		
Equation:	[1]	[1]	[4]	[6]	[7]	[8]		
gGVA$_t$ **x$_1$**	**-0.173***** (0.010)	**-0.033***** (0.009)	**-0.030***** (0.007)	**-0.028***** (0.007)	**-0.029***** (0.007)	**-0.028***** (0.007)	Okun's beta	
gGVA$_{t-1}$ **x$_2$**	**-0.063***** (0.011)	**-0.018*** (0.008)	**-0.021***** (0.006)	**-0.018**** (0.006)	**-0.022***** (0.006)	**-0.021**** (0.007)		
sum (β)	**-0.236**	**-0.050**	**-0.051**	**-0.046**	**-0.051**	**-0.049**		
α (intercept)	**0.005***** (0.000)	**0.013***** (0.001)	**0.015***** (0.002)	see map of **α$_{R=110}$**	**0.015***** (0.001)	see map of **α$_{R=110}$**		
east **x$_3$**	**-0.004***** (0.001)	0.000 (0.001)	n/a	n/a	n/a	n/a	Structural variables	
crisis **x$_4$**	**-0.008***** (0.001)	**-0.017***** (0.001)	**-0.014***** (0.002)	**-0.011***** (0.002)	dropped	See map of **α$_{R=110}$** · x$_4$=1		Crisis response
east·crisis **x$_5$**	**-0.004***** (0.002)	**-0.006***** (0.001)	see uer$_{t-1}$·crisis	n/a	n/a	n/a		
uer$_{t-1}$·crisis **x$_6$·x$_4$**	n/a	n/a	**-0.058***** (0.015)	**-0.085***** (0.016)	See map of **α$_{R=110}$** · x$_4$=1	See map of **α$_{R=110}$** · x$_4$=1		
national gGVA **x$_7$**	n/a	**-0.402***** (0.016)	**-0.375***** (0.043)	**-0.384***** (0.044)	**-0.392***** (0.043)	**-0.402***** (0.044)		
uer$_{t-1}$ **x$_6$**	n/a	**-0.034***** (0.009)	**-0.031***** (0.007)	dropped	**-0.031***** (0.007)	dropped		
W·*gGVA$_t$* **W·x$_1$**	n/a	n/a	**-0.043**** (0.016)	**-0.044**** (0.017)	**-0.036**** (0.017)	**-0.038*** (0.018)	Spatial effects	Spatial lags
W·*gGVA$_{t-1}$* **W·x$_2$**	n/a	n/a	**-0.056***** (0.015)	**-0.057***** (0.016)	**-0.057***** (0.016)	**-0.058***** 0.017)		
W·*uer$_{t-1}$* **W·x$_6$**	n/a	n/a	-0.001 (0.010)	dropped	dropped	dropped		
spatial error (ρ)	n/a	n/a	**0.803***** (0.000)	**0.808***** (0.000)	**0.805***** (0.000)	**0.809***** (0.000)		
R²	0.349	0.640	0.747	0.776	0.762	0.778		
RSS	0.067	0.036	0.037	0.037	0.035	0.034		
log likelihood	2925	3192	3570	3591	3601	3626		
Moran's I on residuals	none	2003: 0.07* 2005: 0.13*	2002: 0.08* 2003: 0.08* 2005: 0.04*	2003: 0.08* 2004: 0.08* 2006: 0.02*	2003: 0.11* 2004: 0.07* 2006: 0.11*	2002: 0.08* 2003: 0.09* 2004: 0.08* 2006: 0.10*		

In column 2 of table 3 the results are listed for a pooled non-spatial model based on equation [1], where both alternative variables for fixed effects are included in the set of explanatory variables (**X**). The estimated regional Okun coefficient, at -0.05, is far lower than for the reference model. The national economic growth rates as macroeconomic effect is the dominant factor, at 0.4. The estimated level effect of the regional unemployment rate has around the same magnitude as the regional Okun coefficient. The other control variables remain significant with more or less the same estimated magnitude. Of particular note is that with the inclusion of the regional level of unemployment rate (uer_{t-1}), the structural dummy variable for the eastern regions completely loses its explanatory power, confirming the assumption that unemployment rates are an appropriate substitute for regional individual fixed effects. Further, the highly significant and relevant coefficients for the unemployment rates indicate, on the one hand, a hysteresis effect and path dependency, and, on the other hand, a slight convergence process between German labor markets *ceteris paribus*. The total explanatory power of the second estimated model increases considerably. While the calculation of the associated Okun threshold for the reference model is relatively simple, it is much less straightforward for the extended models. For the derivation of threshold formulas see Appendix 1. The use of different structural variables leads to different thresholds, and assumptions for the national economic growth rate and the regional level of unemployment have to be made.

Based on the assumption of a regional labor market with an unemployment rate of 9% (median, 2001 to 2007) and an output growth of 2.3% (median, 2001 to 2007), a regional labor market threshold of 1.4% can be calculated. This threshold reduces to negative values with -0.3% for the crisis period and -0.9% for regions in eastern Germany during the crisis. A calculation is only reasonable within "realistic" values for German regions at this time; because thresholds are quite sensitive regarding the assumptions. For example, a macroeconomic situation with an increase in national economic output by 2.3% p.a. is assumed. For a hypothetical regional labor market with an unemployment rate of 25% the estimated unemployment threshold under these macroeconomic conditions is -9.5%. Analogously, for a region with a regional unemployment rate of 5% an unemployment threshold of 4.1% is estimated. Thus, the unemployment threshold for German regions varies by 0.7%-points on a 1%-point variation of the regional unemployment rate. A hypothetical region with an unemployment rate of 9% and a national economic growth rate between 1.8% and 2.8% results in regional threshold-value between 5.4% and -2.6%. Thus, the range of regional thresholds on a 1%-point variation of national growth rates varies by 8%-points. The sensitivity of the associated regional growth thresholds for labor market effects regarding the structural variables as well as the economic environment described by the national economic growth rate (macroeconomic conditions) and the level of regional unemployment rate (current labor market situation) is visualized in figure 3. On the ordinate the calculated regional unemployment threshold are entered, which range from -10% to 20%, and on the abscissa two scales are illustrated, the solid black line for the regional unemployment rates (with a range of 0 to 22.5%) and the dashed blue line for the national economic growth rate on a smaller scale (with a range of 0 to 5.75%). The median values for both indicators for German regions between 2001 and 2007 are visualized with a grey dashed line by 9% and 2.3%. Within the parentheses are the assumed values for the second structural indicator given. The plotted lines correspond to the same colored abscissas and are based on an assumption for the other variable.

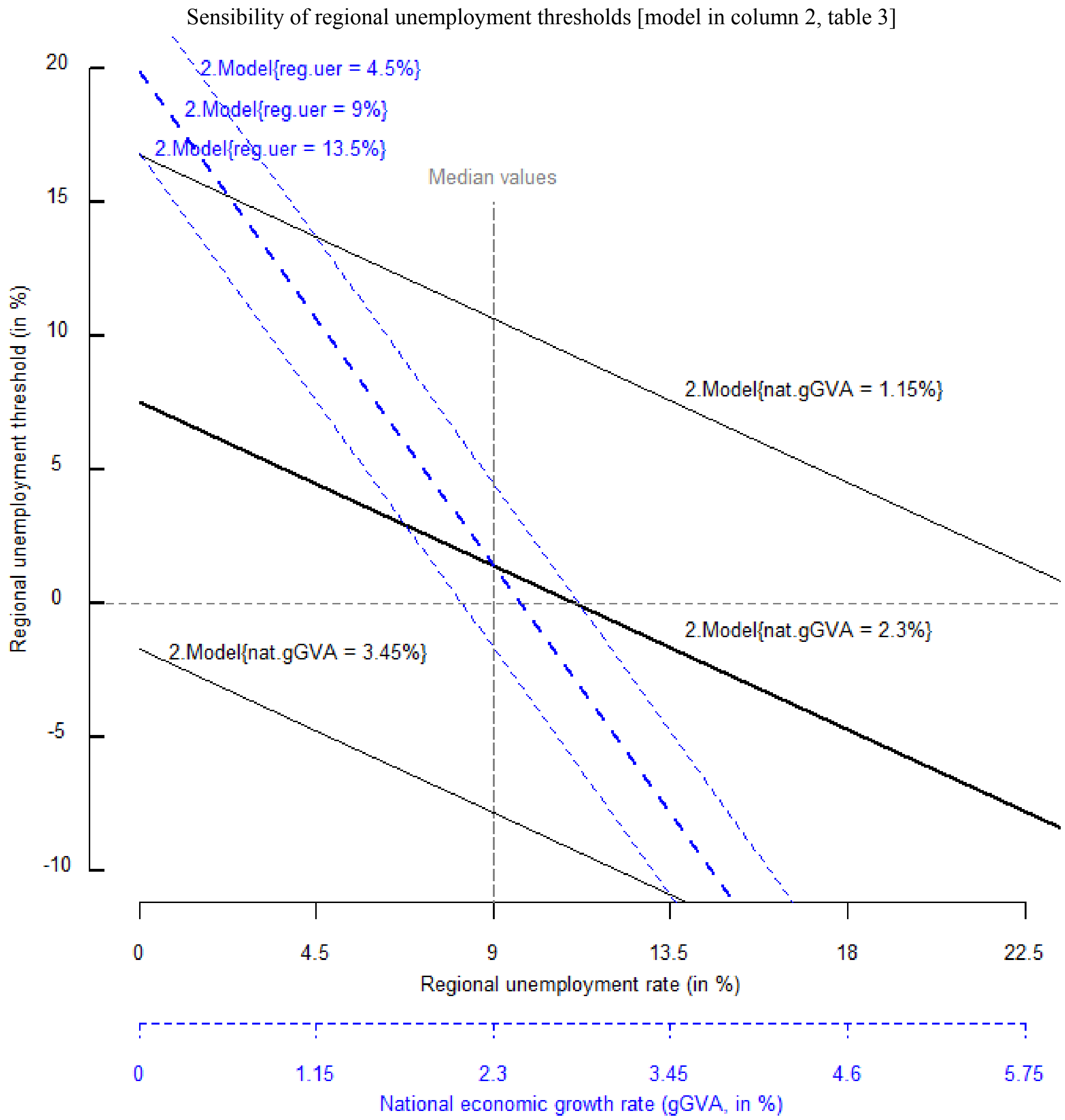
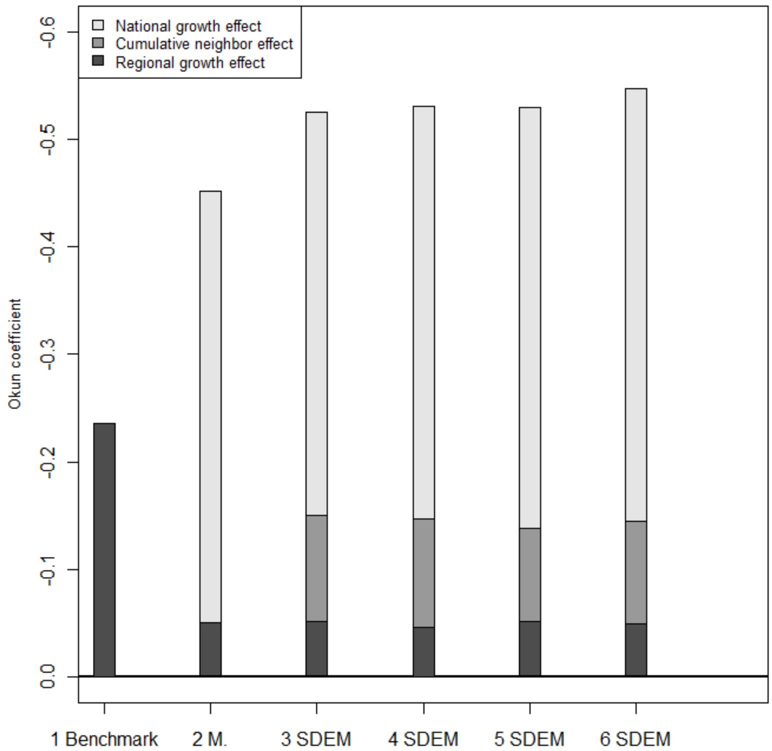


Figure 3: Threshold sensitivity

This first comparison between models [1] and [2], with large changes in the magnitude of estimated effects that are highly significant, illustrates the necessity to account for macroeconomic effects and regional characteristics. However, the deductions of the Chow test that indicate instability over time remain true for the extended model that includes the national economic growth rate and the regional level of unemployment.[xxvi] This indicates evidence for an omitted variable bias. Such a bias is in general likely, due to the variety of influencing factors on the regional labor markets which are not included here. In addition, spatial autocorrelation may be present, for example due to imperfect market delineation. All these issues are addressed with the application of spatial econometric panel data models, in particular the Spatial Durbin Error Model (SDEM) with spatially lagged explanatory variables and a spatial error process, given in [4]. As described in section 5.3, the use of this type of model is advocated in the spatial economics literature (e.g. LeSage/Pace 2010, Elhorst 2010) to address unobserved and spatially dependent effects, and thus can increase the performance of estimation models substantially.

A direct integration of the set of explanatory variables **X** and optional fixed effects into a SDEM structure can result in multicollinearity problems, caused in particular by the structural dummy variable *east* ($\mathbf{x_3}$) (see the overview on variance inflation factors provided in Appendix 3). Therefore, the dummy variable *east* ($\mathbf{x_3}$) is dropped in the following analysis due to its insignificance in the foregoing estimation and multicollinearity problems. In the 3rd column of table 3 the results are given for a SDEM with the extended set of explanatory variables **X** based on equation [3]. The regional level of unemployment rate is interacted with the dummy variable for the crisis ($\mathbf{x_6 \cdot x_4}$) to control for regional differences in response towards the crisis. The spatial lag of this interaction term is not included, again due to multicollinearity problems. In the 4th, 5th and 6th column the results for the estimations on the combined SDEM and regional individual fixed effects model are presented, see equations [6], [7] and [8]. Those allow capturing the regional heterogeneous characteristics and/or differences in regional response towards the economic crisis, while accounting simultaneously for spatial dependency and non-systematic linkages between regional markets. The models in columns 4 and 6 include an individual intercept for each region, while in the 3rd and 5th column the substitute variable level of unemployment rates ($\mathbf{x_6}$) is applied. To capture a regional heterogeneous response towards the economic crisis, the models in columns 3 and 4 contain an interaction term between the regional level of unemployment with the dummy variable for the *crisis* ($\mathbf{x_6 \cdot x_4}$), while the models in column 5 and 6 consist of vectors for the regional intercepts multiplied with the *crisis* dummy variable ($\boldsymbol{\alpha}_\mathbf{R} \cdot \mathbf{x_4}$). Note that for the model of column 5 the response towards the economic crisis in 2008 to 2009 takes into account an interaction term of regional characteristics with the *crisis* dummy variable ($\mathbf{x_6 \cdot x_4}$); and therefore the dummy variable for the *crisis* itself is dropped.

The estimation results for the SDEM confirm the rather low regional Okun coefficients of around -0.05 in the dynamic perspective. From the newly added parameters in the SDEMs, the spatially lagged regional economic growth rates of $\mathbf{W \cdot x_1} \approx -0.04$ and the spatially and time-lagged regional economic growth rates $\mathbf{W \cdot x_2} \approx -0.06$ are indicated as significant. $\mathbf{W \cdot x_1}$ is the effect of the average growth in the neighboring regions on the regional labor market, and $\mathbf{W \cdot x_2}$ the same for the growth rates in the previous period. Although the primary motivation for including spatial lags is to capture unobserved effects, the slightly higher magnitude may require some explanation. For those spatial lags it must be considered that this is a cumulative effect over neighboring regions, summarizing the effects over all regarded regions (Lerbs/Oberst, 2012). With the SDEM, the explanatory power of the estimation increases once again. There is no general preference for the SDEMs with fixed effects in the form of dummy variables (see e.g. 4th column in table 3) or the SDEMs using the substitute variable. Both types of models basically tell the same story and, if anything, this shows the robustness of the Okun estimators. However, the regional individual fixed effects and their interaction term for the regional heterogeneous response towards the crisis are ideal to map geographically, while for the alternative variables a general economic interpretation is more obvious.



Ordinate: inverted scale.

Figure 4: Growth effects on the regional labor market (model comparison)

For a model comparison of the estimated economic growth effects on the regional labor markets and its separation into regional, national and neighbor-region growth effects see figure 4. This illustration supports the conclusion of the robustness of the results. The resulting overall effect of about 0.5 is comparable with estimates in macroeconomic analysis for Germany (see e.g. Schalk/Lüschow/Untiedt (1997), Moosa (1997), OECD (2010)). The magnitude of the cumulative neighbor effect can primarily be attributed to directly neighboring regions. An overview on the resulting regional unemployment thresholds is given in figure 5, see table 3 for associated estimation results. The necessary assumption (except for 1 benchmark model) for macroeconomic conditions for the calculation is a 2.3% increase in national economic output p.a. The bar plots display the general value of the estimated regional unemployment thresholds. For the benchmark model these are two bars (left for western regions and right for eastern ones), for models in columns 2, 3, and 5 the value is calculated on the basis of a hypothetical regional labor market with an unemployment rate of 9% (median, 2001 to 2007), in contrast, for models in columns 4 and 6 no general threshold can be computed. The boxplots display the distribution of 110 regional unemployment thresholds, whose calculation for models 2, 3, and 5 is based on regional unemployment rates for 2001 and for models 4 and 6 on the estimated regional fixed effects ($\boldsymbol{\alpha}_{r=110}$). The scale on the right-hand side of figure 5 displays the shades for the following maps on the geographical distribution of regional unemployment rates depicted in figure 6. These maps are in accordance with the boxplots in figure 5.

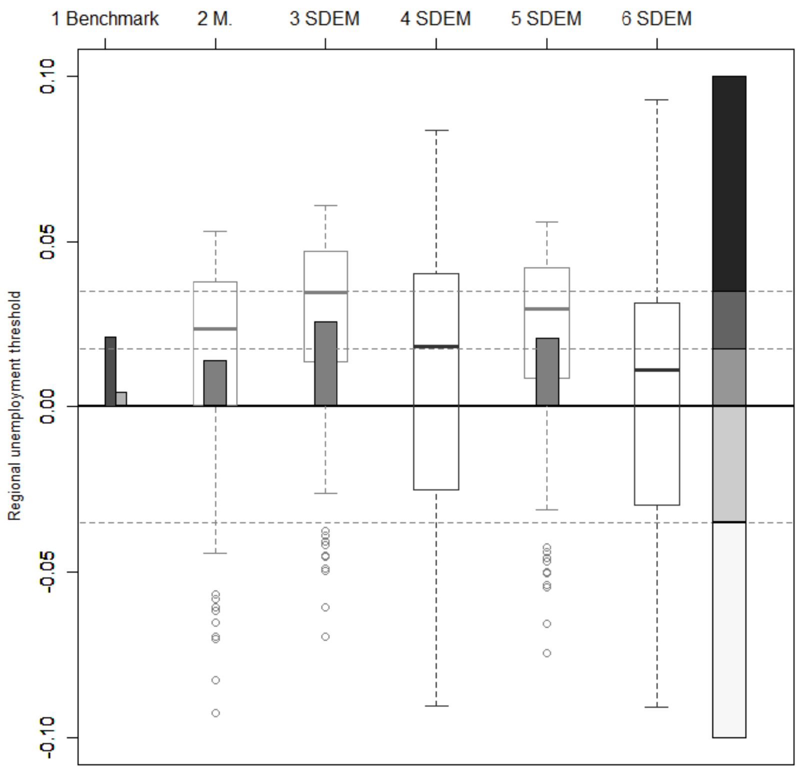


Figure 5: Regional differences in estimated unemployment thresholds across models

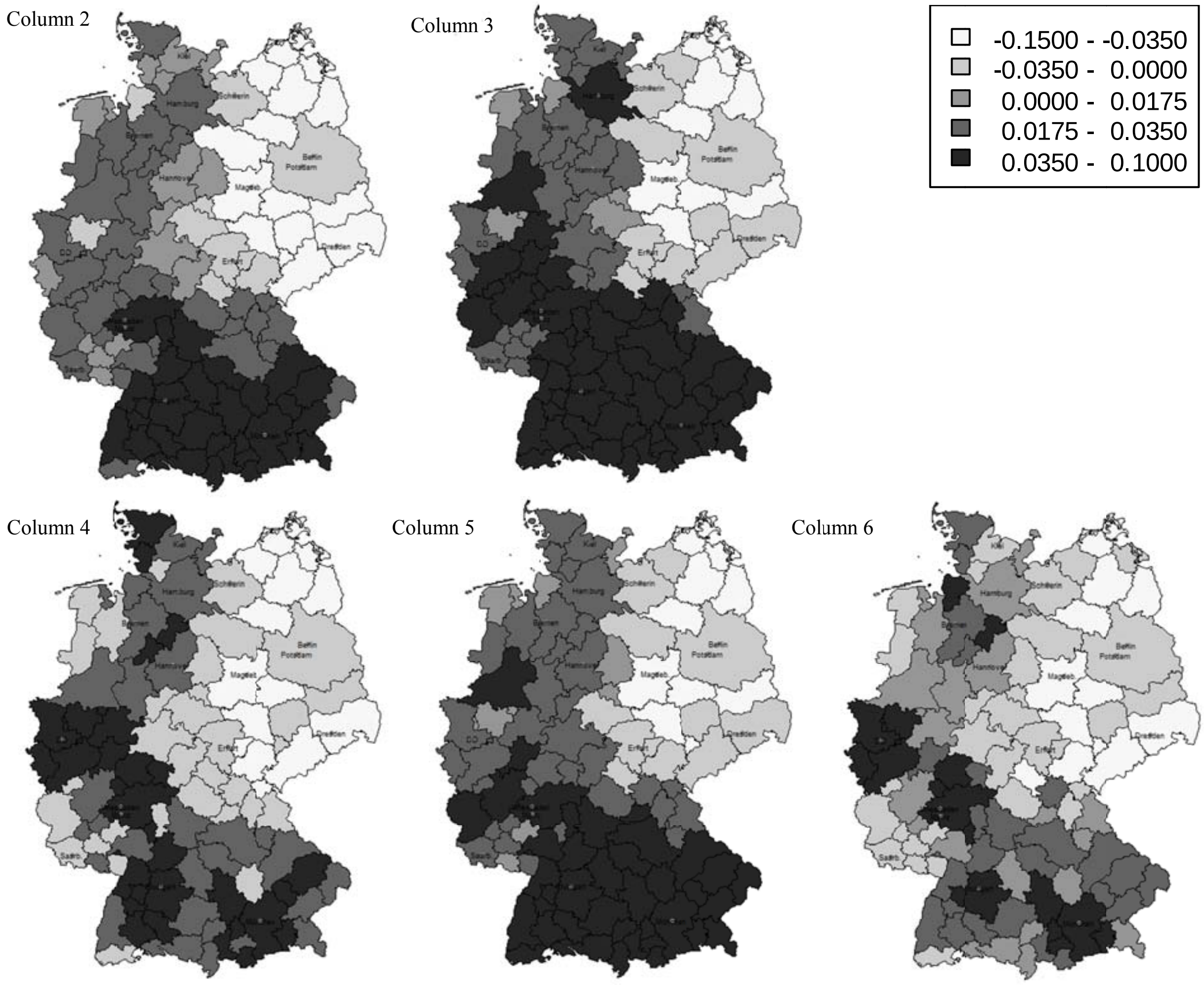


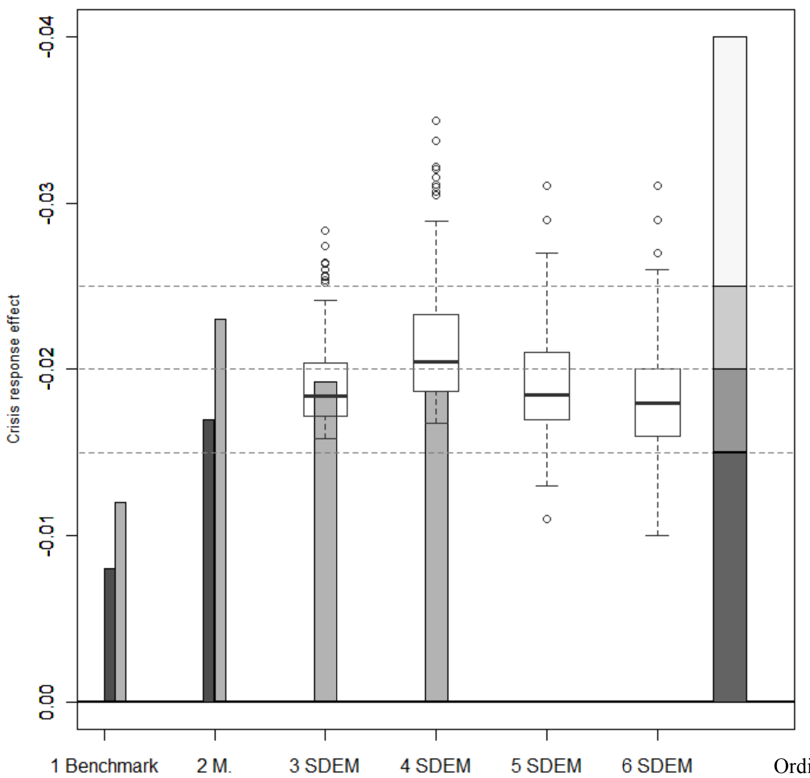
Figure 6: Geographical distribution of regional unemployment thresholds

The crisis response is indicated by regression coefficients of the terms c*risis* ($\mathbf{x_4}$), *east·crisis* ($\mathbf{x_5}$) and uer_{t-1}·*crisis* ($\mathbf{x_6 \cdot x_4}$), respectively. An overview of the estimated crisis response across models is given in figure 7 and can be interpreted analogously to figure 5. The same applies for the geographical distribution of the estimated crisis response, which is visualized by the maps shown in figure 8.

The empirical results show that the Okun relationship between economic output growth and labor market development cannot be transferred one-to-one from the national level to the regional level, and neither can the estimation strategy. Estimations that do not account for spatial dependence can likely overestimate the Okun effect markedly, which is in accordance to Kosfeld/Dreger (2006). Additionally, the results show a level effect, as regions with higher unemployment rates face a more intensive decrease of the unemployment rate, which we interpret as an ongoing convergence process of the regional labor markets in Germany. This is shown to be especially true during the crisis period, which might be explained by the impact of the crisis that was especially driven by break down of international trade. As Burda/Hunt (2011) illustrate, the export shock due to international turmoil predominantly hit regions with high export dependence and a sound labor market situations, mainly in the south-east of Germany. Regions with high unemployment rates in e.g. eastern Germany had minor problems caused by the crisis. However, a general uncoupling effect between economic growth and changes in the labor market is not indicated in the empirical results, but rather a structural shift for the crisis period. One limitation of the analysis is that it cannot predict if this shift will be revoked in an economic revival or if it remains.

6.2 Sensitivity analysis

The empirical results turned out to be very robust over different modeling approaches (with the exception of the reference model), namely: pooled panel data estimation that account for regional characteristics and macroeconomic conditions; time or regional individual fixed effects models; spatial panel data applications (with spatial error models and SDEM); as well as a combination of both with a SDEM including regional individual fixed effects. However, economic theory provides little guidance on which definition of functional regional economic areas or which labor markets are more suitable for this analysis, and how spatial weights for the spatial models should be specified. In order to examine the robustness of the results with respect to this chosen definition of regional markets and spatial weights, three different functional labor market definitions and three different spatial weight matrices **W** are employed.



Ordinate: inverted scale.

Figure 7: Regional differences in estimated crisis response across models

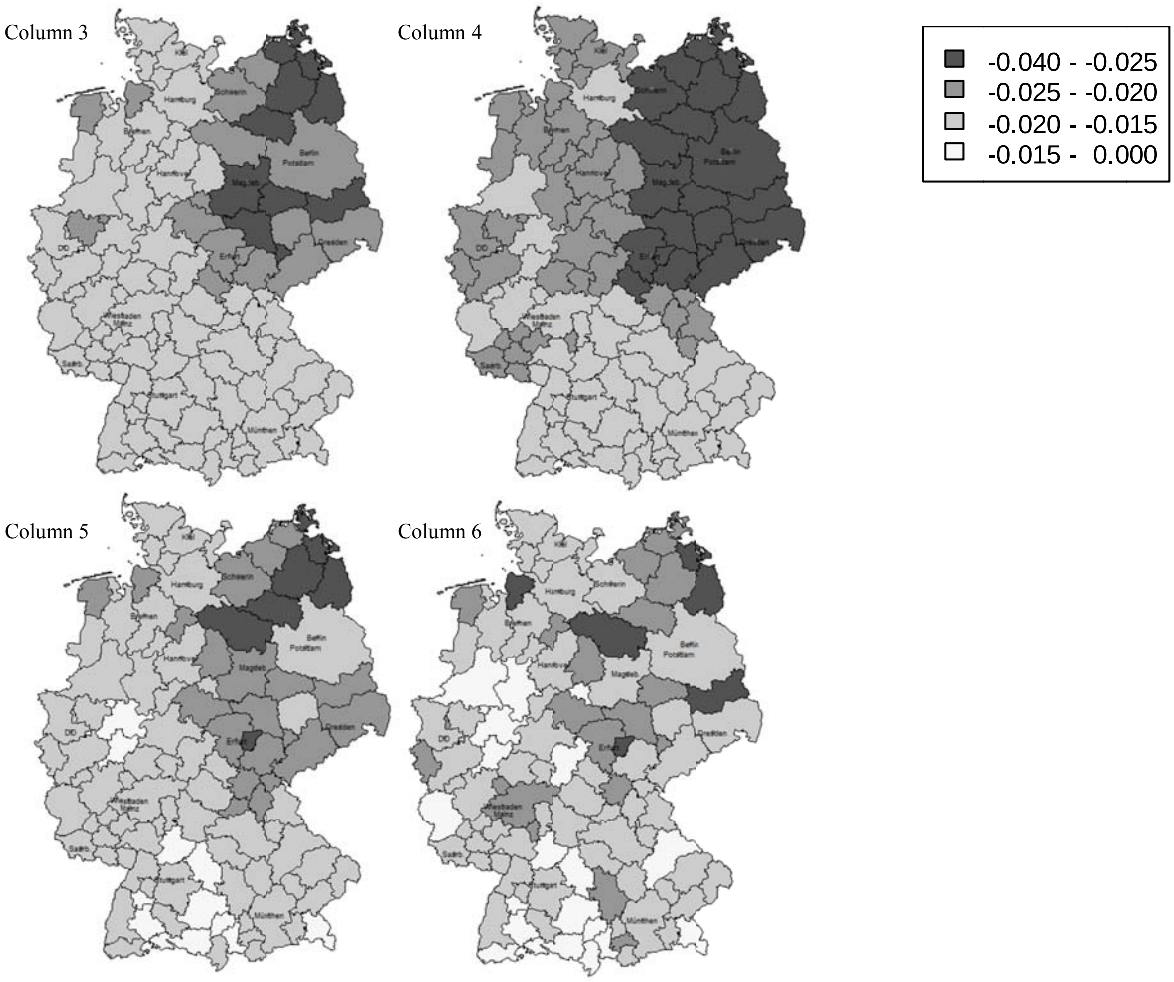


Figure 8: Geographical distribution of the estimated crisis response effect

The results for our 110 reference regions (Oberst, 2012) are compared with those for 50 labor market regions defined by Kropp/Schwengler (2011), and the 413 adminstrative districts.[xxvii] The delineation by Oberst (2012) is based on an evolutionary computational cluster analysis approach, while Kropp/Schwengler (2011) use a graph theory approach. Both delineation procedures are applied on commuting patterns and are aligned with the boundaries of the 413 administrative districts. On the one hand, this selection covers a variety of delineation approaches and on the other hand a bandwidth of different quantity and size of regions, whereby the reference regions here can be classified as middle sized and more homogenous in structure. The results on the basis of the alternative 50 labor market regions mainly confirm the previous presented ones. The utilization of the 413 administrative districts illustrates the shortcomings of administrative borders for regional economic analysis and its distorting effects on estimation results. In a second step, spatial weights matrixes W are varied. In addition to the first-order queen contiguity matrix, all calculations are performed for a four nearest neighbor inverse-distance matrix (using Euclidean distances between the regions centroids) and for a 90-km threshold-distance matrix. The results turned out to be largely insensitive to the alternative weight matrices.[xxviii]

7 Conclusion and outlook

Our results confirm the assumption of a positive impact of economic growth on labor market performance. Although it is likely that other impact factors apart from economic growth influence the utilization ratio of the labor force as well, we conclude that economic growth is an important driving force on regional labor market effects - or at least an appropriate summarizing indicator for these regional economic developments. However, the estimated effect of regional economic growth for German regions is far lower than it would have been expected in view of the macroeconomic literature on Okun’s law. On the one hand, this might be attributable to the regional study areas rather than national economies and, on the other hand, to the drawbacks of spatial dependency, to regional characteristics and to omitted variable bias if regionalized Okun models are designed inappropriate, as discussed in this paper. Our empirical finding for a regionalized Okun coefficient for German regions is in a dynamic perspective about 0.05, meaning that a region with a 1% additional growth in regional economic output undergoes a reduction of regional unemployment rate of 0.05 percentage points per year (e.g. from 10% to 9.95%). About 0.03 percentage points occur directly in the same annual period and 0.02 percentage points are time delayed until the following period. In comparison, an additional national macroeconomic growth of 1% is estimated to correspond to a reduction of regional unemployment rates by 0.4 percentage points per year (e.g. from 10% to 9.6%). This illustrates the limited transferability of empirical results for the macroeconomic rule of thumb of Okun’s law for growth dynamic to a disaggregated regional level, as well as the limitations of regional growth dynamics for regional labor markets. Even when the analysis is based on functionally delineated regions, effects and actions focused on a single regional market will, in addition to the macroeconomic situation, be influenced by adjacent markets, and vice versa. This will occur on an even more intense level if measures are limited to administrative borders and spillovers are neglected. These findings are in line with Niebuhr (2003). The regional economic policy implication that can be derived for the results presented here is an interesting albeit likely depressing one for regional growth strategies that imply labor market effects with a regional focus.

As national economic growth rates are identified as a dominating influence on regional labor market performance it becomes obvious, with regard to the heterogeneous structure of German labor markets, that national prosperity does not reach all parts of the country equally in the long term. Thus, regional characteristics such as sectoral structure, the level of infrastructure, urbanization, etc. and their influence on labor-intensive growth should be areas for further research.[xxix] Here we conclude that regional growth policies are not appropriate to regional and delimited labor market effects. Regarding the suitability of Okun's law in general, the identification of the national growth rate favors the macroeconomic rule of thumb. However, it is also shown that regional characteristics and labor market situations matter. Even though the growth patterns are shown to be significant and stable, the heterogonous regional effects behind such a national indicator demonstrate its limitations.

On the methodological side, this paper shows that the drawbacks of omitted variable bias and spatial dependency lead to overestimation of the relation between regional growth and changes in the labor market. With all three extended estimation approaches, i.e. the fixed effects models, the spatial models, and the combination of both, this overestimation in comparison to the benchmark model can be identified. The ability of spatial models to capture unobserved effects can be shown by the following contra-positioning: estimation results for the Okun relationship with the explanatory variables from the reference model in a spatial model do match with the results from models that control for macroeconomic conditions and regional characteristics. In a non-spatial setting the effects without accounting for such factors are evidently overestimated. On the basis of the argument above regarding the limited possibility of capturing all relevant impact factors on labor market developments on a disaggregated regional level, the suitability and beneficial characteristics of the combined approach of functional delineated labor markets and the Spatial Durbin Error Model (SDEM) is elaborated theoretically and endorsed empirically in this paper.

Acknowledgments

The authors thank the participants of the 50th winter seminar of the GfR, the German speaking section of the European Regional Science Association (Matrei/Ostirol, Austria), the Research Seminar in Economics at the School of Business and Economics, RWTH Aachen University, and the CAWM Doctoral Seminar at Muenster School of Business and Economics, University of Muenster. The authors are also grateful to Reinhard Madlener and Ray Galvin for carefully editing this article. All remaining errors are the authors' responsibility.

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Notes

[i] This expression is widely used in the literature concerning Okun's law; see for example Harris/Silverstone (2001), Freeman (2000), Palley (1993), and Nguyen/Siriwardana (1988).

[ii] The asymmetric development of the Okun coefficient in times of recession compared to expansions is shown by Harris/Silverstone (2001) and is confirmed for Canada and the USA by Beaton (2010).

[iii] Lee (2000), for example, identifies different results for the first-difference and the gap approach.

[iv] The gap version is in line with the original approach of Okun as the output gap is chosen as the parameter for the economic development and the natural unemployment rate for the labor market. Both the potential output and the natural unemployment rate have to be estimated. This is inappropriate for this study, as an estimation of both variables on regional level would lead to further problems and blurry results.

[v] Apergis/Rezitis (2003) estimates quite similar Okun coefficients for six out of eight Greek regions and find, using a first-difference variation, a structural break in 1981.

[vi] A critical review of the influence of sectoral structures on regional unemployment rates can be found in Elhorst (2003).

[vii] In his critical review on Okun's law, Knotek (2010) suggests to use dynamic aspects.

[viii] Further alternative regional labor market definitions for Germany can be found in Eckey/Kosfeld/Türck (2006) and Kosfeld/Werner (2012).

[ix] See Michels/Oberst/Hiller (2011). In addition, Royuela/Vargas (2007), using a delineation approach, find that housing markets defined on commuting areas are more homogenous in price than those defined on migration patterns.

[x] The dependent variable of change in unemployment rates is available up to 2002. The main explanatory variable of economic growth, measured in GVA, is available until 2009.

[xi] Apergis/Rezitis (2003) use a slightly different approach, as they split their regression into two estimations for the pre- and post-period of the structural break for Greek areas. The approach used here is in line with Schalk/Untied/Lüschow (1997).

[xii] There are some concerns about using regional housing prices as an approximation for regional differences in the inflation rate, e.g. potential endogeneity problems with the dependent variable and the major explanatory variable of economic growth. The question whether it reflects asset-price inflation or if it reflects inflation on consumer goods has to be discussed. Nonetheless, this is an important area for future research and the authors are thankful to C C Michelsen for intense discussions about this issue.

[xiii] The growth of "all other regions" is calculated as follows: $\frac{\sum_{k \in R | k \neq r} GVA_{r,t}}{\sum_{k \in R | k \neq r} GVA_{r,t-1}} - 1.$

The total of absolute values for differences between national economic growth rates and the calculated growth of all other regions for the 880 observations is 0.1096, the standard deviation of these differences is 0.0003. The correlation between the national economic growth rates and the calculated growth of "all other regions" is 0.99993.

[xiv] See Lerbs/Oberst (2012).

[xv] Moran's I is defined as: $I = \frac{N}{W_0} \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N} (x_i - \bar{x})^2}$; with $W_0 = \sum_{i=1}^{N} \sum_{j \neq 1}^{N} w_{ij}$.

[xvi] Another common type of systematic linkages between regions is migration flows, which, however, are strongly correlated with commuting patterns.

[xvii] See a comparable argument in favor of a spatial error in Lerbs/Oberst (2012).

[xviii] Besides the pooled and fixed effects model, there is a third type of panel model: the random effects model. The random effects model is less restricted than the fixed effects model, and its estimators of regression coefficients can be more statistically efficient, but its individual effects are assumed to be not correlated with the included explanatory variables. However, there is most likely to be such correlation in the employed regional panel data set, which can be confirmed with a formal statistical test (Hausman-test).

[xix] Note that there are attempts to quantify regional inflation rates. See, for example, Kholodilin/Silverstovs (2012). However, the published regional inflation rates are on a different spatial reference level.

[xx] LeSage/Pace (2010) point out that spatial dependence amplifies conventional omitted variable bias when there is non-zero correlation between the included explanatory variables and any omitted regional characteristics. The magnitude of bias amplification depends on the relative strength of spatial dependence in the dependent and the independent variables and the disturbances. Independence of included and unobserved variables in this regional panel is unlikely here, given that any latent regional characteristics, labor market developments and growth factors should exhibit very similar patterns of spatial dependence.

[xxi] See a comparable statement in Lerbs/Oberst (2012).

[xxii] See Millo/Piras (2011) according to Baltagi et. al. (2007), Anselin/LeGallo/Jayet (2008), Elhorst (2009), and others.

[xxiii] The estimators are the same as if the model is estimated with ordinary least square (OLS); only the standard errors differ very slightly (with no consequences for the indicated significance).

[xxiv] The thresholds indicate the economic growth required to keep the unemployment rate constant.

[xxv] The hypothesis of stability over time can be rejected at common significance levels, while across regions it cannot. Both times a so-called Chow test is applied. Even though the hypothesis of parameter stability across regions cannot be formally rejected, it is doubtful that it has an effect on the relationship (as estimation results will confirm later on). Therefore, the effect of different characteristics on the regional labor markets is tested next, in addition to account for macroeconomic effects. The latter should ensure stability of the estimation over time. Adanu (2005) shows, for example, that the Okun coefficient depends on the regional degree of industrialization and the size of the population. Chow test statistics: the stability of the estimated relationship in [1] between regions cannot be rejected at the common significance level (F = 0.33, df1 = 108, df2 = 766, *p-value* = 1.00), but only the stability over time of the coefficients can be rejected F = 408.6, df1 = 6, df2 =868, *p-value* = 0.00).

[xxvi] Test on stability over regions, F = 0.6327, df1= 109, df2= 763, *p-value* = 0.9984; on stability over time: F = 198.81, df1=5, df2=867, *p-value* = 0.00.

[xxvii] For a comparison of six different labor market delineations see Kropp/Schwengler (2012).

[xxviii] The results are available from the authors upon request.

[xxix] There is still some research being done on this topic; see, among others, Dauth (2010), Elhorst (2003) or Zierahn (2012).

List of FCN Working Papers

2013

Grieser B., Madlener R., Sunak Y. (2013). Economics of Small Wind Power Plants in Urban Settings: An Empirical Investigation for Germany, FCN Working Paper No. 1/2013, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, January.

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