Max-Planck-Institut für demografische Forschung
Max Planck Institute for Demographic Research
Konrad-Zuse-Strasse 1 · D-18057 Rostock · GERMANY
Tel +49 (0) 3 81 20 81 - 0; Fax +49 (0) 3 81 20 81 - 202;
http://www.demogr.mpg.de

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Culture Resurfaces - A Geographic Analysis of Fertility Decline in Prussia

Joshua R. Goldstein (goldstein@demogr.mpg.de)
Sebastian Klüsener (kluesener@demogr.mpg.de)

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Max Planck Institute for Demographic Research

Abstract

In this paper, we re-introduce geography into the analysis of fertility decline in the first demographic transition in Europe. We reanalyze Galloway et al.'s (1994) Prussian data applying econometric spatial modeling techniques. Our multivariate analysis provides evidence both of the predictive effect of economic and cultural variables. Furthermore, even after controlling for all observable cultural, economic and demographic variables, a significant unexplained geographic clustering of fertility decline always remains. Indeed, adjacency to an area of large fertility decline and location along communication and transport corridors seem to be important predictors of fertility decline beyond what one would expect from structural models. This provides some new support for the cultural diffusion hypothesis of the Princeton European Fertility Project, as well as includes direct structural effects of economic and demographic change.

> *"A persistent finding of the recent research on fertility decline in Europe is that the onset and spread of the fertility decline appears to cluster regionally in a way that cannot be explained through common socioeconomic characteristics" (Knodel / van de Walle, 1986, p. 413)*

Introduction – The Emergence of new Patterns of Social Behavior in Time and Space

Geography used to play an important role in the debate on ideational and economic explanations of Europe's historical fertility decline. The geographic clustering of fertility decline and the salience of linguistic borders were prime pieces of evidence in the conclusions of the Princeton European Fertility Project (Coale / Watkins, 1986). Historical fertility decline, it was argued, appeared to be more like the cultural diffusion of a new innovation -- the idea/ cultural acceptability of family size limitation -- than an adaptation to changing economic circumstances. Subsequent research, which made use of richer data both with regard to geographic detail and available demographic and economic covariates, has challenged the Princeton Project's findings (Galloway et al., 1994; Brown / Guinnaine, 2002). These new studies made great strides in statistical modeling. Instead of analyzing variation in fertility levels, they used panel methods to focus on the explanation of changes in fertility rates. Despite the use of geographic data, however, the new panel approaches stopped short of asking whether economic and demographic change can explain the spatial pattern of historic fertility decline in Europe.

In this paper, we aim to reinsert spatial analysis into the debate about historical fertility decline. Focusing on Prussia, where perhaps the finest quality data is available, we show first how there was strong spatial clustering in the fertility decline. Secondly, the available detailed data allows us to demonstrate that this geographic clustering persists even after controlling for all of the available economic, social, and cultural variables. This finding leads us to conclude that the explanation of fertility decline requires **both** economic and ideational explanations of the first demographic transition. Fertility falls in a particular area either because of conditions in that area or because it is next to an area where fertility is falling, or through a combination of these effects.

Previous Research

The idea of explaining fertility decline as either an adaption or innovation was introduced by Carlson (1966), who emphasizes that innovations will diffuse spatially over time, whereas adaptations will follow the patterns of the phenomena of interest, such as economic change or increased infant survival. Ever since, the innovationist perspective emphasizes the diffusion of the idea/ cultural acceptability of parity-specific fertility control, whereas the adaptationist perspective emphasizes that it is changing circumstances that are linked to a new behavior.

During the 1960s, 1970s and 1980s, the work of the Princeton Fertility Project (e.g. Coale / Watkins, 1986) and others such as Cleland and Wilson (1987) leaned strongly toward the diffusionist perspective. In the language of Knodel and van de Valle (1986), the "lessons of the past" were (1) the variety of social, economic, and demographic conditions that accompanied fertility decline (2) the absence of fertility limitation before the fertility decline, despite unwanted births (3) the irreversibility of the decline of marital fertility and (4) the importance of cultural setting "independently of socioeconomic conditions". Cleland and Wilson concluded "clearly the simultaneity and speed of the European transition makes it highly doubtful that any economic force could be found which was powerful enough to offer a reasonable explanation" (1987, p. 18; also Lesthaeghe / Wilson, 1986, p. 209).

The lessons of the Princeton Fertility Project could also be seen in maps. The first color plate of the summary volume shows the "Estimated date of sustained decline in I_g (marital fertility), by province of Europe" (Coale / Watkins, 1986, Map 2.1). Early declining provinces are shown in bright red, entirely within the borders of France. Late declining provinces, clustered in Ireland, Spain and southern Italy are shown in dark blue. The impression of the reader is of enormous geographic clustering, with barriers to the spread of fertility limiting behavior occurring along national and/ or cultural borders, in Watkins words "contiguous provinces that shared a cultural as well as geographic location had similar levels of nuptiality and fertility and similar patterns of decline" (Watkins, 1986, p. 448). Watkins (1991, p. 171) also noted that the "geographic spread of fertility control within marriage is consistent with the existence of networks that stretched across (…) Europe; (…). The patterns of fertility decline are also consistent with the assumptions that these networks decayed with distance". Thereby, "it seems likely that new information about fertility control and new images of ideal family size came into the local communities through personal networks as well as through national institutions such as the press, and eventually, state health and welfare bureaucracies" (Watkins, 1991, p. 171).

Although economic explanations were often invoked as an alternative to diffusionist explanations by Princeton Project authors, the project was open about the crudeness of its economic measures and of the statistical methods used in the analysis[1]. Since the Princeton Project, a number of authors, notably economic historians, have brought finer scale data and more advanced methods to bear on the question of whether fertility decline could be predicted from changing circumstances. Germany has proved site of research, combining the substantive interest of religious and cultural diversity

[1] Watkins notes some of the deficiencies, pointing to Richards (1977) as an example of "More sophisticated statistical techniques [that] may prove to be more fruitful." (1986, p. 439). Watkins should also be credited with considerable foresight with respect to the econometric studies that would follow, noting that an emphasis on *change* in marital fertility would be preferable to the Princeton Project's focus on *levels*. With prescience, she also wrote that the Princeton Project's analysis at the level of provinces "may still mask considerable demographic heterogeneity among smaller geographic regions."

and the availability of fine level administrative demographic, economic, and social statistics. We follow in the tradition begun by Richards (1977) in her broad regional analysis of Germany, Galloway et al.'s (1994) finer level study of *Kreise* (small districts) in Prussia, and Brown and Guinnaine's (2002) study of small areas in Bavaria.

Richards (1977) was the first study that we know of that used panel methods to study the explanatory factors of fertility decline. She used the Princeton dataset for Germany set up by Knodel (1974), where the German Empire was divided in 71 regions. Her finding suggested that structural factors such as the proportion of the population in agriculture vs. industry were very powerful in explaining fertility decline.

Galloway et al.'s (1994) analysis of Prussia advanced Richards' study both in the level of geographic detail and in the covariates available for study. The *Kreis*-level gave 407 geographic time-constant units. Furthermore, the economic variables could include much finer levels of modernization, notably the fraction of workers engaged in categories as such as banking and insurance, as well as female labor force participation. Galloway and his coauthors argued that

> *"Our analysis suggests that inferences drawn from previous research have resulted in a misunderstanding of the spatial heterogeneity of fertility decline, unwarranted rejection of the importance of economic factors, and over-emphasis of cultural or traditional factors. (...) While cultural proxies and education are important, structural and economic forces, especially the growth of financial institutions and communications and female labor force participation, are strongly associated with fertility decline in 19th century Prussia, mirroring those processes often associated with fertility decline in many less developed countries today."* (Galloway et al., 2002, p. 5 f.)

Brown and Guinnane (2002) also take advantage of highly detailed data in Bavaria, which is left out of the Prussian analysis. They emphasize the detection of both cultural and economic effects in their analysis of Bavaria, concluding "the European Fertility Project was right about the role of religion and secularization, but missed an important role for the economic and structural effects stressed by economic historians" (Brown / Guinnane, 2002, p. 35).

At the heart of all three of these econometric studies is an emphasis on using regional fixed effects, which has as a consequence that one is looking at the effect of changes in a local area's fertility resulting from changes in that local area's covariates. Thus, for example, changes in infant mortality within a region are used to predict changes in marital fertility.

In a sense, the regions are treated as *nuisance* parameters, with the underlying causal effect of say infant mortality or female wages being of interest. However, if we wish to explain the geographic pattern of fertility decline, then it is not only the coefficients in the fixed effect models that are of interest but the degree to whether these models explain the geographic pattern of decline. Our approach is to examine this directly, not only from a statistical point of view of explained variance but also to map directly the geographic patterns of unexplained fertility decline.

We can build up on earlier work by Montgomery and Casterline (1994), who studied the diffusion of fertility decline in Taiwan with panel models. They noted that "diffusion exists when the adaption of innovative ideas (and corresponding behavior) by some individuals influences the likelihood of such adaption by others" (Montgomery / Casterline, 1994, p. 458). They expected these processes to play a role in settings (1) where people lack information on fertility control options; (2) where uncertainty exists with respect to the benefits and costs of fertility control. In these cases pioneering behavior of local reference groups can decrease the level of uncertainty and lead to a fast spread of this behavior inside a community. (3) A third important setting is where people fear that deviating behavior from existing cultural norms leads to sanctions. These fears might diminish fast after first pioneers deviated from this behavior without facing substantial negative consequences. In all cases, where such mechanism exists, "the diffusion process itself possesses an explanatory dimension: Change in behavior stimulates further change" (Montgomery / Casterline, 1994, p. 459).

Montgomery and Casterline (1994, p. 479) take the autoregressive behavior of fertility in their model as evidence for diffusion. They find in their models on the Taiwanese case strong evidence for within township diffusion by introducing time-lagged fertility levels as predictor in their models. But when they introduce spatially lagged fertility levels as independent variable, they find only weak support for diffusion across township borders and no proof for city-to-countryside diffusion. But Taiwan should not be considered definitive for at least two reasons. First, the island of Taiwan is small and does not offer the distances one might need in order to see gradual spatial diffusion over time and space. Second, the fertility decline in Taiwan occurred at a time when there were nationwide family planning programs, as well as nationwide TV and radio mass media existing. Prussia, in contrast, covered a vast geographic area, stretching some 1,000 km from east to west and 350-500 km from north to south. Furthermore, although there was some national print media available, the vast majority of media and communication was local in character. Prussia is a case, where if spatial diffusion were important, we would expect to find it.

Other studies focusing on understanding the spatial pattern of fertility decline include the work of Bocquet-Appel and Jakobi (1996), who applied a hierarchical diffusion model to study the spread of fertility decline in Europe between 1870 and 1960 based on the provincial data from the Princeton Fertility project. Importantly, they do not control for cultural or economic factors. With their models they were able to identify major spatial discontinuities in the fertility levels at different points in time. These discontinuities often followed cultural or political borders. Gonzáles-Bailón and Murphy (2008) used an agent-based-model to study the historic fertility decline in France on the provincial level of departments, controlling for the level of secularization. They find support for their hypothesis that the fertility behavior of actors depends partly on the behavior of actors who live close to them. Another interesting explorative approach is the one of Schmertmann et al. (2008), who employed a Knox-Cox-survival model to study the *survival* of a region until the onset of the fertility decline. With this model they analyzed the first demographic transition in Brazil, controlling for a small number of development indicators. They conclude that the covariates are able to capture large-scale spatial differences in fertility levels, but that at smaller scale (below 500 km) unexplained clusters of spatial autocorrelation remain, which might be attributed to diffusion/ social interaction (Schmertmann et al., 2008, p. 14).

However, diffusion is not the only explanation for unexplained spatial autocorrelation. Omitted, spatially clustered explanatory variables are also a possibility. As we argue below, we believe that there are several reasons to suggest that diffusion is part of the explanation, namely that the incorporation of a large number of highly predictive covariates does little to reduce the spatial autocorrelation among the residuals. This does not mean that it is impossible for some yet-to-be-observed factor to be responsible, but it does place a burden on critics of diffusion to discover the omitted variables, or at least to explain, what variables could be even more important than the variables we have already introduced.

Data and Methodology

Data

We study the decline of fertility in Prussia using *Kreis* (small district) level data published in the Preußische Statistik. The dataset was entered and coded by Galloway et al. (1994), who kindly shared their data files with us.

The dependent variable is the General Marital Fertility Rate (GMFR), the number of legitimate births multiplied by 1,000 and divided by the married females aged 15 to 49. The latter is taken from censuses that were conducted in five year intervals in the period between 1875 and 1910. For 1875, 1880, 1885 the number of married females is estimated[2]. For the births yearly data is available. In order to limit the noise caused by short time fluctuations Galloway et al. (1994) took a five years average centered on the census year. For example, to get the value for 1890 the average annual number of legitimate births for the period 1888 to 1892 is taken.

We use the same explanatory variables employed by Galloway et al. (1994)[3]: Percentage Catholic; Percentage Slavic; Church Employees per 100 Inhabitants aged 20+; Education Employees per 100 Inhabitants aged 6-13; Health Employees per 100 Inhabitants; Female Labor Force Participation Rate[4]; Income (based on average male elementary school teacher's salary); Mining Employees per 100 Inhabitants aged 20+; Urbanization Rate[5]; Bank Employees per 100 Inhabitants aged 20+; Insurance Employees per 100 Inhabitants aged 20+; Communication Employees per 100 Inhabitants aged 20+[6]; Legitimate Infant Mortality Rate; Ratio Married Men/ Married Women.

We added to the Galloway variables the Share of Votes[7] for the Social Democratic Party (SPD) at elections for the German parliament (*Reichstag*). This is motivated by research results of Lesthaeghe (1977) as well as Lesthaeghe and Neels (2002, p. 342) indicating that vote for a progressive party is a strong predictor of fertility decline (see also Wolf, 1912, p. 148 ff., for an early account on the German Reich). The inclusion of this new variable is of interest to us because it represents an omitted variable that could explain spatial autocorrelation among the residuals.

A challenge with regard to the inclusion of the election variable is that it is only available at the level of the 236 *Reichstag*-election-districts in Prussia. The borders of these election districts do not always follow the borders of the 407 constant administrative districts used in the analysis as the former were created based on the administrative division of Prussia in the 1860ies and remained unchanged until 1918. We included this variable only in a model for the period 1890-1910, as we did not have the data available for the period prior to 1890. Thereby, we took the mean value of the election results from the elections in 1890 and 1912 and estimated the values for the districts based on the available information. A problematic aspect is that the election districts cover in rural areas several districts and we do not have any information on the internal heterogeneity of the election district. This is likely to cause some artificial spatial autocorrelation in this variable. However, in most of the cases the districts forming one election district exhibit very similar values in the

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[2] See Galloway et al. (1994, p. 142) for details.

[3] See Galloway et al. (1994, p. 139) for details on estimations, intra- and extrapolations.

[4] Women employed outside the agricultural and the service sector per 100 women aged 20-69.

[5] Percentage of population living in places with more then 2,000 inhabitants.

[6] Employed in postal, telegraph and railway work.

[7] In the German Empire only men aged 25 and above were allowed to participate in the *Reichstag* election. Every man had one vote.

dependent and independent variables. Therefore, we believe that the effect of this spatial autocorrelation is not of substantial relevance in the modeling process.

Models

We try two alternative model specifications in order to make sure that the results we obtain are not artifacts of a particular approach. In the first model specification, we begin with Galloway et al.'s (1994) original fixed effect panel specification. This model essentially estimates *changes* in marital fertility stemming from *changes* in economic, cultural, and structural covariates. It is specified as followed:

$$y_{it} = \beta X_{it} + D_i + e_{it}$$

where y denotes the dependent variable, while X represents a vector of independent variables; β is an estimation coefficient, D is a vector of district dummies to capture the district fixed-effect; e is the error term.

In addition to the model with dummy specification we also estimate a fixed effects panel model without dummies, where the input data has been demeaned over time. Both model specifications deliver the same parameter estimates, but differ in the resulting R-squared value. We estimated their model for the 407 constant districts, finding the same coefficients as reported in Galloway et al. (1994). For the remaining modeling process we excluded seven time-constant districts that constitute Prussian exclaves in Thuringia and southern Germany. This is necessary as we want to include spatially lagged variables providing information on fertility development in the neighboring regions. For the exclaves there is only little information on this available. This adjustment reduces the sample size to 400 units.

In order to show the robustness of our findings to other model specifications, we developed an alternative model of fertility decline in Prussia that predicts change in marital fertility as a function of the *change* in some covariates and the *levels* of others. This specification, we believe, offers some improvements over the original specification from Galloway et al. (1994). Our motivation will be discussed below. The alternative change-and-level model is specified as:

$$\Delta y_i = \beta \Delta X_i + \beta \overline{Z}_i + e_i$$

where Δ denotes either percentage (or absolute) change in the period studied, X and Z are vectors of covariates. X is representing change-variables, while Z stands for level-variables, where we introduce the mean value for the period studied.

We choose as our dependent variable the percentage change in marital fertility decline. This is in line with the Princeton Fertility Project (see Knodel, 1974, p. 65), that used a 10%-decrease-threshold as important indicator for the onset of the decline. Our choice is also motivated by the fact that the Prussian regions entered the fertility decline at different marital fertility levels. Particularly predominantly Catholic and Protestant regions differed largely in their marital fertility levels (see Fig. 1). With regard to explanatory variables we use the same set of variables used by Galloway et al. (1994) in order to ease comparison. We also calculate a model in which we additionally include information on voting for the progressive Social Democratic Party.

In contrast to Galloway and his co-authors we introduce for the cultural variables Share Catholic, Share Slavic and Church Employees the average *levels* as explanatory variables in the model. This is motivated by the believe that the intensity of the fertility decline is, for example, rather dependent on the overall share of Catholics in an area, who were more reluctant to start controlling their fertility due to religious observations (Knodel, 1974, p. 130 ff.; Praz, 2009), than on how this share is changing. Also Galloway et al. (1994, p. 151) admit that taking change in the Share Catholic as covariate is problematic. It produces a significant coefficient, but with an unexpected sign. According to their model, an increase in the share of Catholic inhabitants has a negative impact on fertility. We will come back to this point in the discussion of the model results.

Apart from this we keep another variable constant: Urbanization Rate. This is motivated by two considerations. One is that seven important cities such as Berlin, Altona (today a part of Hamburg) or Wiesbaden had already in 1875 an urbanization rate of 100%. This could not increase further, although the cities were experiencing high growth rates between 1875 and 1910, shading doubt on whether changes in Urbanization Rate are able to capture this process. The second is based on our believe that the urban population was more likely to reduce their fertility in the transition because of economic and/ or cultural factors for which we do not have data available. One aspect of this is the economic value of children (Becker, 1991). In the period studied the Federal Government of the German Reich introduced three big reforms aiming to limit child labor (1878, 1891, 1903) (Boenert, 2007). But these child labor restrictions were only imposed on the industrial and the service sector, while the agricultural sector did not face any restrictions until the mid 20th century. With regard to cultural factors we believe that modern values of that time were more spread in cities than in rural areas. Also social control, that might have been a bottleneck to fertility decline, was probably higher in the countryside (Lesthaeghe, 1980, p. 536 f.). All these factors are likely to exhibit a clear urban-rural divide. Therefore, the variable Urbanization Rate can serve to some extent as proxy for these characteristics. Also the descriptive findings suggest that the intensity of the fertility decline was related to the urbanization level (see Fig. 1). In the late 1870s there was no clear urban-rural divide in the fertility levels. But in the course of the first decline in the 1870s, and even more evident with the onset of the large-scale fertility decline after 1890 this divide became more and more pronounced. That we take the level values of Urbanization Rate is to some extent also in line with another paper by Galloway et al. (1998a). In that article they concluded that by analyzing fertility change in Prussia with panel models the effects of some covariates vary considerably by urbanization level.

In analogy to the dependent variable we also define change in the explanatory variable Legitimate Infant Mortality Rate in proportional terms[8]. For all other variables, which are mostly economic, we take the absolute change, because they can take on zero values.

With regard to the time period studied we use for the panel model the period 1875-1910, as in the original specification, using data from eight points in time based on a five year interval. For the change-and-level model we base the analysis on fertility change between two points in time, 1890 and 1910, because this was the sub-period when most of the decline occurred (see Fig. 1). Focus on this period also avoids artifactual results stemming from the rise and fall of fertility surrounding the Franco-Prussian war of 1870. We also calculated the change-and-level model for the 1875-1910 period. Its estimates do not vary substantially from the results of the 1890-1910 model.

In total, we calculate two sets of models. The first set with five models resembles Galloway et al.'s fixed effects panel model specification, while the other one with six models follows the change-and-level specification. In each of these two model sets the first model includes only the cultural covariates, while the second covers all economic and development related predictors. The third model is a combined model of all cultural and economic variables that were used by Galloway et al. (1994). For the change-and-level speciation we calculate an additional model, which next to cultural and economic variables also includes the variable Share of Votes for the progressive Social Democratic Party (model 9).

In the last two models of each of the model sets we include a spatially lagged covariate displaying GMFR-changes in neighboring districts. This is a rather crude way to control for diffusion processes. In case, all important structural economic and cultural covariates are included in the model and the covariate with the spatially lagged GMFR-values delivers a significant coefficient, this can be interpreted as an indicator for a spatial diffusion process, for which we do not have data.

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[8] We use the Legitimate Infant Mortality Rate a little bit reluctantly as their might be endogeneity problems (see Galloway et al., 1998b).

We use two different approaches to model the influence of neighboring regions. The *follow the mean*-approach uses the average GMFR-change in the neighboring districts[9] during the period of observation as an exploratory variable (see also illustration in Fig. 2). This kind of model is also known as *spatial lag model* in the literature[10] (see Anselin, 1988). We also introduce a new *follow the leader*-approach, which only takes the GMFR-change of that neighboring district which experienced the highest decline in the period studied. The latter approach might be advantageous in terms of theoretical considerations. If there was a diffusion process it would have spread out from the centers of decline to neighboring areas. This would mean that not all neighbors are equally important, but particularly those, which are ahead in this process.

In order to measure spatial autocorrelation (see Anselin, 1988), we calculate the Moran's I index[11] on the residuals of the models, which is reported in the diagnostics of the model results. With regard to the Galloway panel model we face the problem that we cannot use the residuals of the model, as a panel model returns different residuals for each time period studied. In addition, by definition, the sum of the residuals of a unit over all time periods is equal to 0. In order to estimate the spatial pattern of residuals in the panel model we define the prediction error as follows:

$$PE_i = \left(O_{i,1910} - O_{i,1875}\right) - \left(P_{i,1910} - P_{i,1875}\right)$$

where PE_i denotes the prediction error for district i, O_i the observed values at given times and P_i the predicted value derived from the model.

[9] It is important to note that we only have information on fertility decline in neighboring regions inside Prussia. In border regions this might cause biases, particularly if those regions are situated close to big cities which might be centers of fertility decline (e.g. the Prussian border regions close to the Saxonian city of Leipzig or the Free Hanseatic cities of Hamburg and Bremen).

[10] However, in a spatial lag model the model procedure is to first estimate the parameter for the lagged dependent variable with a Maximum Likelihood estimation due to endogeneity problems that are likely to cause biases in an OLS-estimation. In a second step, the parameters of the other predictors are estimated by OLS-procedure (see Anselin, 1988). We tested both procedures for the change-and-level model, but the estimates did not differ substantially. Therefore, we decided to use the simpler and more intuitive OLS-specification.

[11] The Moran's I index is defined as: $I = \left(\frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}}\right) \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$

where n is the number of spatial units indexed by i and j, and w_{ij} is a matrix of spatial weights. In our case it is calculated based on a *First Order Queen*-definition of adjacency, meaning that all regions with common borders or vertices are considered neighbors.

Descriptive Findings and Model Results

Before we turn to the model results, we will briefly present some descriptive findings. It has already been mentioned above that the fertility decline in Prussia started around 1890 (see Fig. 1; also Knodel, 1974). In order to display the spatial pattern of the process, we constructed a series of fertility percentage change maps, covering the period 1890 to 1912, with the reference value equal to the mean level of marital fertility for the years 1890 and 1891[12]. The resulting maps are shown in Fig. 3 together with a map displaying the share of employees working in agriculture in the year 1882 as a measure for economic development and degree of urbanization. The maps demonstrate that in the first decade the decline was predominantly centered on Berlin and its adjacent areas[13]. In the period between 1900 and 1906 also other regions such as the ones around Magdeburg and Halle in Prussian Saxony, Hanover and the Ruhr area began to exhibit substantial decline. However, in 1906 there were still some big urban centers existing, where fertility levels had not dropped considerably since 1890. This included Breslau, the second biggest city of Prussia, Danzig and Frankfurt am Main. But by 1912 all big cities and their surrounding areas had experienced a substantial fertility decline compared to the levels of 1890.

Visually, the maps might be interpreted as supporting the view, that diffusion played a role in this process. However, structural factors such as economic development or infant mortality decline could themselves be diffusing spatially over time, producing the same visual pattern. In order to assess the possible diffusion of fertility decline, we turn to multivariate models that allow us to control for the spatial influence of changing covariates. Tab. 1 and Tab. 2 display the results of the eleven models. The Moran's I index shows a highly significant spatial autocorrelation among the residuals of all non-spatial models. This indicates that we have to interpret the R-squared values and the parameter estimates with some caution, as they might not be estimated correctly. But the latter is only of little relevance for our main research question, whether the model is able to predict the spatial pattern of fertility decline.

With the model specification of Galloway et al. (1994) we get the already known result that most of the economic variables are associated with fertility decline and exhibit the right sign (e.g. Insurance Employees, Infant Mortality, Female Employment Rate). Among the cultural variables Share Catholic and Church Employees are significantly related to the decline. However, Share Catholic has a negative sign, which we would not expect, given that predominantly Catholic areas were lagging behind in the fertility decline in contrast to the predominantly Protestant districts (see Fig. 1). Galloway and his coauthors suggested that the wrong sign results

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[12] We used the mean value of two years in order to limit the influence of short-term fluctuations.

[13] The decline observed in rural areas of East Prussia in the 1890s is probably not related to the first demographic transition, but other factors such as substantial out-migration of young females.

from the situation that Protestant areas were in average more developed at that time, and therefore more likely to receive an influx of Catholic people. As these developed Protestant areas were also experiencing higher fertility decline this might have caused the negative sign. This could be the right interpretation, but suggests that the fixed effects model is less than ideal to explore the effects of cultural characteristics that change little over time. As we will see below, the results of the change and level model are more convincing.

If we contrast parameter estimates for the cultural panel model 1 and the economic panel model 2 with the ones of the full cultural-economic model 3 (see Tab 1), the estimates for each variable do no differ a lot. However, the economic model has a much higher R-squared value, suggesting, that changes in the economic variables are more related to the fertility decline than changes in the cultural variables.

Before we turn to the spatial models 4 and 5 we will first look at the results of the four non-spatial models with the change-and-level specification (models 5-9) (see Tab. 2). Those results deviate quite substantially from the one of the Galloway models. In model 8 which includes all cultural and economic variables that were used by Galloway et al. (1994), the Urbanization Rate and Share Catholic are the covariates that are most related with the fertility decline. Notably, Share Catholic has in our specification the expected positive sign. Among the changing economic variables only Infant Mortality Rate, Bank Employees and Insurance Employees are significantly associated with fertility change. But among these three variables only the relation with the Infant Mortality Rate stays stable in case different model specifications are tested (e.g. taking absolute fertility change as dependent variable). Among the three cultural variables, on the other hand, all seem to be related to the fertility decline, even if specifications are altered. If we look at the cultural model 6 and the economic model 7, we find in contrast to the Galloway-type models, that the differences in the R-squared value are much lower. This hints in the direction that also cultural factors are important predictors of fertility decline. In model 9 we introduce the variable Share of Votes for the progressive SPD at Reichstag elections. The variable is highly significant and has the expected negative sign. However, the R-squared value is only marginally affected by the introduction of the election information. The parameters of the other variables do not change substantially in contrast to model 8.

To further investigate the model fit of the non-spatial models with the Galloway specification (models 3 and 8) we will now look at the prediction error/ residual maps (Fig. 4).In Fig. 4a1 we see the pattern of absolute fertility decline from 1875 to 1910, which serves as dependent variable in the panel model specification (models 1 to 5). Fig. 4b1 displays the percentage GMFR-change between 1890 and 1910, which is used as dependent variable for the models with the change-and-level specification (models 6 to 11). As already mentioned above, the major urban centers of Prussia and their surrounding areas are the centers of fertility decline. This is even more accentuated in Fig. 4b1, which focuses on the period, where most of the decline occurred.

Fig. 4a2 displays the spatial pattern of the prediction error for the non-spatial cultural economic panel model 3[14]. In Fig. 4b2 we see the results for the alternative cultural economic level and change model 8. They show that both structural multivariate models are only to a limited extent able to explain the spatial pattern of fertility decline. Both models are able to associate covariates with the huge fertility decline in the big urban centers. In the case of Berlin, this is to some extent also true for some of the adjacent districts, although the panel model overpredicts the decline. But in general the regions around Berlin, Magdeburg/ Halle and Cologne experienced in both models fertility decline over and beyond that which would be predicted from the levels of structural factors observed in these districts. Furthermore, we see that the entire Middle and Lower Rhine valley region from Cologne to Frankfurt (an important transportation and communication corridor) experiences greater fertility decline than predicted. Also in the area around Berlin the clusters of high positive residuals seems to follow important transport corridors such as the *Ostbahn* railway to East Prussia and Russia and the main traffic route to Silesia in the southeast.

In contrast to this we have also cities/ regions with high positive residuals, indicating, that the decline was smaller/ increase was higher than the multivariate model predicts from the observed socio-economic structures or changes. This is the case for Danzig, Königsberg and Posen, the big centers in the rather peripheral east. Another spatial cluster with high positive residuals is the area around Münster, Osnabrück and Emden in the peripheral northwestern part of Prussia. The residual map of model 9, which additionally includes the election variable, does not differ substantially from the one of model 8. Therefore, we refrained from displaying it.

We will now turn to the spatial *follow the mean* and *follow the leader* models, with which we attempt to control for a spatial diffusion process. In all spatial models (4, 5, 10, 11) the model returns a highly significant coefficient for the spatially lagged variable, suggesting that fertility decline in a district appears to be associated with the fertility decline of neighboring districts. In the case of the *follow-the-mean*-specification the Moran's I measure of spatial clustering of the residuals has for the change-and-level regression model specification shrunk to insignificance (at the approximate 5% level). But the latter is very likely to happen based on the nature of the spatial variable we introduce and the way the Moran's I is calculated. The Moran's I for the prediction error of the *follow-the-mean*-specification of the panel model is

[14] The categorization is based on standard deviation from the mean. Thereby, all regions within the range of -1 to +1 standard deviation are colored white, as we are mostly interested in identifying outliers above and below.

even negative. Adding spatial effects in the form of the, in theoretical terms, favored *follow-the-leader*-models, the spatial clustering of prediction errors/ residuals has shrunk considerably compared to the non-spatial models. But it is still significant both in the panel and the change-and-level specification.

In the panel model specification, the predicted effects of most of the covariates remain more-or-less unchanged, when the spatial variable is introduced (see Tab. 1). There are two notable exceptions. The Share Slavic, a spatially highly clustered variable, changes the sign in the expected positive direction and becomes significant. On the other hand, the Share of Communication Employees switches the sign in the unexpected positive direction, while it remains significant. With regard to the level-and-change model, the only notable change is that the election variable is losing significance, which is probably related to the fact that this variable is highly spatially clustered around the centers of fertility declines.

In order to assess the potential impact of omitted variables on the spatial clustering of residuals, we experimented with omitting our observed economic variables. For the fertility decline variable of Galloway et al.'s panel model the overall Moran's I Index of spatial autocorrelation is 0.57. In the non-spatial model with all economic and cultural variables the spatial autocorrelation of the *unexplained* fertility decline (residuals) has fallen to 0.47. When a highly significant variable like Bank Employees is dropped, the Moran's I index only slightly increases to 0.48, suggesting, that adding an unobserved of equal explanatory power and spatial clustering as Bank Employees would not reduce further the amount of unexplained spatial clustering of the residuals. Thus, it seems to us unlikely that omitted economic variables could be fully responsible for the spatial patterns we observe.

Discussion

Our conclusion from our findings is that the actual nature of fertility decline in Prussia is consistent with **both** of the competing theories put forward in the literature. On the one hand, we find that structural economic variables are indeed predictive of fertility decline. We find, using a different specification, that cultural variables such as proportion Catholic are also statistically significant with the expected sign.

Moreover, we find that the pattern of **unexplained** fertility decline from the structural models is consistent with the overall findings of geographic clustering from the Princeton Fertility Project. In our residual maps of Prussia, clusters of high negative prediction errors emerge around the centers of innovation and communication, big cities. Clusters of high positive residuals are situated in rather peripheral rural areas. The geographic pattern of unexplained fertility decline is robust to the specification of the structural model; the same pattern is found with the fixed effect panel model used by Galloway et al. (1994) and the level-and-change model we introduced.

There are several possible reasons for the spatial autocorrelation of unexplained fertility decline. One possibility is model misspecification. But since we find essentially the same pattern of residuals in two quite different models, we are at least somewhat reassured that this is not the main explanation. A related possibility is the omission of some important explanatory variable that is itself clustered. For example, wages are poorly measured in the Prussian dataset, but are thought to be an important economic factor influencing fertility. Since wage levels are probably highly spatially clustered, the omission or measurement error in this variable could produce the spatial correlation of residuals. While it is impossible to reject fully the existence of important omitted variables, we tried to *simulate* the effect of an omitted variable by artificially omitting various observed economic variables. None of these omissions dramatically increased spatial autocorrelation, which suggests that presently omitted variables might not have a large effect on the residual spatial correlation. We also included a new variable – voting behavior that probably reflects new information about both economic and cultural characteristics and found little or no effect on the spatial autocorrelation of the residuals.

A third possibility is that the spatial correlation is evidence of the workings of contagious behavior. This view takes the residual correlation as evidence, unexplained *dark matter* if you will, of culture at work through the transmission of ideas along communication corridors and increasing acceptability of fertility control in a region as soon as some pioneers started this behavior. In support of this, we not only found clusters around cities - which could be evidence of omitted economic variables **or** cultural transmission, but also in transportation and communication corridors, for example, in the Rhine Valley between Frankfurt and Cologne. The Rhine Valley region was not especially economically advanced but did see traffic and communication from the centers of fertility decline.

Taking cultural transmission seriously requires further work in spatial modeling. It is not unlikely that there is a hierarchy in the data making some units more influential than others. The archipelago pattern of spatially unconnected *islands* of large declines around big urban centers supports this hypothesis that has also already been discussed elsewhere (Bocquet-Appel / Jacobi, 1996). This would mean that fertility decline in a region is more likely to occur, if the regional centre has already entered the fertility decline. Through this, regional centers could serve at least temporarily as a bottleneck with regard to the onset of the decline. Also descriptive data hints in that direction, showing that those Catholic regions that do not enter fertility decline in the period studied have in common that they are peripheral and that the regional centers are bishop seats and in some cases also former church state capitals (Braunsberg, Fulda, Gnesen, Münster, Paderborn, Posen, Trier).

Conclusion and Outlook

Overall, our findings suggest that in Prussia one can find strong support for the diffusion of new ideas in addition to economic change as factors of fertility decline. This started first in the areas in which it made structurally the most sense, and spread then to adjacent areas even when structural factors would not by themselves have predicted such a fast spread.

Future directions might include refining our spatial analysis by specifying the nature of the hierarchical relationship between leaders and followers during the fertility decline (see also Bocquet-Appel / Jakobi, 1996). Thereby, we want to incorporate the known historic structure of regions, for example, assigning leading regions based on the presence of state/ church capital cities. In addition, we want to integrate information in the model, to what extent two bordering regions differ in cultural (e.g. Share Catholic) or economic terms (e.g. Urbanization Rate). This is motivated by the believe that the degree of cultural and economic similarity between two regions has an impact on the likeliness and intensity of a diffusion process (see also Montgomery / Casterline, 1993, p. 465).

Finally we believe a good next step in this research is to perform a similar analysis of the spatial pattern of unexplained fertility decline in Hungary, where fertility decline began in some cases in non-urban areas. If we find *neighbor effects* in this context, it would lend support to the thesis that cultural diffusion was an important feature in 19th century European fertility decline.

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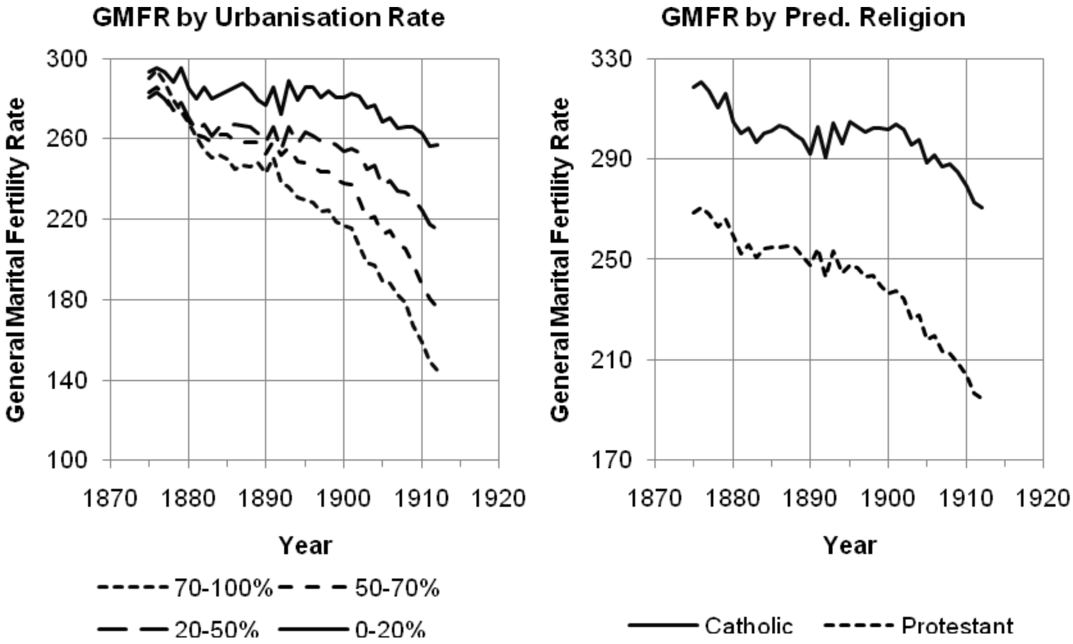
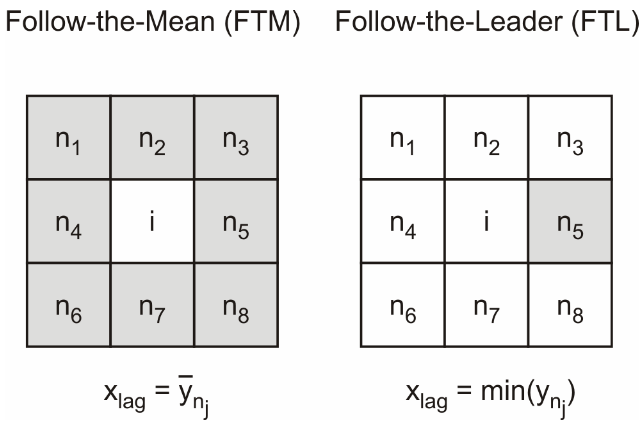
Figures

Fig. 1: GMFR Development by Urbanization and Religion



Source: Galloway et al., 1994; Own calculations

Fig. 2: Calculation of the Spatially Lagged Variables



Tab. 1: Fixed Effects Panel Models 1875–1910

	Model 1 Culture	Model 2 Economic	Model 3 Cul.-Econ.	Model 4 Spatial Follow the Mean	Model 5 Spatial Follow the Leader
Estimates	β	β	β	β	β
Share Catholic	-6.41 ***		-2.13 ***	-0.45 ***	-0.89 ***
Share Slavic	0.54		-0.29	0.76 ***	0.64 ***
Church Employees	-27.84 ***		23.44 ***	15.00 ***	24.89 ***
Education Employees		-10.08 ***	-9.35 ***	-5.84 ***	-5.34 ***
Health Employees		-2.41	-5.84	-4.50	6.90
Fm. Lab. Force Part. Rate		-1.28 ***	-1.25 ***	-0.03	0.18
Income		-0.00	-0.00	-0.00	0.00 *
Mining Employees		0.65 **	0.77 ***	1.43 ***	1.76 ***
Urbanization Rate		0.12	0.15	-0.05	0.06
Bank Employees		-47.60 ***	-54.34 ***	-20.63 ***	-39.85 ***
Insurance Employees		-146.89 ***	-134.63 ***	-91.00 ***	-114.12 ***
Communication Emp.		-7.72 ***	-7.53 ***	1.98 **	1.96 *
Legit. Infant Mort. Rate		0.25 ***	0.25 ***	0.08 ***	0.14 ***
Married Men/ Married Women		34.22	39.48 *	52.10 ***	60.22 ***
Spat. Lagged GMFR (FTM)				0.81 ***	
Spat. Lagged GMFR (FTL)					0.51 ***
Diagnostics					
R-squared - Without Area Dummies - With Area Dummies (not adj./ adj.)	 0.15 0.80/ 0.78	 0.64 0.92/ 0.90	 0.66 0.92/ 0.91	 0.86 0.97/ 0.96	 0.79 0.95/ 0.94
F (df, n)	167.37 ***	445.05 ***	386.03 ***	1046.36 ***	696.22 ***
Moran's I (1st Order Queen)	0.45 ***	0.47 ***	0.47 ***	-0.09 ***	0.18 ***
Significance codes: 0 *** 0.001 ** 0.01 * 0.05					

Source: Galloway et al., 1994; Own calculations

Tab. 2: Change-and-Level Models 1890-1910

	Mod. 6 Culture	**Mod. 7 Economic**	**Mod. 8 Cul.-Econ.**	**Mod. 9 Cul.-Econ.-Elec.**	**Mod. 10 Spatial Follow the Mean**	**Mod. 11 Spatial Follow the Leader**
Estimates	β	β	β	β	β	β
Share Catholic (L)	0.13 ***		0.11 ***	0.09 ***	0.05 ***	0.08 ***
Share Slavic (L)	0.14 ***		0.10 ***	0.07 ***	0.04 **	0.03
Church Employees (L)	8.59 *		10.68 ***	7.97 **	8.03 ***	8.41 ***
Education Employees (C)		-2.43	-1.70	-1.77	-1.49 *	-1.16
Health Employees (C)		5.02	-0.30	-0.68	0.36	-1.05
Fm. Lab. Force Part. Rate (C)		-0.05	-0.20	-0.01	-0.16	-0.05
Income (C)		-0.00	-0.00	-0.00	-0.00	-0.00
Mining Employees (C)		-0.07	-0.23	-0.07	-0.01	0.06
Urbanization Rate (L)		-0.29 ***	-0.24 ***	-0.20 ***	-0.16 ***	-0.18 ***
Bank Employees (C)		-19.51 **	-12.22 *	-11.16 *	-7.49	-9.90 *
Insurance Employees (C)		-18.32 *	-17.39 *	-9.48	-13.36 *	-13.69 *
Communication Emp. (C)		1.13	0.55	-0.07	-0.25	0.05
Legit. Infant Mrt. Rate (PC)		0.15 ***	0.16 ***	0.13 ***	0.12 ***	0.12 ***
Married Men/ Mar. Women (C)		-1.82	35.65 *	19.33	20.32	23.25
Share of Votes for SPD (L)				-0.19 ***	-0.03	-0.07 *
Spat. Lagged GMFR (FTM)(PC)					0.56 ***	
Spat. Lagged GMFR (FTL)(PC)						0.37 ***
Intercept	-22.64 ***	-1.35	-9.18 ***	-6.95 ***	-0.33	-0.19
Diagnostics						
Adjusted R-squared	0.35	0.47	0.70	0.73	0.82	0.80
F (df, n)	71.18 ***	33.67 ***	68.80 ***	72.58 ***	115.2 ***	102.6 ***
Moran's (First Order Queen)	0.54 ***	0.56 ***	0.45 ***	0.46 ***	0.04	0.19 ***
Significance codes: 0 *** 0.001 ** 0.01 * 0.05						

Source: Galloway et al., 1994; Own calculations

Fig. 3: Share Employed in Agriculture 1882/ Percentage Change in General Marital Fertility Rate (1890 = 100)

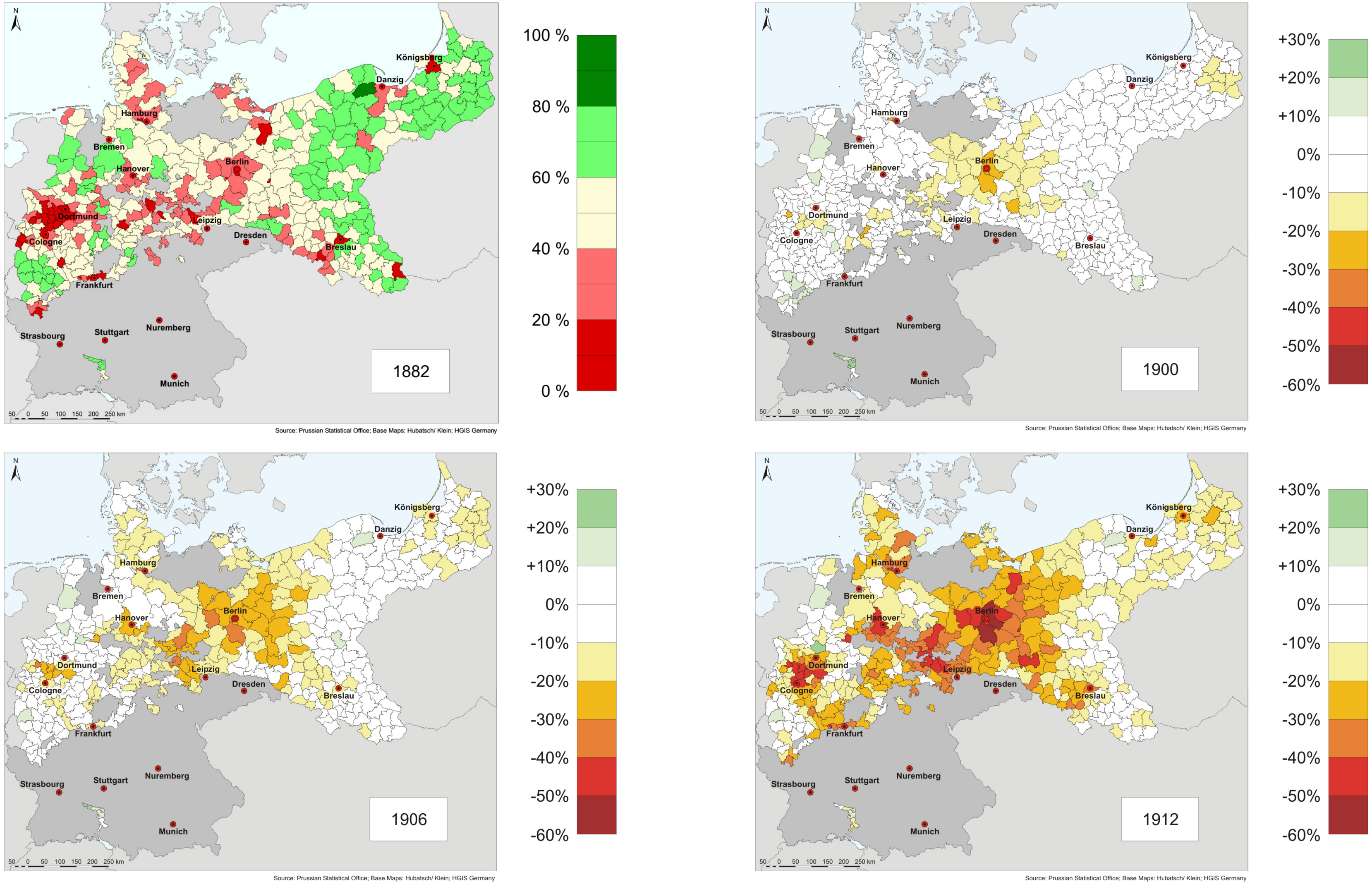
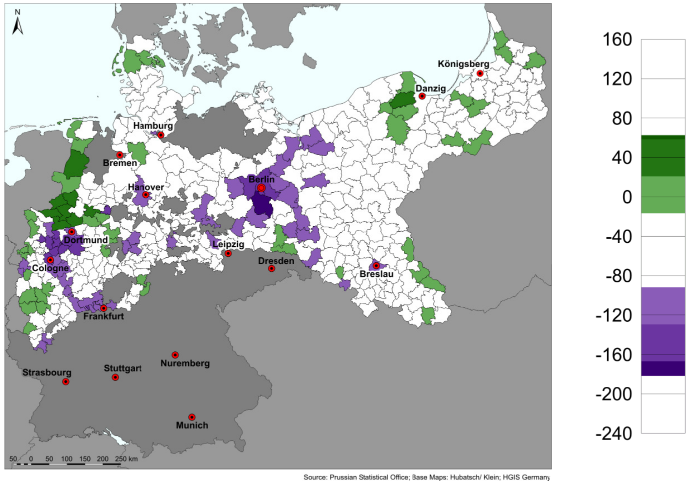
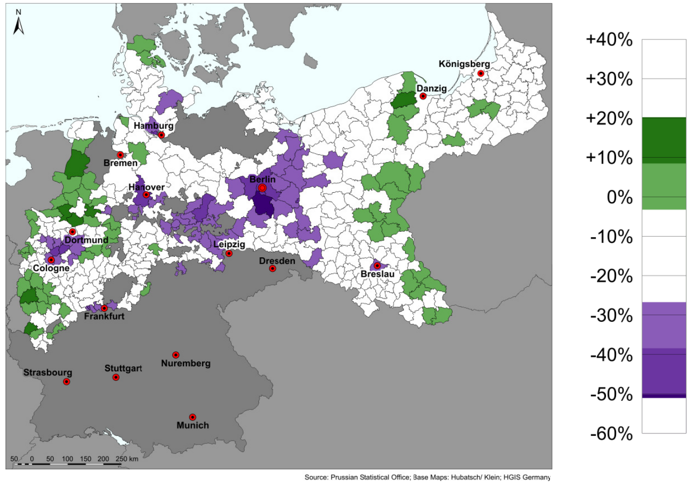


Fig. 4: Fig. 4 Standard Deviation Maps of Dependent Variable/ Residuals

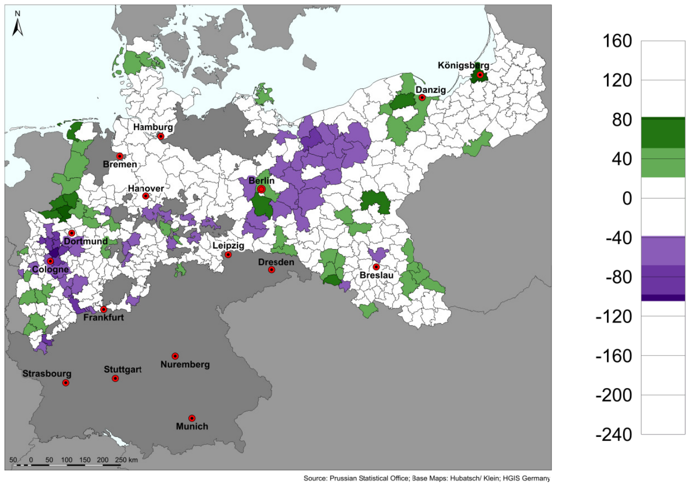
a1) Dep. Var. Mod- 1-5: GMFR abs. Change 1875-1910



b1) Dep. Var. Mod. 6-11: GMFR Perc. Change 1890-1910



a2) Pred. Err. of Mod. 3: Panel Model – Cul.-Econ.



b2) Res. of Mod. 8: Change/ Level on Change – Cul.-Econ.