The Determinants of Maternal Mortality in a Sample of German Villages (1766-1863)

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Abstract: The object of this work is to examine the determinants of maternal mortality in eighteenth and nineteenth century Germany, with a focus on the effects of nutritional stress before the demographic and sanitary transition. Historians generally believe that the quality of maternal care was the strongest determinant of maternal mortality and malnutrition could play only a limited role. This study tests this assumption using a longitudinal approach to assess the effects of short term nutritional crises on maternal mortality during and immediately after childbirth in six historical villages. Preliminary results show that the hazard ratio of maternal death increases significantly one year after an economic stress, confirming that maternal mortality was strongly linked to the malnutrition caused by famines or bad harvests. The analysis demonstrates that farmers were more protected from this effect than other socioeconomic groups, whereas urban workers were more strongly affected.

(Draft, please do not quote)

1. Introduction

In western countries maternal mortality rates remained at significantly high levels during the entire nineteenth century and steadily declined after the 1930s (Loudon 2000). If we consider that nearly half of all maternal deaths in developing countries still occur during childbirth, or in the immediate period after confinement (Ronsmans, Graham 2006), studying past maternal mortality risks can provide useful suggestions for prevention (De Brouwere et al. 1998; Van Lerberghe, De Brouwere 2001).

Previous research has already demonstrated that maternal mortality in the past could be affected by bio-demographic factors such as age of parturient and parity (Hammel, Gullickson 2004; Högberg 1985; Knodel 1988). Naturally, quality standard of assistance in childbirth was also considered one of the main determinants in the past (Loudon 1992). Other recent historical studies also indicate the significance of further socio-economic determinants such as household structure and kinship network (Hammel, Gullickson 2004).

Less attention has been paid to assessing the effects of nutritional stress before the demographic and sanitary transition. This is because scholars generally believed the quality of maternal care was the strongest determinant and malnutrition could play only a limited role (Loudon 2000). Therefore the purpose of this paper is to point out the importance of women's nutritional status by assessing the impact of short term changes in grain prices on maternal survival.

Macro-aggregative studies have already demonstrated that mortality was sensitive to grain price fluctuations - the short-term positive check - in most of pre-industrial Europe (Galloway 1988; Lee R. 1981). In more recent studies, a micro event history approach has also been used to show the effects of short-term economic crises on mortality in historical populations of western and far eastern countries (Campbell et al. 2004). So adopting a similar approach, statistical models will be used on individual micro data to examine the effect of short term economic crisis on maternal mortality in six historical German village populations between the eighteenth and nineteenth century (1766-1863). Maternal mortality will be taken into account in the short period following childbirth using the complete dataset for the six German villages collected by John Knodel (Knodel 1988).

This paper has been divided into three parts. The first part briefly provides an analytical framework followed by a description of the area under study, the data and the methods used. The empirical results are then presented and followed by a concluding discussion.

2. Background

Maternal mortality in the past: definition, measures and trend

The definition of maternal mortality following childbirth should preferably be based on the cause of death. This is obviously not possible for an historical population, since death or burial records for past populations seldom contain reliable clinical diagnoses. Very little quantitative information is available on causes of maternal death before the twentieth century. According to Högberg, in Sweden two-thirds of maternal deaths were directly due to obstetrical causes (difficult labor, eclampsia, hemorrhage and sepsis), whereas one-third was due to indirect causes such as pneumonia, tuberculosis, dysentery, and heart disease (Högberg 1985; 2004). However, during historical times, puerperal sepsis was a frequent and severe problem in lying-hospitals. In addition, abortion and miscarriage represented another relevant risk, since methods of abortion, both mechanical and chemical, frequently provoked air embolism and sepsis. As a matter of fact, most abortional deaths were attributable to illegal abortions (Högberg 1985).

Given the lack of reliable information, we must assume a definition that simply classifies deaths to women within some period following the birth of the last child (alive or stillborn) as constituting a maternal death. Based on traditional family reconstitution, the maternal mortality rate is calculated as the ratio between maternal deaths and the number of childbirths and it expresses the risk of dying during or shortly after childbirth (Knodel 1988; Wrigley et al. 1997; Henry 1987). Relying on this temporal definition, several estimates have also been carried out for other historical populations (Högberg 1985; Cortes-Majo et al. 1990; Humphries 1991).

During the nineteenth century, maternal mortality rates still remained high in Europe with some differences at national level (Hammel, Gullickson 2005). In Sweden, during the nineteenth century, lower levels were due to the better maternal care, based on trained midwives and doctors (Högberg 1985). However, at the end of the nineteenth century, around 300-500 maternal deaths out of 100,000 births were respectively counted in Sweden and England (Loudon 2000). Maternal mortality started to decline significantly in developed countries only after the introduction of sulphonamide in 1937 which were extremely effective against streptococcus and so against puerperal fever (Högberg 1985, Loudon 2000). Further progress followed the introduction of penicillin and blood transfusions, improvements of obstetric services, and better training of midwives (Loudon 2000). However, the decline of maternal mortality appears to have occurred later than the overall mortality reduction. In some historical populations, rapid changes in socio-economic conditions - such as the transformation of the rural world into a modern one - initially had a controversial effect on maternal mortality (Hammel, Gullickson 2005; Knodel 1988). While the workload for women increased, the required improvements in maternal care were more difficult to achieve in a short time. As a matter of fact, the end of the eighteenth century and the nineteenth century was a period of time in which the working conditions of many married women worsened due to rapid industrialization and intensification of agricultural production (Ankarloo 1979; Imhof 1981).

Maternal Depletion

The "maternal depletion syndrome" describes the negative energy balance and/or micronutrient deficiencies resulting from the burden of frequent reproductive cycles (one cycle being conception, pregnancy, lactation/postpartum) combined with under-nutrition and overexertion - and its impact on a woman's health and nutritional status (Jelliffe, Maddocks 1964). Many later studies have used "maternal depletion" to describe the negative impact of repeated childbearing on women's bodies in terms of poor nutrition, greater exposure to disease and other physical and emotional stress. A more recent definition of maternal depletion syndrome takes into account both biological and practical aspects, distinguishing between childbearing patterns and inadequate diet or poor nutritional status (Winkvist, Rasmussen, Habicht 1993). Previous studies based on data from developing countries suggest that maternal and infant mortality could be affected by the number of previous children or spacing between births (Fedrick, Adelstein 1973; Pebley, Da Vanzo 1993). In addition, a hospital based study for contemporary developing countries showed that the durations of interpregnancy intervals are significantly associated to both maternal health and mortality (Conde-Agudelo, Belizàn 2000). However, it is interesting to note that no clear evidence of a general maternal depletion effect was found studying developing countries and European populations in the past (Alter et al. 2004; Davanzo et al. 2004; Ronsmans, Campbell 1998).

Nutritional status

The importance of nutritional status could be considered a controversial point as the debate is still open. On one hand, Loudon (2000) asserts that the decline of maternal death was caused only providing better quality maternal care, not by improving the diet. On the other hand, Högberg (2004) claims that nutritional deprivation could be a major factor underlying maternal mortality. Even if the knowledge base for the contribution of nutrition to maternal survival is too weak, almost every published study has found greatly increased maternal mortality among severely anemic women (Rush 2000). Moreover evidence from other studies suggested the protective effect of vitamin A against puerperal infection (Green at al. 1931; West et al. 1999).

Maternal death could have its roots in the entire female lifetime, since deficiencies of calcium, vitamin D, or iron in infant early childhood could negatively affect adult heights and consequently the risks of obstructed labor in the reproductive ages. Many studies have already related maternal height to obstructed or prolonged labor (Konje and Ladipo 2000; Rush 2000). In addition, evidence from medical literature show that severe malnutrition in childhood commonly provoked small pelves in women and consequently a higher risk of obstructed labor and maternal death in communities without easy access to health facilities (Neilson et al. 2003). In these terms, it is possible to point out the better nutritional status of children's cohort born in the 1920s, who started their reproductive life in the 1940s, experiencing lower risks of obstructed labor (Högberg 2004).

Short term economic and nutritional crisis

In preindustrial Europe, annual variations in grain prices affected the quantity of grain available for consumption and therefore the general standard of living (Galloway 1988). As stated above, clear fertility and mortality responses to short-term changes in food prices or real wages have already been found in micro-individual studies (Campbell et al. 2004) and in macro-aggregate ones for several preindustrial countries, indicating the high degree of vulnerability in those societies (see, e.g., Galloway 1988; Lee R. 1981; Weir 1984). As a consequence of a bad harvest, higher grain prices significantly reduced the survival levels. Moreover the mortality rise could still last some years after the shock prices. From this perspective, one could argue that the malnutrition associated to the prices crisis could negatively impact on maternal health, and could consequently assess the maternal mortality response to short-term economic stress. In addition, previous studies also demonstrated the existence of differential mortality responses by socioeconomic status, since different social groups suffered economic stress in different ways. Although clear evidence has not yet been found (Alter et al. 2004), it is possible to expect that short term changes in food prices could also have selective effects on maternal mortality risks. For example, the mothers of the daily wagers' group would be more affected by the high level of prices than farmers, since they could not rely on stored supplies of grain.

Furthermore, it must be considered that during critical periods an increasing demand for agricultural labor could also create an extended workload for peasant women, including the ones that were pregnant. As recent studies have already demonstrated, during military mobilization the withdrawal of men's labor from subsistence farming increased the labor burden of women and consequently the maternal mortality risks. Women in late pregnancy with increased workloads might suffer miscarriage or stillbirth, and events that carry high risks of death during pregnancy (Hammel, Gullickson 2004, 2005). Similar mechanisms could also be at work during bad economic times, when males migrated to find work elsewhere and rural women remained alone taking on a heavier burden of agricultural work and allowing them less time to nurture women giving birth.

Study Area

The villages which were included in the present study offer a remarkable variety of demographic and geographic conditions since they are situated in the north (Middels), in the center (Braunsen and Massenhausen) and in the south (Kappel, Rust and Öschelbronn) of Germany (see map). Öschelbronn in Württemberg, Middels in East Friesland and the two villages of Braunsen and Massenhausen in Waldeck were predominantly agricultural. Few economic opportunities and growing pressure on scarce sources provoked considerable migration fluxes. In Kappel and Rust situated in Baden, the economy was based on agriculture and fishing, since both these villages were located close to the river Rhine, in the south of the Baden region. A restricted group of rich farmers owned most of the land, making social differences more and more evident. Before embankment works, frequent flooding used to ruin harvests, causing subsistence crisis and hunger (Knodel 1988). As Knodel reported (1988), in these villages people lived close to the subsistence level and were particularly vulnerable during years of poor harvest.

Since lactation is an important determinant of infant mortality and a possible cause of the maternal depletion syndrome, it is important to underline some regional variations in infant-feeding patterns. Based on some information on infant-feeding practices for a number of areas in Germany (Knodel 1988: Kintner 1985), fairly prolonged breastfeeding appears to have been most common in the regions of Waldeck and East Friesland in the north, while more moderate breastfeeding characterized the areas of Baden and Württemberg in the south.

Map here

The demographic behaviour in all these villages has already been studied in great detail by John Knodel in a long-term research project summarized in his 1988 book. He also analysed the determinants and the evolution of maternal death in the eighteenth and the nineteenth centuries, by estimating the maternal mortality rates. These estimates were expressed as maternal deaths per 1000 confinements, according to different lengths of time following childbirth (7, 42, 60, and 90 days). According to his findings, the first week after childbirths was the most dangerous period of time, since it included approximately half of all the deaths occurring within 42 days of delivery. These results show that maternal mortality levels somewhat worsened during the nineteenth century. Maternal mortality rates within 42 days registered 7.8 for the period 1800-1824 increasing to 11.3 for the period 1825-1849. This rate (11) remained unchanged from 1850-1875 and then slightly declined to 9.7 in the last twenty-five years of the nineteenth century. It is also possible that agrarian reform based on more “labour-intensive exploitation of existing resources” (Lee W. R. 1981) contributed to worsening the burden of agricultural work on rural workers and on peasant women that probably were not allowed to rest even during pregnancy or after confinement, or to assist any women in childbed.

Finally, Knodel (1988) noted some variations across villages, since Middels and Kappel registered evidently lower maternal mortality rates within 42 days (respectively 6.5 and 7.4) than the other villages (varying from 10.3 to 11.9). Comparing the Middels rates to other ones calculated for East Friesland, Knodel concluded that this low value was probably due to some statistical fluctuations and not to a remarkable geographic difference.

Data

The used data is based on Ortssippenbuch, literally named “book of local kinsmen”. This typical German source is composed of a collection of village genealogies, which could be reorganized into the same logical scheme as the traditional family reconstitution (Knodel, Shorter 1976; Knodel 1988). Since individual codes allow the linkage of the information of the couples to all children ever born, this data can also be reshaped into a longitudinal format suited for event history analysis (Gutmann, Alter 1993).

The dataset includes a sample of 6 of the 14 villages which were primarily used by Knodel (Brausen, Kappel, Massenhausen, Middells, Öschelbronn and Rust) and it represents a reliable base for analyzing maternal mortality (Knodel 1988).

In these six villages, data includes all vital events of all the families that were registered in the village parish registers, whereas only pre-selected couples were coded for the other eight villages, increasing the risk of possible sample bias. Since all the couples were coded in the six villages under study, possible bias in maternal mortality are avoided (Knodel 1988).

However, basic restrictions on the original data have been defined in order to select the most suitable sample of confinements for the present study. Firstly, complete childbirth date is required. Secondly, the analysis was limited to the childbirths of married women whose marriage year was known. Thirdly, only local confinements that occurred in the village are considered. No restrictions have been imposed on the date of the mother death, taking into account all cases. As a matter of fact, with regard to the adult mortality estimations based on family reconstitution, the bias of the maternal mortality estimation is less severe, since it is unlikely that many women migrate out of a village shortly after giving birth. Consequently women for whom no death date is known can be safely assumed to have survived the critical period after confinement (Knodel 1988).

Since stillbirths would have no genealogical relevance, it is possible that they could be under registered. In such cases, the woman’s death does not appear to follow a reproductive event in the reconstituted family history and thus is not classified as a maternal death affecting the maternal mortality estimates. However, the used dataset provide indications about stillbirths. Their proportions varied considerably from village to village (Knodel 1988: 281, 494). Based on our calculations, the stillbirth rate in the sample of fully-coded villages was 33 per 1,000 births during the period 1766-1863. This level is included within the range of 25-65 per 1000 births that has been estimated for other historical populations in Europe (Woods 2005: 153), as well as the 26-48 per 1000 births at the district level in Germany which official statistics calculated for the period 1875-1877 (Knodel 1988: 481-482).

Considering multiple births as a single childbirth, the present analysis has taken into account a total of 16,596 childbirths from 1766–1863, counting 167 maternal deaths for 4,496 mothers in the following 60 days after confinements. Table 1 shows the distribution of mothers, confinements and maternal deaths in the six villages under study during the period 1766–1863.

Table 1 here

Model

The risk of maternal death within two months (60 days) of childbirth is estimated by using a duration model. To estimate the effects of a set of bio-demographic and socio-economic covariates on the hazard of maternal dying, Gompertz models have been estimated by using the following equation:

$$h(t|x_j) = exp\ (\gamma t)\ exp(\beta_0+x_j\beta_x)$$

In the above formula, j denotes the observed confinement and $(t|\ x_j)$ represents the hazard rate at time t for an observation j with characteristics x_j. The regression coefficients β_x are to be estimated from the data. The shape of the baseline hazard depends on the ancillary parameter γ. So the hazard function increases with time if γ is positive, whereas it decreases, if γ is negative. If γ is equal to 0, the model is reduced to an exponential one (Bernardi 2006; Cleves, Gould and Gutirrez 2004).

It must be said that Gompertz distribution is one of the most frequently used in medical research to model mortality data, since it assumes that the hazard rate is monotone and increases or decreases exponentially with time (Cleves, Gould and Gutirrez 2004). From a theoretical point of view, Gompertz distribution seems to be extremely suitable for studying maternal mortality, since the risk of maternal death after confinement is expected to decrease exponentially with time. However parametric (Exponential, Weibull, and Log-normal) and semi parametric (Cox proportional hazard) models have also been estimated in order to compare the results. The obtained results were extremely similar. However, table A in appendix shows the Akaike Information Criterion (AIC) and the log-likelihood which have been calculated for each alternative model. As is possible to see, Gompertz model has to be preferred since it registers the highest log-likelihood and the lowest AIC value.

Variables

The main covariates of the estimated model are prices and their interactions with socio-economic status. However on the basis of several historical studies, effects of several physiological and bio-demographic factors have to be controlled (Hammel, Gullickson 2005; Högberg 1985; Knodel 1988; Loudon 1992). Thus the analysis includes both bio-demographic covariates, which capture some important physiological aspects involved in maternal mortality risks after confinements (age of mother, interval from the last birth, parity, stillborn, and multiple birthing), and the variables that reflect the economic (price index), and social conditions (socio-economic status).

Parity

Most studies show that the risk of maternal death is high at first parity, decreases from second to fourth parity, and then it rises again (Hammel, Gullickson 2005; Knodel 1988). As a matter of fact primiparity could be associated to increased risk of obstetric hemorrhage and obstructed labor (Rush 2000). Thus, in order to verify the possible existence of this J-shaped relation, a category variable has been created (1, 2-4, 5-7, 8+).

Age of mother

Several studies on historical population show that maternal mortality risks are higher at younger and older age at any parity (Hammel, Gullickson 2005; Knodel 1988; Loudon 1992). So a non-linear effect is also expected for mother the age of the mother at childbirth, with higher risks for younger and older ages. For this reason, the age of the mother was also included as a category variable based on five-year age classes.

Multiple births and still births

Most surveys showed the strong link between increased maternal mortality risk and stillbirths (Loudon 1992). Moreover, empirical evidence demonstrated that multiple gestation increases the risk of significant maternal morbidity and mortality (Conde-Agudelo, Belizàn 2000). Thus higher risks for multiple birthing and stillborns are expected, since they can create the conditions for very dangerous childbirth. The analysis therefore includes two dummy variables equal to one if the confinement outcome was a multiple birth or a stillborn.

Birth intervals

In order to control the possible effect of maternal depletion syndrome, the length from the immediate preceding birth is taken into account (in the case of the first birth, the interval is based on the length from the marriage). Even if it is difficult to verify its effect on maternal mortality risk without adequate pregnancy history, a negative relationship is expected between mortality and the length of the previous childbirth. Some other evidence from historical studies demonstrated the significant negative effect of birth intervals on maternal mortality risks (Hammel, Gullickson 2004, 2005).

Infant-feeding practices

Previous studies showed how lactation can negatively affect maternal weight and energy balance (Dewey et al. 2000; Merchant, Martorell, Haas 1990; Adair, Popkin 1992). According to this evidence, one can logically argue that prolonged breastfeeding can increase the maternal depletion and so the maternal mortality risk. Thus, it is important to control the effect of geographical differences in infant-feeding patterns. An additional dummy variable distinguishes whether the childbirth was given in a northern village (Middels, Brausen and Massenhausen) or in a southern one (Öschelbroon, Kappl and Rust). As stated above, in northern Germany, breastfeeding was prolonged and almost universal whereas in the southern part it was more moderate.

Family and kinship support

In preindustrial society where collective institutions were absent, the co-resident domestic group could perform the function of providing security for individuals (Laslett 1988). Two discrete variables measure the number of potential supportive female relatives that could assist during delivery (number of daughters more than 12 years and number of mother's sisters in the village). The numbers of daughters is counted at childbirth, whereas the number of sisters is calculated at marriage as a proxy of the extension of the kinship. Because of the lack of information in the used data set, it is not possible to elaborate a more precise variable that takes into account the household structure (Hammel, Gullickson 2004, 2005). However, a negative effect on the maternal mortality risk is expected, since more daughters and sisters could imply more support during childbirth.

Mortality levels

As a matter of fact, the number of prior child deaths reflects the general health conditions of the mother and her personal, family and environmental circumstances (Davanzo et al. 2004). So a discrete variable that counts the number of previous child deaths is included in the model.

General mortality levels have also to be controlled. So annual crude death rates were first estimated based on the used villages data set and included in the model. The calculations only took into account individuals whose date of birth and death were known.

As already explained (Knodel 1988; Wrigley et al. 1997), the estimations of adult mortality from family reconstitution data is considerably more problematic than measures of infant and child mortality. Thus it must be kept in mind that crude death rates based only on the individuals under observation from birth to death will not be fully representative of the whole population. However this measure is somewhat useful to our purpose, since it captures the mortality swing over time[1].

Period effect

After a slight improvements at the end of the eighteenth century, increasing maternal mortality risks were observed during the nineteenth century for these same villages under study (Knodel 1988) and other communities of central Europe (Hammel, Gullickson 2004, 2005). In order to assess possible non-linear period effects, a five category variable has also been included (1766-1774, 1775-1799, 1800-1824, 1825-1849 and 1850-1863).

Season effect

A four category variable for each season is also included to control the seasonal variations. As a matter of fact, seasonal weather and meteorological changes could exert some effects on

[1] John Knodel indicated model life tables of Coale and Demeny that best fitted to the estimated mortality risks in infancy and childhood for the villages under study (Knodel 1988; 53-60). So it has been possible to compare the estimated crude death rates to the ones reported in the indicated life tables, just in order to compare the bias degree. For instance, the estimated crude death rate for the period 1800-1849 is on average 31 per thousand, whereas the interpolated value based on the indicated West model is around 35.

parturient conditions. In addition, in rural societies where rural work was organized on a seasonal basis, it is possible to hypothesize that workloads for peasant women could exacerbate in some months of the year.

Socio-economic status

Concerning the effect of socio-economic status (SES), the expected results are by no means clear. As in the case of infant mortality, it may be possible that the risk of maternal mortality increases from higher social groups to lower ones.

The occupation of the husband at marriage is reported in the original data. Unfortunately, this information is not referred at childbirth and it is a clear disadvantage. Firstly, all occupations have been coded by using the standard coding scheme for historical occupations HISCO (Historical International Standard Classification of Occupation). Secondly, they have been classified into HISCLASS (Van Leeuwen, Maas and Miles 2002; Van Leeuven and Maas 2005). This classification scheme represents a basis for arranging different class schemes (see see e.g. Van Leeuwen and Maas 2005; Van de Putte 2006). The socio-economic covariate comprises a 7-category classification based on HISCLASS: 1. Higher managers and professionals, 2. Lower managers, lower professionals, clerical and sales, 3. Skilled workers, 4. Farmers, 5. Lower skilled workers, 6. Unskilled workers, and 7. No occupation, that comprises the cases in which professions were unknown in the original data and also the non-professional status in HISCO. It is important to say that this classification scheme also distinguish rural farm workers from the urban ones.

So a categorical covariate has been coded according to HISCLASS and used in the estimated models. Since the “higher managers and professionals” represent around 2 per cent of the considered cases, they were preliminary grouped to the “lower managers and professionals”.

Prices series

Fluctuations in grain prices have been used to measure short-term economic stress on the level of maternal mortality. The price of rye – an important basic bread grain in the period under study – has been used rather than a composite index.

Rye has been included in this study, since it made up a remarkable proportion of the wages spent by laborers during pre-industrial period (Hagen 1986). Moreover rye cultivation represents a significant proportion of German agricultural production (Friedmann 1978). In early nineteenth-century Prussia, bread was made by using four times as much rye as wheat (Ashley 1921), and in countries like England, France and Germany, the working population generally consumed rye, while wheat was primarily a luxury food, for the upper classes (Ashley 1921).

Prices from three different places have been taken into account to represent the different areas of Germany (see map). Prices of Emden have been used for the northern villages. Since there were some gaps, data from nearby Lüneburg and Stade has been utilized to supplement the series (for a total of 10 years). A series from Göttingen was available for the whole period and has been used for the villages in central Germany. Heilbron's prices have been attributed to the southern villages. Since they were only available until 1832, Göttingen prices have been utilized again after this year (Jacks 2004, 2005). It should also be said that all the used prices refer to harvest years.

Based on these prices, three different indexes were calculated for each area of Germany where the villages were situated (see Figure 1).

Figure 1 here

In order to measure short-term fluctuations, deviations from a medium term trend have been calculated using the Hodrick-Prescott filter with a smoothing parameter of 6.25 (Hodrick and Prescott 1997). In this case, it is better to use this filter than first differences, since we need deviations from what could be considered normal years. On the contrary, first differences would measure just changes from one year to the next. By using first differences, increases from very low levels to normal ones would yield the same value as from normal to very high, whereas residuals from the Hodrick-Prescott filter give a positive value when prices were higher than the normal level, and a negative value in cases when prices were lower. Figure 2 shows the price residuals which have been used in estimated models.

In the estimated models the calculated residuals have been divided by 10. Thus the coefficients have to be interpreted as the effect on maternal mortality risk of a 10 unit deviation in the rye price index compared to the normal level.

This approach is almost the same as was used in a previous study on fertility and prices relationship (Dribe and Scalone 2010).

Both current prices and prices lagged by one year are included, since it is possible to expect that, in some situations, short term economic stress could affect mortality not only immediately but one or some years later as been widely demonstrated (see for example Galloway 1988).

Figure 2 here

In order to assess differential short term price effects by social class, separated interaction models have been estimated. So it is possible to hypothesize that farmers, as grain producers, may have been more protected from market fluctuations than other social categories. Members of laborers' group, who needed to purchase grain, are expected to be more strongly affected by high prices. Higher status groups can be expected to have had access to resources implying that they were not significantly affected by fluctuations in grain prices.

Preliminary Results

Before considering the models' estimates, a first descriptive finding can be considered. Figure 3 shows the smoothed hazard estimates of dying within 60 days after childbirth (Cleves, Gould and Gutirrez 2004). The hazard reaches its peak around one week after childbirth when obstetric haemorrhage is the main medical cause of death (Ronsmans, Graham 2006) and it gradually declines in the following 52 days. This result is fully consistent with theory and is a guarantee of the reliability of the used data.

Figure 3 here

Tables 2 and 3 show the results for three different models: a basic model including only age of mother and parity categories, multiple birthing, stillborns, number of prior child deaths, crude death rate, area of residence, seasons, periods, number of sisters and daughters over 12; a full model with all covariates; and the full model with interactions between socioeconomic status and price.

Table 2 here

Before turning to the price effects, it can be seen that the role of bio-demographic determinants in maternal mortality is confirmed. In addition, their effects are stronger than the socio-economic determinants in terms of magnitude and significance.

The basic model in table 2 clearly shows that multi birthing and stillborns were extremely dangerous, since the respective hazard ratios are equal to 2.8 and 7.5 with a full statistical significance (see also figure 4.1 and 4.2).

Figures 4.1 and 4.2 here

However, it is also possible to see the already known j-shape effect for the age factor, since the hazard ratio is equal to 1.5 before age 20, decreases to 0.8 between 25 and 29 years, then it rises significantly to 1.9 above age 40 (figure 5). Moreover, there are some signs of parity effect. As expected, the highest and most significant risk is registered for the first parity (2.0). Subsequently, the hazard ratio is lower on the following parities. However, other evidence for maternal depletion syndrome is not found, since the last birth interval registers a hazard ratio close to 1 without any significance.

Figure 5 here

Both the control variables for mortality register significant positive effect as expected (much stronger for the number of prior child deaths). No significant differences related to the area of residence have been found, although the lower risk for "north" category appears as an unexpected result. Since in this area breastfeeding was universally spread, a higher mortality risk was expected. Although no significant effects are registered for seasonal category, lower risks than the referred category (springtime) are registered for summer and fall.

Considering the period effects, after a decline of maternal mortality at the end of eighteenth century, the risks increased again on the following periods (even if they remained under the 1766-1774 level and do not register any significance).

The hazard ratio of the calendar year is close to 1 with a weak statistical significance. It might be that this is caused by the presence of a non linear effect or by the scale of the covariate.

Although the number of sisters or daughters over 12 appears not to be statistically significant, the effects are in the expected direction since the respective hazard ratios are less than 1.

Looking at the effect of socio-economic conditions, unskilled workers register a higher maternal death risk than farmers (the reference category). However, the statistical significance of this ratio seems quite weak. Nevertheless, it is not possible to say that lower socioeconomic status was associated with lower maternal mortality. Considering all the other classes, even if no other estimate is significant, it is interesting to note the U-shape of the hazard ratios, which are higher for lower skilled and unskilled workers, decrease for skilled and farmers and then rise again for managers, professionals and sales occupations.

It is also possible to note the effects of short term nutritional crises; as in the full model the hazard ratio increases significantly one year after price rise. In these terms, increases in maternal mortality risk seem also be related to the malnutrition caused by famine or bad harvests.

As already said, the possible differential impacts of economic stress must be assessed by interacting price and SES effects. As expected, farmers registered almost no price effects on both current and lagged year (table 3). Precisely, since their ratio is below 1 (0.907), it seems they experience a slightly reduction in maternal mortality risks. However the other results seem a little bit controversial. Firstly, skilled and lower skilled workers seem to suffer economic stress more than the unskilled ones, since one year after price rise they registered strong significant higher risks (no significance was found for the current year effect). Secondly, upper socio-economic groups do not appear to be more protected than the working groups (although no estimated ratio is significant).

Table 3

It was expected that proletarians should be extremely exposed to the price fluctuations, but this was not confirmed. A possible hypothesis is other differential characters could denote the individuals of the same social group. Fortunately, the adopted HISCOCLASS allows new regrouping by socio-economic class. So in a second scheme, lower skilled and unskilled farm workers have been aggregated in a unique category (rural), whereas lower skilled and unskilled workers in other activities have been grouped in another unique category (non rural).

By using this new SES classification in another interaction model (table 4), it is interesting to note that urban lower and unskilled workers register a significant higher risk than farmers. As a matter of fact, in the following year after a price rise, their risk is 39 per cent higher than that of farmers. In contrast, the lagged price effect of rural lower workers is much more limited. The correspondent hazard ratio almost equal to 1 makes the low rural workers more similar to the farmers. In these terms, it seems that maternal mortality after an economic crisis was affected not by the distinction between lower and unskilled workers, but between urban and rural workers.

Table 4

Discussion

In this preliminary paper, determinants of maternal mortality have firstly been assessed in a sample of German villages before demographic transition. Survival analysis has shown the extreme danger that multiple birthing and stillborn represented during the 60 days following childbirth. Their effects are the strongest in terms of magnitude and statistical significance. The higher risk for first childbirths is consistent to previous findings and theory. As a matter of fact, before 1935 primiparity was associated with high maternal mortality risks from sepsis, toxanemia, shock, and trauma (Loudon 1992). However, it is also interesting to note that higher maternal mortality risks were observed for lower age of mothers (less than 20 years). Risks reduced between parities 2 and 4 and from 20-25 years, but they significantly increased again for higher parties and ages, confirming that older age at childbirth could be dangerous for maternal survival.

Nevertheless, previous-birth interval did not cause any significant effect. From this point of view, the maternal depletion hypothesis has not been confirmed. Extensive reviews of the literature and empirical studies (Alter et al. 2004; Ronsmans, Campbell 1998; Davanzo et al. 2004) lead to similar conclusions since they do not find any evidence of effects of birth spacing on maternal mortality. However, it might be that the precise length of the calculated birth intervals was affected by the presence of unregistered abortions (spontaneous or voluntary), which is not possible to take into account in village genealogies and traditional family reconstitution (see also Hammel, Gullickson 2005). On the one hand, abortions increase maternal mortality risks. On the other hand, they do not shorten the calculated interval from the last birth, since it is not possible to take them into account.

A control for breastfeeding was approximated by a dummy variable which distinguished between northern and southern villages. However the estimated effect was not statistically significant and registered an unexpected direction (the northern villages where breastfeeding was almost universal and prolonged experienced a lower maternal mortality risk). There are two reasons for this. Firstly, even in the southern villages taken into account, breastfeeding practices were somewhat spread. Only in the Bavarian villages, breastfeeding was almost absent. Unfortunately they are not included in our sample and thus it is not possible to see a clear difference. Secondly, as Knodel (1988) already noted the northern village of Middels registered an unusual low maternal mortality rate which was under the East Frisian levels. So the low rates of Middels could be ascribed to some random fluctuations and affected our estimates.

Looking at the estimated period effects, maternal survivorship improved at the end of the eighteenth century and then slightly worsened during the other periods in question. The absence of an evident decline is fully consistent with the maternal mortality trends that have generally been observed in western countries during the nineteenth century. The effective decline took place only after the third decade of the twentieth century. In addition, research on historical German families clearly showed that the end of the eighteenth century and the nineteenth century represented a crucial period for female conditions (Lee R. 1981). As a matter of fact, the labor-intensive nature of agrarian reforms increased female workload and caused an excess of mortality among married women in procreative years (Imhof 1981).

The number of daughters over 12 years old and the number of the mother's sisters in the same village have not shown any significant results. However, the negative direction of these effects is interesting, since it seems that older daughters and sisters could represent a kind of protection. In addition, it must be said that unfortunately the number of sisters refers to the marriage time.

The analysis has also shown some interesting differences by socio-economic status. According to the results of the presented models, skilled workers and farmers experienced lower maternal mortality risk than proletarians. Furthermore, even without any statistical significant, the upper group of “managers and professionals” registered a higher maternal mortality risk. However, this is not a real unexpected result. In nineteenth century Britain, maternal mortality demonstrated a “reversal social class relationship” since it was often higher in middle and upper classes than in the working classes. The possible explanation to this curios anomaly was that women from upper classes were more often assisted by physicians during delivery and, therefore, were more likely to suffer the effects of unnecessary interferences (Loudon 1986, 2000).

Effect of short term change in rye prices became significantly evident one year after the economic stress, since an increased risk of maternal death is registered at lag 1 with a statistical significance on the edge level). This delayed response should not be considered peculiar since it is consistent with previous findings on short term responses of mortality in preindustrial Europe. As several studies have already shown, rises in grain prices had generally a faster impact on fertility and nuptial levels, since they imply deliberate choices (see for example Dribe, Scalone 2010). In contrast, the effect on mortality was often delayed since the nutritional stress took time before severely affecting human health. According to previous explanations, the majority of deaths were not a direct consequence of starvation, but it was mainly due to the weakening of the immune system that was not able to contrast infectious diseases (Livi Bacci 1990). In these terms, it is possible to extend this explanation to the maternal mortality case, assuming that a severe nutritional stress could significantly reduce the mothers’ immune defenses to the infections. During an historical period where the majority of maternal deaths were caused by puerperal fever, this could be considered a determining point. Nevertheless, a further economic explanation is also possible. A bad harvest could negatively affect markets, salaries and the work demand. As a consequence, the migration of male workers could worsen the female workload, exacerbating the risks for late pregnant and parturient women.

Interactions between SES and price effects were also assessed. As expected, farmers were more protected than the other groups, since it seems they did not experience any increase of maternal mortality risk after a rise in rye prices. It must be remembered that bad harvest did not necessary imply worse living standards for farmers. As previous historical studies on preindustrial Europe have already demonstrated, poor harvests often brought about higher grain prices which mainly benefited grain producers. While landless and urban workers suffered, famers could take advantage and somehow increase their profits (Abel 1980).

In addition, urban workers and proletarians appear to be more affected than farmers and rural workers. Since townspeople were basically grain consumers, bad harvest and high grain prices forced them to spend a higher proportion of their income on essential foodstuff. As demand for other services and products fell, urban markets and trade stagnated, further depressing wage and salary (see the literary review in Galloway 1988). As a consequence, skilled workers (e.g. shoemaker, tailors, etc.) and their assistants would surely have suffered the demand decline of their products, making them particularly vulnerable during high price periods. In these terms, it is also possible that rural areas could be less affected than urban areas during economic crises.

Farms seem to offer more protection for lying-in patients. Some explanations are possible. One could be related to different types of maternal assistance during childbirth. At least in the first controversial phases of childbirth medicalization, rural midwives could provide better assistance than urban male physicians (Loudon 1992). Studies on developing countries (Koblinsky 2003) and historical populations clearly show that expert midwives (Högberg 2004; Loudon 1992, 2000) can reduce risks of maternal death, even without proper medical organization. But physiological explanations are also possible. In the pre-industrial era, self-sufficient farmers could rely on better nutritional status than their urban counterparts (Komlos 1994). In these terms, a better physiological capital (Fogel 2003) could protect farmers from maternal depletion and pregnancy risks, making the difference during bad economic times and famine. As a further possible explanation, better nutritional status during their entire life time could also improve adult heights and statures (Livi Bacci 1990), reducing the risks of obstructed labor (Konje, Ladipo 2000).

Finally, the response of rural landless and proletarians in agriculture should be considered with necessary caution. According to the results of this analysis, they registered almost the same prices effect of the farmers (the interacted hazard ratios are almost equal to 1) Moreover they seem to suffer much less the economic crisis effect than their urban counterparts.

This is an unexpected result. On one hand, during bad economic times rural workers could rely on the same protection factors as farmers (e.g. access to stored grain supplies). On the other hand, the limited number of cases (less than 170) do not fully support such a challenging explanations. However a similar result has already been found for a nineteenth century Belgian population (Alter et al. 2004; 355) where relative risk of maternal mortality decreased after a rise in oat prices. In this case, the given explanation takes into account the selection effect at work. As several historical studies have already explained, high prices also reduced fertility and therefore “women who were at greater risk of maternal mortality were probably less likely to give birth in years of high prices”. Actually, a previous study on the same villages taken into account in this analysis has already demonstrated the selective negative effects of high prices on fertility. Compared to the other social groups, poor landless and unskilled workers significantly reduced their fertility during the two years following a bad harvest (Dribe, Scalone 2010). Such response could be due to voluntary (deliberate childbirth postponement) or involuntary factors (cessation of ovulation, lower fecundity, loss of libido).

Finally, it is important to take into account the question of how representative the used data is, since the number of maternal deaths is limited. Even if the estimated effects of the bio-demographic variables are consistent with the previous findings and the theoretical views, the main concern remains about the interactions between prices and socio-economic status which would require a higher number of cases. So it would be necessary to replicate the same analysis on different historical populations.

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Table 1 Distribution of maternal deaths and childbirths 1766-1863 in the six German villages

	Braunsen	Kappel	Middels	Massenhausen	Oschelbronn	Rust	Total
Maternal deaths	14	25	13	18	35	62	167
%	8.4	15.0	7.8	10.8	21.0	37.1	100.0
Women	286	877	742	540	605	1446	4,496
%	6.4	19.5	16.5	12.0	13.5	32.2	100.0
Childbirths	914	3,518	2,540	1,556	2,609	5,459	16,596
%	5.5	21.2	15.3	9.4	15.7	32.9	100.0

Note: Only childbirths and married women selected in the analysis, and maternal deaths occurred within 60 days.
Source: *Ortssippenbucher*, archived at the Population Studies Center, University of Michigan.

Table 2 Gompertz hazard analysis of the risk of dying within 60 days after childbirth in the six German villages, 1766-1863

		Basic Model	Full Model
	Mean	Haz. Ratio	Haz. Ratio
Age of Mother			
< 20	0.01	1.487	1.507
20-24 (Ref.)	0.14	1.000	1.000
25-29	0.24	0.788	0.783
30-34	0.24	1.414	1.385
35-39	0.18	1.413	1.339
> 40	0.10	1.934 +	1.851 +
Unknown	0.09	0.417 +	0.369 +
Parity			
Parity 1	0.24	2.035 **	1.916 **
Parity 2-4 (Ref.)	0.42	1.000	1.000
Parity 5-7	0.23	1.114	1.164
Parity 8+	0.11	0.722	0.755
Multiple Birth			
Single (Ref.)	0.99	1.000	1.000
Two twins or more	0.01	2.807 **	2.968 **
Stillborn			
Born alive (Ref.)	0.97	1.000	1.000
Stillborn	0.03	7.511 ***	7.405 ***
Previous-birth Inteval	2.17	1.059	1.054
Number of Prior Child Deaths	0.77	1.208 **	1.214 **
Crude Death Rate	30.9	1.036 *	1.031 *
Area of Residence			
South (Ref.)	0.70	1.000	1.000
North	0.30	0.876	0.856
Number of Daughters > 12 old	0.15	0.830	0.847
Number of Sisters in the Village	1.22	0.980	0.974
Season			
Springtime (Ref.)	0.23	1.000	1.000
Summer	0.23	0.685	0.682
Fall	0.27	0.846	0.840
Winter	0.26	1.029	1.038
Period			
1766-1774 (Ref.)	0.06	1.000	1.000
1775-1799	0.20	0.556 +	0.565 +
1800-1824	0.26	0.763	0.728
1825-1849	0.30	0.933	0.910
1850-1863	0.19	0.868	0.868
Socioeconomic Status			
Managers, professional and sales	0.06		1.518
Skilled workers	0.23		0.798
Farmers (Ref.)	0.29		1.000
Lower skilled workers	0.20		1.308
Unskilled workers	0.09		1.653 +
No occupations	0.12		1.568 +
Rye price			
Rye price (t)			0.980
Rye price (t-1)			1.067 *
Gamma		-0.088 ***	-0.088 ***
Number of Maternal Deaths		167	167
Number of Childbirths		16596	16596
Log Likelihood		-1145	-1,138

Significance level: + 0.1; * 0.05; ** 0.01; *** 0.001

Table 3 Gompertz hazard analysis of the risk of dying within 60 days after childbirth with socio-economic status*price interactions (first SES classification)

	Mean	Haz. Ratio
Socioeconomic Status		
Managers, professional and sales	0.06	1.508
Skilled workers	0.23	0.704
Farmers (Ref.)	0.29	1.000
Lower skilled workers	0.20	1.273
Unskilled workers	0.09	1.687 +
No occupations	0.12	1.578 +
Rye price		
Rye price (t)		0.907
Rye price (t-1)		0.907
Interactions socioeconomic status*rye price (t)		
Managers, professional and sales		1.146
Skilled workers		1.010
Lower skilled workers		1.137
Unskilled workers		1.156
No occupations		1.080
Interactions socioeconomic status*rye price (t-1)		
Managers, professional and sales		1.223
Skilled workers		1.382 ***
Lower skilled workers		1.266 *
Unskilled workers		1.122
No occupations		0.999
Gamma		-0.088 ***
Number of Maternal Deaths		167
Number of Childbirths		16,596
Log Likelihood		-1,130

Significance level: + 0.1; * 0.05; ** 0.01; *** 0.001.

Note: the model also includes the following variables: age of mother, parity, multiple birth, stillborn, previous-birth interval, number of prior child deaths, crude death rate, area of residence, number of daughters more than 12 years old, number of sisters in the village, season, period.

Table 4 Gompertz hazard analysis of the risk of dying within 60 days after childbirth with socio-economic status*price interactions (second SES classification)

	Mean	Haz. Ratio
Socioeconomic Status		
Managers, professional and sales	0.06	1.501
Skilled workers	0.23	0.700
Farmers (Ref.)	0.30	1.000
Lower skilled and unskilled workers - Not Rural	0.09	1.152
Lower skilled and unskilled workers - Rural	0.20	1.480 +
No occupations	0.12	1.579 +
Rye price		
Rye price (t)		0.906
Rye price (t-1)		0.906
Interactions socioeconomic status*rye price (t)		
Managers, professional and sales		1.147
Skilled workers		1.011
Lower skilled and unskilled workers - Not Rural		1.160
Lower skilled and unskilled workers - Rural		1.130
No occupations		1.080
Interactions socioeconomic status*rye price (t-1)		
Managers, professional and sales		1.224
Skilled workers		1.385 ***
Lower skilled and unskilled workers - Not Rural		1.394 ***
Lower skilled and unskilled workers - Rural		1.064
No occupations		1.000
Gamma		-0.088 ***
Number of Maternal Deaths		167
Number of Childbirths		16,596
Log Likelihood		-1,127

Significance level: + 0.1; * 0.05; ** 0.01; *** 0.001.

Note: the model also includes the following variables: age of mother, parity, multiple birth, stillborn, previous-birth interval, number of prior child deaths, crude death rate, area of residence, number of daughters more than 12 years old, number of sisters in the village, season, period.

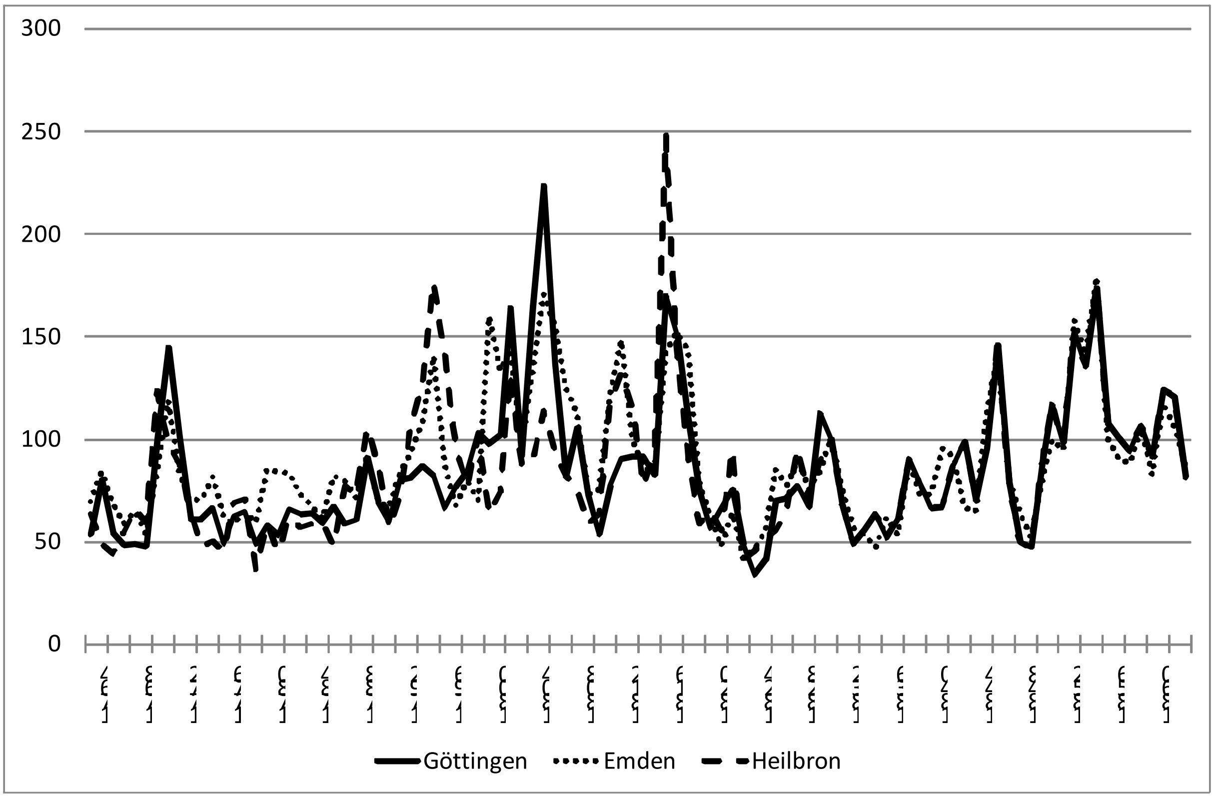
Appendix

Table A Comparison of fit statistics for various versions of Full Model in Table 2

	Log Likelihood	AIC	df
Gompertz	-1138.116	2342.231	33
Log-normal	-1154.402	2374.805	33
Weibull	-1160.723	2387.447	33
Exponential	-1253.667	2571.333	32
Cox	-1531.018	3124.037	31

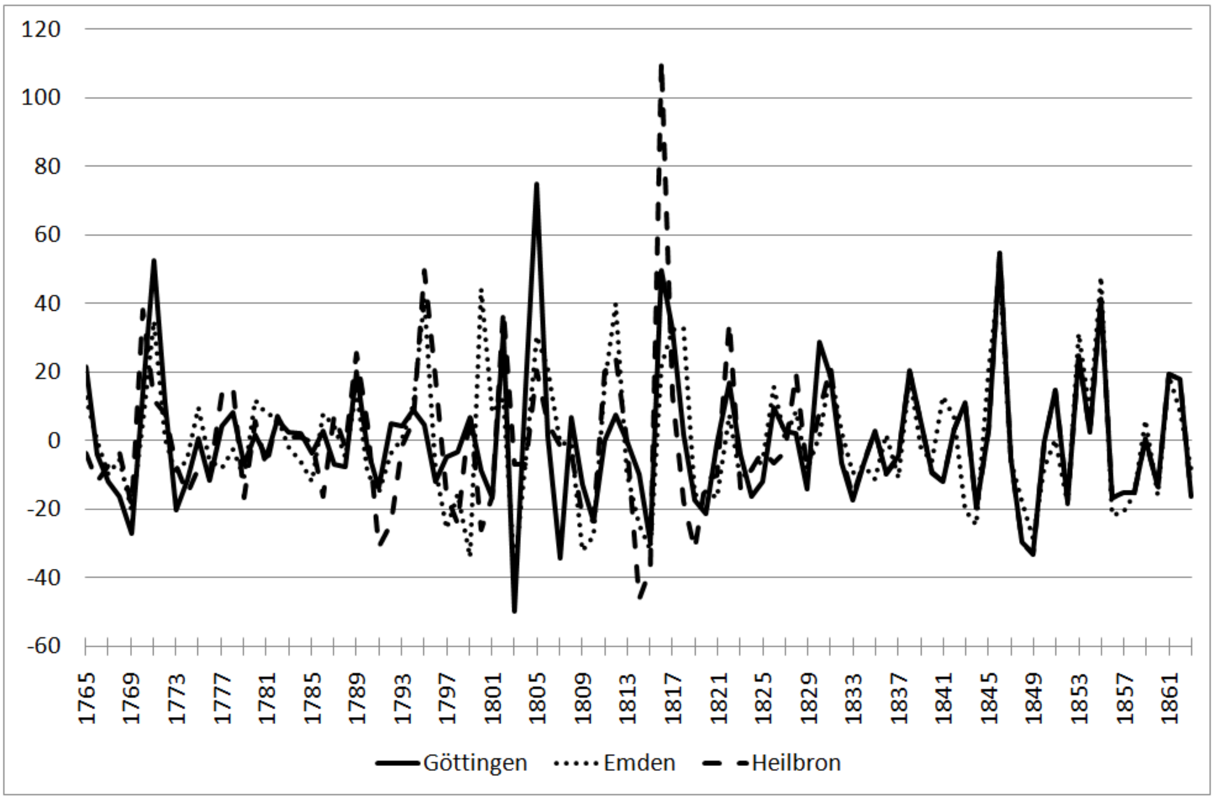
Map – Geographical references of the demographic data and the price series

Figure 1 Rye price index 1764-1863 in Emden, Göttingen and Heilbron (1831=100)



Source: Jacks 2004, 2005. Note: For construction of the series see text.

Figure 2 Rye price deviations from Hodrick-Prescott trend, 1765-1863 in Emden, Göttingen and Heilbron



Source and note: See figure 1. Hodrick-Prescott trend was calculated using a smoothing parameter of 6.25, as is recommended for annual data.

Figure 3 Smoothed hazard estimates of dying within 60 days of childbirth in the six German villages, 1766-1863

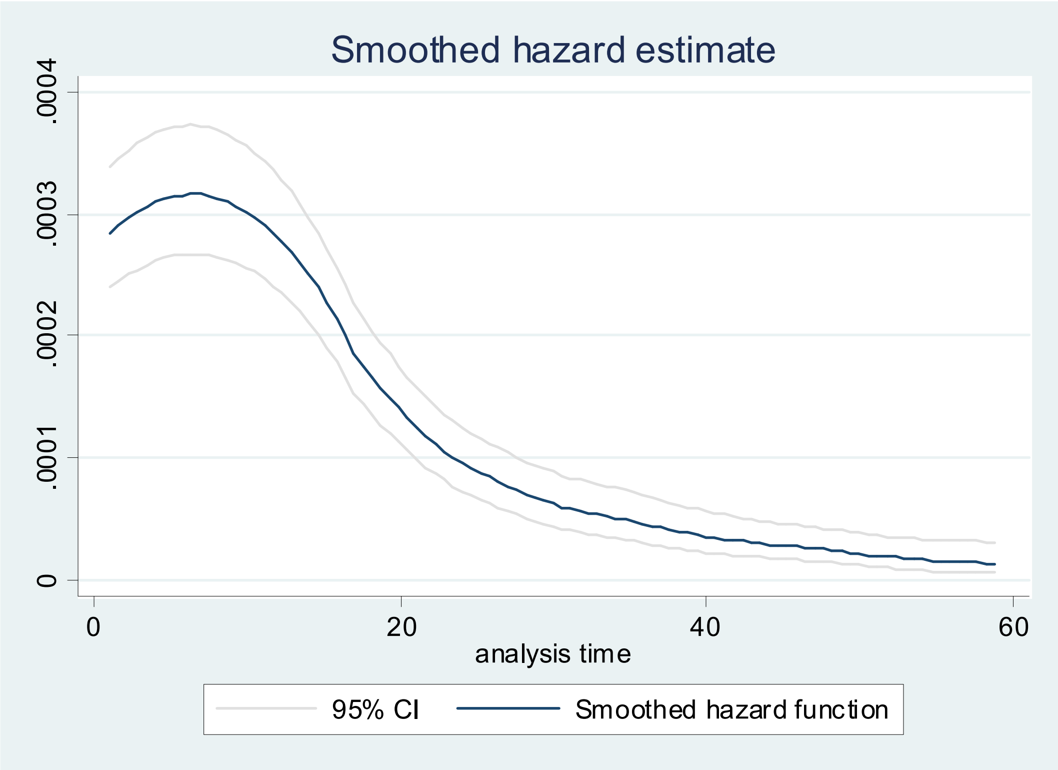
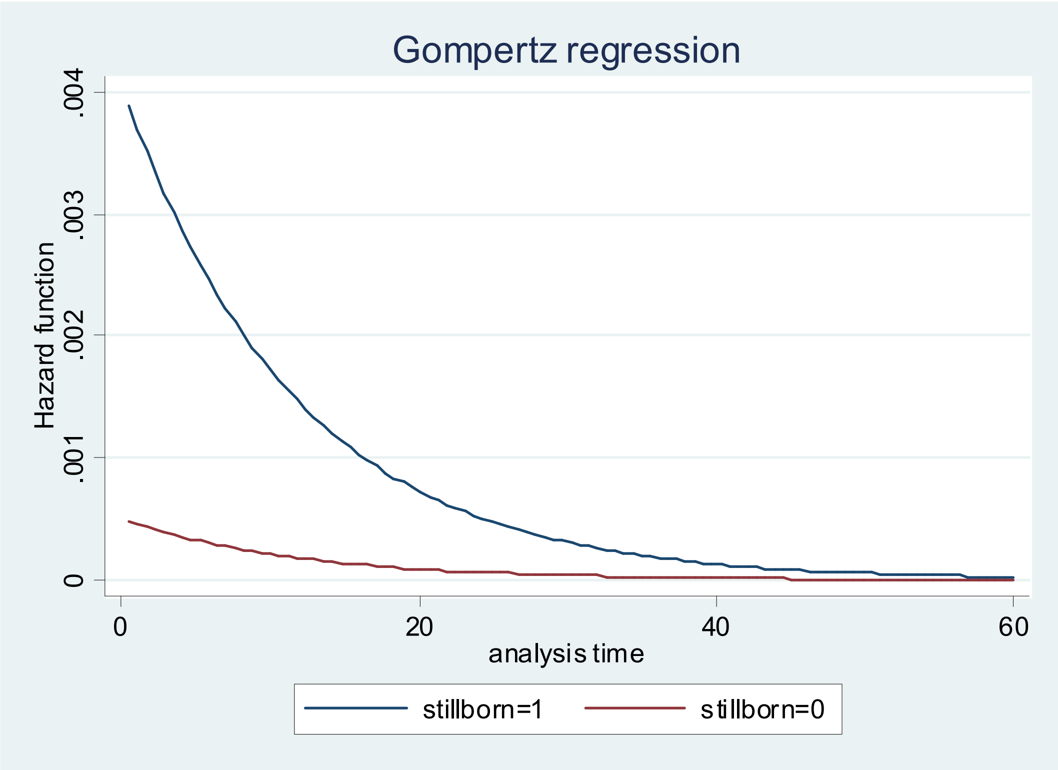
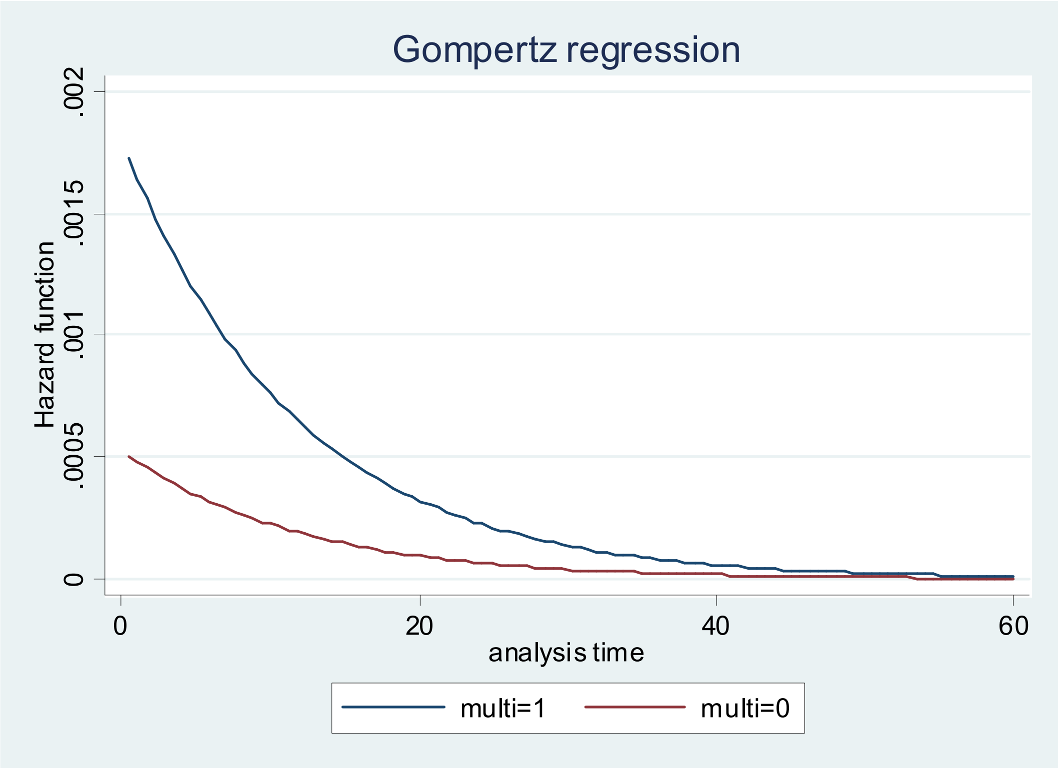


Figure 4.1 Individual hazard of dying within 60 days of childbirth by "stillborn" based on a Gompertz model (stillborn = 1, born alive = 0)



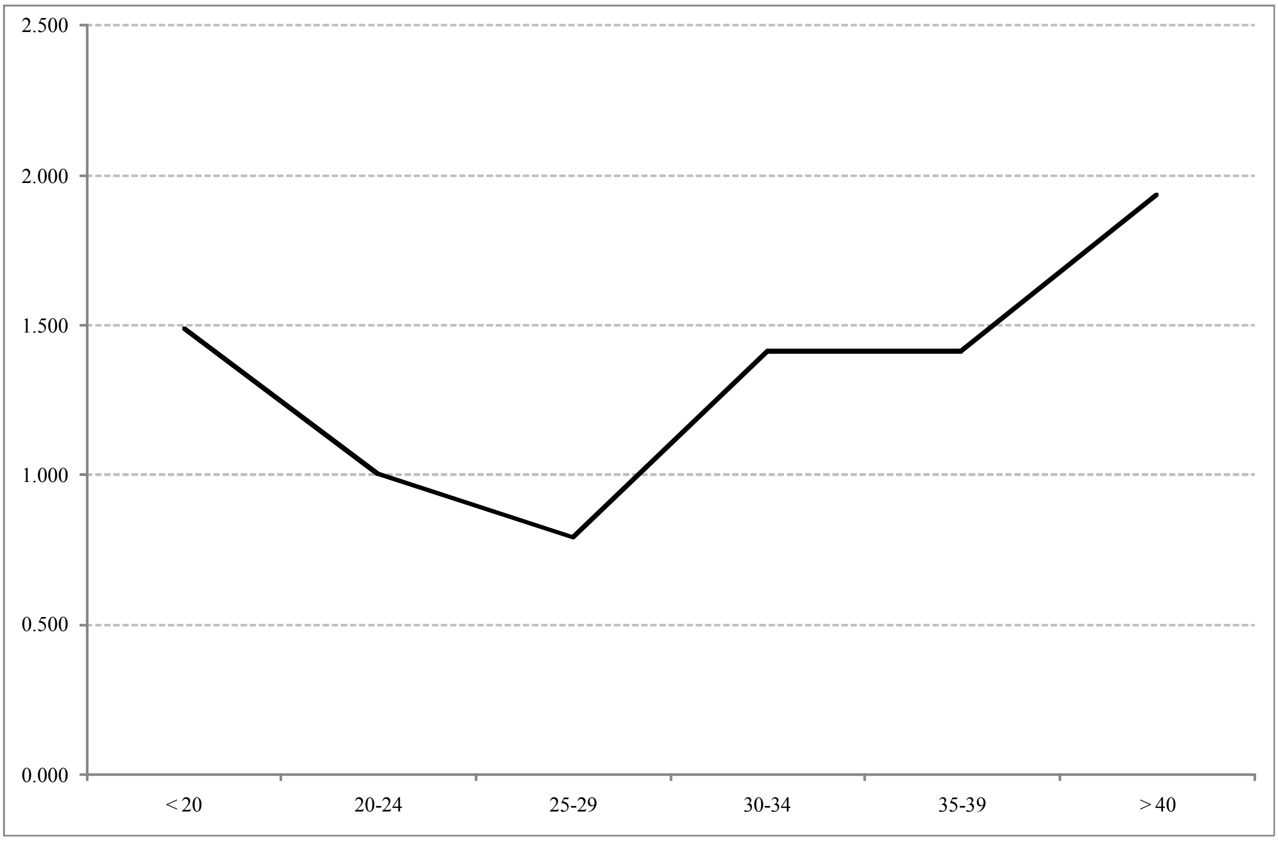
Note: Based on the estimations of the basic model in table 2.
Stillborn = 1 for stillborn, Stillborn = 0 for born alive.

Figure 4.2 Individual hazard of dying within 60 days of childbirth by "multiple birth" based on a Gompertz model



Note: Based on the estimations of the basic model in table 2.
Multi = 1 for multiple birth, Multi = 0 for single birth.

Figure 5 – Hazard ratio of dying within 60 days of childbirth by “age of mother” based on a Gompertz model



Note: Based on the estimations of the basic model in table 2.