Demographic Research a free, expedited, online journal
of peer-reviewed research and commentary
in the population sciences published by the
Max Planck Institute for Demographic Research
Konrad-Zuse Str. 1, D-18057 Rostock · GERMANY
www.demographic-research.org

DEMOGRAPHIC RESEARCH

VOLUME 27, ARTICLE 19, PAGES 507-542
PUBLISHED 16 OCTOBER 2012
http://www.demographic-research.org/Volumes/Vol27/19/
DOI: 10.4054/DemRes.2012.27.19

Research Article

Detecting the evolution of deliberate fertility control before the demographic transition in Germany

Aliaksandr Amialchuk

Elitsa Dimitrova

Table of Contents

Demographic Research: Volume 27, Article 19
Research Article

Detecting the evolution of deliberate fertility control before the demographic transition in Germany

Aliaksandr Amialchuk[1]

Elitsa Dimitrova[2]

Abstract

BACKGROUND
Previous literature has established the existence of deliberate non-parity-specific fertility control in pre-transitional populations. However, less focus has been given to the timing of its onset. In addition, previous studies focused on the changes in fertility in response to the local prices of grains, which may be endogenous.

OBJECTIVE
This paper studies the emergence and evolution of deliberate fertility control by investigating the link between child mortality and economic stress on the one hand and non-parity-specific birth control on the other, in historic German villages between 1700 and 1900.

METHODS
Birth histories from fourteen German villages (1700-1900) and rye price series are used in a micro-level event history analysis. The fertility response of second and higher-order births to the mortality of children over age two and exogenous fluctuations in rye price are used as measures of the extent of deliberate non-parity-specific birth control.

RESULTS
Over the course of the demographic transition, the effect of the death of children generally increases after controlling for the effect of the death of children less than two years old. The negative fertility response to high rye prices before and in the year immediately following the price change occurred only after 1800.

[1] University of Toledo. E-mail: aamialc@utnet.utoledo.edu.
[2] Bulgarian Academy of Sciences. E-mail: elitsa_kdimitrova@yahoo.com.

CONCLUSIONS
The replacement and insurance effects associated with child mortality generally increased before the demographic transition. The emergence of the negative effect of high rye prices on fertility after 1800 further supports the presence and evolution of deliberate non-parity-specific fertility control before the demographic transition.

1. Introduction

The decline of marital fertility and family size during the first demographic transition (FDT) in Germany has been seen primarily as a result of the appearance and spread of efforts to limit family size (e.g., Cleland and Wilson1987; Knodel 1977, 1988). It is also widely held that marital couples did not deliberately limit their family size before the transition (e.g., Knodel 1987, 1988; Henry 1961), nor did they significantly control their fertility in any other way, such as by deliberately spacing births (Coale 1973; Knodel 1987). In addition, the limitation in family size over the course of the transition has not been viewed primarily as a result of the families' adjusting to changing socio-economic conditions (Coale and Watkins 1986). This view implies that, even before the transition, differences in family fertility were not a result of their facing new socio-economic conditions but a result of differences in longstanding norms and traditions, such as those related to breastfeeding and gender preference.

Nevertheless, several recent studies have pointed to the presence of deliberate non-parity-specific birth control (e.g., David and Sanderson 1986; Crafts 1989; Haines 1989; Bean, Mineau, and Anderton 1990; Morgan 1991; Szreter1996; Van Bavel 2004a; Alter et al. 2007) and fertility response to changing socio-economic conditions (e.g., Schultz 1985; Brown and Guinnane 2002; Dribe and Scalone 2010), even in populations largely viewed as "natural fertility" populations. These studies used various strategies to detect these effects in the limited demographic and socio-economic information contained in the historical datasets. Several studies used the effects of the survival status of infants and children (e.g., Knodel 1987; David and Mroz 1989; Van Bavel 2004a) and family size (Van Bavel 2004b) on the length of the subsequent birth intervals to detect deliberate spacing behaviour. The main difficulty in these studies lay in separating biological/physiological effects from the behavioural (replacement and insurance) effects of child death. More recent studies (Bengtsson and Dribe2006; Dribe and Scalone 2010) examined the effect of economic stress (proxied by grain prices) on the length of inter-birth intervals and argued that postponement of births soon after a price increase was likely caused by the family's deliberate action (or "individual agency") to avoid having children in hard times, rather than by a non-deliberate response (malnutrition, spousal separation, induced or spontaneous abortions), which usually comes with a considerable lag. While this literature has pointed to the presence of deliberate non-parity-specific fertility control in pre-transitional populations, less focus has been given to the timing of the deliberate fertility control. Furthermore, the response of fertility to economic stress has been studied exclusively through examinations of the response to local economic conditions (grain prices) (Bengtsson and Dribe 2006; Dribe and Scalone 2010) because researchers tend to believe that local economic conditions are the most salient and proximate predictors of local life events (Alter et al. 2004). However, studies in the economics literature have argued that local prices and wages might be endogenous to fertility because prices and wages reflect the local labour supply, which is a function of fertility (Schultz 1985). Therefore it is important to focus on the exogenous variations in local economic conditions in order to establish their causal effect on fertility.

This paper adopts a micro-level event history approach to studying deliberate response to the survival status of children and short-term economic stress. Our aim is to detect the evolutionary pace of deliberate non-parity-specific birth control, as reflected in the varying degrees of these effects over time. We pursue this aim by comparing the effects of child mortality at different ages and the price of rye on the probability of second and subsequent births among three marriage cohorts (1700-1799, 1800-1849, 1850-1900), after controlling for socioeconomic status and some demographic variables. We use variation in the local price of rye predicted by the price variation in the non-local rye markets to establish the causal effect of short-term economic stress on fertility.

Our analysis uses demographic and occupational data from the fourteen German village genealogies (Knodel 1988) and price data taken from towns located near the villages and from the rest of Germany (Jacks 2005). These villages cover four areas of Germany: the north, the middle, the south-east and the south-west. To the best of our knowledge this study is the first to addresses the issue of the timing of emergence and evolution of non-parity-specific birth control before the first demographic transition in Germany, using child mortality indicators and plausibly exogenous measures of short-term economic stress.

The next section provides an analytical framework, and the subsequent section describes the study area, the data, and the methods used. After that we present our empirical results, followed by a concluding discussion.

2. Analytical framework

John Knodel summarized the demographic behaviour and socio-economic conditions in the fourteen villages under study in his 1988 book, *Demographic Behavior in the Past*. Using a sample of fourteen German villages in the 18th and 19th centuries, Knodel (1987, pp. 143-162) found that deliberate stopping behaviour was minimal in the marital cohorts during the natural fertility period (prior to the late 19th century), while the initial stage of the fertility transition was characterized by the introduction of family-size limitation through stopping behaviour. He concluded that “deliberate stopping was the major behavioural mode through which marital fertility came under volitional control and is the major feature of reproductive change during the initial phases of the fertility transition [in Germany]” (Knodel 1987, p. 157). Knodel (1987) also concluded that “at least during the initial phases of the transition from natural to controlled fertility, couples did not resort to lengthening intervals between births …. It seems safe to conclude that spacing was not an important part of the early stage of fertility transition in rural Germany.” While this point of view has been challenged by more recent studies that found evidence of non-parity-specific birth control, the question remains whether non-parity-specific birth control was uniformly practiced by women at all times before the demographic transition or if it gradually evolved into an early form of fertility control. The general strategy we employ to answer this question is to compare the extent of non-parity-specific birth control across marital cohorts of women in the periods 1700-1799, 1800-1849, and 1850-1900.

As a first measure of non-parity-specific birth control we consider a set of child mortality indicators that approximate and separate the biological/physiological breastfeeding effect from the behavioural (replacement and insurance) effects of the death of children younger than age two and older than age two. Since breastfeeding delays the return of ovulation and postpones the next birth, the effect of breastfeeding on fertility can be detected by looking at the effect of the death of children under age two on the probability of another birth. To detect replacement and insurance effects, coefficients on the indicator variables for the death of children older than age two can be compared. Our main hypothesis is that, after controlling for the biological effect of breastfeeding, the replacement/insurance effect is greater for later marital cohorts than for earlier marital cohorts. Evidence in favour of this hypothesis supports the claim that marital couples started to control fertility in “natural fertility” populations, and it reveals the evolutionary pace of deliberate fertility control before the FDT.

There is ample evidence of the biological effect of breastfeeding on the spacing of births in historical populations. Knodel (1968) used family history data from records of three parishes in Bavaria and found that breastfeeding exerted substantial influence on fertility and that it was associated with longer intervals between births. Knodel and Van de Walle (1967) used information from three German states and found large regional variations in breastfeeding among the rural and the urban populations in the late 19th century. However, breastfeeding failed to account for the variations in marital fertility in those data. While the data did not support the hypothesis that infant mortality was only indirectly associated with fertility by way of lactation, the evidence suggested the possibility of either family planning or other behaviour that adjusted fertility in response to the level of infant mortality. In another paper (1982, pp. 177-200) Knodel studied the replacement effect associated with the death of a child before and at the time of the demographic transition in Germany and found no decisive answer to the question concerning whether replacement behaviour prevailed during the natural fertility regime:

"While the relationship between previous child mortality and subsequent fertility for the cohorts with natural fertility was not very pronounced and could in part have been caused by imprecision in the control variables as well as biases due to variables not taken into account, it seems unlikely that the entire effect could be explained in this manner. If family limitation was being practiced during the pre-transitional period, it appears only in some villages and not others and that even when it was present, it probably was not very extensive, judging the lack of a stronger replacement response and the generally late age at which women ceased childbearing even when their previous children all survived." (Knodel 1982, p. 199).

However, after the start of the demographic transition in Germany (around 1885), efforts to replace children who had died became evident. According to Knodel, couples with the least child mortality experience were most likely to limit their families and reduce their fertility. A high level of child mortality seems to have at least impeded, if not prevented, efforts to reduce the number of children born or to cease childbearing at an early age or at a given parity.

As a second measure of non-parity-specific fertility control, we consider the effect of exposure to short-term food price shocks. Significant fertility response to temporary fluctuations in economic conditions (such as food prices and wages) in pre-transitional populations has been previously documented in aggregate studies (e.g., Lee 1981; Galloway 1988; Hammel and Galloway 2000) and in micro-level studies (e.g., Bengtsson and Dribe 2006, 2010; Dribe and Scalone 2010). The following discussion, which focuses on the role of food prices, draws from Bengtsson and Dribe (2006), Dribe and Scalone (2010), and Schultz (1985).

We consider the effect of exposure to short-term food price shocks within the general conceptual framework of fertility developed by Davis and Blake (1956) and Bongaarts (1978), where fertility is affected by a set of proximate determinants that have an immediate effect on reproduction. These determinants can be grouped into exposure factors (e.g., nuptiality, spousal separation), deliberate actions (e.g., contraception, induced abortion), and physiological factors (e.g., post-partum amenorrhea, sterility, spontaneous abortion). In addition, fertility can be affected indirectly by various socioeconomic, environmental, and cultural factors via their effects on the proximate determinants.

Fertility can be affected by food prices in at least three ways.[3] First, the economic hardship entailed in high food prices may unintentionally influence conceptions by forcing husbands to migrate in search of work opportunities, leading to a temporarily lower probability of conceptions because of spousal separation. In particular, as Dribe and Scalone (2010) argued, workers who were not hired on annual contracts could have migrated in search of work shortly after the harvest, which would have depressed the conceptions for as long as the absence lasted. In addition, if workers foresaw bad times, the migration could have happened even before the harvest, depressing conceptions even earlier. For example, prior to 1700 thousands of poor peasants migrated every summer from north-west Germany to Holland to help with the hay harvest (Hochstadt 1981, 1983; Knodel 1988; as referenced in Dribe and Scalone 2010). However, as Dribe and Scalone (2010) argued, in a grain-producing economy like that of the German areas under study, most farm labourers were expected to stay home until all the crops had been harvested because the work was usually available locally, even in bad economic times.

The second way in which fertility can be affected by food prices occurs when couples deliberately control childbearing via induced abortion, contraception (e.g., *coitus interruptus*), or abstinence, until the economic situation improves. There is some evidence that induced abortion was used to control fertility in Europe before the 20th century (e.g., McLaren 1990; Hammel and Galloway 2000), and less evidence that married women used abortion (Van de Walle 1999). This response to high food prices seems straightforward, as there was widespread awareness of contraceptive methods (e.g., McLaren 1990; Santow 1995), and people could predict local harvest outcomes and form at least a rough idea about food price developments as early as spring–long before harvested crops were stored in the barns and the new grain price was determined. (See the discussion in Dribe and Scalone (2010).) Therefore a deliberate response could have started as early as the high food prices could be predicted and end as late as when the prices dropped.

Third, temporarily higher food prices may indirectly impair fecundity via malnutrition and exposure to disease (e.g., from switching to low-quality grain usually fed to the cattle). A distinction between the second (direct) and the third (indirect) ways that high food prices affect fertility is that, unlike indirect channels, which influence conceptions and pregnancies after food becomes scarce through cessation of ovulation,

[3] Because information on the precise time of conception or the length of gestation is not available in our data, all conceptions in the present study are assumed to have occurred nine months before the observed time of birth.

loss of libido, reduced sperm production, and spontaneous abortions, the direct channels may depress conceptions even before food becomes scarce. As Dribe and Scalone (2010) argued, because food shortages in rural areas are most severe in the spring, malnutrition is likely to affect conceptions no sooner than six months after the grain price goes up on October 1. In addition, because the risk of foetal loss is highest during the first trimester of pregnancy (Wood 1994), pregnancies tend to be spontaneously aborted no sooner than three months after the price change. Therefore, an examination of the conceptions that occurred before and shortly after the food prices were determined on October 1 is likely to separate the direct from the indirect effects of high grain prices on conceptions. A significant reduction in conceptions nine months before to three months after the price change would signify that families could predict bad economic times and could take active steps to deal with the stress by deliberately adjusting the timing of conceptions.

Previous studies of the fertility response to rising food prices relied heavily on the local prices of grains. However, in order to argue that the change in the food price ‘caused’ the change in fertility, the price change must come from outside the family or household sector. It is possible that the local grain prices were partly influenced by the local agricultural labour demand and labour supply conditions, as well as by the agricultural conditions elsewhere in Europe and the opportunity to ship the grain in and out of the area easily in response to the German and international market conditions. This explanation seems more plausible in pre-industrial than in industrial societies, because the lack of railroads and improved roads meant the grain markets were not fully integrated and shipping was costly.

The problem of the endogeneity of local grain prices can be illustrated in the context of local agricultural labour markets. Local agricultural labour supply and labour demand conditions indirectly influence fertility via their effect on the local grain prices. An issue arises in the estimation of the effect of grain prices on fertility because both the labour supply and fertility may have been simultaneously influenced by household decisions, such as the timing of weaning. On the one hand, earlier weaning allows the woman to increase her contribution to the local labour supply, which leads to a lower local grain price. On the other hand, earlier weaning results in higher fertility by reducing the period of lactational amenorrhea, creating a spurious negative correlation between the local grain price and fertility that has nothing to do with the direct effect of the local grain price on fertility. Alternatively, a spurious positive correlation between the local grain price and fertility would arise if more time spent by a woman in the labour market leads to reduced spousal contact at home. The agricultural labour demand also affects the price of grain by influencing the wages of agricultural workers, who are the main input in the production of grain. However, this effect does not pose an issue in estimating the fertility equation because demand for labour comes from the employer’s side, so it is unlikely to be correlated with the household's fertility choices. As Schultz (1985) described in the context of female and male wages and female and male participation in the labour force, the problem of estimating the fertility response to fluctuations in the local grain price can be viewed as a statistical or endogeneity problem: the error term in the fertility equation will be correlated with the error term in the equation for the local labour supply. (See the Technical Appendix for details.)In this paper the aggregate nationwide price of grain, P_g^a, is used as a source of exogenous variation in the local price of grain, P_g, in order to obtain consistent estimates of the effect of grain prices on fertility.

3. Study area and the emergence of family limitation in Germany

The fourteen villages included in the analysis represent a wide variety of demographic and geographic conditions, as they cover the north (Middels, Werdum), the centre (Braunsen, Höringhausen, Massenhausen, Vasbeck), the south-west (Öschelbronn, Grafenhausen, Herbolzheim, Kappel, Rust), and the south-east (Gabelbach, Anhausen, Kreuth) of Germany (see Map). The predominant economic activity in these villages during the period under study was agriculture, but the economy of the five south-western villages was also supported by fishing, since these villages were located in the southern region of Baden, close to the river Rhine. Before the channels were built flooding frequently destroyed harvests, resulting in food crises and hunger (Knodel 1988). Migration was also common during the period under study, as the growing population relied on scarce resources and often had to look for new economic opportunities. Economic inequality and differences in socio-economic status were marked during this period because most of the land was owned by a few wealthy farmers.

In a series of studies from a long-term research project (Knodel 1977, 1978, 1987), Knodel used traditional demographic techniques to study the transition from natural fertility to family limitation (parity-specific control) in these villages. Knodel found that, while the total marital fertility rate over age twenty was above 8.5, there was also a considerable variation in the marital fertility across the villages. For example, the Middels in East Friesland had the lowest levels of marital fertility (a Coale I_g' index of 0.6 in 1800-1924), and the Bavarian villages had the highest levels (an I_g' index of 0.9 in 1800-1924). Knodel suggested that the differences in the marital fertility rates were likely connected to differences in breastfeeding, which was widely practiced in Middels but almost absent in the Bavarian villages (Knodel 1988).

Knodel also provided evidence that family limitation (parity-specific control) was largely absent in these populations until the second half of the 19th century. Moreover, before 1850 marital fertility schedules conformed to the expected age pattern of natural fertility as demonstrated by Coale-Trussel (Coale and Trussel1974, 1978)m values of no more than 0.2. While the M index was gradually increasing among younger married women, the age at last birth remained high in all villages (generally around forty, which was similar to that of other European natural fertility populations) and was unlikely to have been influenced by previous infant and child mortality (Knodel 1988).In addition, socio-economic differences in the average fertility levels within villages were less pronounced than were those differences between villages (Knodel 1988).

Knodel characterized the onset of deliberate family limitation solely in terms of deliberate stopping of births—that is, as a decrease in the female's age at last birth. Using data from fourteen villages in different regions of Germany, Knodel found that the decline in fertility in Germany began during the last fifteen years of the 19thcentury: Coale-Trussel's m value exceeded 0.2 for the marriage cohorts of 1850-1874 (Knodel, 1988, table 10.2). More recently, Dribe and Scalone (2010) relied on evidence related to the effect of short-term economic stress on fertility to argue that deliberate non-parity-specific birth control was practiced even before families started to limit the number of births. In addition, by relying on proto-statistical information on mortality from a sample of German parish registers in Germany from1730-1840, Pfister and Fertig (2010) found that the early onset of secular decline in mortality as part of the FDT dates back to the second half of the 18th century:

"Germany experienced a strong rise of the life expectancy between the end of the Seven Years' War (1756–1763) and c. 1830….The strong increase of life expectancy coupled with the stability or a moderate rise of fertility implied the move from a pattern characteristic of Ancien Régime France to a demographic terrain similar to England's before, and after, the early phase of the Industrial Revolution (the latter itself being associated with a fertility boom)." (Pfister and Fertig 2010, p. 54).

Map: Geographical location of the used demographic data and the price series

Source: Historic German villages used in Knodel (1988), authors' drawing on the modern map of Germany.

4. Data and methods

We study fertility behaviour based on family reconstitution data for a sample of fourteen German villages (also called Ortssippenbücher, or "book of local kinsmen") in the period 1700-1900. Information that is available in the original study includes birth dates and birth places, number of siblings, marital histories, births and deaths of children, religion, family origin, and occupation. All of the vital events of all the families that were registered in the village parish registers are recorded in the dataset. All marriages, separations, children's births and deaths can be connected to mothers, allowing full fertility histories to be analysed. The current study includes all fourteen of the villages that Knodel originally used (i.e., Werdum, Middels, Brausen, Höringhausen, Massenhausen, Vasbeck, Öschelbronn, Grafenhausen, Herbolzheim, Kappel, Rust, Gabelbach, Anhausen, and Kreuth). However, the dataset has limitations because data on couples is collected only if the date of marriage is known, and the dates of birth and death of one or both spouses are missing in many cases. (A missing date of death makes it impossible to determine the end of a woman's reproductive history.) Knodel defined a set of restrictions by which to select a sub-sample of individuals for whom information was complete (Knodel 1988, p. 464).

For the purpose of event history analysis, the information in the original dataset was reshaped in a longitudinal form. Instead of using only closed birth intervals, we included all birth histories and censored the last open interval at five years in order to include all women in the analysis, not only those for whom the full reproductive history is observed. Treating multiple births as a singular childbirth, we used the reconstituted reproductive life histories of 10,896 women married between 1700 and 1900 who had among them more than 40,000 births in these marriages. We selected the first marital cohort as 1700-1799 (100 years) and the last two marital cohorts as 1800-1849 and 1850-1900 (50 years each) so each cohort had an approximately equal number of observations on births. This approach ensured that there was comparable statistical power for the estimated effects from the three (Table 2). In addition, breaking the period 1800-1900 into fifty-year intervals allowed us to focus on the evolution of the replacement effect just before and at the beginning of the demographic transition in Germany, which began around 1885.Table 1 shows the distributions of women and births in the fourteen villages for the cohorts under study.

4.1 Price series

Following the analysis in Dribe and Scalone (2010), we used fluctuations in rye prices as a measure of the impact of short-term economic stress on the inter-birth intervals.

Rye accounted for a significant proportion of agricultural production and consumption of the working population in Germany (Friedmann 1978; Ashley, 1921) and made up a significant proportion of labourers' wages during the pre-industrial period (Hagen 1986).

We used prices from four areas of Germany to construct local and aggregate price series (see Map).[4] Consistent rye price series for all four areas were available only for the period 1764-1863. We used prices from Emden for the northern villages of Middels and Werdum, and since there were some gaps in Emden's price series (1764-1770, 1807-1809), we used the closest towns with available price series, Lüneburg and Stade, to supplement the series. Prices from Göttingen, which were available for the entire period, were used for the villages in central Germany (Braunsen, Höringhausen, Massenhausen, Vasbeck); prices from Heilbronn were assigned to the south-western villages (Öschelbronn, Grafenhausen, Herbolzheim, Kappel, Rust); and prices from Munich were used for the south-eastern villages (Gabelbach, Anhausen, Kreuth). Since the prices from Heilbronn were available only until 1832 and the prices from Munich were available only until 1855, they were supplemented with prices from Göttingen. Price series were merged to women's birth histories by harvest year, which ran from October 1 of the previous calendar year to September 30 of the current calendar year. For example, for a woman who is at risk of giving a birth between 1 October, 1817 and 30 September, 1818, we used the price determined on 1 October, 1817. In other words, our empirical model uses the price from 1 October, 1817 to predict the probability of conceptions that could have happened nine months before birth, between 1 January and 31 December, 1817. This approach is the same as that in Dribe and Scalone (2010), who argued that the presence of a significant contemporaneous response of births to the current rye price (i.e., from the current harvest year, between 1 October and 30 September) is evidence of deliberate fertility control.

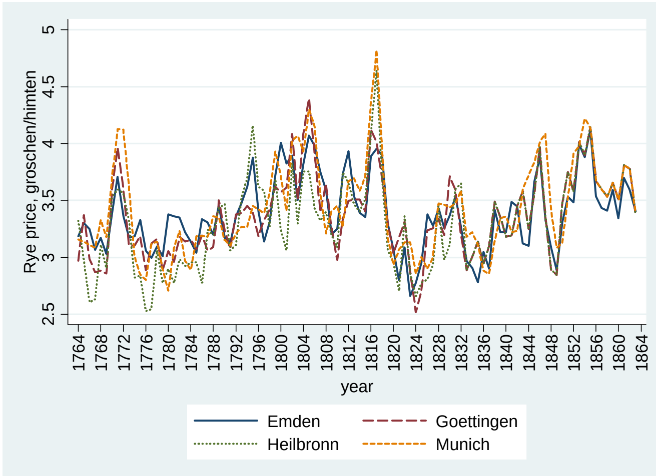
We constructed two types of price series for each area: local prices based on the price in the nearby town, and aggregate prices. The aggregate price for a given area was computed as the average price of all areas excluding the area in question. The map shows the four areas for which we computed prices. Price series were further de-trended using the Hodrick-Prescott filter (Hodrick and Prescott 1997) with a smoothing parameter of 6.25 by subtracting the trend value from the actual price in each year. Subtracting the trend value allows us to focus on the short-term fluctuations around the

[4] Price series used in Jacks (2004, 2005) are available from David Jacks' website: http://www.sfu.ca/~djacks/data/prices/Germany/prices.html. Accessed 09.15.2010. Since prices of rye were measured in different units in different towns, the following scheme was used to convert all prices into Courant groschen/Hannoverschen Himten: for Heilbronn, 20.55 Courant groschen/1 Florin and 5.1361 HannoverschenHimten/1 Heilbronner Malter; for Munich, 20.55 Courant groschen/1 Florin and 7.138 HannoverschenHimten/1 scheffel. Tate's *Modern Cambist* (Easton 1908) and *The Universal Cambist* (Kelly 1831) were used as references for these conversions.

trend by ignoring the medium-term movements in price levels. Figure 1 plots these local and aggregate (excluding a given local) price residuals.

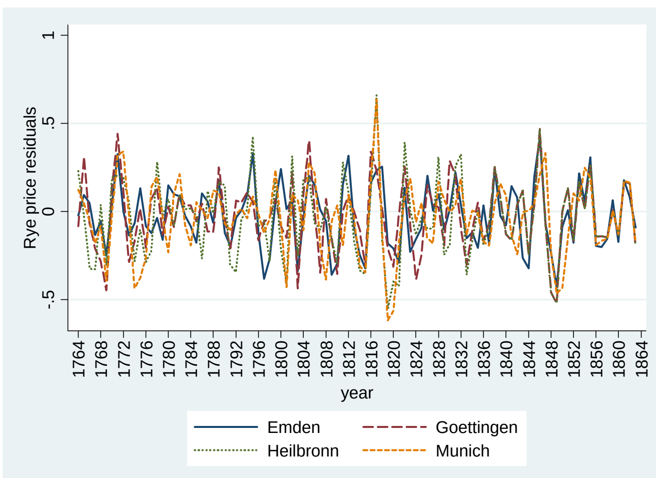
We also transformed the prices into natural logs to make the estimates easier to interpret. According to Wooldridge (2006), using natural logs leads to coefficients with appealing interpretations (in our case, as the reaction of the relative risk of conception to a 1% change in price). In addition, logs allow us to be ignorant about the units of measurement of the prices that appear in logarithmic form because the slope coefficients are invariant to rescaling. Moreover, taking logs can narrow the range of the variable, which makes estimates less sensitive to extreme observations on prices. Therefore, the covariate used in the even-history analysis is the difference between the natural logarithm of the actual price and the natural logarithm of the corresponding price on the trend line.

Figure 1: Rye prices 1764-1863 in the four study areas



Source: Jacks 2004, 2005. Authors' calculations.
Note: See footnote 2 for details about construction of the price series.

Figure 2: Rye price deviations from Hodrick-Prescott trend, 1765-1863 in the four study areas



Source: Jacks 2004, 2005. Authors' calculations.
Note: Hodrick-Prescott trend was calculated using a smoothing parameter of 6.25, which is recommended for annual data.

Figure 3: Rye prices 1764-1863 in each study area plotted against aggregate average price (which excludes given local area price)

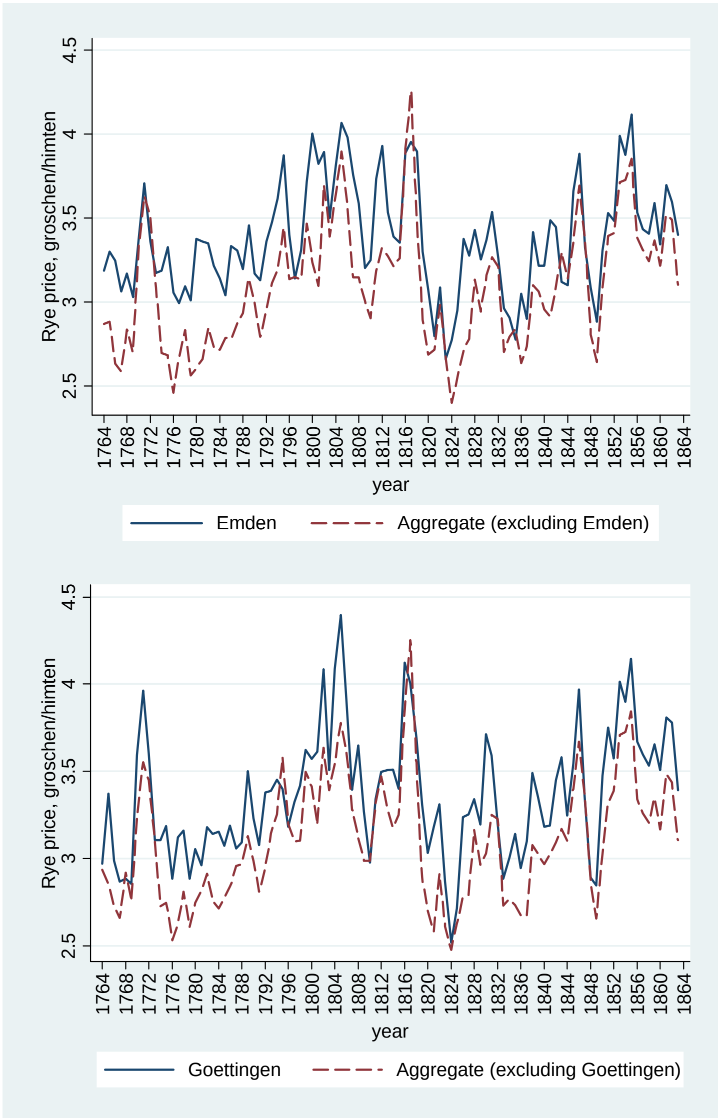
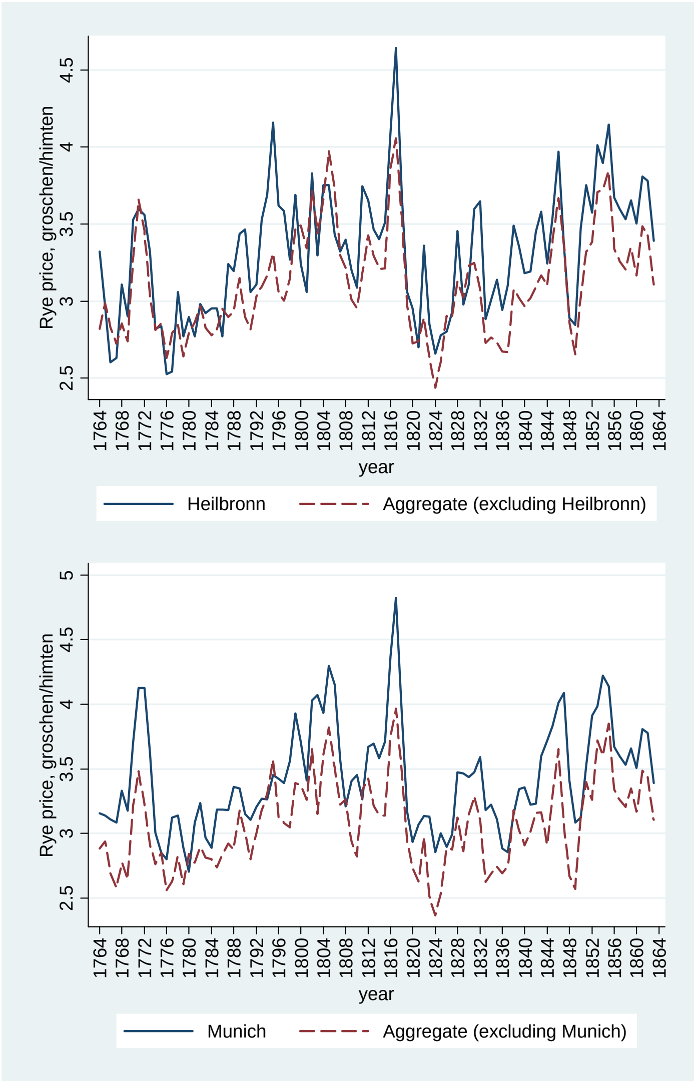


Figure 3: (Continued)



Source: Jacks 2004, 2005. Authors' calculations.
Note: See footnote 2 for details about construction of the price series.

4.2 Model

We follow Bengtsson and Dribe (2006) and Dribe and Scalone (2010) in modelling the time to the next birth as a function of demographic and socioeconomic variables, with the rye price residuals and child death indicators as our variables of interest. We follow married women from the date of first birth, so that no birth histories are left truncated. Our analysis is limited to the second and subsequent births because first births are intimately connected with the marriage decisions (Knodel 1988: 228). We include all birth histories and censor the last open interval at five years in order to avoid sample selection. We estimate Cox proportional hazards model with shared frailty:

$$\ln h_{ij}(c,t) = \ln h_o(c) + \beta X_{ij} + \gamma Z(t) + \mu_j ,$$

where $h_{ij}(c,t)$ is the hazard of woman j's conceiving (the time of the next birth minus assumed nine months' gestation time)a child of parity i at duration c (measured since last birth) at calendar time t; $h_o(c)$ is the baseline hazard—that is, the hazard function when the coefficients on all covariates are fixed at zero; and β is the vector of parameters for the individual covariates X_{ij} in the model. Individual covariates are the age of the woman, the number of children in the marriage, multiple births, the sex of the preceding child, the village of residence, and the husband's occupation. These control variables are not the main focus of our analysis, but they all capture important aspects of the reproductive process. Dummies for the woman's age are included in order to control for the differences in the risk of childbirth and fecundity at different ages. The number of legitimate births is included in order to control for possible differences in fecundity and breastfeeding habits among families. The indicators for multiple births and the gender of the preceding child capture shocks to the number and composition of the children in a family, which may affect the family's willingness to have the next child. Regional dummies at the village level are intended to capture known differences in breastfeeding practices in different parts of Germany (Knodel 1967; 1968), and measures of the husband's occupation are included to control for differences in socioeconomic status among families. Categories for the husband's occupation, which is measured at marriage and is time-invariant, include farmer, white-collar worker, skilled worker, unskilled worker, and missing/unknown. The parameter γ measures the effect of prices and indicator variables for the life status of the previous child ($Z(t)$, which change values with calendar time t). μ_j is a woman-specific random effect (frailty), which is shared across all observations for the same woman and is assumed to follow a Normal distribution. Controlling for frailty accounts for random woman-specific differences in the childbirth risk that are due to behavioural and biological factors not controlled for by the variables included in the model. The end of the reproductive history is marked by the woman's death, the husband's death, the woman's reaching age fifty, the next marriage, or divorce: whichever is earliest.

Since breastfeeding was usually terminated after the first two years, it is possible to separate the biological effect of breastfeeding from the replacement effect by examining the difference between the indicators for a child's death before and after age two. (See the discussion in Knodel 1988: 396.) In order to detect the behavioural effect of replacing the dead child, we introduce the indicator variables of infant died, child 1-2 years old died, child 2-3 years old died, and child 3 years old and older died. In order to measure the insurance effect, we use an indicator for death of the child born immediately before the index child (born at the start of the current between-births interval) before reaching age 9. The values of these indicators were set to 1 from the moment of the death of an infant or a child. Our interest lies primarily in using these indicators to test the following hypothesis: after controlling for the death of infant or child (0-2 years old), the effect of child (>2 years old) mortality on the risk of progression to the next birth increases over time.

5. Results

The distributions of married women and births across the fourteen villages during the period from 1700 to 1900 are displayed in Table 1. South-western villages contributed most of the observations to the analysis, while south-eastern villages contributed the least observations.

We first explore the changes in non-parity-specific birth control by looking at the coefficients on child mortality in Table 2, where the estimates are separately obtained for each of the marital cohorts: 1700-1799, 1800-1849, and 1850-1899. Comparison of the coefficients across these cohorts reveals several regularities. First, the effect of the death of an infant or a child one or two years of age on the probability of the next conception decreases from the oldest to the youngest cohort but remains significant. Second, the effect of the death of a child older than two years of age on the probability of the next conception generally increases across the cohorts, suggesting that the replacement effect associated with child mortality becomes more pronounced over time. These results are consistent with previous findings on family limitation during the demographic transition. In addition, a cross-cohort comparison reveals that deliberate non-parity-specific birth control may have evolved gradually before the demographic transition took place.

Table 1: Distribution of married women and second and higher order births in 1700-1900 in the fourteen German villages

Area	Village	Women	%	Births	%
North	Middels	977	9.0	3443	8.5
North	Werdum	946	8.7	2787	6.9
Centre	Braunsen	351	3.2	1161	2.9
Centre	Höringhausen	434	4.0	1689	4.2
Centre	Massenhausen	650	6.0	1809	4.5
Centre	Vasbeck	388	3.6	1614	4.0
South-West	Öschelbronn	1104	10.1	4323	10.6
South-West	Grafenhausen	1069	9.8	4344	10.7
South-West	Herbolzheim	1839	16.9	7460	18.4
South-West	Kappel	1182	10.8	4756	11.7
South-West	Rust	1956	18.0	7248	17.8
South-East	Anhausen	235	2.2	1086	2.7
South-East	Gabelbach	198	1.8	954	2.3
South-East	Kreuth	137	1.3	516	1.3
	Total	10896	100	40634	100

Source: Ortssippenbuch (Local kinship book), archived at the Population Studies Centre, University of Michigan, authors' calculations.

Turning to the estimates on the other control variables, we make several observations. First, the risk of another birth decreases with maternal age, which is consistent with the expectation that women who are nearing the end of their reproductive years have longer birth intervals. Second, larger family size is associated with a lower probability of the next conception, except in the last cohort where a larger family size increases this probability. This finding is consistent with the general pace of demographic transition, which is associated with the inter-birth intervals becoming shorter and women bearing all their children at a younger age. Third, multiple births decrease the risk of having another child in all cohorts, but the effect loses its magnitude significantly between the second and the third cohorts. This finding implies that women become less sensitive to the 'shock' of having extra children as they come closer to their target number of children (if such a target existed). The time pattern of these effects is contrary to the expectation that, over the course of the demographic transition, women should have become more sensitive to the total number of children born. However, other factors such as maternal morbidity and mortality could be at play here. Finally, families in the latest cohort in which the husbands havewhite-collar occupations have significantly lower risk (relative to that of farmers) of another birth, while families in the earliest and latest cohort in which the husbands are unskilled workers have significantly lower risk (relative to that of farmers) of another birth.

Table 2: Cox proportional hazard estimates of birth spacing in the fourteen German villages, 1700-1900, for all married women, second and higher-order births

	Mean, 1700-1900	Women married in 1700-1799	Women married in 1800-1849	Women married in 1850-1900
Reference category: Age 25-29				
Age 15-24	0.125	1.269***	1.167***	1.151***
		(0.029)	(0.031)	(0.028)
Age 30-34	0.257	0.767***	0.787***	0.834***
		(0.026)	(0.027)	(0.025)
Age 35-39	0.226	0.443***	0.485***	0.548***
		(0.035)	(0.036)	(0.035)
Age 40-44	0.135	0.117***	0.127***	0.159***
		(0.057)	(0.06)	(0.06)
Age 45-49	0.013	0.019***	0.015***	0.037***
		(0.283)	(0.415)	(0.36)
Legitimate parity	0.388	0.853***	0.926***	1.025***
		(0.01)	(0.01)	(0.008)
Multiple birth	0.017	0.682***	0.679***	0.771***
		(0.082)	(0.082)	(0.071)
Reference category: Infant or child survived				
Death of infant before conception of next child	0.139	2.676***	2.22***	1.755***
		(0.027)	(0.026)	(0.023)
Death of child 1-2 y.o. before conception of next child	0.016	2.769***	2.427***	1.99***
		(0.06)	(0.065)	(0.073)
Death of child 2-3 y.o. before conception of next child	0.005	1.586***	1.864***	2.004***
		(0.11)	(0.141)	(0.151)
Death of child 3-5 y.o. before conception of next child	0.003	1.192	1.815***	1.993***
		(0.179)	(0.199)	(0.219)
Death of youngest previous child <9 y.o.	0.018	1.578***	1.499***	1.6***

Table 2: (Continued)

	Mean, 1700-1900	Women married in 1700-1799	Women married in 1800-1849	Women married in 1850-1900
		(0.053)	(0.067)	(0.066)
Preceding child was female	0.484	1.027	1.006	1.015
		(0.018)	(0.019)	(0.018)
Reference category: Husband's occupation: farmer				
Husband's occupation: white collar	0.079	0.991	0.995	0.796***
		(0.052)	(0.053)	(0.047)
Husband's occupation: skilled worker	0.233	1.01	1.093**	1.011
		(0.035)	(0.036)	(0.033)
Husband's occupation: unskilled worker	0.206	0.902***	0.97	0.925**
		(0.039)	(0.038)	(0.034)
Husband's occupation: missing	0.142	0.828***	0.559***	0.486***
		(0.043)	(0.046)	(0.045)
Regional dummies		included	included	included
Gaussian Frailty Variance		0.26***	0.292***	0.274***
Likelihood ratio test		8050	7614	8540
Model p-value		0.00	0.00	0.00
Number of births		14599	13266	15325

Note: Estimates represent relative risk (exponentiated coefficients) with standard errors in parentheses.
Significance levels: * p<0.10 ** p<0.05 *** p<0.01.

Our second set of results considers the evolution of non-parity-specific birth control by examining the reaction to short-run fluctuations in rye prices. Before turning to the discussion of the estimates, we note the expected pattern of the relationship between the local and the aggregate price series (Appendix Table 1) plotted in Figures 1-3. First, the correlation among the local prices is strong, but it quickly decreases with the distance between towns. Second, at around 60%-78%the correlation between the local and the aggregate series is not perfect. Because the rye price series are available only for harvest years 1765-1863, we divide this period into two sub-periods that roughly correspond to the first vs. the second and the third marital cohorts from Table 2 (i.e., 1765-1799 vs.1800-1863). Focusing on the estimates on the local rye prices in Table 3, we do not find strong evidence that women in the marital cohort of 1765-1799 postponed their next conception following an increase in the rye prices. The estimate on the rye price, which is statistically significant only at the 5%level, implies a 12%

reduction in the relative risk of conception following a 1% rise in price. By contrast, the 1800-1863 marital cohort shows a highly statistically significant and strong reaction in which a1% increase in the local rye price is associated with a 16% decrease in the relative risk of conception.

While the individual families are directly influenced by local prices, aggregate prices have an indirect effect on the families via their effect on the local prices. Using aggregate prices enables the identification of the causal effect of local prices on fertility, because the aggregate price changes are likely to have been caused by events outside of the household sector, rather than by the household's own decisions about fertility and labour supply. As an example, if a drought or a war in the north increases the price of rye there, the price of rye would rise in the south as well, as more rye would be shipped out of the south in response to the higher price in the north. This price change would influence families' fertility in the south, but for reasons that are independent of their fertility or labour supply decisions. In addition, families' expectations about future local prices may be affected by outside events related to aggregate prices. For example, a summer drought in the north would make families in the south expect the price of rye to rise because some of the local harvest might be shipped out to the north in the autumn.

Concerned with the possible endogeneity of the local prices[5] to the labour supply and the fertility behaviour of the married couples, in order to identify the causal effect on fertility we estimated two types of models that use variation in the aggregate prices of rye. First, we estimated a model in which we substituted the aggregate average rye price (excluding the local price) for the local rye price. This "reduced-form" model shows the effect of variation in the aggregate rye price that is directly passed onto families, including the part of the effect that works through the local rye prices. As the fourth column of Table 3 suggests, the aggregate rye price does not have a significant effect on the risk of conceptions before 1800. On the other hand, the eighth column of Table 3 suggests that the effect of the aggregate price after 1800 is highly significant, as it implies a 22% reduction in the relative risk of conception following a 1% rise in the price. This effect is much stronger than the effect of the local price for the later cohort, with the corresponding relative risk ratio increasing from 0.843 to 0.776. This finding implies that the reaction to price changes existed as early as the first half of the 19th century and that the magnitude of this reaction is biased and underestimated if one uses the local price. In addition, Table 3, which compares the last thirty-five years of the 18th century (1765-1799) to the period just before the beginning of the demographic

[5]One might argue that, because the prices were taken from the nearby towns and not from the smaller villages under study, these prices can be considered exogenous. However, there is a possibility that these prices are endogenous if changes in the labour supply in the villages under consideration have a significant influence on the labour supply in the nearby towns. On the other hand, aggregate price series, which exclude local prices, can be considered exogenous, as it is unlikely that the village-level labour supply has a significant influence on the labour supply and rye prices in the towns in the other parts of Germany.

transition (1800-1863), demonstrates the same pattern of effects as in Table 2: the replacement effect generally increases over time. Combined, these results suggest that people began to adjust their reproductive behaviour to socio-economic conditions before the start of the demographic transition; that is, reproductive control in Germany was internalized and adopted by individual agency much earlier than previously thought (Knodel 1988).

In the second of the two models that use variation in the aggregate prices of rye, we directly use the values of the local rye price that are predicted by the aggregate price. This model shows the effect of changes in the local price that were produced by plausibly exogenous variation in the aggregate price precipitated by events outside the local household sector. As columns 5 and 9 in Table 3 suggest, the effect of the predicted local price on conceptions is insignificant in the pre-1800 period but is highly significant in the post-1800 period. In addition, the effect in column 9 of Table 3 is almost the same as the direct effect of the aggregate price in column 8, which implies that almost all of the variation contained in the aggregate prices is passed onto households through local prices.

In order to explore the possibility that the absence of behavioural response in the pre-1800 period could be due to small variations in prices in the pre-1800 period, we tabulated the variance of local price residuals in the pre-1800 and post-1800 periods. Appendix Table 2 suggests that price variation was smaller in the pre-1800 period than inthepost-1800 period, but not by much. In order to determine whether this difference in the price variation drove the difference in the effects between the two periods, we ran a sensitivity check. We restricted the periods of estimation to the sub-periods when the price variance was the same before and after 1800: 1779-1799 and 1817-1863. Re-estimating the model for these two sub-periods obtained the same pattern of results as in Table 3: the effect of rye price on birth probability in the pre-1800 period (1779-1799) is small and statistically insignificant, while the effect in the post-1800 period (1817-1863) is large and highly statistically significant (Appendix Table 3).

Table 3: Cox proportional hazard estimates of birth spacing in the fourteen German villages, 1765-1863, for all married women, second and higher-order births

	Women married in 1765-1799				Women married in 1800-1863			
	Mean	Local price	Aggregate price (excl. local)	Predicted local price	Mean	Local price	Aggregate price (excl. local)	Predicted local price
Ln(Rye price)	-0.029	0.882**	0.956	0.948	-0.038	0.843***	0.776***	0.777***
		(0.054)	(0.071)	(0.084)		(0.036)	(0.045)	(0.045)
Reference category: Age 25-29								
Age 15-24	0.109	1.26***	1.259***	1.259***	0.137	1.18***	1.181***	1.181***
		(0.038)	(0.038)	(0.038)		(0.028)	(0.028)	(0.028)
Age 30-34	0.243	0.771***	0.77***	0.77***	0.26	0.808***	0.808***	0.808***
		(0.032)	(0.032)	(0.032)		(0.025)	(0.025)	(0.025)
Age 35-39	0.246	0.455***	0.455***	0.455***	0.216	0.514***	0.514***	0.514***
		(0.042)	(0.042)	(0.042)		(0.034)	(0.034)	(0.034)
Age 40-44	0.17	0.129***	0.129***	0.129***	0.123	0.133***	0.133***	0.133***
		(0.066)	(0.066)	(0.066)		(0.058)	(0.059)	(0.059)
Age 45-49	0.021	0.018***	0.018***	0.018***	0.01	0.017***	0.017***	0.017***
		(0.36)	(0.36)	(0.36)		(0.415)	(0.415)	(0.415)
Legitimate parity	0.837	0.95***	0.95***	0.95***	0.029	0.91***	0.909***	0.909***
		(0.011)	(0.011)	(0.011)		(0.01)	(0.01)	(0.01)
Multiple birth	0.017	0.647***	0.647***	0.647***	0.018	0.674***	0.675***	0.674***
		(0.099)	(0.099)	(0.099)		(0.077)	(0.077)	(0.077)
Reference category: Infant or child survived								
Death of infant before conception of next child	0.115	2.584***	2.582***	2.583***	0.147	2.284***	2.286***	2.286***
		(0.032)	(0.032)	(0.032)		(0.024)	(0.024)	(0.024)
Death of child 1-2 y.o. before conception of next child	0.018	2.807***	2.804***	2.805***	0.016	2.514***	2.519***	2.516***
		(0.074)	(0.074)	(0.074)		(0.062)	(0.062)	(0.062)
Death of child 2-3 y.o. before conception of next child	0.009	1.54***	1.542***	1.542***	0.004	1.864***	1.87***	1.863***
		(0.13)	(0.13)	(0.13)		(0.141)	(0.141)	(0.141)
Death of child 3-5 y.o. before conception of next child	0.004	1.306	1.306	1.306	0.002	1.726***	1.724***	1.728***
		(0.214)	(0.214)	(0.214)		(0.195)	(0.195)	(0.195)

Table 3: (Continued)

	Women married in 1765-1799				Women married in 1800-1863			
	Mean	Local price	Aggregate price (excl. local)	Predicted local price	Mean	Local price	Aggregate price (excl. local)	Predicted local price
Death of youngest previous child <9 y.o.	0.025	1.59***	1.592***	1.592***	0.015	1.51***	1.51***	1.509***
		(0.065)	(0.065)	(0.065)		(0.065)	(0.065)	(0.065)
Preceding child was female	0.493	1.004	1.004	1.005	0.477	1.009	1.009	1.009
		(0.022)	(0.022)	(0.022)		(0.018)	(0.018)	(0.018)
Reference category: Husband's occupation: farmer								
Husband's occupation: white collar	0.078	1.019	1.019	1.019	0.082	0.966	0.966	0.966
		(0.056)	(0.056)	(0.056)		(0.049)	(0.049)	(0.049)
Husband's occupation: skilled worker	0.239	1.057	1.057	1.057	0.242	1.079**	1.079**	1.079**
		(0.038)	(0.038)	(0.038)		(0.034)	(0.034)	(0.034)
Husband's occupation: unskilled worker	0.174	0.91**	0.91**	0.91**	0.222	0.952	0.952	0.952
		(0.044)	(0.044)	(0.044)		(0.036)	(0.036)	(0.036)
Husband's occupation: missing	0.167	0.838***	0.838***	0.838***	0.137	0.529***	0.528***	0.528***
		(0.05)	(0.05)	(0.05)		(0.043)	(0.043)	(0.043)
Regional dummies		included	included	included		included	included	included
Gaussian Frailty Variance		0.158***	0.158***	0.158***		0.313***	0.314***	0.314***
Likelihood ratio test		4469	4464	4464		8986	9004	9004
Model p-value		0.00	0.00	0.00		0.00	0.00	0.00
Number of births		8995	8995	8995		15020	15020	15020

Note: Estimates represent relative risk (exponentiated coefficients) with standard errors in parentheses. Predicted local price refers to linear prediction from OLS regression of local price on the aggregate price (excluding the local area price) and all other covariates used in the second-stage regression. Significance levels: * p<0.10 ** p<0.05 *** p<0.01.

If higher expected rye price made some of the husbands in our sample migrate in search of seasonal work, we could not attribute the estimated effect of rye prices on fertility to deliberate fertility control. Therefore, we performed a robustness check that relies on the observation that mainly the poorest occupational classes were likely to migrate in search of seasonal work (Hochstadt 1983). In particular, we estimated the effect of rye prices on conceptions for two groups of occupational categories: 1) farmers, white-collar workers, and skilled workers and 2) unskilled workers and workers with missing occupations. The difference in estimates between these two groups would indicate that seasonal migration among the poor occupational classes could be driving the difference. Comparison of the coefficients on rye prices between Appendix Tables 4A and 4B in the post-1800 period suggests that higher levels of temporary migration among families with lower-skilled husbands could amplify the negative coefficient on rye prices among these families over that of families with higher-skilled husbands. However, significant negative coefficients on rye price among families with higher-skilled husbands in the post-1800 period suggest that a behavioural response to high rye prices was still present.

In order to further address the possibility that migration biased our estimates of deliberate reaction to fluctuations in rye prices, we re-estimated the models using the sub-sample without the couples from Middels and Werdum, the two north-western villages that were most likely to have been affected by the seasonal migration to Holland. The estimates in Appendix Table 4C show that eliminating the influence of observations from these two villages does not change the coefficients in a significant way, suggesting that no significant bias is due to the seasonal migration.

6. Discussion

Several studies have established the existence of both deliberate spacing of births (e.g., David and Sanderson 1986; Crafts 1989; Haines 1989; Bean, Mineau, and Anderton 1990; Morgan 1991; Szreter1996; Van Bavel 2004a; Alter et al. 2007) and fertility response to changing socio-economic conditions (e.g., Schultz 1985; Brown and Guinnane 2002; Dribe and Scalone 2010), even in populations viewed as “natural fertility” populations. While this literature has established the existence of deliberate non-parity-specific fertility control in pre-transitional populations, less focus has been given to the timing of its onset. In addition the response of fertility to economic stress (local grain prices) has been studied (Bengtsson and Dribe2006; Dribe and Scalone 2010). However, it has been argued in the economics literature that local prices and wages might be endogenous to fertility because they reflect the local labour supply, which is a function of fertility (Schultz 1985). This paper contributes to the literature on deliberate birth control in historic populations by addressing the emergence and evolution of non-parity-specific birth control before the first demographic transition in Germany and by using plausibly exogenous measures of short-term economic stress.

The paper adopts a micro-level event history approach to study the deliberate response to the survival status of previous children and short-term economic stress. The goal of the paper is to measure the pace of deliberate fertility regulation prior to the first demographic transition (FDT), as reflected in the varying degrees of these responses over time. We accomplish this goal by comparing the effect of child mortality and the effect of the price of rye on non-parity-specific birth control for the second and higher-order births among several marriage cohorts (1700-1799, 1800-1849, 1850-1900) after controlling for important demographic and socio-economic variables. In order to establish the causal effect of short-term economic stress on fertility we use variation in the local price of rye, as predicted by the price variation in non-local rye markets.

Using indicators for the survival status of the previous children, we establish that the behavioural (replacement and insurance) effect gradually increased in magnitude between 1700 and 1900. In addition, we find a strong reaction to fluctuations in rye prices only after 1800, which suggests that families started responding to short-term economic stress gradually. All this evidence leads to the conclusion that any non-parity-specific birth control that existed before the demographic transition was itself evolving over the years and emphasizes the importance of seeing the demographic transition as a gradual evolution of methods of deliberate fertility control, even if some of the methods did not lead to a dramatic reduction in the number of children.

The findings in this paper underscore that the concept of “natural fertility” remains problematic in its uncritical application to the description of pre-transitional fertility. At the dawn of the FDT in Germany individual controls of reproduction were at play, as indicated by the empirical evidence of delaying childbearing in times of economic hardship. The increasing child-replacement effect we detect over time also confirms that societal regulation of fertility was mixed with individual-level reproductive strategies that families deliberately practised in the times immediately preceding the FDT. These findings also point to the debate on the analytical sustainability of the concept of demographic transition: in the classic literature this concept has been defined as a shift from societal-level to individual-level regulation of fertility (Notestein 1945; Chesnais 1986; Mason 1997: 443–454), but our empirical findings confirm that this definition does not fully correspond to the actual development of behavioural changes in pre-transition Germany. Furthermore, our findings shed light on the debate concerning whether the decline in fertility during the demographic transition was an innovation process, an adjustment process, or a combination of both. According to Carlsson (1966), fertility transition in historic populations can progress in two ways: as a process of adjustment in couples’ reproductive behaviours in response to a changing environment, and as a diffusion of innovative behaviour (i.e., diffusion of parity-specific birth control). Innovative reproductive behaviour, which spreads from a specific social group to the rest of the population, could originate from new knowledge (e.g., about contraception), or it could be supported by increasing social acceptability in the population. Both approaches have been criticized in the literature (e.g., Brown and Guinnane, 2002), while Lesthaeghe and Neels (2002) argued that the diffusion and adaptation processes are not mutually exclusive. We claim that the two should have co-existed, that any innovative behaviour (related to using parity-specific birth control) should have co-existed with considerable non-parity-specific control of fertility in response to changing socio-economic circumstances. The existence of considerable deliberate marital fertility control in response to socio-economic conditions before the FDT stresses the importance of the adjustment theory, which regards the decline in fertility as an adjustment to a new set of forces. Therefore, the foundations of demographic transition theory should be re-evaluated in light of new findings based on individual-level empirical analyses that estimate the changes in individual reproductive behaviours in historic populations more precisely than before.

References

Alter, G., Oris, M., and Neven, M. (2007). When protoindustry collapsed: Fertility and the demographic regime in rural eastern Belgium during the industrial revolution. *Historical Social Research* 32(2): 137-159.

Alter, G.C., Neven, M., and Oris, M.(2004). Mortality and Modernization in Sart and Surroundings, 1812-1900. In: Bengtsson, T., Campbell, C., and Lee, J. (eds.). *Life Under Pressure: Mortality and Modernization in Sart and Surroundings, 1812-1900*. Cambridge, MA: MIT Press: Chapter 7.

Ashley, W. (1921). The place of rye in the history of English food. *The Economic Journal* 31(123): 285-308. doi:10.2307/2223451.

Bean, L.L., Mineau, G.P., and Anderton, D.L. (1990). *Fertility Change on the American Frontier .Adaptation and Innovation*. Berkeley, CA: The University of California Press.

Bengtsson, T. and Dribe, M. (2006). Deliberate control in a natural fertility population: Southern Sweden, 1766–1864. *Demography* 43(4): 727-746. doi:10.1353/dem.2006.0030.

Bengtsson, T. and Dribe, M. (2010). Economic Stress and Reproductive Responses. In: Tsuya, N.O., Feng, W., Alter, G., and Lee, J.Z. (eds.). *Prudence and Pressure: Reproduction in Europe and Asia, 1700-1900.* Cambridge, MA: MIT Press.

Bongaarts, J. (1978). A framework for analyzing the proximate determinants of fertility. *Population and Development Review* 4(1): 105-132. doi:10.2307/1972149.

Brown, J.C. and Guinnane, T.W. (2002). Fertility transition in a rural, Catholic population: Bavaria, 1880–1910. *Population Studies: A Journal of Demography* 56(1): 35-49. doi:10.1080/00324720213799.

Carlsson, G. (1966). The decline of fertility: Innovation or adjustment process. *Population Studies* 20(2):149-174. doi:10.2307/2172980.

Chesnais, J.-C. (1986). *La transition démographique: Étapes, formes, implications économiques: Étude de séries temporelles (1720-1984) relatives à 67 pays.* Paris: Presses universitaires de France.

Cleland, J. and Wilson, C. (1987). Demand theories of the fertility transition: An iconoclastic view. *Population Studies: A Journal of Demography* 41(1): 5-30. doi:10.1080/0032472031000142516.

Coale, A.J. (1973). The demographic transition reconsidered. In: *International Population Conference, Liège, 1973, Vol. 1*. Liège: International Union for the Scientific Study of Population: 53-72.

Coale, A.J. and Trussell, T.J. (1974). Model fertility schedules: Variations in the age structure of childbearing in human populations. *Population Index* 40(2): 185-258. doi:10.2307/2733910.

Coale, A.J. and Trussell, T.J. (1978). Technical note: Finding the two parameters that specify a model schedule of marital fertility. *Population Index* 44(2): 203-213. doi:10.2307/2735537.

Coale, A.J. and Watkins, S.C. (eds.) (1986). *The Decline of Fertility in Europe*. Princeton: Princeton University Press.

Crafts, N.F.R. (1989). Duration of marriage, fertility and women's employment opportunities in England and Wales in 1911. *Population Studies: A Journal of Demography* 43(2): 325-335. doi:10.1080/0032472031000144146.

David, P.A. and Mroz, T.A. (1989). Evidence of fertility regulation among rural French villagers, 1749–1789. A sequential econometric model of birth-spacing behavior (part 1 and 2). *European Journal of Population* 5(1): 1-26 and 173-206. doi:10.1007/BF01796786.

David, P.A. and Sanderson, W.C. (1986). Rudimentary contraceptive methods and the American transition to marital fertility control, 1855–1915. In: Engerman, S.L. and Gallman, R.E. (eds.). *Long-Term Factors in American Economic Growth*. Chicago: The University of Chicago Press: 307-390.

Davis, K. and Blake, J. (1956). Social structure and fertility: An analytic framework. *Economic Development and Cultural Change* 4(3): 211-235. doi:10.1086/449714.

Dribe, M. and Scalone, F.(2010). Detecting deliberate fertility control in pre-transitional populations: Evidence from six German villages, 1766–1863. *European Journal of Population* 26(4). doi:10.1007/s10680-010-9208-8.

Easton, H.T. (1908). *Tate's modern cambist: A manual of foreign exchanges and bullion with the monetary systems of the world and foreign weights and measures*. London: Effingham Wilson.

Friedmann, H. (1978). World market, state, and family farm: Social bases of household production in the era of wage labor. *Comparative Studies in Society and History* 20(4): 545-586. doi:10.1017/S001041750001255X.

Galloway, P.R. (1988). Basic patterns in annual variations in fertility, nuptiality, mortality, and prices in pre-industrial Europe. *Population Studies: A Journal of Demography* 42(2): 275–303. doi:10.1080/0032472031000143366.

Hagen, W.W. (1986). Working for the junker: The standard of living of manorial laborers in Brandenburg, 1584-1810. *The Journal of Modern History* 58(1): 143-158. doi:10.1086/242946.

Haines, M.R. (1989). American fertility in transition: New estimates of birth rates in the United States, 1900–1910. *Demography* 26(1): 137–148. doi:10.2307/2061500.

Hammel, E.A. and Galloway, P.R. (2000). Structural and behavioural changes in the short term preventive check in the northwest Balkans in the 18th and 19th centuries. *European Journal of Population* 16(1): 67–108. doi:10.1023/A:1006399818470.

Henry, L. (1961). Some data on natural fertility. *Eugenics Quarterly* 8: 81–91.

Hochstadt, S. (1981). Migration and industrialization in Germany, 1815-1977. *Social Science History* 5(4): 445-468. doi:10.2307/1170824.

Hochstadt, S. (1983). Migration in preindustrial Germany. *Central European History* 16(3): 195-224. doi:10.1017/S0008938900013935.

Hodrick, R., and Prescott, E. (1997). Postwar U.S. business cycles: An empirical investigation. *Journal of Money, Credit and Banking* 29(1): 1-16. doi:10.2307/2953682.

Jacks, D.S. (2004). Market integration in the North and Baltic seas, 1500-1800. *Journal of European Economic History* 33: 285-329.

Jacks, D.S. (2005). Intra- and international commodity market integration in the Atlantic economy, 1800-1913. *Explorations in Economic History* 42(3): 381-413. doi:10.1016/j.eeh.2004.10.001.

Kelly, P. (1831). *The Universal Cambist and Commercial Instructor: Being a Full and Accurate Treatise on the Exchanges, Coins, Weights and Measures, of All Trading Nations and their Colonies.* London: Longman Rees and Co.

Knodel, J. (1968). Infant mortality and fertility in three Bavarian villages: An analysis of family histories from the 19th century. *Population Studies* 22(3): 297-318. doi:10.2307/2172997.

Knodel, J. (1977). Family limitation and the fertility transition: Evidence from the age patterns of fertility in Europe and Asia. *Population Studies* 31(2): 219-249. doi:10.2307/2173916.

Knodel, J. (1978). Natural fertility in pre-industrial Germany. *Population Studies* 32(3): 481-510. doi:10.2307/2173723.

Knodel, J. (1982). Child mortality and reproductive behaviour in German village populations in the past: A micro-level analysis of the replacement effect. *Population Studies* 36(2): 177-200. doi:10.2307/2174196.

Knodel, J. (1987). Starting, stopping, and spacing during the early stages of the fertility transition: The experience of German village populations in the 18th and 19th centuries. *Demography* 24(2): 143-162. doi:10.2307/2061627.

Knodel, J. and Van de Walle, E. (1967). Breast feeding, fertility and infant mortality: An analysis of some early German data. *Population Studies* 21(2): 109-131. doi:10.2307/2172715.

Knodel, J.E. (1988). *Demographic Behavior in the Past. A Study of Fourteen German Village Populations in the Eighteenth and Nineteenth Centuries*. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511523403.

Lee, R.D. (1981). Short-term variation: Vital rates, prices and weather. In: Wrigley, E.A. and Schofield, R.S. (eds.). *The Population History of England, 1541–1871. A Reconstruction*. London: Edward Arnold: 356-401.

Lesthaeghe, R. and Neels, K. (2002). From the first to the second demographic transition: An interpretation of the spatial continuity of demographic innovation in France, Belgium and Switzerland. *European Journal of Population* 18(4): 325-360. doi:10.1023/A:1021125800070.

Mason, K.O. (1997). Explaining fertility transitions. *Demography* 34(4): 443-454. doi:10.2307/3038299.

McLaren, A. (1990). *A History of Contraception: From Antiquity to the Present*. Oxford: Basil Blackwell.

Morgan, S.P. (1991). Late nineteenth- and early twentieth-century childlessness. *American Journal of Sociology* 97(3): 779–807. doi:10.1086/229820.

Notestein, F. (1945). Population: The long view. In: Schultz, T. (ed.). *Food for the Worm*. Chicago: University of Chicago Press: 36-57.

Pfister, U. and Fertig, G. (2010). The Population History of Germany: Research Strategy and Preliminary Results. (MPIDR working paper WP 2010-035).

Santow, G. (1995). Coitus interruptus and the control of natural fertility. *Population Studies* 49(1): 19-43. doi:10.1080/0032472031000148226.

Schultz, T.P. (1985). Changing world prices, women's wages and the fertility transition: Sweden 1860-1910. *Journal of Political Economy* 93(6): 1126-1154. doi:10.1086/261353.

Szreter, S. (1996). *Fertility, Class and Gender in Britain 1860–1940*. Cambridge: Cambridge University Press.

Van Bavel, J. (2004a). Deliberate birth spacing before the fertility transition in Europe: Evidence from nineteenth-century Belgium. *Population Studies* 58(1): 95-107. doi:10.1080/0032472032000167706.

Van Bavel, J. (2004b). Diffusion effects in the European fertility transition: Historical evidence from within a Belgian town (1846–1910). *European Journal of Population* 20(1): 63-85. doi:10.1023/B:EUJP.0000014572.66520.0d.

Van de Walle, E. (1999). Towards a demographic history of abortion. *Population: An English Selection* 11: 115-131.

Wood, J.W. (1994). *Dynamics of Human Reproduction. Biology, Biometry, Demography*. New York: Aldine de Gruyter.

Wooldridge, J.M. (2006). *Introductory Econometrics: A Modern Approach.* Mason: Thomson South-Western.

Technical appendix

The issue of estimating fertility response to the fluctuations in the local grain price can be formally described by specifying the system of labour demand and labour supply equations and their relationship to the fertility equation. Labour demand is a function of local grain prices P_g; other observed determinants, such as prices of alternative agricultural inputs and outputs and natural resource endowments, all aggregated in a vector, D; the aggregate grain prices P_g^a; and a modelling and measurement error e_d: $L_d = d(P_g, D, P_g^a, e_d)$. The labour supply equation can be represented similarly as a function of P_g and an error term e_s that incorporates many omitted home production, culture, and taste factors: $L_s = s(P_g, e_s)$. The local price can be solved for using the equilibrium condition, $L_d = L_s$, and represented as $P_g = p_1(D, P_g^a, e_d, e_s)$. The fertility equation can be specified as $F = f(P_g, X, e_f)$, where X is fertility determinants other than grain prices, such as local breastfeeding practices and child mortality, and the error e_f encompasses omitted factors like culturally mediated tastes and expectation of future prices.

The statistical problem with estimating the fertility equation directly is that its error will be correlated with the error in the labour supply equation—probably negatively—that is, $E(e_f e_s) < 0$. This problem occurs because, when the omitted factors in e_s drive up labour supply, the time available for childbearing and childrearing automatically decreases. If these same omitted factors are related in some way to the local price of grain, P_g, the direct estimation of the fertility equation will render the coefficients on the grain prices biased and inconsistent.

Table 1: Correlation coefficients between the price series

Correlation between local prices				
	Emden	**Goettingen**	**Heilbronn**	**Munich**
Emden	1			
Goettingen	0.70	1		
Heilbronn	0.62	0.68	1	
Munich	0.42	0.51	0.64	1
Correlation of the local prices with the aggregate prices (excluding local)				
Emden	0.67			
Goettingen	0.74			
Heilbronn	0.78			
Munich	0.60			

Table 2: Variance of the local price residual, by period

	1765-1799	**1800-1863**
Price residual variance	0.040	0.053
	1777-1799	**1817-1863**
Price residual variance	0.045	0.045

Table 3: Cox proportional hazard estimates of birth spacing in the fourteen German villages, 1777-1799 and 1817-1863, for all married women, second and higher-order births

	Women married in 1777-1799			**Women married in 1817-1863**		
	Local price	**Aggregate price (excl. local)**	**Predicted local price**	**Local price**	**Aggregate price (excl. local)**	**Predicted local price**
Ln(Rye price)	0.869**	0.981	0.977	0.825***	0.749***	0.75***
	(0.069)	(0.099)	(0.118)	(0.046)	(0.058)	(0.058)

Note: The model also includes all of the covariates listed in Table 3. Estimates represent relative risk (exponentiated coefficients) with standard errors in parentheses. Predicted local price refers to linear prediction from OLS regression of local price on the aggregate price (excluding the local area price) and all other covariates used in the second-stage regression. Significance levels: * p<0.10 ** p<0.05 *** p<0.01.

Table 4A: Cox proportional hazard estimates of birth spacing in the fourteen German villages, for all married women, second and higher-order births, for unskilled husbands and husbands with missing/unknown occupation

	Women married in 1765-1799			Women married in 1800-1863		
	Local price	Aggregate price (excl. local)	Predicted local price	Local price	Aggregate price (excl. local)	Predicted local price
Ln(Rye price)	0.902	0.995	0.994	0.77***	0.703***	0.705***
	(0.098)	(0.126)	(0.15)	(0.065)	(0.08)	(0.079)

Table 4B: Cox proportional hazard estimates of birth spacing in the fourteen German villages, for all married women, second and higher-order births, for husbands whose occupation is farmer, white collar, or skilled worker

	Women married in 1765-1799			Women married in 1800-1863		
	Local price	Aggregate price (excl. local)	Predicted local price	Local price	Aggregate price (excl. local)	Predicted local price
Ln(Rye price)	0.872**	0.938	0.927	0.881***	0.816***	0.817***
	(0.064)	(0.086)	(0.102)	(0.043)	(0.054)	(0.054)

Table 4C: Cox proportional hazard estimates of birth spacing in the German villages, for all married women, second and higher-order births, with observations from Middels and Werdum removed from the estimation sample

	Women married in 1765-1799			Women married in 1800-1863		
	Local price	Aggregate price (excl. local)	Predicted local price	Local price	Aggregate price (excl. local)	Predicted local price
Ln(Rye price)	0.87**	0.874*	0.851*	0.848***	0.769***	0.77***
	(0.057)	(0.08)	(0.095)	(0.038)	(0.049)	(0.049)

Note to Appendix Tables 4A-C: The models also include all of the covariates listed in Table 3. Estimates represent relative risk (exponentiated coefficients) with standard errors in parentheses. Predicted local price refers to linear prediction from OLS regression of local price on the aggregate price (excluding the local area price) and all other covariates used in the second-stage regression. Significance levels: * p<0.10 ** p<0.05 *** p<0.01.