Culture Strikes Back - A Geographic Analysis of Fertility Decline in Prussia

Joshua R. Goldstein and Sebastian Klüsener
Max Planck Institute for Demographic Research

01 August 2009

Paper to be presented at the XXVI IUSSP International Population Conference Marrakech, September, 27th – October, 2nd 2009

Please do not cite without permission by the authors

Abstract

In this paper, we re-introduce geography into the analysis of fertility decline in the first demographic transition. In a reanalysis of Galloway et al.'s (1994) Prussian data, we find evidence **both** of the predictive effect of economic variables and of the unexplained geographic clustering of fertility decline. Our methodology is to fit structural models similar to those of Galloway et al. to the Prussian data and to map the residuals. We find that unexplained fertility decline is geographically clustered beyond what one would expect from chance. 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.

> *"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 der Walle, 1986, p. 413)*

Introduction

Geography played initially an important role in the debate between 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 Fertility Project. Historical fertility decline appeared to be more like the cultural diffusion of a new innovation -- the idea of family size limitation -- than an adaptation to changing economic circumstances. Subsequent research challenging the Princeton Project's findings has taken advantage of detailed geographic data that includes not only demographic but also detailed economic measures. This newer research has made great strides in its statistical modeling, using panel methods to focus on the explanation of changes in fertility rates, rather than variation in fertility levels. Despite the use of geographic data, however, the new panel approaches have stopped short of asking whether economic and demographic change can explain the spatial pattern of fertility decline.

In this paper, we aim to reinsert spatial analysis into the debate about historical 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 and second 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.

Previous Research

The idea of explaining fertility decline as either an adaption or innovation is found in 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. The innovationist perspective emphasizes the novelty of the technology or the idea of fertility control, whereas the adaptationist perspective emphasizes that it is changing circumstances that are linked to a new behavior.

During the 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 (Map 2.1) shows the "Estimated date of sustained decline in Ig (marital fertility), by province of Europe". 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 patters of decline". (Watkins, 1986, p. 448)

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 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 found that structural factors such as the proportion of the population in agriculture vs. industry was a powerful factor in explaining fertility decline in 71 German regions.

Galloway's (1994) analysis of Prussia advanced Richard's 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

[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."

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."

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, 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.

Data and Methodology

Data

We study the decline of fertility in Prussia using Kreis (small district) level data published in the Preußische Statistik. The data set 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 1000 and divided by the married females aged 15 to

49. The latter is taken from the census results carried out in a five year intervals from 1890 on. For 1875, 1880, 1885 the numbers are 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 number of legitimate births of the years 1888 to 1892 is taken.

The explanatory variables are the following ones: Share Catholic; Share Slavic; Church Employees per 100 inhabitants; Education Employees per 100 inhabitants; Health Employees per 100 inhabitants; Female Labor Force Participation Rate; Income (based on average Teacher's salary); Mining Employees per 100 inhabitants; Urbanization Rate; Bank Employees per 100 inhabitants; Insurance Employees per 100 inhabitants; Communication Employees per 100 inhabitants; Legitimate Infant Mortality Rate; Ratio Married Men/ Married Women.

Models

We try to 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 stay as close as we can to Galloway et al.'s (1994) original fixed-effect panel specification. This model essentially estimates changes in marital fertility stemming from changes in covariates economic, cultural, and structural covariates. It is specified as followed:

$$y_{it} = \beta_1 x_{1it} + \beta_2 x_{2it} + \beta_3 x_{3it} + \ldots \beta_k x_{kit} + d_1 W_{1t} + d_2 W_{2t} + \ldots d_N W_{Nt} + e_{it}$$

where y denotes the dependent variable, while x represents the k independent variables; β is an estimation coefficient, d stands for dummy, while W = 1 for the ith unit of analysis, =1,…,N and 0 otherwise; e is the error term.

We estimate their model, finding the same coefficients, and then map the spatial distribution of the residuals of unexplained fertility decline. Finding a strong visual impression of geographic correlation, we introduce formally statistical measures of spatial correlation to measure the importance of geographic contiguity.

In order to show the robustness of our findings to alternative 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.

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

This specification, we believe, offers some improvements over the original Galloway specification. 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 percent 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. It is important to stress that this model studies only developments between two points in time, while the panel model uses data from eight time points.

Our basic modeling assumption differs in two points substantially from the one of Galloway et al. (1994). One important deviation is that we believe that the intensity of the fertility decline is not necessarily only influenced by changes in explanatory variables occurring parallel in time. This is to some extent in line with another article by Galloway et al. (1998a), which examines whether the effects of the same covariates vary by levels of urbanization. Particular with regard to cultural variables we think that levels are more relevant for explaining the intensity of the fertility decline. Catholic people, for example, might be more reluctant to start controlling their fertility due to religious reservations. This view is also supported by the findings of Knodel (1974, p. 130 ff.), that Catholic regions were less likely to experience a massive fertility decline in this early period of fertility transition (see also Praz, 2009). Also descriptive findings hint in that direction as they show that Catholic areas lagged behind in the onset of the decline by approximately a decade (see Fig. 1).

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 the wrong sign, than they had expected. 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.

With regard to the time period studied we use for the panel model the period 1875-1910, as in the original specification. For the change-and-level model we base the analysis on fertility change between 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 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).

We discussed already above that we have good reasons to believe that Catholic people might have been more reluctant to control fertility levels. Therefore, we use the average level of Share Catholic in a unit in the period studied for the model instead of changes in that variable. Also for the other two cultural variables (Share Slavic, Church Employees) we introduce the average level in the model. The reasoning is similar to the discussion above on the Catholicism variable.

Apart from this we keep another variable constant: Urbanization Rate. Our reasoning behind this is that we 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 level of urbanization 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. For the other variables, which are mostly economic, we introduce the absolute change between 1890 and 1910 in the model. One exception is the Legitimate Infant Mortality Rate, where we use parallel to the dependent variable percentage change. We use the Legitimate Infant Mortality Rate a little bit reluctantly as their might be endogeneity problems (see Galloway et al., 1998b).

In total, we calculate two sets of four models. The first four models resemble the Galloway specification, while the other four follow 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 includes all cultural and economic variables. In the last model of each of the model sets we include a covariate that displays the average GMFR-change in the 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 spatial variable delivers a significant coefficient, this can be interpreted as a hint for a spatial diffusion process, for which we do not have data. Thereby, these omitted data is likely to be cultural, but can also be of economic character.

Model Results

Tab. 1 and Tab. 2 display the results of the eight models. 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 one would not expect, given that predominantly Catholic areas exhibited a lagging behind in the fertility decline in contrast to the predominantly Protestant districts (see Fig. 1). Galloway suggested that the wrong sign in that way 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.

With regard to this one needs to recall that Prussia was in the 1870s still a country with clear religious borders between predominant Catholic and Protestant areas. This was a legacy effect of the "Peace of Augsburg" of 1555 which gave the rulers of a state the right to determine the religion of the people they rule. It caused that Germany became a rag rug of territories with different religious believes and distinct religious borders following state borders. This only began to weaken in the 18th century in the era of Enlightment and when bigger states such as Prussia acquired new territories, among which where also ones where the population had a different denomination. In the period studied this distinction between Catholic and Protestant regions is weakening as a consequence of the industrial age, which caused substantial internal migration. In this process Protestant areas gained Catholic inhabitants, while Catholic regions received an inflow of Protestant inhabitants (see Fig. 2). Therefore, change data depends to a large extent on initial levels. This view is also supported by a regression model, were change in Share Catholic between 1875 and 1910 is regressed on initial levels in 1875. This suggests that change in the Share Catholic can be interpreted as a proxy for whether the area is predominantly Catholic or Protestant. If one follows this line of argumentation, one would expect that the variable Share Catholic has a negative sign, as one would expect the (Protestant) regions with an inflow of Catholics to have a higher fertility decline than the (Catholic) regions with an inflow of non-Catholics.

The cultural and economic models with the Galloway specification show basically the same results as the full model 3. However, the economic model has a much higher R-squared-value, indicating, 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 model 4 we will first look at the results of the three non-spatial models with the change-and-level specification. Those results deviate quite substantially from the one of the Galloway model. In model 7 with all available cultural and economic variables the Urbanization Rate and Share Catholic are the covariates that are most related with the fertility decline. Thereby, Share Catholic has the expected positive sign. Among the changing economic variables only the Infant Mortality Rate, Bank Employees, Insurance Employees and Infant Mortality Rate are significantly associated with the change. But among these four variables only the relation with the Infant Mortality Rate stays stable in case different model specifications are tried (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 5 and the economic model 6, we find in contrast to the Galloway-type models, that the differences in the R-squared-value are much lower.

To further investigate the model fit of the non-spatial full models 3 and 7 we will now look at Prediction Error vs. Observed plots (Fig. 3, Fig. 4) and Prediction Error vs. Observed maps (Fig. 5 to Fig. 8). With regard to the Galloway model we face the problem that we can not take the residuals of the model, as a panel model returns different residuals for each time period studied. Thereby, by definition, the sum of the residuals of a unit over all time periods is equal to 0. In order to get one prediction error per unit we used the following formula:

$$PE = (O_{1910} - O_{1875}) - (P_{1910} - P_{1875})$$

where PE denotes the prediction error, O the observed values at given times and P the predicted value derived from the model.

The plot of the Galloway model indicates that the model is particularly well fitted for units that experience small-scale fertility decline in the period studied. But the model fit decreases substantially if one looks at cases that deviate from the mean both at the lower spectrum (high fertility decline) as well as the higher one, where some regions had a fertility increase. Basically it seems as if the model error is a function of the deviation from the mean of the dependent variable, which does not indicate a good general model fit. Among the extreme decliners two units deviate from the general picture. They exhibit a positive prediction error, which means, that the decline was lower than predicted. These two regions are the regions Niederbarnim and Teltow that directly bordered the German capital Berlin (see also Fig. 6). These two regions incorporated big cities such as Charlottenburg that later became part of Berlin. Among the Prussian districts these two experienced the most rapid economic development in this period.

For the set of change-and-level models we are able to use the residuals for the model error vs. observed plot (see graph 3). The plot shows that also for this specification the non-spatial full model 7 is far from fitting perfectly to the data. However, particularly with regard to the extreme decliners the level-and-change model is having a better fit than the Galloway-specification. But we also have problems with those regions that exhibited a fertility increase in that period. We will come back to this problem again in the discussion part.

Now we turn to the question of whether the models with all economic and cultural variables account for the spatial pattern of fertility decline. In Fig. 5 we see the pattern of absolute fertility decline from 1875 to 1910, which serves as the dependent variable in the panel model specification (models 1 to 4). Fig. 6 displays the percentage GMFR-change between 1890 and 1910, which serves as a dependent variable for the models with the change-and-level specification (5-8). Notably, declines are centered around the major urban centers of Prussia: Berlin, Hamburg (Altona), Hannover, Cologne, and Frankfurt. This is even more accentuated in Fig. 7, which focuses on the period, where most of the decline occurred.

Fig. 6 and Fig. 8 display the spatial pattern of the prediction error/ residuals of the models 3 respective 7. 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 would have been predicted. Also in the area around Berlin the clusters of high positive residuals seems to follow important transport corridors.

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 visual impression of geographic clustering can be confirmed using statistical measures. The Moran's I index[3] reported in the diagnostics of the model results indicates a highly significant spatial correlation among the residuals of all non-spatial models. The reasons for this spatial clustering of the residuals can be manifold. We will come back to this in detail in the discussion part.

In an attempt to overcome the spatial clustering of residuals we incorporate a spatial variable. This covariate displays the average GMFR levels (in the case of the panel model) or percentage change (in the case of the level-and-change model) in the adjacent units[4]. This is motivated by the believe, that districts bordering hot spots of the decline might be more exposed and have decline beyond what one would expect based on the change/ level of the cultural and economic covariates.

Here, we find from the highly significant coefficient that indeed fertility decline in a district appears to depend on the amount of fertility decline of neighboring districts. The Moran's I measure of spatial clustering of the residuals has for both the panel model and the 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.

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 turns from highly significant to not significant. This is probably caused by the fact that changes among communication employees were most highly in communication corridors that are also spatially clustered. With regard to the level-and-change model, the only notable change is that the Female Labor Force Employment Rate becomes significant with the expected sign.

---

[3] The Moran 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.

[4] Based on the "First Order Queen" definition of adjacency.

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 dependent variable of the change-and-level models the overall Moran's I Index of spatial autocorrelation is 0.63 (Galloway's panel specification: 0.56). In the non-spatial model with all economic and cultural variables the spatial autocorrelation the "unexplained" fertility decline (residuals) has fallen to 0.43 (Galloway: 0.45). When a variable like Female Labor Employment Rate is dropped, the Moran's I index falls to 0.42 (Galloway: 0.43), suggesting, that adding an unobserved of equal explanatory power and spatial clustering as FLFPR 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 these preliminary 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 highly predictive of fertility decline. We find, using slightly different models, that cultural variables such as proportion Catholic are also statistically significant.

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 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. We are only able to overcome the spatial autocorrelation of the residuals by a very crude measure: introducing the spatially-lagged value of the dependent variable as independent variable. And despite this drastic measure we still have problems with those regions that exhibited a fertility increase in the period studied (see plot for spatial model in Fig. 4).

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 data set, but are thought to be an important economic factor influencing fertility. Since wages levels are probably highly spatially clustered, the omission or measurement error in this variable could produce the spatial correlation of residuals. Another, mis-measured variable might be “insurance employees per inhabitant”. At least private insurances developed usually first in the metropolitan areas. Therefore, it is not unlikely that they first focused their marketing efforts on the citizens in these urban centers and their surrounding areas, while citizens in peripheral areas where only reached with some delay. While it is impossible to reject fully such an explanation, we tried to "simulate" the effect of an omitted variable by artificially omitting various observed variables. None of these omissions dramatically increased spatial correlation, which is at least suggestive evidence that the ability of additional (presently omitted) variables might not have a large effect on the residual spatial correlation.

A third possibility is that the spatial correlation is evidence of the workings of "culture". This view takes the residual correlation as evidence, "dark matter" if you will, of culture at work through the transmission of ideas along communication corridors. 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 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 can usually only occur, if the regional centre enters 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 the 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 old church state capitals and bishop seats (Braunsberg, Fulda, Gnesen, Münster, Paderborn, Posen, Trier).

Overall, our findings suggest that in addition to economic change there was a diffusion of a new innovation, starting first in the areas in which it made structurally the most sense, and then spreading to adjacent areas even when structural factors would not by themselves have predicted such a spread.

In developing this work further, we plan to refine our spatial analysis by specifying the nature of the hierarchical relationship between leaders and followers during the fertility decline (Bocquet-Appel / Jakobi 1996). A simple model of this nature, replaces the lag term for the average decline of neighbors, with the lag term for the "most declined" neighbor. This we call the "follow the leader" model. A more sophisticated approach incorporates the known historic structure of regions, for example, assigning leading regions based on the presence of state/ church capital cities.

Literature

Becker, G.S. (1991): A Treatise on the Family. Cambridge.

Bocquet-Appel, J.P. / Jakobi, L. (1996): Barriers to the Spatial Diffusion for the Demographic Transition in Western Europe. In: Bocquet-Appel et al. (ed.): Spatial Analysis of Biodemographic Data. Montrouge, pp. 117 – 129.

Boener, A. (2007) Kinderarbeit im Kaiserreich 1871-1914. Paderborn.

Brown, J.C. / Guinnane, T.W.G. (2002): Fertility Transition in a Rural, Catholic Population : Bavaria 1880 – 1910. In: Population Studies 56, pp. 35 – 49.

Carlson, G. (1966): The Decline of Fertility : Innovation or Adjustment Process. In: Population Studies 20, pp. 149 – 174.

Cleland, J. / Wilson, C. (1987): Demand Theories of the Fertility Transition : An Iconoclastic View. In: Population Studies 41, pp. 5 – 30.

Coale, A.J. / Watkins, S.C. (ed.) (1986): The Decline of Fertility in Europe : The revised Proceedings of a Conference on the Princeton European Fertility Project. Princeton.

Galloway, P.R. / Hammel, E.A. / Lee, R.D. (1994): Fertility Decline in Prussia, 1875-1910 : A Pooled Cross-Section Time Series. In: Population Studies 48, pp. 135 – 158.

Galloway, P.R./ Lee, R.D./ Hammel, E.A. (1998a): Urban vs. Rural: Fertility Decline in the Cities and Rural Districts of Prussia, 1875 to 1910. In: European Journal of Population 14, pp. 209 – 264.

Galloway, P.R./ Lee, R.D./ Hammel, E.A. (1998b): Infant mortality and the fertility transition : Macro evidence from Europe and new findings from Prussia. In: Montgomery, M.R. / Cohen, B. (eds.): From Death to Birth, Mortality Decline and Reproductive Change. Washington DC, pp. 182 – 226.

HGIS Germany (Kunz, A. / Zipf, A.): Historische Grundgeometrien der Staaten des Deutschen Reiches und Mitteleuropas. Mainz.

Hubatsch / Klein, T. (eds.) (1975 ff.): Grundriß der deutschen Verwaltungsgeschichte. Marburg.

Knodel, J.E. (1974): The Decline of Fertility in Germany 1871-1939. Princeton.

Knodel, J.E./ van der Walle, E. (1986): Lessons from the past : policy implications of historical fertility studies. In: Coale, A.J. / Watkins, S.C. (eds.): The Decline

of Fertility in Europe : The revised Proceedings of a Conference on the Princeton European Fertility Project. Princeton, pp. 390 – 419.
Lesthaeghe, R. (1980): On the Social Control of Human Reproduction. In: Population and Development Review 6, pp. 527 – 548.
Lesthaeghe, R. / Wilson, C. (1986): Modes of Production, Secularization, and the pace of fertility decline in Western Europe, 1870-1930. In: Coale, A.J. / Watkins, S.C. (eds.): The Decline of Fertility in Europe : The revised Proceedings of a Conference on the Princeton European Fertility Project. Princeton, pp. 261 – 292.
Praz, A.F. (2009): A Comparative Analysis of Protestant and Catholic Culture (Switzerland 1890-1930), In. History of the Family 14, pp. 88 – 106.
Richards, T. (1977): Fertility Decline in Germany : An Econometric Appraisal. In: Population Studies 31, pp. 537 – 553.
Watkins, S.C. (1986): Conclusions. In: Coale, A.J. / Watkins, S.C. (eds.): The Decline of Fertility in Europe : The revised Proceedings of a Conference on the Princeton European Fertility Project. Princeton, pp. 420 – 449.

Appendices

Fig. 1: GMFR Development by Urbanization and Religion

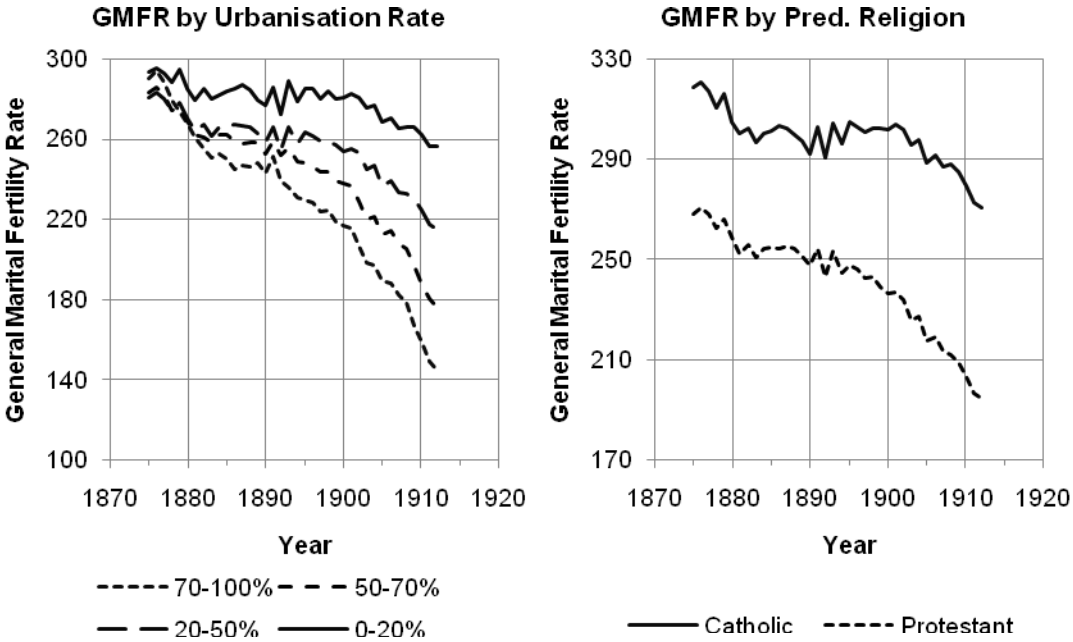
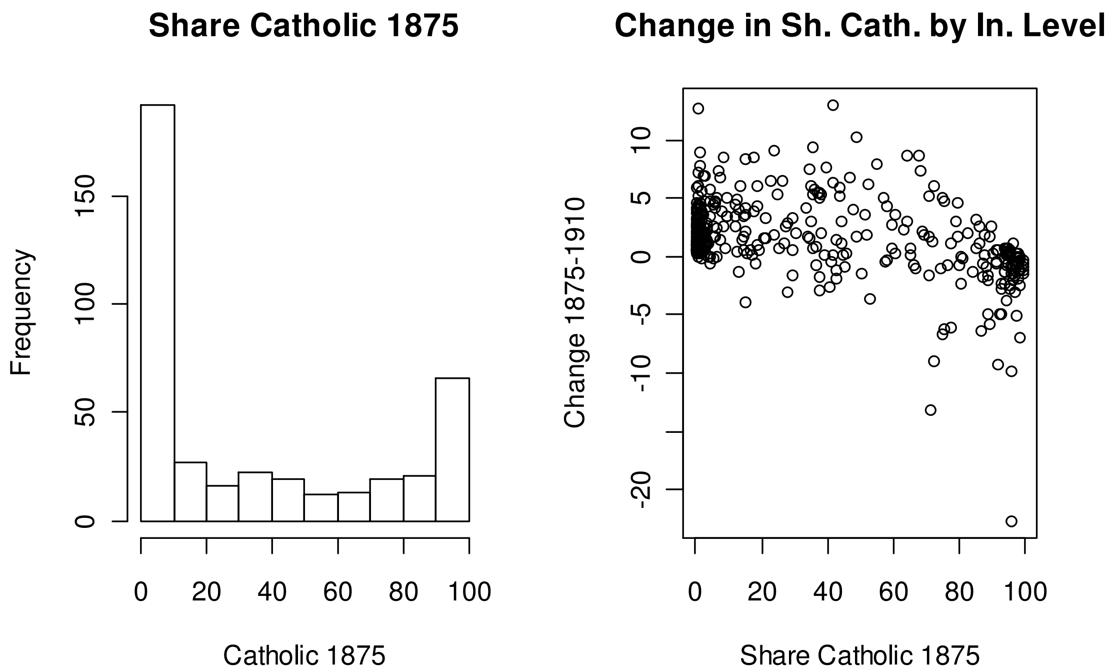


Fig. 2: Histogram Sh. Cath. 1875 and Change 1875-1910 by Init. Level



Tab. 1: Fixed Effects Panel Models 1875-1910

	Model 1 Culture	Model 2 Economic	Model 3 Cul.-Econ.	Model 4 Spatial
Estimates	**β/ T**	**β/ T**	**β/ T**	**β/ T**
Share Catholic	-6.38*** -21.98		-2.14*** -10.79	-0.83*** -5.47
Share Slavic	0.54 1.64		-0.28 -1.32	0.59*** 3.62
Church Employees	-28.36*** -5.23		23.23*** 6.46	16.00*** 5.89
Education Employees		-9.72*** -7.23	-9.08*** -6.95	-6.36*** -6.44
Health Employees		-3.88 -0.75	-6.60 -1.31	-0.00 -0.00
Female Labor Force Participation Rate		-1.26*** -7.59	-1.24*** -7.60	-0.26* -2.06
Income		-0.00 -1.19	-0.00 -0.66	-0.00 -0.62
Mining Employees		0.64** 2.72	0.76** 3.28	1.24*** 7.14
Urbanization Rate		0.07 0.79	0.11 1.16	-0.03 -0.50
Bank Employees		-47.82*** -5.02	-55.33*** -5.97	-28.28*** -4.03
Insurance Employees		-147.17*** -14.65	-133.47*** -13.63	-103.52*** -13.97
Communication Emp.		-7.65*** -8.31	-7.33*** -8.06	-0.33 -0.47
Legit. Infant Mort. Rate		0.24*** 13.14	0.24*** 13.76	0.11*** 8.46
Ratio Married Men/ Married Women		35.65 1.81	40.67* 2.13	47.73*** 3.31
GMFR (First Order Neighbors)				0.62*** 46.39
Diagnostics				
R-squared Without Area Dummies With Area Dummies	 0.15 0.77	 0.63 0.90	 0.66 0.92	 0.80 0.95
F (df, n)	165.54***	446.61***	387.05***	778.78***
Moran's I (First Order Queen)	0.45***	0.46***	0.45***	0.01
Significance codes: 0 *** 0.001 ** 0.01 * 0.05				

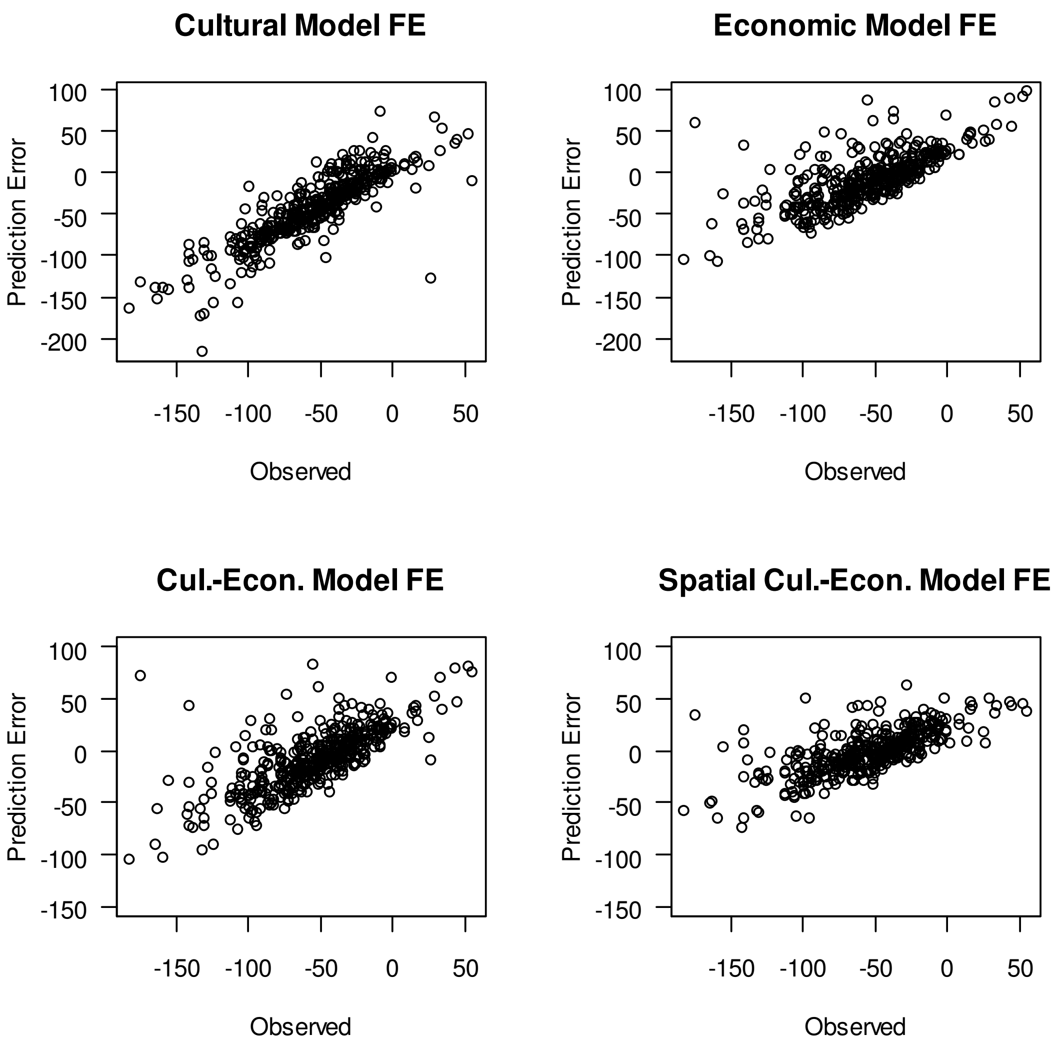
Source: Prussian Statistical Office; Galloway, 1994; Own calculations

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

	Model 5 Culture	**Model 6 Economic**	**Model 7 Cul.-Econ.**	**Model 8 Spatial**
Estimates	**β/ T**	**β/ T**	**β/ T**	**β/ T**
Intercept	-22.42*** -26.57	-1.06 -0.84	-8.89*** -8.33	-0.25 -0.24
Share Catholic (L)	0.14*** 8.09		0.12*** 9.81	0.07*** 6.41
Share Slavic (L)	0.14*** 5.48		0.09*** 5.03	0.04* 2.48
Church Employees (L)	6.87 1.86		8.57*** 3.33	4.84* 2.34
Education Employees (C)		-2.58* -2.04	-1.68 -1.77	-1.47 -1.94
Health Employees (C)		3.63 0.90	-0.33 -0.11	1.27 0.52
Female Labor Force Part. Rate (C)		-0.04 -0.23	-0.18 -1.29	-0.23* -2.07
Income (C)		-0.00 -0.95	-0.00 -0.62	-0.00 -1.01
Mining Employees (C)		-0.07 -0.38	-0.25 -1.74	-0.06 -0.51
Urbanization Rate (L)		-0.29*** -9.82	-0.24*** -10.51	-0.17*** -9.21
Bank Employees (C)		-18.58* -2.46	-12.47* -2.19	-7.95 -1.74
Insurance Employees (C)		-19.23* -2.13	-17.63* -2.58	-14.15** -2.59
Communication Emp. (C)		0.10 1.20	0.48 0.76	-0.21 -0.42
Legit. Infant Mort. Rate (PC)		0.12** 2.97	0.15*** 4.95	0.11*** 4.49
Ratio Married Men/ Married Women (C)		-1.34 -0.06	38.38* 2.28	27.41* 2.03
GMFR (First Order Neighbors) (PC)				0.55*** 14.95
Diagnostics				
Adjusted R-squared	0.36	0.48	0.71	0.82
F (df, n)	74.44***	33.41***	69.18***	116.10***
Moran's I (First Order Queen)	0.53***	0.57***	0.43***	-0.00
Significance codes: 0 *** 0.001 ** 0.01 * 0.05				

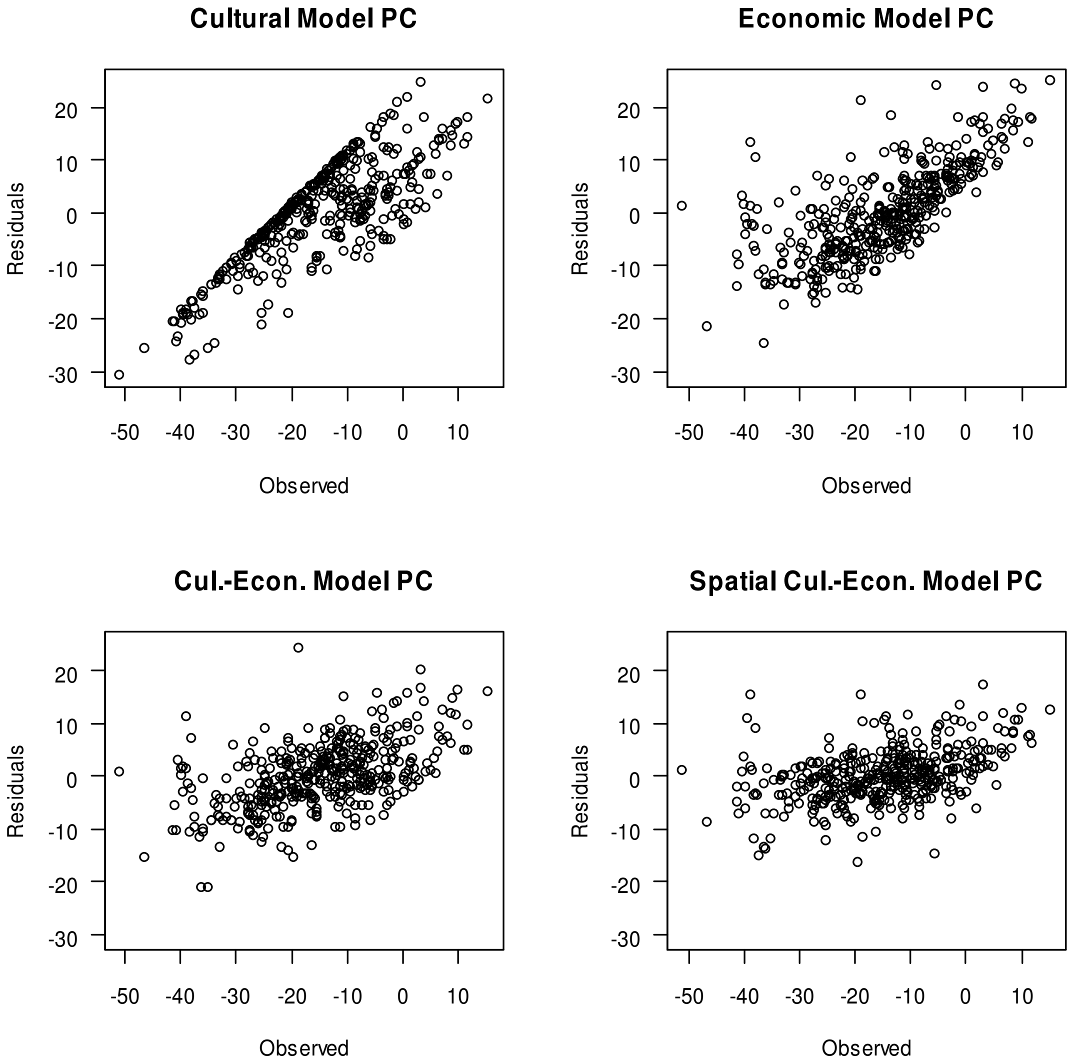
Source: Prussian Statistical Office; Galloway, Own calculations

Fig. 3: Pred. Error vs. Obs. Change (FE Panel Models 1875–1910)



Source: Galloway et al, 1994; Own Calculations

Fig. 4: Residuals vs. Obs. Change (Change-and-Level Models 1890-1910)



Source: Own Calculations