Do Children Affect Life Expectancy?
A Joint Study of Early life Conditions, Fertility and Mortality

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Abstract

Early life conditions are by now an established determinant of later life mortality. Recent studies have also found a strong statistical association between female fertility and mortality. In this paper we use two alternative definitions of female fertility - duration until first child birth/ start of fertility and the duration until last child birth/ end of fertility - to analyze the relationship between these two determinants of adult mortality. The analysis proceeds in two steps. First we analyze the impact of economic conditions at birth and in years leading to puberty on the individual fertility rate. Then we examine the protective effect of fertility on mortality. Given the potential endogeneity of fertility, the impact of a woman's fertility on her later-life mortality is studied within a simultaneous framework using business cycle conditions in early years of life as exogenous determinants of both fertility and adult mortality. We use individual data records from Dutch registers of birth, marriage and death from the years 1850-2000 which are merged with historical data on macro-economic and health indicators. Results indicate that conditions in the years closer to puberty have a large effect on individual fertility with those born in favorable economic times exhibiting lower average fertility rates. Our analysis also shows that while

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women's health suffers from fertility during their reproductive period, fertility has a large, protective causal effect on female mortality in post-reproductive years. The size of this effect is sensitive to the definition of fertility used and varies by age and parity of the woman.

1 Introduction

In the early nineties, a series of epidemiological studies put forth the theory of the 'thrifty phenotype' (Barker, 1992; Hales and Barker, 1992) according to which, when faced with poor nutritional and environmental conditions the fetus adapts by selecting an appropriate trajectory of growth, in a way that aids its survival in an environment in which resources are likely to be short. Since then, recent research in the fields of medicine, epidemiology and economics has established the role of conditions early in life on health and mortality later in life. These studies find compelling evidence in favour of theories suggesting that exposure to poor socioeconomic and environmental cues in utero and during childhood are associated with greater susceptibility to a number of chronic health conditions including coronary heart disease, stroke, diabetes, hypertension and even shorter life expectancies later in life (see for e.g. Barker, 1997, Doblhammer, 2004, Bateson et al.,2004 and Van den Berg et al., 2006a).

Starting from the prediction of the evolutionary theory of senescence that there exists a trade-off between early fecundity and longevity (Williams, 1957), a different body of literature has established the presence of a statistical association between fertility and mortality (for e.g. see Westendorp and Kirkwood, 1998, Doblhammer, 2000, Gavrilova et al., 2004 and Gagnon et al., 2009). Past literature however has defined and measured female fertility in various ways with age of mother at birth of first child, total number of children born to a mother, end of fertility or timing of last birth, proportion of the population with no children etc. being some common examples. The choice of definition of fertility has greatly affected outcomes in an area of study that is predominantly empirical.

Earlier studies continue to provide mixed evidence of the impact of early life conditions or conditions in-utero on start or end of female fertility and the sign of the statistical association between fertility and later life mortality (Núñez-de la Mora et al., 2007, Lumey and Stein, 1997). Moreover, the debate on whether the relationship between fertility and mortality rate is causal or in fact a '*selection effect*' still continues. In case of the latter, factors like age, health, social background, income, occupation, education and race might affect both individual fertility and mortality. Then the better health, for instance, of fertile persons is a consequence of the selection of 'healthy (or unhealthy)' persons into and 'unhealthy (or healthy)' individuals out of fertility. However a large amount of medical and demographic literature proposes that fertility experience in itself could have a '*causal effect*' on mortality (Westendorp and Kirkwood, 1998). This so called 'disposable soma' theory proposes a trade off between fertility and later life mortality in humans with individuals with exceptional longevities exhibiting lower life long fertilities. However, inability to control for selection into fertility could have lead the researchers to overstate the effect of child bearing on mortality.

Establishing the nature of the relationship between fertility and mortality is made further difficult by the potential role of the endogenous event of marriage as an intermediate determinant of these events. In traditional societies where marriage is likely to be a prerequisite for fertility, marriage would be a crucial determinant of fertility. But by now marriage is also an established determinant of mortality. As seen in Chapter 2, unlike past work that finds a protective causal effect of marriage on male mortality alone, marriage is found to have a favorable impact on mortality risks of women in their post-reproductive years as well. The fact that marriage appears detetrimental to female health only during her child bearing years and appears significantly benefical thereafter suggests that in case of women marriage could be acting as a proxy for fertility. This appears likely since in the absence of modern contraceptives the event of marriage is likely to be soon followed by the start of fertility. This chapter therefore, attempts to investigate whether the protective causal effect of marriage on female mortality in her post-reproductive years, as found in Chapter 2, is in fact driven by fertility or not.

In order to do so, in this paper we analyze the interaction between early-life conditions and fertility as determinants of female mortality at older ages. We also explicitely address the issue of whether the recurrently observed correlation between fertility and mortality is a causal or a selection effect. The current study considers two most frequently used, alternative definitions of female fertility - the duration until start of fertility i.e. first child birth or the duration until end of fertility i.e. last child birth. Together, the start and end of fertility determine the entire length of the female reproductive window and hence in a way also influence other measures of fertility namely parity, child spacing etc. The analysis proceeds in two steps. First, we study the impact of economic conditions early in life on the individual rate of starting or ending fertility. Second, we examine the causal effect of timing of first or last child birth on later life mortality. In the specification employed, duration until first or last birth controls for not only start or end of fertility but also whether the woman ever had any children, number of children borne by her, the timing of these births and the current age of the woman.

Acknowledging the potential endogeneity of fertility, fertility and mortality are jointly analyzed allowing for selectivity on unobservables. The empirical analysis uses business cycle conditions in early years of life as an exogenous indicator of early-life conditions. Our investigation of the role of fertility in determining high-age female mortality uses individual data records from Dutch registers of birth, marriage and death certificates which is combined with recently made available records of female fertility and covers the exceptionally long observation window from 1850-2000. This individual level data are merged with indicators of historical macro-economic and health conditions. The semi-parametric empirical analysis is an application of the 'timing-of-events' approach (Abbring and Van den Berg, 2003) in which bivariate duration models with unobserved heterogeneity and causal effects are estimated.

In the next subsection, we provide a detailed overview of the existing literature on the subject from the fields of economics, epidemiology, medicine and demography. Given our two alternative definitions of fertility - first child birth or last child birth, we preview past literature using these options separately.

2 Past literature

2.1 *Determinants of fertility*

Fertility preferences have driven reproductive outcomes in both historical as well as contemporary societies. The reasons underlying these preferences however remain unclear especially given how much these choices have varied over time and cultures. Consequently past commentators on fertility choices have interpreted these fertility realizations in numerous ways. Barro and Becker, 1989 for instance propose that parents optimal fertility decisions are jointly determined with decisions on consumption, inter-generational transfers and capital accumulation. Utility from children (number of children and quality of children) directly enters the utility function of the parents in an altruistic inter-generational model of endogenous fertility, economic growth and macroeconomic performance. This model predicts that a decline in infant mortality, that leads to a reduction in the cost of child creation and increases parental utility as more children survive to consume, would lead to increased fertility. This implication of the model however is strongly contradicted by dramatic observed declines in infant mortality and fertility, in light of economic development and medical innovation over the past century in both Europe and the US (Boldrin et al., 2005).

An alternative theory of inter-generational transfers, put forth by Caldwell, 1978 and 1982, suggests that children in fact are investments in old-age consumption for parents. With this interpretation of preferences, the consumption by old parents in years when their productivity is low enters directly into the utility function of children. Lillard and Willis, 1997 using Malaysian data find evidence in favour of this 'old age security' (Nugant, 1985) objective behind procreation by parents while finding little support for the parental altruism motives underlying fertility as in Barro and Becker, 1989. Another interpretation of old age transfers from children to parents, given by Boldrin and Montes, 1997, is that adult children repay elderly parents for implicit loans made when children are young. An extension of these studies is presented by Boldrin and Jones, 2002 in which the support elderly parents get from children depends not just on the number of surviving offspring but on the cooperation between children. So while, old age security motive might induce individuals to bare children, the extent of non-cooperative behavior amongst children might determine the optimal parity. A natural outcome of this class of models is a decline in fertility with an increase in government provided pensions or better access to capital markets that allow non-familial means of consumption smoothing for parents over their lifetimes. Several past studies have in fact found strong empirical evidence of declining fertility rates accompanying development of social security systems and capital markets over time (refer Boldrin et al., 2005 for a detailed review on these studies). Caldwell, 1982 goes so far as to hypothesize that the sharp decline in fertility rates witnessed in the third stage of the demographic transition starting around 1850, can be attributed to a large extent to such changes in socioeconomic customs within the family.

While economic concerns driving fertility could influence earlier as well as contemporary societies, limited means to reproductive planning in yester years have led medical, demographic and epidemiological research to distinguish between contemporary and historical determinants of fertility. In current times, society specific fertility preferences aided by modern methods of contraception that allow family planning and hormonal replacement therapies have become central determinants of female fertility (Nguyen-Dinh, 1997) and may well influence the relationship between fertility and longevity (Doblhammer, 2000). In historical populations however, in the absence of contraceptives, demographers have recorded a 'natural fertility' rate which is determined by inherent individual health rather than socially driven factors like parity preferences (Doblhammer and Oeppen, 2003). This reproductive health of the individual is reflected through direct physiological as well as intermediate socioeconomic factors.

Considering the onset of fertility, it has been defined as either the onset of menstruation (age at menarche) or the timing of first child birth. Medical research that has focused primarily on physiological factors determining the start of reproduction, find mixed evidence for the impact of conditions in-utero, during childhood and especially in the period just prior to puberty on developmental tempos such as menarcheal age and patterns of ovarian function influencing conception. For instance, a medical study based on a migrant population of Bangladeshi women in London finds that women who spend their childhood in better socioeconomic conditions of low energy expenditure, stable energy intake, good sanitation, low immune challenges, and good health care in the UK have an earlier maturation (younger age at menarche) than women who develop in less optimal environment in Bangladesh (Núñez-de la Mora et al., 2007). This result however is refuted by another study that finds no effect of in utero malnutrition on age at menarche (Lumey and Stein, 1997).

Start of fertility of a woman, as defined by first child birth, is also likely to be influenced by intermediate factors like age at first marriage and individual longevity. It is worth noting that in societies of yester years where, pre-marital sexual interactions were a taboo and first child birth followed almost always within the first year of marriage, timing of marriage could be a good determinant for timing of start of risk of fertility. However, while marriage is an important determinant of start of fertility, the close temporal proximity of the two events and the lack of precise information on the sequence of marriage and conception in several traditional societies where pre-marital conception was often quickly followed by matrimony[2] it is hard to distinguish between the two events with nuptiality and mortality acting as close proxies for each other and making the direction of the causality extremely hard to determine.

Coming to the determinants of end of fertility, defined as menopause, medical evidence suggests that a woman's age at menopause is also determined by early life conditions and positively correlated to size at birth and weight gain in infancy (Cresswell et al., 1997). However, these themselves are now widely accepted to be 'programmed' by in-utero nutrition and environment like maternal smoking and alcohol consumption during pregnancy (Barker et al., 2002). Additionally, retarded early growth is associated to reduced number of primodial follicles in the ovary leading to an earlier menopause. Evidence has also been put forth suggesting an impact of dietary, lifestyle and reproductive factors on the age at natural menopause. In a study using a sample of about 33000 Chinese women between the ages of 40-70 who have experienced natural menopause, the authors find that amongst other factors early menarche, younger age at first child birth, later last birth, high parity, and a high protein diet and alcohol consumption (Torgerson et al, 1994) are associated with later menopause (Dorjgochoo et al., 2008). Other studies find smoking

[2] In traditional, three generation households the number of marriages was often restricted in an attempt to contain the birth rate and form a procreative unit. The resulting biological pressures on those who could not start a family owing to financial reasons led to the widespread practice of semi-licensed pre-marital sex almost universally across North-west Europe. Pre-marital conceptions resulting from such relationships however were mostly honored by marriage and while the numbers of such marriages declined throughout the nineteenth century the numbers remained high (for the Netherlands these numbers stood at 21% in 1820 and 16% in 1850 of all marriages) (Wintle, 2000)

(Parazzini et al, 1992; Torgerson et al, 1994; Bromberger et al, 1997; van Noord et al, 1997) and the nutritional disorder of anorexia nervosa (Keck, 2005) result in an earlier menopause. Effect of obesity on timing on menopause however continues to be mixed with some studies finding BMI at age 20, mid-life weight gain and general relative obesity being positively correlated with age at onset of menopause (Sherman et al., 1981; Dorjgochoo et al., 2008) and other work by for instance Beser et al.,1994 providing support for the opposite. While several of these proposed factors could potentially have significant causal effects on end of fertility many of these factors (for instance BMI and weight in adulthood) are now themselves known to be determined by conditions in early years of life (Power, et al., 2003; Power and Parsons, 2000).

In the absence of modern contraceptives menopause is likely to be proxied well by the timing of last child birth - which is the second definition of fertility used in our study. In addition to all factors mentioned above that influence the onset of menopause, longevity of the woman herself could act as a determinant of fertility with death prior to the end (or even start) of the reproductive age abruptly limiting the woman's fertility. For this reason, any attempt to determine the factors influencing female fertility need to take into account the continuous competing risk of mortality.

2.2 *Impact of fertility on mortality*

Past evidence on the effect of fertility on mortality is also mixed. Considering the impact of the timing of first child birth on later life mortality Westendorp and Kirkwood in their influential 1998 Nature article provide descriptive statistics reflecting a negative correlation between age at first child birth and late life mortality. The authors consider this evidence as support for the so called 'disposable soma theory' that proposes that longevity requires investments in the upkeep of the body that lowers the resources available for reproduction - hence there exists a trade-off between fertility and mortality. While this study suddenly brought into the spotlight the subject of the association between human reproduction and longevity, this work was severely criticized and refuted by several studies thereafter. According to Gavrilov and Gavrilova, 1999, Westendorp and Kirkwood do not take into account the timing of marriage or husband's fertility, which are important determinants of the start of and total fertility. Furthermore, since the sample of British aristocrats that was used for the study exhibited an unrealistic sex ratio of 1.42[3], the data was suspected to have large under-reporting of female births in addition to incomplete genealogies and overall non-representativeness and suitability of the sample owing to the aristocratic background

[3]Sex ratio is defined as the ratio of males to females in a population at the time of birth and is mostly around 1.05.

of the members. Using a contemporary sample of English, Welsch and Austrian women and estimating multivariate logistic regressions, Doblhammer, 2000, however found a similar result with a significant positive coefficient on the variable 'first birth before age 20' in the regression determining mortality risks. The study however does not consider other age intervals for first births and the author repeatedly acknowledges that health amongst other factors like socioeconomic background and education could be a vital confounding factor influencing fertility as well as mortality. Adult health however is now widely recognized to be significantly influenced by early nutrition and environment (see for e.g. Bateson et al.,2004). The inability to entirely control for such health selection in the cross sectional sample of women aged 40-59 leads Doblhammer (2000) to conclude that studies using full life histories rather than just fertility histories and careful accounting for confounding early life conditions are required to determine the sign and direction of causality between fertility and mortality decisively. It is probably for exactly these reasons that in another study Le Bourg et al, 1993 find no clear evidence of such a trade-off between fecundity and longevity. Using a natural fertility population of immigrants to Quebec and first Canadians in the seventeenth and eighteenth centuries, who were further selected to only include women with only one marriage and death, both in Canada, precisely recorded birth, marriage, fertility and death dates, and who gave birth to at least one child, the authors in fact find some evidence of higher early fecundity amongst the most longevous Canadians. A third set of studies (for instance, Helle et al., 2004) find no relationship between age at first child birth and female longevity.

Coming to the impact of timing of last birth on mortality, past literature finds diverging results regarding this relationship as well. Authors like Voland and Engel, 1986 (using historical populations in East Friesland, Germany), Helle et al., 2004 (using historical sample of Sami women) and Gagnon et al, 2009 (compare 3 natural fertility populations) find a negative correlation between age at last child birth and mortality. Each of these studies however are based on highly selected samples of women. For instance these studies consider only married women (Helle et al., 2004, Gagnon et al, 2009), who survived till the end of their reproductive years (beyond the age at which 99% of all women in the population had completed their fertilities in Helle et al, 2004 and up to the age of 50 in Gagnon et al, 2009) and for whom complete life histories were known. Such a selection process fails to take into account the competing risk of fertility and mortality during the reproductive years. Naturally the pool of women who survived till the end of their fertility windows is a selected sample with relatively superior unobserved characteristics (for instance health) than that of the total population. As mentioned above, early death (due to any reason besides maternal mortality) shortens the fertility window of a woman resulting in a younger age at last birth amongst early diers. While in this case we would find a negative correlation between age at last birth and mortality, this association is a driven by selection on unobserved factors like health of the woman which could lead to the selection of unhealthy individuals into early end of fertility and also early death and cannot be interpreted as an impact of fertility on mortality. This idea of strong selection effect in fertility is supported by the findings of Doblhammer and Oeppen, 2003. Separately estimating the probability of survival up to 50 and parity, the study finds that indeed the sample of survivors up to the age of 50 is strongly selected and factors like health influences both fertility and mortality amongst women. Controlling for some of this selection in an otherwise non-representative Hollingsworth sample of British peerage from 1603-1959, the study find no mortality advantage for late mothers (at least one birth after age 40). The authors conclude that earlier studies that found a positive correlation between age at last birth and mortality are likely to be not taking into account selection based on important socioeconomic factors like income or education that might be delaying the age at last birth as well as the age of mortality. If this is the case, then having a child after age 40 may not necessarily be an indicator of slower biological aging (Perls et al., 1997).

2.3 *Factors affecting both fertility and mortality*

As suggested by Doblhammer and Oeppen, 2003, there are a wide range of factors that influence both fertility and mortality outcomes for women. Exclusion of any factor that affects each of these events from the estimation of the impact of fertility on mortality would lead to a spurious correlation between these events. One such important factor mentioned earlier that has recently come into prominence is socioeconomic, nutritional and environmental conditions in early year of life that are found to influence both fertility (via age at menarche in Núñez-de la Mora et al., 2007 and through the influence on age at menopause in Cresswell et al., 1997) and mortality (for instance Barker, 1992 and 1997). More traditionally socioeconomic and demographic factors like income and education, social class and gender have been found to influence both fertility as well as mortality. Another apparent confounding factor is marriage since matrimony would imply a potential start of risk of fertility. But as mentioned earlier, timing of marriage and first child birth are likely to be highly correlated in traditional societies without access to modern contraceptive methods making it hard to distinguish between the two. Moreover, since a considerable percentage of marriages were preceded by pre-marital conception assigning a direction of the causality could prove to be difficult as well. Recent literature also finds evidence for the presence of a selection as well as a causal effect (see Lillard and Panis, 1996) explaining the statistical association between marital status and mortality for both men and women. Unlike men however women appear to be benefitting from matrimony only post child-bearing years (as seen in Chapter 2) suggesting a possible adverse role of fertility, initiated by matrimony, on female life expectancy. In the process of jointly studying the events of fertility and mortality, our study will also be able to shed light on whether the relatively adverse effect of marriage on female mortality is driven by fertility or not.

While past literature has not fully pinned down the factors determining female fertility and is inconclusive on the sign, magnitude and direction of causality of the association between fertility and mortality, it does shed light on vital factors that need to be taken into account in an attempt to identify and disentangle these relationships. Firstly, given the potential endogeneity of fertility in the individual's life course, any study of the impact of fertility on mortality needs to take into account not only the entire fertility history but also the life history of the individual. Such an approach will help control for selection effects and, consequently, allow the disentangling of the causal effect. Secondly, rather than looking at fertility experiences amongst selected samples of women surviving until old age or women belonging to elite families, a more representative sample of women should be considered in order to learn more about the impact of fertility on mortality while controlling for the competing risks of mortality and fertility.

In our paper, we use exogenous, cyclical macroeconomic conditions in early life and other socioeconomic and demographic individual characteristics as determinants of fertility. Due to the close proximity of the events of marriage and fertility, with the former almost always preceding the latter by about a year in a historical population, timing of marriage is not included as an exogenous determinant of start of child baring. However, since marital status is a crucial determinant of the individual health, it is included as a determinant of the competing risk of late life mortality. The importance of taking into account the timing of death is also well recognized. Death would imply an abrupt end to the individual's risk of exit into marriage or fertility. We base this approach on recent literature on mortality, which establishes the vital role of early conditions in life on mortality in later life (Van den Berg et al., 2006a).We combine this approach to the so-called Timing-of-Events method for the analysis of the effect of a potentially endogenous event on the moment at which a susequent event occurs (Abbring and Van den Berg, 2003). Given that mortality is an extreme, negative health outcome, any factor influencing mortality would influence health throughout life. Therefore any study of the impact of conditions earliest in life, on later events like fertility and mortality would provide fundamental understanding of what really determines these events. This in turn would provide insight into what could potentially be the underlying workings of the correlation between the two. We consider women, and we rely strictly on register data for all information on explanatory variables.

3 The data

3.1 *Individual records*

Individual data records are constructed using two separate data sources. Information on key events in an individual's life- birth, marriage and death and individual background characteristics like occupation of parents, gender and geographical location is drawn from the Historical Sample of the Netherlands Data set release UZF.02. This data set is created by merging Dutch registers of birth, marriage and death certificates and includes a random sample of 4,491 women born between 1850-1922 in one of the three provinces of Utrecht, Friesland or Zeeland[4]. The last day of observation of the sample is December 31, 1999.

Detailed individual fertility histories from the Historical Sample of the Netherlands 2007.01 Beta (HSN) are consistently merged into this information. The HSN Beta data set combines information spanning individual lifetimes from four different systems used by official population records of the Netherlands- 'the registers', 'family cards', 'person-family cards' and 'person lists'. These methods were used either concurrently or sequentially in different parts of the country and together cover the same observation window from 1850-1999.

Individual lifetime durations are noted in days and if the individual is still alive at the end of 1999, the date of death is not observed. Migration out of the regions of birth does not pose a problem as the population data continues to keep track of timing and location of migration as well the information on key events of migrants over their lifetimes. Limited right censoring of life times arises due to missing dates of death for about 8% of individuals born before 1922 - right censoring being less frequent for later cohorts. The lifetime durations of these individuals are right censored at their last day of observation- i.e. at birth, marriage or child birth. There is also limited non-systematic right censoring of individuals at time of birth (i.e. at age 0) and these cases are dropped as they do not provide any additional information. Since only 2 child births are observed for women before the age of 14, this is assumed to be the age of start of fertility. Consequently the girls who died before this age cannot contribute to the likelihood of fertility and have been excluded as well. Further loss of observations owing to missing values of explanatory variables results in a final sample of 1,945 women.

The original register data does not include any variable that provides information about the long-run economic status of the individual or his/her family. Families however, could

[4] The Netherlands, at the time, had 11 provinces and in terms of economic activity the three provinces included in this study were jointly very representative of the country. The same is true for aggregate mortality rates in our data which closely resemble patterns at the national level.

use their long-run economic status to insure against shocks, for instance by means of accumulated assets, and this could be used to ensure proper nutrition and provision of healthy environment to infants even in times of adverse economic conditions and epidemics. Such insurance would then affect the sensitivity of fertility and mortality later in life to unexpected macro-economic down turns during childhood. We therefore want to derive and include in our study some indicator of such a long-run family economic position from the available variables. For this we adopt the idea of 'social class' operationalized by the 'HISCLASS' classification based on the 'Historical International Standard Classification of Occupations' (HISCO) codes. The HISCO occupational code is a historically sensitive and internationally valid occupational classification across the nineteenth and twentieth centuries. The HISCO classifies all historical occupations into 1,600 basic categories, in line with present-day schemes using the information from the Dictionary of Occupational Titles (DOT)[5]. These 1,600 occupations are in turn classified into 12 social classes in HISCLASS with an attempt to group within each social class a set of persons with the same life chances. Table 1 specifies how the 12 social classes in HISCLASS are derived (in a slightly stylized way) from the main dimensions of class (van Leeuwen et. al, 2002).

In order to avoid endogeneity or confoundedness, only those individual attributes that are realized at birth as opposed to those acquired later in life are included as explanatory variables for individual fertility and mortality. Following existing literature marriage however, is included as an explanatory variable for mortality. The place of residence at birth is included as a binary urbanization indicator which takes a value of 1 if the person is born in a city and 0 otherwise.

For the purpose of the analysis we distinguish between 4 types of people. The first group consists of people whose fertility and death are both observed. The second group comprises individuals who bare no children over their lifetimes and for whom death is observed. For the two following groups individual death dates are missing and the individual is last observed either at childbirth or at time of marriage (no child birth observed). For each of these groups, marriage dates are also recorded and included as a factor contributing to mortality. Table 2(a) briefly presents the sizes of the 4 groups and statistics like age of first marriage, start of fertility, number of children born, end of fertility and life expectancy for these groups separately. The striking aspect of these figures is the much shorter, average longevity in the group who are not observed to bare children as compared to those with reported fertility. One reason for this could be that early death prematurely ends the individual's exposure to risk of exit into fertility making mortality a 'competing risk'. We also observe a relatively higher age of marriage amongst women with no children. This

[5] U.S. Department of Labor, The Dictionary of Occupational Titles, 2 vols (Washington, DC, 1965), vol. 1, p. ix.

seems plausible in light of the fact that later marriages, especially for women, is likely to shorten the length of a woman's fertile window. On the other hand however, given the societal contempt of pre-marital motherhood, an accidental pregnancy would also often lead to a quick 'shotgun wedding' thereby abruptly shortening the duration of singlehood for the individual and lowering on average the marital age amongst the fertile. This in fact was not so uncommon with 16% of all Dutch marriages in 1850 being followed by a live birth within seven months with Calvinists having much higher levels of such forced marriages than Catholics (Wintle, 2000). We check the distribution of the time interval between marriage and first births and this is presented in Figure 1. The plot confirms the proximity of the timing of marriage and start of fertility and also a significant number of pre-marital conceptions.

In order to shed some more light on the role of marriage, Table 2(b) presents the sample composition and summary statistics for the sample of married women only. Comparing sample sizes by 'type' across Table 2(a) and 3.2(b) we note that while the majority of the women reporting no fertility consists of unmarried women 11% of married women also experience no childbirth. Further, from Table 2(b) we note that married childless women have longer average life expectancy (mean of 68.15 years) than unmarried childless women (mean of 62.05 years). But, average life expectancy of childless women, irrespective of marital status, is lower than that of women with children (for married women 74.22 years and for unmarried mothers 76.69 years). This seems to suggest that having a family, in form of partner, children or both, on an average has a beneficial impact on female longevity. However, presence of children seems to have a larger favorable impact on women's life expectancy than having a partner. Women with neither partners nor children seem to be therefore the most vulnerable.

Table 2(b) also shows that average age of marriage is higher for women without children than women with children. In this case then the longer life expectancy of married women with children could also be due to a longer favourable impact of marriage rather than a consequence of fertility. We further investigate the potential role of marriage as a determinant and proxy of fertility by restricting our sample of married women to those who get married in the age interval of 23-28 years. By doing so we only consider those childless married women whose average age at marriage is similar to those with children and therefore are likely to have enjoyed similar durations of marriage at each point in their lives. Descriptive statistics for this sample are presented in Table 2(c). Firstly we note, that even with a relatively younger age interval of marriage 9.33% of women remain childless. Since later marriage could shorten a woman's fertile window and leave her childless, this figure suggests that infertility is largely not a result of later marriage. Next, comparing the longevities of these relatively younger married women to our sample of all married women (sample of Table 2(b)) we note, that once again married women with children enjoy longer average life expectancies (74.03 years) than married women without children (64.90 years). This reiterates that the differences in longevity between women with and without children is not an outcome of differential marital exposure but is indeed driven by fertility.

3.2 *Macro-economic data: business cycles and historical events*

Following the approach of Van den Berg et al., 2006a we combine with the individual data records external information on macroeconomic conditions and vital historical events of the time. Most importantly, this information is captured using the historical time-series data on log annual real per capita GNP over the observation window. The GNP series, instead of the conventionally used GDP, is chosen purely for reasons of availability of mutually consistent observations over the years of interest. Figure 2 presents the plot of the log annual real per capita GNP over our observation window, measured in 1,000 Euros with 1995 as a base year. The graph highlights both, the upward trend and the many cyclical fluctuations[6]. Note firstly, that years with low and negative growth are observed more frequently in the 19th as opposed to the 20th century. Secondly, the GNP fluctuations are strongly correlated to the business cycles in the United States and the United Kingdom.

In principle, one would like to compare fertility and mortality outcomes of cohorts born in economic booms to those born during economic troughs with otherwise identical conditions over life. However this is not trivial due to the steady secular improvements in living conditions over time. This issue can be dealt with by comparing a cohort born in a specific boom to that born in the immediately following recession as the latter benefit from secular developments that occurred during the immediately preceding economic upturn but suffer from the temporary cyclical downturn. In this case any change in longevity across these cohorts can be attributed purely to the cyclical effect. More in general, one may relate the fertility and mortality rates of individuals to the state of the business cycle in early years of their lives. In order to do this however one needs an indicator of the cyclical macro-economic condition for each year. Such an indicator is obtained by a trend/cycle decomposition of the log annual real per capital GNP using the Hodrick-Prescott filter with smoothing parameter 500. Figure 2 presents the cycle and trend as functions of calendar time. The plot shows that periods of economic booms and recessions are clearly identifiable in the data. The fluctuations are robust with respect to the choice of the decomposition method and smoothing parameter. For most of the analysis we round-off the value of the cyclical term to a binary outcome representing economic upturns or

[6] Jacobs and Smits (2001) discuss in detail the GDP movements in the Netherlands in the 19th Century.

downturns. Additionally we control for incidence of epidemics and war because these cause pronounced spikes in the marriage and mortality rates.

One disadvantage of an unprecedented observation window, spanning more than a century, is the absence of several explanatory variables commonly used in the mortality literature. Notably, we do not observe the individual's adult health status, cause of death and public health expenditures and numbers of medical innovations.

3.3 *Data issues*

Certain important issues need to be taken into account during the course of our study[7]. Firstly, given the small sample size of 1195 women, its impossible to compare outcomes from two consecutive years. Therefore, following Van den Berg et al., 2006b we aggregate rows of successive years into "boom" and "recession" periods. This allows semi-parametric comparison of the average lifetimes in a cohort born in a single boom to those in the cohort born in the subsequent recession. However, it needs to be borne in mind that such a comparison allows women in the recession to benefit from secular improvements. Secondly, we also note that the booms and recessions should not include any epidemics and should also be long enough to have reasonable sample sizes. Finally, while studying the role of social class in determining marriage and mortality, we need to worry about differences in birth rate or composition of newborns by social class. Note however that Van den Berg et al., 2006b find no significant effects of cyclical components of the business cycle at birth on the over-all cohort size or the cohort size by social class.

A major disadvantage of comparing durations until fertility and death across cohorts is that one ignores the cyclical patterns in the macro-economy throughout the childhood and puberty years of an individual. A person who is born in bad times is likely to experience good times during some childhood years, and vice versa, just because good and bad times succeed each other with an average frequency of a few years. This leads to the possibility of what literature refers to as 'catch up growth'. This refers to the situation where favorable socioeconomic and environmental conditions in years after birth help mitigate the adverse effects of exposure to poor conditions in utero or at birth. But several recent studies (for instance: Hack et al., 2003) have shown that long-run affects of poor conditions early in life continue to persist later in life. To proceed, in the following sections, we estimate duration models where the start or end of fertility and mortality rates are allowed to depend on conditions at birth and on conditions during childhood and puberty. The estimation of

[7] This section draws heavily from our earlier work Van den Berg and Gupta, 2007 that also employes the HSN UZF.02 data release.

these models exploits the variation in the timing of the stages of the business cycle across individuals, to disentangle the long-run effects of conditions at birth and during childhood. This results in parameter estimates of the effect of cyclical macroeconomic conditions at birth on the events of fertility and mortality later in life, given the conditions during childhood years following birth. Survival analysis also controls for individual characteristics at birth. These advantages however come at a price - functional form model assumptions are required in order to proceed with the duration analysis.

4 Empirical methodology

Two alternative definitions of fertility (f_i) are considered through out this study - duration until first birth (FB) or the start of fertility and duration until last birth (LB) or the end of fertility. These together determine the total reproductive span for a woman and consequently impose some limits on the possible number and spacing of children in between. The empirical analysis looks at first the impact of early macro-economic conditions in life on the individual fertility. Next we test the possible causal effect of fertility on later life mortality and finally, we consider which factors might influence this causal effect of fertility on life expectancy.

As mentioned earlier, duration until fertility T_{f_i}, $i \in \{FB, LB\}$ and timing of mortality mortality (T_d) can be associated in multiple ways. The following simple diagram illustrates the various pathways of association:

$$\begin{array}{ccc} & x & \\ & \swarrow \searrow & \\ & \delta_i & \\ \textbf{Fertility} & \longrightarrow & \textbf{Mortality} \\ & \nwarrow \nearrow & \\ & v & \end{array}$$

Fertility and mortality could be determined by a set of observable time varying and time constant explanatory variables x. In addition, timing of both these events are also likely to be influenced by some common or highly correlated unobserved individual specific characteristics or heterogeneities of the woman v. This could gives rise to the problem of 'selection' as discussed in section 1 above, where the correlation between fertility relevant ($v_{f_i}, i \in \{FB, LB\}$) and mortality relevant (v_d) unobserved heterogeneities can lead to a spurious association between the duration until first or last child birth and the duration until death. This study acknowledges the issue of potentially correlated unobserved heterogeneities by simultaneous modelling of the events fertility and mortality hazard using a bivariate duration model. We apply the flexible 'timing-of-events' approach as developed in Abbring & Van den Berg, 2003 which, controlling for observables x and potentially correlated unobservables v, allows the identification of the causal effect $\delta_i, i \in \{FB, LB\}$ even with single spell data without any parametric assumptions or exclusion restrictions. In this section we describe the implementation of this approach to our study of fertility and mortality.

4.1 *Timing-of-Events Method: Bivariate Duration Analysis*

In our model the variables of interest are the duration until fertility, denoted by a continuous and non-negative random variable T_{f_i} where $i \in \{FB, LB\}$ and denotes the events of first/last births and the duration up to death, T_d. We assume that all individual differences in the joint distribution of these two processes at a given time (in our case of the individual) t is conditional on calender time τ, other socioeconomic and demographic factors x, current macro-economic conditions $z(\tau)$, trend components and cyclical indicators $z_{tr}(\tau - t + j)$ and $z_c(\tau - t + j)$ of macro-economic conditions in earlier years of life ($j \in \{0, ..., t-1\}$), various interaction terms and the unobserved characteristics 'v'. We assume x to include time constant covariates and v to be independent of x. Let t_{f_i} be the moment at which an individual gets their first or last child and the indicator function $I(t_{f_i} < t)$ is used to denote whether an individual has experienced start or end of the fertility experience or not. As mentioned earlier, timing of marriage (t_m) is likely to be an important pre-requisite for start of fertility in a historical setting. In the absence of modern contraceptives marriage is almost always followed by child birth within the first year of marriage (median time gap between marriage and first birth being 1.07 years). Given this role of marriage as a pre-requisite of fertility a study of the relationship between fertility and mortality should include marriage as a determinant of fertility. But, given the endogeneity of the event of marriage (as shown in Chapter 2) and the potential endogeneity of fertility as well, a joint analysis of marriage, fertility and mortality should include all correlated unobserved heterogeneities and model multiple transition rates. This however is beyond the scope of this study. Furthermore, in case of last births, the relevance of the timing of marriage would anyway be reduced as nuptiality is not an immediate predecessor to last births (at least in case of last birth not coinciding with first birth). However, we still go some way in acknowledging the potential role of marriage as a determinant of high-age female mortality, by including marital status as an exogenous explanatory variable for mortality. Lastly, δ_i captures the causal effect of fertility on individual death rate with fertility having a permanent multiplicative effect on the transition rate.

The hazard of mortality at any time t, conditional on τ, x, $z(\tau)$, $z_{tr}(\tau - t + j)$, $z_c(\tau - t + j), t_m$ and t_{f_i} is denoted by $\theta_d(t, x, z(\tau), z_{tr}(\tau - t + j), z_c(\tau - t + j), t_m, t_{f_i}) = \theta_d(t, x(t), v_{d,} t_m, t_{f_i})$ where $j \in \{0, ..., t-1\}$, $i \in \{FB, LB\}$ and is assumed to have the Mixed Proportional Hazard (MPH) specification

$$\theta_d(t, x(t), v_{d,} t_m, t_{f_i}) = \lambda_d(t) \exp(x'(t)\beta_d + \beta_d^m I(t_m < t) + \delta I(t_{f_i} < t) + v_d) \tag{1}$$

in which $\lambda_d(t)$ captures the duration (in this case age) dependence of this function and is same for all individuals in the sample. $x(t)$ includes linear parametric functions of socioeconomic factors, as well as time varying explanatory variables. The first group includes time constant socioeconomic characteristics at birth like social class, literacy of father, degree of urbanization of place of residence at birth (x) etc. The time varying component of $x(t)$ incorporates macro-economic information on contemporaneous economic conditions ($z(\tau)$) and cyclical and trend components of the GNP series $z_{tr}(\tau - t + j)$ and $z_c(\tau - t + j)$ obtained using Hodrick-Prescott decomposition method. For $z(\tau)$ we take log annual real per capita GNP at τ, as well as dummy variables for years with epidemics and World War II[8]. Finally, the time varying indicator function $I(t_m < t)$ captures the marital status of the person i.e. whether an individual is married or not at any time t with β_d^m capturing the effect of this marital status on individual death hazard.

We note that since the focus is on studying the impact of fertility on mortality, we only consider mortality after the age at which fertility becomes feasible i.e. post menarche. In the absence of actual ages at menarche of the women in our sample 14 years of age is assumed to be the start of 'risk of pregnancy'/ puberty. This assumption seems reasonable as only 2 women report first child births at ages younger than 14. In order to include information about the conditions prevailing in early years of life we distinguish between three relevant childhood age intervals - between 1-5 years which are considered as most vulnerable years in terms of childhood health shocks, 6-8 years and finally 9-14 years as the ages leading right up to puberty. The cyclical component $z_c(\tau - t + j)$ of the log annual real per capita GNP series is used to calculate average cyclical indicators that captures information on economic conditions in the year of birth, childhood and adolescence. These are summarized using 4 dummies. A binary boom/ recession dummy is used to record a favorable/ adverse period of the business cycle in the year of birth. 3 additional indicators of average cyclical macro-economic conditions during the age intervals of 1-5, 6-8 and 9-14 years are also included by means of dummies for whether or not the averages of the cyclical element of the GNP series is positive or negative between these ages.

[8]This takes care of the fact that GNP series is missing for the years of World War II.

The trend component $z_{tr}(\tau-t+j)$ of the GNP series in the years of birth and childhood, obtained from the Hodrick-Prescott decomposition, captures the secular long-run effects. It is empirically difficult to distinguish the effects of these trend components from the effects of current log GNP $z(\tau)$, due to multicollinearity. Both these variables are almost always increasing over time, and at the individual level the latter can be captured relatively well by the sum of the former and an increasing function of age. We therefore omit the trend component for the early years of life from the model specification. For similar reasons calendar time τ is also left out. However, we include in our analysis the cyclical and trend components of the contemporaneous GNP series in order to control for any correlation between cyclical conditions in early and later years of life. This would automatically take into account any possibility of compensatory gains that favorable economic conditions during adulthood might offer after having faced adverse cyclical conditions before age 14. Furthermore, contemporaneous cyclical conditions in the macro-economy are an indicator of current employment opportunities. Therefore inclusion of the cyclical component of the GNP would additionally control for the impact of on-going employment conditions on the fertility outcomes of the individual. The trend component of the series captures all secular effects from birth to the current age.

Therefore, the coefficients on the 3 indicators of early life conditions along with δ_i, the coefficient on the dummy of exit into fertility (included using the indicator $I(t_f < t)$) are the parameters of interest.

The conditional density function of $t_d|x(t), t_m, v_{d,}t_{f_i}$ can be written as:

$$f_d(t_d|x(t), v_{d,}t_m, t_{f_i}) = \theta_d(t_d|x(t), v_d, t_m, t_{f_i}) \exp(-\int_0^{t_d} \theta_d(z|x(z), v_d, t_m, t_{f_i})dz \qquad (2)$$

For an individual of age t years ($t < t_{f_i}$), the fertility hazard at t conditional on observed and unobserved characteristics $x(t)$ and v_{f_i} is denoted by $\theta_{f_i}(t|x(t), v_{f_i})$ and is also assumed to have the MPH specifications given by,

$$\theta_{f_i}(t|x(t), v_{f_i}) = \lambda_{f_i}(t) \exp(x'(t)\beta_{f_i} + v_{f_i}) \qquad (3)$$

where once again $x'(t)$ is independent of v_{f_i} and the individual's background characteristics x are constant over time. The time dependence of the fertility hazard is $\lambda_{f_i}(t)$. If t_{f_i}

is the moment of first or last child birth, the conditional fertility duration density function of $t_{f_i}|x(t), v_{f_i}$ is

$$f_{f_i}(t_{f_i}|x(t), v_{f_i}) = \theta_{f_i}(t|x(t), v_{f_i}) \exp(-\int_0^{t_{f_i}} \theta_{f_i}(z|x(t), v_{f_i})dz \tag{4}$$

Now consider the joint distribution of t_d and t_{f_i}. Conditional on $x(t)$, v_d and v_{f_i}, the only possible relation between the variables t_d and t_{f_i} is the relation by way of the direct/ causal effect of a fertility on the hazard of death. In case of independence of v_d and v_{f_i}, we would have a standard duration model for $t_d|x(t), t_{f_i}$ in which $I(t_{f_i} < t)$ can be treated as a time-varying regressor that is orthogonal to the unobserved heterogeneity term v_d. However, if v_d and v_{f_i} are not independent, inference on $t_d|x(t), t_{f_i}$ has to be based on $t_d, t_{f_i}|x(t)$. Let G(v_d, v_{f_i}) be the joint distribution function of the unobserved characteristics v_d and v_{f_i}. Then using equations (2) and (4) above we find that the joint density function of t_d, t_{f_i} conditional on $x(t)$, equals

$$f_{d,f_i}(t_d, t_{f_i}|x(t)) = \int_{v_d} \int_{v_{f_i}} f_d(t_d|x(t), v_{d,}t_{f_i}) f_{f_i}(t_{f_i}|x(t), v_{f_i}) dG(v_d, v_{f_i}) \tag{5}$$

This joint density function can be used to derive the individual contributions to the likelihood function easily (note the recursive nature of the expression in the integral above). The right censoring of individuals at the time of marriage or child birth (i.e. death date not registered) is exogenous and is therefore solved in a straightforward manner within the hazard rate framework.

The identification of the framework is proven and discussed at length in Abbring and Van den Berg (2003). The model identification follows in two natural steps that arise due to the 'timing-of-' the events of fertility and mortality. The data can be broken into two parts: (i) a competing risk part for the duration until a woman either gets her child (first or last depending on the definition of fertility being considered) or dies, whichever comes first, and (ii) the residual duration from the moment of child birth (first/last) until death. From Heckman and Honoré (1989), it follows that under some general conditions the whole model except for the causal effect δ_i is identified from the data corresponding to the competing risk part. Subsequently, δ_i is identified from the data corresponding with part (ii) of the model.

To clarify what drives the identification of δ_i, consider women who start/end their fertility at time t. The natural control group consists of women who are of the same age at t but who have not yet started/ended their fertility. A necessary condition for a meaningful comparison of these groups is that there is some randomization in who reproduces at t. The duration model framework allows for this. In addition, we have to deal with the selection issue that the unobserved heterogeneity distribution is different between the treatment and control groups at t. This is handled by exploiting the information in the data on what happened to individuals who got their first/last child or died before t.

4.2 *Parameterization*

All components of the hazard function of fertility and mortality are flexibly specified. In order to allow the causal effect of fertility on mortality δ_i, $i \in \{FB, LB\}$ to vary over the individual's lifetime, δ_i is captured using Chebyshev polynomials, for instance of degree 4, in the age of the individual. This polynomial could be specified simply as a sum of terms $\eta_k t^k$, $k = 0, 1, ..., 4$ where t is the age of the individual. However, since the terms of t^k are not orthogonal, estimation of the parameters η_k is afflicted by multicollinearity. We take care of this problem by using Chebyshev polynomials of the second kind. In this case, the polynomial is specified as a sum of terms $\eta_k U_k(t)$, $k = 0, 1, ..., 4$ where $U_0(t), U_1(t), U_2(t), U_3(t)$ and $U_4(t)$[9], are mutually orthogonal polynomials of indexed degree. The age dependent causal effect (ace) of start/end of fertility on the hazard of death is therefore given by

$$\delta_i(t) = \sum_{k=0}^{4} \eta_k^{ace} U_k(t) \tag{6}$$

where η_k^{ace} are the parameters corresponding to the mutually orthogonal polynomials $U_k(t)$ of degree $k \in \{1, 2, 3, 4\}$ capturing the age dependence of the causal effect of fertility on individual death rate. A value of $\delta_i \neq 0$ would imply a causal effect of fertility on exit probability of death.

[9] To start, the domain of the ages t where $t \in [0, 103]$ is linearly transformed to the domain of the orthogonal Chebyshev polynomials such that now $\widehat{t} \in [-1, 1]$. This is done in our case by using the simple rule $\widehat{t} = 2\frac{(t-t_0)}{(n_t-1)} - 1$ where n_t is the year of the individual's life that is being considered.

Then our orthogonal polynomials are

$U_0(\widehat{t}) = 1$
$U_1(\widehat{t}) = 2\widehat{t}$
$U_2(\widehat{t}) = 4\widehat{t}^2 - 1$
$U_3(\widehat{t}) = 8\widehat{t}^3 - 4\widehat{t}$
$U_4(\widehat{t}) = 16\widehat{t}^4 - 12\widehat{t}^2 + 1$

The time dependence of the hazard functions is similarly expressed using flexible Chebyshev polynomials of the second kind of degree 4 in age of the woman. Thus, the duration dependence of exit probabilities into fertility and mortality are respectively given by:

$$\lambda_{f_i}(t) = \exp\left[\sum_{k=0}^{4} \eta_k^{f_i} U_k(t)\right] \tag{7}$$

and

$$\lambda_d(t) = \exp\left[\sum_{k=0}^{4} \eta_k^{d} U_k(t)\right] \tag{8}$$

where t is any given age of the individual and once again fertility could be defined as either the start (FB) or end of fertility (LB). Consequently, the duration dependences $\lambda_{f_i}(t)$, $i \in \{FB, LB\}$ and $\lambda_d(t)$ are piecewise constant functions with shapes determined by the polynomial expressions in equations 6 and 7 above. These piecewise, baseline specifications lead to 10 parameters ($\eta_k^{f_i}$ and η_k^d, with $k = 0, 1, ..., 4$).

We take the joint distribution of the unobserved heterogeneity terms v_d and v_{f_i} , $i \in \{FB, LB\}$ to be bivariate discrete, with two unrestricted mass-point locations for each term. Let v_d^1, v_d^2, $v_{f_i}^1$, and $v_{f_i}^2$ denote the points of support of v_d and v_{f_i}, respectively. The associated probabilities are denoted as follows:

$$\begin{array}{ll} \Pr(v_d = v_d^1, v_{f_i} = v_{f_i}^1) = q_1 & \Pr(v_d = v_d^2, v_{f_i} = v_{f_i}^1) = q_3 \\ \Pr(v_d = v_d^1, v_{f_i} = v_{f_i}^2) = q_2 & \Pr(v_d = v_d^2, v_{f_i} = v_{f_i}^2) = q_4 \end{array}$$

with $0 \leq q_p \leq 1$ for $p = 1, ..., 4$, and $q_4 = 1 - q_1 - q_2 - q_3$.

The covariance of v_d and v_{f_i} is given by, $cov(v_d, v_{f_i}) = (q_1 q_4 - q_2 q_3) \cdot (v_d^1 - v_d^2) \cdot (v_{f_i}^1 - v_{f_i}^2)$. We note that $cov(v_d, v_{f_i}) = 0$ would imply independence of v_d and v_{f_i} and $q_1 = q_4 = 0$ or $q_2 = q_3 = 0$ would mean perfect correlation.

5 Estimation results

Table 3 presents the estimation results, for the bivariate duration model for the durations until first birth and mortality and last birth and mortality respectively. Parameter estimates are presented for both the impact of early conditions in life on the duration until first/last birth and mortality and the effect of fertility, as defined by duration until first/last birth, itself on mortality δ_i. For the estimates concerning exit probabilities into fertility, a positive value is associated with an earlier child birth. On the other hand for the exit rate into mortality, positive values of estimates signify a shorter lifetime.

5.1 *Factors determining first birth and it's impact on mortality*

The central result we find is a significant, age-dependent, negative causal effect of duration until first birth on the mortality hazard for women. Moreover, as expected this favorable effect of start of fertility on longevity appears to only kick in during the post-reproductive years (ages between 38-80 years), after women have already survived the actual process of child bearing itself. Figure 4 presents this age dependent causal effect of start of fertility or first birth (FB) on mortality hazard, along with the 95% confidence intervals. The results show that start of fertility has a significant 'protective' causal effect on mortality hazard in a woman's post-reproductive years implying later death for women exiting into first births[10]. It is worth noting that a very low hazard for first birth could imply no off-spring at all for the woman. In a traditional society, that lacks a formal old age security system, our results make sense since the unavailability of any old-age insurance as provided by children could have adverse consequences on the woman's health that could prove to be life shortening. Moreover, this beneficial effect of child bearing for a woman is likely to crop up only in post-child bearing ages when she no longer suffers from the stress and strains of reproduction itself and their first born are probably old enough to provide them with some support as well. While this result is in contrast with some past work that consider correlations and suggest a positive relationship between early fecundity and mortality (for instance Westendorp and Kirkwood, 1998) it does provide support for studies that find no trade-off between fertility and mortality for women in their post-reproductive years (for e.g. Le Bourg et al., 1993, Helle et al., 2004). Moreover, our results are in line with some more recent work that find adverse effect of early fecundity on mortality for very young mothers (for instance 'first birth before age 20' in Doblhammer, 2000). However, since our data has relatively few very young mothers, although we find a positive causal effect of first child birth hazard on the exit probability of mortality as seen in Figure 4 this effect is insignificant (may be due to a small sample). Doblhammer, 2000 does not consider other age intervals for start of fecundity making further comparison of our results impossible as the effect of age on the impact of first birth on mortality is unlikely to be constant or

[10] Prior to any interpretation of these results it needs to be borne in mind that a higher hazard of first birth in our sample implies a larger exit probability into fertility but does not imply very young motherhood (for instance in teenage years) since the average age of first birth is about 28 years in our sample. This distinction is important since, unlike motherhood in general very young motherhood is medically known to be harmful to the health of the mother (also found in Doblhammer, 2000).

linear. However, given higher maternal mortality risks in the nineteenth century we again investigate this using our alternative definition of fertility below. Finally, shrinking number of survivors at older ages makes polynomial specification of the age dependent causal effect of fertility on mortality harder to fit the data for the elderly and could be partly responsible for the absence of a consistent protective effect beyond 80 years of age.

Considering the factors that are likely to affect both fertility and mortality, the crucial result we find is a significant negative impact of favorable average macroeconomic conditions in years of childhood but not in the year of birth on first birth hazard for women. Even though good economic conditions during both age intervals of 6-8 years and 9-13 years significantly lower the exit probability into first birth for a woman the economic conditions in the years closer to puberty (9-13 years in our case) appear to have a larger effect (refer Table 3 for coefficients corresponding to these variables). These results are in line with past studies that find no adverse consequences of acute malnourishment in years just around birth on a woman's fertility (for instance Lumey and Stein, 1997 who study the fertility outcomes of Dutch women born during the 'hunger winter' of 1945) but instead suggest that the female body exhibits developmental plasticity by adapting and adjusting to it's environment over an extended period of the life cycle prior to reproductive maturation in order to be prepared for projected conditions it might encounter as adults. Our study reiterates the relative importance of years just before puberty found in this earlier work. However, unlike for instance Núñez-de la Mora et al., 2007 that considers the age at menarche, and finds a negative relationship between economic conditions in early years of life on age at menarche, our study focusses on the age at first birth and finds a positive relationship between start of fecundity and favorable economic conditions in years of childhood. But in the absence of any conclusive past literature on the relationship between age of menarche and age at first child birth, no inference can be drawn on the consistency of these results. No significant effect of average macro economic conditions in early years of life is found on the death hazard for women. This result is consistent with the findings of Van den Berg et al, 2006 and those of Chapter 2.

The dummy for marriage is found to have an insignificant effect on hazard of female mortality in our joint model of fertility and mortality. This result is in line with our earlier work (as seen in Chapter 2 above) that finds a similar result when the marital effect on mortality is specified using a simple time varying binary variable.

While social class affiliation is found to have no significant impact on death hazard (reiterates results of Chapter 2) class differences are very important for start of fertility hazard for women. Women belonging to higher social classes exhibit later start of fertility than women from lower social classes. Several social reasons are likely to contribute to this result. Firstly, greater stress on financial stability and certain amount of material wealth accumulation prior to starting a family, amongst the higher classes led to delayed fertility (Van Poppel, 1992).Secondly, greater emphasis on morality and contempt of promiscuity amongst the upper classes would also reduce the hazards of unplanned, pre-marital start of fertility.

Coming to the contribution of other coefficients to the likelihood of start of fertility and mortality, we find large regional differences in probabilities of start of fertility and death. Individuals born in Friesland have a much lower mortality rate. This observation supports a previously well established result and is explained by the high prevalence of breast-feeding in Friesland and the poor quality of water in the other two provinces (Van den Berg et al., 2006).

The model also takes into account other potential factors influencing the events of fertility and mortality in our sample - namely the severe influenza epidemic of 1918 and the degree of urbanization of the place at birth. Urbanization and exposure to influenza is found to have no significant effect on the hazard of first birth or death. The details can be seen from Table 3 below.

The trend in GNP has a significant negative effect on the exit probability into death (similar to Chapter 2 above). This result is expected since the trend component captures long term increases in national income and consequently improvements in public health expenditures on, for instance, sanitation and medical care.

The estimates in Table 3 indicate that significant unobserved heterogeneity exists in the sample, both for the events of start of fertility as well as mortality. High and low hazards of mortality are almost equally distributed within the sample with marginally more women ($\approx 58\%$) exhibiting a significantly higher hazard of death ($v_d^1 = 0.33, v_d^2 = -0.82$). Likewise in case of the exit probabilities into first child births, the proportion of the women with high unobserved heterogeneity for the hazard of starting fertility ($v_{f_{FB}}^2 = 0.72$) is again close to those with a lower value ($v_{f_{FB}}^1 = -1.33$). In terms of joint probabilities, about 31% of the sample have a low exit probability of first child birth and a high hazard of death, 27% has high hazards of both starting fertility and death, 14% has a low hazard of both events and about 28% has high exit probability of first child birth and a low one for mortality.

Finally, considering age dependence of exit rates into first child births and mortality we find the expected inverted U-shape for the former and a monotonically increasing one for the latter (refer fig.4). We observe that the hazard of starting fertility increases till the age of 29 for women and consistently declines thereafter.

5.2 *Factors determining last birth and its impact on mortality*

Similar to our results of the effect of age at start of fertility on mortality we find a significant, age-dependent, negative causal effect of duration until last birth on the mortality hazard for women in their post-reproductive years. However, compared to the effect of first birth on mortality the favorable effect of earlier last birth on longevity appears to be relatively short lived being significant only during the short age interval of 59-61 years. Furthermore, and unlike the results of fertility defined as first birth, we find the expected significant adverse effect of child bearing on a womens' health during her reproductive ages of 14-40 years. Figure 4 presents this age dependent causal effect of last birth (LB) on mortality hazard, along with the 95% confidence intervals. These results are in line with past observations of excess maternal mortality in the late 19th and up till World War II, owing to puerperal fever and other diseases of pregnancy responsible for between 5.4 and 10.1 per cent of all deaths among women aged 20–49. It is also likely to be more pronounced when fertility is defined as last birth since maternal mortality was directly related to the number of pregnancies experienced, with additional risks associated with pregnancies occurring in the late stages of a woman's reproductive window (Van Poppel, 2000). The result of the significant 'protective' causal effect of fertility on mortality hazard for a woman in her post-reproductive years reinforces the findings of studies like Doblhammer and Oeppen, 2002, that suggest that the positive statistical association between age at last birth and longevity amongst samples of post reproductive women is likely to be driven by selection on the basis of socioeconomic factors rather than causation. Controlling for the influence of background characteristics and early life conditions on both the fertility and mortality hazard of the woman, we find that an earlier end of fertility[11] in fact increases female longevity. Recent evidence from medical studies that find a greater risk of diseases like breast cancer amongst women with later menopause (Martin et al., 2006) would then also be in line with our results. However, in the absence of information on the cause of death of women in our sample we are unable to comment any further on the underlying mechanisms driving this protective effect of early last births on female life expectancy. Once again, small number of survivors at older ages could be partly responsible for the absence of a consistent protective effect beyond a certain age (refer Figure 4).

Another vital result that emerges from our joint study of duration until last birth and mortality is the significant negative impact of favorable average macroeconomic conditions in years of childhood (age intervals 6-8 years and 9-13 years, refer Table 3) on hazard of last birth for women. Given that last child birth is likely to be a good proxy for menopause in a natural fertility population, this result is in line with recent medical and epidemiological literature that has shown that a diet rich in meat, which is more likely to be the case in

[11] Earlier end of fertility could also imply fewer pregnancies and related risks.

better economic times, is associated with later menopause (Beser et al, 1994; Torgerson, 1994; Keck, 2005; Martin et al, 2006). The fact that we find a greater effect of economic conditions in the years just prior to puberty could once again be in line with the theory of developmental placticity mentioned above and might suggest an association between the age of menarche and the end of fertility (Frisch, 1978). Study of this relationship is however left for future work. Once again, no significant effect of average, cyclical macro economic conditions in early years of life is found on the death hazard for women.

Once again, while social class is found to have no significant impact on death hazard class affiliations are found to be very important for end of fertility hazard for women. Female members of higher social classes exhibit later end of fertility than their lower social class counterparts. Since in a natural fertility population menopause is a vital determinant of age at last birth, it is possible that later menopause, as observed to result from rich dietary and environmental factors, could lead to later age at last birth. However, in the absence of information on timing of menopause, no conclusions can be drawn on the reasons underlying this result.

Results similar to those found in the joint model of first child birth and mortality are also found in the simultaneous analysis of the event of last child birth and mortality for the coefficients of region of birth, urban or rural place of birth and exposure to the influenza epidemic of 1918 (refer Table 3 for parameter estimates).

While the trend component of the GNP continues to have a significant negative effect on the exit probability into death in the joint model of last child birth and mortality unlike the study of first child birth, contemporaneous trend of the GNP is now found to have a significant positive effect on the hazard of last child birth. This result would be in line with long term increases in availability of family planning methods over time that have allowed women to stop their fertility prior to menopause.

Estimation of unobserved heterogeneity in the bivariate model of duration until last child birth and mortality led to convergence of two of the joint probabilities (q_3 and q_4) to zero. The results found from the re-estimation of the model with q_3 and q_4 set to zero (refer Table 3) illustrate the presence of significant unobserved heterogeneity in the joint model of last child birth and mortality as well.

Age dependence of exit rates into last child births and mortality from the joint model of these events are plotted in Figure 3. Once again we find the expected inverted U-shape for the former with a peak in hazard of last child at age 40 years (as compared to age 29 years for first child births). Baseline death hazard from the joint model of fertility and mortality, with the former being defined as duration until last birth, is once again a monotonically increasing function of age (refer Figure 3).

6 Sensitivity analysis

6.1 *Alternative specifications of effect of fertility on mortality*

Following from past literature and some of our own earlier work, we estimate some alternative specifications of the effect of start (FB) or end of fertility (LB) on mortality. The first model we try ensues from our earlier study of marriage and mortality as documented in Chapter 2, that finds that not only do early conditions in life directly influence later life mortality but in fact they also interact with other life events like marriage thereby bringing about an additional indirect effect of conditions early in life on mortality. We try to check for the presence of any such interactions between average, cyclical macroeconomic conditions during childhood on our causal effect of fertility (first/ last) on mortality. In order to do so, we now not only allow the causal effect of fertility on mortality $\delta_i, i \in \{FB, LB\}$ to vary over a woman's lifetime (i.e. as a function of age) but also allow this effect to vary by conditions in early life of the woman. This is achieved by including interactions of δ_i with the dummy of being born in a boom or not in the total causal effect of fertility on mortality. With this set up then, the total causal effect of fertility δ_i with $i \in \{FB, LB\}$ on death hazard as presented in equation 4.2 would be replaced by

$$\delta_i = \sum_{k=0}^{4} \eta_k^{ace} U_k(t) + \left(\sum_{k=0}^{4} \eta_k^{a,int} U_k(t) \cdot I_{boom} \right) \tag{9}$$

where the first term is defined exactly as before and captures the age dependence of the causal effect of fertility on mortality. The second term $\left(\sum_{k=0}^{4} \eta_k^{a,int} U_k(t) \cdot I_{boom}\right)$ captures any effect of early life conditions, represented by the dummy (I_{boom}) for being born in a year of economic boom, might have on this age dependent causal effect of fertility on mortality hazard. $\eta_k^{a,int}$ are then the estimated coefficients corresponding to this interaction term. With this set up, the second term enters the expression for the causal effect of fertility on mortality only for a person born during an economic boom ($I_{boom} = 1$). For a person born in a recession ($I_{boom} = 0$), the second term would vanish and we would be back to our original specification (equation 4.2). Figure 5(a) and (b) present plots of this age dependent causal effect of fertility and the interaction term of this effect with early life conditions for duration until first birth and last birth respectively. We note that with this specification the protective effect of first birth on mortality is significant at the 5% level but during a shorter age interval of 41-76 years only (Figure 5(a)). When defined as last birth the effect of fertility on mortality continues to be adverse during child bearing ages and is favourable but now insignificant during the post-reproductive period. Moreover, the plots of the age dependent causal effect of fertility interacted with conditions early in life show that this effect is not significant throughout (Figure 5(b)). Results for other explanatory variables from this model remain unchanged and are presented in Table 4. However our original model is nested in this larger specification, and a simple likelihood ratio test rejects this larger model in favor of our initial model without interactions[12] since the larger model adds 5 additional variables with no significant gain in likelihood. This implies that while conditions in early life have a crucial direct effect on the timing of start or end of fertility, probably through their impact on age at menarche and menopause, these early life conditions to not indirectly influence mortality outcomes via interactions with fertility unlike in the case of marriage.

Parity or the number of children borne by a woman over her lifetime has also been frequently used as a measure of fertility in past literature. While the start and end of fertility, together, are likely to strongly bound total parity, one could expect that after the start of fertility birth spacing and consequently the total number of children born could in fact influence the impact of the initial start or end of fertility on mortality. Our next specification allows for such a parity dependent causal effect of fertility (first/last child birth) on mortality. This is done by setting up a 'child birth vector' for each woman in the sample. This vector takes a value of 0, corresponding to total parity, at the start of life for each woman (in our case till age 14 up to which no woman in the sample has borne any children). Subsequently this vector is updated each year for each woman on the basis of her fertility experience in the previous year. So if a woman bares her first child at age 30, the first 16 entries in her child birth vector are 0 and take a value of 1 in year 30 of her life. Thereafter this vector is cumulatively updated to take into account each subsequent birth. Therefore an entry of 1 will appear in all years between her first child birth and until her second child birth, after which the child birth vector is updated to 2. The same pattern follows for all higher order births. Once the child birth vectors are generated for each woman in the sample, fourth order Chebyshev polynomials of linear transformations of these vectors[13] are used to express the parity dependent causal effect of fertility on

[12] LR statistic for model without interactions vs. model with interactions, 1.70 ($\chi^2(5)$, 5% critical value 11.07).

[13] Since the maximum number of children borne by a single woman is 21 in the sample the domain of the values in the child birth vector is $n \in [0, 21]$. Similar to our case of age dependent causal effect of fertility on mortlity this is linearily transformed to the domain of the orthogonal Chebyshev polynomials such that now $\widehat{n} \in [-1, 1]$.

Then our orthogonal polynomials once again are mortality. As one might note, in addition to the total parity this set up allows us to take into account the timing (and hence the spacing) of the birth of children as well. Figure 6 presents plots of this parity dependent causal effect of first and last birth respectively on mortality hazard along with the 95% confidence interval. Our results show a significant, negative parity dependent causal effect of both the duration until first and last birth on mortality hazard. In case of start of fertility this effect continues to be significantly protective up to 5 children with the maximum marginal protective effect of the third child. In case of duration until the last birth, a significant protective effect of fertility is found for up to 4 children with the maximum marginal protective effect of the second child. These results are in line with recent literature that finds similar U-shaped relationship between parity and mortality amongst women (Doblhammer, 2000). This result seems intuitive if one was to accept the insurance motive behind fertility. While baring some children provides a woman with some old age insurance a very high parity is likely to take a toll on a woman's health and therefore longevity. This adverse causal effect of high fertility on mortality however cannot be interpreted as a general trade-off between fertility and mortality as suggested by theories of overall somatic senescence (Westendorp and Kirkwood, 1998). As seen from the results in Table 5 the results for all other explanatory variables of fertility and mortality remain qualitatively unchanged with this specification as well.

Following past literature we next estimate a baseline model where the causal effect of fertility (defined as either first or last birth) is measured using a time varying regressor that takes a value of 0 before the person bares their first or last child and 1 thereafter. In this simple specification (Table 6) while start of fertility is still found to be 'protective' and lowers the death hazard for the woman, the duration of last birth now has no effect on her mortality hazard[14]. Our result for first births from this basic specification is in line with some earlier studies using historical data (e.g. Le Bourg et al, 1993) that find higher incidence of early fecundity among selected samples of extremely longevous women. Looking at other explanatory variables, all other coefficients remain almost unchanged. We note that this basic specification is nested in our original specification of the age dependent causal effect of fertility on mortality and also in the parity dependent fertility effect on exit probabilities into mortality just presented above. A simple LR test shows that for the effect

$U_0(\widehat{n}) = 1$
$U_1(\widehat{n}) = 2\widehat{n}$
$U_2(\widehat{n}) = 4\widehat{n}^2 - 1$
$U_3(\widehat{n}) = 8\widehat{n}^3 - 4\widehat{n}$
$U_4(\widehat{n}) = 16\widehat{n}^4 - 12\widehat{n}^2 + 1$

[14]The reader is reminded of the fact that relatively higher hazard of first birth does not necessarily imply very young motherhood which is medically known to be injurious to the mother since the average age of the mother at first birth is our sample is 28 years.

of first birth on mortality this basic specification performs just as well as the larger model with age dependent causal effect of fertility on mortality[15]. This smaller model however, fails to take into account the crucial age dependent nature of the impact of fertility on mortality with the effect being favorable only in the post-reproductive years of a woman making our original model the model of choice. Moreover, for the case of the effect of duration until last birth on mortality hazard however, our original age dependent causal effect specification rejects this basic model[16] but cannot be compared to the model with parity dependent causal effect of last birth on mortality[17] as these models are non-nested.

The results from these alternative specifications of the causal effect of fertility on mortality highlight the extreme sensitivity of the measure of the impact of fertility on mortality to the definition of fertility being used. This is probably the factor underlying the extreme diversity in past literature on the impact of fertility on mortality. Earlier studies that consider a time/age invariant impact of fertility on mortality or assume a constant, marginal effect per extra child on the health of the mother are bound to overlook the complexity of the time and parity varying causal effect of fertility on mortality. This research then is at best a crude indicator of the potential relationship between fertility and mortality for women.

6.2 *Other sensitivity tests*

Certain other checks were undertaken to check the sensitivity of our results to alternative specifications of other explanatory variables as well. For instance, instead of the 4 binary indicators used to capture economic environment during these early years of life - dummy for being born in a year of an economic boom or not and 3 dummies for whether on an average the individual enjoyed an economic boom or not during the ages of 1-5, 6-8 and 9-13 years of age we tried to estimate our model of marriage and mortality using the actual values of the cyclical component of the GNP series. We find that our results are robust to this variation. Next, we tried alternative age intervals for our average cyclical indicators and once again our results remain unchanged. Irrespective of the choice of the intervals the relevance of the average cyclical conditions in years closer to puberty has the largest influence on the fertility outcomes for women. Finally, we tried different order polynomial specifications for the duration dependence of fertility and mortality on the age of the

[15] LR statistic for our age dependent causal effect vs.baseline model, 3.74 and parity dependent causal effect vs. baseline model, 5.95 with $\chi^2(4)$, 5% critical value 9.49.

[16] LR statistic for our model with age dependent causal effect vs. baseline model, 63.36 with $\chi^2(4)$, 5% critical value 9.49.

[17] Parity dependent causal effect of duration until last birth on mortality performs better than the baseline model with an LR statistic of 25.88 and a $\chi^2(4)$, 5% critical value of 9.49.

individual. Once again, are results remain unaffected with the fourth order polynomial having the highest likelihood.

7 Robustness checks - the role of marriage

Given the potential role of marriage in exposing a woman to the risk of fertility, we check to what extent our results are driven by marriage. This is done in two ways. First, following literature (for instance Helle et al., 2004 and Gagnon et al, 2009) we re-estimate our model with age dependent causal effect of fertility (first/last birth) on later life mortality for a selected sample of married women only. Limiting our sample to include only those women who did get married we in a way eliminate the role of marriage in determining a woman's fertility. In the resulting sample, all women could potentially procreate and any delay or inability in doing so would be a owing to factors besides marriage. Results of the estimations for the sample of all married women are presented in Table 7 and Figure 7. First considering the impact of conditions in early years of life on individual exit into first and last child births we find that while these conditions continue to have a significant negative impact on a woman's start of fertility this effect is no longer significant for end of fertility. Looking at the age dependent causal impact of either first or last births on death hazards, even in the sample of all married women, we find a significant adverse effect of fertility on mortality during reproductive years[18] and a significant protective effect of fertility on later life mortality, in post-reproductive years. However, the age dependent protective effect[19] of first/ last birth on mortality in post-reproductive period is significant for the selected sample of married women during slightly different age intervals of 37-52 years and then again between 73-87 years in case of start of fertility and during the age interval of 68-87 years for last births. In absence of information on spousal demise, family structure and transfers from partner and children in post-reproductive years we are unable to comment

[18] In the sample of all married women only, the expected adverse effect of fertility during reproductive years is also seen for fertility defined as duration until first birth.

[19] Other specifications for the causal effect of fertility on mortality, namely age dependent causal effect with interactions between early life conditions, parity dependent causal effect and a baseline specification with a single binary time varying explanatory variable capturing the effect of fertility on mortality, were also tried. Simple likelihood ratio tests showed that the more complicated model with interactions did not significantly improve the likelihood (LRT of 1.38 in case of first births and 1.44 for last births, with $\chi^2(5)$ 5% critical value 11.07) and the baseline model for rejected (LRT of 23.13 for first births and 98.06 for last births, with $\chi^2(4)$, 5% critical value 9.49). The parity and age dependent causal effect of fertility or mortality specifications are not nested and hence cannot be compared that easily. However, unlike the full sample of women for the selected sample of married women only the parity dependent causal effect of fertility on mortality is no longer statistically significant at any parity for first births and only significant for upto 3 children in case of last births.

on the reasons underlying these subtle differences. Other parameters remain unchanged for this selected sample of married women.

As a second robustness check to evaluate the impact of marriage on our results we re-estimate our bivariate model of fertility (again separately for first and last child births) and mortality without the exogenous time varying indicator for marriage as an explanatory variable for death (i.e $\beta_d^m I(t_m < t) = 0$ in equation 4.1 now). Table 8 and Figure 8 present the parameter estimates and the plots of the age dependent causal effect of fertility (start and end) on death hazard respectively. All results remain unchanged with this alternative specification with once again us finding a significant, protective causal effect of fertility (both first and last child births) on mortality only in post-reproductive years for the full sample (both married and non-married) of women. A LRT of our model of choice with age dependent causal effect of fertility on mortality and an exogenous time varying contribution of marital status on mortality hazard vs. a model without marriage as a determinant of death yields an LR statistic of 0.33 in case of first and 0.07 for last births with $\chi^2(1)$, 5% critical value 3.84. Hence the model without marriage as an exogenous determinant of fertility performs just as well as our preferred model. However, given the emphasis in past literature on the importance of marriage in the study of fertility and mortality including this indicator seems reasonable.

These robustness checks seem to suggest that fertility more than nuptiality seems to be driving our crucial results of the vital role of early life conditions in determining individual exit into fertility and the significant protective impact of fertility on mortality in a woman's post-reproductive years. This result is in line with the well recorded, 'old-age security' benefit from fertility which is likely to kick in for women during their older ages irrespective of their marital status.

8 Discussion, policy implications and further work

These results indicate that while early conditions in life do not directly influence longevity amongst women, economics conditions in childhood are crucial determinants of female fertility which in turn has large effects on a woman's life expectancy. Coming to the impact of fertility on mortality we find that a measure of this effect is very sensitive to the choice of fertility definition. This necessities the use of multiple alternative definitions in order to decipher the relationship between fertility and mortality. Moreover, our study shows that earlier work that only look at the effect of conditions in-utero on fertility overlook the importance of years just prior to puberty that seem to have the largest influence on a woman's fertility outcome. This result is particularly relevant since it reiterates medical research that has found evidence for reproductive, developmental tempos with continued adjustments in growth trajectories extending over years of childhood and well into adolescence. Our results also show that start and end of female fertility also depends on other current factors like social class and current economic conditions and studies that do not take into account these other confounding factors are likely to end up with biased estimates of the impact of fertility on mortality[20]. Finally, our study finds that early life conditions influence mortality hazard of women only via fertility and this result reiterates earlier work that found direct effects of early life conditions on mortality hazard for men but not for women (also seen in Chapter 2 above).

Although this study is based on a historical data set it is important to point out the current day relevance of this work. Firstly, several obvious similarities exist between 19th century Dutch society and current day developing world. Both scenarios involve mostly natural fertility populations[21] with a relatively small upper class, absence of formal insurance against macro-economic shocks and little access to active family planning methods. Therefore results drawn from this study using 19th Century Dutch data could help shed some light on the determinants of and interaction between fertility and mortality for policy makers in less developed economies struggling with high fertility and mortality rates. In developing countries the adverse effects of poor economic conditions during childhood on outcomes later in life are likely to be particularly stark for the girl child who often enjoys only a secondary status to her male siblings. Our results then imply that, one consequence of exposure to poor economic conditions during childhood and adolescence is early start of fecundity for women and this in fact is highly prevalent in less developed economies and by known to be injurious to the health of both the mother and the child. Early start of fertility is likely to imply high parity over her reproductive window as well and this would have adverse consequences for the woman and in turn for the whole economy by means of increased pressure on the limited resources of a poor country. Hence, additional focus should be on the female children during macro-economic down-turns as this might have long term health consequences for them, their off-spring and the economy as a whole. Besides extra provisions of food, housing and health care this can be done by encouraging more equitable distribution of household resources between male and female children. Moreover, family planning policies discouraging high parity should be put into place since our results confirm adverse health consequences of high fertility for women. Furthermore, since

[20] This fact has been acknowledged by other authors as well, notably Doblhammer and Oeppen, 2002, and our study renders support to their views.

[21] In current day developing world limited use of modern contraceptive methods due to lack of knowledge of contraceptive use, limited access to modern methods of contraception or inabiltiy of women to take decisions regarding their fertility in male dominated societies are often responsible for close to natural fertility rates.

the beneficial effect of fertility on a woman's health kicks in only in her post-reproductive years women should be supported during their child bearing ages. Increased knowledge of and access to modern contraceptives would help women plan their fertilities better by allowing a later start of fertility and preventing quick successive pregnancies that lead to high infant and maternal mortality rates. Better health care and support during pregnancies would also be vital.

In future work we would like to further investigate the mechanisms underlying the impact of conditions early in life on fertility and the causal effect of fertility on mortality. In Chapter 2 we found that conditions in early years of life do not significantly influence the marital rate of a woman. However, the current study shows that these very early life conditions in fact have a large effect on the start and end of fertility which then seems to suggest that the mechanism underlying the effect of early life conditions on start or end of fertility is then likely to be of a physiological nature and not driven by factors like marriage. Data on the timing of menarche and menopause, along with the fertility histories would be very useful in deciphering the nature of mechanisms underlying the causal effect of fertility on mortality since physiological factors are more likely to influence the former than the latter. Another useful exercise could be to apply our method of investigation to another sample of women with relatively lower average ages at first birth. Doblhammer, 2000 finds an adverse effect of very young motherhood (before the age of 20) on later life mortality. Given the relatively high average age of first births in our sample (28 years) we do not find evidence for this effect in our study but a sample of younger first time mothers would be better suited to capture this effect. Such an exercise would also be useful in demarcating 'healthy' and 'unhealthy' age windows for female fertility which can be used to channel public health policy. Third, to facilitate comparison of our results to those from past studies it could be useful to repeat our analysis for selected samples of women who have all survived till the end of their reproductive cycles since such selected samples have been popular in earlier work on the relationship between fertility and longevity. Although this approach overlooks important selection effects that might drive the measure of the effect of fertility on mortality, in case of our second definition of fertility, duration until last child birth, this approach could help make the timing of last birth a somewhat closer indicator of menopause. Moreover, undertaking such an exercise might help resolve any discrepancies between past results and those of this study.

9 Conclusion

Defining fertility in two alternative ways, duration until first child birth and duration until last child birth, this study shows that business cycle conditions in the early years of life play a significant role in determining a woman's exit probability into fertility (first or last child birth) and mortality. Using a sample of Dutch women born between 1850-1922, we find that after controlling for other things, on average women who enjoy favorable macro-economic conditions during years of childhood and adolescence leading up to puberty exhibit a lower hazard into and out of fertility. We take this result as evidence of a negative causal effect of individual economic conditions in years prior to puberty on the rate of motherhood. By considering the differential impacts of economic conditions during various childhood age intervals this study goes beyond past works that only focused on in-utero or contemporaneous factors influencing female fertility. In doing so our results reiterate medical evidence on the importance of different age intervals for the development of diverse bodily functions.

Furthermore, the simultaneous analysis of fertility (defined as first or last child birth) and mortality, controlling for early conditions in life and marriage, yields evidence of a causal protective effect of fertility on mortality during the post-reproductive years of a woman. Moreover, this protective effect is not constant over a woman's lifetime but in fact varies by her age and parity. While on an average, fertile women gain from reproduction in their post-reproductive years this effect is more pronounced when fertility is defined as duration until first child birth (significant causal effect of fertility on mortality between ages 38-80 years) than when defined as duration until last child birth (significant only during short interval of 59-61 years). Similarly, when the causal effect of fertility on mortality is expressed as a function of parity of a woman, we find that the marginal protective gain from an extra child is not constant and peaks at the third child in case of fertility being defined as duration until first child birth and already at the second when defined as duration until last child birth. Therefore, our study finds that there indeed is a causal effect of fertility on mortality, this effect is favorable only after the woman has survived her reproductive years, this effect is not constant over a woman's life or across her total parity and is sensitive to the choice of definition and specification of fertility.

Several policy implications can be drawn from the results of this study. Firstly, extra attention should be paid to female child in years leading to puberty in bad economic times. This could be done by provisions of food, housing and health care. Secondly, public health efforts should be made to increase knowledge of and access to modern methods of family planning that allow women to better plan their fertilities. Finally, women should be supported during their child bearing ages. This can be achieved by putting in place suitable legal age of marriage to avoid very young motherhood and its consequent adverse health effects for women and, by providing better medical care during pregnancies to women.

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Figure 1: The distribution of time in years between marriage and start of fertility

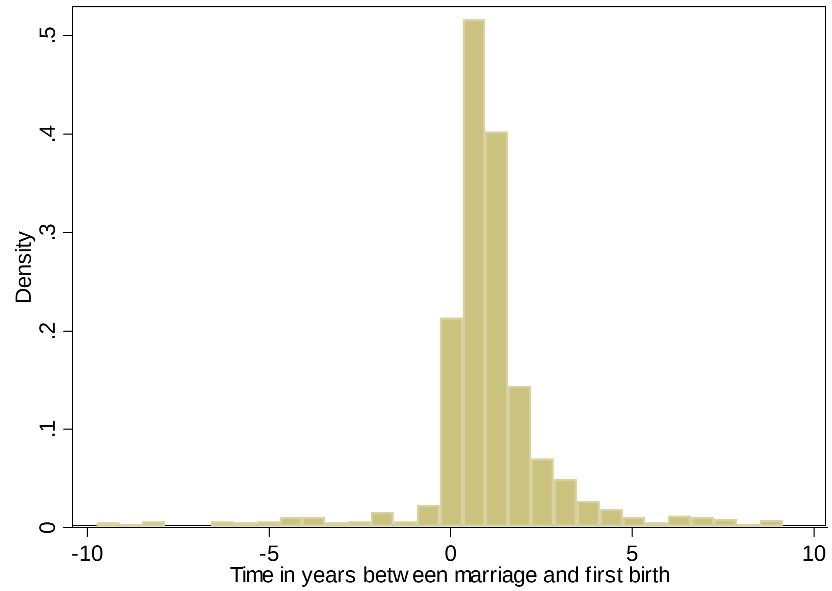


Figure 2: log annual real per capita GNP

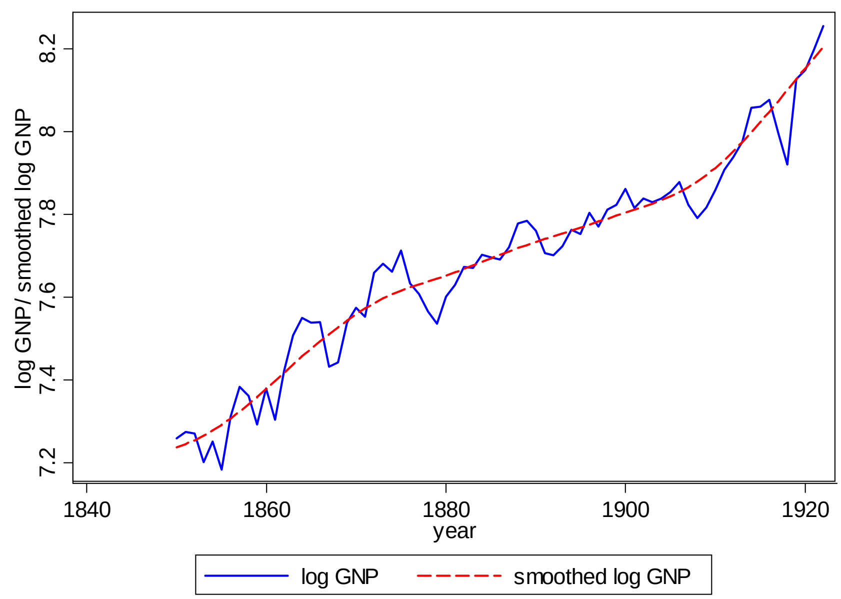


Figure 3: Age dependence of first child birth and death (baselines)

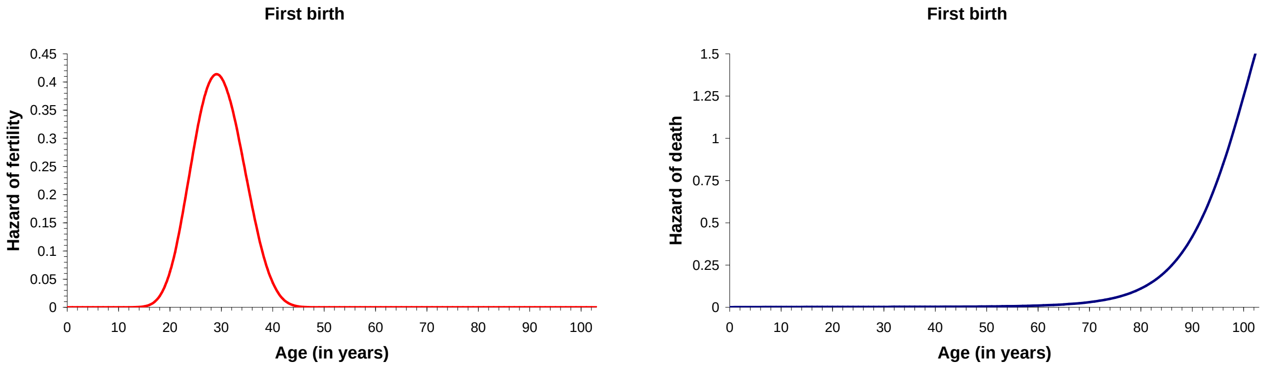


Figure 3(contd.): Age dependence of last child birth and death (baselines)

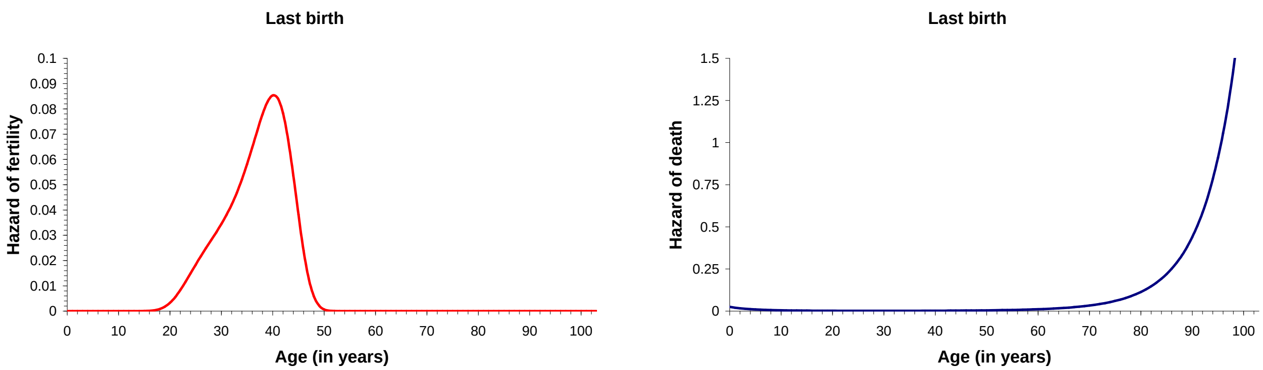
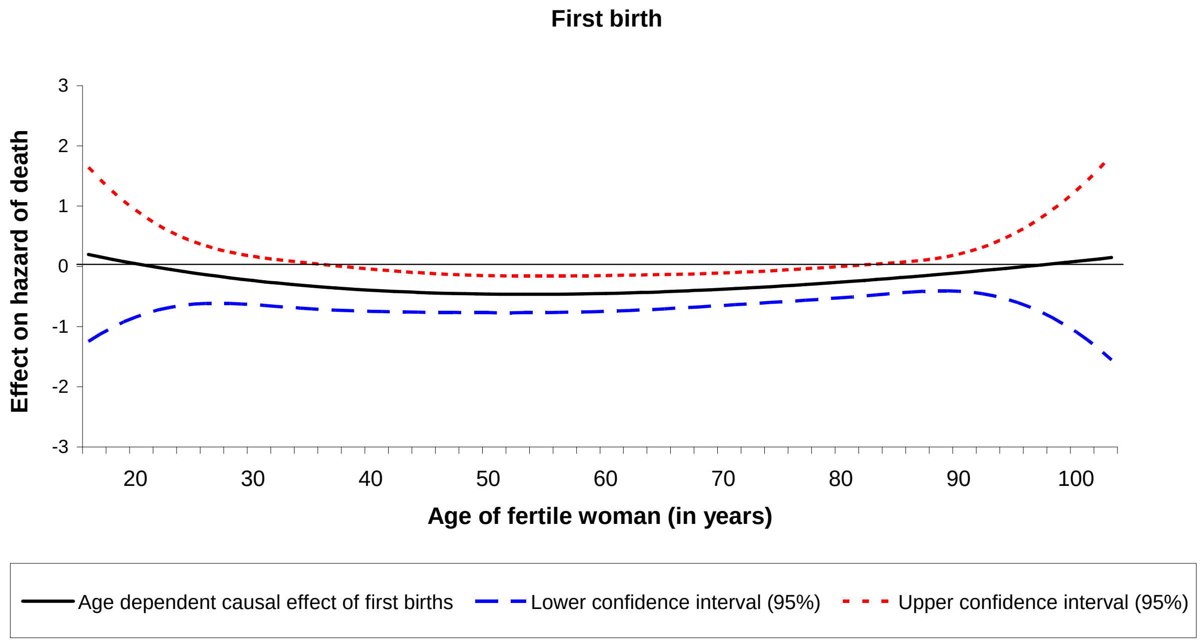


Figure 4: Age of the individual dependent, causal effect of fertility on the hazard of death



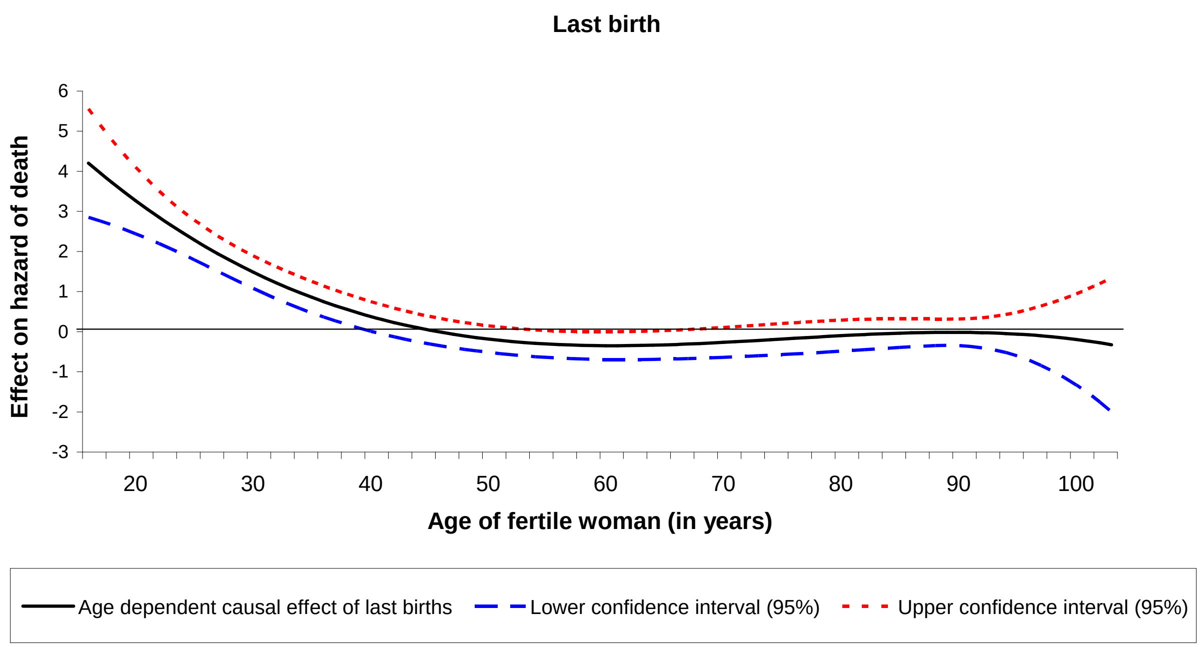
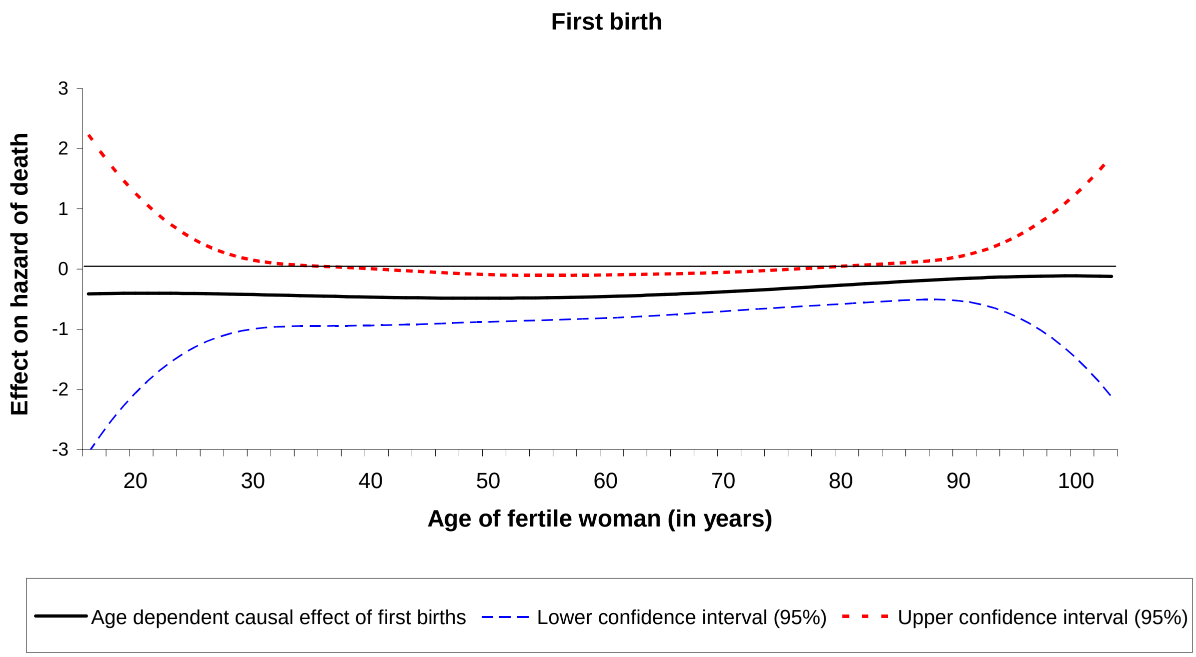


Figure 5(a): Age of the individual dependent, causal effect of first child birth on the hazard of death interacted with born in a year of an economic boom or not



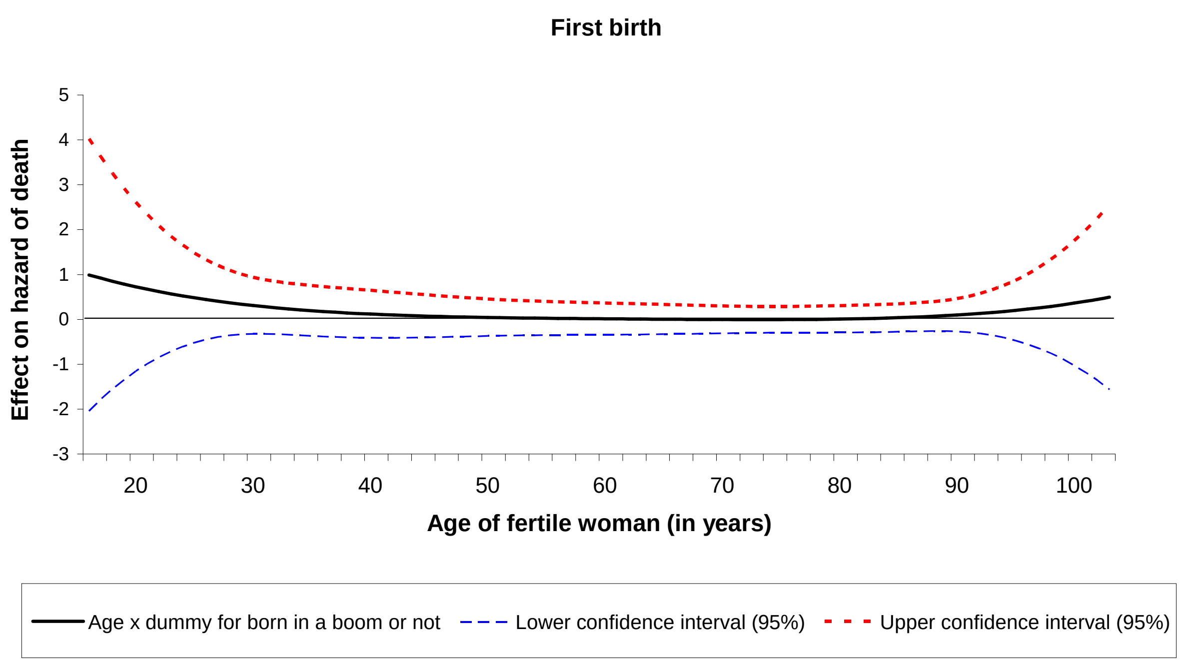
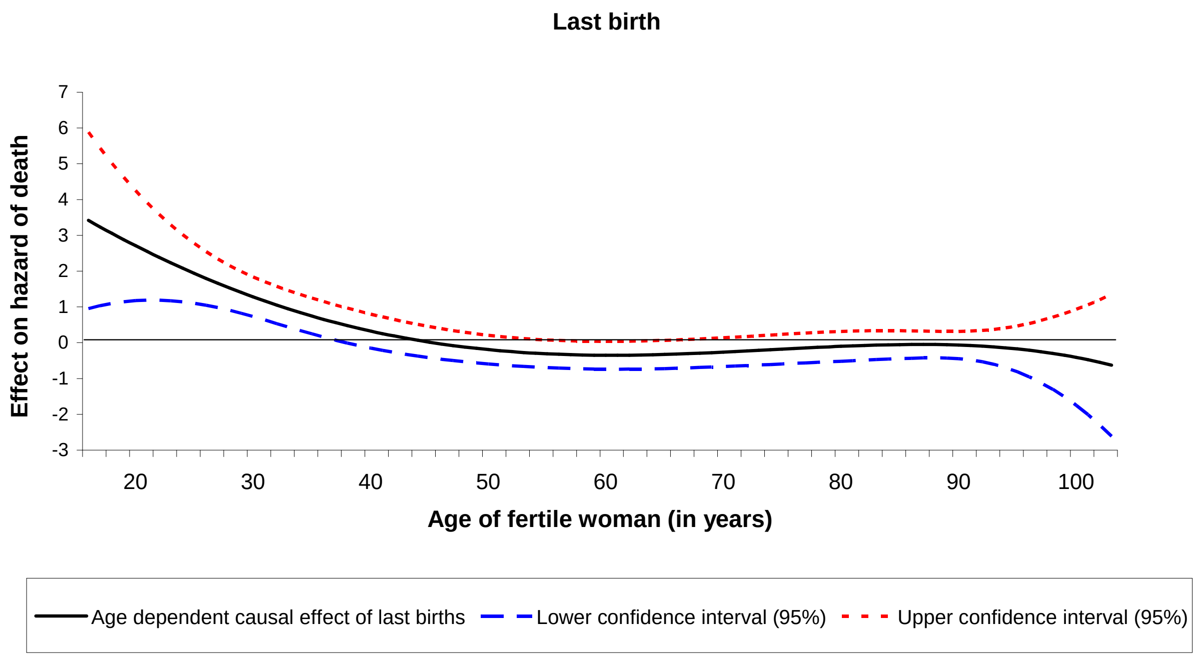


Figure 5(b): Age of the individual dependent, causal effect of last child birth on the hazard of death interacted with born in a year of an economic boom or not



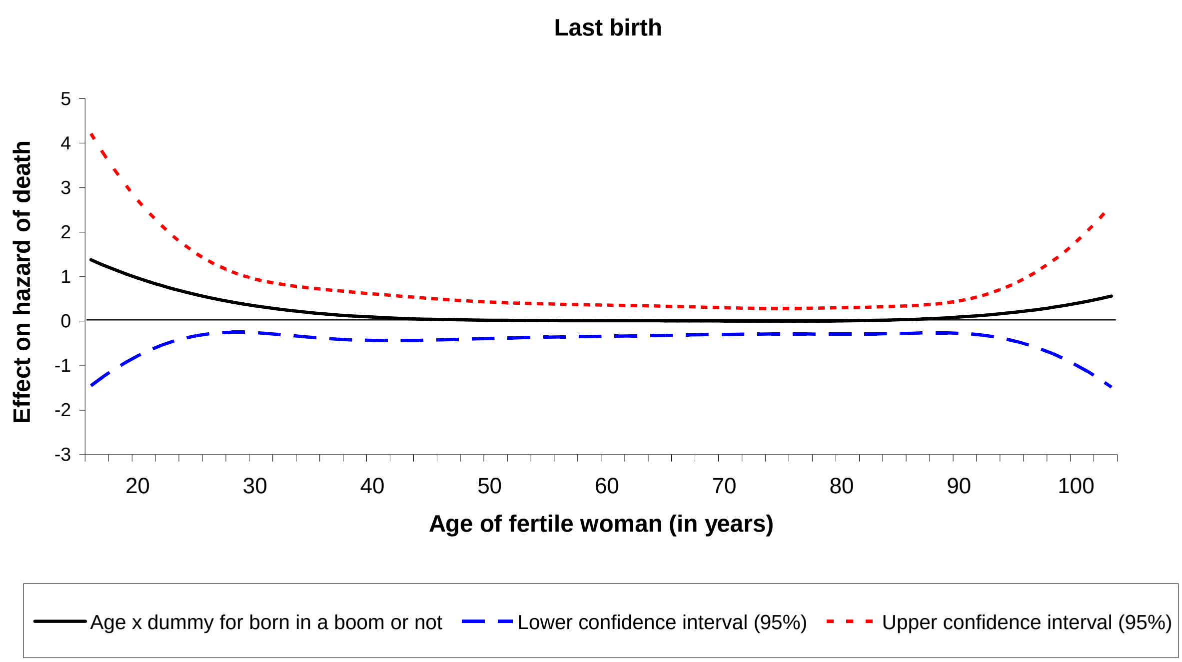


Figure 6: Parity dependent, causal effect of fertility on the hazard of death

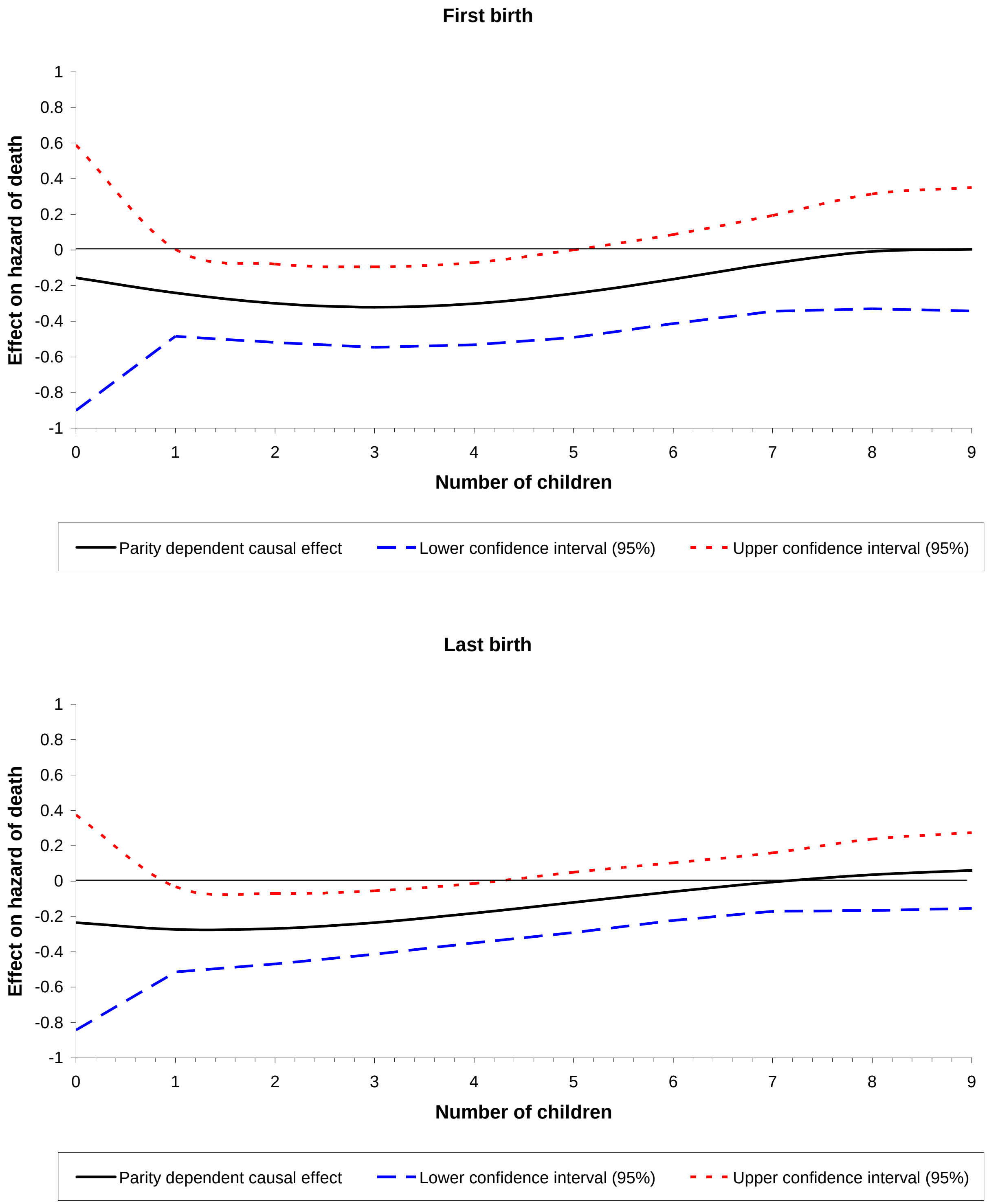
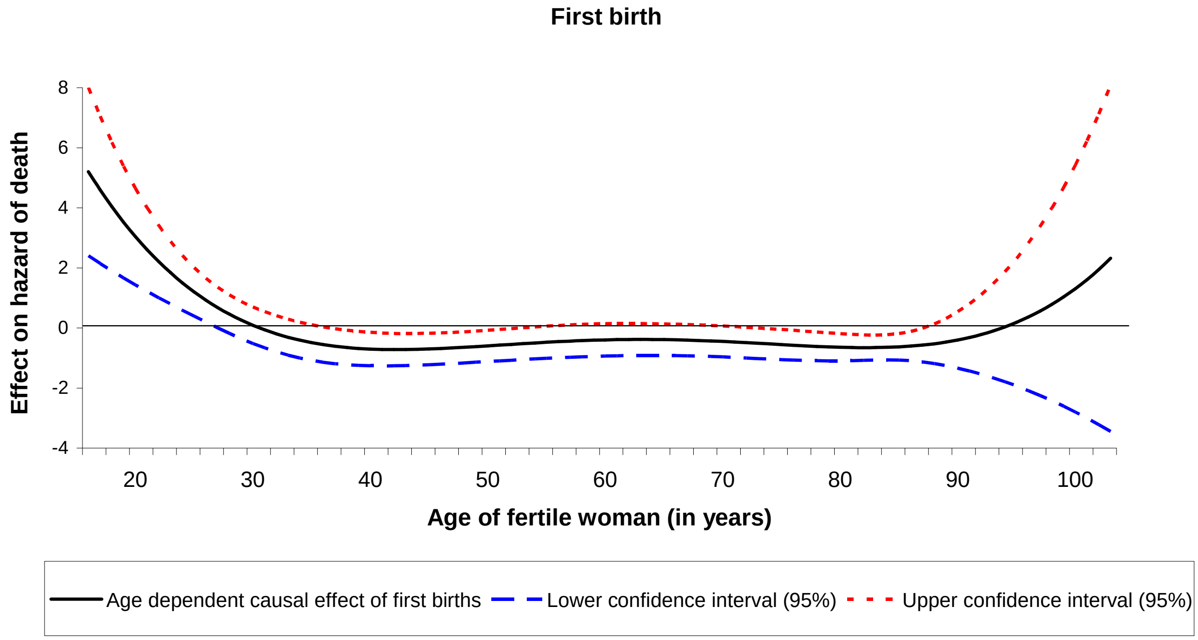


Figure 7: Age of the individual dependent, causal effect of fertility on the hazard of death for sample of all married women



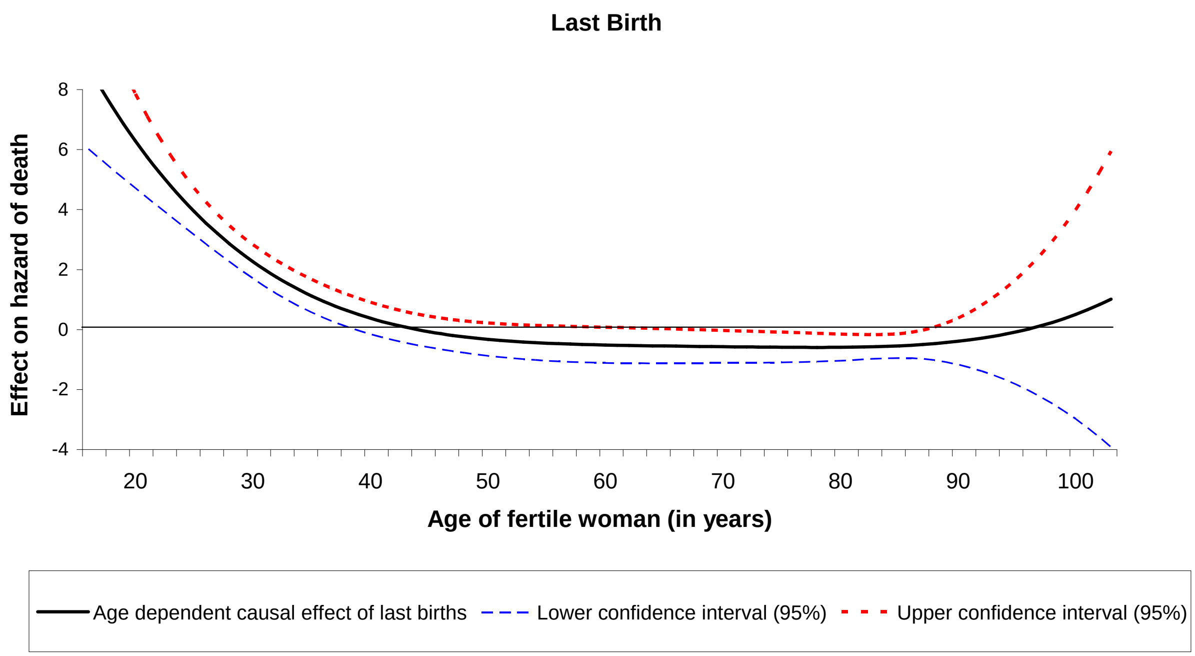


Figure 8: Age of the individual dependent, causal effect of fertility on the hazard of death from model without marriage as exogenous determinant of mortality

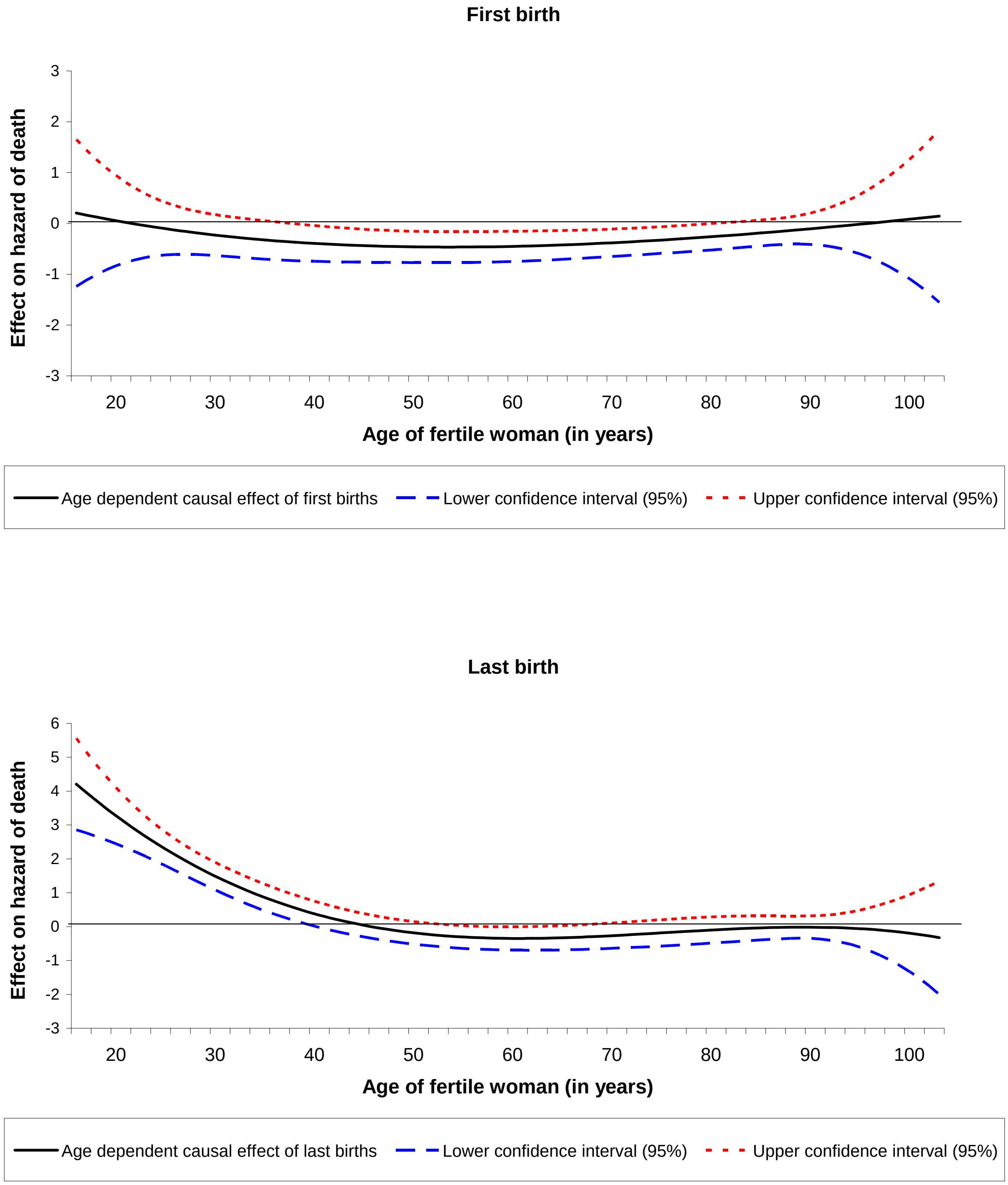


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Table 1 Dimensions of social class in HISCLASS

Manual/ non-manual	Skill	Super-vision	Sector	Class labels	Number
Non-manual	higher skilled	yes	other	Higher managers	1
			primary		
		no	other	Higher professionals	2
			primary		
	medium skilled	yes	other	Lower managers	3
			primary		
		no	other	Lower professionals, clerical and sales personnel	4
	lower skilled	yes	primary		
			other		
			primary		
		no	other	Lower clerical and sales personnel	5
			primary		
	unskilled	yes	other		
			primary		
		no	other		
			primary		
Manual	higher skilled	yes	other		
			primary		
		no	other		
			primary		
	medium skilled	yes	other	Foremen	6
			primary		
		no	other	Medium-skilled workers	7
			primary	Farmers and fishermen	8
	lower skilled	yes	other		
			primary		
		no	other	Lower-skilled workers	9
			primary	Lower-skilled farm workers	10
	unskilled	yes	other		
			primary		
		no	other	Unskilled workers	11
			primary	Unskilled farm workers	12

Table 2(a) Sample composition and summary statistics for full sample of women						
Type	Number, %	Age at Marriage	Age at First Birth	Age at Last birth	Number of Children	Age of Death
1: No reported Fertility	515 26.48%	30.20* [28.11] (7.93)	–	–	–	63.89* [71.95] (23.41)
2: Fertility and Death known	1073 55.17%	25.60* [24.32] (5.74)	26.01* [25.39] (4.58)	34.51* [34.8] (6.14)	4.34* [4] (3.08)	74.60* [78.07] (14.79)
3: Censored at Child Birth	295 15.17%	25.20* [24.46] (4.99)	25.45* [24.68] (4.52)	33.90* [34.05] (6.74)	4.46* [4] (3.12)	–
4: Censored at Marriage	62 3.19%	27.59* [24.70] (6.76)	–	–	–	–

∗ : mean
[] : median
() : standard deviation

Table 2(b) Sample composition and summary statistics for sample of married women						
Type	Number, %	Age at Marriage	Age at First Birth	Age at Last birth	Number of Children	Age of Death
1: No reported Fertility	155 11.18%	30.20* [28.13] (7.93)	–	–	–	68.15* [73.65] (17.92)
2: Fertility and Death known	906 65.32%	25.60* [24.33] (5.74)	25.94* [25.23] (4.56)	34.48* [34.48] (6.10)	4.34* [4.00] (3.09)	74.22* [77.75] (15.13)
3: Censored at Child Birth	264 19.03%	25.20* [24.48] (4.99)	25.48* [24.76] (4.47)	33.90* [34.04] (6.70)	4.36* [4.00] (2.97)	–
4: Censored at Marriage	62 4.47%	27.59* [24.70] (6.76)	–	–	–	–

∗ : mean
[] : median
() : standard deviation

Table 2(c) Sample composition and summary statistics for sample of married women with marriage ages between 23-28 years

Type	Number, %	Age at Marriage	Age at First Birth	Age at Last birth	Number of Children	Age of Death
1: No reported Fertility	53 9.33%	25.44* [25.39] (1.59)	–	–	–	64.90* [73.38] 21.23
2: Fertility and Death known	387 68.13%	25.13* [24.94] (1.36)	26.40* [26.20] (2.44)	34.36* [34.20] (5.50)	4.21* [4.00] (2.88)	74.03* [77.34] (15.04)
3: Censored at Child Birth	105 18.49%	25.08* [25.08] (1.31)	26.13* [25.93] (2.30)	34.77* [34.51] (5.67)	4.40* [4.00] (2.77)	–
4: Censored at Marriage	23 4.05%	24.65* [24.00] (1.47)	–	–	–	–

∗ : mean
[] : median
() : standard deviation

Table 3 Parameter estimates for bivariate model for duration until *first* (FB) *or last* (LB)*child birth* and mortality with age dependent fertility effect on mortality rates

Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Background characteristics affecting hazard of fertility:				
Social class father at birth (highest)	-0.71	-5.54	-0.28	-3.45
Social class father at birth (middle)	-0.54	-5.87	-0.22	-3.44
Born in urban area	-0.14	-1.41	0.00	0.07
Born in province Utrecht	0.01	0.17	-0.11	-1.64
Born in province Zeeland	-0.04	-0.35	-0.08	-1.16
Business cycle conditions early in life affecting hazard of fertility:				
Boom (instead of recession) at birth	-0.06	-0.67	0.10	1.67
Cycle indicator for age 1 up to 5	-0.16	-1.80	-0.11	-1.82
Cycle indicator for age 6 up to 8	-0.22	-2.36	-0.18	-2.62
Cycle indicator for age 9 up to 13	-0.26	-2.93	-0.18	-2.96
Contemporaneous macro conditions affecting hazard of fertility:				
1918 influenza	0.11	0.46	0.17	0.79
Current Trend (log annual real per capita GNP)	0.04	1.73	0.08	4.33
Current Cycle (log annual real per capita GNP)	0.64	1.06	-0.61	-1.13
Age dependence of hazard of fertility:				
$\eta_0^{f_i}$	-117.98	-1.77	-177.64	-8.46
$\eta_1^{f_i}$	-150.96	-1.66	-236.57	-8.20
$\eta_2^{f_i}$	-117.00	-1.65	-198.10	-8.15
$\eta_3^{f_i}$	-49.33	-1.49	-93.75	-7.88
$\eta_4^{f_i}$	-15.30	-1.70	-30.99	-7.59
Unobserved heterogeneity terms for fertility:				
$v_{f_i}^1$	-1.33	-5.20	-0.02	-0.17
$v_{f_i}^2$	0.72	10.29	0.03	0.19
Unobserved heterogeneity terms for death:				
v_d^1	0.34	2.29	0.32	2.03
v_d^2	-0.82	-1.28	-0.79	-1.18
Joint probabilities of unobserved heterogeneities:				
q_1	0.31	2.80	0.58	3.17
q_2	0.27	3.67	-	-
q_3	0.28	2.56	-	-
q_4	0.14	2.05	0.42	2.22

Table 3 (contd.)				
Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Individual background characteristics affecting hazard of death:				
Social class father at birth (highest)	-0.17	-1.92	-0.15	-1.61
Social class father at birth (lowest)	-0.07	-0.95	-0.05	-0.66
Born in urban area	-0.03	-0.44	-0.03	-0.43
Born in province Utrecht	0.33	4.06	0.35	4.15
Born in province Zeeland	0.23	2.86	0.24	2.91
Business cycle conditions early in life affecting hazard of death:				
Boom (instead of recession) at birth	0.00	0.03	0.00	0.02
Cycle indicator for age 1 up to 5	0.03	0.37	0.04	0.47
Cycle indicator for age 6 up to 8	0.08	1.00	0.09	1.10
Cycle indicator for age 9 up to 13	0.11	1.50	0.12	1.61
Contemporaneous macro conditions affecting hazard of death:				
1918 influenza	-0.15	-0.31	-0.15	-0.33
Current Trend (log annual real per capita GNP)	-0.03	-2.50	-0.03	-2.45
Current Cycle (log annual real per capita GNP)	-0.19	-0.31	-0.23	-0.39
Effect of marital status on the hazard of death:				
Married	0.40	0.56	0.19	0.27
Effect of fertility ($i \in \{FB, LB\}$) on the hazard of death:				
η_0^{ace}	-0.21	-0.98	0.97	4.68
η_1^{ace}	-0.13	-0.43	-1.56	-5.70
η_2^{ace}	0.26	0.77	1.20	3.57
η_3^{ace}	-0.05	-0.20	-0.44	-1.86
η_4^{ace}	0.01	0.04	-0.02	-0.09
Age dependence of hazard of death:				
η_0^{d}	-4.37	-6.02	-4.32	-5.92
η_1^{d}	1.80	14.72	1.71	14.03
η_2^{d}	0.64	3.80	0.96	5.74
η_3^{d}	0.05	0.46	-0.23	-1.96
η_4^{d}	-0.17	-1.31	0.05	0.40
- Log likelihood	11414.22		11803.72	
Number of individuals	1945		1945	

Table 4 Parameter estimates for bivariate model for duration until *first* (FB) *or last* (LB) *child birth* and mortality with age dependent fertility effect on mortality and age dependent fertility effect interacted with a whether the woman is born in a boom or not

Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Background characteristics affecting hazard of fertility:				
Social class father at birth (highest)	-0.71	-5.54	-0.28	-3.45
Social class father at birth (middle)	-0.54	-5.87	-0.22	-3.44
Born in urban area	-0.14	-1.42	0.00	0.07
Born in province Utrecht	0.02	0.17	-0.11	-1.64
Born in province Zeeland	-0.03	-0.35	-0.08	-1.15
Business cycle conditions early in life affecting hazard of fertility:				
Boom (instead of recession) at birth	-0.06	-0.67	0.10	1.67
Cycle indicator for age 1 up to 5	-0.16	-1.79	-0.11	-1.82
Cycle indicator for age 6 up to 8	-0.22	-2.36	-0.18	-2.62
Cycle indicator for age 9 up to 13	-0.25	-2.92	-0.18	-2.95
Contemporaneous macro conditions affecting hazard of fertility:				
1918 influenza	0.11	0.46	0.11	0.46
Current Trend (log annual real per capita GNP)	0.04	1.72	0.04	1.72
Current Cycle (log annual real per capita GNP)	0.64	1.06	0.64	1.06
Age dependence of hazard of fertility:				
$\eta_0^{f_i}$	-118.07	-1.77	-177.63	-8.46
$\eta_1^{f_i}$	-151.08	-1.66	-236.56	-8.19
$\eta_2^{f_i}$	-117.09	-1.65	-198.10	-8.14
$\eta_3^{f_i}$	-49.37	-1.49	-93.75	-7.88
$\eta_4^{f_i}$	-15.31	-1.69	-30.99	-7.59
Unobserved heterogeneity terms for fertility:				
$v_{f_i}^1$	-1.33	-5.19	-0.02	-0.19
$v_{f_i}^2$	0.72	10.79	0.03	0.19
Unobserved heterogeneity terms for death:				
v_d^1	0.34	2.28	0.33	1.96
v_d^2	-0.83	-1.27	-0.79	-1.15
Joint probabilities of unobserved heterogeneities:				
q_1	0.31	2.75	0.59	3.02
q_2	0.27	3.62	-	-
q_3	0.28	2.52	-	-
q_4	0.14	2.04	0.41	2.12

Table 4 (contd.)				
Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Individual background characteristics affecting hazard of death:				
Social class father at birth (highest)	-0.19	-1.94	-0.16	-1.63
Social class father at birth (lowest)	-0.07	-0.96	-0.05	-0.65
Born in urban area	-0.03	-0.41	-0.03	-0.38
Born in province Utrecht	0.34	4.06	0.35	4.14
Born in province Zeeland	0.23	2.82	0.23	2.87
Business cycle conditions early in life affecting hazard of death:				
Boom (instead of recession) at birth	-0.03	-0.26	-0.03	-0.26
Cycle indicator for age 1 up to 5	0.03	0.36	0.03	0.46
Cycle indicator for age 6 up to 8	0.08	0.99	0.09	1.09
Cycle indicator for age 9 up to 13	0.10	1.42	0.11	1.55
Contemporaneous macro conditions affecting hazard of death:				
1918 influenza	-0.15	-0.32	-0.16	-0.35
Current Trend (log annual real per capita GNP)	-0.03	-2.55	-0.03	-2.51
Current Cycle (log annual real per capita GNP)	-0.20	-0.33	-0.24	-0.40
Effect of marital status on the hazard of death:				
Married	0.39	0.55	0.19	0.26
Effect of fertility ($i \in \{FB, LB\}$) on the hazard of death:				
η_0^{ace}	-0.39	-1.08	0.75	2.19
η_1^{ace}	0.09	0.16	-1.28	-2.60
η_2^{ace}	0.06	0.10	0.92	1.64
η_3^{ace}	0.03	0.07	-0.31	-0.83
η_4^{ace}	-0.04	-0.16	-0.08	-0.34
Age interacted with boom at birth $\left(\eta_0^{a,int}\right)$	0.30	0.73	0.39	1.01
Age interacted with boom at birth $\left(\eta_1^{a,int}\right)$	-0.34	-0.57	-0.49	-0.88
Age interacted with boom at birth $\left(\eta_2^{a,int}\right)$	0.34	0.50	0.50	0.77
Age interacted with boom at birth $\left(\eta_3^{a,int}\right)$	-0.12	-0.27	-0.23	-0.52
Age interacted with boom at birth $\left(\eta_4^{a,int}\right)$	0.08	0.29	0.12	0.46
Age dependence of hazard of death:				
η_0^d	-4.35	-5.94	-4.30	-5.86
η_1^d	1.80	14.51	1.71	13.73
η_2^d	0.64	3.77	0.96	5.66
η_3^d	0.05	0.46	-0.23	-1.94
η_4^d	-0.17	-1.33	0.05	0.39
- Log likelihood	11413.39		11802.62	
Number of individuals	1945		1945	

Table 5 Parameter estimates for bivariate model for duration until *first* (FB) *or last* (LB) *child birth* and mortality with parity dependent fertility effect on mortality rates

Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Background characteristics affecting hazard of fertility:				
Social class father at birth (highest)	-0.71	-5.59	-0.52	-4.52
Social class father at birth (middle)	-0.56	-5.94	-0.41	-4.81
Born in urban area	-0.14	-1.45	-0.03	-0.35
Born in province Utrecht	0.05	0.50	-0.09	-0.94
Born in province Zeeland	-0.01	-0.06	-0.02	-0.25
Business cycle conditions early in life affecting hazard of fertility:				
Boom (instead of recession) at birth	-0.07	-0.77	0.08	0.94
Cycle indicator for age 1 up to 5	-0.16	-1.78	-0.14	-1.69
Cycle indicator for age 6 up to 8	-0.23	-2.47	-0.29	-3.18
Cycle indicator for age 9 up to 13	-0.29	-2.94	-0.27	-3.22
Contemporaneous macro conditions affecting hazard of fertility:				
1918 influenza	0.09	0.41	0.13	0.58
Current Trend (log annual real per capita GNP)	0.04	1.57	0.08	4.27
Current Cycle (log annual real per capita GNP)	0.63	1.04	-0.81	-1.39
Age dependence of hazard of fertility:				
$\eta_0^{f_i}$	-142.83	-2.21	-191.93	-7.44
$\eta_1^{f_i}$	-185.04	-2.10	-257.91	-7.24
$\eta_2^{f_i}$	-143.84	-2.10	-212.42	-7.07
$\eta_3^{f_i}$	-62.11	-1.94	-99.93	-6.74
$\eta_4^{f_i}$	-18.79	-2.16	-30.46	-6.02
Unobserved heterogeneity terms for fertility:				
$v_{f_i}^1$	-1.36	-5.31	-1.71	-8.10
$v_{f_i}^2$	0.64	9.58	1.02	17.79
Unobserved heterogeneity terms for death:				
v_d^1	0.32	3.31	-0.09	-1.95
v_d^2	-1.01	-1.67	0.17	2.23
Joint probabilities of unobserved heterogeneities:				
q_1	0.34	4.73	0.61	17.72
q_2	0.29	4.46	-	-
q_3	0.20	3.08	-	-
q_4	0.17	2.90	0.39	11.49

Table 5 (contd.)				
Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Individual background characteristics affecting hazard of death:				
Social class father at birth (highest)	-0.16	-1.73	-0.14	-1.78
Social class father at birth (lowest)	-0.06	-0.71	-0.06	-0.98
Born in urban area	-0.03	-0.34	-0.02	-0.25
Born in province Utrecht	0.35	4.11	0.29	4.24
Born in province Zeeland	0.25	2.99	0.19	2.97
Business cycle conditions early in life affecting hazard of death:				
Boom (instead of recession) at birth	0.01	0.10	0.00	0.00
Cycle indicator for age 1 up to 5	0.03	0.38	0.04	0.67
Cycle indicator for age 6 up to 8	0.09	1.13	0.06	0.97
Cycle indicator for age 9 up to 13	0.10	1.39	0.10	1.66
Contemporaneous macro conditions affecting hazard of death:				
1918 influenza	-0.17	-0.36	-0.17	-0.36
Current Trend (log annual real per capita GNP)	-0.03	-2.19	-0.03	-2.43
Current Cycle (log annual real per capita GNP)	-0.18	-0.29	-0.20	-0.34
Effect of marital status on the hazard of death:				
Married	0.43	0.61	0.33	0.47
Effect of fertility ($i \in \{FB, LB\}$) on the hazard of death:				
η_0^{pce}	-3.05	-0.49	-0.13	-0.03
η_1^{pce}	-3.97	-0.46	-0.06	-0.01
η_2^{pce}	-3.12	-0.46	-0.14	-0.03
η_3^{pce}	-1.38	-0.42	0.01	0.00
η_4^{pce}	-0.24	-0.29	0.05	0.07
Age dependence of hazard of death:				
η_0^{d}	-4.50	-6.17	-4.54	-6.32
η_1^{d}	1.87	18.32	1.57	23.00
η_2^{d}	0.75	5.89	0.63	6.33
η_3^{d}	0.14	1.58	-0.08	-1.01
η_4^{d}	-0.20	-2.16	-0.14	-1.95
- Log likelihood	11413.12		11822.46	
Number of individuals	1945		1945	

Table 6 Parameter estimates for bivariate model for duration until *first* (FB) *or last* (LB) *child birth* and mortality with constant fertility effect on mortality rates (Baseline model)

Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Background characteristics affecting hazard of fertility:				
Social class father at birth (highest)	-0.70	-5.54	-0.29	-3.45
Social class father at birth (middle)	-0.54	-5.89	-0.22	-3.39
Born in urban area	-0.14	-1.40	0.00	0.12
Born in province Utrecht	0.01	0.11	-0.12	-1.66
Born in province Zeeland	-0.04	-0.40	-0.08	-1.15
Business cycle conditions early in life affecting hazard of fertility:				
Boom (instead of recession) at birth	-0.06	-0.65	0.10	1.65
Cycle indicator for age 1 up to 5	-0.16	-1.79	-0.11	-1.75
Cycle indicator for age 6 up to 8	-0.22	-2.36	-0.18	-2.64
Cycle indicator for age 9 up to 13	-0.25	-2.92	-0.18	-2.95
Contemporaneous macro conditions affecting hazard of fertility:				
1918 influenza	0.11	0.47	0.16	0.73
Current Trend (log annual real per capita GNP)	0.04	1.75	0.08	4.35
Current Cycle (log annual real per capita GNP)	0.64	1.05	-0.654	-1.19
Age dependence of hazard of fertility:				
$\eta_0^{f_i}$	-112.76	-1.68	-177.66	-8.49
$\eta_1^{f_i}$	-143.79	-1.57	-236.63	-8.22
$\eta_2^{f_i}$	-111.36	-1.56	-198.17	-8.18
$\eta_3^{f_i}$	-46.64	-1.40	-93.80	-7.91
$\eta_4^{f_i}$	-14.56	-1.59	-31.00	-7.63
Unobserved heterogeneity terms for fertility:				
$v_{f_i}^1$	-1.32	-5.19	-0.12	-1.17
$v_{f_i}^2$	0.73	11.09	0.17	1.43
Unobserved heterogeneity terms for death:				
v_d^1	0.25	2.88	0.33	3.25
v_d^2	-1.03	-1.18	-0.94	-1.72
Joint probabilities of unobserved heterogeneities:				
q_1	0.38	4.45	0.61	5.41
q_2	0.30	5.11	-	-
q_3	0.22	2.80	-	-
q_4	0.10	2.08	0.39	3.51

Table 6 (contd.)				
Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Individual background characteristics affecting hazard of death:				
Social class father at birth (highest)	-0.17	-1.80	-0.15	-1.60
Social class father at birth (lowest)	-0.06	-0.77	-0.03	-0.43
Born in urban area	-0.03	-0.43	-0.02	-0.21
Born in province Utrecht	0.33	4.08	0.36	4.30
Born in province Zeeland	0.24	2.96	0.25	3.12
Business cycle conditions early in life affecting hazard of death:				
Boom (instead of recession) at birth	0.01	0.09	-0.01	-0.10
Cycle indicator for age 1 up to 4	0.04	0.55	0.03	0.37
Cycle indicator for age 5 up to 13	0.09	1.20	0.09	1.09
Cycle indicator for age 5 up to 13	0.11	1.60	0.20	1.62
Contemporaneous macro conditions affecting hazard of death:				
1918 influenza	-0.15	-0.33	-0.16	-0.34
Current Trend (log annual real per capita GNP)	-0.03	-2.50	-0.03	-2.24
Current Cycle (log annual real per capita GNP)	-0.19	-0.31	-0.21	-0.34
Effect of marital status on the hazard of death:				
Married	0.41	0.58	0.36	0.52
Effect of fertility ($i \in \{FB, LB\}$) on the hazard of death:				
Causal effect of Fertility	-0.30	-3.19	0.10	0.81
Age dependence of hazard of death:				
η_0^d	-4.43	-6.11	-4.64	-6.36
η_1^d	1.84	18.01	1.76	16.05
η_2^d	0.73	5.57	0.83	6.72
η_3^d	0.11	1.28	0.06	0.66
η_4^d	-0.15	-1.70	-0.17	-1.89
- Log likelihood	11416.09		11835.40	
Number of individuals	1945		1945	

Table 7 Parameter estimates for bivariate model for duration until *first* (FB) *or last* (LB) *child birth* and mortality with age dependent fertility effect on mortality rates for subsample of married women

Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Background characteristics affecting hazard of fertility:				
Social class father at birth (highest)	-0.56	-4.37	-0.12	-1.29
Social class father at birth (middle)	-0.40	-4.29	-0.08	-1.20
Born in urban area	-0.12	-1.22	0.07	0.97
Born in province Utrecht	0.04	0.37	-0.19	-2.46
Born in province Zeeland	0.12	1.14	-0.09	-1.14
Business cycle conditions early in life affecting hazard of fertility:				
Boom (instead of recession) at birth	-0.10	-1.09	0.14	2.03
Cycle indicator for age 1 up to 5	-0.18	-1.90	-0.07	-0.98
Cycle indicator for age 6 up to 8	-0.19	-1.97	-0.09	-1.19
Cycle indicator for age 9 up to 13	-0.18	-2.02	-0.10	-1.50
Contemporaneous macro conditions affecting hazard of fertility:				
1918 influenza	0.08	0.31	0.11	0.45
Current Trend (log annual real per capita GNP)	0.04	1.10	0.05	2.44
Current Cycle (log annual real per capita GNP)	0.78	1.21	-0.38	-0.64
Age dependence of hazard of fertility:				
$\eta_0^{f_i}$	-236.67	-3.24	-179.00	-7.48
$\eta_1^{f_i}$	-314.59	-3.16	-239.41	-7.28
$\eta_2^{f_i}$	-246.50	-3.19	-202.41	-7.31
$\eta_3^{f_i}$	-111.16	-3.09	-96.48	-7.13
$\eta_4^{f_i}$	-32.02	-3.34	-32.45	-6.98
Unobserved heterogeneity terms for fertility:				
$v_{f_i}^1$	-1.54	-4.34	0.09	1.09
$v_{f_i}^2$	0.30	4.85	-0.11	-1.01
Unobserved heterogeneity terms for death:				
v_d^1	0.43	3.85	0.49	3.70
v_d^2	-1.13	-1.72	-1.05	-1.71
Joint probabilities of unobserved heterogeneities:				
q_1	0.16	2.71	0.51	4.91
q_2	0.41	5.17	-	-
q_3	0.16	2.83	-	-
q_4	0.28	3.72	0.10	4.74

Table 7 (contd.)				
Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Individual background characteristics affecting hazard of death:				
Social class father at birth (highest)	-0.29	-2.30	-0.29	-2.31
Social class father at birth (lowest)	-0.12	-1.18	-0.13	-1.28
Born in urban area	-0.09	-0.89	-0.10	-1.03
Born in province Utrecht	0.47	4.02	0.48	4.17
Born in province Zeeland	0.28	2.46	0.28	2.44
Business cycle conditions early in life affecting hazard of death:				
Boom (instead of recession) at birth	-0.08	-0.83	-0.06	-0.69
Cycle indicator for age 1 up to 4	-0.05	-0.54	-0.05	-0.48
Cycle indicator for age 5 up to 13	-0.06	-0.55	-0.05	-0.49
Cycle indicator for age 5 up to 13	0.15	1.61	0.15	1.60
Contemporaneous macro conditions affecting hazard of death:				
1918 influenza	-0.25	-0.41	-0.24	-0.40
Current Trend (log annual real per capita GNP)	-0.41	-0.93	-0.01	-0.90
Current Cycle (log annual real per capita GNP)	-0.58	-0.79	-0.60	-0.83
Effect of marital status on the hazard of death:				
Married	-0.20	-0.20	-1.07	-1.08
Effect of fertility ($i \in \{FB, LB\}$) on the hazard of death:				
η_0^{pce}	1.03	2.31	2.02	4.63
η_1^{pce}	-2.19	-4.02	-3.45	-6.39
η_2^{pce}	2.45	2.99	2.95	3.91
η_3^{pce}	-1.42	-3.18	-1.37	-3.00
η_4^{pce}	0.87	2.00	0.54	1.33
Age dependence of hazard of death:				
η_0^{d}	-4.91	-4.49	-3.99	-3.69
η_1^{d}	3.99	8.25	3.68	7.52
η_2^{d}	-1.53	-2.01	-0.74	-1.08
η_3^{d}	1.50	3.85	0.74	1.83
η_4^{d}	-1.07	-2.56	-0.55	-1.43
- Log likelihood	8060.62		8382.62	
Number of individuals	1387		1387	

Table 8 Parameter estimates for bivariate model for duration until *first* (FB) *or last* (LB) *child birth* and mortality with age dependent fertility effect on mortality rates and without marriage as an exogenous determinant of mortality

Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Background characteristics affecting hazard of fertility:				
Social class father at birth (highest)	-0.71	-5.54	-0.28	-3.45
Social class father at birth (middle)	-0.54	-5.87	-0.22	-3.44
Born in urban area	-0.14	-1.42	0.00	0.07
Born in province Utrecht	0.02	0.17	-0.11	-1.64
Born in province Zeeland	-0.03	-0.35	-0.08	-1.16
Business cycle conditions early in life affecting hazard of fertility:				
Boom (instead of recession) at birth	-0.06	-0.67	0.10	1.67
Cycle indicator for age 1 up to 5	-0.16	-1.80	-0.11	-1.82
Cycle indicator for age 6 up to 8	-0.22	-2.36	-0.18	-2.62
Cycle indicator for age 9 up to 13	-0.25	-2.93	-0.18	-2.96
Contemporaneous macro conditions affecting hazard of fertility:				
1918 influenza	0.11	0.46	0.17	0.79
Current Trend (log annual real per capita GNP)	0.04	1.73	0.08	4.33
Current Cycle (log annual real per capita GNP)	0.64	1.06	-0.61	-1.13
Age dependence of hazard of fertility:				
$\eta_0^{f_i}$	-117.96	-1.77	-177.64	-8.46
$\eta_1^{f_i}$	-150.92	-1.66	-236.57	-8.20
$\eta_2^{f_i}$	-116.98	-1.65	-198.10	-8.15
$\eta_3^{f_i}$	-49.32	-1.49	-93.75	-7.88
$\eta_4^{f_i}$	-15.29	-1.69	-30.99	-7.59
Unobserved heterogeneity terms for fertility:				
$v_{f_i}^1$	-1.32	-5.19	-0.02	-0.17
$v_{f_i}^2$	0.72	10.80	0.03	0.17
Unobserved heterogeneity terms for death:				
v_d^1	0.34	2.29	0.33	2.02
v_d^2	-0.82	-1.29	-0.79	-1.19
Joint probabilities of unobserved heterogeneities:				
q_1	0.31	2.79	0.59	3.16
q_2	0.27	3.67	-	-
q_3	0.28	2.56	-	-
q_4	0.14	2.05	0.41	2.22

Table 8 (contd.)				
Variable	First Birth ($i = FB$)		Last Birth ($i = LB$)	
	Estimate	t-stat.	Estimate	t-stat.
Individual background characteristics affecting hazard of death:				
Social class father at birth (highest)	-0.18	-1.92	-0.15	-1.62
Social class father at birth (lowest)	-0.07	-0.96	-0.05	-0.66
Born in urban area	-0.03	-0.44	-0.03	-0.43
Born in province Utrecht	0.34	4.06	0.35	4.16
Born in province Zeeland	0.23	2.86	0.24	2.91
Business cycle conditions early in life affecting hazard of death:				
Boom (instead of recession) at birth	0.00	0.03	0.00	0.02
Cycle indicator for age 1 up to 4	0.03	0.37	0.03	0.47
Cycle indicator for age 5 up to 13	0.08	1.01	0.09	1.10
Cycle indicator for age 5 up to 13	0.11	1.50	0.12	1.61
Contemporaneous macro conditions affecting hazard of death:				
1918 influenza	-0.14	-0.31	-0.15	-0.33
Current Trend (log annual real per capita GNP)	-0.03	-2.51	-0.03	-2.45
Current Cycle (log annual real per capita GNP)	-0.19	-0.31	-0.23	-0.38
Effect of fertility ($i \in \{FB, LB\}$) on the hazard of death:				
η_0^{pce}	-0.21	-0.97	0.97	4.68
η_1^{pce}	-0.13	-0.44	-1.56	-5.70
η_2^{pce}	0.27	0.77	1.20	3.58
η_3^{pce}	-0.05	-0.20	-0.44	-1.86
η_4^{pce}	0.01	0.03	-0.02	-0.09
Age dependence of hazard of death:				
η_0^{d}	-3.99	-21.97	-4.13	-21.54
η_1^{d}	1.80	14.77	1.71	14.07
η_2^{d}	0.64	3.79	0.96	5.74
η_3^{d}	0.05	0.46	-0.23	-1.96
η_4^{d}	-0.17	-1.31	0.05	0.40
- Log likelihood	11414.39		11803.77	
Number of individuals	1945		1945	