The Decline of Infant Mortality across Europe, 1910-1930

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Abstract

While spatial aspects of the fertility decline in Europe have been investigated in great detail, an in-depth spatial account of the European infant mortality decline is so far lacking. This paper investigates determinants of the infant mortality decline across Europe in the period 1910-1930. A special emphasis is put on shifts in urban-rural differences. We show that between 1910 and 1930 the infant mortality decline was centred on countries in Central Europe including Germany and Austria. This is remarkable considering that these countries lost World War I and faced very unstable economic and social conditions in the 1920s. In addition, we also find evidence for a swift elimination of the urban infant mortality penalty in these two decades. For 1910 we could still detect such a penalty in many countries, while we find for most countries by 1930 a strong negative association between infant mortality and population density levels.

Keywords: infant mortality, decline, spatial analysis, urban-rural-differences

Introduction

The reduction of premature mortality is one of the most remarkable achievements of human societies in modern times. In the 19th and early 20th centuries, the risk to die between birth and the first birthday was in many areas of the world still far above 20% (see, e.g., Corsini and Viazzo 1997 for Europe). And also after the first birthday, mortality risks remained relatively high for the years to come. The reduction of premature mortality lowered the risk of human capital investments in single children. This contributed to the rapid human development of societies over the last generations (Reher 2011).

There are many studies that investigated spatial aspects of the infant mortality decline in specific European countries (e.g., van Poppel and Beekink 2002 on the Netherlands; Gregory 2008 and Woods et al. 1989 on England and Wales, Kintner 1988 on Germany), or that contrasted national level trends for different countries (Corsini and Viazzo 1997). But apart from comparative research on the Nordic countries (e.g., Edvinsson et al 2008) there is little cross-country comparative research at an intermediate level.[1] Here we look at infant mortality decline across Europe between 1910 and 1930 using a dataset of about 500 sub-national regions. While Europe had experienced a quite prosperous and relatively peaceful period between 1880 and 1914, this came to a dramatic end with the onset of World War I in 1914. In the 16 years to follow, Europe did not only experience a massive war that caused millions of deaths but also a period of massive economic crisis in the 1920s. As infant mortality and life expectancy are frequently used as measures of human development, it is interesting to explore to what degree different countries and areas in Europe were able to achieve infant mortality reductions under these rather unstable social and economic conditions.

Our paper has two main research objectives. The first is to explore whether a spatially detailed account of the infant mortality decline allows us to improve our understanding of the determinants that contributed to improve the survival chances of infants. The second is to investigate spatial and temporal aspects of the end of the urban infant mortality penalty in Europe, which was an important feature of spatial variation in infant mortality up until the early 20th century (van de Walle 1986). Our findings show that between 1910 and 1930 particularly Central European countries such as the German Empire, Austria and Hungary were able to catch up with other countries in Northern and Western Europe. This catch-up is remarkable given that these three countries lost World War I and faced very unstable social and economic conditions in the 1920s. The trends between 1910 and 1930 contributed to the emergence of a contiguous

[1] For a recent global account of current infant mortality variation across and within countries see Storeygard et al. (2008).

territory covering Northern, Western and Central Europe in which infant mortality was already very low, while high levels of infant mortality still persisted in most parts of Southern and Eastern Europe. We also find evidence that the urban mortality penalty for infants, which was still visible in large parts of Europe in 1910, had largely disappeared by 1930.

Theoretical considerations

The reduction of infant mortality is a very complex process and likely to be affected by frequent interactions between the strategies of individuals and changing contextual conditions. At the beginning of the mortality transition, European societies were characterized by a high disease burden with frequent epidemics (Omran 1998). These were also related to poor hygienic conditions and seasonal variation in access to nutrition (see also Szreter 2003). Under these circumstances, single individuals had less influence on the survival chances of their offspring. Even if they followed hygienic rules, about which awareness was gradually rising, it was difficult to prevent that the infant caught infections in one of the frequent epidemics. This was particularly true in spatiotemporal contexts in which parents were faced by limited access to food. Such situations occurred still frequently also due to limitations in transport and storage systems and markets, and the absence of modern welfare states.

In pre-transition times, there existed still strong regional variation in the levels of infant mortality within countries (see, for example Thorvaldsen 2002 on Norway). This variation was in part also affected by variation in regional customs. In Central Europe, for example, there existed a quite large area covering parts of southern Germany and Austria in which many children were not or only for a short period breastfed (see Kintner 1985 for Germany). Instead many infants were fed with meal pap. As the water was frequently contaminated, many infants suffered and died from diarrhoea, making this area of Europe a hot spot of infant mortality (Klüsener et al. 2014). It is also important to point out that a positive relationship between levels of economic development and mortality levels was in the 19th century not yet completely established within countries. Particularly infants living in fast growing cities of the 19th century faced due to high pollution levels and sanitation problems high mortality risks. As a result, these economically most developed places were also mortality hot spots (see, e.g., Kibele et al. 2015 for Germany). There were also no clear-cut distinctions across social-status groups. Whether or not individuals belonging to the higher social strata were able to translate their wealth in better survival chances seems to have been subject to substantial variation across space and time (see Bengtsson and van Poppel 2011 for overall mortality).

This is changing with the onset of the (infant) mortality transition (see also Omran 1998). The local or regional disease burden loses relevance, which is likely to be driven by an interaction between strategies of individuals and changes in contextual conditions (see also Watkins 1990). Better access to nutrition around the year as a result of better economic conditions and/or increased trade with other areas of the world is likely to make individuals more resistant at least to bacterial infections (Cutler et al. 2006). At the same time, new scientific knowledge about how to prevent infections through the observation of hygienic rules and vaccinations is spreading in societies. This has a decreasing effect on the overall disease burden and the frequency of epidemics, which in turn has a positive effect on the overall health status of societies. During the transition social status differences in survival chances might grow as better educated people who are usually concentrated in the big cities might be the first to benefit from improved access to nutrition, better sanitation, and new knowledge (see also Cutler et al. 2006).

As the infant mortality decline is a complex process, it is not surprising that the role of specific factors is subject to substantial debates in the literature. European societies have throughout the 19th and 20th century generally experienced increases in economic development (Bolt and van Zanden 2014). Thus, this aspect has been frequently put forward as a factor driving the mortality decline (for a general account see, e.g., Birchenall, 2007). However, puzzling in this regard is that the Scandinavian countries as forerunners in the infant mortality decline were in the late 19th century rather laggards in terms of the economic development in Europe. In addition, Easterlin (2004) has pointed out that the onset of modern increases in economic development is more temporally dispersed across countries compared to the onset of the mortality decline (see also Cutler et al. 2006). In addition, there is also rising evidence that reductions of infant and child mortality had a strong impact on economic development as they lowered the risks of human capital investments in single children (see Kalemli-Ozcan 2000). That causality can exist in both directions makes it more difficult to identify effects of economic growth on mortality.

We already mentioned that economic growth was in the 19th century also frequently linked with higher pollution levels in the most developed areas, which might have counteracted to some degree the positive effects of economic growth prior to the decline of heavy industries in the mid-20th century and the establishment of strict environmental standards. Also increases in trade relations can have positive and negative effects. As Sen (1981) has shown, functioning trade relations and markets are instrumental to reduce food shortages and malnutrition. However, at the same time they increase the risk that epidemics may spread due to the higher frequency of contacts between places. This might again particularly affect trading hot spots such harbour towns and surrounding areas.

Another important factor seems to the accumulation and diffusion of knowledge how to improve the survival chances of infants. To this also campaigns by state authorities, other institutions or individuals contributed. As early as in 1755 there was in Sweden a campaign aiming to improve the health of infants (Thorvaldsen 2013). Another example is Germany, where in the early 20th century campaigns were promoting the benefits of breastfeeding (Kintner 1988). In our study period, many nation states were also aiming to establish national health systems that contributed to reduce spatial variation in the access to health services. The latter also became increasingly efficient in the treatment of illnesses, to which also the introduction of strict hygienic standards contributed.

The identification of factors might also be complicated by the fact that some factors might constitute bottleneck conditions for change (see also Coale 1973 related to the fertility transition). Under the absence of knowledge about hygienic rules it is, for example, very difficult to limit the spread of infectious diseases. At the same time, in periods of crises existing scientific knowledge helps little if people are weakened through malnutrition which supports the spread of diseases. This is important for the interpretation of spatio-temporal decline patterns as they might be more informative for identifying factors that constituted bottleneck conditions than to obtain a full account of all factors that are necessary for an infant mortality decline to occur. Thus, we need to interpret the outcomes of our analyses with great precaution. Nevertheless, we hope that the analyses of the spatio-temporal aspects of the fertility decline between 1910 and 1930 will contribute to improve our knowledge on the determinants of the change.

Data and Analytical Strategy

For the analyses we gathered official local and regional infant mortality statistics for the periods around 1910 and 1930. A challenge in studying regional trends in infant mortality during this period is that due to World War I many national and regional boundaries changed. However, to analyse changes over time it is preferable to work with a dataset with time-constant regional boundaries. We thus aimed as a first step to obtain such a dataset. A number or considerations motivated us to take the regional boundaries as they existed in 1930 as a point of reference. These include that we are rather interested in the outcomes in 1930 than in the starting condition in 1910. In addition, we had for 1910 already compiled very detailed data for more than 5000 localities in Europe (Klüsener et al. 2014) which allowed us to derive with spatial interpolation techniques that are described below quite reliable estimates of infant mortality levels in 1910 for the 1930-regions. In terms of the regional division in 1930, we take the one used by Kirk (1946) for his book on the European population in the interwar years. This allows us to benefit from the fact that this book contains a large data section which provides for these regions data for a substantial number of social and economic indicators. These include demographic indicators such as population density, crude birth and death rates, migration rates, as well as gross and net reproduction rates. As social and economic indicators it provides information on illiteracy levels, the percentage dependent on agriculture and a measure of agricultural productivity. Another advantage of the regional division used by Kirk is that it was also taken as a reference point by the Princeton European Fertility Project, which provides regional data for a number of demographic indicators (general fertility rate, marital fertility rate, share married).

But before we explain how we derived our dataset with time-constant boundaries, we will first discuss data quality challenges. In the early 20th century there was still substantial variation across Europe in how state authorities were able to collect information on demographic events (SGF 1907, Edge 1928) as well as statistics on other social and economic phenomena as compiled in the volume by Kirk (1946). We will focus here on limitations in the vital registration systems as those states that had already established reliable vital registration systems were usually also better able to collect statistical information on other social and economic phenomena. Most countries in Northern and Western Europe had already at the beginning of our study period implemented quite efficient vital events registration systems. The situation was different in most of Eastern and Southern Europe were states particularly faced problems in recording birth and death events of children who died within the first days of life (see also Gourbin, and Masuy-Stroobant 1995, Klüsener et al. 2014). But also most of the latter states were able to improve their vital registration systems during the period under study. If this contributed to achieve a higher coverage in the registration of birth and death events of children who died shortly after birth, this would reduce the downward bias in reported infant mortality levels due to registration problems. These infant mortality “increases” would, however, be an artefact of improvements in the vital registration systems. Shortcomings in the vital registration system are of special concern for regional analyses as presented in this paper, as the degree to which the systems were able to register vital events was likely to vary across sub-national regions. Analyses by Klüsener et al. (2014) suggest that the registration systems in Eastern and Southern Europe had particularly shortcomings in peripheral rural areas. It is also relevant to note that the distinction between a live and stillbirth varied across countries. While the Scandinavian countries and Germany only defined those births as stillbirth where the child did not show any signs of life at birth, countries such as France and the Netherlands also considered those births as stillbirth were the child died prior to registration, which usually had to occur within the first three days.

As any attempt to correct for deficiencies of the vital registration systems in place would be based on bold assumptions, we decided not to implement corrections. Instead we will divide the countries that existed in 1930 up into two groups. The first includes countries that only comprise areas which had already quite reliable vital registration systems in place in 1910. The second is formed by those countries which include areas that had at least in 1910 still substantial problems in registering vital events. The analysis outcomes for the second group of countries have to be interpreted with great precaution. Our decision whether to include a country in the first or the second group was based on existing literature on the quality of vital registration systems in the period under study (SGF 1907, Edge 1928) and empirical analyses (Klüsener et al. 2014). The first group consists of the following countries: Austria, Belgium, Denmark, Finland, France, the German Empire, Ireland, Italy, Luxembourg, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom. The second group comprises Bulgaria, Czechoslovakia, Hungary, Poland, Portugal, the Soviet Union, Spain, and Yugoslavia. The only two bigger countries we are not able to cover in our analysis of trends in infant mortality are Greece and Romania. For Greece no vital statistics were compiled at the national level for 1910, while for Romania we were for this period only able to obtain data for Bucharest and the rest of the country. We are, however, able to provide regional data for these two countries for 1930.

In order to derive estimates on infant mortality levels in 1910 for the regions that existed in 1930, we use a spatial interpolation technique based on area weighting (Goodchild and Lam 1980). The underlying assumption of the estimation procedure is that the births and infant deaths are homogenously distributed both within the so-called *source regions* for which data are available, and the *target regions* for which estimates are produced. This might be considered to be a bold assumption as a homogenous distribution of the population and birth events is rather unlikely across regions. However, it is important to note that the accuracy of the estimation is largely dependent on the size of the source region in comparison to the target regions. In our case, we have data for more than 5000 regions available in 1910 to derive estimates for the 491 target regions in 1930. We thus believe that this rather simple interpolation technique is sufficient enough to derive reliable estimates.

In addition to socio-economic data, we also benefit from access to a GIS-dataset providing information on the development of all railways across almost whole Europe since the 19th century (Martì-Henneberg 2013). These shapefiles allow us to derive information on railroad density in our European regions which we consider in the early 20th century to be a good proxy for industrial development and economic development in general.

In the empirical section we will apply in the first part descriptive analysis techniques such as cartographic representations and correlation analyses. This is followed by a modelling part in which we apply spatial modelling techniques that allow us to control for the political geography of Europe and a number of socio-economic characteristics. In these models we will include only regional data from our first group of countries with relative good data quality. The spatial modelling techniques enable us to detect and potentially control for bias that is introduced by spatial autocorrelation in our models. As we work with spatially detailed data we are at risk to violate standard assumptions of regression models. This is particularly true for the assumption that all observations in the model should be independent from each other. This assumption is likely to be violated as neighbouring regions that e.g. belong to the same country are likely to share many similarities. In order to detect spatial autocorrelation we use the Moran's I test for spatial autocorrelation (Moran 1950). This test operates similarly as Pearson's product moment correlation coefficient, only that we are not controlling for the correlation of two variables x and y in regions i, but for the correlation of y in regions i with the average value of y in adjacent regions j. In defining adjacency we use a first-order queen definition in which all regions are considered to be neighbours that share at least one border point. The index can reach from -1 (strong negative spatial autocorrelation) over 0 (no spatial autocorrelation) to 1 (strong positive spatial autocorrelation). We will apply the test on the different dependent variables of our models as well as on the model residuals. Next to models with an OLS specification, we will also run Spatial Error models. These constitute an extension of the OLS model which allows us to assess the bias introduced by spatial autocorrelation in our model estimates (Anselin 2009). The general idea is to divide the spatially autocorrelated error up into a dependent and an independent part. The extended OLS equation is as follows:

$$y_i = \beta_o + \beta_1 x_{1i} + \ldots + \beta_k x_{ki} + \lambda \sum_j w_{ij} \varepsilon_j + \xi_i$$

in which ξ_i denotes the independent part of the error for each region i, while ε_j represents the spatially autocorrelated part which is derived through obtaining information on the errors in neighbouring regions j. The term w_{ij} represents a spatial weight matrix which defines the adjacency (in our case first-order queen), while λ denotes the coefficient estimate for the correlated error term. The latter cannot be derived through OLS estimation due to endogeneity concerns. Thus, in the estimation of the model we will first derive λ through a Maximum Likelihood estimation, before the β-coefficients are obtained with an OLS estimation. The isolation of the spatially autocorrelated error allows us explore to what degree the estimates and significance levels of the β-estimates are biased by spatial autocorrelation.

While we have particularly for 1930 a large number of potential covariates available, we face the problem that many of these variables are highly correlated (see Table 2). Thus, in order to avoid multicollinearity problems we present here model estimates for a very restricted number of covariates (details will be given in the results section).

Results

In discussing the results we will first turn to the descriptive maps. In Figure 1 we present maps of the infant mortality levels in 1910 and 1930 for our time-constant regions that reflect the regional division in 1930; Figure 2 shows absolute and relative changes over time. In the 1930 map of Figure 1 and the maps in Figure 2 we included next to the country borders that existed in 1930 also as dotted lines national borders that had been in place in 1910, but had been eradicated by 1930. All maps are based on a standard deviation categorization centred on the mean. The regional mean for our time-constant regions decreased from 142 to 93 infant deaths per 1000 live births between 1910 and 1930 which is indicative of a substantial infant mortality decline. In addition, we see notable changes in the variation across and between countries. In 1910, Norway and Sweden were still clear forerunners in the trend towards lower infant mortality, followed by Western European countries such as France, United Kingdom and Switzerland, while the Iberian Peninsula and Central and Eastern Europe were lagging behind. By 1930, many Western and Central European countries were able to narrow the gap to the forerunner countries in Scandinavia, while Southern and Eastern Europe reported still relatively high levels of infant mortality. We also observe drastic changes in within-country variation patterns. Many Western European countries exhibited still quite substantial within-country variation in 1910. This is particularly true for the German Empire, but also for the Netherlands, Belgium, France, and the United Kingdom. When contrasted with overall variation across Europe, this within-country variation had substantially declined by 1930. The only exception is Italy where differences between the North and the South were rather increasing between 1910 and 1930. As a result of these developments, a quite large contiguous zone emerged in the Northwest of Europe, in which infant mortality levels were already quite low. This zone comprised next to the Nordic Countries, the British Isles, the Benelux countries, France, Switzerland, the German Empire (with the exception of eastern Bavaria), the western part of Austria, large parts of northern and central Italy, and Catalunya in northwestern Spain.

In order to carve out the infant mortality change in the period 1910-1930, we present in Figure 2 two maps. The first displays trends in absolute numbers, while the second provides declines in per cent relative to the values observed in 1910. In both maps the German Empire stands out as an area which witnessed strong decline. This is particularly true for those areas in the eastern and the southern part that in 1910 had still reported quite high infant mortality levels compared to northwestern Germany. Also for Austria and Hungary we obtained quite high declines, if we look at the absolute levels, while the position of these two countries is less exceptional in the map that shows percentage decline. Another area with substantial absolute decline comprises the southern Netherlands, northern Belgium and the northern Rhineland in Germany, which had in 1910 constituted a local hot spot of infant mortality in Northwestern Europe. The declines in Russia and Yugoslavia have to be interpreted with great precaution as the vital registration was in these two countries over the whole study period still suffering from substantial shortcomings (Edge 1928). In the map that shows relative declines, also the Netherlands, Switzerland and England and Wales stand out as areas with above-average infant mortality declines.

In the second part of our results section we will turn to our correlation analysis between infant mortality and population density as a proxy for urbanization, and railroad density as a proxy for industrial development. As the distributions of both the population density variable as well as the railroad density variable are right-skewed, we log-transformed both variables. The outcomes of this analysis are presented in Table 1. As explained in the data section, we consider for this analysis countries in their boundaries as they existed in 1930. This implies that for a non-negligible share of countries the data for 1910 includes regions that were not yet part of that country in 1910. For other countries, we exclude regions that still belonged to the county in 1910. All countries that experienced changes in their borders are marked with a star. For our correlation analysis we only consider countries that had at least four regions in 1930. In Table 1 we separated the countries in two groups. The first contains countries that had relatively high standards of vital statistics collection by 1910, while the other countries are in the second group.

When we first turn to the population density variable, we see that of the 13 countries with relatively good data quality, we obtained for seven still a positive correlation with infant mortality levels in 1910. This group included all Scandinavian countries (Denmark, Sweden and Norway), the United Kingdom and Ireland, as well as Belgium and France. Among the countries with a negative correlation only Switzerland had a correlation below -0.3, which was mostly driven by the fact that two Alpine areas with low population density in southern Switzerland were lagging behind in the infant mortality decline (Wallis and Italian-speaking Tessin). Most of the countries for which we obtained negative correlations already for 1910 were situated in Central Europe. The correlations that we get for 1930 are for eleven countries more negative compared to 1910 suggesting that the negative effect of high population density on infant mortality risk was weakening. Only for France it increased, while it remained for Ireland at the same high level. In Ireland, the most densely populated region Leinster (which includes Dublin) reported the highest infant mortality decline between 1910 and 1930 (see Figure 2), but had still higher levels than the other Irish regions. By 1930, we obtain only for three of the 13 countries a positive correlation. These are next to Ireland the neighbouring countries of Belgium and France. On the other hand, the number of countries for which we derived a correlation below -0.3 increased from one to five (in addition to Switzerland also Austria, the Netherlands, Sweden and Finland). The persisting positive coefficient in Belgium seems to be related to the fact that the more densely populated Flemish-speaking northern part was lagging behind in the infant mortality decline. In France, it was related to the situation that the central part of France had at least initially been at the forefront of the infant mortality decline while the more densely populated North with Paris and South with Marseille and Lyon had been lagging behind.

For the eight countries that still faced substantial problems in the collection of reliable vital statistics, we would expect for the internal variation within the countries that particularly the quality of statistics in rural areas would be low and contribute to a downward-bias in the published infant mortality statistics (see also Klüsener et al. 2014). This downward bias would decrease as the quality of the registration system also improves in rural areas. This would imply that in countries with low-quality registration systems we would expect the problem of the incomplete registration in peripheral areas to contribute to a upward bias in the correlation between population density and infant mortality. However, interestingly, even in 1910 we obtain for five of the eight countries already a negative correlation. We will come back to this aspect in the discussion part. By 1930, we obtain only for one of the eight countries still a positive correlation (Portugal).

The outcomes for railroad density vary a bit in terms of the correlations that we obtain for specific countries. But the general trends are the same. Among the 13 countries with relatively good data quality, the correlation is decreasing for eleven countries while Belgium and France pose exceptions to this general trend. The number of countries with negative correlations increases from six to nine. Among the eight countries with less-reliable vital registration systems, the number of countries with negative correlations increases from four to seven. Thus, overall, our correlation analyses provide support for the view that the urban infant mortality penalty was rapidly disappearing, and that this was true not only for densely populated areas, but also for heavy industrialized ones where air pollution levels were also in the 1930s still quite high. However, these findings might be affected by spatial autocorrelation challenges, so that we will look at this in more detail in the spatial regression models.

We will now turn to the outcomes of our models with which we analysed regional data from our first group of countries with relative good data quality. For these models we consider three dependent variables. The infant mortality levels in 1910 (models 1 and 2) and 1930 (models 3 and 4) and the decline in per cent between 1910 and 1930 relative to the levels in 1910 (models 5 and 6). The models with uneven numbers just contain two control variables: population density in the respective period[2] and the agricultural productivity in 1930. Instead of the latter we would have preferred to include the illiteracy variable which might be a good proxy for human capital accumulation. But we faced the limitation that illiteracy was already very low in many Western European countries by the end of our study period so that many countries were not even collecting information on this aspect any longer in their censuses. Thus, for a substantial number of countries only national-level estimates are available. We therefore decided to use agricultural productivity instead which might to some degree serve as a proxy for development levels and human capital accumulation (outside highly urbanized metropolitan areas). The latter variable is not available for 1910, but we also included it in the model for 1910 as we believe that regional variation in agricultural productivity was not subject to drastic changes over time even if productivity generally increased. Nevertheless, the outcomes for this variable in the 1910-model should be interpreted with precaution. In addition, we added a factor variable for the country a region was part of in 1930. For this we use France as a reference category as it is the country with the highest number of regions in the sample. In Table 3 we present our model outcomes for the six models with a normal OLS specification. Table 4, on the other hand, contains the same models as in Table 3 in terms of the specification of the included covariates. However, the estimates are not derived with an OLS, but with a Spatial Error specification.

If we first turn to the outcomes of our population density variable, they provide confirmation for the outcomes of our correlation analysis. In model 1 we obtain for 1910 still a positive significant association between population density and infant mortality, while it is by 1930 negative and significant (model 3). That infant mortality was particularly fast declining in densely populated areas is also supported by the high negative and significant coefficient in model 5. When we control in addition for country dummies, only the negative coefficient for the change model 6 remains significant. The outcomes for the models with the Spatial Error specifications (Table 4) show similar tendencies, only that the positive association is with this specification not significant in model 1S, while it gets significant in model 4S. Overall, the outcomes provide support for the view that the relationship between population density and infant mortality is changing and that this is not just an artefact of spatial autocorrelation. The outcomes for the agricultural productivity variable are less conclusive. For the change models it is in all specifications negative and significant in the expected direction (models 5, 5S, 6 and 6S), but particularly the positive significant outcomes in models 2 and 2S are puzzling. These

[2] For models 5 and 6 we use the average value of the population density levels of 1910 and 1930.

problems might be related to the fact that we have for this variable only information on the level in 1930 available, which might be less meaningful for understanding regional infant mortality variation in 1910. In terms of the country dummies, we will focus on the outcomes for the change models. They support the visual pattern visible in the maps that the infant mortality decline was in the period 1910-1930 focused on the Central European countries. This includes the Netherlands, Germany, Austria[3] and Switzerland. These findings are interesting in light of explanations that link improvements in infant survival with economic development, as Germany and Austria were the countries with lowest increases in GDP between 1910-1930 in our sample (Bolt and van Zanden 2014). We are currently waiting to get access to regional GDP data for that period which would allow us to account for these aspects in our models.

Discussion and Conclusion

Our findings show that the infant mortality decline was in the period 1910-1930 centred on countries in Central Europe. This finding is remarkable considering that countries such as Germany and Austria lost World War I and faced very volatile economic and societal conditions in the 1920s. In Germany, the decrease might be related to campaigns that promoted the benefits of breastfeeding (Kintner 1988). In addition, we also find evidence for a swift elimination of the urban infant mortality penalty in these two decades. For 1910 we could still detect such a penalty in many countries, while we find for 1930 for most countries a strong negative association between infant mortality and population density levels. However, we find less support for such a penalty in the peripheral countries in the East and South of Europe. This might be related to the situation that urbanisation processes and industrial development were less intense in these areas which also had potential effects on the degree to which infant mortality rates were elevated due to pollution and sanitation problems. The outcomes of our models also provide support for the view that this period marked the end of the urban infant mortality penalty. As next steps we are considering to improve our data for the models by applying corrections for false stillbirths to the Dutch and French data both for 1910 and 1930. In addition, we aim to further improve our models by e.g. integrating regional controls for GDP development.

[3] For Austria, the negative coefficient is not significant in the Spatial Error specification model 6S, but that might be related to the spatial position of Austria in the far Southeast of our sample and the way we specified the Spatial Error model.

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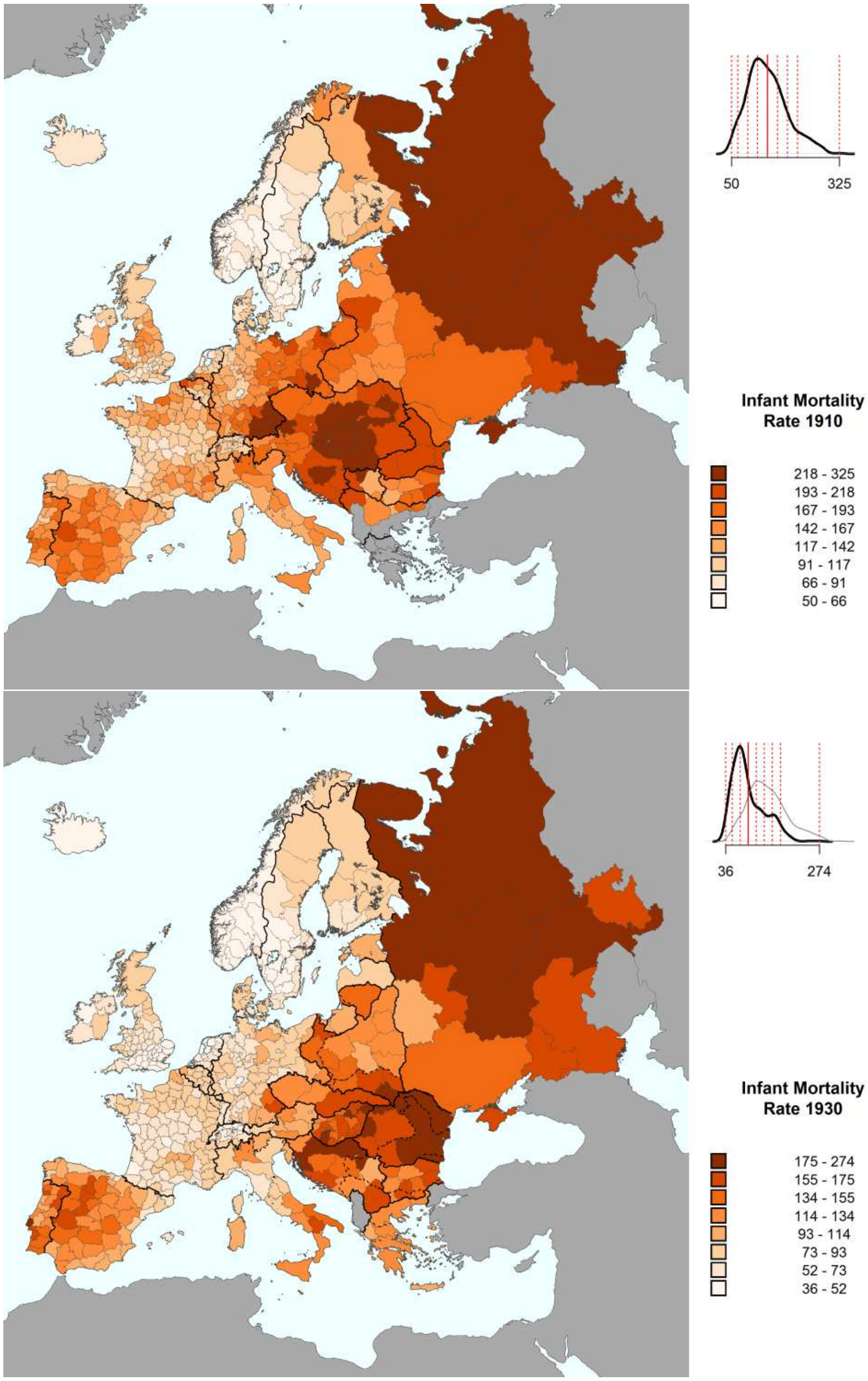
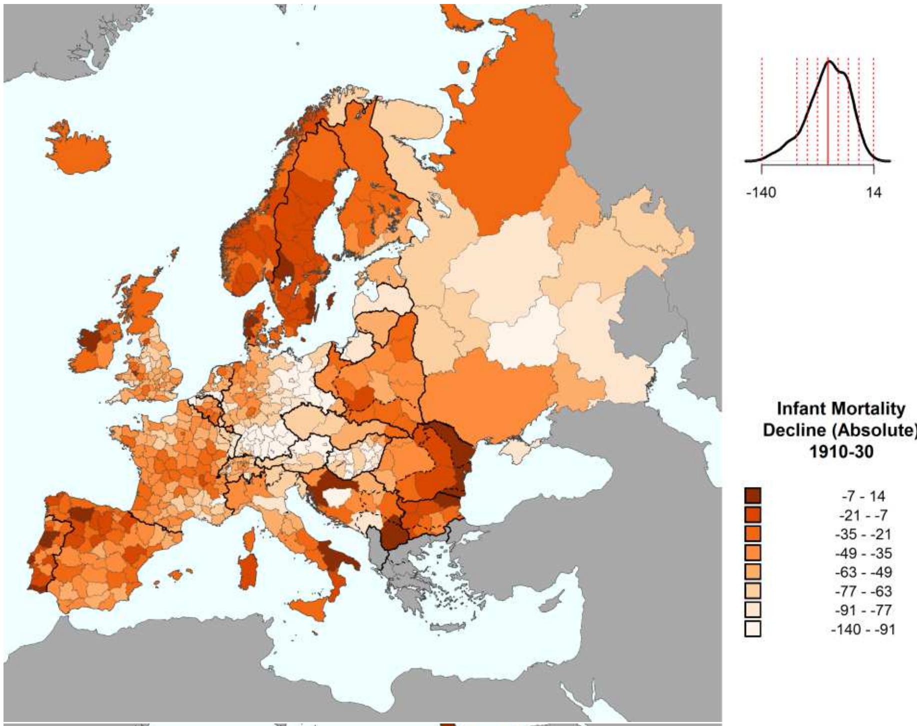
Figure 1: Infant Mortality Levels 1910 and 1930 (491 time-constant regions*)

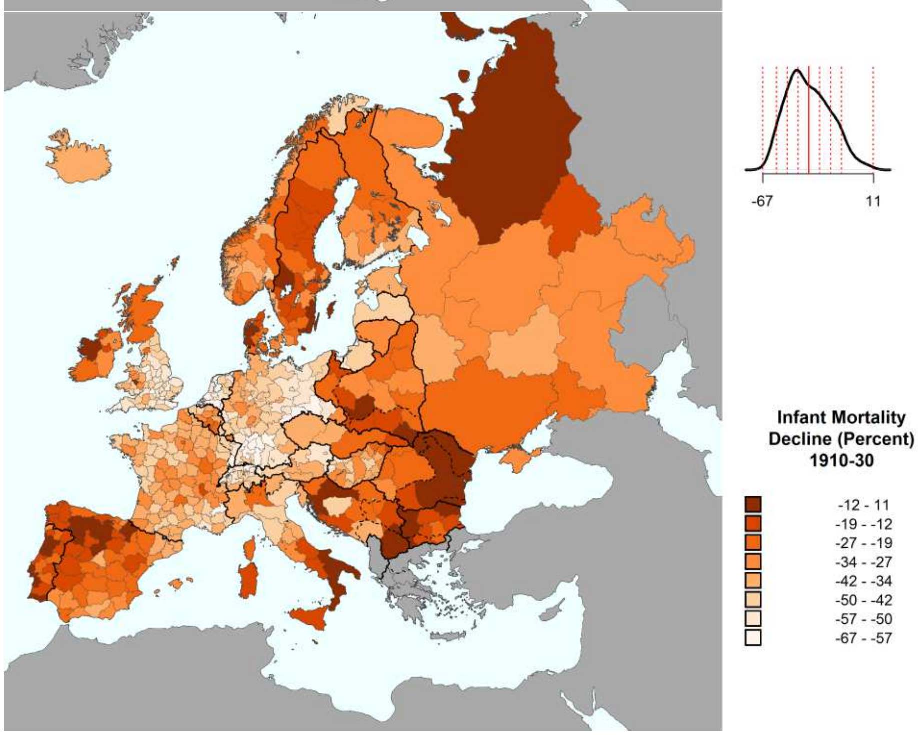


* Plus ten Greek regions in 1930.

Source: State Statistical Offices; Kirk (1946); own calculations
Base Map: MPIDR Population History GIS-Collection

Figure 2: Infant Mortality Decline 1910-1930 (491 time-constant regions*)





* Plus ten Greek regions in 1930.

Source: State Statistical Offices; Kirk (1946); own calculations
Base Map: MPIDR Population History GIS-Collection

Table 1: The end of the urban mortality penalty across Europe

Country (Borders of 1930)	Number of Regions	Population Density (ln) 1910	Population Density (ln) 1930	Railroad Density (ln) 1910	Railroad Density (ln) 1930
Countries with relatively good data quality					
Austria*	9	-0.13	-0.31	-0.19	-0.39
Belgium*	9	0.48	0.36	-0.09	0.11
Denmark*	8	0.25	-0.11	-0.44	-0.81
Finland*	9	-0.16	-0.61	-0.10	-0.78
France*	90	0.11	0.22	0.00	0.04
Germany*	67	-0.13	-0.27	-0.18	-0.31
Ireland*	4	0.97	0.97	0.79	0.77
Italy*	18	-0.03	-0.26	0.11	-0.04
Netherlands	11	-0.14	-0.34	0.42	0.29
Norway	20	0.10	-0.28	0.82	-0.03
Sweden	25	0.10	-0.43	0.01	-0.48
Switzerland	10	-0.35	-0.60	-0.16	-0.29
United Kingdom*	70	0.50	-0.01	0.29	-0.20
Countries with problematic data quality					
Bulgaria*	7	-0.63	-0.63	-0.18	-0.46
Czechoslovakia*	4	-0.63	-1.00	-0.71	-0.96
Hungary*	26	0.13	-0.38	0.25	-0.41
Poland*	17	0.35	0.00	0.5	0.51
Portugal	18	-0.10	0.19	-0.48	-0.25
Soviet Union*	12	-0.24	-0.52	-0.58	-0.15
Spain	48	-0.56	-0.62	0.04	-0.01
Yugoslavia*	10	0.31	-0.18	0.24	-0.02

Notes: Countries which came into existence or experienced changes in their boundaries between 1910 and 1930 are marked with a *. Correlations are only presented for countries with at least four regions.

Source: State Statistical Offices; Kirk (1946); Martí-Henneberg (2013); own calculations

Table 2: Correlation matrix

	Imr10	imr30	lnpop den10	lnpop den30	lnrrdn 10	lnrrden 30	cbr10	cbr30	illit30	depagr 30	prodagr 30	north	east
imr10	1	**0.74**	*0.34*	*0.33*	0.19	0.19	*0.40*	0.28	0.11	-0.12	-0.00	*-0.41*	0.17
imr30	**0.74**	1	0.07	0.07	-0.06	-0.07	*0.41*	**0.54**	*0.44*	0.17	-0.16	*-0.40*	0.28
lnpopden 10	*0.34*	0.07	1	**0.98**	**0.82**	**0.81**	0.04	-0.15	-0.03	**-0.54**	0.29	*-0.36*	-0.24
lnpopden 30	*0.33*	0.07	**0.98**	1	**0.80**	**0.80**	0.10	-0.14	-0.04	**-0.59**	0.29	*-0.30*	-0.19
lnrrden 10	0.19	-0.06	**0.82**	**0.80**	1	**0.99**	-0.14	-0.28	-0.23	**-0.56**	*0.42*	-0.20	*-0.33*
lnrrden 30	0.19	-0.07	**0.81**	**0.80**	**0.99**	1	-0.12	-0.28	-0.24	**-0.56**	*0.41*	-0.17	-0.29
cbr10	*0.40*	*0.41*	0.04	0.10	-0.14	-0.12	1	**0.60**	0.24	-0.00	-0.10	0.17	**0.57**
cbr30	0.28	**0.54**	-0.15	-0.14	-0.28	-0.28	**0.59**	1	**0.58**	*0.33*	-0.22	-0.16	0.25
illit30	0.11	0.44	-0.03	-0.04	-0.23	-0.24	0.24	**0.58**	1	*0.40*	*-0.34*	*-0.39*	0.19
depagr30	-0.12	0.17	**-0.54**	**-0.59**	**-0.56**	**-0.56**	-0.00	*0.33*	*0.40*	1	**-0.52**	-0.14	0.21
prodagr30	-0.00	-0.16	0.29	0.29	*0.42*	*0.41*	-0.10	-0.22	*-0.34*	**-0.52**	1	0.09	*-0.45*
north	*-0.41*	-0.4	*-0.36*	*-0.30*	-0.20	-0.17	0.17	-0.16	*-0.39*	-0.14	0.09	1	
east	0.17	0.28	-0.24	-0.19	*-0.33*	-0.29	**0.57**	0.25	0.19	0.21	*-0.45*		1

imr10: infant mortality rate 1910; imr30: infant mortality rate 1930;
lnpopden10: population density 1910 (ln); lnpopden30: population density 1930 (ln);
lnrrden10: railroad density 1910 (ln); lnrrden30: railroad density 1930 (ln);
cbr10: crude birth rate 1910; cbr30: crude birth rate 1930;
illit30: Illiteracy levels in 1930 (for some countries only national level estimates available);
depagr30: share dependent on agriculture 1930;
prodagr30: agricultural productivity 1930;
north: latitude of region centroid
east: longitude of region centroid

Notes: Includes only regions of countries with relatively good data quality and at least four regions: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom. Correlations above 0.5 are shown in bold, correlations above 0.3 in italic.

Table 3: Model outcomes – Linear models

Dependent Variable	Model 1 Infant Mortality Rate 1910	Model 2	Model 3 Infant Mortality Rate 1930	Model 4	Model 5 Infant Mortality Rate % change 1910-1930	Model 6
Intercept	123.37***	100.00***	99.36***	76.53***	-20.10***	-25.71
Log population density*	3.80*	0.92	-0.99**	-0.55	-2.25***	-1.12*
Productivity agriculture 1930	-0.03	0.10***	-0.08***	0.03	-0.05***	-0.03**
Country dummies						
Austria*		67.70***		19.55***		-12.26***
Belgium*		12.59		7.19		0.81
Denmark*		-41.37**		-6.35		17.90***
Finland*		5.19		-3.25		-5.13
France*		-		-		-
Germany*		39.88***		3.54		-12.22***
Ireland*		-22.45#		-8.73		8.43
Italy*		36.96***		30.92***		4.82*
Luxembourg		40.31		10.95		-9.71
Netherlands		-20.98*		-30.55***		-16.44***
Norway		-45.93**		-31.94***		0.17
Sweden		-47.31***		-23.46***		11.86**
Switzerland		-17.66		-29.50***		-17.36***
United Kingdom*		-12.73		-16.56***		-6.67***
Moran's I dependent variable	0.76***		0.69***		0.59***	
Moran's I residuals	0.68***	0.47***	0.55***	0.41***	0.49***	0.37***
Adj. R-squared	0.02	0.52	0.12	0.48	0.18	0.45
AIC	3499	3302	3167	3007	2801	2681
N	334	334	334	334	334	334

Significant at: * p<0.05; ** p<0.01; *** p<0.001

Notes: Models are weighted by population size of regions (mean of numbers for 1910 and 1930).

Table 4: Consistency checks – Models 1-3 with Spatial Error specification

	Model 1S	Model 2S	Model 3S	Model 4S	Model 5S	Model 6S
Dependent Variable	**Infant Mortality Rate 1910**		**Infant Mortality Rate 1930**		**Infant Mortality Rate % change 1910-1930**	
Intercept	126.15***	110.25***	113.75***	92.24***	-11.42***	-17.78
Log population density*	1.33	1.14	-2.07***	-1.33*	-1.68***	-1.47***
Productivity agriculture 1930	0.05*	0.10***	-0.04*	0.01	-0.05***	-0.04***
Country dummies						
Austria*		10.37		6.40		-2.67
Belgium*		2.39		0.89		-0.03
Denmark*		-44.93**		-12.11		13.10*
Finland*		-14.66		-17.76		-8.34
France*		-		-		-
Germany*		26.89**		-2.35		-12.70***
Ireland*		-13.86		-13.46		-1.51
Italy*		17.84*		23.06***		5.13#
Luxembourg		47.89		7.14		-16.26
Netherlands		-8.01		-32.22***		-21.84***
Norway		-53.99*		-40.41**		-4.75
Sweden		-50.97**		-32.85**		2.56
Switzerland		-35.11*		-44.10***		-19.18***
United Kingdom*		-5.88		-9.65		-6.67***
AIC (OLS)	3499	3302	3167	3007	2801	2681
AIC (ERROR)	3195	3170	2954	2879	2586	2548
N	334	334	334	334	334	334

Significant at: * p<0.05; ** p<0.01; *** p<0.001

Notes: Models are weighted by population size of regions (mean of numbers for 1910 and 1930).